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STEEL OPTIMIZATION AND SUBSTITUTION FOR 1980 OLDSMOBILE OMEGA X-BODY CAR

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ARMCO INC.
Middletown, OH 45043

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16. Abstract

This report studies the potential of weight reduction for a 1980 Oldsmobile Omega X-body four-door sedan through steel optimization and substitution of newer steels. The study shows that 74 pounds can be removed from this vehicle using current steel technology. An additional 100-pound weight saving can be achieved through the use of newer steels in the 1990 time span.

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PREFACE

This report is a result of a study conducted by ARMCO Inc. for the U.S. Department of Transportation, National Highway Traffic Safety Administration under Contract No. DTRS 57-80-P-81379. The study was initiated to identify potential weight saving in passenger cars through the optimization and substitution of higher-strength steels, coated steels, stainless steels and other recent and anticipated developments in steel technology.

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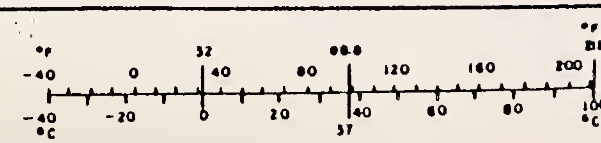
METRIC CONVERSION FACTORS

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. SUMMARY

The following report is a study of over 100 components of an early 1980 Oldsmobile Omega X-body car. These parts are now made of sheet steel or cast iron. They were analyzed regarding the optimization of low carbon sheet steel or the substitution of high strength sheet steel. This study concluded that this particular General Motors car was well engineered regarding the application of sheet steel, and only 33.5 Kg (74.0 lbs) or 2.7% of the curb weight can be removed without component re-design. An additional 6.7 Kg (14.8 lbs) of the initial total weight savings estimate was either in error or the steel has already been eliminated from this car model through part re-design or a reduction of sheet gage.

Considering a longer time span to 1990, it is felt that an additional 100 lbs. could be removed through the use of newer steels, embossed and rigidized steels and steel/plastic laminates in a re-design and development of sheet metal components, such as the engine block, intake and exhaust manifolds, brake rotors and drums and other parts now made of castings or forgings.

Although parts to be made from steel are not the lightest when compared with aluminum or plastics, they are very cost competitive, and in large volume production are almost always the most economical. Regarding total energy consumption, studies show that steel is competitive with aluminum and, in many cases, competes well against plastics.

2. INTRODUCTION

Traditionally, the primary structural material for automobiles has been steel because it offered the best combination of engineering properties, reproducibility, availability, high speed fabrication, and overall low cost. Emphasis has always been to achieve the lowest cost with the desired performance. Lately, there has been a shift in priorities brought on by the world fuel shortage and the emphasis on safety. Fuel economy has become a primary driving force behind changes occurring in the world automotive industry and even more dramatically in the U. S. automotive industry. Fuel economy improvement is being achieved in many ways: improved lubricants, lower rolling resistance tires, more efficient engines and drive train systems, more energy efficient accessories, lower aerodynamic drag and reductions in both size and weight. The emphasis is still on lowest cost, but the desired performance has changed.

The size/weight efforts to date have been primarily toward reducing weight through reductions in size and much less through material substitution. Some substitutions of materials have taken place since 1975 as evidenced by the increased usage of plastics, aluminum and high strength steels (see TABLE I). This trend will increase during the first half of the '80's, but will slow down late in the decade as the cost/weight become more difficult to justify. For significant changes in weight reduction and materials substitution to occur during the '90's dramatic breakthroughs in material technology would be required.

Steel has been the dominant material in automobiles in the last half century. From a rather steady position of 60-65% of the automobile prior to the downsizing and material substitution starting in 1976, its position has slipped to a range of 52-57%. Steel is not expected to lose position in the early '80's, but is forecast to remain at about 55% to 1990.[1] *

The biggest mistake material analysts make in forecasting future material usage trends is their failure to treat steel as a constantly improving product. The strength of readily available steel has changed from a standard 207 MPa yield strength (30,000 psi) to a range as high as 1034 MPa (150,000 psi). Additionally, improvements have been made in ductility, formability and weldability of high strength steels to meet the needs of automobile manufacturers. Although the density of these higher strength steels has remained nearly constant, (7.82 g/cm^3, .283 lbs/in^3), the gage reductions possible allow corresponding weight reductions of 10-30% in many components.

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*Superscripts refer to references listed in Section 6.

TABLE I

TRENDS IN AUTOMOTIVE MATERIALS USE [3] [4]
(1000 Tons)

	1975	1980	1985 [1]	1990 [1]
Low Carbon Steel [2]	11,825	8,900	8,800	6,145
High Strength Steel [2]	565	1,790	2,200	4,390
Aluminum [2]	562	700	1,130	1,465
Plastics	675	990	1,430	1,755

(1) Estimated.
(2) Includes 25% offal.
(3) Does not include spare parts.
(4) Does not include heavy trucks and trailers.

Unfortunately, steel researchers have been unable to solve the Gordian Knot of Young's Modulus of Elasticity which is 200,000 MPa (28 to 30 million psi.) Therefore, those parts that are stiffness dependent cannot be reduced in weight by steel substitution and gage reduction alone. However, changing section modulus does permit, through redesign, weight to be reduced in these parts. Treatments such as rib stiffeners, flanged lightening holes, rigidizing, or sandwich panels, also can be used to increase section modulus.[2]

Although this study emphasizes reduction in weight to improve fuel economy, the overall national objective is reduction in life cycle energy consumption. This includes the energy required for extracting the raw materials, shipping and refining, processing into basic materials, shipping to manufacturers, manufacturing the vehicle and components, operating the vehicle and, finally, recycling.[3]

3.1 OBJECTIVE

The objective of this study was to evaluate the potential weight savings in a passenger automobile through the optimization of steel usage and substitutions. The analysis included consideration of high strength steels and corrosion resistant steels to reduce gage and subsequent weight, without sacrificing performance and reliability. Consideration was given to cost and availability of the steels. An early model 1980 Oldsmobile Omega, (General Motors X Car body style), four-door sedan, was used in the analysis.

3.2 COMPONENT ANALYSIS

Preliminary component analysis was conducted by South Coast Technology, Inc.[4], and their report was used as the point of departure for this work. Component names, descriptions, quantity, weight, dimensions and other information was found to be very useful; however, some differences were noted and are pointed out in this study.

For the most part, only those components currently made of sheet steel or iron castings were considered in this study. Parts made of nonferrous and non-metallic materials were not analyzed for steel substitution because: 1) To use steel in place of plastic would require complete component redesign to achieve material effectiveness, and this was considered beyond the scope of this study; 2) Since most new designs of cars evolve from years of steel application, a part made out of alternate materials was assumed to have been compared with a steel counterpart and found better or more cost effective. An example of the latter might be the aluminum bumpers. A study by The International Nickel Company[5] confirmed that the Omega bumper system with its aluminum face bar weighed 30% less than the Citation (both X-body cars) with a steel face bar, but at a cost penalty of 62%. It should be recognized that the Citation is manufacted in greater volume, an important factor in analyzing the weight/cost trade-off. The total car weights are comparable.

TABLE II is a summation of the Omega parts that offer a potential for weight savings through steel optimization and substitution.

Some of the very large and heavy components were beyond the scope of this exercise, for example, the engine and transmission assemblies which account for 20% of the total vehicle weight. It is known that research and development programs exist that have resulted in fabricated sheet metal engine systems with considerable weight reductions;[6] however, these developments do not appear feasible for the '85 time period. They could be developed by 1990 on certain vehicles of a specialty class - perhaps small commuter cars.

The total weight savings calculated in Table II is 113.8 lbs. Noted items were subsequently removed from the final suggested savings and the gages of some parts were corrected after discussions with General Motors representatives.

TABLE II. STEEL PARTS CONSIDERED FOR WEIGHT SAVING WITHOUT CHANGING SIZE OR FUNCTION OF COMPONENT

Component	Part	Item	Present Weight lbs.	Present Thickness (in.) Gage	Proposed Thickness (in.) Gage	Proposed Weight lbs.	Weight Savings lbs.	Materials Change (7)
Body	Hood	Outer panel	21.7	.034	.030	19.2	2.5 (1)	HS 40XK
		Inner panel	16.7	.031	.026	14.7	2.0	HS 40XK
		Hinges	1.4	.156				
		Latch	2.0	.109				
		Hood Holdup	0.7					
		Light	0.2					
		Total	192.7				4.5	
Body	Rear deck	Outer panel	18.2	.037	.032	15.8	2.4	HS 40XK
		Inner panel	13.7	.031	.029	11.9	1.8	HS 40XK
		Latch and lock	1.4					
		Gas spring cylinder	0.7					
		Total	34.0				4.2	
Body	Front fender	Fender panel	20.0	.034	.032	17.6	2.4 (2)	
		Total	20.0				2.4	
Body	Valance-dam	Support panel	0.6	.036	.028	0.4	0.2	
		Total	0.6				0.2	
Body	Front door	Outer panel	21.5	.035	.030	18.4	3.1	HS 40XK
		Inner panel	38.0	.042	.035	31.7	6.3 (2)	
		Lock and latch	5.1					
		Hinges on door	2.7	.194	.150	2.1	0.6	
		Safety door beam	12.5	.092	.075	10.2	2.3 (1)	HS 80XK
		Total	79.8				12.3	

TABLE II. STEEL PARTS CONSIDERED FOR WEIGHT SAVING WITHOUT CHANGING SIZE OR FUNCTION OF COMPONENT (CONT.)

			Present		Proposed			
Component	Part	Item	Weight lbs.	Thickness (in.) Gage	Thickness (in.) Gage	Weight lbs.	Weight Savings lbs.	Materials Change (7)
Body	Rear door	Outer panel	16.5	.036	.030	13.8	2.7 (2)	
		Inner panel	23.3	.031				
		Lock and latch	4.3					
		Hinges on door	2.2	.179				
		Safety door beam	9.0	.061	.040	7.7	1.3	HS 80XK
		Total	55.3				4.0	
Body	Door hinges	Front pillar	3.2	.213	.200	2.8	0.4	HS 50XK
		Rear pillar	2.6	.179	.160	2.3	0.3	HS 50XK
		Total	5.8				0.7	
Body	Exterior trim	Air intake grille	4.3	.036	.032	3.8	0.5	
		Front end panel support	0.7	.060				
		Total	5.0				0.5	
Body	Front seat	Frame	29.5	.030 .049 .075	.024 .039 .060	23.6	5.9	HS 50XK
		Seat track LH	4.2	.085	.060	3.5	0.7	HS 50XK
		Seat track RH	3.6	.085	.060	3.0	0.6	HS 50XK
		Total	37.3				7.2	
Body	Body panels	Radiator brace	2.3	.080				
		Qtr. panel outer	26.9	.032				
		Rear wheel well	21.5	.032				
		Tail light panel	6.0	.035	.032	5.4	0.6	
		Roof outer panel	33.3	.035	.032	30.5	2.8 (2)	
		Roof inner ribs	16.7	.032	.028	14.7	2.0	
		Windshield frame						
		Front of Dash	7.9	.035	.032	7.3	0.6 (2)	
		Sill (Rocker panel)	32.2	.040				
		Floor panel	56.4	.032				
		A post, pillar	23.1	.040 .068				

TABLE II. STEEL PARTS CONSIDERED FOR WEIGHT SAVING WITHOUT CHANGING SIZE OR FUNCTION OF COMPONENT (CONT.)

Component	Part	Item	Present Weight lbs.	Present Thickness (in.) Gage	Proposed Thickness (in.) Gage	Proposed Weight lbs.	Weight Savings lbs.	Materials Change (7)
		B post, pillar	19.1	.032 .048				
		Rear shelf	12.1	.035	.032	11.0	1.1	
		Front center support	1.6	.050				
		Total	409.1				7.1	
Frame	Frame	Cradle	35.0	.080 .095	.070 .075	31.0	4.0 (2)	
		Total	35.0				4.0	
Front suspension		Lower control arm	10.5	.110	.094	8.5	2.0	HS 50XK
		Steering stop bracket	1.4	.125	holes	1.0	0.4	
		Attaching parts	0.9					
		Knuckle	20.0	Cast iron→steel		16.0	4.0	
		Strut damper	16.0					
		Spring seat	2.6	.077				
		Strut mtg. assembly	6.4					
		Stabilizing bar	9.7	Bar→Tube		7.5	2.2 (2)	
		Brackets	1.5	.098 .118				
		Hub and bearing assembly	9.1		holes	8.8	0.9	
		Total	78.1				8.9	
Rear suspension		Axle beam (add ½" flange)	27.1	.175	.150	26.0	1.1 (2)	
		Control arm	6.1	.165	.140	5.2	0.9	HS 80DF
		Spring perch	4.2	.125	.100	3.3	0.9 (3)	HS 70XK
		Anti-roll bar (eliminate)	8.2			0	8.2	
		Track bar	3.8	{.093 .187	.083} .150}	3.3	0.5	HS 50XK HS 50XK
		Shock absorber	6.5					

TABLE II. STEEL PARTS CONSIDERED FOR WEIGHT SAVING WITHOUT CHANGING SIZE OR FUNCTION OF COMPONENT (CONT.)

Component	Part	Item	Present Weight lbs.	Present Thickness (in.) Gage	Proposed Thickness (in.) Gage	Proposed Weight lbs.	Weight Savings lbs.	Materials Change (7)
		Bracket, trailing arm	1.7	.092	holes	1.5	0.2 (2)	
		Hub and bearing assembly	10.5	3/8	holes	10.0	0.5	
		Total	68.1				12.3	
Brakes	Front	Calipers	14.0	Iron →	Steel	13.0	1.0	
		Rotors	20.0	Iron →	Steel	16.0	4.0	
	Rear	Drum	14.0	Iron →	Steel	10.0	4.0	
		Backing plate	4.2	.100	.080	3.6	0.6	HS 70XK
		Shoes	3.1		holes	2.4	0.7	
		Total	55.3				10.3	
Brakes	Parking Controls	Pedal and lock	2.5	.090	.081	2.0	0.5	HS 50XK
		Master cylinder	4.2	Al →	Steel	3.5	0.7	
		Power assist	8.2	.055	.045	7.0	1.2 (3)	HS 80DF
		Pedal assembly of pad	2.1	.375	tube	1.2	0.9	
		Mount bracket pedal	1.4	.093		1.1	0.3 (3)	
		Total	18.4				3.6	
Engine		Air cleaner	6.0	.028	.024	5.3	0.7	S/P/S laminate
		Valve cover	3.7	.045	.036	3.3	0.4	Deep Draw Qlty.
		Oil pan	5.1	.045	.040	4.6	0.5	HS 40XK
		Total	14.8				1.6	
Engine	Power steering	Bracket	3.4	.200	.170	3.0	0.4(2)	
	Air conditioner	Bracket	5.0	.193	holes	4.3	0.7	
Engine	Mounts	Bracket	6.5			5.5	1.0(2)	
		Vibration	5.7			5.0	0.5(2)	
		Torque link	1.4			1.2	0.2(2)	
		Damper	0.7					

TABLE II. STEEL PARTS CONSIDERED FOR WEIGHT SAVING WITHOUT CHANGING SIZE OR FUNCTION OF COMPONENT (CONT.)

(7)

Component	Part	Item	Present Weight lbs.	Present Thickness (in.) Gage	Proposed Thickness (in.) Gage	Proposed Weight lbs.	Weight Savings lbs.	Materials Change
Engine	Throttle	Arm	0.5	.375	Tube	0.3	0.2	
		Bracket	0.9	.078	.062	0.7	0.2 (2)	HS 60XK
		Total	24.1				3.2	
Transaxle		Valve cover body	2.4	.050	.045	2.2	0.2	Deep Draw Qlty.
		Total	2.4				0.2	
Transaxle	Drive shaft	LH axle shaft	2.8			2.0	0.8 (2)	HS 50XK
		RH axle shaft	3.6			2.5	1.1 (2)	HS 50XK
		Total	6.4			4.5	1.9	
Fuel-exhaust	Gas	Tank	21.8	.036	.030	18.0	3.8	HS 40XK
		Filler neck pipe	2.3			2.0	0.3	
		Tank door	1.1	.035	.032	0.9	0.2	
		Tank straps	2.1	.090	.050	1.2	0.9	HS 80XK
		Total	27.3				5.2	
Fuel-exhaust	Muffler	Muffler	11.8			9.8	2.0*	HS 50XK
		Tail pipe	8.2			6.8	1.4*	HS 50XK
		Catalytic converter	11.5					
		Hangers	3.6	.120	.084	2.8	0.8**	HS 50XK
		Upper shield	2.2					
		Lower shield	1.0					
		Side shield	.6					
		Total	38.9				4.2	
Fuel-exhaust	Emission	Pulsair valve	3.4			2.9	0.5	S/P/S laminate
		Hardline pipes	3.0					
		Total	6.4				0.5	

* Must be coated with aluminum or stainless steel.
** Corrosion protection should be considered.

TABLE II. STEEL PARTS CONSIDERED FOR WEIGHT SAVING WITHOUT CHANGING SIZE OR FUNCTION OF COMPONENT (CONT.)

Component	Part	Item	Present Weight lbs.	Present Thickness (in.) Gage	Proposed Thickness (in.) Gage	Proposed Weight lbs.	Weight Savings lbs.	Materials Change (7)
Steering	Column	Wheel	5.1		tube	4.2	0.9	
		Shaft PRI	2.7	.125	.110	2.0	0.7	
		Jacket assembly	2.6	.072	.050	1.8	0.8	HS 50XK & 80DF
		Shift tube	1.2	.060	.040	0.8	0.4	HS 50XK
		Column mount bracket	1.1	.133	.100	0.9	0.2 (2)	HS 50XK
		Rack and pinion assembly	18.0	Steel	tube	15.0	3.0	
		Shaft assembly	3.7	Steel	tube	2.9	0.8	HS 40XK
		Total	34.4				6.8	
Wheels and Tires	Wheel	Wheel rim	69.0	.120	.105	61.0	8.0	HS 70XK
		spider		.150	.130			HS 60XK
		Wheel covers	17.0	.034	Eliminate			
		Bumper jack	7.0					
		Total	93.0					
TOTAL			1,342.2				113.8	

(1) Gage has been reduced on later models.

(2) Not included in Table III.

(3) Change not suggested after consultation on fatigue and durability.

3.3 MATERIALS APPLICATION, STATE-OF-THE-ART

It was the general opinion that this Oldsmobile Omega reflected the present state-of-the-art of design and application of steel. Members of the team have conducted as many as five previous car stripping analyses. Although it was not known for certain the philosophy General Motors used in developing this car, the team felt it was the best U. S. designed car of its size and weight class made at that time, and probably highly competitive in the world. Considering the degree of acceptance in the market place, the American public has apparently judged this car to be well conceived regarding the traditional standards of rideability, handling, performance, space, sound level, etc.

This car offered a particularly difficult challenge for weight reduction using steel, because it represents the latest design. When new steel grades are developed and released for commercial sale, the automotive industry is the first to receive these technical developments. The car industry is essentially a fabricator and assembler of steel and is very quick to adopt new steel materials and technology. The only delay is that required to test and prove suitability and availability of the new materials.

Therefore, it was no surprise that the steel in the Omega represented the leading edge of new steel design and application. Since the car was initially conceived in 1975 and materials decisions were made during 1977 and 1978, there is a steel development gap of only two years. This is very current technology considering the historic lead times required.

3.4 WEIGHT REDUCTION POTENTIAL

3.4.1 1985 TIME PERIOD

The majority of the weight reduction potential is in the area of "strength related" components (as opposed to stiffness related components.) Table III summarizes the weight savings proposed. The initial phase of the study conducted on the floor at the Transportation System Center - Cambridge, Mass. showed a potential weight savings of 51.6 Kg (113.8 lbs) out of the 608.0 Kg (1342.2 lbs) represented by the components studied, or about an 8% savings. Compared to the total weight of the car 1224.1 Kg (2702.2 lbs), the savings amount to 4.2%. Subsequent detailed analysis and discussions with automotive engineers changed this original proposal from 51.6 Kg (113.8 lbs) to 33.5 Kg (74 lbs) or 2.7%. These proposals are considered realistic and could be implemented with minimum development and testing by the automotive manufacturer.

TABLE III. COMPONENTS SUGGESTED FOR WEIGHT SAVING

Part	Item	Present Weight lbs.	Present Thickness (in) Gage	Proposed Thickness (in) Gage	Proposed Weight lbs.	Weight Savings lbs.	Change
Hood	Inner Panel	16.7	.031	.026	14.7	2.0	HS
Rear Deck	Outer Panel	18.2	.037	.032	15.8	2.4	HS
" "	Inner Panel	13.7	.031	.029	11.9	1.8	HS
Valance	Support Panel	0.6	.036	.028	0.4	0.2	
Front Door	Outer Panel	21.5	.035	.030	18.4	3.1	HS
	Hinges	2.7	.194	.150	2.1	0.6	
Rear Door	Safety Beam	9.0	.061	.040	7.7	1.3	HS
Door Hinges	Front Pillar	3.2	.213	.200	2.8	0.4	HS
	Rear Pillar	2.6	.179	.160	2.3	0.3	HS
Grille	Air Intake	4.3	.036	.032	3.8	0.5	
Front Seat	Frame	29.5	.030	.024	23.6	5.9	HS
	Tracks	7.8	.085	.060	6.5	1.3	HS
Body Panels	Tail Light	6.0	.035	.032	5.4	0.6	
	Roof Outer	33.3	.035	.032	30.5	2.8	
	Rear Shelf	12.1	.035	.032	11.0	1.1	
Front Suspension	Lower Arm	10.5	.110	.094	8.5	2.0	HS
	Steering Stop	1.4	.125	Holes	1.0	0.4	
	Knuckle	20.0	Cast Iron	Steel	16.0	4.0	
	Hub Assembly	9.1		Holes	8.8	0.3	
Rear Suspension	Control Arm	6.1	.165	.140	5.2	0.9	HS
	Spring Perch	4.2	.125	.100	3.3	0.9	HS
	Track Bar	3.8	.093	.083	3.3	0.5	HS
	Hub Assembly	10.5	3/8	Holes	10.0	0.5	
Wheels	Rim & Spider	69.0	.120	.105	61.0	8.0	HS
			.150	.135			HS

TABLE III. COMPONENTS SUGGESTED FOR WEIGHT SAVING (CONT.)

Part	Item	Present Weight lbs.	Present Thickness (in) Gage	Proposed Thickness (in) Gage	Proposed Weight lbs.	Weight Savings lbs.	Change
Brakes	Calipers	14.0	Iron......>	Steel	13.0	1.0	
	Rotors	20.0	Iron......>	Steel	16.0	4.0	
	Drum	14.0	Iron......>	Steel	10.0	4.0	
	Backing Plate	4.2	.100	.080	3.6	0.6	HS
	Shoes	3.1		Holes	2.4	0.7	
	Parking Pedal	2.5	.090	.081	2.0	0.5	HS
	Master Cylr.	4.2	Al ....>	Steel	3.5	0.7	
	Power Asst.	8.2	.055	.045	7.0	1.2	HS
Engine	Air Cleaner	6.0	.028	.024	5.3	0.7	S/P/S
	Valve Cover	3.7	.045	.036	3.3	0.4	DDQ
	Oil Pan	5.1	.045	.040	4.6	0.5	HS
	Air Cond. Brkt.	5.0	.193	Holes	4.3	0.7	
	Throttle Arm	0.5	.375	Tube	0.3	0.2	
Trans Axle	Valve Cover	2.4	0.50	.045	2.2	0.2	DDQ
Fuel	Tank	21.8	.036	.030	18.0	3.8	HS
	Filler Neck	2.3			2.0	0.3	
	Tank Door	1.1	.035	.032	0.9	0.2	
	Straps	2.1	.090	.050	1.2	0.9	HS
Exhaust	Muffler	11.8			9.8	2.0	HS
	Tail Pipe	8.2			6.8	1.4	HS
	Hangers	3.6			2.8	0.8	HS
	Pulsair Valve	3.4			2.9	0.5	S/P/S
Steering	Wheel	5.1		Tube	4.2	0.9	
	Rack & Pinion	18.0		Tube	15.0	3.0	
	Shaft PRI	2.7	.125	.110	2.0	0.7	
	Jacket Assy.	2.6	.072	.050	1.8	0.8	HS
	Shift Tube	1.2	.060	.040	0.8	0.4	HS
	Shaft Assy.	3.7	Steel	Tube	2.9	0.8	HS
		496.3			422.6	**73.7**	

It is doubtful that such changes will occur in this vehicle because of the unfavorable cost/weight ratio. The present manufacturing tooling may not be able to handle the recommended gage reductions. New tooling costs would not be justified for the relatively small weight reductions in each part.

3.4.2 1990 TIME PERIOD

A number of cast iron components are candidates for fabricated sheet metal construction at considerable weight savings. Many of these have been suggested[6] and are repeated here. TABLE IV summarizes these applications.

The largest weight savings would be in a fabricated sheet metal engine. U. S. Steel conducted prototype development work on a four cylinder, 2.3 litre (140 cid) engine and achieved a 40.8 Kg (90 lbs) weight savings. Inlet and exhaust manifolds and the brake systems could have saved an additional 22.7 Kg (50 lbs). Sheet metal exhaust manifolds are now under test by many car manufacturers. The current Ford Mustang has a tubular stainless steel exhaust manifold.

Three other areas that can lead to weight savings are embossed, rigidized and steel/plastic laminated metals. An embossed steel roof would be about 6% lighter than a smooth steel roof and for the Omega this would amount to about 0.9 Kg (2 lbs). If the patterned steel replaced a vinyl roof, an additional 0.9 Kg (2 lbs) would be saved, for a total of 12%. Ribbed panels have been used in the past to stiffen parts that are light in gage, in order to prevent "oil canning" or similar vibrational noise. Automobile designers frequently use character lines to achieve this effect.

Rigidized metals, produced by rolling between matching rolls so that the resulting pattern is at least three times the metal thickness from the centerline of the sheet, could lead to additional weight savings. Rigidized metals could be used for structural parts as well as body panels. Such parts as the engine-transmission cradle, control arms and many brackets are candidates for rigidized metals. In areas of tight radii, the pattern would be flattened. This is usually the area of minimum or "critical" gage of the part and dictates the overall starting gage of the blank, for example a 2.79 mm (.110 in) thick control arm may have a critical gage area of 2.03 mm (.080 in). With rigidized steel, the patterned blank could be 2.03 mm (.080 in) because thinning would not occur. The pattern instead would be "ironed" at the critical gage area. This technology needs further study.

Steel/plastic/steel laminates are material sandwiches made of thin steel sheets bonded to either side of a plastic sheet or filler. Parts considered for sps laminates are engine rocker covers, fender liners, seat frames and other components that do not require weld joints. Sps compositions offer dent resistance, sound deadening and weight savings. Price appears to be the deciding factor when competing against aluminum and plastics.

TABLE IV. COMPARISON WEIGHTS OF POSSIBLE MATERIALS FOR AUTOMOBILE COMPONENTS AS REPLACEMENTS FOR CAST IRON(6).

	Original		Savings
Intake Manifold	Cast Iron	55 lbs.	
	Sheet Steel	15 lbs.	40 lbs.
	Cast Aluminum*	11.3 lbs.	43.7 lbs.
Exhaust Manifold	Cast Iron (4 cyl.)	16 lbs.	
	Stainless Steel (4 cyl.)	6 lbs.	10 lbs.
	Cast Iron*	12 lbs.	4 lbs.
Brake Master Cylinder	Cast Iron	6.75 lbs.	
	Sheet Steel	2.00 lbs.	4.75 lbs.
	Cast Aluminum*	4.19 lbs.	2.56 lbs.
Disc Brake Rotor	Cast Iron*	20.0 lbs.	
	Sheet Steel	18.0 lbs.	2.0 lbs.
Drum Brakes	Cast Iron*	14.0 lbs.	
Cone Brake	Replacement	(re-design including wheel spider)	47% Savings
Engine	Cast Iron*	(See Text)	
	Sheet Steel		90 lbs.
		Over	100 lbs.

*Currently used for the Oldsmobile Omega.

3.4.3 SECONDARY WEIGHT SAVING

A reduction in the weight of one component will ultimately allow reductions in the strength and size, and thus the weight, of other components with which it interacts. This additional potential for weight savings was not tabulated, since it is not a realistic approach on an existing car model. As this technology is applied to new model development, the full advantage would be gained.

3.5 MANUFACTURING CONSIDERATIONS

The automobile industry has extensive experience in working with sheet steel. Materials handling, blanking, stamping, scrap handling, welding and final finishing operations, are essentially geared to steel. All these operations lend themselves to extremely high production rates. Any substitution of alternate materials for steel in fabrication and assembly requires extensive study, reduced production rates and, in many cases, capital expenditure for new equipment. This, coupled with the current profit generating problems in the domestic automotive industry, could have a delaying effect in the material substitution trends.

3.6 SUBSTITUTING HIGH STRENGTH STEEL FOR LOW CARBON STEEL

High strength steels are those having yield strengths of 241 MPa (35,000 psi) or higher. These include many variations in composition and processing to achieve specific strength and forming properties. The general product descriptions are structural quality, low alloy, and dual phase, as described in "High Strength Sheet Steel Source Guide."[7] When substituting high strength for low carbon steel, most of the equipment and fabricating techniques remain the same so there is a minimum requirement for capital expenditure or development. Stamping and assembly speeds are comparable and the same general welding techniques can be used in joining high strength steels. Properties of these steels are predictable and reproducible. As with low carbon steel, properties are essentially isotropic and there is no need to consider material orientation in designing a complex part.

Because of the lighter gage of a high strength steel part compared to its low carbon counterpart, there will be increased need for corrosion protection via metallic coatings or improved paint systems. Numerous proven corrosion protection systems, including a variety of zinc, aluminum and organic coated products are available[8] as mill applied finishes on high strength steels.

The main concern in substituting with high strength steel is reduced formability. This requires additional attention to part and die design. Springback increases with strength and gage reductions. However, these are small differences when compared with the substitution of non-ferrous materials for parts normally made from low carbon steel.

COST COMPARISON

Generally speaking, high strength steels carry a price premium of from 5 to 25% over standard sheet steel, SAE 1008, depending upon alloying additions and additional processing required. An average gage reduction of 10% would offset the added cost in those applications involving the 276 and 345 MPa (40,000 and 50,000 psi) yield strength grades, so that material substitution of these grades is cost effective. There may be added one time costs due to necessary tooling and press adjustments.

3.7 SUBSTITUTING ALUMINUM FOR LOW CARBON STEEL

Aluminum is often considered for weight savings because of its low density compared to low carbon steel. Often this substitution requires some capital equipment as well as design changes. Unfortunately, a part designed to use one metal may require different dies to form it from the other metal because of required gage changes. This difference in thickness in body panels is 20-40%. The Omega hood was designed to be made from 0.86 mm (0.034 in) aluminum. The steel hood on this car was 0.86 mm (0.034 in) thick also. The hood has been re-designed to be made of 0.71 mm (0.028 in) steel. This could be reduced further to 0.66 or 0.64 mm (0.026 or 0.025 in) using high strength steel 40 XK if other problems are not encountered (see Other Considerations 3.9).

The same presses and handling equipment can be used, but there may be significant changes necessary in some material handling procedures, especially if magnetic devices are used (aluminum is non-magnetic). Scrap handling of dissimilar materials adds to manufacturing costs. Resistance welding of aluminum requires about three times more power and consequently larger welding units may be necessary.

Joints of dissimilar metals are subject to galvanic corrosion problems if they are not insulated from each other. Hang-on parts, such as an aluminum hood on a steel body, have not presented a great problem as they can be isolated from adjacent steel parts. Many aluminum automotive parts in recent years have been "hang-ons" and have not presented a problem since they are not part of the integrated structure. These applications have been more expensive but they are used when resulting weight savings place the vehicle in a lower test weight class. There are many examples of running changes from aluminum to steel to gain cost savings. This is done when weight reductions in other component areas are sufficient to maintain the test weight class.

3.8 SUBSTITUTING PLASTICS FOR LOW CARBON STEEL

Plastic components can replace low carbon and high strength steel, but the weight savings advantages are less in the latter case. Such substitutions require an entirely new design, and different fabrication and assembly procedures, in order to optimize engineering and cost efficiencies. Plastics have been substituted for steel in the past while maintaining the same general configuration. Realistically, this has not allowed a fair comparison of the performance of plastics. This was an expedient way to gain experience and increase production volume in order to gain cost benefits. For plastic parts to be cost effective compared with steel, complete re-design and the replacement of several steel parts with one of plastic is necessary. Generally, different presses or molding equipment are required, special and slower joining techniques must be employed, and greater attention paid to surface finish and painting procedures. Overall production rates are slower.

3.9 OTHER CONSIDERATIONS

Several parts examined during this study appeared to have the potential for weight savings through the use of high strength steel or by simply reducing gage of the low carbon steel. These parts offered a total weight savings potential of 6.75 Kg (14.8 lbs), but were not included in the final analysis. They are discussed below and summarized in Table V.

Hood Outer Panel - The gage of the steel hood was 0.86 mm (0.034 in). This was believed to have been established for an aluminum hood. Apparently this vehicle met the requirement for the planned weight classification; therefore, it was decided to use steel. This part has subsequently been reduced in gage to 0.71 mm (0.028 in) saving 1.1 Kg (2.5 lbs). A further reduction in gage may be possible from a purely structural consideration; however, experience has shown that problems such as palm printing and fluttering can occur if the sheet metal is too thin. Other areas of concern are hinge pull out, hood distortion when propped open on the corner, and buckling if blown open.

Front Fender - The gage of 0.86 mm (0.034 in) seems unusually heavy for fender construction since it is more than enough metal for the normal function of the fender. Upon impact, the fender is one of the energy absorbing components for passenger protection. Thus, a fender change is not suggested, for it is assumed that the fender was designed to absorb a portion of the energy during front end collision.

Rear Door Outer - The gage was 0.91 mm (0.036 in). Present X-cars from General Motors have rear door outers of 0.79 mm (0.031 in). This discrepancy cannot be explained. A further reduction to 0.069 mm (0.027 in) could be made based upon experiences with other vehicles, provided there were no other difficulties, i.e., denting upon door slamming, hinge pull-out, or distortion problems, latch problems, etc.

Front Door, Inner - The gage was reported by South Coast Technology to be 1.06 mm (0.042 in); however, this is not likely. Subsequent investigation revealed that the front door inner is currently 0.90 mm (0.035 in) or 2.9 Kg (6.3 lbs) lighter - Further reduction to 0.80 mm (0.032 in) might be possible; however, since the front door is expected to be opened more frequently than the rear door, the inner panel is subjected to fatigue loads and possible premature failure.

Reinforcement - This part is at the belt line and is currently high strength steel. This area is sensitive in barrier tests and serves as part of the hinge reinforcement; therefore, further gage reduction is not possible.

Door Beam - It is currently 2.03 mm (0.080 in) steel of 415 MPa (60,000 psi) yield strength rather than 2.33 mm (0.092 in) as reported by South Coast Technology or 0.7 Kg (1.6 lbs) lighter.

Roof Inner Ribs - These were reported to be 0.82 mm (0.032 in) by South Coast Technology. Some errors apparently occur in measuring thickness in flange areas, in convoluted areas or on painted surfaces. These ribs are not all the same gage but average 0.73 mm (0.028 in).

Engine Cradle - 2.03 mm (0.080 in) gage and weighs 15.86 Kg (35 lbs). It was felt that this gage could be reduced to 1.78 mm (0.070 in), thus saving 1.81 Kg (4.0 lbs). However, this is a very complex part that performs many functions and it was decided after further study not to recommend a gage reduction. Fatigue, rideability, NVH (noise, vibration, harshness) could be introduced with an arbitrary gage reduction.

Front Suspension - These assemblies weighed 35.3 Kg (78 lbs) and first analysis suggested a reduction of 4 Kg (8.9 lbs). Due to the higher <u>costs</u> of fabricating a stabilizer bar out of tubing and fit-up problems introduced by lightening holes, no changes were recommended in these assemblies.

TABLE V. DIFFERENCES NOTED IN SIZE AND WEIGHT OF THE OMEGA COMPONENTS FROM CURRENT GENERAL MOTOR'S X-BODY CARS

	South Coast Technology Report: Early 1980 Omega		GM Information: Current X-Body Cars		
	Thickness Gage-in	Weight Lbs.	Thickness Gage-in	Weight Lbs.	Difference Lbs.
Hood Outer Panel	.034	21.7	.028	19.2	- 2.5
Rear Door Outer	.036	16.5	.031	14.2	- 2.3
Front Door Inner	.042	38.0	.035	31.7	- 6.3
Door Beam	.092	12.5	.080	10.9	- 1.6
Roof Inner Ribs	.032	16.7	.028	14.6	- 2.1
		105.4		90.6	-14.8

Brackets - These parts are critical to the tuning of the vehicle. Reducing gage and introducing lightening holes will affect rideability and cannot be made on the basis of strength alone.

Brake Pedal Mounting Bracket - The thickness of this part, 2.3 mm (0.093 in) cannot be reduced due to the strength and stiffness required in panic stop situations.

Drive Shaft - The original thought of making this part out of tubing is not recommended due to greater diameter and obvious fit-up problems. The tube ends would require "solid" metal to accommodate the spindles.

Caution should be exercised in reducing the gage of any part discussed in this study. Generally, the gage calculated for a particular part was based upon its capacity to perform its normal function and does not take into account the unusual abuse the part may receive in actual service. For example, tests conducted on a newly designed wheel are extensive and include rotary fatigue and radial fatigue. If warranty records show a high rate of failure due to various abuses, then gage increases are made.

Finally, there is the requirement of good rideability, elimination of excessive road noise, and freedom from resonance, shakes and shimmys. This is detected during proving ground rolling tests. Very sophisticated sensing equipment and human judgment are used to locate problems in these areas. One solution is to add weight until the problem goes away. This change may cause a gage increase in an otherwise design optimized part.

4. CONCLUSIONS

From this study, it appears that 33.5 Kg (74 lbs) could be removed from this Omega X-Body and similar General Motors X-Body cars using current steel technology. It can be concluded that this vehicle does incorporate up-to-date steel technology.

Considering the year 1990, advances in applying sheet steel in areas now using iron castings could result in an additional 45.2 Kg (100 lbs) savings in this type and size vehicle. Such components include:

- Engine blocks and cylinder heads
- Intake and exhaust manifolds
- Brake drums, rotors and master cylinders

The application of steel/plastic/steel laminates, embossed and rigidized steels could allow weight reduction in those components that are stiffness limited.

This total weight reduction of about 80.0 Kg (175 lbs) or 7-10% agrees with many of the projections being made regarding the future consumption of steel by the automotive industry.

To this can be added secondary weight savings, making a grand total of 120-160 Kg (250-350 lbs) removed from a vehicle representing the size and weight of the GM X-Body.

This study did not take into account the entire energy impact of the automobile; such as the energy required for materials refining and shipping, for manufacturing the components and vehicle, operating the vehicle and, finally, recycling.[3]

5. RECOMMENDATIONS

In the spirit of reducing energy requirements in personal transportation, several areas of research and study are suggested.

1. Base data and comparisons are needed to show the most fuel efficient materials to be used in automotive construction. World wide raw materials availability, environmental impact and social and economic problems should be included in this study.

2. Component development in the area of replacing iron castings with sheet steel fabrication in: engine and cylinder head blocks, brake parts, intake and exhaust manifolds and forged, suspension applications. Rigidized, embossed and steel/plastics/steel laminated products may show promise in these applications.

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