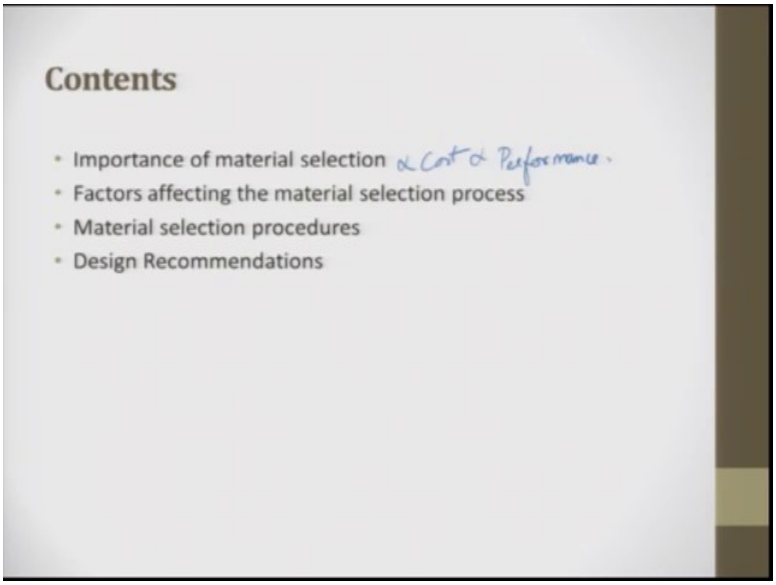
Product Design and Manufacturing
Prof. J. Ramkumar
Dr. Amandeep Singh Oberoi
Department of Mechanical & Design Program
Department of Industrial and Production Engineering
Indian Institute of Technology, Kanpur
National Institute of Technology, Jalandhar

Lecture – 14
Material Selection (part 1 of 2)

In this lecture we will more focus towards Material Selection. So, today there is a big spectrum of materials available for the product designer to choose and interestingly, today the materials have become something like cooking. So, it add to taste, same way here you add material to the base material to get the necessary properties.

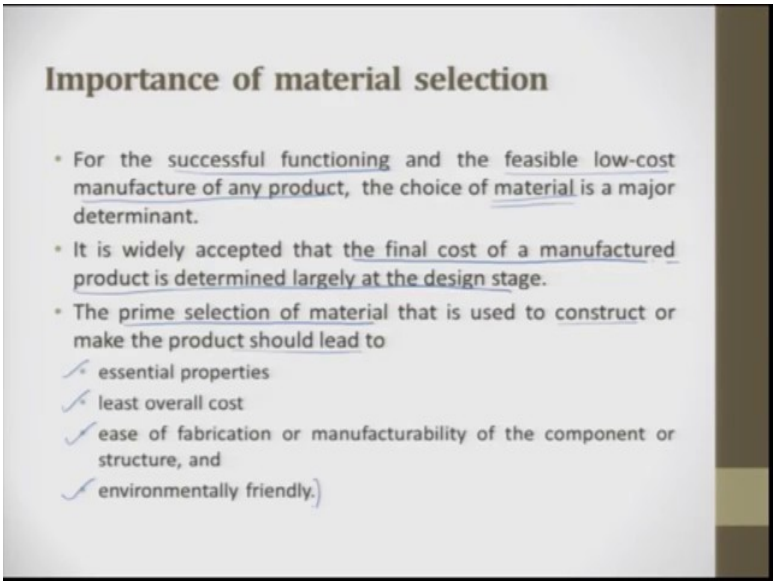
(Refer Slide Time: 00:46)



Materials are of three basic classification; one is polymer, metal, and then you have ceramics. So, you have to decide which one to choose and today interestingly, you have a combinational material which is called as composites. So, where in which you use polymer and metal, polymer and ceramic, you can have metal and ceramic. And, today the technology has gone to such an extent you can have a combination of all the three; that means, to say you can have a material which is made out of metal, polymer and ceramics together to meet out the customer requirement or the products requirement.

So, in this lecture we will have the following content. The first one is going to be the importance of material selection which is very important because this is directly proportional to your cost and performance, ok. So, importance of material selection, then factors affecting material selection process, material selection procedure and then design recommendations. So, this is; these are the four topics we will try to cover in our lecture.

(Refer Slide Time: 01:48)



So, importance of material selection: For a successful functioning and the feasible low cost manufacturing of any product the choice of material is important. A simple example is your chair; initially these chairs were made out of wood, then it changed into steel and today it is all made out of plastics. Initially, the customer could not digest how can I sit on a plastic chair, but the product designers presented the chair in such a nice fashion.

They brought in lot amount of comfort in the chair plus they tried to have maximum strength which got integrated into the chair, the design of the chair was very wonderful. So, this slowly over a period of time plastic chairs have got accepted by people and today plastic chairs are the most common thing you find in any living room or dining hall in any house. So, it is the material which changed from it is properties from a soft material to a very hard material and a design which is integrated into the material made it a robust structure for people to sit on it.

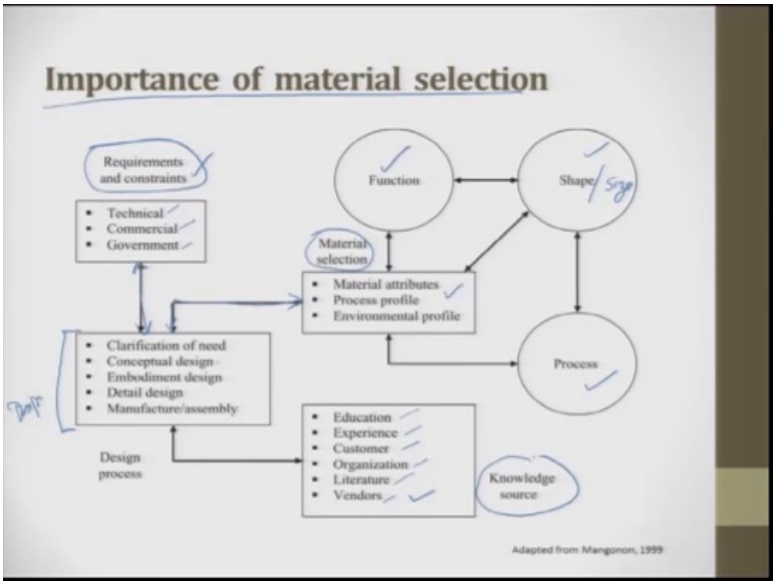
It is widely accepted that the final cost of the manufactured product is largely determined at the design stage. So, here at this point clearly states that the designer, product designer has to

have an idea or has to have a team member who is in material expert in his team to make a proper choice of material and manufacturing you make a wonderful product, but if it could not be manufactured then the product fails miserably. So, it is always good to have a materials expert in the design stage itself and try to keep manufacturing so that you make your final cost less. So, this is widely accepted that the final cost of manufacturing a product is dependent largely at the design stage itself.

The primary selection of material is used to construct or make a product should lead to essential properties, least overall cost, easy for fabrication and environmental friendly. Till now we were not bothered about environmental friendly. Today, we talk about sustainability in the products or sustainable materials. So, this environmental friendliness is also talked up in a big way. So, plastic bags for example, slowly are getting removed or processing is done such that the plastic can be modified or reused into a different product.

So, you have to have a proper for selecting a material, you should essentially know it is properties and it has to have a least cost and it has to have the ease in manufacturing. Ease in manufacturing is very very important. For example, plastic parts are very economical because it is one shot process. So, the fabrication is very easy whereas, when you take steel, it has multiple steps have to be done to manufacture and make a product. So, this is what ease for fabrication. So, these are the prime selection for the material construction we have.

(Refer Slide Time: 05:03)



So, when we talk about importance of material selection, shape is very important. Shape and size is very important. Shape means goes to form, then there is a link between function and then there is a link from the shape to the process, shape and size to the process. You change the dimensions if you go larger and larger and larger in your dimensions, the process which is involved in making those large dimension products are going to be offered through a different process. So, process and then; here are materials.

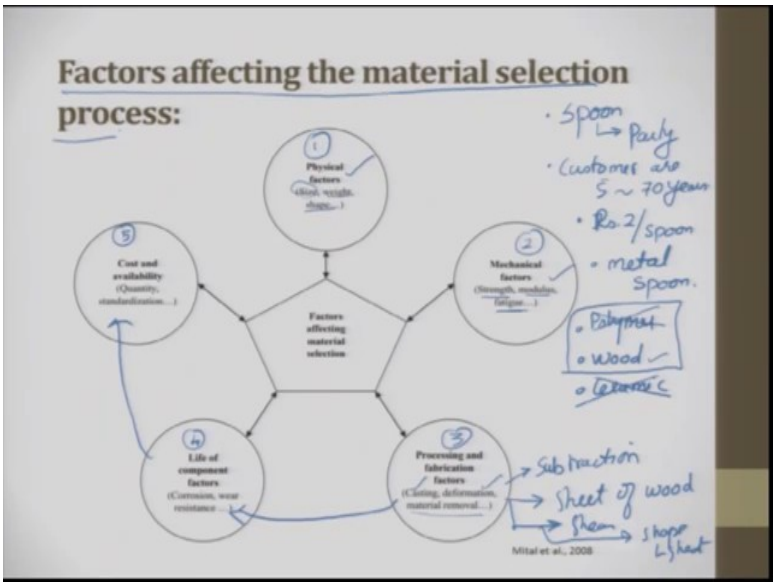
So, the function you have to do a material selection which is here and this in turn is linked or the properties linked are material attributes, process profiles and environmental profile. So, where are you going to use, what is the process to be done, material attributes how are they, what are they which is going to make the product very successful is there. So, the function with this if you try to take this as material selection they look at these properties and they are linked with the process. So, this happens to be back and forth the functioning, processes, shape and size and this, all these things go back and forth to get a good product.

So, the requirements and constraints come from the customers. So, you will have technical you have commercial and you have government constraints which are there and then this will lead to classification of clarification of need, conceptual design embodiment design, detailed design and manufacturing design they in turn are linked with the material selection or material attributes. So, this one is again a back and forth motion; these are the typical steps which are involved in designing.

So, if you try to look at the knowledge source where do they get from; education, experience, customer, organization, literature and vendor. So, it is nothing, but the voice of the customer which we discussed in the QFD. So, this is what it is.

So, these are put together, this entire schematic diagram integrates function, shape size process, knowledge and the constraints with the material selection. So, all these things put together are very important when you try to choose a material.

(Refer Slide Time: 07:29)



So, the factors affecting the material selection process; one is physical form, size, weight, shape. Today, we look at aspect a product to be as light as possible and then we also look at a product which has more comfort that means, to say more customized. The shape has to be very smooth and it is sleek. They are looking at shapes which are very elegant weight which is as light as possible and we also look at products which are sized as small as possible. For example, cell phones these sizes have gone down. The first cordless phone which came into the market had was at around the weight of 1.5 kilos. Today, we talk about a cell phone of 100 grams or less than 100 grams.

So, then this one the mechanical factor is the other thing where in which we talk about the strength, modulus and fatigue. So, the strength modulus strength is talked about in the plastic region, modulus is talked about in the elastic region fatigue is nothing, but cyclic loading happening on the on the material which it has to the product on the product which it has to withstand for a longer time.

So, for example, a chair, chair when a person sits it is going to be an impact load and then he gets up and then once again he sits or he slides. It is cyclically it is getting loaded, impact load is there. When one person gets up the other person sits, it is another load which comes in. So, it is a compressive load which comes here. So, it is fatigue. So, all these factors are mechanical factors.

So, here are size factors, these are mechanical factors. Then you will have processing and fabrication factors, say for example, whether to be done by casting, deformation. Casting means you try to take it to a higher temperature melt it and then pour it into a die casting. Deformation is you apply load and you try to deform a material; it is deformation and then you have a subtractive process called material removal wherein which this, the unwanted material is removed and then you get the feature what you want.

So, the processing and fabrication factor is also important to decide whether what is the material for the given product, the life of the component and factors like corrosion, wear resistance this is also very important and then the cost and the availability plays a major role. So, the five major factors which play a major role are physical factors, mechanical factors, processing factors, life factor; life and component factors and finally, cost.

So, let us take a simple example and just work for a product. I would like to develop a spoon which is used in party and my customers are going to be customers are from the age of 5 years to 70 years. So, this is what I decide. So, I want to make a spoon and the cost what I give is going to be per spoon I am going to give rupees 2 per spoon and I would also try to have the spoon which looks very close to that of a metal, little spoon, ok. Naturally, by looking at the cost, you can quickly say that it cannot be a metal spoon.

So, I have to look for alternatives in ceramic spoons or I can look for wooden spoons or I can look for polymer spoons, ok. So, then this is what I conclude. So, first what I do is I try to take polymer, I try to take wood or I try to take ceramic, but what is the problem with ceramic? Ceramic is always brittle. So, I try to remove this option also. So, I am left with only two options, with these two options I will start working.

So, first I would look at what should be this polymer material or wood material, what is the maximum size I can make, what is the intricate shapes I can make in the spoon and what is the weight; maximum we can give it for that spoon and I have said it is 2 rupees and this spoon has to be also long lasting ok. So, if it is to be long lasting. So, then you can remove wood, but if it decides to have a use and throw spoon. So, both these materials can be considered next.

So, from here I move to the next one. So, I have chosen these two physical factors; size shape and weight I choose these two metal go ahead. Next factor is I look for strength modulus and fatigue. This is very important because when people try to eat heavy when that spoons are

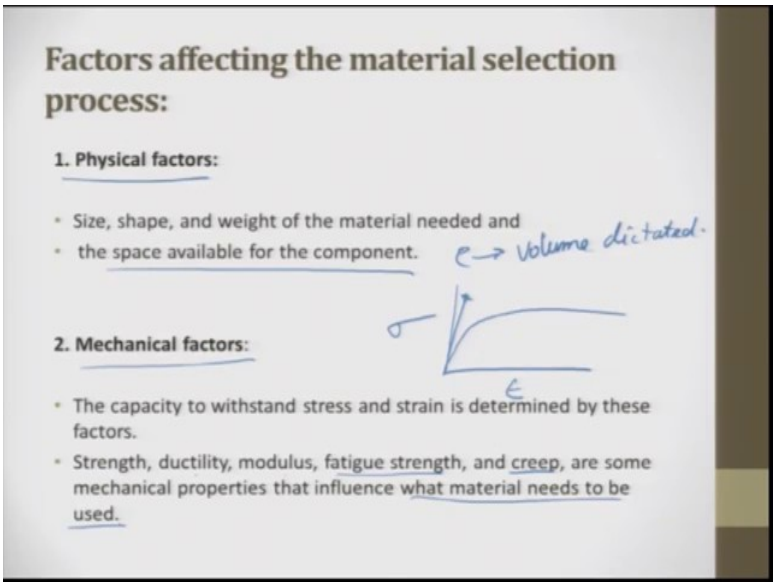
loaded very heavy it should not deflect. Second thing, it should not ascend when I start using in hot environment it should not deform very fast. So, now, what I do is I try to take these two spoons and I proceed further, but moment I said that it has to withstand heat then, the polymer spoon goes away. What I am left with now? Wood. So, now, I choose wood because wood can withstand all these things. So, I move to the next one.

Now, I should decide a process for making wood spoons, the processes has to be decided. So, when I talk about wood so, the subtractive process, machining is one. The other one is I try to take a sheet of wood and then I try to press it; try to shear it and then I try to give a shape to it by heat. So, that I get the impression of a spoon. So, you see here the processing route is completely different from whatever was thought about for a wood or other things.

Next, I move to this factor and I say it has to have corrosion resistance and wear resistance, wooden spoon can withstand that. Wear resistance of course, if it is a use and throw spoon, so, you do not bother much, right. So, then we look at cost, yes; wood is available and the standard things can be manufactured. So, the cost and availability the wood fulfils it can be taken further. Suppose, you decide to choose polymer as an alternative and today there is a technology where in which you can do metalizing of polymers which has become a very common feature. So, when you look at spoons today, it looks as though it is a metal spoon, but it is a polymer spoon.

So, if you make that choice the processing route is completely different. Then the life cycle is completely different. The mechanical properties are completely different. So, looking at the options whatever a customer wants, you can keep start changing the material and if you make a wrong choice of material, you might not be able to meet out the customers demand, ok. So, this factors which affect the material selection process, all the five factors are very important. They are all links for to the material selection; factors affecting the material selection.

(Refer Slide Time: 14:42)



So, the physical factors as I discussed earlier it is size, shape, weight of the material is needed. The space availability for the component is also very required, is also very important. So, when I talked about the example of a spoon; spoon is a single part which is a product, but many a times in reality you will have several parts put together forms a sub-assembly. Several sub-assemblies put together forms a main assembly, ok.

So, the shape of the space available for the component is also very important because you might increase. For example, if you choose a material with lower density, so, here the volume is dictated not the weight for example, cotton old taking of a cotton wool the volume is dictated not the weight ok. So, you should understand the space. So, when you choose the material also you should choose in such a way it tries to fit in the space which is available.

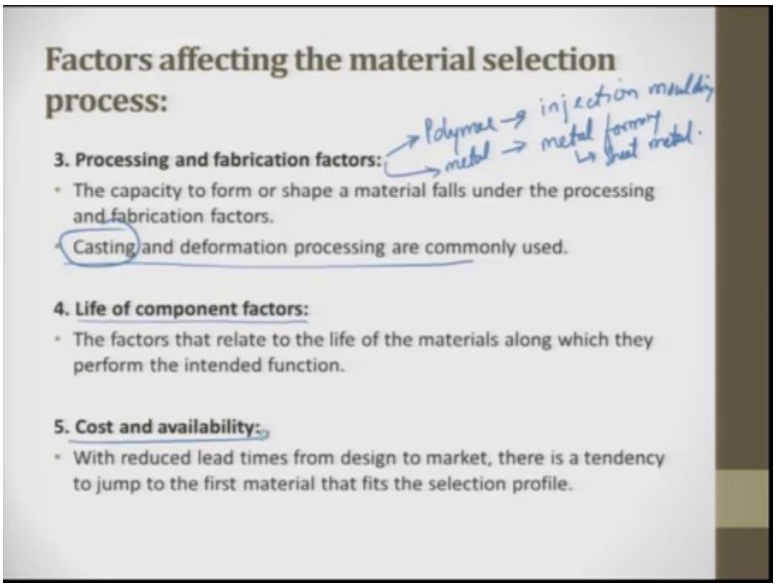
So, what are the mechanical factors? The mechanical factors which are very important are the capacity withstanding the stress strain. So, we always go by the stress strain graph for the given material. So, if it is a ductile material it goes like this, if it is a brittle material it goes like this. So, it stands here. So, we always look at what are the stress strain behaviour responses for a given material such that it can meet the requirements. The strength, ductility, modulus, fatigue say strength, creep, are some of the mechanical properties that influence what material needs to be used. Many a times it will be pretty interesting to see all of a sudden your flower pot which was hanging, fails. So, it is, it has failed because of the creep behaviour.

So, what happens polymer is not having a very good creep resistance. So, that is why people suggest whenever you put a flower pot which is hanging, please hand it were using a steel rod or steel wire. But, the only problem with the steel wire it does not have the freedom of easily changing or manuring to the requirement whereas, a polymer has that facility. So, when you try to choose this you have to see those things and second thing, it is also the when you see the rope which we use for drying clothes, so, what happened that also fails in creep behaviour and it also fails when it is exposed to temperature.

For example, comes summer, the temperature goes to 40 - 45 degrees and it is oh, it is for 8 hours or 7 hours it constantly maintains then immediately the polymer starts yielding whereas, a metal does not yield in those points, but when you try to choose a metal, metal always corrodes when you try to put a wet cloth on top of it. So, polymer has its advantage. So, you have to strike a balance between these two.

So, today what has happened people have started buying polymer with a metal coating on top of it. It works fine or people have started taking metal core and the polymer tube on top of it which is just like your wire, those rope materials are used for drying of cloths. So, mechanical factors are also very important for material selection.

(Refer Slide Time: 18:00)

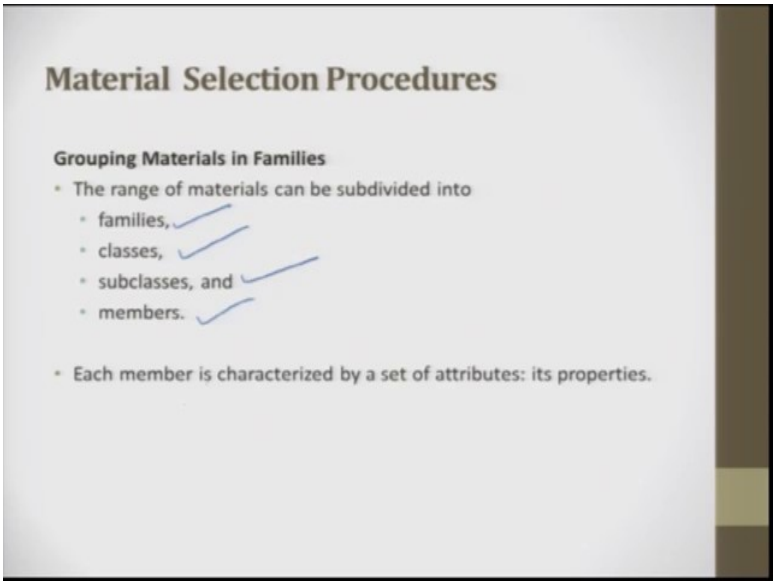


Next is processing we have discussed enough. So, if you want to produce any part which is very economical, we look for polymer and then we also look for a process called as injection moulding. So, injection moulding; the cycle time is enormously less. It is there about 45

seconds you get spoons made. So, injection moulding is a process whereas, when you try to look at metals and if you want to do it at very economical price, so, then what we do is we always go for metal forming. So, that means, to say sheet metal pieces are used; sheet metal. Sheet metal are used so that it can start making it.

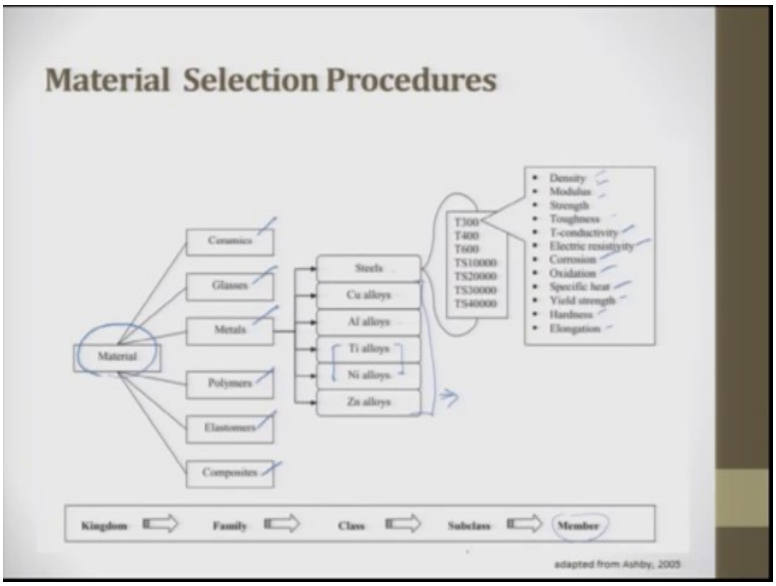
So, casting and deformation process are constant volume process where in which the starting material and ending, if you sum up the end products it will be almost the same. It is a constant volume process. Here, it is not thought of this process is not thought of for a mass production. Mass production, where the product cost is economical. The life of the component plays an important factor and the cost and availability also plays a very very important role in choosing the material.

(Refer Slide Time: 19:08)



The like in biology, botany and in zoology, we have a taxonomy followed. So, here in material selection also we follow a taxonomy which we talk about family, class, subclass and members, ok. So, a range of materials can be subdivided into families; families further will be divided into classes; classes will be further divided into sub class and subclass will be divided into members. So, why is it done, suppose, if you are able to you are able to identify the customer need and you are looking for a material for your product so, then by do by looking at this you can quickly find out which material suits you. So, each member is characterized by a set of attributes, its properties.

(Refer Slide Time: 19:58)



So, look at it here you have family which is ceramic, glass, metal, polymer, elastomer and composite. These are all family is attached to a kingdom called material. When I choose a metal it is basically; ferrous and non-ferrous. So, it is steel and then you have non-ferrous materials. So, it is steel and all the non-ferrous copper alloy, aluminium alloy, titanium alloy, nickel alloy and zinc alloy. So, all these material are having strength which are lower than steel and then they are also that density is also less cost compared to that of steel.

If you are looking for primary application, that means, to say primary application has weight taking primary structure, load bearing, so, then it is better to have a steel one. Suppose, you are looking at some structure wherein which it is a secondary structure not of load, but it needs to have lot of heat conduction then we go for copper. If it is going to be secondary structure which has to be light and no heat taking, you can think of aluminium.

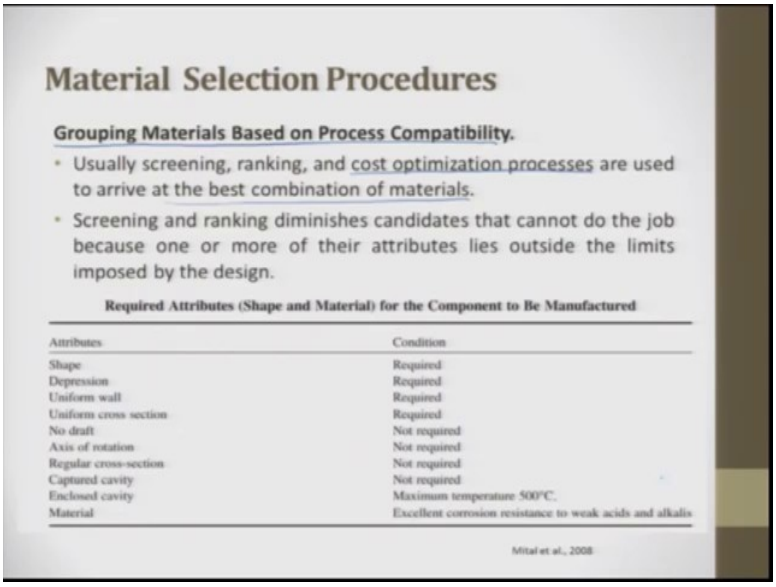
All the space vehicles they try to use titanium alloy and nickel alloys because they are light and weight, they have very high strength properties and this by combination with several alloys show different performance when you put in even vacuum or when you put it at very low temperatures.

So, when you again, so, this falls in that class. So, first is kingdom, family, metal family and then from the family we get into fall in the classes. So, this steel is again sub classified into T300, T400, 600 whatever it is 10000, 20000, TS10000, TS20000, 30000, 40000. So, this these nomenclatures basically tries to talk about the copper which is present in the carbon,

which is present in the steel and also some properties. So, this is a subclass of this is a class, this is a subclass then what are then you will have members. So, these members are nothing, but these are the properties which are there.

So, you have thermal conductivity, electric resistance, corrosion, oxidation, specific heat, yield strength, hardness and elongation. These are the members which are attached to this subclass, subclass to class, class to family, family and then you go to the kingdom. So, this is very important property which is nothing, but grouping out the materials in a family.

(Refer Slide Time: 22:24)



So, grouping of material based on process capability; so, here what we did was we grouped it according to only mechanical characteristics or mechanical properties and physical properties, but this has nothing to do with that of process capability or processing. So, here we group the material based upon the process, process capability. So, usually screening, ranking and cost optimization process are used to arrive at the best combination of material. Screening and ranking diminishes the candidate that cannot do the job because one or more of the attributes lie outside the limits imposed by the designer.

Say for example, quite attributes, shape and material for a component to be manufactured. Shape is required, the pressure is required, uniform wall required, uniform cross section required, low draft not required, axis of rotation not required, regular cross section not required, capture cavity not required, closed cavity maximum, temperature of 500 degree

Celsius, material excellent corrosion resistance to weak acids and alkali. So, these are the attributes these are the conditions what is given.