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AUTOMOTIVE MANUFACTURING PROCESSES
VOLUME V - MANUFACTURING PROCESSES AND EQUIPMENT FOR THE MASS PRODUCTION AND ASSEMBLY OF MOTOR VEHICLES

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FINAL REPORT

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16. Abstract

Extensive material substitution and resurging of the domestic automotive fleet, as well as the introduction of new technologies, will require major changes in the techniques and equipment used in the various manufacturing processes employed in the production of automobiles. The purpose of this report is to document (and analyze) the publically available data on current and projected motor vehicle production processes and equipment and to report on impending changes.

This report provides an overview of recent trends and developments in the automotive manufacturing processes, with emphasis placed on technology and equipment. Special attention is paid to key issues, the reaction by the process technology to these issues, new development and specific applications and trends in the use of light weight materials. Major sections are devoted to economic and market conditions, processes and equipment, and manufacturing materials.

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PREFACE

This report is Volume V of a series of five reports which address changes occurring in motor vehicle manufacturing processes, materials, and equipment during the period 1978 to 1980. The reports present an overview of the major manufacturing processes and materials, and a summary of historical improvements in motor vehicle fuel economy, emissions reduction, and safety. Also included are detailed discussions of vehicle components designed to improve motor vehicle fuel economy, emissions, and safety. The reports also present detailed examination of motor vehicle manufacturing process industries, trends, and issues.

The five volumes in this "Automotive Manufacturing Process" series are listed below:

- Volume I - "Overview"
- Volume II - "Manufacturing Processes for Passive Restraint Systems"
- Volume III - "Casting and Forging Processes"
- Volume IV - "Metal Stamping and Plastic Forming Processes"
- Volume V - "Manufacturing Processes and Equipment for the Mass Production and Assembly of Motor Vehicles."

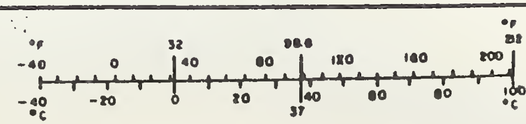
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

1.1 GENERAL

This report on developments within the automotive manufacturing processes encompasses the casting, forging, stamping, forming, machining, finishing, joining and assembly processes. It covers the period October 1978 to October 1979, and is a year-end report of a study sponsored by the U.S. Department of Transportation. The purpose of the study is to gather and assess publicly available information on the impact of automotive weight reduction, increasing government regulation, and the changing socioeconomic structure on these processes.

1.2 STUDY BACKGROUND AND OBJECTIVES

Recent fuel shortages, combined with government mileage regulations, are forcing the major automotive manufacturers to redesign their cars and produce smaller and lighter vehicles. These changes—combined with an escalating shortage of skilled production workers—are having a profound effect on the automotive manufacturing processes.

In the casting (foundry) industry, for instance, foundrymen must produce smaller, lighter, more precise iron castings, and also learn to cast more aluminum.

Metal stamping operations face record orders for their products, but search in vain for skilled workers to turn out these products. Plastics processors grope for means to increase the production rates of their lightweight components, while at the same time increasing quality and durability.

Machining operations, also faced with an increasing dearth of skilled workers, turn increasingly to automated, numerically controlled turning centers to meet production quotas and still maintain quality. Assembly and joining operations seek new ways of holding the lighter, smaller cars together, while finishing operators develop new methods of finishing the lightweight plastics which are now an integral part of every vehicle, and also seek improved corrosion resistance for major vehicle components.

1.3 SCOPE OF THIS REPORT

This report provides a comprehensive overview of major trends and developments within the automotive manufacturing processes over the past year. The report places special emphasis on technological and equipment trends within the various processes and provides information on:

- The key issues affecting the various processes over the past 12 months
- The manner in which the processes reacted to these issues and problems
- New automotive applications within the various processes
- Trends and applications in lightweight materials usage.

The information is presented in loose-leaf, unbound form to facilitate using the report section by section.

1.4 METHODOLOGY

As a part of the study which initiated this report, a cross-section of consumer and business media relevant to the automotive manufacturing processes is scanned and monitored each month, and significant material is excerpted from these publications, indexed, and filed for future reference. It is primarily from these files that information for this report was drawn.

In addition, some contact was made with sources in the field to augment or verify information obtained from the study's library files and other published sources. Every attempt was made to ensure that the report is thorough and comprehensive, within the study's constraints of utilizing publicly available source material.

1.5 ORGANIZATION

This year-end report is divided into three sections. The first provides a brief appraisal of activity within the regulatory and overall automotive market areas within the past 12 months. The second section deals with significant trends and equipment developments within the casting, forging, stamping, plastic forming, machining, finishing, joining and assembly processes. And the last section discusses trends and developments within the lightweight materials areas. These include High Strength/Low Alloy (HSLA) steel, aluminum, plastics and composites.

2. TRENDS IN REGULATORY, ECONOMIC AND MARKET CONDITIONS

2.1 GENERAL

Historically, the automotive manufacturing and supply industry has operated relatively unrestrained, guided only by those controlling the various companies and the markets those companies served. However, little by little governmental control—federal, state and local—of the automobile manufacturing industry as a whole has broadened. And this increased government activity has combined with other forces—such as a suddenly chaotic market for automotive products, declining relative productivity of the workforce, and an era of prolonged energy shortages—to confront the automotive industry with its greatest set of challenges since the early part of this century.

This section of the report deals briefly with the various regulatory and economic impacts on the automotive manufacturing and supply industries in general during the last 12 months (October 1978 to October 1979).

2.2 AUTOMOTIVE INDUSTRY REGULATION

The automobile manufacturing and supply industry is regulated by a wide variety of governmental agencies. These regulatory agencies affect the industry in two broad areas. The first area is the regulation of various vehicle parameters, while the second is regulation of the industry's manufacturing facilities. The following is an historical perspective and discussion of recent developments in both areas.

2.2.1 Vehicle Regulation

The primary federal agencies with regulatory authority over various vehicle design parameters are the Department of Transportation (DOT) through the National Highway Traffic Safety Administration (NHTSA), and the Environmental Protection Agency (EPA). NHTSA has regulatory responsibility for general vehicle operational safety, including defect determination and correction, occupant safety, vehicle crashworthiness, the establishment of Corporate Average Fuel Economy Standards (CAFE), tire grading standards and promulgation of a variety of Federal Motor Vehicle Standards relative to safety and maintenance economy. EPA has regulatory responsibility over mobile source pollution of all types, including: pollution control component warranties, establishing testing procedures and conducting tests to assure compliance with standards, and vehicle fuel economy tests for compliance with NHTSA CAFE standards.

The standards and regulations now in place and being administered by these two agencies encompass virtually the entire vehicle. The cumulative effect on new vehicle prices through 1978 as a direct result of the regulatory effort has been a substantial retail price increase ($665.78 average for all 1978 cars, according to industry estimates published in "Automotive News," April 1979 issue).

The benefits automotive consumers received for this rather large expense are also substantial. Vehicle occupants are much safer in collisions if available safety equipment is employed, the new vehicles are more fuel efficient, standardized transmission controls and rear view mirror placement make it easier to move from car to car, vehicles are more theft-resistant, less prone to catch fire in collisions and emit far less pollutants.

2.2.2 Trends and Developments

Vast differences of opinion still exist between government and the automobile industry as to the necessity, severity and cost effectiveness of the various vehicle standards for 1980 vehicles and beyond. The ways in which some of these differences were aired in 1979 are highlighted in what follows.

Industry Challenges Regulations

The differences between EPA and industry boiled over into the courts in vehicle emissions cases, and the Federal Trade Commission (FTC) entered the automobile industry arena in a variety of areas, including direct and indirect vehicle warranty requirements.

The controversy surrounding the NHTSA requirement for passive restraint installation in passenger cars, particularly the air bag alternative, in 1982 and beyond continued, and NHTSA reaffirmed its commitment to enforcing the law as it now stands. Industry feels the current active seat belt, coupled to a mandatory seat belt usage law is the most cost-effective and most practical solution.

NHTSA feels the manufacturers are overstating the costs of compliance when the air bag alternative is used, but both NHTSA and industry agree that the air bag will save lives.

And although the 5 mph bumper standard currently in effect has survived various challenges, industry in 1979 continued to challenge its wisdom and validity and questioned how further refinements of the system will affect systems cost, and whether actual benefit will accrue.

Front-Loaded CAFE Standards

The auto manufacturers challenged NHTSA over the front loading of the CAFE standards. The manufacturers charged that fuel savings are minimal and can only be achieved through massive capital expenditures when compared to the cost of straight line increments to achieve the mandated 27.5 mpg CAFE by 1985. The media reported NHTSA indicating the fuel saved by the front-loaded standards will equal the output of 10 synthetic fuel plants, a significant factor when fuel conservation is of primary importance.

Safety Recalls Make News

In its role as vehicle safety guardian, NHTSA also monitored or ordered a number of safety-related recalls during the previous twelve months. Most of the recalls were minor and progressed from defect determination to defect correction with relative ease. One protracted recall—that of the "Firestone 500" radial tire—attracted widespread national attention, and resulted in the Firestone Tire and Rubber Co. recalling and replacing nine million of its radial tires at a cost of hundreds of millions of dollars, according to trade press reports.

In this recall situation Firestone was found to have been aware of a potentially dangerous defect while continuing to produce millions of the defective tires. After lengthy negotiations with NHTSA, the recall was initiated, but in the process Firestone tire sales plummeted.

Automakers Struggle to Meet Emission Standards

Stringent vehicle emission standards have forced the automakers to develop new and radically different engine and fuel management systems. And the costs of developing these systems will skyrocket as the standards become more stringent, the automakers report.

In the past year EPA granted a variety of exemptions from future standards in an attempt to smooth compliance problems. The most significant of these waivers will allow the use of diesel engines in passenger cars at least until EPA can make definitive determination of the diesel's carcinogenic effects.

Also, Chrysler Corporation received permission to purchase emission control technology and engineering assistance from General Motors, thus saving itself time and considerable expense.

Several manufacturers took EPA to court over emissions certification procedures and/or procedural changes, charging that EPA certification procedures were excessively costly, unnecessary or hindered fuel economy efforts unnecessarily. The courts upheld EPA's position.

Warranties and Product Liability

The Federal Trade Commision (FTC) challenged the Ford Motor Co. over the durability of its 2.3 liter engine, and the manner in which Ford advertised the engine. And FTC challenged the durability of General Motors' THM 200 automatic transmission. Ford eventually offered extended warranties and repairs to owners of the engine, but GM insists there are no grounds for FTC's THM 200 charges.

Consumer Complaints

Additionally, news reports indicate Congress and the FTC are investigating the terms of current warranties and the difficulties consumers have encountered attempting to obtain warranty repair service. The FTC views the manufacturer and car dealer as the same entity in the resolution of warranty matters, although the manufacturers claim to have little control over the individual dealer because of former FTC rulings separating the dealer from the manufacturer's control.

The manufacturers appear to be moving to alleviate these consumer complaints through the use of arbitration boards to help settle problems that arise from inadequate, excessive or unsatisfactory warranty repairs. The manufacturers report that they are also undertaking stepped up mechanics' training programs to help assure initial repair quality.

2.2.3 Manufacturing Facility Regulations

Regulations that have increasingly far reaching and financially significant impact on the automotive manufacturing processes than the vehicle regulations are those which affect the manufacturing facilities themselves. A variety of Federal agencies administer and mandate regulations that affect the nation's manufacturing facilities. The Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and Equal Employment Opportunity Commission (EEOC), are the most involved, although other agencies affect the industry to varying degrees.

The primary federal laws having direct impact on manufacturing facilities and processes are the Occupational Safety and Health Act of 1970, The Clean Air Act of 1970, the Moss-Magnuson Act of 1974, and the Civil Rights Act of 1964.

Control of water pollution, air pollution, noise pollution, and safety in the work place are the four primary regulatory areas. Two federal agencies, the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA), share jurisdiction over these four areas.

2.2.4 Worker Safety and Health

OSHA has wide-ranging regulatory responsibility, administering and assuring compliance to approximately 9,000 standards relative to worker environment and safety according to business media reports.

OSHA regulations, covering everything from fire extinguisher placement and exit marking to the quality of the workers' environment relative to toxic substances exposure have altered some production processes. New products such as leadless solder have been developed to meet safety standards, and workers have been retrained and reassigned to different areas. Some tasks have been automated to satisfy OSHA safety regulations.

Lead Standards Hit Hard

Newly enacted OSHA lead standards brought prompt industry response this year in the form of a rash of court appeals. OSHA then reconsidered its demand for an engineering solution to the lead contamination problem.

But the real cost effect of the new lead standards will impact most heavily on battery manufacturers, who insist they will have to rework their entire manufacturing establishment to comply, at a cost of hundreds of millions of dollars. Skyrocketing battery prices already indicate the impact on consumers. The worker, of course, will have a more lead-free environment to work in.

Two areas of current concern to industry are OSHA mandated workplace carcinogenic standards and noise levels. The carcinogenic standards in particular—while of course protecting the worker from cancer—may well add one percent to the cost of manufacturing and reduce labor and capital productivity according to studies done for industry. The cost to American industry is projected to range from a low of $9 billion a year if 38 substances are regulated to a high of $88 billion if 245 substances are regulated. Industry spokesmen also assert that engineering solutions to OSHA noise standards may cost hundreds of millions of dollars, increase the use of automation in certain processes, and displace hundreds of workers.

Both of these regulations will affect many segments of the manufacturing and supply industry at various stages, individual components will reflect price increases and the finished vehicle will, of course, reflect the total of all the individual component and assembly cost increases.

Environmental Impacts

The Environmental Protection Agency, drawing its authority from the Clean Air Act of 1970 and the Clean Water Act of 1972, has broad ranging impact on the automobile manufacturing and supply industry. Media reports over the past year indicate the cost of compliance with clean air and water standards weighing heavily on small suppliers. The capital required to install necessary pollution abatement equipment appears to be simply beyond the capital generating capability of small foundries and metals processors and finishers, they assert.

Along with foundries, the steel industry is wrestling with an avalanche of environmental constraints and over the past year conducted a running battle with EPA over compliance with the various environmental regulations. Although many of the steel industries facilities are now in general compliance with the clean water standards, air quality compliance—particularly fugitive emissions—is low. EPA in the previous 12 months has resorted to virtually every enforcement tool available to them. Various steel producers were taken to court, and civil penalties threatened or imposed.

Significant—and expensive—pollution abatement agreements were hammered out between EPA and the steelmakers. Several coke ovens were shut down, blast furnaces were replaced by cleaner electric furnaces. The biggest hurdle for the steel industry in achieving air quality compliance appears to be the elimination of fugitive emissions at a cost of $400,000 per pound per hour, according to steel industry estimates.

Industry Will Comply, But Challenges Cost-Effectiveness

The industry reports it is committed to complying, but feels the law is overly stringent and not applied in a cost-effective manner. Steel has secured governmental help in the form of loan guarantees for the purchase of pollution abatement equipment and modernization. The EPA offered industry a bubble concept where total plant emissions will be monitored instead of individual emissions, which is current practice.

This bubble concept, however, is available only to steel companies currently in compliance with law. The EPA this past year assured the steel industry of their willingness to be flexible should the industry move toward compliance with overall environmental standards while also modernizing their facilities.

EPA Enforces Compliance

EPA also served warning that it intends to enforce the letter of the law should steel attempt to modernize without moving toward facility compliance. According to various articles appearing in business publications such as "American Metal Market", "Business Week", and other publications, the cost of compliance with Federal environmental facility regulations—regardless of their merit—is staggering. One report indicated the steel industry alone spent $2 billion for 48 companies to meet air and water pollution standards out of $2.6 billion spent for all standards, in one year alone. One steelmaker spent $21.6 million for one water treatment system at one plant plus a $3.5 million penalty for failure to be in compliance with the standards. Electroplaters, according to EPA, will spend $461 million to comply with current water pollution standards. So great is the financial impact that the EPA, along with the GAO (Government

Accounting Office), and the Council on Wage and Price Stability expressed concern over industry's economic ability to meet environmental standards.

Product Liability Works Its Way Down

Additional federal regulations that impact the automobile manufacturing and supply industry include the Moss-Magnuson Act of 1974. The Moss-Magnuson Act imposes third party product liability. While it affects the supply industry in general, certain segments of the industry are placed in a specially tenuous position. Machine tool manufacturers, for instance, have had to accept drastically increased product liability costs while approximately 22 percent of their number are no longer able to obtain insurance at any price. The increased insurance costs are certainly passed on to the auto manufacturers in the form of higher priced machine tools.

And metal stampers reported that one of the major automakers was inspecting stamped components supplied to them with less severity. The stampers inferred from this that the automaker was in effect passing on any product liability problems to its suppliers.

2.2.5 Economic Conditions

Economic conditions in the automobile manufacturing and supply industry during the October 1978 to October 1979 period varied widely not only across the entire industry, but within each segment of the industry. The extensive activity to develop radically new vehicles for the 1980's received strong new impetus from the fuel crises of 1979. The automobile manufacturers entered the period faced with mounting inventories of small fuel efficient vehicles but an overall strong market. They ended the period in October 1979 with delayed new vehicle introductions, a gross shortage of small vehicles, an overabundance of large vehicles and a sluggish market.

Machine Tool Sales Still Booming

Machine tool builders continued in a boom period because of heavy demand for new tooling from the automobile manufacturers, while the steel industry is reeling under productivity declines, profit decimation, soaring regulatory costs and increased foreign competition. The rubber industry, suppliers of tires, belts and sundry other rubber products, has been and continues to be in its own major recession as a result of intense internal competition, materials substitution and stagnating sales due to the longer life of radial tires (and depressed new vehicle sales which caused an overabundance of tires).

The electronics and plastics industries are growing at phenomenal rates due to materials substitution in the vehicle manufacturing industry and the need for sophisticated controls to comply with federal emission regulations.

The individual automobile manufacturers are in various states of general economic health. General Motors is exceptionally strong, generating most, if not all, of its capital needs through internal mechanisms. Ford Motor Company is profitable by the grace of its foreign operations, and Chrysler Corporation may be teetering on the brink of bankruptcy due to a combination of management decisions, the weight of federal regulations, collapse of the light truck market during the 1979 fuel crisis, and its limited small vehicle production capacity.

2.2.6 Market and Political Conditions

The market and political conditions for the automobile manufacturing and supply industry were chaotic in the October 1978 to October 1979 period. This 12-month period saw tens of thousands of workers laid off in the various automotive-related industries due to declining sales. The automobile market was in almost constant turmoil as it began the period with an over-supply of small cars and luxuriated in large car and light truck sales. But the industry watched the small car supply rapidly consumed, large car inventories bulge, and light truck sales evaporate as gasoline lines and talk of shortages of petroleum turned the market upside down.

New vehicle production held for a while, then dropped off considerably when compared to 1978.

2.2.7 Labor Cost and Availability

Shortages of skilled labor in several process areas critical to the industry's survival and the generally increasing cost of all labor were highly significant over the past year. Skilled labor, particularly tool makers, die makers and machinists, is in very short supply. Industry analysts advanced several reasons to explain the shortage of these skilled workers, including the current boom in the tool and die industry and disinclination of young persons to enter the field.

As a result of the shortage of skilled personnel, manufacturers and suppliers have sought employees from well outside their normal sphere of employment. This generates relocation costs and other related recruiting expenses. Additionally, the intense competition for this skilled labor has driven up the salary of the individual worker which benefits the large employer, who is more able to offer attractive fringe benefits in addition to higher salaries.

Many supplier companies have resorted to hiring unskilled labor and supplying on-the-job training to fill their requirement for skilled operators—a practice which results in productivity losses.

The end result of this shortage of skilled labor is the maximization of salaries and benefits and the cost of attendant activities such as personnel recruitment, relocation and worker training skyrocketing during the past few years.

2.2.8 Energy Costs and Availability

Every facet of the automobile manufacturing and supply industry is either directly or indirectly affected by the skyrocketing cost of energy and is concerned with the unpredictability of energy availability. Viewing the industry from the supplier of the smallest part up toward the final producer of the automobile, the dramatic increases in energy costs are in part being translated into higher product costs during a period of depressed vehicle sales.

Most of the manufacturing processes involve the use of large amounts of energy, although some processes, such as the production of aluminum or steel, consume an enormous amount of energy.

Increased costs for energy have caused a wide variety of automobile manufacturing and supplier organizations to initiate programs to significantly reduce their energy consumption. They also are attempting to shift their energy reliance to sources that are more abundant than petroleum or are renewable. Reports in various industry publications indicate that the industries have allocated millions of dollars to these energy use reduction efforts and have already significantly reduced energy use and costs.

3. TRENDS AND DEVELOPMENTS IN AUTOMOTIVE MANUFACTURING PROCESSES AND MANUFACTURING EQUIPMENT

3.1 GENERAL

The automakers' compelling need to downsize and pare weight from the vehicles they produce affects immediately and directly the manufacturing processes that collectively produce the finished automobile.

Each of the processes—casting, forging, stamping, plastic forming, machining, finishing, joining and assembly—is currently feeling the crunch to eliminate excess weight from the parts and components it produces.

To an increasing degree, success at decreasing the weight of components by changes in the processes themselves as well as the design of the components they produce—influences Detroit's success in meeting Federal fuel economy and emission guidelines. At the same time, each of the processes is faced with obstacles which lie directly in the path of continued success in responding to the automakers' weight-reduction needs. These obstacles include:

- An accelerating shortage of trained, skilled workers to perform the various processes. This is especially true in the casting, forging, stamping and machining processes. This is compounded by a general slowdown in worker productivity growth.

- A host of Federal regulations which have suddenly intruded into their business management prerogatives. These regulations are primarily intended to control the emission of industrial pollutants, and to improve worker safety and health.

- Soaring costs of materials and energy, which complicate even further the attempts to counteract the dearth of skilled workers and declining productivity growth.

- The need for more rapid technological and equipment advancement.

Organization of Section

For simplicity in reporting, and because some processes complement one another, the processes studied have been placed in four major groupings—Casting and Forging, Stamping and Forming, Machining and Finishing, and Joining and Assembly. In each of the sections, the manner in which the practitioners of each process met the challenges of the past year are highlighted.

3.2 THE CASTING AND FORGING PROCESS

The casting and forging processes have been critical to the automobile from its inception. Both the casting industry (foundries) and the forging industry are major suppliers to the auto manufacturers, along with the auto manufacturers' own captive foundries and forging facilities.

Casting is widely used to make automotive blocks, brake drums, cylinder heads, manifolds, and housings. Approximately 25 percent of all domestic casting shipments go to the automotive industry, and castings accounted for approximately 17 percent of the weight of a car in 1978.

Forging is used to manufacture such highly stressed automotive components as connecting rods, ball joints, differential spiders, tie rods, and stabilizer bars. Other forged components include spark plug bodies, hydraulic valve lifters, and power steering shafts. Cold forging is a much newer and smaller contributor to the automotive industry than hot forging, but it is growing. Overall, 26 percent of all non-captive forging sales are made to the automotive industry.

3.2.1 THE CASTING PROCESS

Casting is the process of pouring molten metal into a mold, allowing the metal to cool and take the shape of the mold cavity, and finally removing the mold from the finished piece, also called a casting. There are four basic casting processes—sand, shell mold, permanent mold, and die casting—pertinent to the automotive community. All four of these processes, although distinguished from one another by mold construction, have common characteristics.

During the first step of any casting process the metal to be cast is melted and alloyed in preparation for pouring and the molds and cores (pieces inserted into the outer mold before the metal is poured to form holes and passages) prepared. In the next step, the metal is poured into the mold and allowed to solidify before the mold and cores are removed. The casting is then cleaned and in some cases heat treated. Finally, the casting is trimmed, machined and inspected.

Sand Casting Predominant

Sand casting is the predominant method for casting automotive parts. In this process, expendable molds of dry or wet sand are formed into shape around a pattern. Molten metal is then poured into the sand cast, which is discarded or recycled after use. Wet, or green, sand molding is the primary method for casting auto parts.

Sand casting can be highly automated and is usually the least expensive casting method. Metals which can be cast by this process include iron, steel, aluminum, brass, bronze, and copper. Automotive parts which are sand cast include engine blocks, cylinder heads, brake drums, calipers and rotors, intake and exhaust manifolds, transmission parts, and chassis components. But sand casting for automotive parts is, temporarily at least, losing its total dominance as the use of lightweight aluminum parts increases. Sand casting is less useful for casting aluminum than for other metals, and sand cast aluminum only comprises 10 percent of all cast aluminum parts.

Sand casting, including both aluminum and iron foundries, is the largest of the casting industries. Overwhelmingly, almost all iron castings are made with this process, while in the aluminum segment sand casters take a back seat to die and permanent mold casters.

Shell Mold Casting

In shell mold casting resin coated sand is pressed over a hot pattern, where the resin melts. This forms a thin sand shell in the shape of the pattern. After curing, the shell halves are glued together and the mold is then ready for pouring.

Gray and ductile iron are the two metals most commonly shell mold cast for automotive parts. The major automotive shell cast applications are cam and crank shafts made in the automakers' own captive shops. Other shell mold cast automotive parts include exhaust valves, transmission parts, hubs, and carriers.

Traditional shell mold casting, a specialty molding segment of the casting industry, has gained only limited automotive popularity. Its use is currently restricted to parts requiring good surface finish and dimensional accuracy, such as cam and crank shafts, to minimize machining costs. Shell molded parts account for an estimated eight percent of cast iron automotive parts (aluminum is not shell mold cast). Most of the major auto manufacturers have captive shell mold foundries, but shell casting in the auto industry is declining as die casting and permanent mold casting grow in importance.

Permanent Mold Uses Metal Dies

Permanent mold casting is distinguished from other casting by the use of a long-lasting metal mold. A lubricating and insulating coating is applied to the permanent mold and cores to prevent soldering of the molten metal to the mold. Metal must be poured evenly throughout the mold cavity to insure a good casting. This casting process, best applied to lower melting point alloys such as aluminum, copper and magnesium, results in a casting with good surface finish free from burnt-in sand.

Permanent mold casting accounts for 22 percent of all aluminum automotive casting, more than any other process except die casting. And application of the process for making automotive components has increased in recent years. Permanent mold casting automotive applications include pistons, cylinder heads, manifolds and brake master cylinders. And new techniques promise to overcome leakage and porosity problems once characteristic of permanent mold cast aluminum parts.

Die Casting Utilizes Pressure

In die casting, molten metal is forced under very high pressure into the die (mold) cavity. The metal is kept under pressure until it has solidified, at which time the core is retracted, the mold opened, and the finished casting ejected. Die castings are characterized by high dimensional accuracy, good surface finish, and economy of metal; they require little or no final machining.

The most commonly used metals for automotive die casting are aluminum, magnesium, and zinc. Automotive parts which are die cast include power steering pumps, rack and pinion power steering housings, and decorative trim.

Die casting is growing in importance to the automotive industry primarily because die castings can be produced with thinner, lighter walls, and because it is currently the preferred casting method for aluminum. At present, most automotive die casting applications involve thin-walled aluminum or zinc. The American Die Casting Institute predicts record growth in aluminum die casting sales through 1985.

3.2.2 The Forging Process

Forging is the process of compressing metal in order to give it superior strength as well as shape it. There are two basic types of forging processes—hot and cold—used to make automotive parts. Both have common operations.

Forging starts with metal sized to the proper volume for the part being shaped. Cold forging requires stock that is heated and softened and lubricated, while hot forging requires even hotter, softer metal for compression. Both operations require metal that is free of scale. Hot forging is defined as the forging of metal heated above its recrystallization temperature. Cold forging is the compression of metal below that temperature.

Die Determines Type of Hot Forging

The major types of hot forgings are categorized by the types of dies used. Open die forging is the compression of metal between dies which impinge upon the piece tangentially and restrict the flow in only one direction. Roll forging is the shaping of metal between a pair of rollers. Impression die forging is the shaping of metal completely within the cavity of two dies that enclose the workpiece on all sides. Upset die forging is the reshaping of a cross-section area of a bar by applying a compression force along the axis of the workpiece.

The principal types of cold forging used in the manufacture of automotive parts are: cold extrusion, cold upset and coining. In cold extrusion metal is forced to flow either backwards or forwards through a die. Cold upset forging is similar to hot upset except that the metal is not heated but is coated with a zinc phosphate lubrication. Coining is a sizing operation where pressure is applied to obtain closer tolerances and smoother surfaces either before or after extrusion.

Metals commonly used in the automobile—aluminum, carbon steels, and engineering alloy steels—are all easily hot forged. Wrought aluminum parts in the car are not hot forged because they are so easily cold forged. Magnesium alloys, candidates for increased automotive use, will also be cold forged. Steel is the only metal used for cold forging automotive parts.

3.2.3 Trends and Developments in Casting

For the beleagured and capital intensive casting industry, maintaining continued success in the 1980's will depend on more efficient use of equipment and materials as well as the development of new techniques. The most critical challenge facing the casting industry is the automakers' effort to bring cars in line with federal mileage mandates. The two approaches holding the most promise for the automakers—downsizing and substitution of lighter materials for more traditional ones—could spell trouble for some foundries.

As automakers continue to downsize and lighten our automobiles, lighter and more precise automotive castings will be required. And even as foundrymen scramble to meet that technical challenge, they are faced with the probability of an overall reduction of casting tonnage required by the automotive industry. The smaller, lighter cars of the future will simply require less casting tonnage, no matter what material the tonnage is cast from.

And as automakers replace more and more iron casting with lightweight aluminum, the casting processes will have to adapt to utilize the metal. Two processes, die and permanent mold casting, are already in a better technical position to handle aluminum than are the sand and shell mold processes. These latter processes simply might be impractical for casting aluminum, or at least have trouble catching up with the other processes.

With increased economic and technological pressure, most foundries are developing new techniques to reduce operating and production costs, improve quality, and compensate for the decreasing availability of skilled craftsmen. Foundries are scrambling to respond to a rapidly growing demand for automotive thin-wall castings. Major trends in 1979 for the casting industry include:

- Automation—One of the major problems facing foundrymen is a shortage of skilled, reliable labor. In fact, the labor shortage is choking off growth in many smaller, non-captive foundries. The larger foundries, with greater capital resources, are increasingly investing in automation. And it is paying off in higher productivity. Use of robots, new methods of automated control, and increased mechanization of the entire casting process has brought the industry closer to total automation in 1979.

- Emerging Technology—A new method of shaping molten metal, called squeeze casting, combines the best of casting and forging processes and has gained increased acceptance this year. This new process saves expensive raw materials and increases production runs as does another new Swiss process called the Fischer process.

- New Casting Methods—Foundries made improvements in all four major casting methods in an effort to capture their share of the growing cast aluminum parts market. The automakers' choice of a preferred casting method will profoundly affect the industry in the coming years.

Automation

Industrial robots, defined as programmed manipulators designed to work automatically without human assistance, are now common among die casters and have joined ranks in cleaning, heat treatment, shakeout, core dipping, core machine loading, mold pouring, and other areas of foundry processing. An impressive increase in the number of foundries using robots was recorded in 1979.

The robot invasion of the foundry industry, in part, has been the direct result of 250 percent increase in U.S. labor costs over the last ten years. In contrast, the average cost of a robot has increased only 50 percent. And the robot industry believes that concern and government regulation for safety in the workplace will create a rapidly escalating demand for industrial robots in foundries, as well as other industries.

Mechanization of foundry cleaning and finishing departments—the cleaning room bottlenecks—lagged behind automation in the rest of the casting process until the end of the 1960's when companies were required to meet federal safety and health regulations.

Automated Finishing Increases

In 1979, U.S. development of automated casting finishing equipment increased, and in fact, showed indications of accelerating partly to achieve regulatory compliance, as well as improve profitability. Robot adherents claim the benefits of automating the foundry's cleaning and finishing process include: less worker turnover, greater safety, more output per labor hour, and higher quality castings.

Equipment builders have developed a variety of machines to simplify, speed up, and improve casting finishing, in addition to diminishing or eliminating the need for muscle power.

One company has developed mechanized arc gouging equipment for weld joint preparation. Base metal is melted by an electric arc blown by a high-velocity air stream, all completely mechanically controlled. This process equipment is claimed to save up to 90 percent in production time over manual methods.

Green Sand Casting Automation

In another area of the casting process, the degree of automatic control required for green sand casting is becoming more critical with the advent of thin-wall castings engineered for automotive weight reduction. New methods of automated control in green sand systems, such as real time process control of sand moisture level, temperature, and binder content, are now within the reach of foundries of all sizes. A combination of real time (instantaneous) process controls such as solid state electronics, microprocessors, and remote sensing provide instrumentation that is capable of controlling sand casting in a way that was only dreamed of a few years ago. Such controls came into increased use in 1979.

Automation in Pouring

Pouring is of paramount importance to all the casting procedures. Since the early days of the foundry, however, pouring procedures have advanced only slightly beyond the

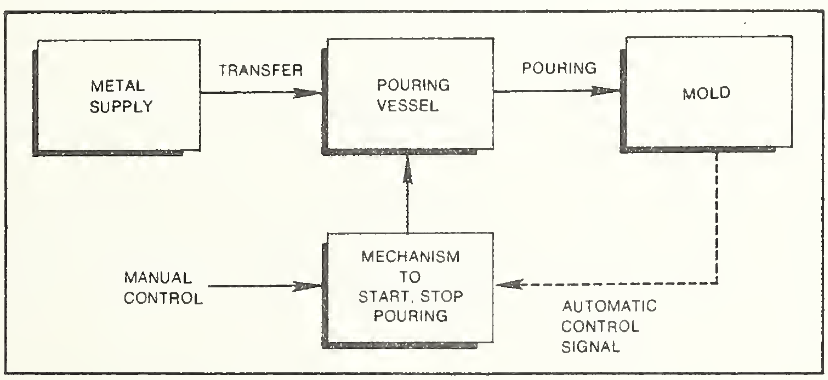


FIGURE 3-1. WORK FLOW FOR MECHANIZED POURING

manual transfer of molten metal from ladle to mold. Many foundries still believe that a "correctly lined and pre-heated ladle of good design in the hands of a properly trained person is hard to beat as the optimum pouring device for most foundries." But in 1979, with the ever-increasing demand for more sophisticated cast metal products, decreasing availability of skilled labor, and spiralling production costs, various approaches to the automation of pouring systems were refined or introduced. These include the use of:

- Stopper ladles
- Pressure-operated devices, with teapot filling and pouring spouts
- Linear induction elevators
- Passive ceramic bubble tubes
- Digital electronics
- Air-powered ladle carriages.

These are primarily applicable to sand mold casting methods, including ferrous and nonferrous metal. Permanent metal molds for nonferrous castings, such as aluminum die castings, often involve cold chamber machines in which metal is ladled separately for each shot. Automatic and mechanical ladling in cold chamber die casting commonly imitates the work of a human operator. For larger castings, however, automatic pressure systems are more likely to be used.

Velocity and Pressure Automation

Controlling the velocity and pressure of the metal shot in die casting has emerged as the last barrier to total automation in the industry. Die casters believe they have part of the solution in high-speed servo-controlled valves, which saw widespread use in 1979. The control of the shot makes possible the full computerization of the process, going beyond microprocessors by closing the control loop electronically.

Servo valves adjust pressure on consecutive shots, giving complete control over both the speed at which the molten metal is injected into the die cavity and the fill rate which is a function of velocity and pressure. This close control eliminates the drifting of speed and pressure which causes improperly filled molds and rejected castings, and therefore saves material and cuts production time.

Because the shot travels so fast, molten metal is rammed into the mold at speeds up to 100 inches a second, valve response time must be in hundredths of a second. In the future, die casters hope to find a valve that operates so quickly it will adjust the pressure during the current shot, not the next.

In another area of automation, recent surveys indicate that foundries are adding automated N/C (numerical control) machining equipment to their manufacturing facilities. Advantages cited include better control over final casting quality and costs and the ability to better serve customers without adding expensive and hard-to-find additional skilled labor.

Only 25 years ago it took 25 man-hours to produce a ton of iron castings. Today, on the average, it requires about 20 man-hours, and a few foundries are achieving 12 hour or less production rates. Castings may be produced at a rate of five man-hours per ton in the future, some industry members predict. Much of this improvement resides in the application of new technology by the industry. The most significant developing technology in 1979 is squeeze casting.

Squeeze Casting

Squeeze casting, the process of pouring molten metal into a die and then forging it as it solidifies, has emerged as the latest metalworking technique. The process, a cross between casting and forging, has been developed and refined over the past year (by IIT Research Institute, among others) to counteract the disadvantages and extend the advantages of die casting to product better cast components.

This technique provides the benefits of molten metal forging, including lower unit production costs and better metallurgical properties than conventional casting or the machining of forgings. These advantages are achieved by the use of less metal, faster production rates, and finer grain in material structure. Squeeze casting combines near-wrought properties like forgings plus the ability to produce near-net shapes. Several domestic foundries began experimentally squeeze casting relatively large parts, including aluminum wheels, in 1979.

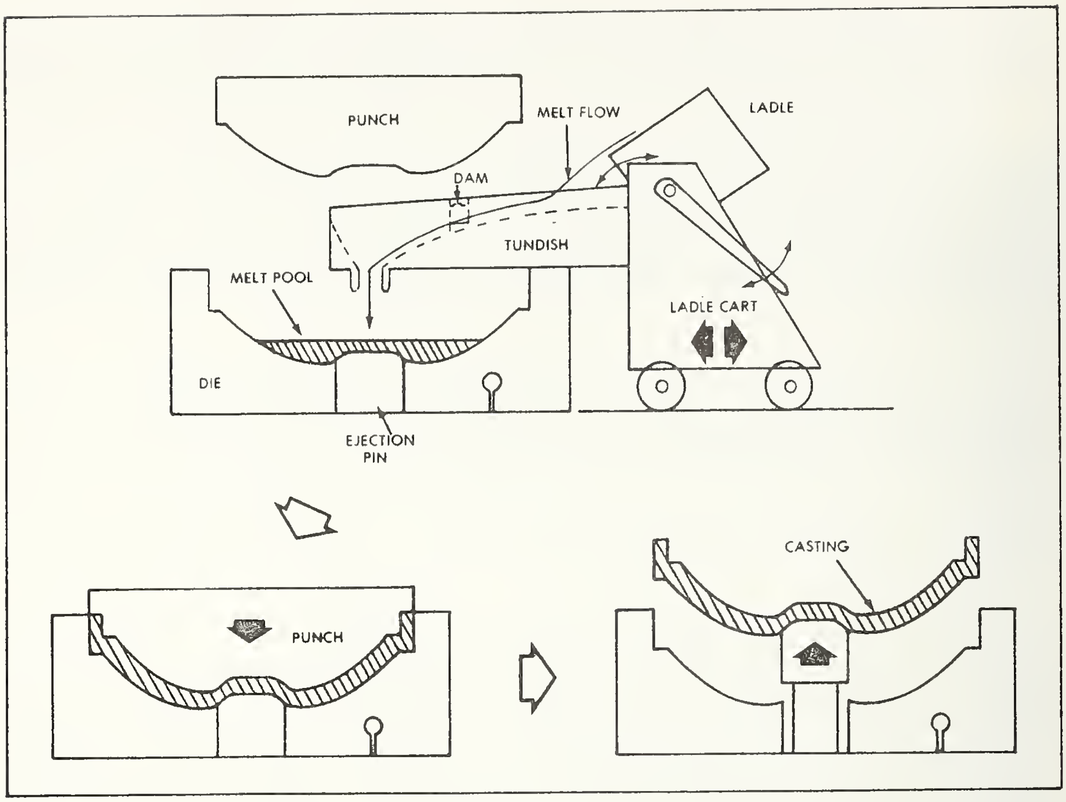


FIGURE 3-2. SQUEEZE CASTING PRODUCTION METHOD

In the squeeze casting method, a ladle cart carries molten metal to the die. The metal flows under a dam and into the die, then the punch is inserted into the semi-molten metal. After the workpiece cools, the punch is withdrawn and the casting ejected.

New Casting Methods

Four years of research and experimentation by Swiss scientists at AG Schaffhausen have led to a new process for producing high-quality, abrasion-resistant alloy castings in a metal mold by a variation of permanent molding. The process is so new that it is not yet in commercial use, although it could be soon.

Called the Fischer process, it is a hybrid technique that involves application of low pressure to molten metal in the bath, but not as in the conventional low-pressure permanent mold method. Using the Fischer process, metal is actually poured, not pushed, up a stalk into the mold.

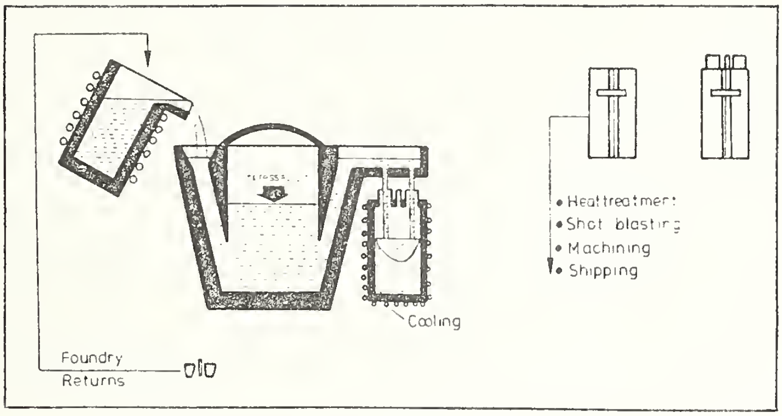


FIGURE 3-3. FISCHER DIECASTING PROCESS

Schematic drawing shows major equipment required for the Fischer diecasting process.

The main element of the process is the metal die, which has high thermal conductivity and is made in two vertical halves. The die has core pullers and cast ejectors as needed. Hot metal is poured under pressure from the top by a mechanized process. The principle of this method is to adjust the pouring rate to the high solidification rate of the pressurized metal so that the solidus level and the level of the melt top surface remain constant during pouring. This is intended to ensure a porosity-free casting from all white cast iron, gray cast iron, and non-ferrous metals such as aluminum.

Injection Inoculation

Significant savings in materials and energy are just some of the results claimed for an improved injection inoculation process developed by GM's Central Foundry Division. The process produces cast iron with more uniform microstructure, making possible the design and production of lightweight castings whose performace equals the same heavier castings produced by previous methods. The process also improves the quality and machinability of castings since it produces a finer texture, according to GM.

The GM system combines an automated auger feed device with a low pressure air supply to deliver precisely metered amounts of inoculant through a flexible hose directly into the stream of molten metal on its way from ladle to mold.

New Mold Technology

Technology is also showing foundrymen new ways to make molds. Several foundries, including GM's Central Foundry, are investigating application of an economical lost foam process for making thin-wall automotive casting molds. To make patterns for this process, small polystyrene beads are heated to 200° F and drawn into an open molding press. The beads are closed in the mold and further heated to melt the surface and fuse the skins. After fusing, mold and pattern are water cooled.

The bead process allows production of smooth surfaced, complexly shaped automotive castings 0.25 inches or thinner. Close tolerances are gained and cores and binders are not required. Capital costs are reduced, foam patterns cost 50 percent less than wood ones, and skilled labor is not required to make the molds.

In response to government and consumer demands for lighter, more fuel efficient cars, automakers continue to replace more and more iron castings with aluminum castings. At this time there is no dominant or preferred casting technique for new automotive aluminum parts, although die casting has a distinct edge. Eventually, however, one or two methods are likely to be preferred by the automakers. And the automakers' choice will have a profound affect on the foundry industry. Presently, many independent foundries supply aluminum components to automakers using all four major casting methods.

Sand casting foundries, traditionally the predominant automotive supply foundries, were bidding on much new cylinder head business in 1979. The sand casters feel their aluminum casting technology has come far in recent years and can compete with die and mold casting for the increasing cast aluminum parts business—although die and mold casters disagree. Right now, sand cast aluminum parts account for only 10 to 15 percent of all cast aluminum.

Sand and Mold Casters Compete

Sand casting foundries and mold casting foundries are in head-to-head competition for future automotive parts contracts. Chrysler is considering both processes for some jobs, while General Motors will use both sand and mold cast manifolds on its 1980 and 1981 models. Ford is considering mold, sand and die casting for lightweight heads on PROCO (programmed combustion) stratified engines they plan to introduce in two or three years, and in 1979 asked for bids from outside companies representing all three processes. But the PROCO heads may be too complex for sand or die casting.

Conversely, sand casting will most likely be used to produce aluminum heads for Ford's new four-cylinder engines. Chevrolet will use sand and mold cast aluminum manifolds, but only die cast front covers for diesel engines. Some of those covers will be made in-house by GM's Central Foundry.

Die castings, which can be produced with thinner, lighter walls than other types of castings, appear to be leading in the race for aluminum automotive parts contracts. The auto industry is expected to use at least 1.1 billion pounds of aluminum die cast car parts by 1985, according to the American Die Casting Institute. At least 700 million pounds will be consumed in 1979, according to the Institute's figures.

Two-Piece Manifolds Proliferate

A two-piece die cast aluminum intake manifold, pioneered by Chrysler, is being used by Ford on its 1.6 and 1.3 liter, four-cylinder engines in 1980. Two-piece, electric beam welded aluminum die cast parts are gaining wide-spread industry acceptance. Chrysler will use die cast intake manifolds for its smaller engines in 1981. Die cast engine blocks, first produced in 1960 for some Chrysler and AMC cars and subsequently dropped, will be used again, but this time with iron cylinder liners. Such engine blocks are common in Europe, and as American automakers turn to aluminum blocks, die casting and green sand molding will fight to produce this part. Die casting will provide closer engine block tolerances and minimal machining, but green sand casting will produce more of the large, heavy castings per hour per automatic line.

In the face of continued weight reduction and downsizing, foundrymen producing automotive castings expect an overall tonnage loss over the next few years. Production efforts, therefore, must continue to be geared toward increased productivity, improved techniques in thin-wall casting production, and greater material utilization.

3.2.4 Trends and Developments in Forging

The forging industry, described as being extremely strong by members of the Forging Industry Association and expected to shatter all previous sales records for commercial forging in 1979, faces the same challenges as the casting industry today—how to squeeze greater forging productivity out of limited capital and material resources. And forgers are using many of the same solutions as the foundries. Trends in 1979 for the forging industry fall into two major categories:

- Automation—Use of automatic feed systems and computers has reduced industry dependence on hard-to-find skilled labor in addition to speeding up production time.

- Emerging Technology—Three new hot forging techniques have shown promise for near-net shape forging, eliminating material waste and reducing costs.

Automation

Automation in hot forge production, where steel bars are fed in at one end and pierced precision parts emerge at the other, grew steadily in 1979. By using an automatic hot forging system small shops can produce parts in volume for consumption by the automakers.

The new systems revolutionize the age-old forging method with a mechanical feed-in process that transfers mill-length bars from die to die until the multi-station forging is completed. Depending on the size of the part being forged, automatic forging system speeds range from 70 to 180 parts a minute. And unlike conventional forging, waste flash is not produced and there are no parting lines.

Solid or hollow symmetrical components up to six inches in diameter and 10 pounds in weight can be automatic hot forged out of carbon and alloy steel grades that are either hot-rolled or unannealed. The process is limited to parts with a length to diameter ratio of less than one, and thus is not feasible for long shafts.

Machining is Decreased

The forging part emerges at about 1900° F and is cooled slowly which often eliminates the need for heat treatment before machining. Machining time is decreased because the automatic forged parts have closer tolerances, cleaner surfaces, and minimum draft angles.

Automotive components produced by automatic hot forging in 1979 include: ball joint sockets, bearing races, wheel hubs, elbow and T fittings, front wheel drive components, gear blanks, pinions, radiator plugs, and universal joint flanges.

Two independent forgers, Rockford Drop Forge Company and Martin Marietta Aluminum, Inc., have pioneered the use of CAD/CAM systems for forging dies. Spokesmen feel CAD/CAM will soon be used in all large forge shops.

The CAD/CAM system will be used to design forgings and the dies to make them, prepare working drawings, and punch paper tapes to operate numerically controlled machine tools that will cut carbon electrodes. The electrodes are used to cut the dies used in forging hammers and presses.

Expected benefits of CAD/CAM systems in forging operations include: reduced dependence on skilled labor, forgings with closer tolerances and infinite repeatability, and quick and inexpensive generation and modification of engineering drawings of dies. Forges producing seamless rolled rings are also looking into computerization to reduce the amount of stock they use and to speed their production flow-through.

New Generation of Equipment

Between now and late 1981 several U.S. foundries will begin production on computerized forging presses and mills built in Germany. The feature of these mills that have attracted so much forging industry attention is a system of electro-hydraulic controls linked to a computer that simultaneously regulates radial and axial rolling faces. The control system measures ring diameter and height throughout production and automatically shifts axial and radial rollers to achieve the desired finished dimensions. The computer control is expected to reduce stock use by 15 percent.

In addition to computers, robots, now common in casting shops, will soon be doing the hot, noise work that humans now perform in the open-die forging of small workpieces. And doing it faster and more productively.

A research team at the University of Nottingham, England, used a simple three-axis robot with a peg-and-drum control and compliant wrist to work a bar of lead in a hydraulic press successfully. But the process is not quite ready for commercial use. It still requires more advanced controls than were used in testing, as well as an adaptive control method to compensate for cumulative error in some forging sequences.

Emerging Technology

The pressure to produce high quality forging at reduced cost is becoming stronger every day. And the industry is answering this need with a major trend toward near-net forging. Using the older, more conventional processes, much of the cost of forging parts was tied to the cost of the material plus the cost to machine the forging to its final shape.

Countering this trend to higher costs are three new metals engineering techniques developed by Wyman-Gordon Company for near-net shape forging. These are hot die forging, isothermal forging, and HIPing (hot isostatic pressing). Hot die and isothermal forging are closed die impression forging processes. In these techniques, the alloys are heated to the plastic state and formed into complex shapes by the pressure of the forging press.

Using Powdered Metal

HIPing is a method by which sophisticated shapes can be made by consolidating metal powder under high temperatures and pressures. One way HIPings are used is as preforms which are later forged into the final desired shape. The other way is to produce final shapes by HIPing.

In the HIPing process, metal powder is placed in a metal can, and under the high heat and pressure of an autoclave the powder is consolidated to 100% of its theoretical density, higher than that of other powder techniques. After the part has been HIPed the metal can is stripped away either by machining or pickling. HIPing can be combined with conventional, hot die, or isothermal forging to get greater shape sophistication than can be obtained by any single process.

Hot Dies Produce Finer Detail

In the hot die process, the dies are heated to between 1400° and 1600° F. The forging material is heated to between 1750° and 2100° F, depending on the alloy. In conventional forging dies and material are normally heated to only 600° to 900° F. The much higher temperatures give the forging material better flowability because the heat loss from the workpiece to the dies is reduced. Thus, the new process produces forgings with finer detail and closer tolerances, yet requires less raw material. The costlier die materials required to withstand the higher temperatures will be a consideration for the smaller forge shops.

In isothermal forging, the dies are heated to the same temperature as the forging material. At these temperatures (2000° to 2100° F for nickel-based super-alloys) forging must be done with molybdenum alloy dies either in a vacuum or inert gas atmosphere. As in the hot die process, isothermal forging permits better metal flow and brings the forging much closer to its final dimensions.

In the quest for near-net shape forging, Federal-Mogul has developed two processes, Sinta Forge and Accu/Form. In Sinta Forge, blended metal powder is compacted into preforms with 75 to 80 percent density and they are sintered at 2050° to weld the particles. The preforms are then cooled, dipped in lubricant, heated to 1700° to 1900°, and then forged in a die press. The result is parts formed to near-net shape while saving up to 50 percent of the input material, Federal Mogul reports.

Accu/Form produces forgings from billets cut from hot-rolled carbon and alloy bar stock. The billets are again dipped in lubricant, heated and forged at 1300° to 1500°. The process forges a near-net shape symmetrical part in one stroke of a closed die press at temperatures below the critical point of the metal so that annealing is eliminated. The process saves up to 30 percent on input stock and up to 50 percent on machining time, its developers assert.

Open Die Forging Advances

In another area, high-quality forgings are being produced faster at lower costs, and will create less noise and no vibration in new hydraulic presses specifically designed for the open die forging process. While traditionally small to medium size open die forgings were

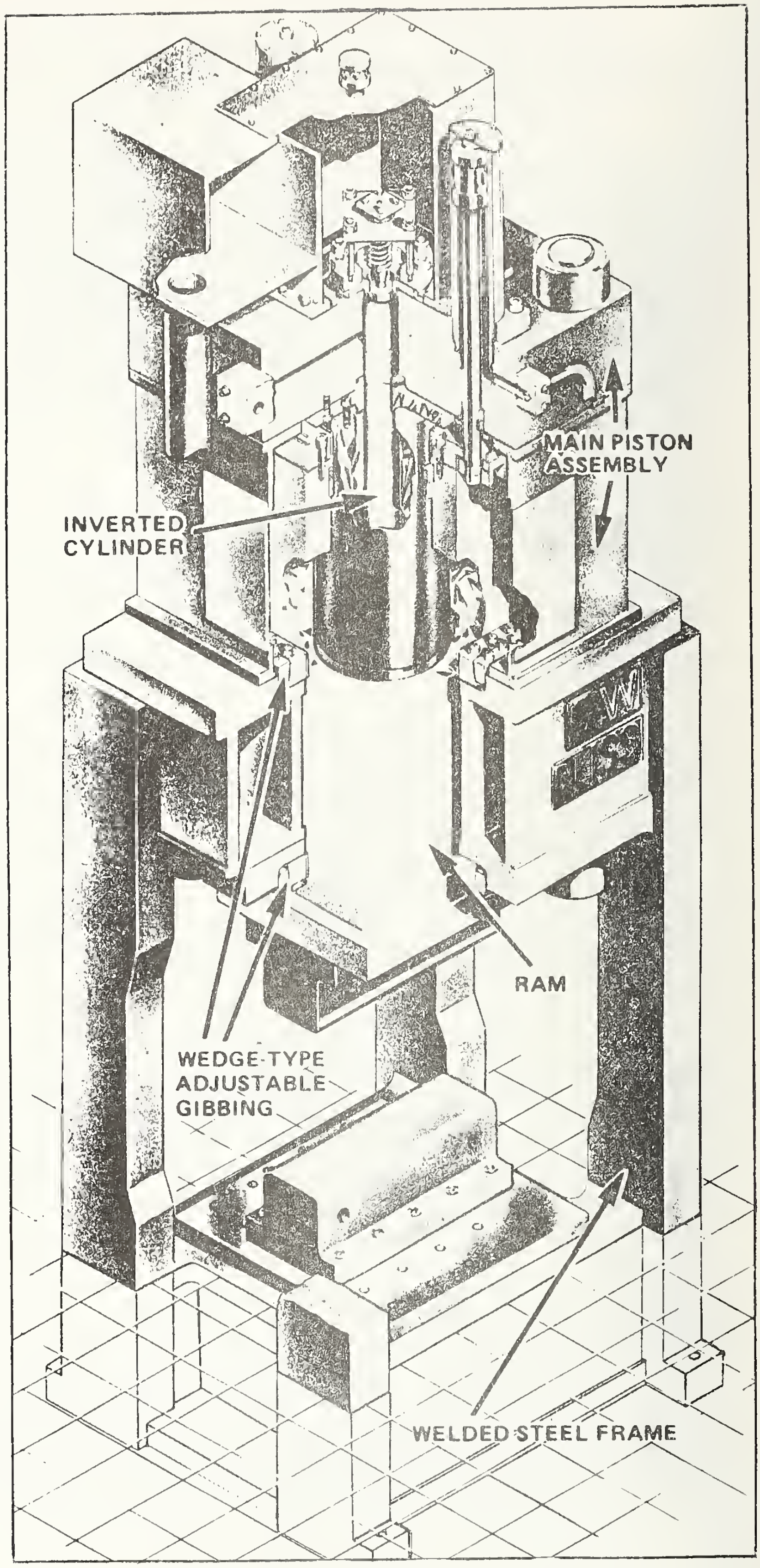


FIGURE 3-4. HYDRA FORGE PRESS

Design features of these new presses include off-center loading capability, reduced fire hazard and reduced maintenance.

produced on compressed air or steam hammers, in 1979 those hammers are being replaced by an economically justifiable hydraulic press developed by E. W. Bliss Company.

These 2,000 ton Hydra-Forge press systems feature the ability to take off-center loadings, minimized fire hazard, ease of maintenance, and quieter production, according to its developers. Some users claim the conversion to press forging from hammer forging is revolutionizing the industry by increasing its profitability.

An important advantage of using hydraulic presses for the open die process is that by delivering a squeezing action instead of hammer impaction, internal bursts and ruptures as well as surface cracks are eliminated, producing a better forging. Parts having large cross sections are deep forged, producing quality centers not available on a hammer forge. Also, more accurate control of forging depth often eliminates the need for subsequent straightening. Material savings through reduced waste is another major advantage.

3.3 THE STAMPING AND FORMING PROCESSES

The forming and stamping of automotive parts and components—formerly strictly a metalworking process, but increasingly a plastic-shaping process as well—is one of the most diversified and critical areas of automotive production.

At one time the terms metal stamping and metal forming were used to describe two similar but distinct metalworking processes. Metal stamping was, as the name implies, the process of "stamping" shapes from flat sheets of metal to form specific flat shapes. Forming was a more complicated process, which basically imparted various shapes and contours to flat steel (or aluminum) through what was basically a stamping type of process.

Today, however, the term "stamping" has increasingly taken on a broader meaning, and is used to describe the stamping of sheet metal or plastic into a wide variety of shapes, both flat and contoured (such as automotive fenders, suspension components, nearly the entire outer skin of the vehicle, and a wide variety of engine and drive train components).

Forming is increasingly applied to the molding of various plastics into parts and components.

3.3.1 The Stamping Process

The basic stamping process is the same, whether the end product is a flat stamping or a more complex shape. In either case, the material being shaped is literally "stamped" into specific shapes and contours by being pressed between two dies—a movable "punch" and a stationary "bed".

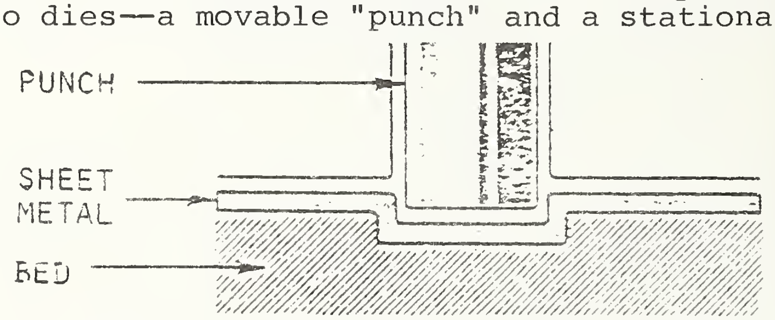


FIGURE 3-5 THE BASIC STAMPING PROCESS

The pressure exerted by the punch on the sheet of metal or plastic forces the sheet to take the shape of the die. In most stamping operations the sheet material is first "blanked," or cut to proper size, before being stamped. It is then stamped into its final form.

While stamping presses vary in size, all have the same basic components. The basic difference between stamping presses is in the method through which the force is developed--mechanically or hydraulically. There are two types of dies used: cutting dies and forming dies.

As the name implies, cutting dies punch, pierce, blank, trim, notch and shave while forming dies bend, draw, curl, fold and emboss. Some forming dies also combine one or more of the individual operations. Flanges and other projections increase the complexity of the die and the stamping operation itself, thereby increasing the cost. In general, the simpler the shape, the simpler the operation.

Another type of die is a cam die. Complex parts such as hoods, fenders and quarters are often formed in a single operation with complex dies which may incorporate up to 10 cams. These cams will form flanges and other shapes perpendicular to the stroke of the cam. A single die of this type can cost up to one half million dollars.

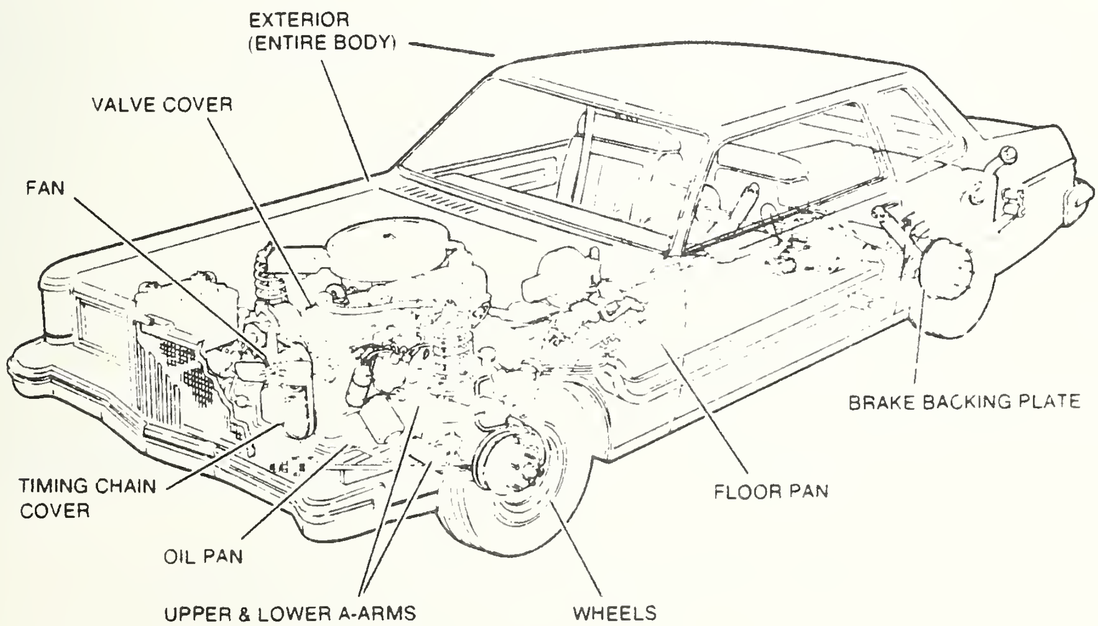


FIGURE 3-6. MAJOR STAMPED COMPONENTS

The stamping process is most often seen in automotive body and chassis components—"light" stampings such as the hood, fenders, doors, truck lids and roof, or "heavy" stampings such as frame rails and suspension components.

3.3.2 The Forming Process

Forming is, increasingly, a term applied to the various processes used to mold and form raw plastic compounds into usable shapes and components. The basic forming processes include:

- Extrusion
- Calendering (plastic)
- Casting (plastic)
- Foam processing (plastic)
- Laminating
- Molding.

Plastic molding—primarily compression molding, injection molding, and reaction injection molding (RIM)—are the most significant of the plastic processing techniques as far as the automotive community is concerned.

Compression Molding

Used almost exclusively for thermoset forming, compression molding involves the squeezing of a material into a desired shape by application of heat and pressure to the material in the mold. Plastic material is put directly into the open mold cavity. The mold is closed, pressing down on the plastic and causing it to flow throughout the mold. While the heated mold is closed, the thermosetting material undergoes a chemical change which permanently hardens it into the shape of the mold.

Compression molding within the auto industry is performed largely on sheet molding compounds (SMC), generally polyester materials processed in the form of a sheet containing roughly equal amounts of resin (plastic), fiberglass and calcium carbonate together with a catalyst.

Injection Molding

Injection molding is the principal method of forming all thermoplastic materials and with modifications the process is sometimes also used with thermosets. In the injection molding process plastic material in the form of powder or pellets is deposited in a hopper that feeds a heating chamber; a plunger pushes the plastic through the long heating chamber where the thermoplastic material is softened to a fluid state; at the end of the chamber, the fluid plastic is forced through a nozzle at high pressure which opens into a closed, cold mold. When the plastic cools to a solid state in the shape of the mold, the finished product is ejected.

Reaction Injection Molding

The process seen as offering possibly the most potential benefits to the auto industry is reaction injection molding (RIM), or more specifically, reaction injection molding of polyurethane. In this process, the liquid components of urethane, polyol and isocyanate are impingement mixed and inserted into a closed mold. Their reaction produces its own heat to which external heat of around 130° F may or may not be added. The final product of the process is generally a polyurethane sandwich with a non-porous skin on both sides and a microcellular core of varying thickness.

Although the other plastic-forming processes are utilized to varying degrees in the automobile, the three forms of molding described above are of such overriding significance that this report will restrict itself to trends concerning them.

3.3.3 Trends and Developments in Stamping

As in all the manufacturing processes, some issues affecting the metal stamping and forming industry in 1978-1979 are unique to this process, while others are universal throughout all American industry. The key issues affecting this industry are:

- Difficulty in hiring, training and keeping skilled workers. By no means peculiar to metal stamping and forming, this is a critical area, metal stampers report. This is a major factor in declining workplace productivity growth.

- Coping with government regulatory pressures—especially OSHA—which require enormous expense in compliance equipment and constant paperwork. The primary regulatory constraints affecting the stamping industry are OSHA noise requirements.

- Meeting increasing demand for better quality control. Both the automakers and government are demanding more consistent quality control in stamping and forming operations performed by individual suppliers. This is a real challenge, especially with the previously mentioned dearth of skilled labor.

And independent stampers have another problem that they hope won't go away—record orders and shipments in excess of $2 billion in 1978. Meeting these orders profitably involves overcoming the obstacles outlined above.

Dearth of Skilled Labor Mandates Automation

The inability of metal stampers, whether independents or captive shops, to hold onto skilled and competent workers is a worldwide problem, U.S. metal stampers discovered at a recent international conclave of sheet metal stampers. Metal stampers in this country are calling for improved training procedures and a campaign by the stamping industry to make those just entering the work force more aware of the opportunities in the field.

To counter the situation, stampers are turning increasingly to more sophisticated controls, testing equipment, and other forms of automation. This helps stampers increase productivity, improve quality control, as well as beat the labor shortage problem. And one metal stamper has developed a simplified systems approach to the making of stamping dies, to make it easier for unskilled workers to understand the process and produce satisfactory quality.

The system divides die-making into narrow areas of responsibility that are easily understood, and couples this with numerically controlled (NC) equipment. This shop also utilizes a standardized die "sandwich" featuring alignment bushings on each die that match alignment posts on the stamping presses. This assures alignment throughout the stamping operation, regardless of which die is inserted, or whether skilled or non-skilled workers are operating the presses. Much of the equipment in this shop—as in an increasing number of facilities—is plugged into mini-computers or a computer center, which tracks each job from initial order through every phase of its production and eventual shipment.

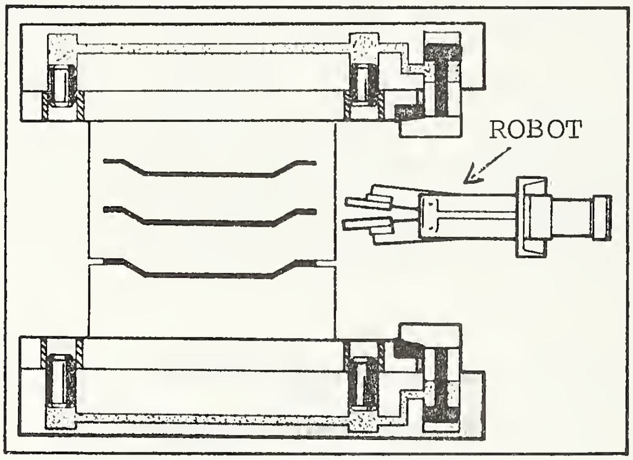
Productivity and Worker Safety

With orders for stampings skyrocketing and skilled workers vanishing, productivity is a real problem in the stamping process. And so is worker safety and health. Increasingly, metal stamping operations are turning to more sophisticated equipment to help solve both problems. In addition to numerical control, which invaded the press-room some time ago, stamping operators are now utilizing industrial robots to improve press efficiency and help prevent accidents.

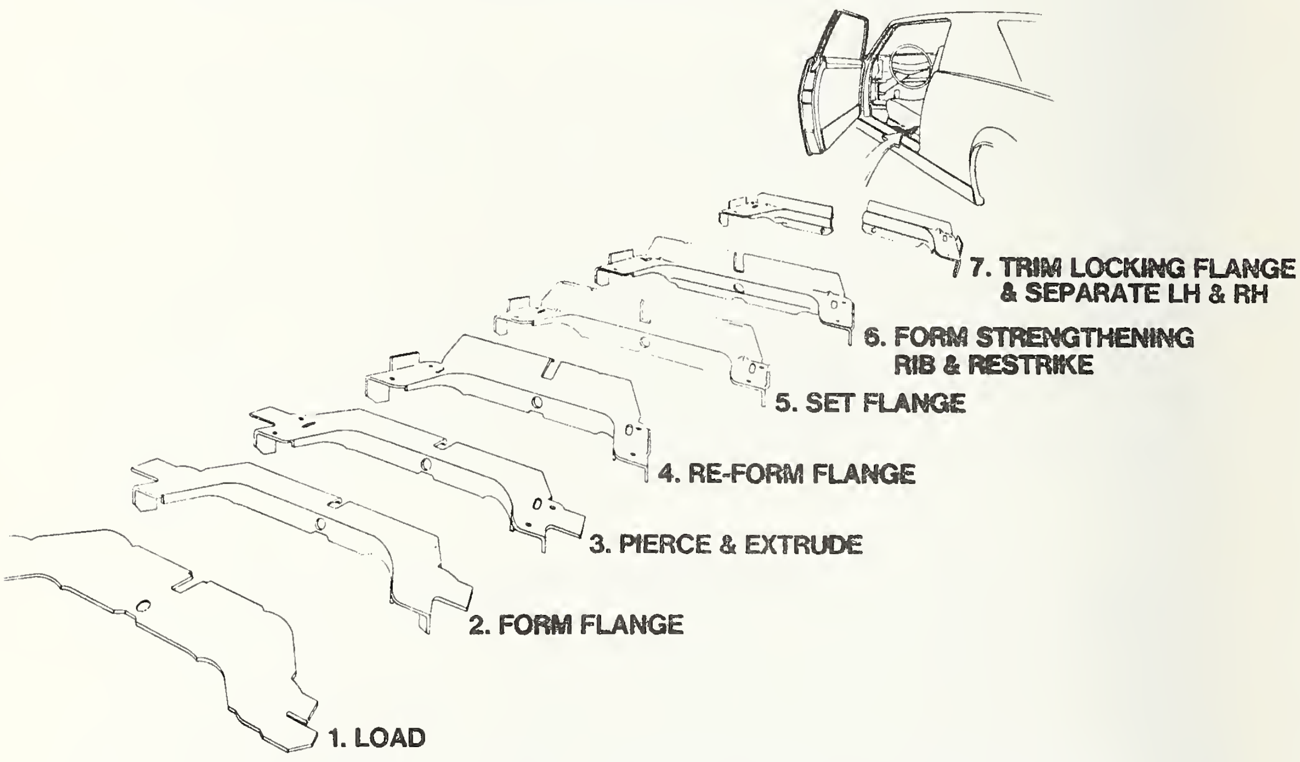
Robots designed for the pressroom are intended to produce more work with each stroke of the press. Several die stations can be mounted over the press-bed area if a multiple-arm robot is available to handle the die stations, for instance, robot manufacturers were telling metal stampers in 1979.

One such system used in punch press operations is the Multi Robot system manufactured by Livernois Automotion Company in Dearborn, Michigan. Covered extensively in the metalworking business press in 1979, this system is actually a form of a transfer die. It is composed of a series of gripper jaws set for each die station and attached to a common finger bar, moving together through predetermined movements to grip, lift, transfer, rotate or tilt the part through as many die stations as is necessary for its completion. Its flexibility permits lower production runs which, in turn, create a need for faster changeover of the dies. For this reason, sub-dies for each operation are fastened to a master quick clamping die set.

Originally intended only for difficult-shaped stampings, the system has been refined to work also on simpler punch press operations. It is applicable to various automotive stamping operations, such as stamped seat supports, engine component covers, and various other applications. In multiple-contour stampings, there is often a limited area for the presses to grip, and designers must provide clearance for the press jaws without affecting the performance of the die. Longer parts often need gripping at both ends to ensure stability during workpiece transfer. Multi-station robots relieve the need for multiple gripping, and permit lower production runs of complex parts. They also facilitate rapid transfer of the workpiece and die changeover. (see Figure 3-7, below)



Dies for a simple part are transferred with a robot at the rear of the press. Sub-dies for each operation are fastened to a master die set featuring quick clamping and release.



Seven steps in robot controlled press operations produce stamped automotive seat supports.

FIGURE 3-7. MULTI-STATION ROBOT

Robot-controlled die automation also facilitates the stamping of components with critical hole orientation. In typical operations such as that shown below, rough locators for the part go in the lower die and pilots for the more accurate position are placed in the upper die.

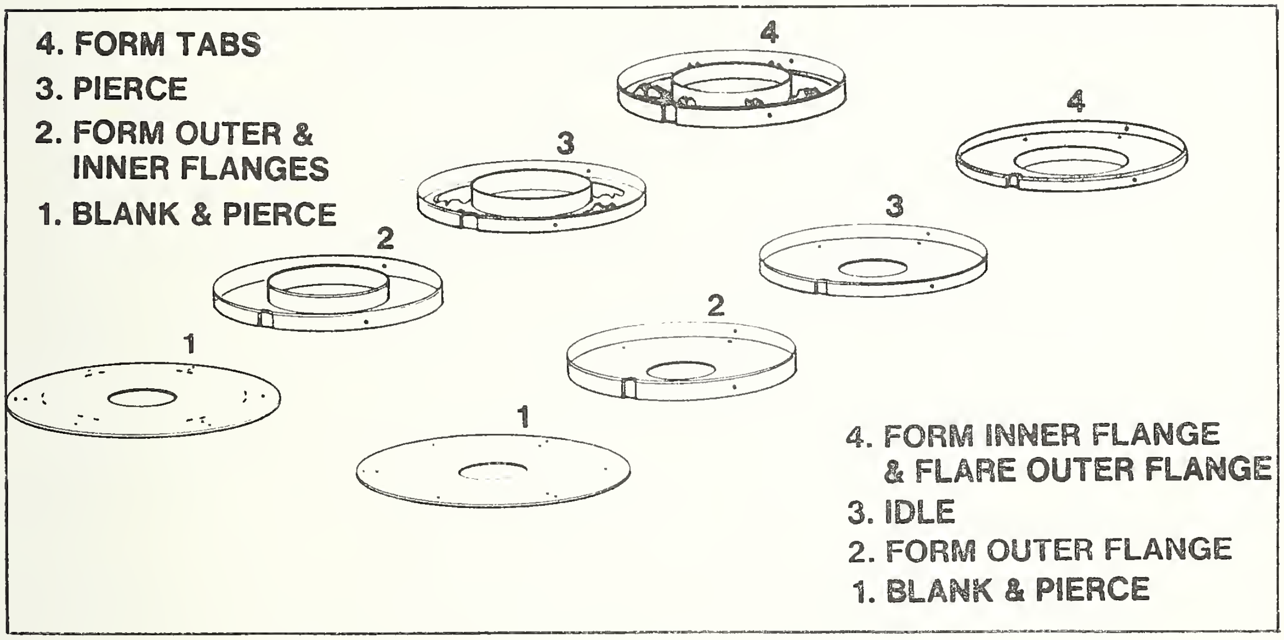


FIGURE 3-8. ROBOT-CONTROLLED STAMPING

Steps in robot-controlled stamping of components with critical flanges and hole orientation.

"Quiet Presses"

OSHA regulations state that protection must be provided for workers when sound levels in the workplace exceed 90 dBA during an eight-hour day. And taking this requirement one step further, General Motors, in its "Sound Level Specification for Machinery and Equipment," mandates that "all steady state or cyclical sound levels produced by machinery or equipment at the operator's position, and at all other points three feet (0.9 meters) from the equipment shall not exceed 80 dBA."

Meeting the requirements was viewed as costly and difficult by large stamping press manufacturers, but apparently not impossible. Last year one manufacturer, USI Clearing, announced that it was developing a series of large tonnage stamping presses whose noise levels average 80 dBA.

Although the new "quiet" presses cost more than standard versions, manufacturers say they are finding a market for them. One of the reasons is that these presses are able to cut production cost from 10 to 25 percent over the operation of equipment fitted with enclosures.

GM Gets One Too

A 1,000 ton progressive die press developed by AC Spark Plug and Verson Allsteel Press engineers also has a sound level average of only 80 dBA at the operator's station, utilizing an enclosure as well as sound reducing technology. This "quiet" press operates with a link-type press drive, an enclosed die area, a lower speed motor, special gearing, a modified clutch/brake, an enclosure of the crown connection openings and has sound dampened conveyors. The press is used to produce two sizes of mounting plates for oil filters from SAE 1010 coil stock which are progressively blanked, formed and pierced.

Manufacturers categorize press noise in three types: tool or gear operation, workpiece movement, and motor sound.

Most press noise comes from tooling, including dies and gears. To subdue these noises, manufacturers must control tool speed. Noise varies directly with the speed at which the top tooling of a press touches bottom. The Verson press employs a noise reduction technique in which the tools move more rapidly as they approach the workpiece but slow down just before contact. The stroke of this press takes more time, but the noise is substantially cut.

And while die life is not normally a consideration in such a press, GM anticipates that the reduction in contact velocity will indeed lengthen die life.

Equipped with standard progressive dies, the press, as utilized at GM, performs the eight operations at successive die stations.

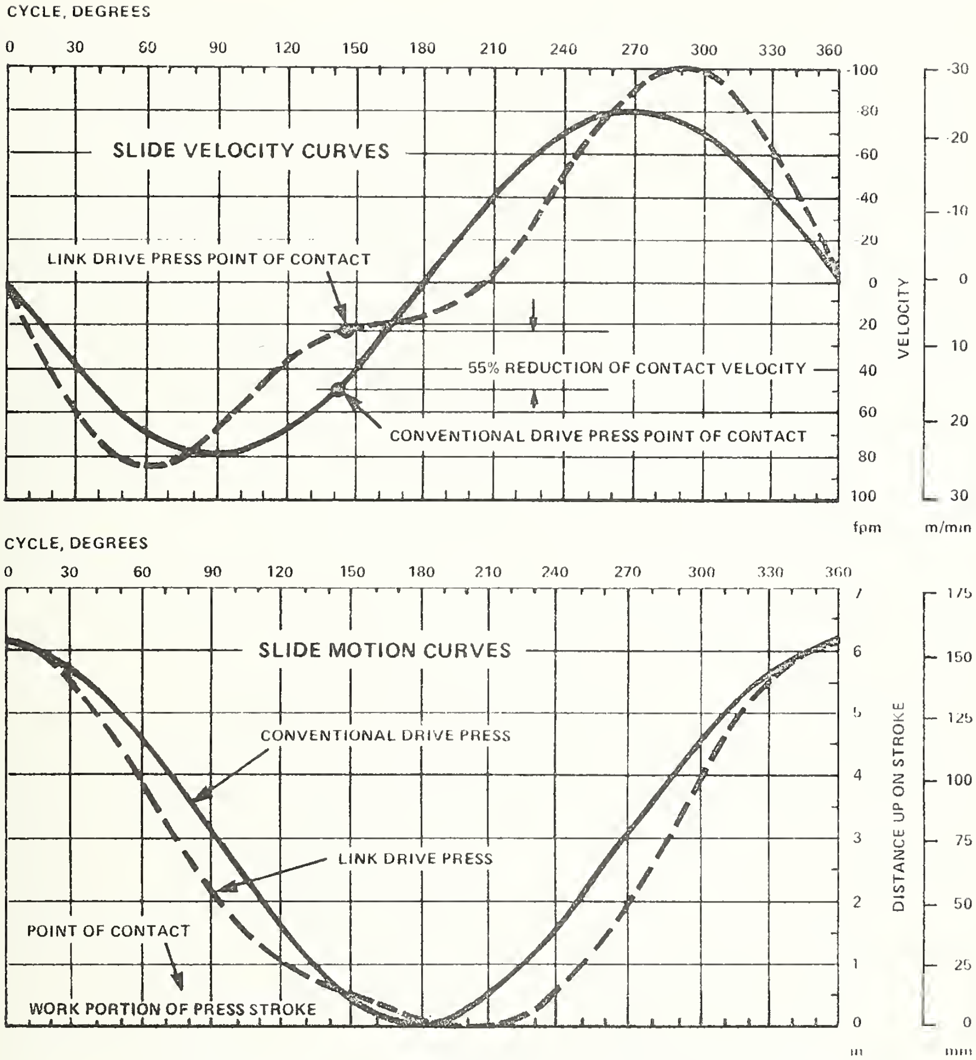


FIGURE 3-9. COMPARISON CURVES FOR LINK AND CONVENTIONAL DRIVE PRESSES

Contact Velocity is reduced 55 percent with link drive press compared to one with a conventional drive.

GM has mounted an eccentric operated, slide-type scrap cutter on the exit end of the press. A divided conveyor deposits completely formed mounting plates and chopped strips of containers, while pierced slugs are conveyed out the entry end of the press.

Quiet Blanking with Shock Arrest

In high speed blanking operations, reversal loads or "snap-thru" loads are a prime cause of presswear and a major source of noise. But a snap-thru arrestor has been developed by the E. W. Bliss Division of Gulf and Western that is designed to reduce reversal loads by as much as 70 percent. The Bliss shock arrestor provides a dual stage absorption, according to Bliss. It senses any increase in fluid velocity at the beginning of the blanking break-through and actuates a valve in less than .001 seconds (see diagram). This shifts the fluid absorption system from a low pressure mode to a high pressure mode while retaining all the fluid in the cylinders to provide maximum restraining force. The system is said to be highly effective in reducing shock and noise, with little heat generation in the fluid.

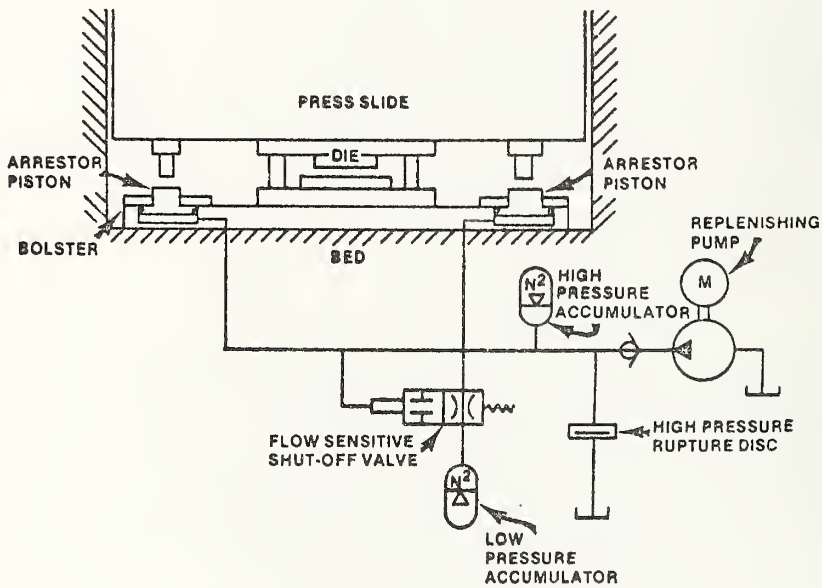


FIGURE 3-10. BLISS SHOCK ARRESTOR

Schematic of the newly developed Bliss shock arrestor for blanking operations.

Blanking Grows More Sophisticated

Fine blanking is a process developed in Switzerland 25 years ago to produce small precision parts (primarily for watches) in great profusion on a single machine. The fine blanking process eliminates virtually all additional machining steps—when a part, such as a small gear or sprocket, emerges from a fine blanking machine it is effectively ready to go. This obviously is a great cost-saver, although the fine blanking machine itself is highly expensive.

The advent of electronic watches and calculators in the early 1970's took away much of the need for tiny watch and calculator gears, and fine blanking equipment makers turned their attention to new markets, and especially the automotive market. Today, the automotive community performs 40 percent of all fine blanking produced in this country, according to 1979 trade press reports. Typical automotive applications which have recently become the province of fine blanking are the production of small air conditioner valve plates. Four of these plates are used in the average automotive air conditioner, and they were formerly made from powdered metal. The parts were insufficiently strong, however, and now one automotive air conditioner manufacturer is producing 170,000 of them each working day.

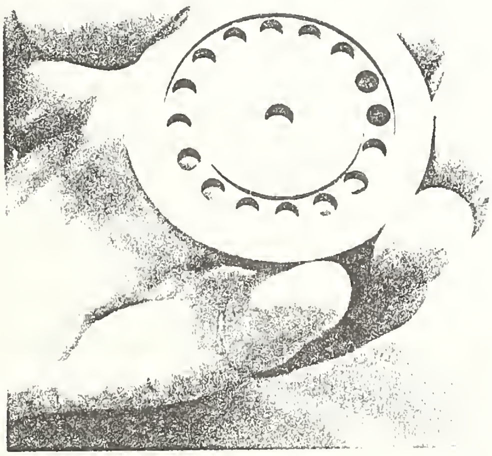


FIGURE 3-11. AIR-CONDITIONER VALVE PLATE

Four air-conditioner valve plates such as the one above are used in the average automotive air conditioner. One U.S. air-conditioner manufacturer now produces 170,000 of them daily on fineblanking presses.

And the process has expanded to include the production of parts having semipierced gear sections made into them. Because many operations formerly performed in several steps are now reduced to one, considerable cost savings result.

Zig-Zag Blanking Saves Material

Rapidly escalating materials costs have prompted stampers to seek new ways of getting the most from each piece of stock they stamp. A technique introduced in 1979, zig-zag blanking, promises significant, if not dramatic, materials, handling and cost savings over straight-line blanking, especially when round blanks are required. Developed and marketed by Verson Allsteel, the new system was designed to nest blanks together on a wider coil of stock. This reduces waste generated around the blanks by 7 to 10 percent, according to Verson.

The technique produces more blanks per coil, consequently reducing material handling and downtime for coil changeover. The system's decreased changeover makes it possible to use coil stock where it would otherwise be impractical.

The system apparently saves most when it allows the press operator to substitute wide, large diameter coils for narrow, small diameter coils. The manufacturer asserts that some customers have increased run times by a factor of four by zig-zag blanking a double row of blanks cut from large coils.

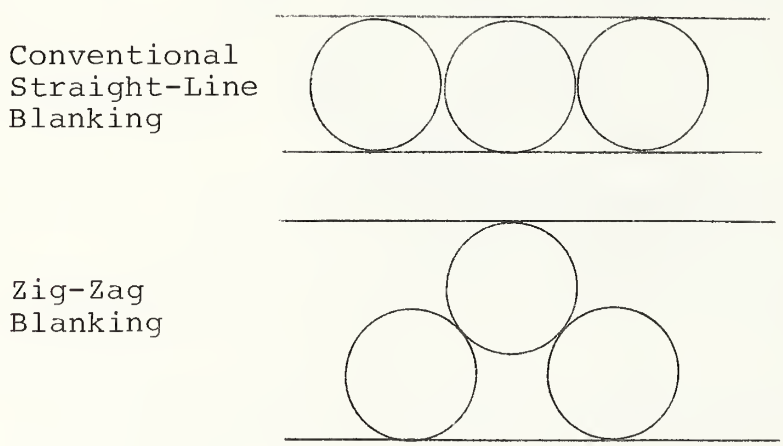


FIGURE 3-12. ZIG-ZAG VERUS CONVENTIONAL STRAIGHT-LINE BLANKING

Quality Control Pressures Increase

The lack of skilled labor complicates quality control efforts, and a new surface strain measuring device shows promise for the detection of flaws in stamped components before they ever leave the stamping facility. General Motors announced development of the automated system designed to replace tedious laboratory procedure to measure the surface strains in sheet metal after the metal has been stamped. The new system combines an electronic camera with a computer to read the relative deformation of small grids, which are placed on a sample piece of metal before it is stamped.

Called the Grid Circle Analyzer (GCA) by GM, the system allows the procedure to be performed right at the stamping facility. In operation, a relatively inexpensive electronic camera "sees" the deformation of the grids on various parts of the stamped component, and feeds what it sees into a suitcase-size mini-computer.

In a paper presented at the Society of Automotive Engineers (SAE) annual conference in Detroit this year, GM engineers reported that side-by-side comparisons of stamping deformation measurements taken with their new system versus measurements taken using the old laboratory system (a toolmaker's microscope is essential in the laboratory procedure) indicate that the new system was far faster, and lessened or eliminated the possibility of operator error.

Although GM released no prices for the unit, it would theoretically offer every metal stamper, large and small, the potential for far greater quality control, plus quick response to stamping deformation problems right at the stamping facility.

This could eventually lead to more uniform quality in all stamped automotive components, and lessen or eliminate many product defects which often turn up long after the automobile has been assembled, sold and driven.

Other Developments

In other significant 1978/1979 developments within the stamping process, General Motors announced that it was redesigning several transmission parts, usually made of cast iron, to allow the parts to be stamped from steel. This allows GM to lighten its THM 125 front-wheel drive automatic, produced by GM's Hydra-Matic Division and used in the firm's front-wheel drive "X" cars.

The new transmissions, which also make extensive use of lightweight aluminum, powdered metal and plastic parts, feature a stamped steel direct clutch housing, forward clutch housing and drum, reaction and input carriers, low reverse clutch housing, direct clutch pistons, converter pump and blades, converter inner shell, turbine, converter cover, oil pan and side cover pan. Many of the parts are joined or assembled by electron beam welding, which works well with stamped parts, GM reports.

To facilitate its swing to stamped transmission components, Hydra-Matic bought a 4,000-ton stamping press, two 2,000-ton transfer presses, one 800-ton straight side press, and 25 electron beam welders.

Powdered metal parts include the converter turbine hub, stator race and stator cam, rotor for variable capacity pump, driveshaft spacers, clutch backing plates, and low roller clutch. Plastic parts include the converter stator retainer, thrust washers, seal rings, and thrust washers in the gear unit assembly.

Many of the stamped parts are similar to stamped components first developed for GM's larger THM 200 transmission.

And in another highly significant stamping development Chrysler Corporation marketed stamped aluminum wheels on several of its models early in 1979 in an effort to better its CAFE averages. The wheels, produced by Kelsey-Hayes with conventional stamping, roll-forming, butt welding and arc welding techniques, employed an aluminum-magnesium alloy in the rims and spiders.

In production, the wheel's spiders were stamped in several operations, while the rims were flared and roll-formed on standard equipment, then joined to the rims by shielded arc welding. These are the same processes used in the manufacture of conventional steel wheels.

The use of the aluminum wheels saved Chrysler 32 pounds per car before they were dropped from the firm's line-up due to the changing product mix of its automobiles. When the firm's Omni and Horizon compacts became the hottest selling cars in its line-up, it shifted Chrysler's CAFE average to such a favorable position that Chrysler felt it could save money by returning to steel wheels, without damaging its CAFE advantage.

3.3.4 Trends, Developments and New Applications in Plastic Forming

As in all processing areas, one issue stands out above the others in plastic forming—the lack of skilled labor. And this overriding factor, combined with the need to overcome plastic processing's historically slow production rates, and increasing demands for precision and superior quality control, created the most obvious trend in 1979. This is the rapid acceptance and growth of sophisticated, computerized process controls throughout the industry.

Other key issues include:

- Improvement of Process Controls
- The development of significant new techniques for finishing injection molded plastics
- The development of new techniques for injection molding TMC (thick molding compounds)
- The development of new techniques for blow molding large parts and components
- New testing procedures for evaluating the practicality of molded plastics.

Improvement of Process Controls

Plastic molders reported significant, often dramatic, improvement from computerized control throughout their operations in 1979. Dramatic reduction in reject rates, reduced cycle time and reductions in setup times on injection molding machines (IMM) are the principal benefits reported. The new breed of programmable controls combine sequence and process control functions, and are more attuned to the human factor in machine operation. They are designed to be more easily introduced into new plants with a minimum of training and orientation required.

Combining sequence and process controls in a single programmable unit offers several advantages, since both functions are required to operate a molding machine. Sequence functions control the cyclical process of basic molding steps the machine repeats over and over again in the molding cycle. The sequence control takes the machine "through the numbers" automatically, although it can be overridden by the operator if necessary.

Process controls dictate combinations of mold pressure, hydraulic pressure, ram velocity, ram position, and other functions such as temperature. Early plastic molding controls were electromechanical, with motor driven clutches, switches, and relays all interconnected to provide the information needed for control. The newer equipment is solid state, with improved reliability. It offers the operator of the machine a wider range of process control functions. And the new controls can automatically monitor and adjust 4,000 parameters in the molding cycle, one million times a second.

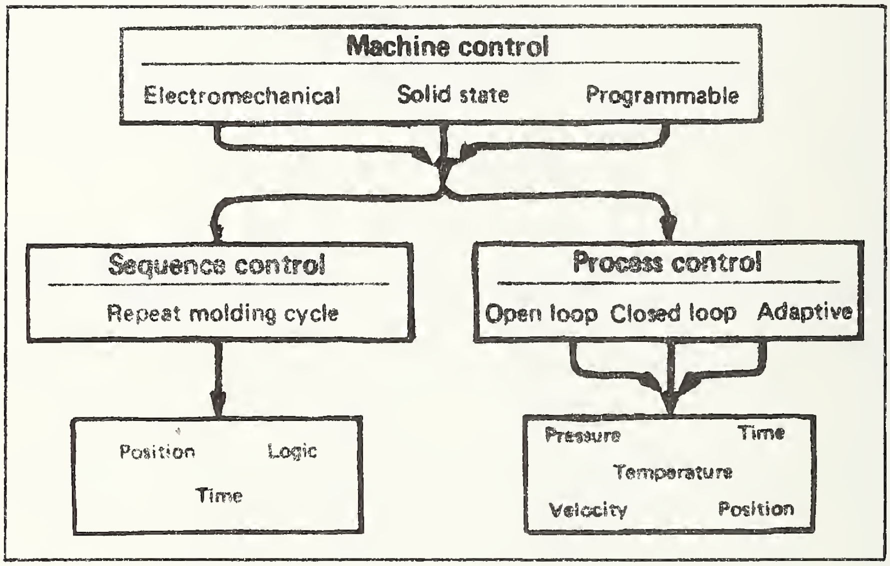


FIGURE 3-13. SCHEMATIC OF INJECTION MOLDING MACHINE CONTROLS

Electromechanical controls have no ability to compensate if the plastic going into the machine somehow changes, or if the shop temperature and overall environment changes. Any change in these factors require that the equipment be shut down and the controls changed.

Constant Flow of Information

With the newer control units, sophisticated electronic sensors and timers feed a constant flow of information to the control unit. If the situation changes, the controls react within fractions of a second, and the forming operation keeps right on going.

Extend Machine Capabilities

New combinations of solid state sequence and process controls and mini-processors are also extending the possibilities available on each machine even further. This is due to the reaction time of the solid state, computerized control units.

A typical molding cycle consists of: clamp close, inject plastic, hold ram forward until gates freeze, plasticize new material, open mold and eject parts. In an electromechanically controlled operation, the magnitude and duration of each phase is locked in when the cycle starts and the cycle repeats itself every cycle.

Programmable controls allow the operator to easily change any part of the cycle, at any time.

Currently, 80 percent of all new IMM's sold use hard-wired solid state controls. Four years ago less than 50 percent were solid state. Costs of programmable sequence and process controls range from $5,000 to $15,000.

Advances in Injection Molding Finishing Processes

Sophisticated controls are only one of the significant trends impacting on injection molding in 1979, and a second one—the achievement of high-gloss appearances right out of the mold will make injection molded components more potent candidates for increased use in Detroit's automobiles.

Two new in-mold finishing systems are giving injection molding this new capability. The two systems provide Class A finishes (integrally colored or paintable just as they come from the mold) and are:

- Thermal Cycling of Class A finishes in low-pressure structural foam molding (developed by Ex-Cell-O). This method first melts the molded component's surface by pressure-forcing the resin against the surface of the heated mold, then cooling the component rapidly.

- In-Mold, Smooth Skin method (developed by Farrel Division of USM) forms a cosmetic skin before blowing action starts in the mold. This technique injects compressed gas into the mold before the resin is injected, and the gas counterpressure inhibits blowing action until a high-gloss skin is formed.

Time Penalty is Slight

The new thermal cycling process avoids heating the entire mold, but instead injects water vapor into the mold, then rapidly withdraws the vapor. The technique adds only 15 seconds to a normal three-minute cycle, a small price to pay for a component with such a smooth skin it can be painted right away, or assembled as is if colorant has been included in the resin.

The thermal cycling feature costs approximately $8,000 if included in a new machine, or $10-12,000 to retrofit to older injection molding equipment.

High Pressure Method Works with ABS

The Farrell/USM high pressure gas counterpressure method of achieving high gloss relies on the use of inert gas injected in a carefully controlled sequence, as well as precise monitoring of gas and melt temperatures and pressures. The system, according to Farrel, is easily applicable to producing plateable ABS foam surfaces for new applications such as automotive wheel covers. The gas counterpressure eliminates surface burning and plateout on ABS surfaces, Farrell claims. The technique costs $6,000 if included on new injection molding equipment.

To make the process more appealing to Detroit, the manufacturer has developed guidelines and molding parameters for a foamed trunk lid for future automobiles.

One Painting Operation

And, perhaps most significant of all, Farrel asserts that the better finish obtainable on the molded component with this process will allow components such as the trunk lid to be painted right along with the rest of the vehicle—and bring total part cost down to slightly more than $12.

Other possible automotive applications for the "out-of-the-box" high gloss finish molding processes include glove box doors, instrument panels, luggage concealment trays for hatchbacks, fenders and hoods.

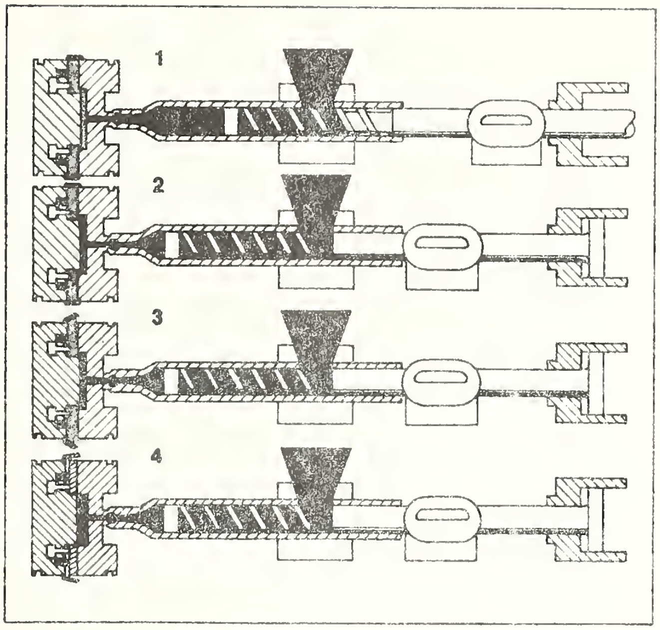


FIGURE 3-14. THE COUNTERPRESSURE PROCESS FOR HIGH GLOSS SURFACES

In the counterpressure process, (1) mold cavity is filled with inert gas. As material is injected against the pressurized gas (2), solid skin forms on part under conditions that inhibit blowing action. Gas pressure is varied in the mold for surface effect. Gas exhaustion relieves pressure in cavity (3); permitting foaming (4) with mold expansion.

Injection Molding TMC

A recently developed system for injection-molding TMC (thick molding compound) may provide the automakers with the inherent strength needed to use these reinforced polyester compounds for large body components.

Sheets of TMC can be as much as two inches thick, and are composites of polyester resin, thermoplastic copolymer, catalyst, mold release agent, pigment, inorganic filler, and glass fiber reinforcement. Because of its method of glass impregnation it is stronger in almost every way than other compounds such as SMC (sheet molded compound) and BMC (bulk molded compound).

The newly developed process utilizes a faster flow rate and high pressure loading of the basic compound to produce a Class A surface of considerable strength. The process allows various combinations of reinforcement and resin to provide corresponding trade-offs of strength versus appearance. Developed by U.S.S. Chemicals Division of U.S.S. Corporation, the process is still experimental.

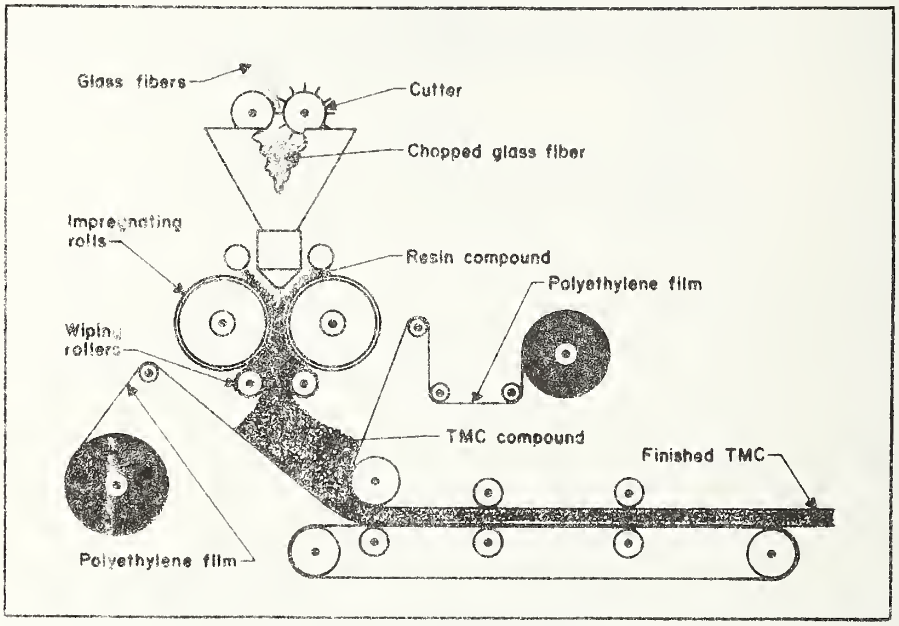


FIGURE 3-15. PROCESSING EQUIPMENT FOR PRODUCING THICK MOLDING COMPOUND (TMC) SHEET IN VARIOUS THICKNESSES

Blow Molding Fuel Tanks Now Feasible

Although so far used only in limited production applications in this country, mass-produced polyethylene fuel tanks appear to be much closer to reality due to new blow-molding techniques developed in West Germany. Developed by Kautex (Bonn) and Elbatainer (Eitlingen), the new blow molding techniques have so far produced polyethylene fuel tanks for Daimler Benz trucks operating in Europe and for automobiles made by Ford of Australia.

The technique utilizes a method of stretching part of the mold to permit blow molding of odd-shaped fuel tanks. In the 35-gallon tank made for the Daimler Benz trucks, injection molded interior partitions control fuel movement within the tank. The tank is blow molded around the partitions using equipment designed especially for the task. The interior partitions' diameter is slightly smaller than the interior diameter of the tank to allow the fuel to fill the tank, and the partitions are sealed into position in molded recesses in the tank wall during the blow molding process.

Quality Control Moves Ahead

As plastics become candidates for an increasing number of automotive components, many of them highly stressed and subject to severe vibration, quality control and component testing becomes more critical. A new procedure (a refined version of the existing solvent-stress-cracking method) promises to give the automakers and their suppliers a new level of plastic component testing and quality assurance before the part or component reaches the assembly line.

Developed at the Illinois Institute of Technology, the procedure is applicable to parts molded from various resins, including polycarbonates, with which the test procedure was first evaluated.

The test assesses what effect residual molding and assembly stresses have on the component tested to determine whether the component has sufficient stress resistance remaining to withstand the rigors of the road.

In practice, a portion of the material used to form the plastic component is machined to remove all rough edges, then annealed to relieve all stresses. It is then bent, and a special solvent or lubricant applied. The lubricant or solvent is replenished for 30 seconds; then the specimen is wiped clean.

Any sign of edge cracking indicates insufficient stress resistance. The same series of solvents are applied to the formed part for similar evaluation.

The test is still a laboratory procedure, but its developers feel it has great potential for future field use.

And Ford is reportedly developing an X-ray test procedure to inspect and evaluate the orientation and consistency of structural foam and glass fibers, as well as ultrasonic scanning techniques to detect voids and faulty laminations.

Other Developments

The increasing importance of plastic processing to the automotive industry is underscored dramatically by the growing injection molding capacity at both General Motors and Ford.

At GM's Saginaw Steering Gear Division alone, the in-house molding facilities have expanded within the past two or three years into a major portion of the seven steering component plants in Saginaw which make both manual and power steering systems.

And the company has just made operational the second of two manufacturing plants in Alabama. The new plant operates 22 new injection molding machines. This follows the installation of 27 new 200-ton injection machines which became operational two years ago at the Saginaw complex.

Sophisticated Materials Handling

The Saginaw operations feature a sophisticated materials handling system which operates on two levels. A centralized vacuum system allows operators to channel any material to any machine in the facility. And control panels monitor up to 16 machines at a time, telling the conveyor system operators which machines need to be filled. Other computerized controls monitor all phases of machine operation.

Ford Enhances Internal Capacity

And Ford Motor Company's recent emphasis on plastics produced internally centers on new equipment and automated processing to tighten quality control and accelerate curing. Ford is also using in-mold coating to eliminate surface porosity and related defects.

To make grille opening panels and fender extensions, Ford is using glass-reinforced BMC (bulk molding compound) thermosetting polyester resins in injection molding. But for larger, flat surfaces, such as body panels, Ford is experimenting with co-injection and sandwich molding methods. In this process two materials are injected into a mold simultaneously, to form a solid skin and a solid or foam core. The firm is also researching: reinforced glass fibers for urethane reaction injection molding (RIM) fenders; vacuum forming; and a reinforced, high modulus RIM material which could be painted in the conventional way.

3.4 THE JOINING & ASSEMBLY PROCESSES

The joining and assembly processes are intimately related in automotive manufacturing in that both involve holding the car and its various components together. Individual parts are joined together to form components and sub-assemblies; these components and sub-assemblies are assembled to form whole vehicles. The basic distinction between the two processes is that parts joined together are, for the most part, considered permanently joined while parts that are assembled can, in general, be taken apart for repair or replacement. Because of the integral nature of both processes in the production of automobiles, both are immediately affected by any change in the auto such as changes in materials or tooling.

3.4.1 The Joining Process

The three main types of joining used in automotive manufacturing are welding, adhesive and solvent bonding, and mechanical fastening. These joining processes are applied to almost every part in the automobile. Welding is used for exhaust manifolds, chassis construction, transmissions, flywheels, and other applications. Applications for adhesives include bonding vinyl roofs, bonding brake shoes, hoods and other exterior panels, attaching rear view mirrors, body molding, and carpeting. Mechanical fastening is used in such applications as engines, wheels, powertrains, and body components.

Welding

Welding is the joining of parts by applying heat and either melting extra material into the joint or forcing the joint together. When the softened material solidifies a permanent bond is formed. Traditional forms of welding include brazing, gas, resistance, arc, and solid state welding.

One innovative welding technique coming into greater use in the automotive industry is electron beam welding. This technique bonds materials by heating them to pliancy with kinetic energy transfer. That is, electrons from the beam collide with atoms on the surface of the part, thus forming a bond by melting.

Though requiring a capital outlay of $100,000 to $800,00 per unit, electron beam welding has many advantages over traditional techniques, not the least of which is speed. These machines can weld up to 400 inches a minute or more for fast production rates. In addition, material savings are obtained by substituting joined stampings for single-forged parts. Distortion from welding is minimized, eliminating the need for straightening and machining operations.

New welding techniques and equipment are needed for joining aluminum and HSLA steels, both of which are more difficult to weld than steel. Aluminum alloy combinations and surfaces can adversely affect the durability of spot welds, putting the burden for capital investment on new equipment on joiners as the use of aluminum car parts increases. HSLA requires more care in welding than does conventional steel in order to obtain a component of quality consistant with traditional automotive steel. Although HSLA welding does not require new equipment, it does require alterations in the normal welding techniques as well as greater quality control.

Adhesive and Solvent Bonding

Adhesive and solvent bonding is the joining of parts with a material such as glue or chemical cement. The adhesives distribute loading stress uniformly across the entire joint area which increases the life of the joint by providing resistance to buckling, cracking, and other fatigue.

The use of adhesives in the automotive joining process is increasing rapidly. Reasons cited include low cost, relative convenience, and performance. In addition, materials such as plastic and glass can be joined without cracking or splitting when adhesives are used.

The adhesive process itself is less expensive than any other joining process and it does not add to noise or air pollution as other joining processes, such as welding, do. The drawback to increased use of adhesives is that adhesive materials have not been shown to withstand the same amount of pressure and stress as weldings and mechanical fastenings. As methods are found to increase the bonding strength of glues and chemical cements, the increased adhesive joining will reduce manufacturing costs.

Mechanical Fastening

Mechanical fastening is the joining of parts by screws, bolts and rivets. This method of joining has been vastly improved in the past few years with the development of new tension control systems. Tension control systems measure the clamping force generated in a fastener more precisely and accurately than traditional torque control can. While torque control, still the most commonly used method in applying mechanical fasteners, can only measure 60 percent of the proof load of a bolt, tension control can measure 100 percent of the proof load making a more reliable joint.

Another advantage of tension control is that it allows the design engineer to take a close look at the efficiency of the mechanical fasteners. Full use of a fastener can reduce the number of fasteners needed and therefore, cut the costs of a given unit.

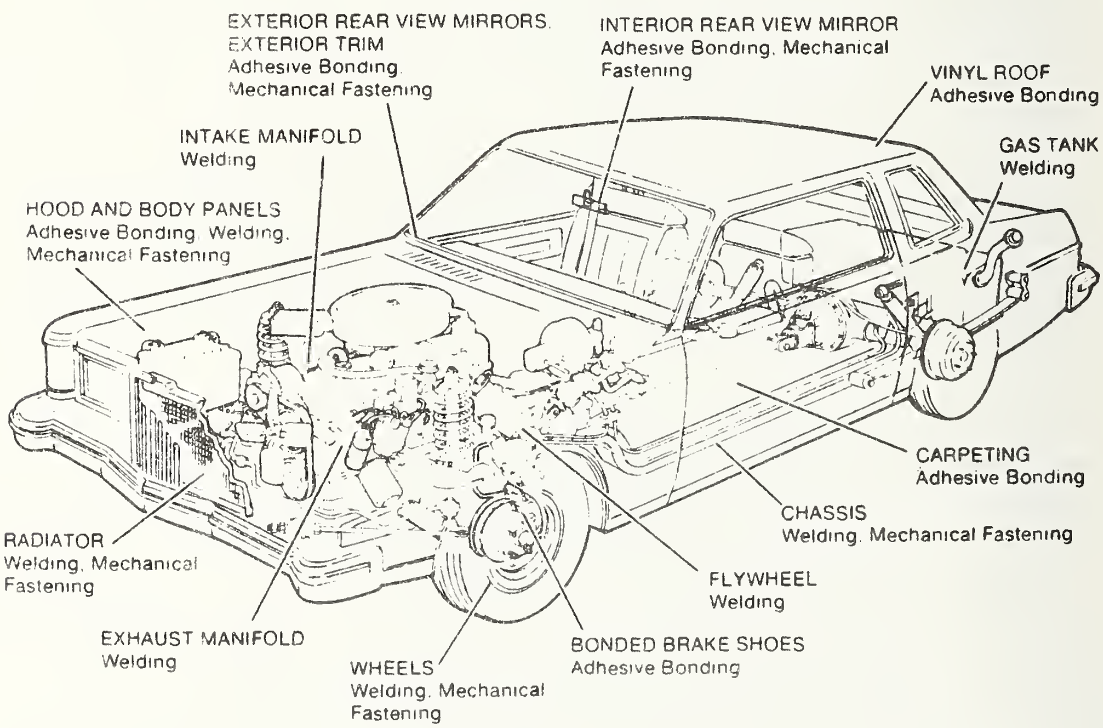


FIGURE 3-16. JOINED COMPONENTS

3.4.2 The Assembly Process

The two main types of assembly operations used in automotive manufacturing are the assembly of component parts along feeder lines within the automotive plant and by component suppliers in their own plants, and the final assembly of the automobile along the main assembly line. Assembly processes encompass almost the entire automobile and include such components as the seat and seatbelt unit, dash panel, valve and cylinder head assembly, engine block, roof, exhaust systems, fuel tank, rear and front bumpers, doors, transmission and drive train, steering assembly, battery, water pump, and radiator grille.

Feeder Lines

Assembly is first carried out on the feeder lines to produce many of the components that are then assembled on the main line. For example, one feeder line clamps together, welds, solders, grinds, and finishes body panels to form a smooth body shell which is fed to the main assembly line for final assembly into the finished car. Many of the automotive components such as engines and transmissions are fully assembled at other plants and simply placed on the feeder line supplying the main line.

Main Assembly Line

The main assembly line consists of two separate lines, a chassis assembly line and a body assembly line. On the chassis line, axles and wheel suspensions are hung on the frame, as are the completed and tested engines, transmissions, and other components from the feeder lines. On the body line, body panels are welded together, doors and windows installed, and the body painted.

The completed chassis and body meet at the drop point where they are joined. From there, the car receives minor adjustments, the steering column, gas and brake pedals are all connected, body accessories added and fluid levels filled. Checks and adjustments are made all along the line and a completed car rolls off the end.

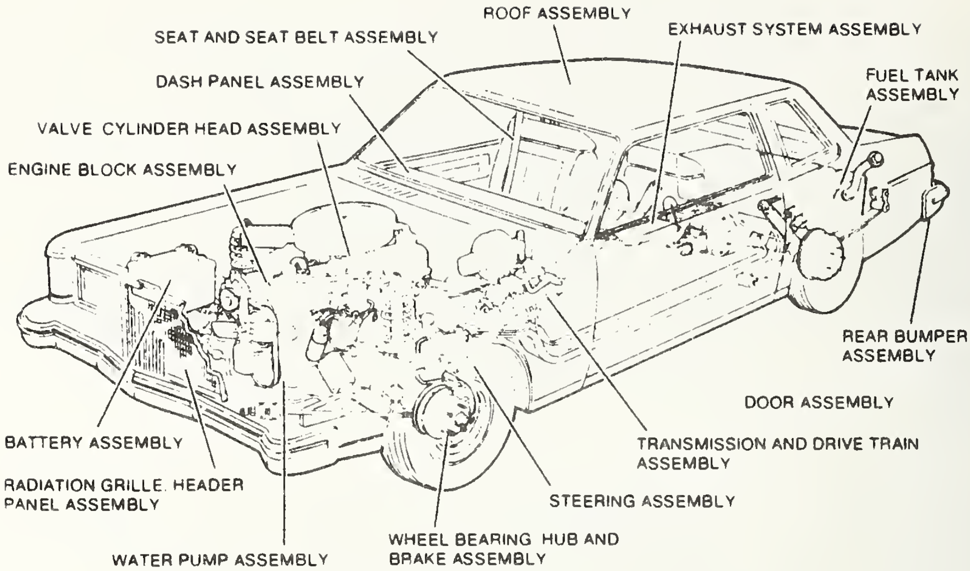


FIGURE 3-17. ASSEMBLED COMPONENTS
(Encompasses almost entire car)

3.4.3 Trends and Developments in Joining

Like all the other automotive manufacturing processes, the joining process is under pressure to become faster and more productive. And since it is so integral to the total production of a car, the joining process is under additional pressure to adapt to changing automotive component materials. Trends in the joining process in 1979 include:

- Welding—In 1979 welding shop operators, including automotive plants and non-captive shops, searched beyond electron beam methods for new ways of joining automotive parts. Developments include robots, vibration welding, and a breakthrough in adaptive controls that may eliminate the need for human welders altogether.

- Adhesive and Solvent Bonding—Use of adhesives in automotive manufacturing increased again in 1979, in part due to the use of lightweight materials in the newest models.

- Mechanical Fastening—Developments in 1979 for this joining method included a new machine designed to reduce assembly time for oil pans. And another machine went on line to speed the riveting process considerably.

Welding Is Major Joining Process

Single-phase spot welding is the major joining process used in automotive manufacturing, according to the American Welding Society (AWS). For example, welding is used to join exhaust manifolds, transmissions, flywheels, and the massive jobs of chassis and body construction. In the continuing search to do it better, faster, more productively and within government standards, the automotive industry and its suppliers in 1979 explored new welding techniques such as automation and robots, submerged-arc, vibration, high-speed electron beam and laser welding. These involved both new methods and new equipment.

While the efficiency of the human welder is relatively high in that he transfers about 15 kilowatts of energy per hour to the workpiece, the fundamental welding picture appears to have changed irreversibly. For example:

- Welding manpower continues in short supply.

- Quality control is a persistent problem.

- Government regulators are addressing themselves increasingly to the toxic compounds in welding fumes.

- Technological breakthroughs in electronics promise long-awaited universal sensors for tracking joints automatically.

Productivity is Paramount

The need for increased productivity in all aspects of automotive production is also influencing the use of such advanced equipment as welding robots. For instance, an automotive exhaust system part that takes 20 minutes to weld manually requires only seven minutes with a robot. And the robot will perform the exact job seven days a week without suffering boredom.

And the automakers increased their use of robots in 1979. At Chrysler's recently renovated Lynch Road plant, 14 new Unimate robots are making 450 welds on each auto body. The robots are fully automatic and computer controlled. They grab the workpiece, make the weld, hold the metal until the weld cools, and put the piece down. The cycle is repeated 450 times in seven minutes. General Motors currently uses 150 robots, with 32 robot welders at the Lordstown plant alone. And the Chevrolet division is moving toward a total system where the body panels are held together with toy tabs until clasped, lined up, and robot welded in one operation on the assembly line.

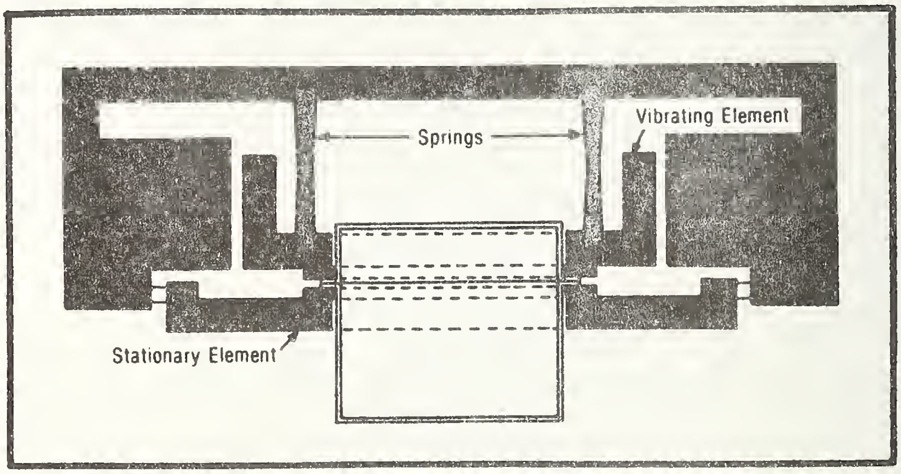


FIGURE 3-18. VIBRATION WELDER

This cross section shows major components of a vibration welder.

Source: Assembly Engineering

1979 saw increased development and use of vibration welding for joining thermoplastic automotive parts. Vibration welding is a joining process that uses friction to join plastic and rubber components. Vibration welding uses a small reciprocating linear motion. One part is fixed and the other is moved against it under pressure, generating heat that melts the material at the part interface.

The melted material solidifies and the parts are permanently bonded with joint strength approximately that of the parent material—all in six to 15 seconds, including loading and unloading.

Most thermoplastic or elastomer auto parts can be vibration welded at a high production rate. A range of dissimilar materials can be joined and part surfaces need no special preparation or cleaning. In 1979 Ford replaced its steel fuel vapor emission control cylinders with vibration welded nylon ones. Chrysler used vibration welded headlamp doors of clear polycarbonate in two of its 1979 cars.

Electron Beam Continues Growth

Also introduced in 1979 was USM Corporation's Farrell Division's new twin-chamber electron beam welder. A high-production machine with double work chambers working alternately, the welder has few moving parts, high up-time, low maintenance and dependable mechanical efficiency, according to Farrell.

The welder is a change from any existing design in that most electron beam welders feature a stationary gun and a rotating index table with multiple work stations. In a standard model, the tooling package is brought up to the gun for evacuation and welding at each index point. With the new machine, the rotating table has been eliminated and the work stations reduced to two tooling packages, each with a separate chamber. As soon as one operation is completed, the gun shifts over a few inches and the opposite positioning arm snaps the next tooling package into place.

Skid Welding Uses Laser

A new type of welding was developed in 1979 by the industry to efficiently join metals such as aluminum alloys. The process, called skid welding, uses a laser beam aimed into the interface of the two parts to be joined. The beam intensity and reflection combine to drive the beam a substantial distance between the sheets of metal.

First intended for joining torque converter housings by its developer (ITT Research Institute), the concept has been refined sufficiently so that it can be used to join aluminum gas tanks as well as some assembly tasks. And since the laser beam is directed only to the interface of the weld, the process can be used to weld coated and stainless steel as well as aluminum, since skid welding does not reduce the resistance of the outer surface to corrosion.

Strip Overlay Welding

Another welding development in 1979 centered on productivity gains with a new strip overlay welding technique developed by Sandvik, Inc. Not yet in actual use in the automotive industry, the strip surfacing process utilizes an electrode in the form of a 1.2 to 4.7 inch wide strip rather than wire. With the strip as filler metal, the arc burns all along the strip edge, so high intensity arc forces are not developed on any single point. This minimizes dilution and penetration of the base metal, a desirable characteristic due to the reduced quantity of filler metal needed.

Joining Transfer Line

Chevrolet initiated a high-volume carrousel transfer line for joining fuel tanks in 1979 using programmable controls. The line is able to run continuously at 80 feet per minute and can handle parts with six different sides, with no two being parallel. Up to 600 tanks per hour can be joined on the 22 station line.

Resistance seam welding is used to seal the tanks and there are seven welding stations at each carrousel. These include an on-line tack welding station and six direct current independent, retractable seam welders, plus an additional back-up welder. The seam welders are all synchronized to the line demands by individual programmable controllers. To keep production moving, each is set up to release a following on-line task for seam welding when a preceding one is about half through the machine.

Adhesive and Solvent Bonding

For more than 35 years, organic adhesive bonding has been in competition with other joining processes such as welding and mechanical fastening. It is the newest joining process, according to a study by the Welding Research Council. And in 1979 adhesive bonding agents found increasing automotive acceptance. These adhesives are particularly effective at holding plastics, aluminum, and HSLA steels, according to the welding council.

The advantages of using adhesive bonding for automotive joining include:

- Adhesives distribute the loading stresses uniformly over the entire joint area. This uniformity in stress distribution often increases the joint's resistance to fatigue, cracks and buckling.

- Metals joined by adhesives are not in direct contact with each other, thus reducing galvanic corrosion between dissimilar metal sheets.

- Adhesives give a smooth surface finish to joints, reducing the need for machining.

- With adhesives, no thermal compensation is needed when joining a thin structural member to a thick one.

- Adhesive bonding does not require the thick backing area needed to countersink rivets or bolts.

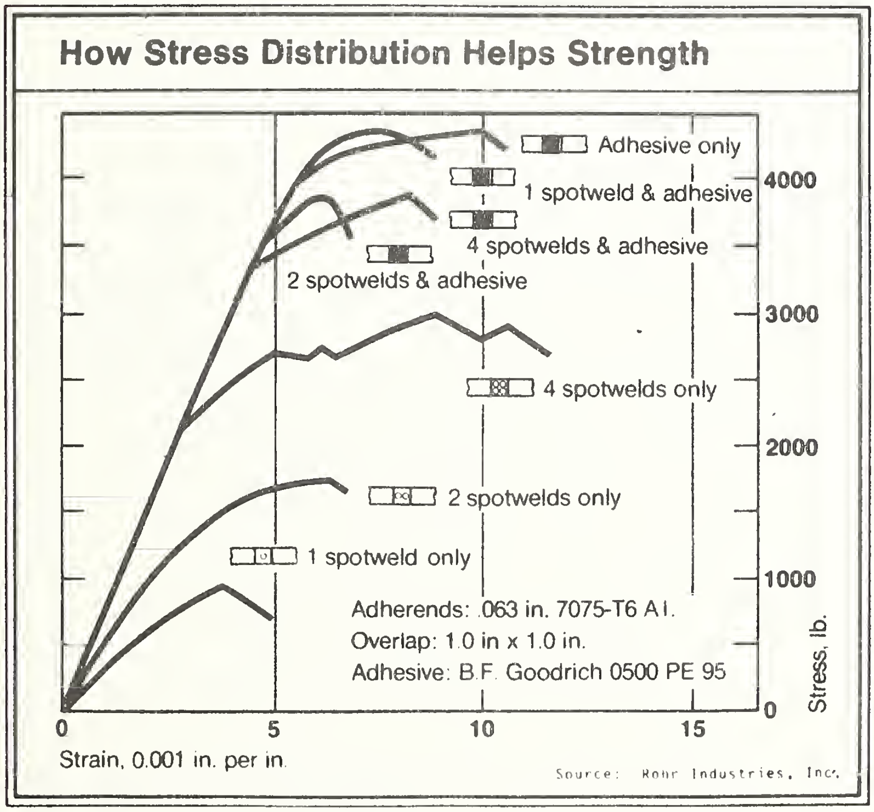


FIGURE 3-19. ADHESIVE STRESS DISTRIBUTION AND ITS EFFECT ON STRENGTH

Source: Iron Age

Automotive adhesive bonds do have disadvantages. For instance, flexible adhesives with adequate peel strength for automotive use are limited to long-term service temperatures of under 350° F. Some automotive assemblies must perform under stress in high humidity and/or in a hostile chemical atmosphere at high temperatures.

The most important consideration for adhesive bonding is that the joint be designed specifically for adhesives. Quality in adhesive bonding must be built into the joint from the start by relying on strict in-process controls. Also, bonding requires careful joint preparation, especially in metal-to-metal bonding. Proper cleaning of metal surfaces is one of the critical operations in adhesive bonding.

Overall, cost, convenience and performance were the criteria which determined use of adhesives in the automotive industry in 1979. And product design was also considered—often a simpler design is possible when adhesives were used instead of rivets, bolts and screws or welds. Also, bonding enables automotive manufacturers to reduce parts inventory, use less floor space, and less energy. And in some cases adhesive bonding is the only practical way to join two materials such as glass and metal. Automotive joining applications for adhesives in 1979 included:

- Brake shoes bonded with nitrile-phenolic to withstand impact at high temperatures.

- Back-up lights joined with urethane adhesives have good durability and low temperature properties, and the adhesive also provides an excellent wind and water seal.

- Exterior rear-view mirrors increasingly rely on silicone adhesives to provide cushioning against vibration fatigue and resistance to low temperature impact. The adhesive clings tenaciously to metal and glass, eliminating the need to drill holes or depend on crack-inducing metal clips. Applications of other exterior trim with adhesives eliminates the need to stock different fender and door panels with unique hole patterns and provides styling latitude.

- Hoods, roofs and other exterior panels depended on adhesives for stiffening as well as easy assembly and smooth finishes.

- Application of vinyl car is only possible with adhesives. Though the application is not demanding as far as strength is concerned, it does require an easy manual process with considerable open time so that the vinyl may be positioned and the wrinkles removed.

- The use of hot melt adhesives for securing automotive carpet permits high production rates and eliminates holes through the body floor and seal plate.

- Liquid gaskets and sealing casting pores with anaerobic adhesives products represent two more adhesive applications in 1979.

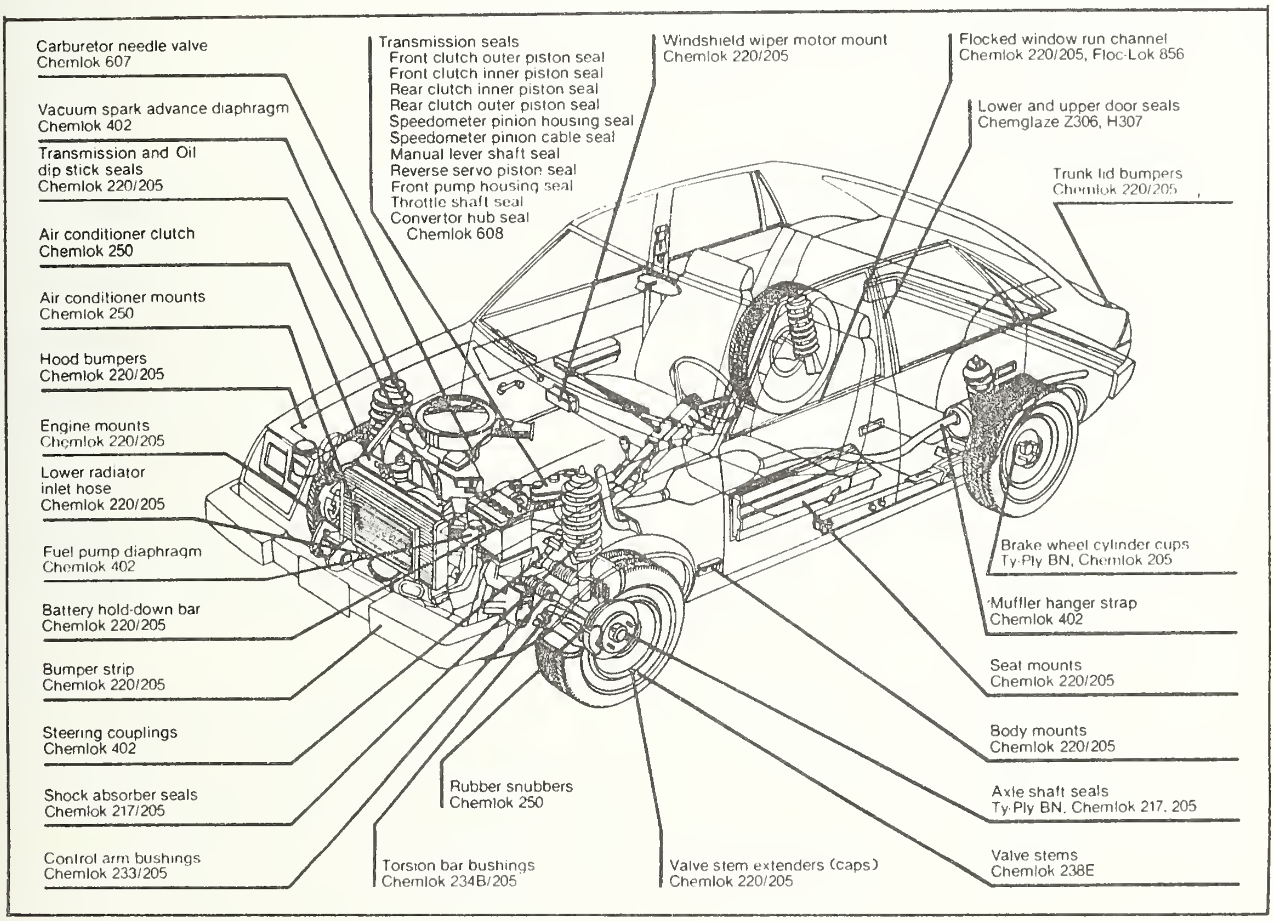


FIGURE 3-20. CURRENT ADHESIVES USED IN DOMESTIC AUTOMOBILES

Source: Iron Age Magazine

In addition to the above, automakers are expected to further expand their use of adhesives. According to Goodyear Tire and Rubber Company, major suppliers of adhesives to the automotive industry, automakers will use adhesives in the following areas in the near future:

- Doors made of lightweight structural plastic will incorporate flanges, bosses and other parts that must be attached to thin metal skins. And structural adhesive systems lend themselves to high volume production methods needed to meet the requirements of this type of door assembly.

- Other areas where structural bonding systems will be considered will be in bonding lightweight frame components and in bonding seats to car floors. Both of these applications will need to be extensively tested, but are expected to be implemented in the early 1980 models.

Ford Motor Company has already demonstrated the length to which structural adhesives can be taken in its one-of-a kind, lightweight graphite car. The model was the first car to be joined almost entirely with structural adhesives as a replacement for conventional joining methods. Adhesives were used for more than 90 percent of the car's joining needs, including most load-carrying parts. Goodyear supplied the adhesives to join the graphite-reinforced experimental plastic modified LTD. The car would have weighed 3,750 pounds, but with plastics and adhesives the weight was reduced to 1,250 pounds.

As automakers switch to lightweight material, adhesive suppliers expect the market for structural adhesives to grow 350 to 400 percent in the next five years. Some of the common automotive adhesives include:

- Hot Melt Adhesives—These are made usable by heating them to a molten state, then applying them while hot (usually above 200° F). As they cool, they adhere to the materials with which they are in contact. The U.S. market for hot melt adhesives has grown from 24 million pounds in 1967 to 240 million in 1975, and is predicted to increase to 335 million by 1980, according to the Adhesive and Sealant Council.

- Anaerobic Adhesives—These are one part liquid resins which are stabilized by air. Metal contact initiates a free radical cure mechanism only inhibited by air. Enclosing the liquids between close-fitting parts prevents air inhibition and the resins cure rapidly without shrinkage. Use of this adhesive eliminates precision machining, extra parts like fasteners and elaborate assembly methods such as press fits, splines or keyways.

- Silicone Adhesives—These are available in several automotive forms. Silicone pressure sensitive adhesives and solvent based high temperature curing silicone resins are two forms designed to meet automotive demands. The widest use is in the form of paste-like sealants which cure at room temperature into silicone rubber.

Mechanical Fastening

Mechanical fastening, or putting things together with screws, bolts and rivets, is the oldest of the three automotive joining processes. This method of joining was recently improved with the development of new tension and torque adjustment control techniques. In 1979 new equipment combining riveting with welding, making it possible to join oil pan assemblies for small cars in ten seconds, was introduced.

The machine is an eight-station indexing dial-table set up to assemble ten different components at once. It keeps two operators busy, one at the first station loading dip stick and gasket assemblies onto the table, the other at the third station loading pre-formed oil pans over a retaining die.

All other operations, including hopper feeding required oil drain inserts to the appropriate fixture, feeding and upsetting four rivets into the pan, feeding and torquing-in the drain plug, and unloading the finished assemblies, are completely automatic.

3.4.4 Trends and Developments in Assembly

The trend to more automated assembly and testing continued in 1979. The automotive assembly line of the 1980's will incorporate more robots, more quality control monitoring, more in-process gaging and checking, and more computer programming. And automated quality testing procedures help ensure proper assembly. Trends in automatic assembly and quality control in 1979 include:

- Assembly—Increased use of robots and at least six new assembly production machines—all of them automated—were introduced.

- Quality Control—Improved automatic electronic quality control systems including lasers, computers and digital readouts went on-line in major automotive assembly plants.

Assembly

Automation in automotive assembly is a direct response to the intense pressures being felt by the domestic automotive industry. Federal standards for fuel economy, emissions and safety have resulted in an avalanche of design and model changes each year and rapid weight reduction through downsizing and materials substitution. For example, Ford will launch a new car line every 12 months instead of every 18 months; it will bring out an average of one new engine a year between 1980 and 1984 compared to one every 30 months for the past 12 years. All this—combined with intense cost pressures—is producing a rush to robots and other automated processes on the feeder and main assembly lines.

Assembly Robots Highly Programmable

Assembly line robots can be infinitely programmed to perform different assignments as models change and components are re-designed. In addition to the robot manufacturers themselves, General Motors has conducted considerable research and pioneering work in the field of assembly line robotics. GM's research and development work on robots has led to the development of two new robotic systems either already in use or soon to be used in the firm's assembly line production. The Consight system, a computer controlled parts transfer system with visual capabilities, was developed by GM in conjunction with Cincinatti Milacron, Inc., and GM's PUMA system (Programmably Universal Machine for Assembly), a programmable point-to-point robot for assembly line work, was developed with Unimation, Inc.

The probable site for pilot application for the Consight system is GM's Central Foundry Division in Saginaw, Michigan. Exact application has yet to be determined, but the Consight robots, which employ solid state video cameras as their principal visual element, will probably be used to sort, place and otherwise direct automotive castings onto assembly feeder lines.

This new breed of robots embody some type of position feedback or servo control to record the position of each axis at any time.

The first production application for assembly-oriented PUMA robots in 1979 was at GM's Delco Products Division. The programmable assembly machine picks up a 450° F motor armature as it emerges from the furnace, positions it, loads a commutator ring onto it, and then places the assembly on a track that carries it to a subsequent heat treating operation.

Another dozen or so new robot designs are in experimental use at other GM assembly plants. One of the most advanced applications involve the use of a visual robot at the Delco Electronics Division. The robot inspects integrated circuit chips for electronic ignition systems.

Other automakers also experimented with additional assembly robots in 1979. At Ford Motor Company's Transmission and Chassis Division, an industrial assembly robot transfers over 50 tons of transmission cases per day from

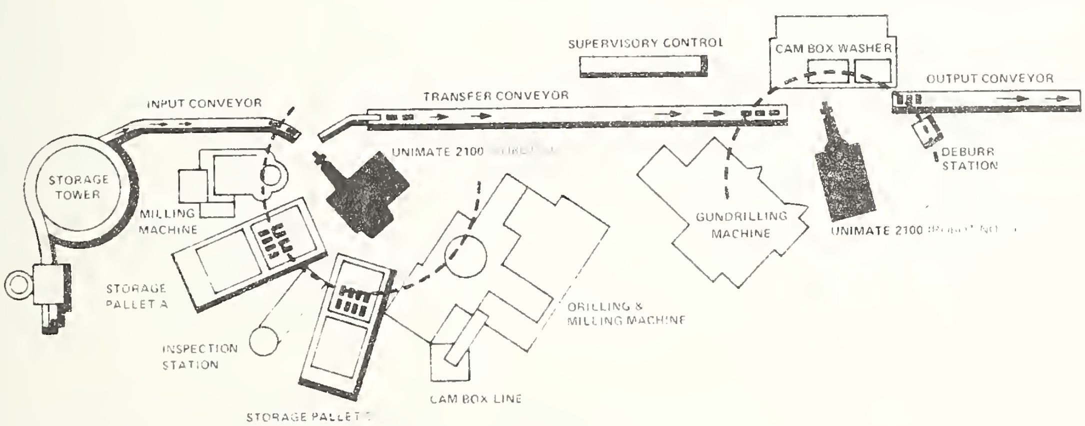


FIGURE 3-21. ROBOTIC TRANSFER LINES

A robot system developed by Unimation and Ford adds transfer-line capabilities to medium-run parts production. Operators can change robot cycles to assure the correct flow of parts, and if one machine breaks down, the work flow still continues.
Source: Manufacturing Engineering

the feeder to the main transmission assembly line. The robot has the capability to transfer three different sized transmission cases that emerge from a transfer line and inspection station, and is programmed with a memory system. The memory unit is designed to be removed and replaced in less than 30 seconds. Ford has approximately 255 programmable robots at its various North American automotive assembly plants. And last year Chrysler ordered 90 to 100 programmable robots for use in 1980 on its assembly lines.

Automated Automatic Transmission Assembly

Other assembly innovations in 1979 include a large, automated, palletized front-wheel drive transaxle assembly line designed for Ford's Batavia plant by Bendix. The system, largest such system ever built according to Bendix, will be used to assemble Ford's ATX three-speed automatic transaxles for subcompact cars in 1980.

Composed of three non-synchronous, oval-shaped sections, the assembly system has 156 assembly, inspection, checking and testing stations linked together by more than 1,500 feet of conveyor. It is capable of handling approximately 300 different parts and as many as 15 versions of the ATX assembly. Although the system is almost totally automatic, it is so large that 67 operators will be needed as monitors. The system uses 350 pallets to move components and will cost Ford about $10 million.

Other automatic transmission assembly developments included a new machine that automatically places eight solid plastic balls, used to control the flow of transmission fluid, in each transmission valve body within four seconds. The machine receives an incoming valve body and indexes it to horizontal ball-placing position, inserts seven one-quarter and one five sixteenths inch plastic balls, and releases the valve for further assembly.

Carrousel Transfer Lines

Two carrousel-type transfer lines were developed in 1979 (by Cargill Detroit Corporation) to speed-up universal joint and wheel assembly. Used to assemble universal joint components for Ford at a Dana Corporation plant, one of these systems is a 19 station non-synchronous machine that performs automatic loading and assembly operations on two malleable iron parts, a center yoke and a flanged center socket, at one time. The $22 million machine has a 22 second cycle time and turns out 325 parts an hour.

Automobile wheels of varying sizes are assembled automatically for further processing at the rate of 733 per hour by a nine station carrousel machine introduced in 1979. The system assembles wheels 13 to 17 inches in diameter and 4 to 10 inches wide with less than 30 minutes needed to change from one size to another, according to its developer (Newcor). Assembly is completed in six steps. After loading, the machine presses wheel discs into rims, MUG arc-welds them and pierces each one for a valve stem whole; it then stamps each assembly with a code number. Each cycle, including transfer, is said to take five seconds. The loading station is followed by an idle station which allows the operator to orient a rim and position a disc before the line takes over.

Electronics Parts Assembly

Electronic parts assembly is an integral aspect in the total production of every car. In 1979, computers were utilized to ensure fast and reliable assembly of electronic parts at the Oldsmobile Cutlass Assembly Center. Cutlass assembly and subassembly takes place on several conveyors specially designed to maximize operator efficiency. The chassis is transported down the line, and is automatically shifted for ease of subsequent parts assembly. Separate lines feed major in-house assembled subassemblies to the chassis transporter line where needed. Total length of the assembly line is over five and a half miles, according to company spokesmen.

Basic body wiring and engine electronics are in place and functional when they arrive at the final assembly line. Instrument panel wiring is subassembled per computerized order code lists that travel with the assembly. Controls are progressively added as the assembly travels from station to station.

Quality Control

The technology of testing and quality control on the automotive assembly line is rapidly changing. Some of the reasons for this rapid growth include Federal safety and emissions standards, product liability laws and consumer concern over product quality. And while some automotive testing has taken on a space-age flair, hot and cold engine testing still occupies center stage at most assembly plants.

Cold Testing

Cold testing, driving engines with compressed air, hydraulically or electronically, is newer to the industry than is hot testing. Cold testing can handle most engine functions, except emissions, automatically.

A cold test system for the Ford 1981 Erika is intended to detect, with the aid of a computer, imbalance, noise and vibrations that may indicate engine flaws. Operators control the computer, and check things the machine cannot detect. Further hot testing analyzes emissions, temperature, vacuum and timing.

Lasers Enter, Stage Left

Ford, as well as the other automakers, has shown great interest in lasers in the past year or so. Special laser gages have been installed to inspect for the presence of an undercut in a U-joint bearing cup. At a feedrate of 200 parts a minute, the bearing cups are rotated while scanned by the laser. Scan and static laser beams check dimensions and presence of parts on transmissions at the rate of 350 an hour at Ford's Batavia plant.

At a General Motors plant, laser beams are reflected from the surface of a valve lifter after face grinding and are detected by an optical receiver where they are transformed into electrical signals. An electronic processor evaluates deviations and generates a signal for part rejection if needed.

Electronics are also being used in other ways to improve quality control on the assembly line. Working with outside electronics and computer firms in 1979, Ford developed half a dozen non-contact testing gages which are unique to the industry. Some of the gages or inspection machines use lasers while some use conventional light sources. All employ sophisticated computers and reading devices that inspect each part.

Thin, flat washers must be present on both ends of small revolving gears in Ford C-4 automatic transmission assemblies. Until this year, these were checked by hand, now they are checked by laser. Another noncontact gage inspects axles using a conventional light source, projecting bulbs focused by lenses, to instantly determine the gear ratio of the axle.

3.5 MACHINING AND FINISHING

Machining operations are among the most precise in the entire automotive manufacturing process, and are basically the cutting off of excess material from a casting or forging by using specialized machinery. The cutting operation gives the piece being machined a particular shape or finish. While some machine tools cut material off as shavings, pieces or large chips; others saw, drill, bore, hone or grind by cutting away fine particles of the material. The equipment itself ranges from large, automatic multi-operation machine tools to small, handheld drilling or grinding devices.

3.5.1 The Machining Process

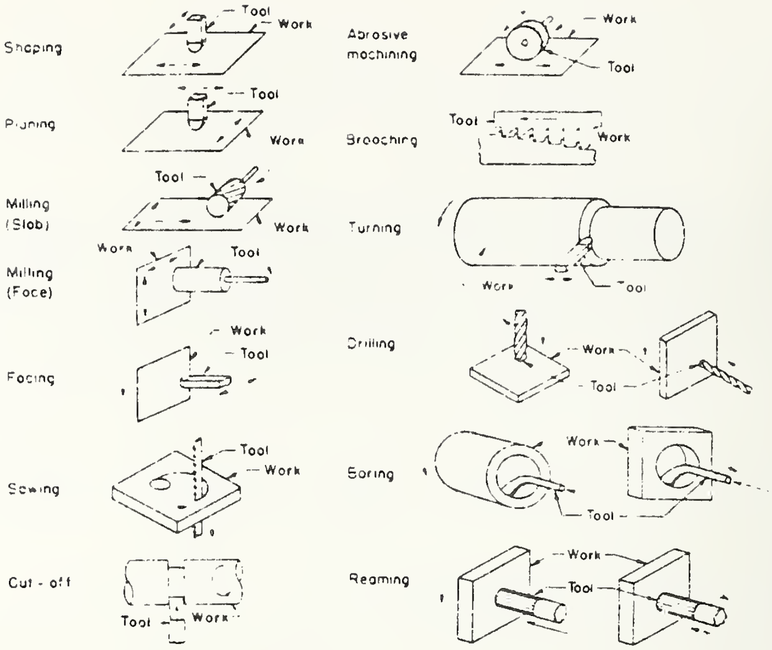
The basic determinants in selecting a machine tool for a particular assignment are the desired configuration of the component to be machined, and the surface characteristics of the material being machined. For machining purposes, surfaces are considered to be flat, flat contoured, curved, externally cylindrical (turned), or internally cylindrical (bored). As such, machine tools are divided into three basic groups:

- Cylindrical Surface Machine Tools—Machine tools intended primarily for cylindrical surfaces include drilling and boring machines, vertical and horizontal lathes, grinders and broaching machines.

- Flat Surface Machine Tools—Machine tools intended primarily for flat surfaces include milling machines, vertical and horizontal planers, shapers, surface grinders, and nibbling machines.

- Trimming and Parting Machines—Machines intended primarily for trimming or parting of material include circular and band saws, and flame cutters.

Many machine tools can handle more than one surface classification, although each is intended primarily for a particular application. A schematic representation of the basic machining processes is shown in Figure 1.



Source: Materials and Processes in Manufacturing, 4th Ed., E.P. DeGarmo, 1974.

FIGURE 3-22. SCHEMATIC REPRESENTATION OF BASIC MACHINING PROCESSES

Machining operations of some kind are needed on most mechanical automotive components. Examples of major machined components include:

- Carburetor body
- Valves
- Cylinder head
- Camshaft
- Engine block cylinder bores
- Crankshaft
- Pistons
- Disc brake rotors
- Transmission case
- Rear axle housing
- Brake drums.

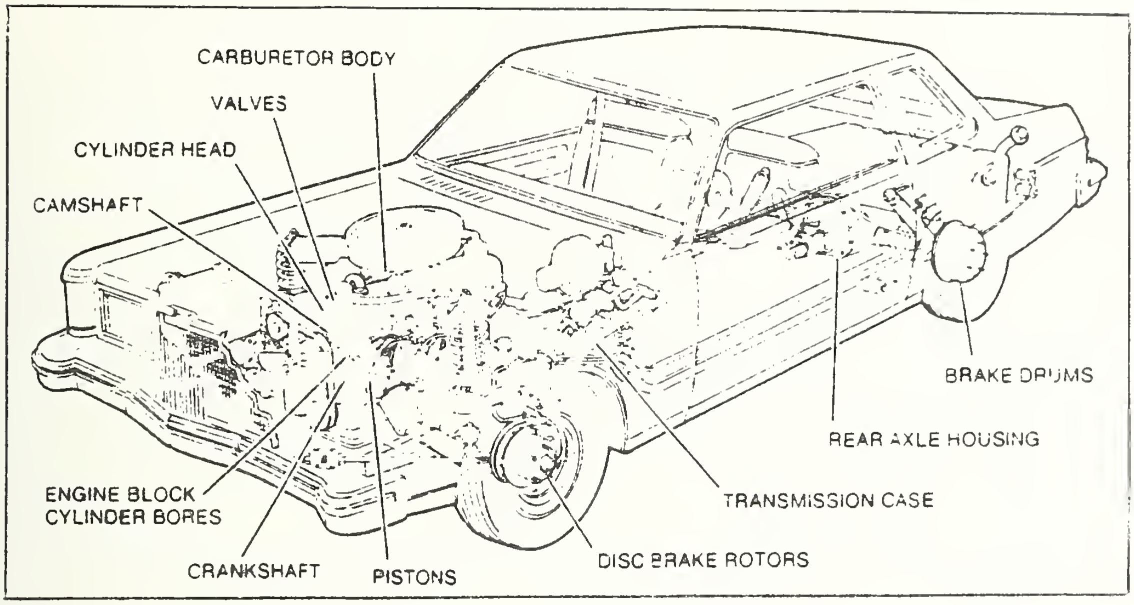


FIGURE 3-23. SCHEMATIC DIAGRAM OF AUTOMOBILE SHOWING PARTS AND COMPONENTS WHICH ARE MACHINED

3.5.2 The Finishing Process

Finishing, as its name implies, is the last operation performed on each automobile before it is ready for final assembly and market availability. It is during this stage that all of the rough edges are smoothed down and the protective coatings applied.

Unlike the majority of other automotive manufacturing processes, some type of finishing is necessary for almost every component in the car, from the interior all the way to the chassis itself. It is important to note, however, that these components do not necessarily go through each phase of the entire finishing operation.

The basic finishing processes include:

- Metal cleaning
- Mechanical finishing
- Electroplating
- Painting and corrosion protection.

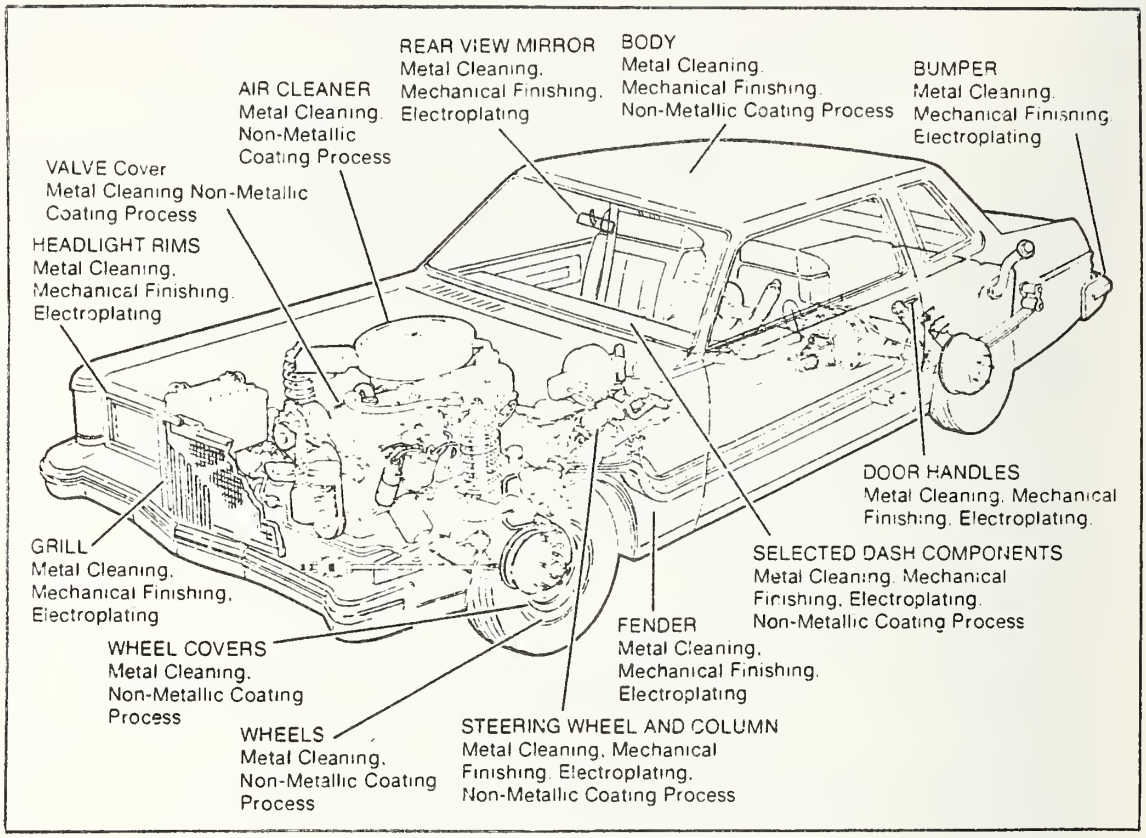


FIGURE 3-24. SCHEMATIC DIAGRAM OF AUTOMOBILE SHOWING PARTS AND COMPONENTS WHICH ARE FINISHED

3.5.3 Trends and Developments in Machining

The increasing shortage of skilled labor—which affects nearly all the manufacturing processes—is nowhere more critical than in machining operations. Machining is by its very nature a precise and highly skilled trade, and an unavailability of competent machining operators cuts at the very core of the process.

In addition to instituting training and recruiting programs both locally and nationally, machining operations are adapting automated machinery at a torrid pace. And in the past year, the pace continued in all phases of machinery, primarily in computerized numerical control (CNC). But there was grumbling within the industry about the wholesale adaptation of numerical control, computerized or otherwise.

Other significant developments include:

- New, harder cutting tools gave longer tool life and less downtime.

- Centerless and high-speed grinding increased grinding productivity.

- High speed broaching grew in importance to the automotive community.

- Machining operations responded to safety and effluent regulations with innovative shop designs and practices.

Automation Steps Up The Pace

Numerical control (NC)—the concept of controlling many of a machine's operation by some sort of repetitive control, such as punched tape—is now more than two decades old, and it has been enhanced greatly in recent years by computerization and called computerized numerical control (CNC).

At first numerical controls were added to existing machining equipment, but today most numerically controlled machines are built with the NC an integral part of the machine. And increasingly, the NC has been enhanced with the addition of a small computer (CNC).

The Turning Center Emerges

Within the past year or so, some within the machine tool industry have begun calling their computerized turning equipment "turning centers" to indicate how different the new machine tools are from their earlier manually operated brethren.

Simplified Programming

The most significant trend in CNC is a move toward control and software improvements to simplify programming and reduce the time programming consumes. In the new machines, the operator himself can alter the machine's cycles.

In many cases, when machining operations are extremely complex and volume high, more sophisticated computer programming is required than can be done manually, and outside time-sharing—or an integral computer—is employed to achieve the lowest possible overall programming and machining costs. Most CNC controls now placed on machine tools can operate alone, at the machine, or as part of a central computer-controlled network.

Computer Controlled Feed Selection

General Motors has developed a computer aided system to select machine tool feed and speed rates. Now in use at GM's Delco Products Division in Dayton, Ohio, the program covers all pertinent characteristics of the workpiece, including selection of the proper machine, cutting tool, and type of machining operation.

The program currently involves 20 machine tools at the Delco plant, used in batch-type production of electric motor and generator parts. Ten of the machines are NC

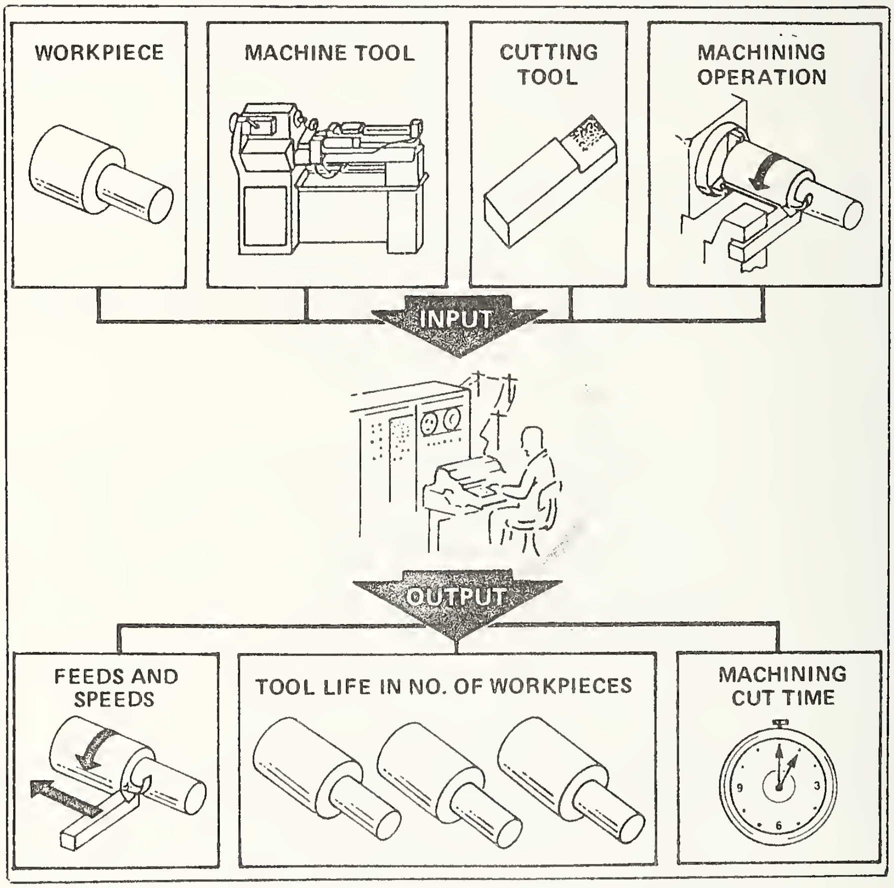


FIGURE 3-25. FEATURES OF GENERAL MOTORS' COMPUTERIZED MACHINING CENTER

units, and the machine mix includes lathes, vertical boring mills, and chuckers.

A GM engineering spokesman reports that the computer control is based on specific input data for each application that arises, rather than data taken from a handbook. The results are productivity improvements as high as 50 percent in certain operations, plus improved overall quality and better control of surface finish. Engineers can specify a certain finish, and the computer gives the proper feedrate to achieve the finish.

A side benefit has been lower tool costs. The computer program helps identify when a tool is worn out, which avoids changing a tool prematurely or leaving it in too long.

NC Turns Out Drive-Train Components

In an automotive manufacturing operation that exemplifies the current dependence on NC and CNC, a machine shop supplier of transmission housings, drive axles, steering axles and hydraulic control valves has progressed in less than a decade from a small shop with manual machining operations to one utilizing 23 NC machines in addition to conventional equipment. One third of these machines are turning centers devoted to specific part production.

In machining cast iron transmission housings, the machining center mills the location surfaces and drills location holes. It then finishes the mounting side of the housing, and bores and drills it. The part is then turned over to face, rough and finish bore, and chamfer the motor mounting side. The entire operation is automated.

A similar cycle nearby machines cast aluminum transmission housings. But this machine works in tandem with an automated pallet changer, which moves another casting into position and unloads the already-machined part automatically at the end of each cycle. The pallet changer then positions the machined part at another segment of the machining center, where inner surfaces are turned, faced, bored and chamfered—all at the command of the turning center's numerical controls.

After machining, the housings go directly to assembly. All of the turning centers can handle workpieces weighing up to 2,000 pounds, and feature five-second tool changes.

This shop's management reports that NC gives it lower manufacturing costs through savings in machining time, increased equipment versatility and, perhaps most important, allows them to operate in a rural area where trained, journeymen machinists are virtually nonexistent. The accuracy and repeatability enables the shop to meet its production schedules while still developing a skilled workforce.

New Cutting Tools Decrease Downtime

The past year or two has seen a whole new breed of cutting tools for machining. The new tools have come about as a result of potential shortages in key materials and demands for greater productivity. They are, by and large, based on ceramics.

The principal objectives in developing the new tools were: longer service life between sharpenings (which cuts downtime); stronger, more reliable cutting tools to lessen sudden tool failure (often with catastrophic results); cutting tools that perform equally well with or without coolants; and systems capable of monitoring and reporting tool wear. All of these are production-related goals, and are reason enough to seek harder new tools. But there are other reasons.

High prices and shortages of cobalt, traditionally used to make cutting tools, and technical improvements in ceramic cutters have led to increased use of the latter. And ceramic cutters are now performing machining operations with greater speed. Rough turning of disc brake rotor surfaces, for example, now requires a cutting time of only 10 seconds, when it previously took one minute. Ceramic boring of heat-treated crank and pin ends of steel connecting rods has shortened the operation from a 50-second cycle to a 30-second cycle, with speeds increased from 1,400 rpm to 8,600 rpm.

The advantage that ceramics bring to the workplace is their ability to withstand extremely high temperatures. Increased cutting speeds generate so much heat, for instance, that they induce plastic flow in the cutting tool's shear zone, reducing cutting forces. Ceramics keep right on going under such circumstances.

There are two types of ceramic tools--"cold-pressed" aluminum oxide types and "hot-pressed" cermet (or ceramic/ metal carbide) types.

Cold-pressed ceramics are widely used in turning, facing, boring, milling and threading soft cast iron, hot-rolled and cold-drawn carbon steel, brass, bronze, and aluminum.

Hot-pressed ceramics are newer developments being used increasingly to machine hardened steel, chilled cast iron, superalloys and other hard materials.

With their potential for higher productivity, intense research is underway at several universities to further improve their properties. Most research is centered on maintaining closer control over the development of excessive porosity in the tool's microstructure during manufacture.

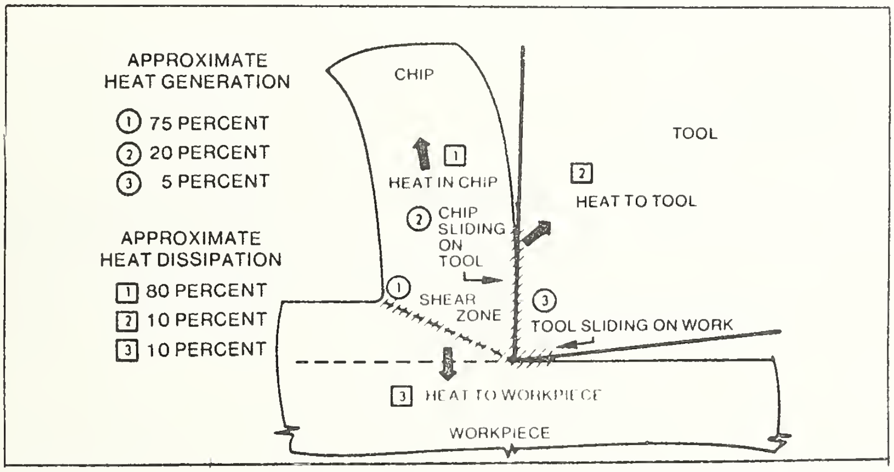


FIGURE 3-26. HEAT GENERATION AND DISTRIBUTION WITH CERAMIC TOOLS

Typical heat generation and distribution in metal cutting. Ceramic tools dissipate heat into chip as well, or better, than other types without the use of coolants.

Grinding Grows in Importance

Rigid parameters of part downsizing, higher speeds of part-moving equipment, more critical applications, and the drive to reduce equipment failures have prompted a trend to increased use of centerless and high speed grinding.

Centerless grinding is accounting for a growing segment of automotive machining largely because the process can use any type of round steel bar stock. Even abrasion-resistant alloy steels--nickel, molybdenum and chrome--can be ground to precise part shapes and sizes.

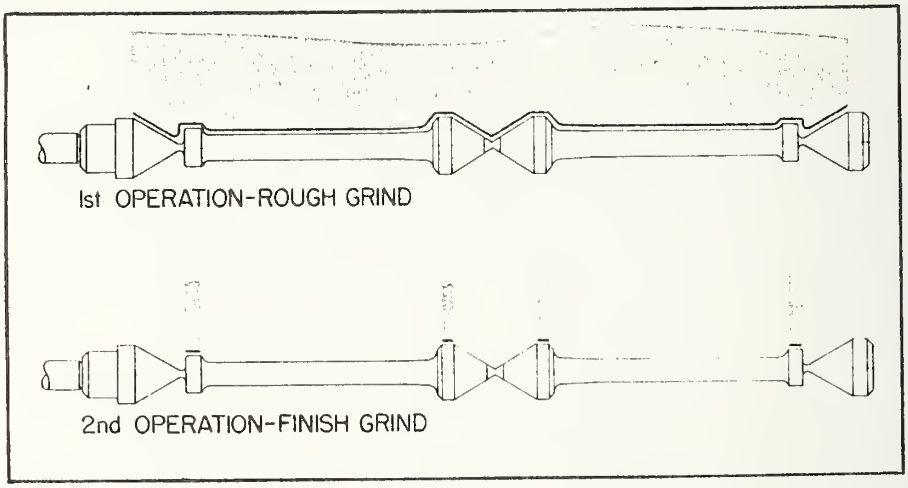


FIGURE 3-27. CENTERLESS GRINDING

Steel bars (at top) are centerless ground to form a torsion bar. Almost the entire bar length contacted the wheel during rough grinding; four small sections contact the wheel on the finish grind (lower sketch).

Multiple diameter and contoured components are now being ground on automatic centerless grinding equipment to meet several specific criteria: when tolerances need to be closer than .004 inches in volume production; heat treating distortions have to be corrected; and finishes must be better than 125 microinch.

Machinists at General Motors have been plunge grinding (high speed grinding) medium carbon steels at ultra-high speeds up to 36,000 surface feet per minute. For the most part, grinders operate at 6,500 to 8,500 surface feet per minute.

Research to date has concentrated on medium carbon steels, used for parts such as wheel hubs and spindles. Productivity is increased through faster metal removal rates. Part quality is improved by exposing the workpiece to increased grinding from a high-speed wheel in a given length of time, permitting lower grinding forces.

Diamond Grinding Wheels

And automotive uses of diamond grinding wheels increased during the past year. One automaker replaced silicon carbide abrasive wheels with diamond wheels to regrind face-milling cutters. The cutters are used in machining cast iron engine blocks, cylinder heads, and other components.

Tests run with the diamond wheels yielded time (to grind) savings, decreased maintenance and improved machine life, and less noise in the work area. Grinding time decreased by 25 percent and dust was virtually eliminated because of the closed structure of the grinding wheel.

The lack of dust produces less wear and tear on the machinery, as well as the operator. And the elimination of high-speed whine has made OSHA inspectors happy.

Deburring More Critical

Downsizing is making deburring of parts and components more difficult and more critical, especially in the manufacture of smaller automotive transmission pinion gears, valve bodies, and clutch pistons.

In selecting the deburring media to be used, there must be a careful examination of part material, type of burr, part shape, and burr location.

Ford is now using blasting to deburr its transmission clutch pistons, abrasive belts to deburr transmission races and barrel tumbling to deburr transmission valves.

Electromechanical Deburring Arrives

Electromechanical Deburring (ECD) uses both electricity and chemicals to remove burrs. It is a fast method, suitable to a wide variety of metals. It is also one of the few processes that does not require a tool which cuts, scrapes, abrades, or otherwise touches a burr.

But it is a high technology process which requires more care, skill and knowledge than many older, conventional processes. ECD can deburr areas totally untouchable by other methods.

ECD, which is applicable to all sizes of burrs, selectively works only in one area and exerts no cutting forces which would distort thin sections.

Perhaps one of the most economical methods currently available to remove burr from a wide variety of shapes and sizes of metal parts in low, medium, and mass produced quantities is localized mechanical deburring.

An outgrowth of the buffing and polishing method of surface finishing parts, localized mechanical deburring machines apply many of the production concepts once used for those processes.

Broaching On the Increase

Broaching machines have been put into service in increasing numbers by the automakers and their suppliers. Broaching, the shaping of metal by pushing or pulling a multiple tooth, bar-like tool across a surface or through an existing hole in a workpiece, is used to produce internal gears and racks and gear segments.

Several large, high speed broaching machines are being used to produce axle, wheel-end and differential components for Ford. The components are being produced by the Dana Corporation of Toledo on new broaching machines supplied by General Broach and Engineering of Detroit. One machine, used to broach forged steel differential side gears, is a 30-ton pull-down unit with a broaching stroke of 60 feet per minute and a retrieval speed of 100 feet per minute. The potential production rating of the machine is 1,000 side gears per hour.

Two other pull-down machines installed at Dana's Fort Wayne plant manufacture wheel-end knuckles for Ford cars. The machines broach between caliper arms on the knuckles. And a newly introduced machine is designed to broach solid steel steering column shafts. The machine is capable of broaching and deburring 1,326 steering column shafts per hour. GM's Saginaw Steering Gear Division's Alabama plant is using the machine to broach two 0.115 inch deep slots in 0.550 inch diameter extruded steel bar.

In the first application of pot broaching in the domestic auto industry, Delco Remy, in an effort to streamline production capacity, purchased a pull-up pot broaching machine with automatic loading and unloading capabilities to replace six conventional gear hobbing machines. Made by National Broach and Machine Gear, Division of Lear Siegler, Inc., the new machine is used in production of steel starter motor pinions for heavy duty diesel engines.

Pot broaching, a special broaching technique gaining increasing acceptance in high volume manufacturing, uses broaching tool inserts inside a broach holder, called the pot. And unlike conventional broaching, where the broach is moved against or through the part, the parts to be machined are pushed through the pot, usually in one pass. A pot broaching machine was put into operation at GM's Buick Motor Division to produce 12 external lugs on 5½ inch diameter cast iron final drive gears. Ford utilizes broaching in its transmission hub-making system. And GM's Detroit Diesel Allison Division uses broaching for manufacturing external straight tooth gears for heavy duty automatic transmissions.

Broaching Automatic Transmissions

Broaching equipment manufacturers say much of the new business they're receiving from the automotive industry is due to the development of new fuel-efficient transmissions, both front and rear wheel drive. The development of entirely new generations of transmissions and transaxles that are smaller, lighter in weight and more efficient has led to a need for smaller components of somewhat different design, and new smaller broaching tools.

The business press reported that U.S. manufacturers of broaching machines and tools were enjoying a boom in sales due to healthy conditions in their customers' markets and a general increase in demand for more productive equipment. To fill existing orders, many broaching machine manufacturers were operating two shifts, six days a week.

The development of new, more fuel efficient transmissions has naturally required retooling for large scale production of the new gearboxes. Recently the Olofsson Company shipped 60 turning machines to Ford's Transmission and Chassis Division in Livonia, Michigan. The new machines will be used in the machining of cast and forged parts for Ford's new four-speed automatic transmission with over-drive. Fifty-six of the machines feature automatic loading and unloading. And ten of the machines employ three spindles each and are capable of machining three parts at a time. Price tag for the 60 machines—$11 million.

Additionally, the tooling programs for these new transmissions have afforded automotive manufacturers the opportunity to upgrade the productivity of their equipment, resulting in increased demand for high production equipment, such as pot broaching machines and automated machines.

But while auto downsizing efforts in the drivetrain have brought about a vigorous demand for broaching equipment, downsizing efforts under the hood may be producing the opposite effect. The advent of thin wall cast and aluminum engine blocks has signaled a widespread move to milling, rather than broaching, of engine blocks. The reason--high forces in the broaching process create strains that cause cracking and breaking in the new, lighter engine blocks.

New Tooling, Old Transfer Lines

General Motors placed orders for several million dollars worth of engine tooling transfer lines—for an aluminum Cadillac V-8, Chevrolet V-8, and Chevrolet and Oldsmobile V-6 diesels—while Ford continued tooling for its own V-6 engine program. But the automakers also found ways to utilize their old lines for new applications.

Unlike the manufacture of Ford's new transmission, which requires an extensive re-tooling, GM has been able to utilize its existing gasoline engine machine tools in the manufacture of 5.7 liter diesel engines. GM's Oldsmobile Division, which builds all GM diesel engines, has developed several new machining techniques to handle the increased pressure and durability requirements of the 5.7 liter diesel engine piston. The diesel piston differs from the normal gasoline engine piston in several respects. These include the addition of: cast-iron insert for top compression ring, floating piston pin requiring additional retaining ring grooves, valve-clearance pockets, and specific piston skirt contour.

Machining the cast iron insert proved particularly troublesome, since it requires machining ring grooves in both cast iron and aluminum on the same machine tool. Oldsmobile uses eight-spindle chucking lathes for this operation. These lathes allow one group of spindles to turn at one speed while other spindles turn at a different speed. One speed cuts aluminum, the other cast iron.

Additional machining operations were also required to machine retainer ring grooves in the piston-pin bores and cut valve clearance pockets in the top of the piston. For the latter operation, a plunge-cut milling station was added to existing equipment, and the valve clearance pockets are cut on one machine that converts from one valve pattern to the other by operator selection of the milling head.

After all machining operations are completed, each piston assembly is inspected using specially built air or electronic gauges.

By utilizing existing equipment—with modified procedures—and maintaining a production rate similar to that for a conventional piston, Oldsmobile is keeping the conversion to diesel for many of its 5.7 liter V-8 within reasonable cost limits, and keeping its normal engine assembly time schedules undisrupted.

And the new equipment the company is buying is compatible with either gasoline or diesel engine production. It was reported in September (1979), for example, that the Olds engine plant had purchased a 20 station weight milling transfer machine capable of balancing three types of gasoline engine pistons as well as two types of diesel engine pistons. Manufactured by Synder Corporation of Detroit, the machine uses a Modicon 384 programmable controller.

The machine pre-weighs the aluminum pistons for either bottom milling or milling of the side lugs, and then performs the milling operations and check weighs the parts. It automatically rejects parts that are out of tolerance. The weight tolerances are held to plus or minus one gram.

Production rates vary for each of the five types of pistons, but average around 850 parts per hour.

Ford's purchase of cutting systems was part of a major retooling effort necessary to produce two new automatic rear drive transmissions for its passenger cars, beginning with the 1982 and 1983 models. Ford sources have estimated that the company will need more than $100 million worth of new manufacturing equipment to accommodate the two new transmissions. Ford says it is sticking with the rear wheel drive cars because it believes these conventional drive systems will continue to be popular with the American public in the 1980's.

In the production of another transmission component, machine tool technology has been imported from Japan. It was reported in April that Ford Motor Company had ordered a big transfer-type metal cutting system for lock-up torque converter housings from Japanese special machine tool builder, Toyama Machine Works, Ltd. The system is to be installed at Ford's Sharonville, Ohio, transmission plant and will cost between $4.6 and $4.7 million, or about $500,000 less than the cost of a domestically-produced cutting system.

Like Ford, Chrysler is also tooling up to produce transmission components. Production of gears used in its front wheel drive transverse engine passenger cars, such as the Dodge Omni and Plymouth Horizon, will soon be produced on new spur and helical gear cutting equipment produced by Gleason Works of Rochester, New York. The new machines are designed to significantly decrease the costs of cutting spur and helical gears up to 14 inches in diameter, and can produce gears three to ten times faster than hobbing and shaping machines currently on the market.

Besides producing the main drive gears for front wheel drive transverse engine cars, these machines cut transmission gears for cars, trucks, buses, tractors and construction equipment. Fully tooled, the machines are priced at between $450,000 and $500,000.

3.5.4 Trends and Developments in Finishing

In addition to the constant search for more cost-effective finishing methods, automotive finishing management must now wrestle with the increasingly stringent demands of Federal effluent discharge restrictions, worker safety and health, better corrosion resistance, and the intense search for new and lighter automotive parts and components.

Several significant developments during the past year promised to help the industry improve its performance toward all these goals.

New Plastic Coatings

The increased use of plastic components which must stand up to stress, wear and weather has initiated the application of several new coating techniques.

These new plastic finishing developments include such operations as a new solvent-recovery system that enables conventional solventborne coatings to meet federal emission standards while providing energy savings of up to 90 percent.

Greatly improved waterborne (WB) coating, such as a series of high performance urethane-based coatings, came into automotive use within the past year. They are noted for their low emissions, special performance features, and economy in storage. These improved WB coatings are designed to meet automotive specifications in terms of hardness, impact, abrasion, appearance, gloss, humidity, and watersoak performance.

Automotive applications for WB coating, because of its high resistance to wear, include topcoats for vinyl upholstery--now being used in 1979 Volkswagens produced in this country.

The newly-developed WB technology was matched this past year by developments in existing solventborne (SB) coatings. New one-step SB systems for finishing polypropylene increased possible applications for this material. Available since 1970, this single-step coating method suffered from severe limitations due to its poor gasoline resistance and low pencil hardness. Improvements in 1979, however, have resulted in increased gasoline resistance and hardness.

Good gasoline resistance is especially important because gasoline, which comes in contact with untreated PP components like certain automobile dashboards, could create deformity in the component.

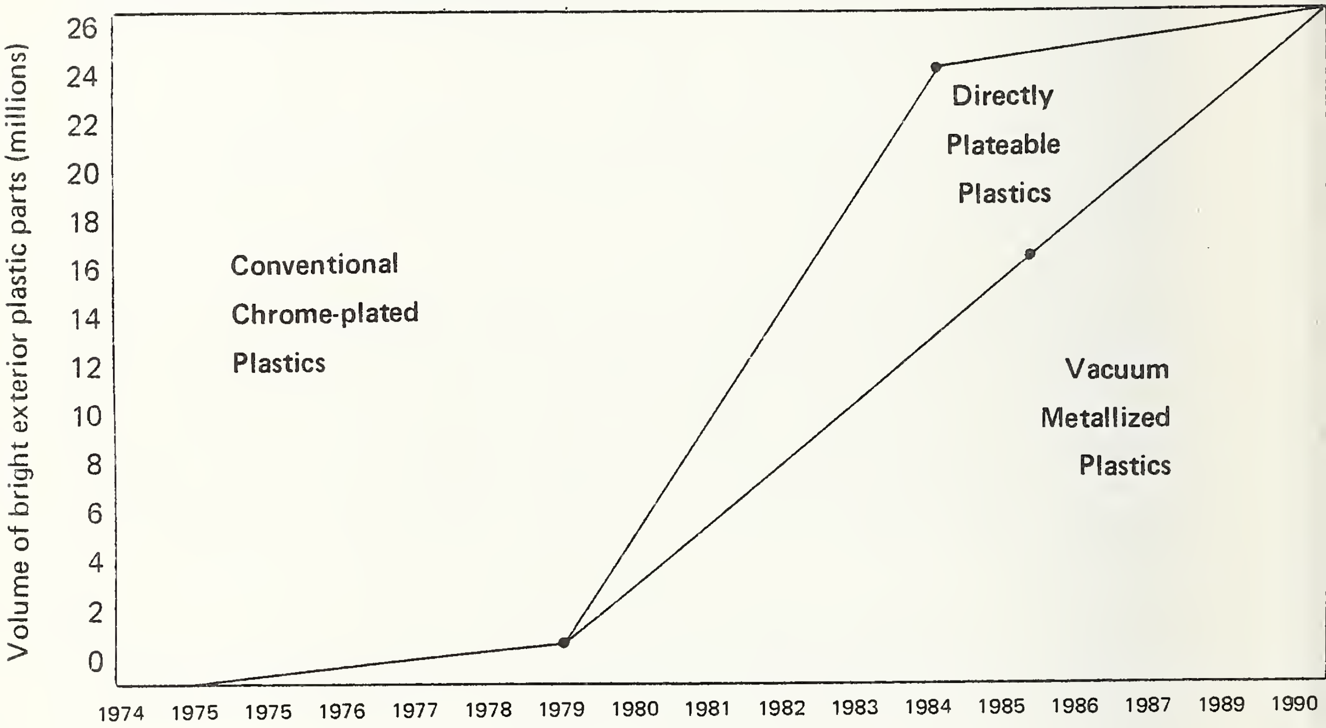
Sputtering (Sputter Coating)

One of the most highly significant new trends in finishing is sputtering. The sputtering operation--a refinement of vacuum metallurgy--involves depositing microthin films of chrome alloy on parts in a partial vacuum chamber. The chamber contains an argon atmosphere which is loaded with chromium and, in operation, "attacked" by excited argon ions. Automakers and their suppliers increased their use of this technique in 1979.

In operation, the ions bombard the metal targets, sputtering or chipping off the chromium atoms, forming a cloud within the chamber and fogging the parts with a thin layer of chrome.

This entire process uses only 20 percent of the energy consumed by conventional electroplating. Also considerably lower is the amount of pollution emitted by sputtering. Because it is a closed-loop system, the problem of disposing with the toxic chemicals encountered during electroplating is virtually non-existent.

In addition, overlay paint adhesion on metallized parts is greatly improved, compared to overlay paint adhesion to chrome plate.



Metallized Parts		Caprex Parts	
1975	0		
1979	1,000,000	1979	0
1985	14,000,000	1985	10,000,000
1990	26,000,000	1990	0

FIGURE 3-28. SPUTTER COATING AT CHEVROLET

Prediction of Chevrolet usage of vacuum metallized (sputtered) and directly plateable plastics.

These three advantages, combining with the enormous cost reduction (the February, 1979, issue of AD&D reports a potential $21 million annual cost savings for Chevrolet if all of the 26 million chrome-plated exterior plastic parts on Chevrolet vehicles were sputtered in-house instead of plated at outside sources), make sputtering increasingly popular.

Exterior use of metallized parts had been limited, because of an absence of test procedures, to quantify sputtering's abrasion resistance. But GM reports that cosmetic durability has been enhanced to such a point that sputtering is being used for entire grilles on certain cars.

High Volume Urethane Application

A high-volume, completely automatic urethane application system is now being used at Chevrolet's pressed metal plant to prime seal plastic front header panels.

Urethane's attractive properties—low-temperature cure and coating toughness—have long appealed to the auto industry, but its toxic nature had restricted its use. The system, therefore, is being carefully controlled and monitored to ensure safe handling of the toxic component.

The new finishing system is contiguous to presses where the plastic panels of a new design replacing seven metal components (eliminating half the weight) are molded from sheet molding compound (SMC).

Protecting Aluminum

The increasing popularity of the chrome-plated aluminum bumper to help reduce vehicle weight has been made possible by the increasing use of a pre-treatment process called Alstan 80.

Developed by M&T Chemicals, Inc., Alstan 80 is a necessary step if the chrome-plated aluminum bumper is to accept the required copper, nickel and chromium platings.

After the bumper is cleaned, etched and desmutted, the Alstan 80 process, which consists of a micromolecular coating of tin, is applied in a few-second dip into a bath. This is followed by another flash bath in which the bumper is electroplated with a coat of bronze.

Following the process several additional applications are made before the bumper system, estimated to be 60 percent lighter than comparable steel systems, is complete.

Dow Corning Corporation has also been working on a new concept in surface protection for aluminum wheels, bumpers, trim and other aluminum components.

Dow's concept involves application of a new, clear silicone material to aluminum automotive parts by conventional dipping, flow-coating, rolling, spraying or brushing techniques.

Dow says the material, which is a very thin, hard hybrid material evolved by chemically bonding extremely small inorganic particles into a silicone resin matrix could be used as an alternate to the Alstan process for coating chrome-plated aluminum bumpers.

High Speed Plating

General Motors (GM) has developed a process that they believe can plate such metal parts as pistons, shock absorber rods and front-wheel suspension units anywhere from 10 to nearly 100 times faster than conventional techniques.

In GM tests of this high-speed plating (HSP) technique, eight minutes were needed to coat bearings with a 127-cm thick alloy of lead and tin. Conventional plating completed the same process in approximately 80 minutes.

For chromium, GM says HSP takes about one minute for a 25-cm deposition, compared to 60 minutes conventionally.

Cathodic Electrodeposition Fights Corrosion

In an attempt to curb the ever-increasing costs to consumers of metallic corrosion, one manufacturer (PPG) introduced a method of corrosion resistant finishing it claims is capable of achieving several times the corrosion resistance of previous methods.

The process, called cathodic electrodeposition, employs electric charges to apply the primer coat to automobiles.

Operating on the principle that opposites attract, materials carrying positive electric charges are drawn irresistibly to materials than bear negative charges. Currently about one-half of the automobiles produced in the U.S. are primed in tanks using cathodic electrodeposition.

The increased corrosion resistance stems from the fact that, with this process, all surfaces and edges can be covered with a continuous and evenly deposited coating.

Frame Plant Builds In Rust Prevention

In another significant anti-corrosion development, A.O. Smith Company, the largest automotive frame producer in the world, has altered its steel preparation procedures to add rust-prevention to the automotive frames it ships to the automakers.

By adding a water-soluble acrylic-resin coating to the final solution the steel is dipped in prior to forming, and using barium hydroxide as a neutralizing agent, the firm can now leave formed and stamped frame parts in outdoor storage for up to 30 days without rusting. This means that an overproduction of parts at various areas in the continuous manufacturing line can be alleviated by simply storing the excess until it is needed, rather than shutting down the entire line.

The company also reports that the changes in steel preparation also made the steel easier to stamp and form.

Honing Improvements

A new metal bond stone introduced this year (by General Electric) promises improvement in honing. Traditionally a low-speed surface finishing operation, honing removes stock by chewing action of abrasive grains. The key to improved production rates is the abrasive stone used, which GE asserts increases production rates dramatically.

Another manufacturer, Ex-Cell-O Corporation, says its metal-bonded diamond, superabrasive hones are "the wave of the future."

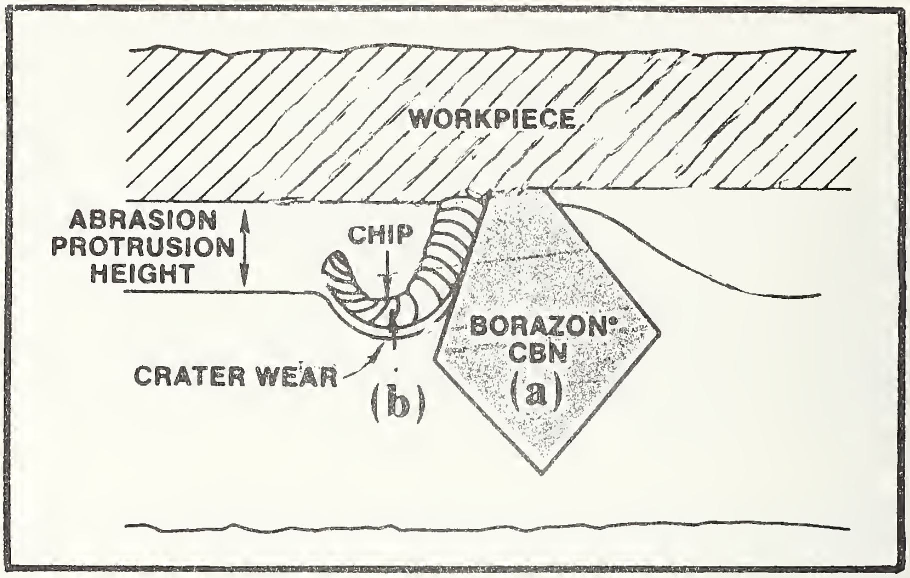


FIGURE 3-29. NEW HONING TECHNIQUES

A typical Borazon CBN crystal during honing operations. As a chip is generated, it wears a crater in front of the crystal. The chip is carried around the sides of the crystal as the stone is reciprocated during honing.

Although these hones do not improve the production rate, transfer line uptime is improved significantly. In use, five sticks are placed around the diameter of the tools which fit into each of six spindles. The depth of the diamond grit is related to the number of parts the operator wishes to finish per set.

The sticks are currently in use to finish the bores on a Chevrolet six-cylinder engine, using water as the coolant.

4. TRENDS AND DEVELOPMENTS IN AUTOMOTIVE MANUFACTURING MATERIALS

4.1 GENERAL

In the intensive weight-trimming campaign currently underway in Detroit, materials are playing a central role. And their pivotal posture involves both newly developed materials as well as new applications and refinements for older ones.

To some extent, a chicken-and-egg relationship prevails between new materials development and innovative applications by the automotive industry: auto designers and manufacturers need factual data on new material properties, to optimize usage; and material developers need over-the-road material behavior and manufacturing production data from the automotive industry to modify properties toward expanding usage and quantity production.

One outcome of the intensive search for lighter materials and designs has been the active participation of materials producers in the development of car component design and fabricating techniques until recently the exclusive province of car manufacturers.

All Face Same Challenge

And although each of the material groups has a unique role to play in today's automotive scene, they all must attempt to help the automakers by providing:

- Lighter weight with equivalent or greater strength
- Improved—or at least satisfactory—production qualities
- Competitive pricing structure
- Satisfactory availability.

Examples of new combinations of materials and designs, and attendant issues and problems that surfaced in 1979 are highlighted in the sections that follow. Four materials in the vortex of the automotive manufacturing revolution—high strength/low alloy steels, aluminum, plastics and graphite composites—will be considered.

4.2 HIGH STRENGTH STEELS

Since the early adoption of mass-production techniques by the automotive industry, regular low-carbon sheet-steel has served as the car builders' workhorse metal. Until recently low-carbon steel offered the optimum combination of cost, strength, modulus and fabricability. More recently, with the necessity of improving gas mileage by lightening the vehicles, designers turned to using higher strength, low-carbon steels at reduced thicknesses. But there was a catch: the addition of carbon and manganese, which gave steels strength and hardness, decreased ductility (formability) and weldability.

Metallurgists resolved this problem by developing a family of high-strength low-alloy steels (HSLA). These steels were strengthened by the addition of microalloying elements such as columbium, vanadium, titanium, and zirconium; or low levels of alloying elements such as silicon, chromium, molybdenum, copper and nickel. HSLA steels are designed to be 1.5 to 3 times stronger than low-carbon steels, and therefore make it possible to reduce car component weight some 15 to 25 percent.

Over the past few years GM 980X dual phase low-alloy (DPLA) steel was developed by General Motors Research Laboratories. This material, now produced by all major steel manufacturers, may be the single most dominant steel used by the auto industry by the mid-1980s.

This steel has good formability when it goes into the stamping press; then it picks up considerable yield strength after it's stressed or worked in the die.

4.2.1 Strength Causes Problems

HSLA's greatest attributes—superior strength in a lighter-weight sheet—are also stumbling blocks to its increasing use. HSLA requires greater press loads to form it into the many sophisticated contours in the modern automobile, and it often refuses to stay where it is put—it springs back toward its original flat state. Refined forming techniques and modified HSLA alloys will be required to overcome this problem.

In the initial process of learning to use the higher strength steels, a variety of other problems have been encountered, including: material inconsistency from batch to batch, surface defects, spot-welding difficulties, stretched-edge failure, and in some cases incapacity of some old presses to provide the higher loads needed for shaping the tougher materials.

In fact, some HSLA applications introduced on 1979 models were called back and temporarily abandoned because of technical and economic considerations. Among the delayed HSLA applications are the left- and right-hand front-frame rails on Ford's full-size LTD and Mercury Marquis models, and the wheels on GM's Cadillac Eldorado, Buick Riviera and Olds Toronado.

Earlier this year unacceptably high scrap rates in production of HSLA steel wheels for GM's Eldorado, Riviera and Toronado caused a reduced build schedule for those cars. However, a company source indicated GM has no plans to discontinue use of HSLA wheels.

The material was a DPLA steel with an 80,000 psi yield strength. A GM source indicated the problems they were having were attributable to material inconsistency.

4.2.2 HSLA Trends and Applications

The major auto manufacturers were in general agreement in 1979 over projected usage of HSLA. Ford spokesmen have been especially vocal in this respect, claiming that their cars use more HSLA than any other make in the auto industry, and that Ford has led the industry in the development of some HSLA applications that also include frames. One Ford estimate projects HSLA usage is growing in their average passenger car from 115-120 pounds in 1978 and 180-190 pounds in 1979, to 220-230 pounds in 1980, and to 400-465 pounds in 1985.

This growth, according to Ford product and business planners, will progress through three phases of usage:

Phase 1: Now under way, emphasizing the use of phosphorized (for added strength), or 40,000 psi (yield strength) steels will affect Ford's 1979, 1980 and 1981 model years and continue through the 1980's. Most applications in this phase will involve exposed components like hood and door panels.

Phase 2: This phase will begin slowly in the 1980 model year and progress through 1983, before leveling off; it will involve unexposed structural components made of cold-rolled steels. In this phase Ford expects to use more SAE 980-type, dual-phase steels in the 80,000-100,000 psi range, and ultra-high-strength steels. Some component and/or tooling redesign may be needed to work these tougher materials.

Phase 3: Projected to be mostly beyond 1983, the objective of this phase will be to determine the theoretical maximum usage of HSLA. Both component and tool redesign are expected for most of the parts and materials to be used. Materials will include phosphorized, SAE 950-980, dual-phase 60,000 to 140,000 psi, and ultra-high-strength steels in combination.

The ultra-high strength steels that have recently become available in sheet began in 1979 to be tested for use, without expensive tooling and costly modeling. Engineers may now analyze critical stress areas in car component designs, by computer, and determine what physical properties would be desirable in the steels to be used.

GM executives also see high-strength, low-alloy steels, together with thin-wall ferrous castings, playing an even more significant role in progressively reducing the weight of future cars. They also feel that because much of this material will be so-called specialty steels, it will command special prices.

Chrysler Corporation is equally optimistic about the structural integrity of high-strength steel applications. And as far as feasibility is concerned, Chrysler technical people report experiment results showing that thinner, lighter car parts of high-strength steel would function as well as heavier parts of mild steel. Extrapolating from these findings, GM experts have said: "Instead of building 30 percent of a car with high-strength steel, we can build all of it of high-strength steel."

Foremost among the optimists who see a great future for high-strength steels is U. S. Steel Corporation, the major producer of Dual Phase 80 (80,000 psi yield strength). U. S. Steel estimates that Detroit will be using up to a million tons of dual-phase steel by 1985. The U. S. Steel forecast, issued in 1979, also projects the automotive high-strength steel market by 1985 to breakdown into the following demand categories:

- 60 percent of demand will be for 35,000 to 55,000 psi yield strength steels.

- Over 31 percent will be for dual phase steels.

- Approximately 8 percent of the market will go to the 60,000 to 100,000 yield strength steels.

- Approximately 1 percent of the market will be for 100,000 to 160,000 psi yield strength steels.

New HSLA Applications

Newly introduced 1979 and 1980 model year high strength steel applications include:

Ford's Thunderbird and Cougar XR-7

Front fenders
Hood outer panels and hinges
Front-door outer panels
Wheel spiders
Rear-floor crossmembers
Axle tubes
Rear suspension upper and lower arms
Engine mounts
Cowl side-extension panels
Rear floor crossmembers
Upper and lower rear suspension

Lincoln

Front door outer panels
Rear-axle tubes
Door hinges and intrusion beams

Ford Mustang

Rear suspension U-arm bracket
Rear seat-belt anchor
Rear bumper isolator mounting
Fuel tank strap, front
Front side member, upper
Front fender apron, upper and lower
Body brackets
Rear spring, upper
Rear suspension lower and upper mounting
Guide rear bumper isolator
Door intrusion beam

Bumper isolator brackets
Engine mounts
Rear suspension arms
Front shock mounting bracket (spindle)
Wheel spider
Rear brake shoe web
Front/rear bumper (2.8L and 2.3L turbo and all Ghia)

Chrysler Mid-size Station Wagon

Luggage load floors
Rear-seat filler-panel assemblies

Dodge Mirada

Reinforcement bar between body structure and bumper

Dodge Omni and Plymouth Horizon

Hoods
Doors
Deck lids

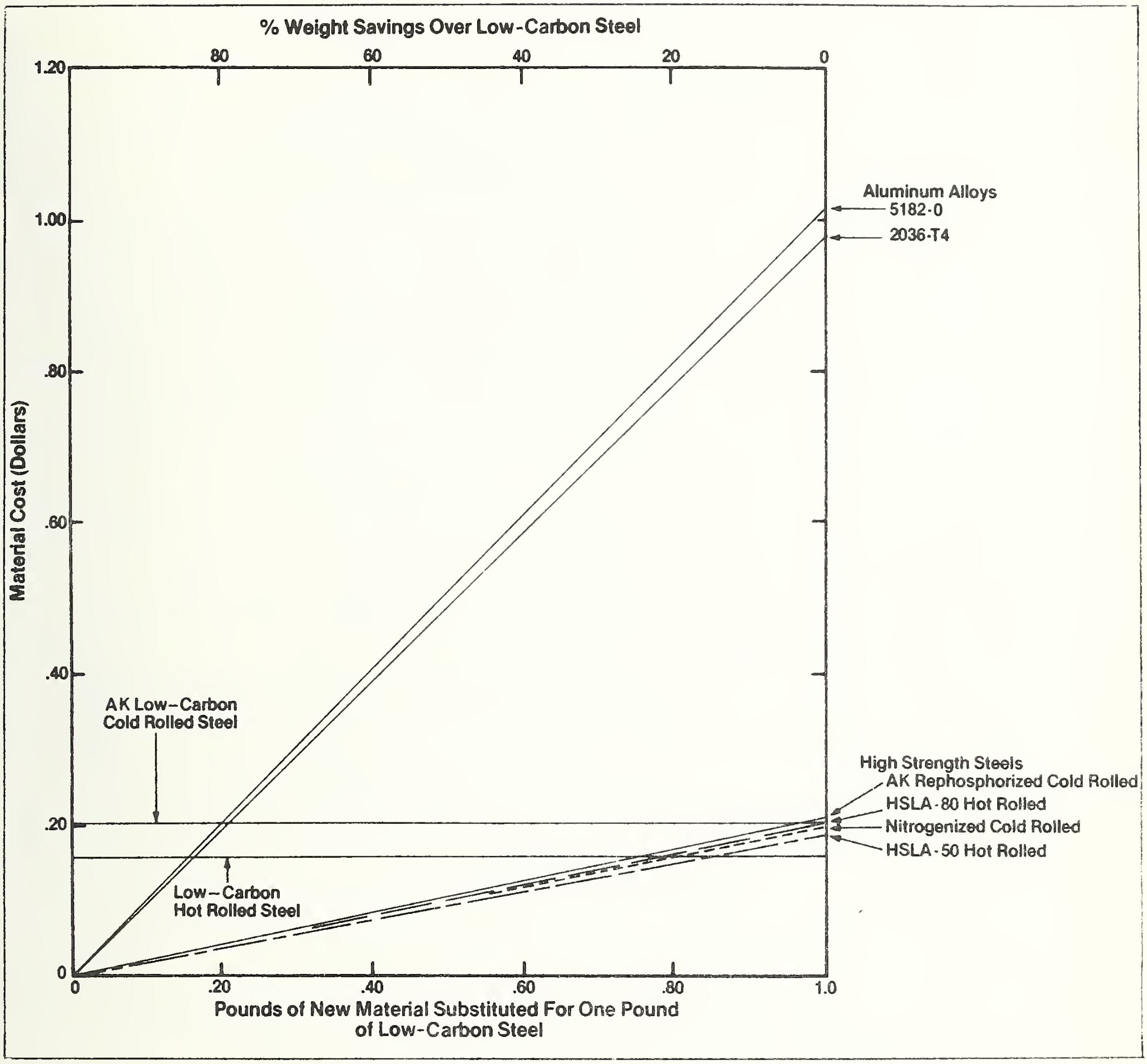
Cadillac Seville, de Ville and Brougham

Bumper-face bar (dual-phase - 80,000 psi yield strength)

Pontiac Grand Prix

Front bumper

In summarizing today's competitive situation between high-strength steels and aluminum in the automotive sector, the American Iron and Steel Institute (AISI) maintains that for any given weight reduction, substitution with high-strength steel is, in general, cheaper than aluminum (see chart). However, says the AISI, a complicating factor has entered the picture: legislation aimed at reducing fuel consumption provides monetary penalties for non-compliance. And this situation, AISI feels, has altered the economics of automobile weight reduction to the point where some aluminum components are economically more attractive.



Source: American Iron and Steel Institute

FIGURE 4-1
COST OF WEIGHT REDUCTION THROUGH MATERIAL SUBSTITUTION

The cost of reducing the weight of a low-carbon steel component by substituting a high strength steel or an aluminum alloy is shown here.

4.3 ALUMINUM

As a light and workable metal, aluminum has been around for some time in the transportation industry, yet it has been used only sparingly by car manufacturers. This is primarily because low carbon steel entrenched itself early in the automotive development as the most economical, all-purpose material available—and it remains the most economical. The limited entry of aluminum into car design and production is attributed to the inherently energy-intensive nature of primary aluminum production methods, and their sensitivity to rising energy costs.

Bauxite is the raw material for aluminum production and it is refined in "alumina plants" into alumina, an oxide of aluminum. In a separate smelting plant, or primary aluminum plant, the alumina is converted into aluminum. This process requires a powerful electric current to wrest the aluminum from the oxygen.

Molten aluminum is usually cast into ingots which are shipped to fabricating plants for further processing. The most important aluminum products for the auto industry are sheet products and castings. To make sheet products, the ingots are sent to rolling mills where they are rolled into flat sheets or coils. For castings, the primary ingots are sent to aluminum foundries where they are re-melted and cast into new products.

4.3.1 Trends and New Applications

Today aluminum sheet stock comes in an increasing variety of thicknesses and mechanical characteristics developed through special combinations of cold-work and heat-treatment. Basically there is no lack of technology to be blamed for the slow adoption of aluminum in cars.

From the car builders' viewpoint the major problem with aluminum is its rising price, which is motivating them to experiment with other light materials. After a round of aluminum price increases about a year ago, one irritated GM vice president commented: "Would you believe they've increased aluminum prices by an incredible 54 percent in the past year?"

Price Brings Reaction

Following another price increase, word went out to GM vehicle divisions to get as much aluminum off their car and truck designs as possible, and to eliminate aluminum from future programs where practical.

As a result of this dictum, some unprecedented last-minute changes were made on 1979 cars. Just before introduction of 1979 models, Oldsmobile dropped aluminum hoods and bumper reinforcements, while Buick eliminated the aluminum rear deck lid on the Regal. And other GM divisions eliminated some small aluminum parts.

Ford, in turn, backed away from some massive aluminum bumper programs, and Chrysler changed its plan to use several hundred thousand stamped aluminum wheels on some of its 1979 models.

Were to Serve as Fleet Tests

These aluminum deletions were significant because the programs were major fleet tests before the components would be accepted for much wider use in the coming years. The auto companies haven't turned away from aluminum, but seemingly intend to acquire field-test experience at a slower rate than originally planned.

The resulting reduction in demand, added to the aluminum industry's existing concerns, provides little incentive to expand facilities and boost production toward improving prices. Aluminum producers' concerns were voiced recently by Alcoa economist Louise L. Wilson at the American Mining Congress annual convention. She said the construction of new plants is presently inhibited by rising power prices, lack of new uninterruptible power, and the heavy cost of meeting ever-stricter environmental rules in most parts of the western world. Meanwhile, aluminum demand continues to increase worldwide at about 4 percent per year.

Casting a look at future needs, aluminum industry analyst Steward R. Spector of Oppenheimer & Co. sees aluminum supplies continuing to grow progressively tighter through 1983, with aluminum prices rising faster than the inflation rate. His forecast of a 66-cent-a-pound domestic ingot price before the end of 1979 was on target, and he is now expecting to see a 70-cent tag by the mid-1980's.

Aluminum Applications Continue to Grow

But despite the automakers' concern over aluminum's weight/cost relationship, aluminum made significant inroads into areas that not too long ago were solely the domain of iron and steel.

- An impressive new application for aluminum involves the housings for Ford's new automatic-overdrive transmission which weigh 39 pounds each as raw castings, and 33 pounds as finished parts. Each casting incorporates the bell-housing, front pump and valve body into a single integral unit, which Ford reports is the largest and most complex die casting they have ever produced. Ford makes about 60 percent of these cases, and NL Industries, Inc.'s Doehler-Jarvis Division and GM's Central Foundry Division supply the other 40 percent.

- Another major application in the growing use of aluminum is Ford's use of cast aluminum manifolds on its 4.2 liter V-8 engine. This represents a truly high-volume application. The manifolds are supplied by Cast Metal Industries, Inc., Farmington, Michigan, and Metalloy Foundry Co., Tupelo, Mississippi. Ford makes its own stamped and assembled aluminum hoods as standard on its new Lincoln and Mark VI.

- A third major aluminum innovation involves stamped frames and pans for a light, shell-type, split-bench seat assembly used in GM's 1980 Cadillac de Ville. General Seating Division of Lear Siegler, Inc. produces these components. There are also reports that Ford plans to introduce cast aluminum blocks on a V-6 for the 1980's.

- Aluminum's attractiveness to the automakers may also be enhanced by a new protective coating that Dow Corning has developed to preserve the metal's natural bright appearance when polished. The coating is described as a thin, hard, hybrid material evolved by chemically bonding extremely small inorganic particles into a silicone resin matrix. Dow Corning claims the coating is suitable for aluminum wheels, bumpers and exterior trim and resists abrasive action from road use and washing. They assert that it will withstand years of exposure to weather without breaking down.

Usage to Double, Says Study

The average domestic passenger car today incorporates 110 to 114 pounds of aluminum, and based on recent increases this usage is expected to approximately double by 1985, according to a 1979 Battelle Institute study. This study forecasts that demand for aluminum castings in vehicles (excluding cylinder blocks) will nearly quadruple from the 385,000 tons of 1976, to 1.54 million tons in 1991. However, says the study, the tonnage for cast aluminum engine blocks will grow slowly during this period.

GM projections for cast aluminum demand are considerably more conservative, as are estimates for sheet aluminum usage. GM feelings about aluminum usage may perhaps typify the feelings of most auto manufacturers at the moment. GM purchasing activities estimate some 55 pounds of cast aluminum parts were used on the 1978 composite car. And they think this may reach about 100 pounds on the 1987 car, with primary uses for intake manifolds, water pump housings, and other engine accessories. They indicate there may possibly be also some aluminum cylinder heads.

When it comes to aluminum sheet usage, however, GM buyers seem less certain about its future. Approximately 50 pounds of sheet aluminum is used on GM cars now, and they think this may go up to 70 or 80 pounds by 1987. "If we had our choice, there are a lot more materials preferable to aluminum sheet, and that is primarily because of cost," GM purchasers report.

4.3.2 Aluminum Components Introduced on 1980 Model U.S. Built Automobiles

New aluminum applications introduced in 1980 model vehicles include:

American Motors Corporation:

- Chain case and differential housing for the new lightweight transfer case in four-wheel drive Eagle models
- Cast aluminum wheels on certain Jeep models.

Chrysler Corporation:

- Rear bumper of Dodge Mirada
- Forged wheel options for all Chrysler midsize cars.

Ford Motor Company:

- Aluminum and/or bumper-reinforcement bars in some new Lincolns
- Cast-aluminum wheels on T-Bird and Cougar XR-7.

General Motors:

- Intake manifold for Oldsmobile's new 5-liter V-8 engine
- Radiator supports for selected Buick intermediate models
- Decklids and hoods on some Pontiac Bonnevilles
- Hoods for Oldsmobile Toronado Ninety-Eight and Eighty-Eight models
- Pistons on Pontiac's 4.3 liter, small block V-8
- Cast-aluminum wheels on Chevrolet's Camaro
- Aluminum brake drums with cast-in-iron liners on Buick's full-size and intermediate cars
- Differential housing and supports on the Corvette
- Cast wheel options for all Buick Century and Regal models.

4.4 PLASTICS

The prolific strain of made-to-order synthetics, collectively called plastics, makes up the most rapidly growing category of contestants in the automotive light materials race.

The term "plastic(s)," is used to identify a category of material that: (a) contains one or more organic polymers (substances composed of recurring molecules) of heavy molecular weight; (b) is solid in its finished state; and (c) at some stage in its conversion into finished articles can be shaped by flow.

Starting with the invention of semi-transparent "celluloid" in 1868, and later used as side curtains on early carriages and motor vehicles, this industry now markets well over 4000 varieties of commercial plastics. Estimates indicate close to 40 billion pounds of plastics are produced in the US today, of which some 2.3 billion pounds are of the reinforced variety.

Land transportation is the largest single market for reinforced plastics, accounting for 57 percent of the total composite poundage. This market, consisting mainly of cars and trucks is projected by the Society of Plastics Industry (SPI) to show a conservative gain of 9 percent in 1979, and reach 580 million pounds.

Steady Growth Accelerates

The history of plastics use in cars, which reflects a steady growth in recent years, has generated bullish forecasts for the future. In 1965, the average car contained only 35 pounds of plastics. By 1968 this usage doubled, and by 1974 it doubled again to 152 pounds.

The typical 1979 GM car incorporates 185-190 pounds of plastics, which is expected to increase to about 210 pounds by 1982, according to GM sources. There are even optimistic forecasts today that project plastics usage in the average American car close to 400 pounds by 1985. While these forecasts fluctuate, the thrust of this sector's imaginative technology continues to bring it more and more automotive applications.

Plastics first penetrated the automotive market by way of interiors, providing flexibility in decorative design at low cost. Safety considerations then motivated the use of plastics as crash-protection padding. In a third-stage expansion plastics applications began to show up under the hood. Today, plastics are being adapted to exterior envelope applications and are being tested even as purely structural materials — wherever weight-reduction and durability offer promise.

Additional features of plastics that appeal to auto manufacturers are the feasibility of consolidating separate components into unitized assemblies, generally less expensive tooling than for metal parts, and often fewer post-fabrication finishing operations.

With the growth of this technology has also grown a bewildering array of processes and products. A basic description of processes and generic families of products associated with automotive component manufacture follows.

4.4.1 Resin Production

The raw materials for the manufacture of plastic materials or resins are called intermediates or monomers, and are derived from natural gas, crude oil, or petroleum products. The major intermediates are ethylene, benzene, and propylene. In the basic process of making plastics, called polymerization, simple monomers are joined together in large chains called polymers. A single type of repeating unit is called a homopolymer and a chain of two or more monomers is called a copolymer.

Modifiers, chemicals and additives are introduced into the plastic such as pigments for coloring, plasticizers to increase flexibility, stabilizers to make the product more resistant to heat and light, or fiber reinforcements to make the material stronger. This process is called compounding.

Two broad categories of plastic resins exist, thermosetting polymers and thermoplastic polymers.

- Thermosetting polymers, once polymerized or hardened, cannot be softened by heating without degrading the material. Thermosets are usually liquid mixtures or molding compounds which are "cured" or solidified with chemicals or heat.

- Thermoplastic materials can be repeatedly softened or hardened by heating and cooling. Usually, thermoplastic resins are purchased as pellets or granules that are softened by heat under pressure so they can be formed then cooled and hardened into the final desired shape.

The largest selling plastic resins are polyethylene, polyvinyl chloride, polystyrene, and polypropylene. These four resins account for 70 percent by weight of all resins sold in 1977.

4.4.2 Basic Types of Automotive Plastics

The most important automotive plastics are polyurethane, polypropylene, polyvinyl chloride, and ABS.

Polyurethane

Polyurethanes are important in automobiles for use in seat cushioning, bumpers and fascia. Flexible foams are polyurethane materials that are flexible and resilient and can be used for seat cushions or other padding. Semi-rigid foams have less resilience and are finding applications in bumpers and fascia. Rigid foams have the potential to be used in many automobile parts, including exteriors. Urethanes are made from precursors called polyols and isocyanates. The types and mixture of these chemicals determine the properties the urethanes will have. The reaction-injection molding process has recently become widely accepted for molding urethane foams, especially semirigid foams used in automotive front ends. Approximately 20 percent of the polyurethane foam consumed in 1978 was used in cars.

Reinforced Polyester

Reinforced polyester refers to a composite of thermosetting polyester plastic and, in most cases, glass reinforcing materials called fiberglass. The reinforced plastic is strong, can be used in various engineering applications and has exceptional strength to weight. Automotive uses include front fascia, spoilers, grille opening panels, fender skirts, and side rails. Reinforced plastic parts often come as mixed components such as sheet molding compound (SMC), a roll of thick sheet, or bulk molding compound (BMC), a slab of extruded log or rope. A common processing method used is press or compression molding where the materials (SMC, BMS, etc.)

are placed in matched metal dies and pressed into shape. Automobiles accounted for over 20 percent of 1978 reinforced polyester consumption.

Polypropylene

Polypropylene is a thermoplastic found in many under-the-hood parts such as ducts, battery cases and fan shrouds. In some cases it is also glass reinforced. Polypropylene automotive parts, generally injection molded, accounted for 12 percent of total polypropylene consumption in 1978. The plastic can also be extruded into fibers, used in automotive carpeting.

Polyvinyl Chloride

Polyvinyl chloride (PVC), or vinyl, has exceptional chemical, weathering and abrasion resistance. The plastic is often processed by calendering and used for automotive upholstery. PVC is also used for vinyl roofs and for certain molded parts. In 1978 autos accounted for about 5 percent of PVC consumption.

ABS

ABS is known as both a commodity plastic and an engineering plastic depending on the specific formulation. This thermoplastic possesses outstanding impact strength and high mechanical strength. In automobiles it is used in grilles, lamp housings and instrument panels. Medium and high-heat grades of ABS are used for many automotive components which are usually injection-molded. Autos accounted for about 15 percent of ABS consumption in 1978.

4.4.3 Trends, Developments and New Applications

Key issues associated with plastics as automotive materials, in general, center on the following aspects: plastics are generally more expensive than the traditional automotive metals; production rates are lower than those possible with metals; so far plastics have exhibited limited capacity for recycling and most plastics are obtained from the chemical processing of petrochemical feedstocks and intermediate chemicals.

In 1977 use of plastics in automobiles was over five percent of total U.S. plastic consumption. On the other hand, over 20 percent of U.S. steel production, over 10 percent of aluminum production and over 25 percent of U.S. casting production were used by the automotive industry. Thus, in terms of share of the market, automobiles are relatively less important in the plastics industry than they are in the metal industries. However, the impact of changes in automobile design on the plastics industry will still be quite significant. Growth of plastics use in the automobile is expected to be quite large over the next decade and the plastics industry may find itself vying in the near future with other needs for basic energy.

Plastics Applications at GM

In General Motors alone, the overall consumption of plastics today amounts to an impressive 780 million pounds. The most widely used resin at GM is polypropylene, of which some 230 million pounds will be used this year. Next most used are urethane, acrylonitrile-butadiene-styrene (ABS) and polyvinyl chloride (PVC). GM interest spans almost the entire spectrum of plastics, concentrating primarily on: ABS, acetal, fiber glass, nylon, polyethylene, polypropylene, PVC resin, styrenics (polystyrene and styrene-acrylonitrile), urethane and thermoplastic elastomers.

Manufacturers Seek Improved Quality

Two specific issues tackled in 1979 at GM are the improvement of sheet molding compound (SMC) quality, and the enhancement of the modulus (ability to recover from deformation) and fatigue properties of fiberglass reinforced plastics. GM is currently conducting development work in this sector, to iron out obstacles in the way of future volume production. This work includes some cosmetic components consisting of 45 to 50 percent glass content, and some structural parts containing continuous fibers or chopped strands. This effort also includes projects involving reaction injection molding of urethane parts, some with high-modulus reinforcement and others with low-modulus and no reinforcement.

GM is also developing two new processes for SMC, aimed at improving surface quality and structural integrity. The processes include an in-mold coating system and a programmable pressure-control system. GM views molding compounds (SMC) as offering the greatest potential for large body panels. GM's Oldsmobile Division is continuing its extensive applications research, as are other GM divisions, to a lesser degree.

Light, New Headliner

Three years ago the Amoco Foam Products Company, Atlanta, Georgia, working with GM's Fisher Body Division developed a foam backing for one-piece headliner application. Called Amocor, the foam is made from a polystyrene co-polymer, and is thermoformable. The GM headliner currently consists of three material parts: a urethane foam backing, a cloth cover, and Amocor sheet. The urethane is flame-bonded to the cloth, then glued to the Amocor sheet substrate. Compared with the traditional cut-and-sew method, the new headliner concept is claimed to reduce weight and speed production.

Besides its GM use, Amocor will also be featured in some 1980 Ford pickups. Other typical applications for which it's being considered include rear shelves, door panels and angel wings (part of the headliner between the rear side-window and the rear windshield).

Additional Applications

Additional plastics applications in GM cars introduced in 1979 include:

- Three-piece front-bumper system on the 1980 Chevrolet Corvette—the first major application of 65 percent glass-fiber-reinforced SMC on a domestic car.

- Compression-molded SMC tailgate on some 1980 Oldsmobile full-size station wagons, made by GM's Fisher Body Division.

- In-mold-coated (IMC) urethane front header panels, fenders, hoods on Pontiac Phoenix and removable roof panels made of SMC glass fiber-reinforced polyester for the Corvette. IMC process was jointly developed by GM and General Tire and Rubber Company, which is producing the Corvette parts.

- Front-end panels on 1980 Buick's full-size cars, made on injection-molded reinforced polyester.

- Expanded use of plastic-tape-controlled window-cranking mechanisms in GM cars. The systems involve an elastomeric polyester (Dymetrol EPS) tape formulated by DuPont, and includes parts molded of polyethylene terephthalate (PET), nylon, and acetal.

- Bucket seats stamped from glass-reinforced polypropylene sheet for the Corvette.

- Structural foam-molded instrument panels (of Arco Polymer's Dylark styrene copolymer) for the 1980 Chevrolet Citation X-body compact. The panel has a post-molding finish consisting of a vacuum-formed vinyl skin and a foamed-in-place urethane padding. The finished panel is produced in-plant on Ex-Cell-O low-pressure equipment.

- A spoiler, with reinforced RIM fenders, is scheduled to be introduced later in the model year, as a customizing accessory for Pontiac's Sunbird Formula subcompact.

- Some 5000 fenders made of reinforced RIM are to be installed on Oldsmobile's Omega X-body in the current model production run. Candidate materials for this part are Union Carbide's and Mobay's high-modulus urethane elastomers, and Dow's recently introduced "analymer" material.

Plastics Applications at Ford

While exploring a variety of plastics processing avenues, Ford Motor Company is concentrating mostly on compression and injection molding. Ford's near-term objective is to add 90 to 140 pounds of plastics to its cars by 1985. The 1980 Econoline van hood, which weighs 18 pounds, or 10 pounds less than the metal unit it will replace, is a good example of Ford's current work in compression-molding.

The sink-resistant plastic (SRP) hood is formulated with a thermoplastic additive which tempers polyester's tendency to shrink and sink. The reinforcement in this application consists of polyester resin and one-half-inch-long glass fibers. These two ingredients become the underside of the hood, because the short glass fibers allow the flow of SMC.

The remainder of the charge contains two-inch fiberglass that spans the surface areas prone to shrinkage and distortion. This work is done at Ford's Plastics, Paint and Vinyl Division, Milan, Michigan, which has capacity to produce 60,000 to 300,000 hoods per year.

Ford Goes To In-House Processing

Ford's recent emphasis in plastics part production centers on new equipment and automated processing to tighten quality control and accelerate curing. Ford is also using in-mold coating to eliminate surface porosity and related defects.

To make grille opening panels and fender extensions Ford is using glass-reinforced BMC (Bulk Molding Compound) thermosetting polyester resins in injection molding. But for larger, flat surfaces, such as body panels, Ford is experimenting with co-injection and sandwich-molding method. In this process two materials are injected into a mold simultaneously, to form a solid skin and a solid or foam core.

Ford is also researching: reinforcing glass fibers to urethane reaction-injection molding (RIM) fenders; vacuum forming; and a reinforced, high-modulus RIM material which could be painted in the conventional way. Ford also plans to use a luggage compartment tray molded of 30 percent glass-reinforced polypropylene foam--a part measuring 46x30 inches--on its 1982 compact that will replace the Pinto.

Additional Applications

Other plastics applications on Ford vehicles include:

- New timing-belt cover, made of mineral-filled nylon, injection molded at the Milan plant. The cover is for Ford's 1980, four cylinder, 140.3 cid engines.
- A lower bumper-slot grille made of "sputter-chromed" ABS plastic with a base coat of modified urethane, for the 1980 Mercury Marquis.
- Fenders, an integral grille-opening panel, and a radiator support made of compression-molded SMC for the 1980 new F-Series, medium-duty truck.
- One-piece soft-face urethane bumper systems on the 1980 downsized Thunderbird and Mercury XR-7.
- Plastic lower-back panels and vacuum reservoirs on 1980 Lincoln Continental and Mark VI.

- New molded laminate headliners and plastic differential cover plates on 1980 Lincoln Continental.

- Plastic front disc-brake shields on 1980 Lincoln Continental.

- Plastic luggage load floors in the 1980 LTD and Mercury Marquis station wagons.

- First sealed-beam halogen headlamp with lens and reflector molded of polycarbonate (PC), for the 1980 Lincoln. Compared to conventional incandescent glass-based systems, the new units are intended to provide 20 to 30 percent more light, are 400 times more impact resistant, and weigh only 0.39 pounds, instead of 1.25 pounds.

- One-piece instrument panel molded of a new PC resin for the 1980 Thunderbird, Cougar XR7, and the Ram pickup. These panels weigh about seven pounds each and feature a foamed-in-place urethane padding.

Plastics Applications at Chrysler

Although Chrysler generated more copy this year concerning its financial status than its technological achievements, Chrysler has continued to incorporate plastics into its weight-reduction war. Notable evidence of such efforts are Chrysler's newly introduced mid-size 1980 Dodge Mirada, which weighs 500 pounds less than the Magnum it replaces, and the Mirada's Cordoba running mate, which shed some 400 pounds compared with its 1979 version. New plastic applications accounted for much of this pound paring.

The Mirada features an energy-absorbing plastic front bumper system that functions without hydraulic shock absorbers. The system uses a urethane foam energy-absorbing "bun" instead of shocks, and is enclosed in a one-piece RIM urethane shell bonded in the rear to a steel reinforcement bar.

Also on Omni and Horizon

A similar soft-fascia and front-bumper system is used on the Plymouth Horizon and Dodge Omni subcompacts, but these also use hydraulic energy absorbers.

In January of 1980 a new Chrysler 300 model will be introduced featuring a front-end system similar to Mirada's. The Baily Division of USM Corporation produces Mirada's front bumper system; Davidson Rubber Division of Ex-Cell-O Corporation makes the front-end system for the Chrysler 300.

Polyolefin foam front and rear bumper guards are optional on all Chrysler mid-size 1980 cars. On mid-size wagons and on Diplomat and Le Baron sedans, only the rear guards are made of the foam.

Additional Applications

Additional 1979 plastics applications in new Chrysler cars include:

- A one-piece glove box for Cordoba and Mirada. This 1.5 pound unit is molded of calcium carbonate-filled polypropylene foam on high-pressure equipment, and consists of a door, integral hinge, and frame and bin. It is produced in one shot in an expanding mold.

- Fender and quarter-panel extrusions made of injection-molded urethane, for Cordoba and Mirada.

- Glass-filled-nylon end-tanks for heater cores in mid-size specialty and full-size cars.

- A plastic servo body for the automatic speed-control systems in Chrysler cars. This 30 percent mineral, 10 percent glass and 60 percent type 6 nylon plastic replaces die-cast zinc servo body of earlier models.

- One-piece polypropylene evaporator housing that saves 3.5 pounds in air conditioners.

- New thermoplastic glass-filled polyester distributor caps on all 1980 Chrysler 4-cylinder engines.

- New black-polyester carrier for windshield wiper blades, and an optional spray-on chip-resistant plastisol as corrosion protection on lower-body panels for all 1980 models.

Fiberglass Reinforced Plastics

Glass-reinforced plastics (FRP) are expected to gain another round of acceptance with the 1981 model year, when new body panels and structural components are approved. Components now on test vehicles include radiator core supports, truck and car doors, deck lids, hoods, bumpers and transmission supports. Among other FRP possibilities for 1981 and 1982 are hoods, station wagon tailgates, sliding and rear van doors, and springs.

A broad-base effort is also underway to produce durable and cost-competitive fiberglass-reinforced plastic wheels. Most automakers or their suppliers have already developed such wheels, and in some cases achieved weight savings up to 50 pounds per car. Plastic wheels are currently being subjected to intensive testing for long life, as well as to keen competition from the high-strength steel sector.

Owens-Corning, a major supplier of the fibers for FRP, recently projected the use of fiberglass-reinforced plastics in the transportation industry will increase at a 15 percent compound annual rate, from the 1979 volume of 599 million pounds to 1.1 billion pounds by 1983. Other applications on the horizon include reaction-injection molding (RIM) applications such as soft fenders and fascia panels; and stampable reinforced thermoplastic parts.

To meet the growing demand for plastics reinforcements, Owens-Corning is opening a new Fiberglass plant in Amarillo, Texas, next year with a capacity of over 200 million pounds of reinforcements per year.

Bulk Molding Compunds Arrive

Another branch of plastics development showing increased promise is injection-molded polyester bulk molding compounds (BMC) used for the first time on 1979 cars. BMC applications include grille opening panels on Buick Regal, Ford Granada and Mercury Monarch, front-end retainer panels on Chrysler's Omni and Horizon, and headlamp doors on the Chrysler New Yorker.

With about 25 percent glass content, BMC is used for structurally less-demanding applications while SMC (sheet molding compound), which may have up to 70 percent glass, is favored for larger body panels.

Engineering Plastics

The engineering plastics are generally low-volume, high priced plastics with relatively few suppliers. The transportation industry accounts for over 25 percent of the consumption of these materials. The major automotive engineering plastics are nylon, polycarbonates (PC), polyphenylene oxide (PPO) and polybutylene terephthalate (PBT). In 1976 automobiles accounted for 31 percent of nylon consumption, 7 percent of PC consumption, 42 percent of PPO consumption and 46 percent of PBT consumption.

Plastic Window Regulator

The new window regulating mechanism on GM's "X" type front-wheel-drive cars contains several engineering plastics parts developed by DuPont, including an elastomeric polyester (EPS) actuating tape, Delrin acetal resin sash and drive, a housing of Zytel glass-reinforced nylon resins, and a nylon guide. The plastic assembly saves seven pounds on two-door models and eleven pounds on four-door models.

Other 1979 weight-saving engineering plastic applications with these materials are window brackets which save up to five pounds per car in some cases, gas caps, stone shields for steering gears, seat-belt components and rear license plate "pockets" on several car models.

Several GM cars are now using a steering column lock housing made of 33 percent glass-reinforced nylon. This part is said to provide cost and weight savings over the zinc die-casting it replaced.

Body Applications

The Monsanto Company and General Electric are also active in this field. Monsanto is strong in reinforced nylons, developing almost tailor-made materials for automotive uses. Monsanto's Vydyne R220, a mineral-reinforced nylon, has found new uses in exterior mirror housings, a cowl vent grille, side marker lamp housing, two quarter-panel ornament assemblies and seven rear-fender extensions on 1979 cars. Vydyne's claimed benefits include high rigidity, chemical resistance, good paintability and improved impact resistance.

4.5 COMPOSITES

Currently at the very leading edge of the light and tough plastics technology are the composite materials. As suggested by their name, "composite" materials are compounded, through various proprietary processes, by combining usually chopped glass and some other type of roving (fiber) with special resins. Varying combinations of glass and graphite roving are used to produce graphite composites. The unusually high strengths attributed to some composites are attained by increasing fiberglass content from approximately 30 percent to as much as 80 percent, by weight.

These exciting new compounds are finding use in high-performance race cars and consideration for car and truck applications such as drive shafts, leaf springs, bumper beams and radiator supports.

Trends, Developments and New Applications

Automakers are accustomed to thinking in terms of high production rates and low-cost materials. For example, some steel parts are stamped out at the rate of 600 per hour--a significant factor that makes the manufacture of ten million vehicles a year possible.

The current problem with graphite composites in particular is that they represent a brand new technology utilizing, as yet, hardly-off-the-lab materials. The newness involved in both of these aspects makes these materials extremely expensive to produce, except where they can redeem themselves through major weight-savings.

At a current price of approximately $20 a pound--versus steel at under 20 cents a pound--composites are clearly in the category of exotic materials.

Composites and the Automakers

At present, General Motors has no graphite-fiber-reinforced plastic parts on any of its cars because of prohibitive cost. But, with improving costs and accumulating manufacturing experience and component performance data, composite uses are expected to start growing within the next few years.

Ford Launches Experiment

Ford has taken the first over-the-road evaluation step in this field by adopting a graphite-fiber-reinforced plastic (GFRP) bracket for mounting a 20-pound air conditioner-compressor on some 1,000 of its 1980 models with 2.3 liter, 4 cylinder engines. These composite brackets weigh 1.7 pounds each, compared with the approximately 7.7 pound of the malleable iron units they replace.

Compression molded of polyester resin, the bracket contains a mixture of one-inch chopped fiberglass and continuous graphite fiber. The composition of constituents, by weight, is: 30 percent polyester resin, 20 percent graphite roving (unidirectional fibers), and 50 percent chopped glass roving. Armco Composites, St. Charles, Illinois, a unit of Armco, Inc.'s Metal Products Division, makes the bracket.

But Ford's interest in composites extends well beyond this bracket. This was made clear earlier this year at the annual SAE Congress and Exposition at Detroit's Cobo Hall, where Ford exhibited its experimental "graphite" LTD. With the same basic dimensions as the production LTD, this one-of-a-kind car weighs 1,200 pounds less and, says Ford, equals compacts and some subcompact models in fuel economy.

Virtually the Entire Car

The graphite-fiber-reinforced plastic components of the special LTD include the hood, deck lid, doors and door-guard beams, wheels, frame, drive shaft, bumpers, fenders and quarter panels. The car was designed primarily to demonstrate the weight-saving and fuel-economy possibilities of graphite composites; no attempts were made to develop fast production techniques.

The second show-stopper at this year's SAE exhibit was an experimental Chrysler Le Baron coupe that combined graphite-composite components with other currently available lightweight materials. Le Baron's graphite components included rear springs, valve push-rods and the drive shaft. In addition, glass-reinforced thermoset components were used, such as door inner panels, wide-column bumper energy absorbers and transmission cross-members; and thermoplastic headlamps, engine oil pan and transmission oil pan.

Armco Composites is developing a bracket similar to Ford's for the Chrysler Corporation. The part is expected to be used on 1981 models.

Reflecting the accelerating interest in graphite-fiber-reinforced plastics, this year's SAE meeting also featured two well-attended all-day technical sessions on the subject.

Composites in Engine Applications

Beyond the arena of passenger and commercial cars, composite materials have also been penetrating, without much fanfare, the highly guarded sector of high-performance race car engines.

Here again, where competition is the keenest, and where determination, ingenuity and resources combine toward ultimate performance, engine designers are already thinking and testing composites reinforced with glass and graphite. And setting aside, for the moment, the customary high-cost aspects of new-born materials, here is how the experience and tests with composites are startinq to shape new engine design concepts.

Race experience on the Grand Prix Formula 1 circuit, combined with bench stress-tests, indicate composite connecting rods have greater fatigue resistance than aluminum, steel or cast-iron ones. The expected life of an aluminum rod is about 150,000 cycles, while composite rods have been run for some 11 million cycles. Also, composite components are claimed to be 60 percent lighter than steel and 30 percent higher than aluminum. As a result, reciprocating inertia loads are reduced.

Other plus factors to composite materials are:

- Lower thermal conductivity than that of metals
- Thermal expansion rates similar to those of steel, thus allowing integration with steel
- Greater part stiffness than found in steel or aluminum parts
- No need for heat-treatment
- Few or no secondary finishing operations.

These factors add up to design and performance advantages the automotive industry has noted. For example, lighter valve-train components can lead to lower valve spring rates and longer spring life, and reduced camshaft lobe wear. With lighter pistons, pins and rods, less weight is moved by the crankshaft, leading to lighter crankshaft and counterweights. Also, as a result, lighter reciprocating weights, lower inertia loads that allow engine to run at higher rpm and deliver more power. And lower thermal conductivity than metals' means that the engine can retain more heat inside the cylinders and produce more power at lower rpm.

Comparison of Major Weight-Saving Production Composite Parts to Steel and Aluminum in the Engine

Parts	Steel(g)*	Aluminum(g)*	Composite(g)*
Piston	NM[1]	500	350
Connecting rod	750	600	385
Push rod	75	NM[1]	75
Piston pin	140	NM[1]	35
Retainer	25	15[2]	7

[1]Not made in this material for race engines
[2]Titanium

*Grams

GM, Ford and Chrysler have shown special interest in the performance of composite engine parts on the racing circuit, and are conducting some of their own bench durability tests with similar components. At present, interest in developing composite parts for passenger car engines seems to center mostly on piston rods and pins, but both part design and production methods are in their infancy. The development of experience in both of these areas should serve to expand the market, and help lower the cost of automotive grade graphite or carbon fibers, which at the moment hovers around a prohibitive $20 per pound.

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