Product Design and Manufacturing

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Lecture – 15
Material Selection (part 2 of 2)

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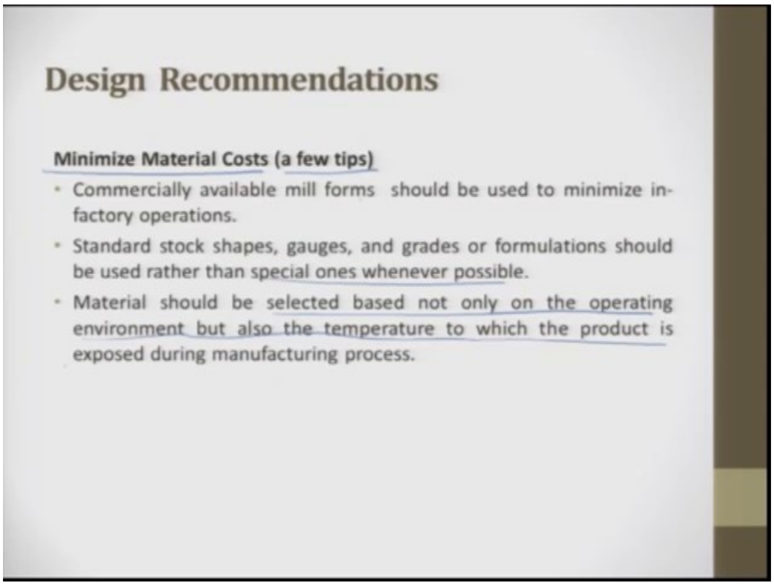

So, minimising material cost; a few tips are there. So, you always try to choose. The cost is the major parameter, if you have a cost which is economical, so, then the product is going to be the cost to customer will not be very high. If you choose a product which has a material cost very high or the processing cost very high it is going to affects its performance or its sales performance in the market. So, minimising material cost.

So, there are few tips we are giving here commercially available mill form should be used to minimise in-factory operations. So, basically what we are trying to say is you go to the market, find out whatever is very easily available, choose those material, come back, tweak your design little bit and make sure that it meets outs the customer requirement. So, if you use a commercially available one then the success of your product is going to be very high the cost of your product is going to be low standard and whenever you try to give a design try to use the standards which are already available in the market.

So, standard stock, shapes, gauges, grades or formulation should be used rather than special ones wherever possible. So, that is why we try to standardise the screws and bolts m 1, m 2. m 3, m 4 and shafts when we are there we get half inch shaft, quarter inch shafts, 1 inch shaft or 20 millimetre shafts whatever it is, we get it according to the standards and when we have a nut or when we have some mating component that dimensions also we get it accordingly. So, it is always good to use easily available material it is always good to use a standard material so you do not have to worry much.

Just for your information, the price of a computer falls down drastically year after year after year, but an automobile cost does not fall drastically year after year after year. Why because in computers they have established standards. The standards are given to every vendor and they say if you want to make a computer, your computer should have all the standards to be followed. The shape standard size standard is given.

So, if you want to make a laptop so ,they say your laptop should have a serial port which is used for giving a thumb drive of this standard size and the other standard, which is given to all those people who manufacture thumb drive they say if you are manufacturing at thumb drive and that shaped should we finally, this you can have in the memory, that is left to you, that is your capability, but when it gets attached to a laptop this is how it has to make.

So, now what has happened these standards are given so, there is huge competition and people work on those standards and come to the market. So, whoever gives it at a better performance lower cost succeeds and goes forward and the rest of the people over a period of time die so, it’s only because using the standards the computer price of the laptop price falls down drastically.

The material should be selected based not only on the operation environment, but also the temperature to which the product is exposed during the manufacturing process. For example, polymer if you say a polymer has to be machined the polymer predominantly can with stand up to 100 – 150 degree Celsius. So, when you try to machine the temperature always goes above 150 – 160 degrees. So, what happens just it tries to distort the material while machining, but in real time it can withstand the temperature or I will share a recent experience what I had.

We were trying to drill holes on rubber, on rubber sheet for developing a set up. So, when we were trying to drill the hole, the rubber on the rubber material, the hole was perfect 6 millimetres hole has to be done; we got 6 millimetre and over a period of time maybe after a day or so this 6 millimetre always used to becomes 7 or it used to become 5. So, we were not able to understand why is this variation always happening. Then, later we realise that while machining there is a temperature, this temperature induces thermal stresses and these thermal stresses relaxes over a period of time. So, there can be a shrinkage or expansion of the hole geometry. So, that is what we are trying to say.

So, if you are trying to use a material and if that material has to be machined or processed, for example, injection moulding; in injection moulding what we do we increase the temperature convert the solid material into a visco-elastic material and then we inject it inside a die. So, when we do that also there is a temperature phenomenon which is involved in the process and once you injected into a die and if you do not hold it for some time while holding it you also try to cool it if you do not do this properly then as soon as the product is made and left in the free atmosphere it tries to get distorted. So, this is what we are trying to say.

So, that three tips are going to be the commercially it has to be available, you have to always used standards and you choose a material which does not get distorted while manufacturing.

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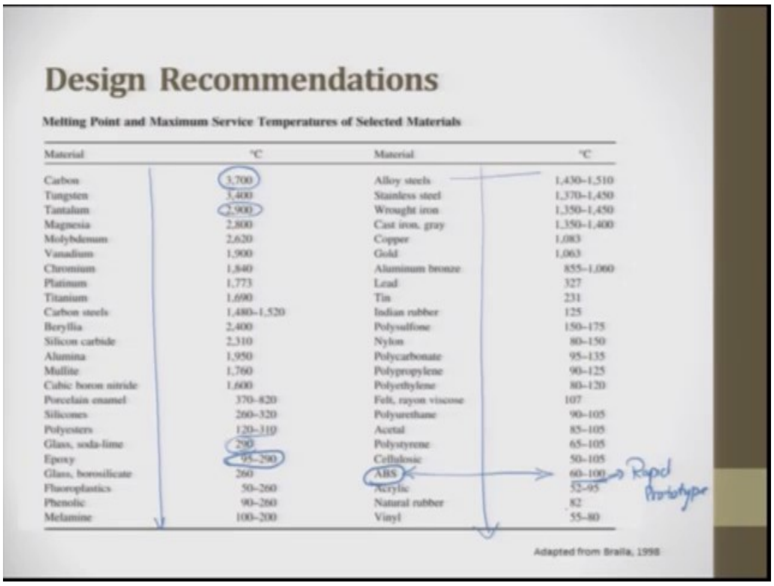

Design Recommendations

Melting Point and Maximum Service Temperatures of Selected Materials

Material	°C	Material	°C
Carbon	3,700	Alloy steels	1,430–1,510
Tungsten	3,400	Stainless steel	1,370–1,450
Tantalum	2,900	Wrought iron	1,350–1,450
Magnesia	2,800	Cast iron, gray	1,350–1,400
Molybdenum	2,620	Copper	1,083
Vanadium	1,900	Gold	1,063
Chromium	1,840	Aluminum bronze	855–1,060
Platinum	1,773	Lead	327
Titanium	1,690	Tin	231
Carbon steels	1,480–1,520	Indian rubber	125
Beryllia	2,400	Polysulfone	150–175
Silicon carbide	2,310	Nylon	80–150
Alumina	1,950	Polycarbonate	95–135
Mullite	1,760	Polypropylene	90–125
Cubic boron nitride	1,600	Polyethylene	80–120
Porcelain enamel	370–820	Felt, rayon viscose	107
Silicones	260–320	Polyurethane	90–105
Polyesters	120–310	Acetal	85–105
Glass, soda-lime	290	Polystyrene	65–105
Epoxy	95–290	Cellulosic	50–105
Glass, borosilicate	260	ABS	60–100
Fluoroplastics	50–260	Acrylic	52–95
Phenolic	90–260	Natural rubber	82
Melamine	100–200	Vinyl	55–80

Adapted from Bralla, 1998

So, here are a list of materials we have display. So, all these things are metals and we have given also the processing temperature. So, you look at epoxy is around about 95 to 290, if you are look at carbon it is 3700, that is why all the high temperature applications we always go for carbon. So, if you are looking for a crucible which has to be kept inside a furnace temperature might go up 1800 – 2000 we always go for a graphite or a carbon crucible where and which the component is made.

You can also have Tantalum, but it is expensive; tantalum and tungsten are expensive if you look at the lower side all the borosil, borosil are nothing, but the glasses soda lime glass it is 290, polyester which is a polymer material. So, soda lime is around about 290 degree Celsius that is why you see in the chemistry lab they always used to work on glass bars because if they want to make a tight air tights setup so, then they always use glass and then they go either for silicate or they use glass deform it to make the shape, ok.

So, if you look at steel it is given at very high temperature when you look at this place like ABS; ABS and all it is 60 to 80 degrees 60 to 100 degrees Celsius. So, ABS is one material which is used for rapid prototyping wherein which you have an FDM process where and wherein which a wire is used polymer wire is used ABS is one material which is exhaustively used.

So, looking at this you can choose material for your choice. So, it is only talked in terms of temperature. We have not put cost, there is only one variable, cost is another variable, third variable is the manufacturing it, fourth variable is the physical properties, fifth variable is the lifetime, that is lifetime efficiency. For example, polymer cannot withstand very high temperatures and fatigue look for a longer time in rapid prototyping whereas, rubber can withstand for a fatigue cycles.

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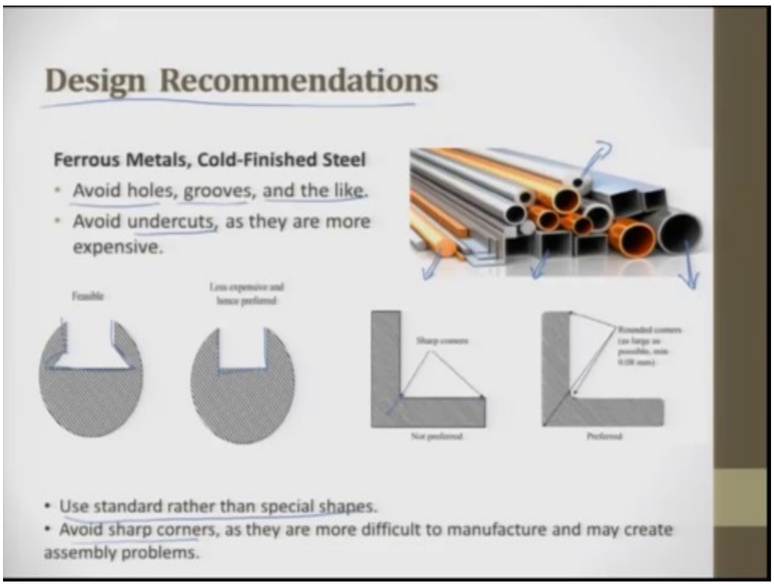

So, some design recommendations we are just giving it for your knowledge. So, when you talk about ferrous metals, cold finished steels; avoid holes, avoid grooves and the avoid undercuts they are very expensive. So, this is feasible cutting it under (Refer Time: 08:28). This is less expensive and this is very much prepared, but here you will have something like a dovetail, this is also feasible, but manufacturing this is expensive. So, if you want to have sharp corners it is not advisable because a stress can grow and second thing when you want sharp corner to be manufactured, it is very difficult.

So, it is always advisable to give a small radius at different corners. So, that it tries to make. So, this is a L angle. These are all rectangle channels, cylindrical channels you can this is made out of copper, this is made out of aluminium, steel is also there you can get, You can these are standards which are available, you can get a rectangular cross section, you can get a circular cross section. Rectangular cross section with varying aspect ratio can be a square. So, you get that also you get a solid shaft, you get a hollow shaft. So, you can get for varying materials.

So, these are all standards which are available in the market. So, use standards rather than special shapes which I have already discuss. Avoid sharp corners as they are also they are stressed concentrated point, but on top of it they are all manufacturing is very very difficult.

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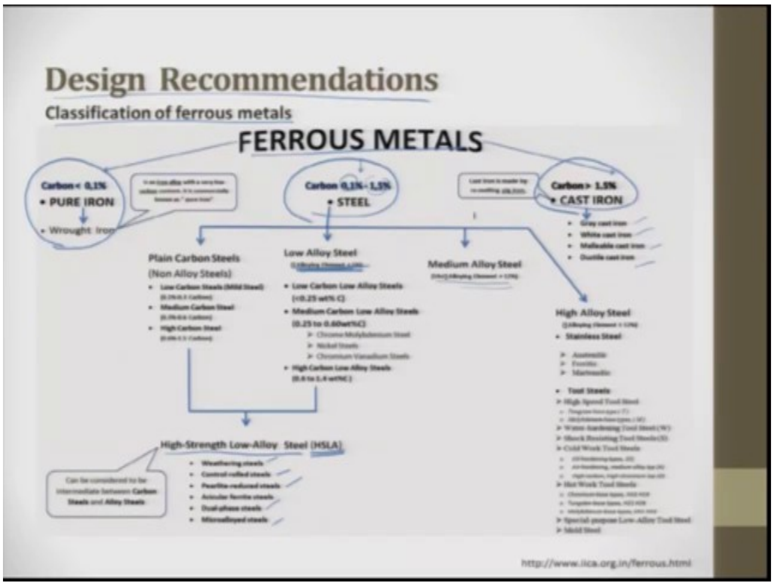

So, when you try to take the design classifications of ferrous metals. So, the ferrous metals are classified into pure iron, then for steel, then for cast iron. Many a times this pure iron and all they do not pure metal does not have any functional application. They always get mixed with an alloy so that they try to have some property strength properties or conducting properties, whatever it is. So, here you see wrought iron, which is where the carbon percentage is less than 0.1 percentage.

So, here wrought iron is an alloy with a very low carbon content, it is commercially known as pure iron, but this has no use. So, we had carbon into it and more of carbon we put it becomes a cast iron, the cast iron is made by re-melting pig iron. So, you get more than that.

So, cast iron you will have classification grey cast iron, white cast iron, malleable cast iron and ductile cast iron. See here also you try to have varying cast iron depending upon your requirement use where is cast iron exhaustively used, wherever you have heavy load for example, church well made out of cast iron. It does not corrode, it has graphite in it. So, if you play with the heat treatment properties you can try to play with the microstructure and try to get varying requirements.

So, when you talk about steel, the steel and again classified into three; one is called as plain carbon steel and low alloy steel and medium alloy steel. Of course, you also have a higher alloy steel. The difference between these three is the difference in carbon content which falls between 0.1 to 1.5 or anything above 1.5 goes to cast iron. So, here what I have done this I have put you the list. So, you can see low carbon, medium carbon, and high carbon. So, this is all plain carbon steel, this is non alloy steel and here alloying elements are greater than or less than 5 percent.

So, here you see that low carbon, low alloy steels are there medium carbon, low alloy steel, high carbon alloy steel. So, here the difference between this one and this is the alloying element less than 5 percent. So, when you talk about medium, the alloying element can it should be between 5 to 12 percent and the alloying element anything less than 12 percent you go on this steel. So, here we have given all this tool steels another things. Today, we talked about the new steel which is called as high strength low alloy steel.

So, here which is now talked about in automobile application, very high-strength low-alloy steel so, here you have weathered steel, the control rolled steel pearlite-reduced to steel ah, dual phase steel, micro alloyed steel. So, all these steels are different varieties which are falling under the category of high strength low alloy. So, it is a combination of plain carbon steel and low alloy steel. So, it can be considered to be intermediate between carbon steel and alloy steel is this and this has a huge application today. So, I am just put you how is the ferrous getting classified.

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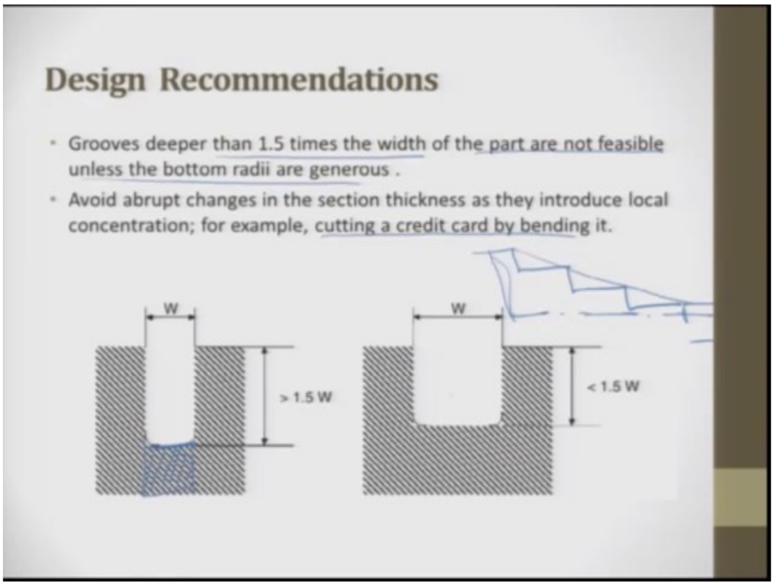

Again, getting back into design recommendations, so, the grooves deeper than 1.5 times width of the part are not feasible. So, if many a times what happens, if you want to have a blind group so, what generally people do is there trying to make a through hole and then that try to put a closure and close it, one way of doing it. The other way of doing it, because they talk about something called as aspect ratio. So, aspect ratio is nothing, but width versus depth or depth versus width whatever it is. So, you can try to talk and anything which is late greater than 1, it is very hard for a tool to get inside and machine. So, what people do the other way around as they try to enhance the width and make it equal to 1, of the depth.

So, here making high aspect ratio features is a big challenge and if at all there is any try to use this logic or try to change the width. So, that you get the output. So, grooves depend rather deeper than 1.5 times the width of the path are not feasible unless the bottom radius are generous. Avoid abrupt change in the cross section thickness.

What they are trying to say if you have something like this a step so, what they say is rather than continuously changing try to have something like a taper such that you tried to get whatever it is and finally, you have a step one here. So, that it does not have sharp edges and it does not have anything. So, avoid sharp change in the cross section as they introduced local concentrations, so, cutting a credit card by bending it, ok.

So, that is what is one of the thing. So, you should always try to avoid having a change in geometry.

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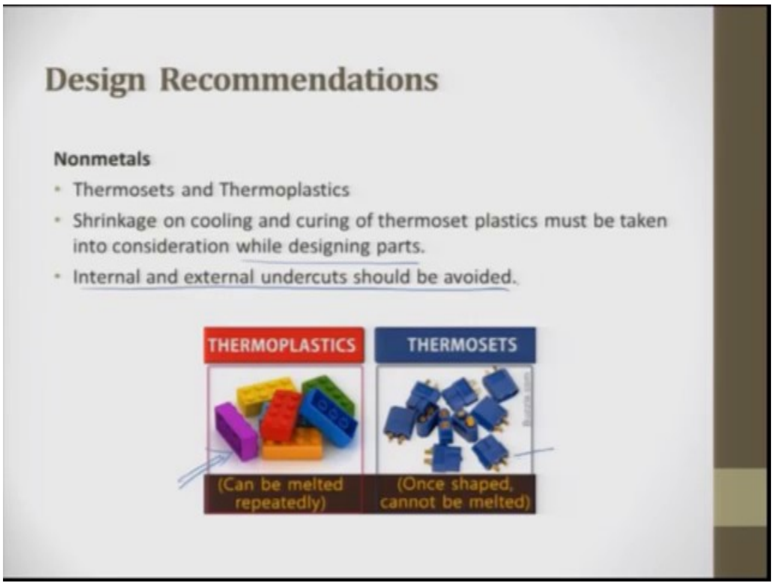

So, when you talk about non metals there are thermoplast and thermoset; thermoplast can be re-melted and used thermosets are one time melt and used for example, it is Bakelite. So, you can see you can interesting and polymers you can also having these are inserts which are kept inside the thermosets and they try to make a product which meets of the customer requirement. So, when you tried to work on this there is not much to worry the shrinkage is very less, but when you try to work on thermoplastic there is going to be a huge amount of shrinkage.

So, when you try to create a die and then when you try to inject a component inside a die, a component is injected inside. So, you will try to hold it for some time and you will also take into account for the shrinkage of a polymer. So, shrinkage on cooling and curing of thermoset plastics must be taken into thermosets or thermoplast must be taken into consideration while designing a part. Internal and external undercut should be avoided. So, ah, so, this is also a recommendation which can be followed for metals, but for polymers, yes it has to be followed.

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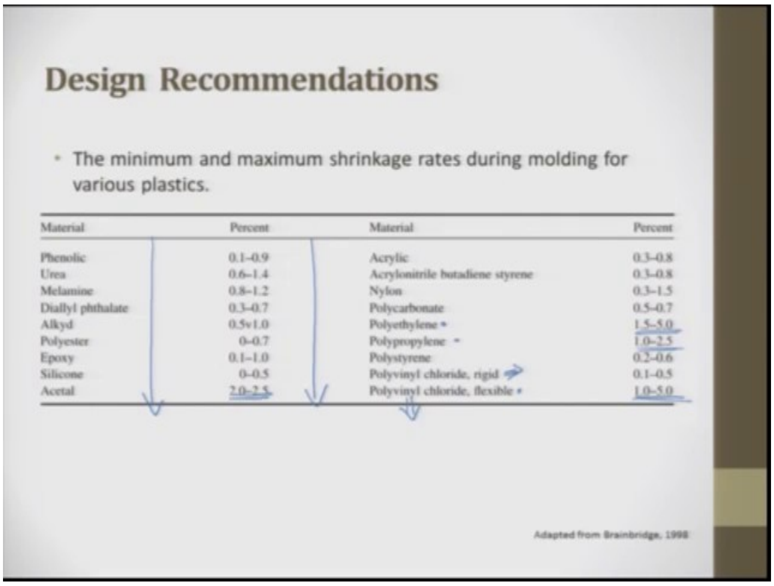

So, here we have listed varying polymers what is the percentage of shrinkage it can do. So, phenolic 0.1 to 0.9 percent if you look at it ah. So, here are 2 to 2.5 acetate; acetal. Acetal is 2 to 2.5 and you can see PVC can go up to 5 percent, polypropylene can go up to 2.5 percent, and polyethylene can go up to 5 percent. See these are some things which you should be very careful, polycarbonate does not undergo.

So, people try to replace from polyethylene to polycarbonate, polypropylene they also try to work polyvinyl chloride PVC, PVC are flexible it can go from 1 to 5 percent. So, almost all the tubes which are used for agricultural applications are made out of PVC which is a flexible tube, PVC flexible, you can have transparent, you can have non transparent you can have rigid tubes which is generally used for construction civil constructions. We use a rigid to venture of flexible and when we think of applications in the garden agriculture, we always talked about flexibility in the plastic.

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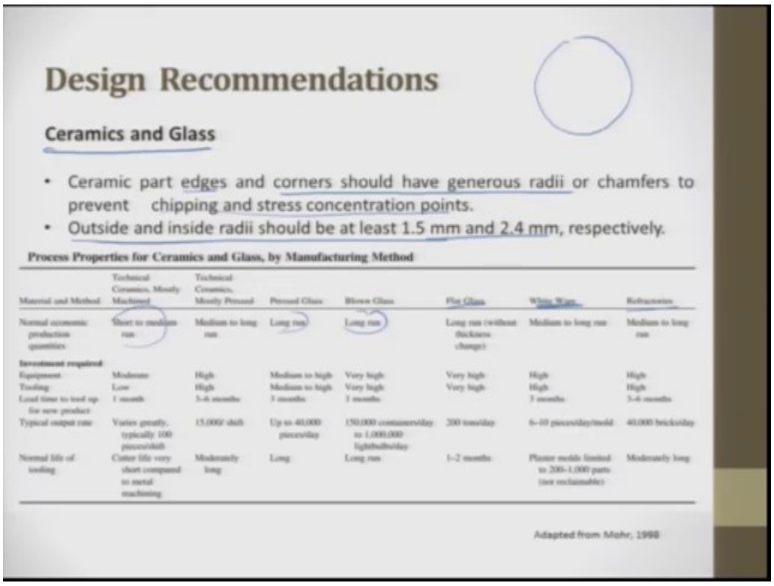

So, by the way today plastics have taken over in the agricultural field. Lot of lot of agriculture implements today are made out of plastics because it tries to have the flexibility, it tries to have the impact load, it is non corrosive and it is light. To a large extent people have moved from metals to this when we talk about ceramic and glasses ceramic parts part edges and corners should be generous radius because in ceramics it is always prone to have defects, that defect density in ceramics is very high as compact to the tough polymer and metal.

So, here what will we are we suggest or it is suggested it is you should give a generous radius such that the crack densities are; the sharp edges do not act like a stress concentration points and the cracks can grow very easily and here that cracks growth is not there. It is brittle, so, it can easily fragment into two pieces or several pieces. So, generally in ceramics what we do is we always try to say please be generous in giving radius around. So, that is why if you see many components it will always be made into circular or chamfers to prevent the chipping on the stress concentration point, the outside and inside radius should be at least 1.5 millimetre to 2.4 millimetre respectively.

So, when we talk about the ceramics and glasses by manufacturing method. So, you can take material and method, normal economic production quantity, typically ceramics mostly machine does short to medium, technical ceramics mostly pressed is medium to long run, pressed glass are for used for long run, blown gas are used for low blown gases nothing, but your bulb incantation bulb, then flat glass are used for long run, white wares are used for medium to long and refractories are used for medium to long. So, we have put various processes and their costing in developing these ceramic pieces.

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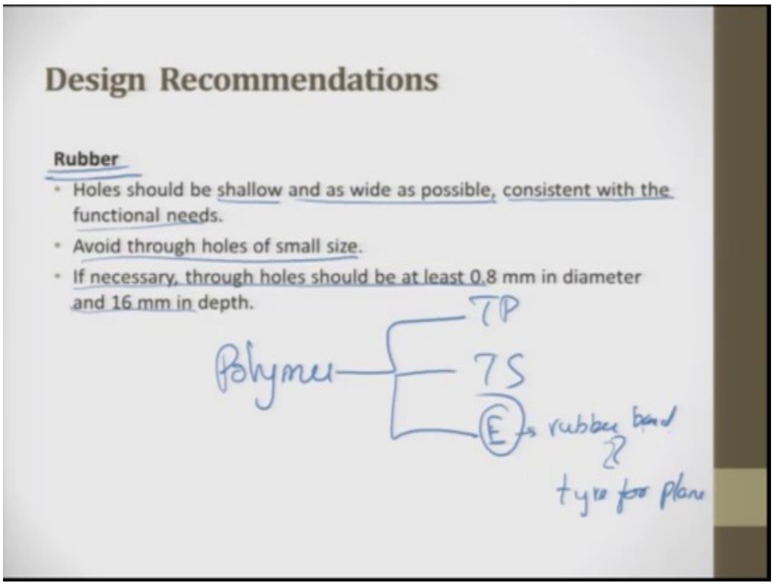

So, rubber, rubber is one interesting material, but if you look at the periodic table there are so many elements there, right and all these things are to a large extent you have metals, rare metals and rare earth metals and this and that. In the entire periodic table, you have you will never have a slot for polymer, but today polymer dictates the world 30 to 40 percent or even 80 percent of the domestic products are made out of polymers, ok.

So, in polymers the, we classify them into three; one is thermoplast, one is thermoset and third one is elastomer. Elastomer is pretty interesting, you see a rubber band to tyre for a plane, all these things are elastomers. Elastomer and the thermoplast, the only difference is the ductility, of course, the bond structure, but here you see elastomer, it can make it, can be used for making rubber bands from there to a spectrum it goes and it can go for making tyres of planes. Huge friction, huge weight, and impact load, you take and it is very successfully used material. So, the hole should be shallow and should be as wide as possible consistent with the functional need. Avoid through hole for small surface if necessary through hole should be at should be at least 0.8 millimetre in diameter and it can go and 16 millimetre in depth.

So, I have just put all those because we had a recent experience of drilling of rubber. So, we have just put those example and this is also taken from literature, but elastomers are another set of materials which are becoming more and more common today and they have a wide application from rubber band for that is a domestic to heavy loads.

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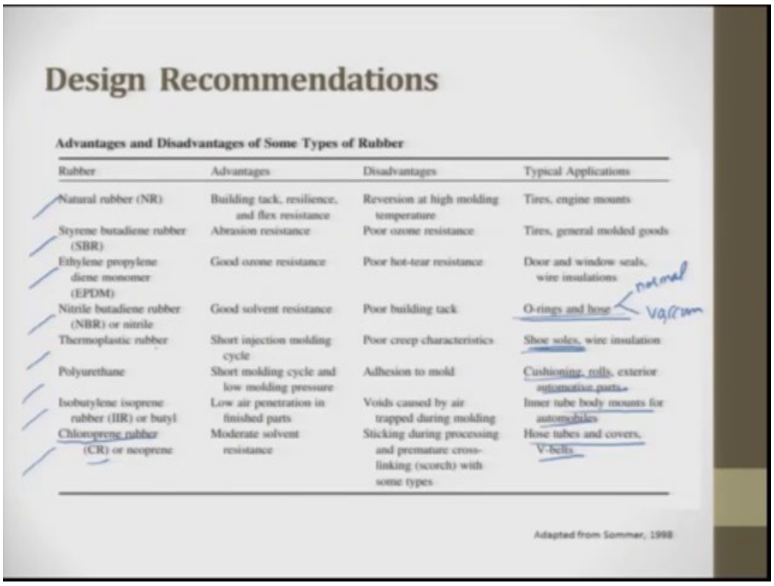

Rubber	Advantages	Disadvantages	Typical Applications
Natural rubber (NR)	Building tack, resilience, and flex resistance	Reversion at high molding temperature	Tires, engine mounts
Styrene butadiene rubber (SBR)	Abrasion resistance	Poor ozone resistance	Tires, general molded goods
Ethylene propylene diene monomer (EPDM)	Good ozone resistance	Poor hot-tear resistance	Door and window seals, wire insulations
Nitrile butadiene rubber (NBR) or nitrile	Good solvent resistance	Poor building tack	O-rings and hose
Thermoplastic rubber	Short injection molding cycle	Poor creep characteristics	Shoe soles, wire insulation
Polyurethane	Short molding cycle and low molding pressure	Adhesion to mold	Cushioning, rolls, exterior automotive parts
Isobutylene isoprene rubber (IIR) or butyl	Low air penetration in finished parts	Voids caused by air trapped during molding	Inner tube body mounts for automobiles
Chloroprene rubber (CR) or neoprene	Moderate solvent resistance	Sticking during processing and premature cross-linking (scorch) with some types	Hose tubes and covers, V-belts

Somebody talk about rubber, these are different types of rubber; one is natural rubber, you have styrene butadiene rubber, EPDM ethylene propylene diene monomer, then you have nitrile butadiene rubber, then you have thermo plastic rubber, polyurethane rubber, isobutyl isoprene rubber, then chloroprene rubber. So, you can see here these are the advantages, these are the disadvantages.

Look at the applications natural rubber tyres, SBR you can use for tyres, EPDM you can use for seals NBR you can use for O-rings and O-rings what, whatever O-rings and hoses. So, this there are two things; one it is used in normal; normal room temperature, another one is in vacuum. Whatever rubber, rubber O-ring which works in normal need not work in vacuum, ok, but whatever works in vacuum can work in normal. So, vacuum if you see O-rings are used in vacuum the rubber is completely different.

So, then thermoplastic rubber; your shoe soles are made out of thermoplastic polyurethane you have cushion in rolls automobile parts are made out of polyurethane, isobutyl isoprene rubber which is used for making inner tube body mount for automobile and then the chloro CR rubber, CR rubber is used for making host tubes and V-belts which are used.

So, you can see these are the rubber, these are the application there advantage and disadvantage. So, you have to choose a rubber to your choice, you have to choose a rubber based upon your product.

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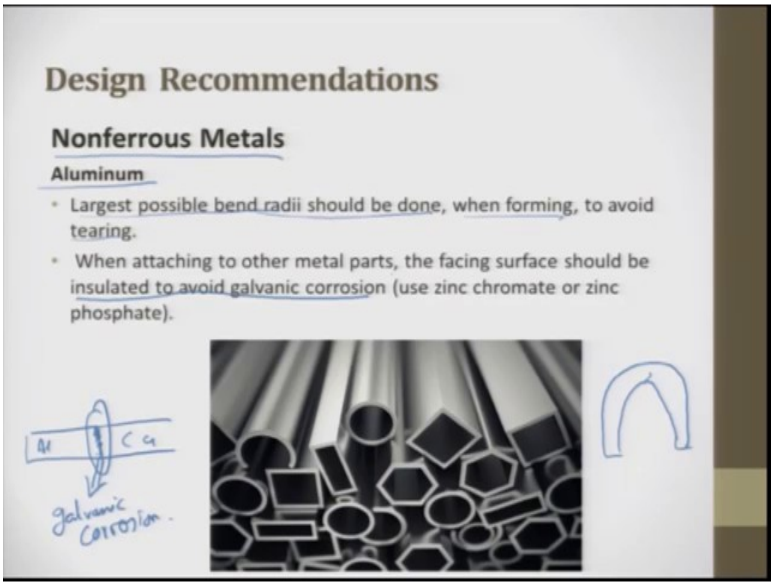

When we talk about non-ferrous till now; what we have studied as we have studied steel then we went into polymers and ceramics, elastomers and now last we will get into aluminium. So, ah, we will take into non ferrous metals. Nonferrous metals most commonly used for secondary structure as well as primary structure primary structure means load bearing area it is aluminium.

In almost all the automobile, automotive ;automotive structures today are made out of aluminium and if it is more moving towards high performance people have started going towards titanium, which is much lighter and people have started moving towards magnesium which is much more lighter, but the processing of titanium and magnesium is expensive. So, people are happy with aluminium. So, aluminium again it is not aluminium; it is not aluminium alloy there are several elements which are added to it to meet out to the requirements.

So, it aluminium the largest possible bend radius should be done when forming and to avoid tearing. So, what we are trying to say bend radius, largest bend radius has to be given otherwise it will try to tear and then start failing. While attaching to other metal parts the facing surface should be insulated to avoid galvanizing corrosion. This is very important many a times what happens we try to, but aluminium with that of copper. So, at this portion there is always something called as a galvanic corrosion. So, this corrosion tries to destroy the material. So, you should always try to insulate the material such that this corrosion is not transferred.

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So, you have copper and brass. So, copper and brass so, generally copper is highly conducting materials. So, we try to avoid machining ah, we try to extrude copper machining to large extend is avoided. So, avoid copper machining, use extrusion and press forming to avoid loss of material, use stock size requiring minimum processing such that you try to get output. So, this is, you put your fingers inside. So, this is something like that tool which is used for yourself protection are people nowadays used it for just for fun. So, you put your fingers inside. So, that you get it right. So, ah, so, copper and brass copper, brass is alloy of copper. So, we try to avoid machining here.

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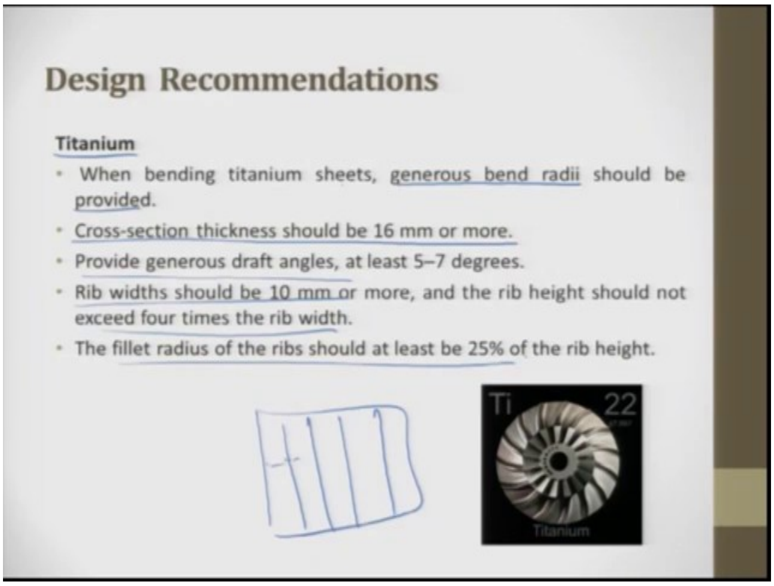

Titanium is one material which is talked about more in aerospace, biomaterial, and nowadays in automobiles. So, here when bend; when bending and titanium sheet generous bending radius should be provided, the cross section should be 16 millimetre or more, the cross section thickness, whatever it is a because when you try to machine titanium the heat gets accumulated at the cutting zone.

So, next you have to provide enough generous draft angle so that you can easily remove the material. Rib widths should be 10 millimetre or more. Rib is what? So, you have a material, so, you have several ribs. So, the rib width should be 10 millimetre or more and the rib height should be exceed four times the rib widths so, that makes it little stable. The fillet radius should be at least 25 times of the rib height.

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Zinc and its alloy. So, zinc is also nowadays becoming little general to use for various applications. Bending is regular commercial rolled zinc should be at right angles to avoid green or directional green or rolling directions. The bend radius should be at least equal to the material thickness. The forging zinc used a combination of zinc and manganese which put up to 25 percent. So, these are some of the nipples which are made out of zinc for various applications uses zinc alloyed.

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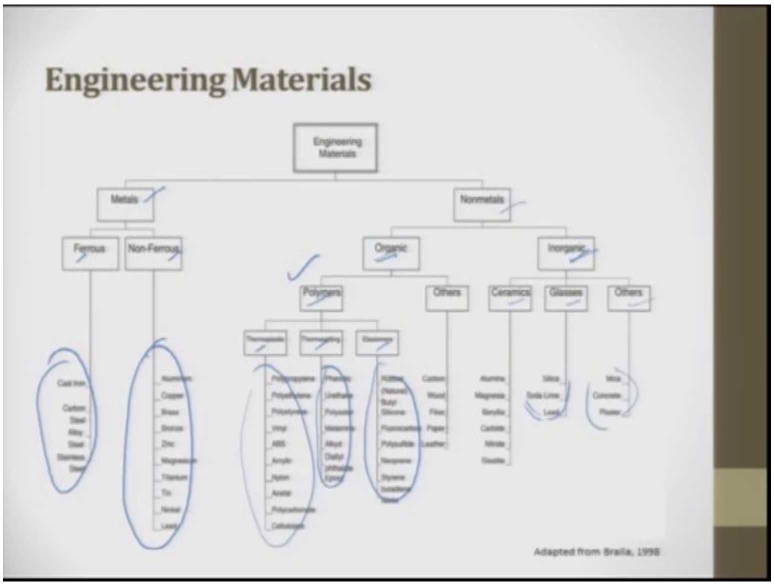

So, if you see engineering materials you have metals, ferrous, non ferrous, non metal, organic, inorganic. In organic, you have polymer; polymer you have thermoplast thermoset, elastomers. This is a spectrum of material in each and then when we look at organic others; we see the carbon, wood, fibre, paper, leather these are all naturally available. Then when you talk about inorganic we talk about ceramics, we talked about glass and we look at others when it is when we talk about ceramics or at high temperature ceramics there all alumina, magnesia, berylia, carbide, nitride and sterlite. So, carbide is silicon carbide, nitride is silicon nitride. So, these are all ceramic materials. When you talk about glasses it is silica, soda lime glass and lead which is part of glasses and you have the other spectrum here.

When you talk about ferrous I told you earlier, it will be steel and cast iron and it will be plain steel medium carbon steel and then cast iron when you look at non-ferrous today is picking up. Nonferrous materials and polymers are picking up in the market. So, aluminium, copper, brass, bronze, zinc, magnesium, titanium, tin, nickel and lead all these things are getting very popular today which gives hell a lot of combined properties, strength + thermal conductivity, strength corrosion resistance. So, it tries to give combined properties for non ferrous materials are also thought about in a big way.

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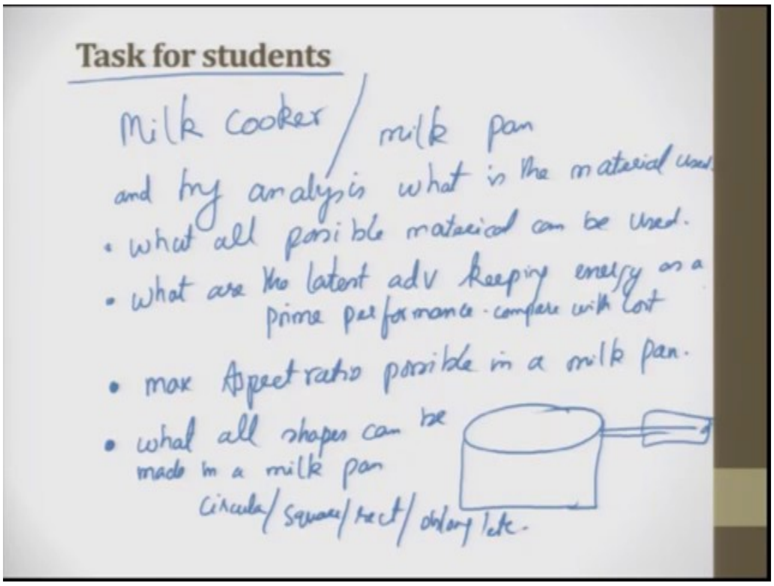

So, the task for the students today you will try to take a milk cooker or a milk pan and try to analyse what is the material used. Next, what all possible materials can be used; can be used. Next, what are the latest advancements keeping energy as a prime performance. Next one, what is the maximum aspect ratio; aspect ratio possible in a milk pan? What is the aspect ratio? Aspect ratio diameter to depth, ok next one is what all shapes can be made; what all shapes can be made in a milk pan. So, that means, to say whether circular, square, rectangle, oblong, etc. ok.

So, you are supposed to do this assignment and when you do this assignment you will try to understand what is a big spectrum of materials which are available and how did you choose or what all can you make a choice and here when I said latest development today we talked about copper bottom vessels. So, please look at those options also. The bottom is made out of copper it has a steel on top. So, what is the advantage? How is the performance varying with respect to energy and then you also compare with cost, compare with cost, right.

Thank you very much.