Material Selection

Jacob Klinginsmith, Russ Glass
Naomi Sanders, Becky Moffitt

The most significant feature of our poster is the slider bar graph at the top of each material category. This quick reference will enable students in Mind Works to see how the selection of a material may affect their project. The base line that we chose for comparison was mild steel; through our research this seems to be the accepted norm. The criterion used for machinablity and weldablity was the amount of skill and special equipment needed to manufacture a part. Also important is whether the part would need a special process to be successfully welded. Corrosion resistance was determined by comparing the materials with stainless steel (high resistivity) and zinc (low resistivity) based on the information taught in MSE 201. Availability and price were determined by searching the internet for steel suppliers and manufactures, and comparing the data. Actual data was unavailable because of the highly volatile steel market. Fortunately, the relative prices are consistent.

Carbon Steels

Carbon steels in general are easy to work with exhibiting excellent machinablity and weldablity. Though as the carbon content increases, the ease of manufacture decreases. The added carbon changes the behavior of the material at high temperature and therefore needing a more refined process.

Low carbon or mild steel has carbon content less than 0.3 %. These carbon steels make up wire, sheet metal parts, structural steel, and low strength gears. Car bodies are built using these low carbon steels. Mild steel is used in buildings, piping, bridges and the like.

Medium carbon steel is made up of between .3% and .6% carbon. Medium carbon steels are used in machinery, mining equipment, and tractors. In addition, machined parts, bolts, and concrete reinforcing bars are made of this class of carbon steel. This type of carbon steel is abrasion and impact resistance due to its high hardenability and good fatigue. Gears, wire rods, seamless tubing, hot-rolled/cold-finished bars and forging products are more objects constructed from medium carbon steel.

High carbon steel consists of carbon at more then .6%. These steels make bearings, railroad car wheels, springs, and such things that need to be highly durable. This kind of carbon steel is hard and therefore not easy to machine or weld. No surface treatments are needed for this high carbon steel because it is so tough.

Tool steels are in fact carbon steels capable of achieving high hardness though heat treatment. Elements other than carbon are added to increase the machinablity or stability of the finished product. Not all of the information on our chart is complete for this category because we were unable to find the information. The standard process for manufacture is to rough machine a part then heat treatment and finish machining afterward. These steels are very sensitive to the heat affected zone caused by welding; so special care must be taken. Supply can fluctuate greatly due to being entirely imported.

Aluminum

At extremely high temperatures, (200-250°C) aluminum alloys tend to lose some of their strength. However, at subzero temperatures, their strength increases while retaining their ductility, making aluminum an extremely useful low-temperature alloy. Aluminum alloys have a strong resistance to corrosion, which is a result of an oxide skin that forms as a result of reactions with the atmosphere. This corrosive skin protects aluminum from most chemicals, weathering conditions, and even many acids, however alkaline substances are known to penetrate the protective skin and corrode the metal. Aluminum also has a rather high electrical conductivity, making it useful as a conductor. Copper is the more widely used conductor, having a conductivity of approximately 161% that of aluminum. Aluminum comes in heat treatable and non-heat treatable alloys. Heat treatable aluminum alloys get their strength from a process called ageing.

Aluminum can be rolled, stamped, drawn, spun, roll-formed, hammered and forged. The metal can be extruded into a variety of shapes, and can be turned, milled, and bored in the machining process. This metal can be riveted, welded, brazed, or resin bonded. For most applications, aluminum needs no protective coating; however, it is often anodized to improve color and strength. Aluminum can be a difficult alloy to weld. Aluminum oxide should be cleaned from the surface prior to welding. Significant decrease in tensile strength can occurs when welding aluminum due to over aging.

The first number in a three-digit cast alloy designation indicates the principal alloying element though this system does not parallel the one used for wrought alloys. (An initial three indicates that the principal alloying element is manganese in wrought alloys and silicon in cast alloys.) Modifications to a cast alloy makeup are indicated by a letter prefix. Dash, letter, and number suffixes are also used to describe the process used to obtain particular mechanical properties.

Temper designations of wrought aluminum alloys consist of suffixes to the numeric alloy designations. For example, in 3003-Hl4, 3003 denotes the alloy and "Hl 4" denotes the temper, or degree of hardness. The temper designation also reveals the method by which the hardness was obtained. Temper designations differ between non heat-treatable alloys and heat-treatable alloys.

Stainless Steel

Stainless steels are high-alloy steels that have superior corrosion resistance than other steels because they contain large amounts of chromium. Stainless steels can contain anywhere from 4-30 percent chromium, however most contain around 10 percent. Stainless steels can be divided into three basic groups based on their crystalline structure: austenitic, ferritic, and martensitic. Another group of stainless steels known as precipitation-hardened steels is a combination of austenitic and martensitic steels.

Ferritic stainless steels are magnetic, non heat-treatable steels. They have good heat and corrosion resistance, in particular seawater, and good resistance to stress-corrosion cracking. Their mechanical properties are not as strong as the austenitic grades.

Martensitic grades are magnetic and can be heat-treated by quenching or tempering. Martensitic steels are not as corrosive resistant as austenitic or ferritic grades, but their hardness levels are among the highest of the all the stainless steels.

Austenitic stainless steels are non-magnetic non heat-treatable steels that are usually annealed and cold worked. Austenitic steels have excellent corrosion and heat resistance with good mechanical properties over a wide range of temperatures. There are two subclasses of austenitic stainless steels: chromium-nickel and chromium-manganese-low nickel steels. Chromium-nickel steels are the most general widely used steels and are

also known as 18-8(Cr-Ni) steels. The chromium nickel ratio can be modified to improve formability; carbon content can be reduced to improve intergranular corrosion resistance. Molybdenum can be added to improve corrosion resistance; additionally the Cr-Ni content can be increased.

The fact that stainless steel has a great resistance to corrosion means that using stainless will result in a very long life compared to mild steel. Therefore, while stainless steel is probably more expensive to buy in the beginning -- because it lasts a long time, it is usually cheaper in the end because there is little or no maintenance and repair costs. In addition, once the useful life is over, stainless steel is 100% recyclable.

Sources used to find information for this project are as follows:

Efunda.com

Home.netcom.com

Matweb.org

Suppliersonline.com

"The Science and Engineering of Materials" (Fourth Edition)

Donald R. Askland and Pradeep P. Phule

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www.crucibleservice.com/

www.bethsteel.com

Weldingengineer.com

Autoaluminum.org

Ez.org

Selection of Aluminum

General Qualities:

	Poor	Moderate	Excellent
Corrosion Resistance			■
Weldability		■	
Machinability			■
Availability		■	
Price		■	

Temper Designations

F	As fabricated
O	Annealed
T	Heat treated

Heat-Treatable Temper Designations

T3	Solution heat treated, then cold worked
T4	Solution heat treated, then naturally aged
T6	Solution heat treated, then artificially aged
*Other Designations Exist	

Common Alloys:

Mechanical Properties

Alloy & Temper	Density lb/in³	Modulus of Elasticity (Msi)	Tensile Strength (ksi)	Yield Strength (ksi)	Typical Use
3003-O	.0986	10.0	16	6	Pressure vessels, piping, sheet metal
2024-T4	.1	10.6	68	47	Aircraft, rivets, truck wheels
6061-T4	.0975	10.0	35	21	Railroad cars, furniture, pipelines
7075-T6	.102	10.4	83	73	Structural aircraft components

Selection of High Carbon Steel

General Qualities:

	Poor	Moderate	Excellent
Corrosion Resistance		■	
Weldability		■	
Machinability		■	
Availability			■
Price		■	

Surface Treatment

Not necessary

Hardness Range

1060	**241 HRb**
1080	**293 HRb**
9260	**184-235 HRb**
52100	**875 HRb**

Common Alloys:

Mechanical Properties

Alloy & Treatment	Density lb/in³	Modulus of Elasticity (ksi)	Tensile Strength (ksi)	Yield Strength (ksi)	Typical Uses
1060	**.284**	**29700**	**118**	**70.3**	Springs, railroad car wheels, and the like
1080	**.284**	**29700**	**140**	**84.8**	
9260	**.284**	**29700**	**112-221**	**63.8-167**	
52100	**.284**	**30500**	**-**	**-**	**To make bearings**

Composit

AISI #	%C	%Mn	%Si	%Ni	%Cr	Other
1060	**.55-.66**	**.6-.9**	**0**	**0**	**0**	**P .04 S .05**
1080	**.74-.88**	**.6-.9**	**0**	**0**	**0**	**P .04 S .05**
9260	**.56-.64**	**.88**	**.2**	**0**	**0**	**P .035 S .04**
52100	**.98-1.1**	**.35**	**.23**	**0**	**1.45**	**P .025 S .025**

Medium Carbon Steel

General Qualities:

	Poor	Moderate	Excellent
Corrosion Resistance			
Weldability			
Machinability			
Availability			
Price			

Surface Treatment

Carburizing, nitrating, chrome plate

Hardness Range

1040	**201 HRb**
1050	**229 HRb**
4140	**179 HRb**
4340	**217 HRb**

Common Alloys:

Mechanical Properties

Alloy & Treatment	Density lb/in³	Modulus of Elasticity (ksi)	Tensile Strength (ksi)	Yield Strength (ksi)	Typical Uses
1040	**.283**	**29000**	**89.9**	**60.2**	bolts, machined parts, concrete reinforcing rods
1050	**.284**	**29700**	**105**	**60.2**	forging, hot-rolled and cold-finished bars, wire rods, and seamless tubing
4140	**.284**	**29700**	**95**	**60.2**	gears
4340	**.284**	**29700**	**108**	**68.2**	**Formula car frame**

Composition:

AISI #	%C	%Mn	%Si	%Ni	%Cr	Other
1040	**.37-.44**	**.6-.9**	**0**	**0**	**0**	**P .04 S .05**
1050	**.47-.55**	**.6-.9**	**0**	**0**	**0**	**P .04 S .05**
4140	**.38-.43**	**.7-1**	**.15-.3**	**0**	**.8-1.1**	**P .035 S .04 Mo .15-.25**
4340	**.37-.43**	**.7**	**.23**	**1.83**	**.7-.9**	**P .035 S .04 Mo .2-.3**

Selection of Mild Steel

General Qualities:

	Poor	Moderate	Excellent
Corrosion Resistance		■	
Weldability			■
Machinability			■
Availability			■
Price			■

Surface Treatment

Carburizing, nitrating, chrome plate

Hardness Range

1010	60 HRb
1018	71 HRb
1020	78 HRb

Common Alloys:

Mechanical Properties

Alloy & Treatment	Density lb/in³	Modulus of Elasticity (ksi)	Tensile Strength (ksi)	Yield Strength (ksi)	Typical Uses
1010	0.284	29.7	47.1	26.1	Low strength, good formablity (wire, sheet metal parts)
1018	0.284	29.0	58.0	31.9	Good weldablity and machinablity (Structural steel)
1020	0.284	29.0	65.3	47.9	Shafts and case hardened parts (low strength gears, motor arbor)

Composition:

AISI #	%C	%Mn	%Si	%Ni	%Cr	Other
1010	0.08-0.13	0.3-0.6	0	0	0	P 0.04 S 0.05
1018	0.14-0.2	0.6-0.9	0	0	0	P 0.04 S 0.05
1020	0.17-0.23	0.3-0.6	0	0	0	P 0.04 S 0.05

Selection of Stainless Steel

General Qualities:

	Poor	Moderate	Excellent
Corrosion Resistance			■
Weldability		■	
Machinability		■	
Availability		■	
Price	■		

The Branches:

	Definining Element	Notes	Grades
Martensitic	Chromium (>.2% C)	Basic stainless steel, magnetic, heat treatable	410,420,440C
Ferritic	Chromium (<.2% C)	Magnetic, cannot be hardened with heat treatment	409,430
Austenitic	Nickel	Not magnetic, best corrosion resistance	304,310,316,317
Duplex	Molybdenum	Combination of Ferritic and Austenitic	2205

Selection of Tool Steel

General Qualities:

	Poor	Moderate	Excellent
Corrosion Resistance			
Weldability			
Machinability			
Availability			
Price			

Surface Treatment

Chrome plating,

Titanium-Nitriting

Hardness Range

A2	60-62 HRc
H13	48-52HRc
O1	50-52 HRc
S7	56-58 HRc

Common Alloys:

Mechanical Properties

Alloy & Treatment	Density lb/in³	Modulus of Elasticity (Msi)	Tensile Strength (ksi)	Yield Strength (ksi)	Typical Uses
A2	.284	29.4			Air cooled very stable tough Good fatigue
H13	.282	30.5	289000	239000	Thermal shock
O1	.283	31.0	245000	218000	Tough, very stable
S7	.283	30.0			Impact resistant

Composition:

AISI #	%C	%Mn	%Si	%Ni	%Cr	Other
A2	0.95-1.05	1	0.5		5.13	1.15 Mo
H13	0.32-0.4		1		5.13-5.25	1 V
O1	0.85-1	1.2	0.5		0.5	0.03 S
S7	0.5	0.7			3.25	1.4 Mo