Product Design and Manufacturing

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Lecture - 16
Manufacturing Process Selection (part 1 of 2)

Last lecture, we were more focused towards material selection and this lecture we are going to talk about manufacturing process selection. If you choose a material, then naturally the process has to be chosen next step; and many a times it will be process dictating the material or material dictating the process. So we, it is a trade-off we have to keep both the weightages, if you give; both has to be given uniform weightages while you choose you also choose the process or you choose the process and then choose the material; because finally, what you want to do is?

You want to give an economical product to the customer. Economical product which is performing such that by using the product the customer is happy so, in this criteria; I said cost is one of the major thing. So, the costing is predominantly decided by the material used and the process which follows after the choice of the material.

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So, here we will see an introduction followed by it, we will see how to select a manufacturing process; a small algorithm and then, next we will see a primary manufacturing process; what are primary manufacturing process? What is secondary manufacturing process? What is ternary manufacturing process? And some design guidelines which will be slightly taking up from yesterday lecture or the previous lecture.

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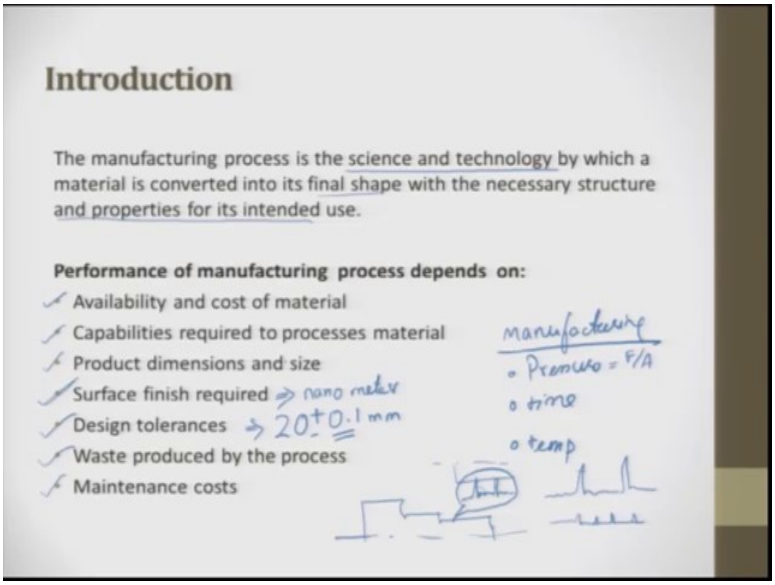

So, we will try to add some more design guidelines for while choosing a material; or a process, manufacturing process is a science and technology by which the material is converted into a final shape with the necessary structure and properties for its intended use. So, this is called manufacturing process.

In manufacturing process, if you see there are only three major parameters, they are nothing, but pressure, time and temperature. You take any manufacturing process, you will have basically three process parameters; if I want to convert this pressure, I can write it as force per unit area. So, now in any manufacturing process, these are these three major parameters which dictate the efficiency of the process or the output product. So, it can be all the three be involved or it can be only one involved or a combination of two involved.

So, we have. So, much of clarity, but why we are not able to dictate the manufacturing process such that; we get very good products; the only thing is the weightages of individual parameters are still not known or during the process, the weightages keep

dynamically changing which is very difficult for us to understand and model. So, that is why many a times the manufacturing process is called; is told to be as trial and find out or hit and go so; that means, to say you do some experiments you get a good output. So, then freeze the parameters saying that these are the best parameters for making this output it need not be optimum over a period of time many company start working on the manufacturing process and move from the hit and go trial experiments, whatever they are frozen parameter towards the optimum and fine tune the quality of the product.

So, it is very clear in manufacturing we have three process parameters; the science and technology by which a material is converted into a final shape. This shape is basically, if you go back to design; the principles, we talked about shape and form that is; what is the final shape with the necessary structure and properties; for which it is intended to use; the performance of the manufacturing process depends on first is; availability of material which is directly proportional to the cost, then the capability required to process material. Then the product dimensions and size, surface finish. Surface finish is very important, because if you are trying to mate two parts, the surface finish is going to be the contact surface, we would like to have as good surface finish as possible today, we talk about nanometre surface finish.

So, basically what is surface finish; if you try to take a surface of a shaft and I tried to take zoomed place at this point; you will have undulation on the surface something like this. So, here what happens when you mate it with the bolt or when you mate it with another contacting surface, the contacting surface will sit on this peaks. So, if you see these peaks over a period of time gets destroyed and they try to fall in between the two mating surfaces.

And if you see in the beginning, the load bearing area will be very less, if you have a rough surface. So, that is why people talk about getting nano finish surface. So, nano finish means these peaks will be very less. So, these peaks would have now changed into peaks something like this. So, here and when you do this you will have because; when these peaks are predominant when you try to meshing this peaks there will be next other peaks which come into existence. So, the load bearing area is now distributed.

So, because of this wear and tear of the material is very less. So, nano finish is very important. So, people talk about surface and the interesting part is people also talk about

textured surface for various applications people also talk about it and in surface finish, please do keep in mind that you can have two different signatures having the same roughness value it is possible two different signature; that means, to say two different surfaces can have the same roughness value. So, you have to look at the figure and you have to correlate with the magnitude and then decide what is to be done.

So, this is very important; the next one is tolerance, what is tolerance? Tolerance is nothing, but when I try to make a part, it is very difficult to repeat and get the same accurate dimensions. So, because there is a variability in the import raw material, there is variability in the human and there is a variability in the machine; that means, to say as and when time goes the machine parts have averment. So, because of this; what I try to officially do it? I tried to say ok, I allow you to have a small deviation. So, that deviation is the tolerance so; that means, to say you will have a basic size maybe 20 millimetre ± 0.1 millimetre I say.

So, here what I do is; I officially give you a small variation on the basic size saying that you cannot exactly make this. So, this is called as tolerance. So, this tolerance dictates the process or looking at the tolerance you have to choose processes. So, that is what is called as design tolerance and then waste produced by the process is also very important today; we talk about sustainable manufacturing. In sustainable manufacturing or in green manufacturing, whatever we use in during the process and the by-products, whatever it gets developed on the waste, whatever it gets developed; it is nowadays becoming a big challenge for environment friendly discarding. So, that is what we have just put waste produced by the process has to be as low as possible.

So, the next one is the maintenance costs of the process see; for example, to when you talk about nanometre surface finish or when you talk about IC chips, it demands a room or an ambience, where the machine is to be maintained in a proper manner. So, there is lot of maintenance cost which is involved. So, all this process; manufacturing process depend on all these parameters; availability, cost, capability then product dimensions, surface finish, design tolerance, waste produced by the product and maintenance cost. All these things we have to be considered while deciding a process, if I have to logically select the process I follow these steps.

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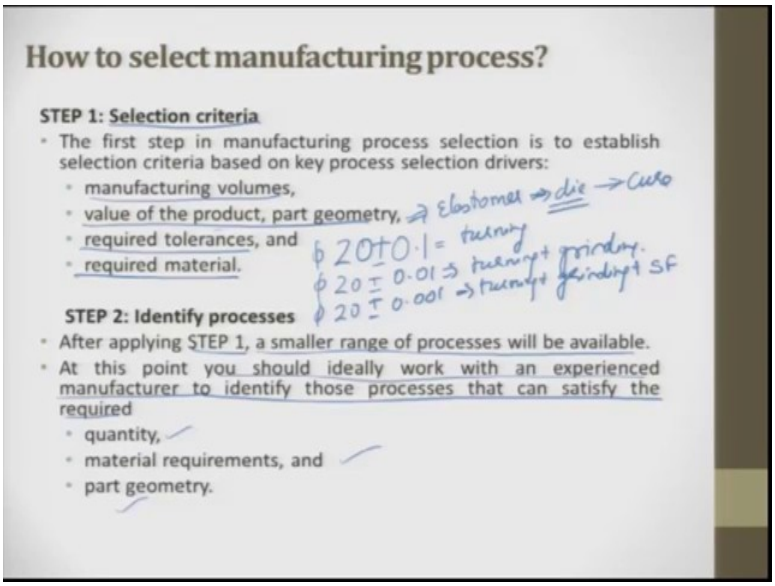

So, the selection the first step is selection criteria as have to be returned; manufacturing volume. In manufacturing, there is nothing called a unique solution. Suppose, if I want to produce a shaft of 10 numbers, then I use machining process if I have to produce something like 100 or 1,000 I always go for a rolling process. So, you see depending upon the number, depending upon the cost which you can pay for the product the process differs.

So, manufacturing volume is one of the major criteria, which helps in deciding a process Same shaft, same material only the number changes; the process changes if I have to machine, I buy a lathe and then I start doing turning which is not an expensive process. When I start going for a rolling, it is a capital intensive machine. So, it is little expensive. So, here the output has to be produced in bulk same way. Let us take plastics, if I have to produce 5 spoons. So, I will not do injection moulding process. In injection moulding process you will have to produce at least 100 or 1,000 in volumes such that you take out the cost of the die which is used for injection moulding; the machine is also very intensive.

So, the other way round is, I will try to go for manual injection and I will try to have a very small sprue around which I put a heater and then I press it vertically down and then I injected into a die and try to pick one piece at a time. So, here the product might not be of a high quality and the time taken is large, but you have to understand that just by the

volume, the process changes it will be injection moulding, but it will be manual injection moulding. The value of the product and the part geometry is also very important.

Suppose you try to say, the part geometry; part geometry means, if it is very large; if it is very large. So, then you can say for example, you take a lathe machine, in a lathe machine the work piece has to be held in a chuck. So, you have various types of chuck; 1 is 3 jaw chuck, you have four jaw chuck sometimes you call it sometimes you put between centres, put a dark plate and then start doing it depending upon the geometry of the shaft you decide, what will be the work holding device, same way depending upon the geometry you decide; how the machine should be.

For example, if you look at tires which are used for heavy trucks, heavy duty machines heavy duty vehicles like trucks and buses, the tires have to be done by elastomer as the starting material and then they put it inside a die and then they allow to cure, the rubber is allowed to cure, but reinforcing with various items in inside. So, the die is extremely large which might run for a meter size.

So, if you want to hold the die and then machine it, you can't do it on a lathe machine which is having horizontal axis. So, what we do is we try to mount the die which is of around about a meter again circular or cylindrical. So, we try to mount it on a chuck which is which is having in and the tool list in the vertical axis. So, you see depending upon the part geometry the machine axis itself changes; it can be horizontal axis or it can be vertical axis just by the geometry I give you one example.

So, the part geometry also tries to dictate; what should be the process? So, why is this important, because the vertical, it is otherwise called as vertical turning machines or some people call it is as also vertical boring machines and other names are given, but vertical turning machines are rare, you never find it and this machine occupies lot of space, the investment is too heavy, the manufacturing process itself is different, though it is done by turning, but it is completely different.

So, part geometry dictates and same ways; if you have a prismatic job and you have to do some machining operation or a lathe machine or you have to do make holes. So, then what people do is they try to use a four jaw chuck, mounting on a four jaw chuck is not an easy job it needs skill. So, part geometry dictates the manufacturing process, the value

of the product is also very important, the value of the product is the performance for example, if you want a single piece; single piece to be done or a single shaft to be done.

So, then what happens you try to do it by casting and when you want to do 10, you do it try to do it by machining and when you want to do it by 1,000 you do it by metal forming operations. So, if you see the property or the mechanical property or the behaviour when you try to put this; shafts on real time application, the casting fails first because of the grain orientation. Next machining happens and the third one, last to fail is going to be the sheet metal or the metal forming operations.

So, the performance; that is what is called the value of the product also dictates the manufacturing process. Next is the required tolerance, the tolerance if it is very tight or if it is very small, then it demands for more and more and more processes. For example, you turn afterwards you try to grind and then you try to lap whatever it is. So, that's you why? Because the tolerance is given; for example, if you say 20 ±0.1, then I will do turning; if I do 20 ± 0.01, I do turning + grinding if I say ± 0.001, I will do turning then, I will do grinding and then I will also do one another surface finishing process to get the output.

So, look at it is all diameter of a shaft. So, you see only by wearing the tolerance, I add processes to whatever it is right. So, this is what and last one is the material see; if I take polymer as a material, if I take rubber as a material I will try to avoid machining, I will try to do it by other process, where is like injection moulding or I will try to do curing and I will try to get the output. So, depending upon the material you try to choose different-different processes. For example, if I have a ceramic material, ceramic pipe to be made, it is very hard to do machining why? Because in ceramic, it is a brittle failure and moment there is a brittle failure; the surface finish whatever you get is not going to be under the control of the process you have to do some other applications or you have to apply some other forces to make sure that; the machining happens use your very good surface finish or people do not even try to do machining, they try to take a starting material will be a powder ,they put it inside a die compacted it this compaction can be in cold isostatic processing or high hot isostatic processing, you get the finished product directly rather than undergoing any of the machining cycle.

So, here depending upon the application if it is going to be high temperature, then you choose a ceramic; then when you choose a ceramic you do not use subtractive process or you do not use the deformation process or casting is not thought about. So, this is what we I am just trying to put it here. So, based on these four points you trying to you keep it as a selection criteria and decide the process. After identifying the process by step, one has smaller range of process will be available.

So, here to a large extent you have you have narrowed it down to; what is that? Then in the next will be with small variations. So, wherein which we try to put the fixture, we try to talk about the tool all these things will come here at this point, you should ideally work with an experience manufacture to identify those processes that can satisfy the requirement of quantity, material requirement and part geometry.

So, it is after deciding the first step manufacturing process it is, now going to be more towards the process parameters, work holding device, tool geometry something.

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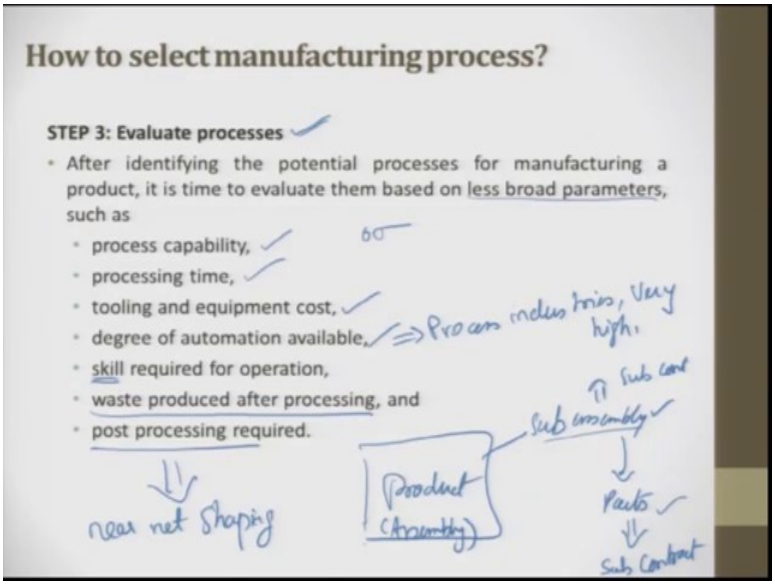

Then what you do if you try to evaluate. So, now, you have chosen, once your chosen a process the next step which comes into existence is to; how do I evaluate the process you already have a result now. So, you have to now check the result whether, whatever I have got is correct or not and manufacturing, I repeat there is nothing called unique. So, you will have multiple solutions for the same problem.

Now, you have to evaluate each solution and try to identify, whether it is good or not. So, next comes the evaluation of the process; evaluation of the process here we are trying to talk also about reducing the scrap. So, that is what to visit of prime focus. So, after identifying the potential process from manufacturing a product, it is time to evaluate them based on less brought parameters such as process capability. So, you can talk about six sigma; whether whatever I produce, I get it within the tolerance and I can produce it for a longer time; what is the processing time, see in product design.

When I started itself I told you, there are customers they need a product and you have to have it in mind, how quickly you reach out to those customers with those products., if you are time is very large, let it be for prototype making or let it be for final product making, if the processing time is large, then you will not be there in the race ok; processing time is what parameter which we try to evaluate the process, next to the tooling and the equipment cost, if it is very expensive and if the volume is very less. So, naturally; what happens the investment you made by number of parts you produce you just divide and the unit price will be exorbitant.

So, now what will happen if you it, because your investment what you did on the manufacturing process is very large. So, we do it for example, in IC chip manufacturing the investment on the process is extremely large; extremely high, but the volume what they produce is very high. So, when you divided by the investment by the number of parts produced the cast goes down. So, in electronics industry by and large they follow batch production.

So, in silicon one wafer can produce almost close to some 100 Ic's. So, so here you should look at the tooling and equipment cost. If it is very large that is only the volume should be large, if it is very small you can always try have a trade off I can have a very small volume. Then the degree of automation is very important, why is degree of automation which is very important today we talk we are in the era of internet of things.

So, when you have internet of things understanding there is a customer he wants twenty parts to be produced quickly what we do if we try to automate place I will place an order to him get the material added to the to your inventory and immediately from the inventory you have a conveyor which moves to the machine and you start producing. So, that is the level of automation we are talking about.

So, if you look at all the process industries the level of automation is very high process industries, the level of automation is very high; it is very high. So, next one is the skill required for operation today, what is happening is we are trying to; once you move towards automation we are trying to remove all the unskilled labours and use only us at certain places we try to use a skilled operator to do it for example, for quality check for assembly today industries have gone to a level all the parts, For example, we have a product, it has sub assembly it; from this sub assembly save it as parts almost all the parts are nowadays, it has been given for sub contract and from here.

Now what has happened is they have also given from here to here; sub-assemblies are also not given subcontract. So, what industries have started doing is they are started doing only assembly, the products. So, here what is happening you have to evaluate the performance of the sub assembly and then you have to assemble inside of product and get the required output?

So, here we are looking for the skilled operator. So, you should also look at what is the skill you expect in your process. So, this is very important because you do not have a skilled operator everywhere or skilled operator is very expensive, that is why I ended today, what has happened if people have started working on computer assisted process planning or computer aided process planning; people have started using so that the skill of the operator need not be a bottleneck in deciding the process.

Next, the waste produced after the process is very important you talk to you; when you do any of the machining operation we use coolant and once the coolant is used. So, these coolants there are two types of coolant: one is natural coolant, other one is synthetic coolant. Synthetic coolants are predominantly used which are it can be oil based on it can be chemical based. So, these coolants have to be discarded. So, discarding this is a big challenge; say me when you work on process industries and chemistry you have to discard some of the by products.

So, that is very important, if the discarding cost is very high then it is not going to be a viable process. The last one is the post processing required; I tried to make a chair and in that chair I would like to have a texture of my choice if you say that after making the chair try to use a single point cutting tool and the machining or use a skilled operator and

try to remove it is going to be costly or if I say that after making a chair try to paint the chair with a green colour it is not possible.

So, the post processing operations have to be as minimum as possible or I will put it this way today we look at near net shape manufacturing. So, to a large extent we try to get the required product to the final state just do final small tweaking, such that it can get to the market. So, these are the criterias which we always use in evaluating the process which is chosen for producing a product; process capability to reduce the scrap produced and have a consistency in the process.

Processing time it has to be less tooling and equipment cost has to be as low as possible the degree of automation has to be as high as possible, skilled labour requirement for operation has to be as low as possible; that means, to say I have automated then the waste produced by the process has to be has minimum as possible and then it is the process industry.

See for the PCB, the biggest challenges they used led as one of the element; let it be PCB computers or let it be given mobile phones smart phones they use lot of rare earth materials. One it is expensive; two discarding is a big problem. So, people are now working on; how do I salvage the rare earth material; which is used in those computers and bring it back to use.

So, for example, cadmium is used, platinum is used. So, people are working hard on it. And now what has happened because you have used it, now it has got discarded, you cannot discarded in free in nature. So, you tried to process it and when you process it you try to make it once again a useful material and then start going and in the same way when you try to talk about chips which are getting produced it is the same thing.

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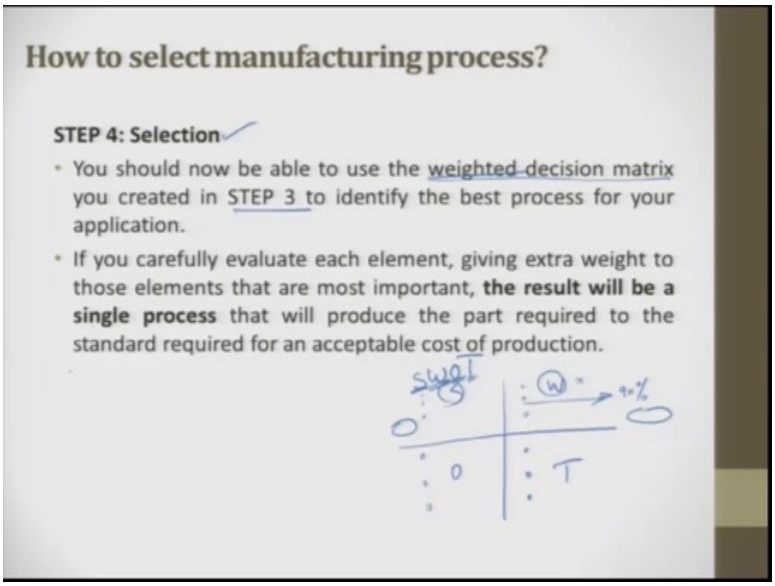

What do I do the chips?

So, the selection after doing this three first what did you do you had some selection criteria you had, then you have identified a process then you are evaluated the process. Then the fourth step is selection; you should now be able to use the weighted decision matrix many a times in your selections.

Selection if you have three parameters, it is always the weightages you have to put and weightages and you have various criteria for each criteria you give some weightage and you multiply it with some factor and that when you sum it up it tries to give you in some numbers. So, these numbers help you in taking a decision for example, people talk about SWOT analysis; strength weakness opportunity and threats.

So, here also what people do as they try to say put all the points and strength, put all the point and weightages, put all the points and opportunities S W O and threats and now; what they say is? They try to say you give some weightages wait; this is weakness. So, weakness suppose you feel the weakness whatever is there any process or is there in the individual; this weakness is going to completely dictate the performance of his future when you say weakness this is ninety percent you give.

So, when you multiply all those things you will get a summation. So, with this you can see whether the strength is very high for this particular process, weakness is very high

opportunities are high, threats is high. So, then what you do is you try to change those things and convert or choose another process where and which the weakness are not high strengths are high. So, that you can start taking it.

So, always in taking decisions we have the weightages factor let it be QFD, we have this weightage factor you should now be able to use weightage decision matrix, you created in step three to identify the best process, if you clearly evaluate each elements giving extra weightage to those elements that are most important, the results will be single process that will produced the part required to the standard requirement for an acceptable cost of production. So, these criterias you try to give a weightages and after doing these weightages you sum it up, get it and then you choose a process.

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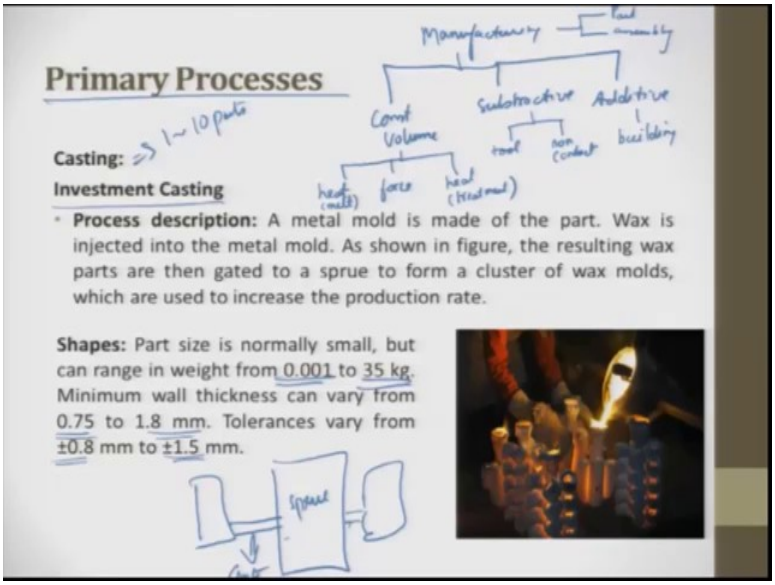

So, now let us see some of the process, when you try to talk about manufacturing. So, first classification of process are primary processes; primary processes are you try to take it from an ore or you try to take it from ore and then you try to take it from metal which is there in bulk what you do is you try to melt it and then you try to give a shape to it.

So, if you talk about manufacturing; manufacturing I can very crudely classify into constant volume process, subtractive process, additive process. In constant volume I can apply heat which is nothing, in casting I can apply force which is nothing, but metal forming and I can. So, here you can also do this is heat is to melt. Then heat I can do to

do a treatment; heat treatment here the volume the shape is not even changed, the size is not changed only the microstructure is changed.

When you talk about subtractive process you have tool where in which you use tool in coming in contact or you do non-contact machining and then you try to remove material from the starting material to produce a required output. additive manufacturing; which is very much talked about today it is nothing, but you use building blocks and you try to add material at those places where you want to construct a material now keep moving.

So, this is how we predominantly classify and if you want to do in manufacturing much more classification is trying to produce a part and trying to assemble parts. So, assembly is the other classification. So, when you try to look at the process constant volume heat. So, here what we talk about is you have starting material you try to heat it about the melting point of the material. So, that you try to induce viscosity so; that means, to say you take it to lower viscosity and then you allow it to pour inside a confined mould or a die to get the required part.

So, that is here casting and then by force is nothing, but you try to give a force through a machine tool and then try to deform a bulk material or sheet material and get the required output. So, those things are called a metal forming and here force is predominantly used Heat treatment is try to play with only the temperature and time you try to play with a grain structure which in turn influences its performance in terms of mechanical property as well as in ware and te. So, that is what you do.

So, here we are more focus towards the investment casting. Investment casting is very much used for those products where the features which as sharp features, which has to be produced. So, we always go for investment casting, here I have just taken only a glimpse of certain process and I have put here, but there is spectrum of process available. So, investment casting So, this is called manufacturing process ting. So, a metal mould is made for a part a wax is injected into the metal mould. So, this metal mould can be made through additive manufacturing also today. So, a metal mould is made; a wax is injected to the metal mould as shown in the figure. So, these are all the moulds the resulting wax part are then gated. So, gate is nothing, but you have a part you have to connected to the main reservoir. So, this is the gate.

. So, gate to the sprue the reservoir is nothing, but the sprue to form a cluster of wax moulds which can be used to increase the production rate so; that means, to say I can have gates I can these are the part lets what. So, what happens when I try to pore a hot metal this wax melts of and then it. So, the metal whatever gets filled up is the final product.

So, here you can make it up to from the weights can be from 0.001 gram to 35 kilos you can starts making it up and then you can have a minimum wall thickness of this to this the tolerance are which are given as this, you can also do it by sand casting you can do by die casting, you can do it by pressure die casting. So, all this things are some of the advancement and all these things are classify comes under classifications of casting.

So, that you I request the students to read some introduction to manufacturing process book you get more knowledge.

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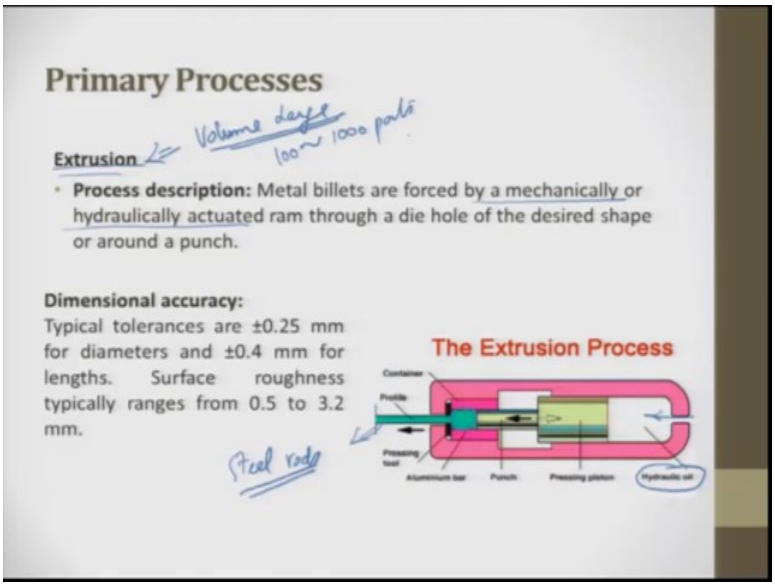

Next one is a metal forming process. So, this process is nothing, but an extrusion. So, extrusion what we do is we try to keep we try to keep the raw material. Raw material inside a die and then here you see there is a punch which is pushing and this punch is activated by the hydraulic system, whatever is there and this tries to give you the pressure.

So, this pressure tries to get applied on top of the aluminium and then; what we do is? we have a small exit and orifice through which the material is squeezed out. So, this squeezing out is called as extrusion. So, you whatever you have on the die ship you get the profile or the extrusion which comes out. So, here we can do it for aluminium people are starting using for steel and many more application you can start doing it right.

So, here a metal billet or forced by a mechanical or by a hydraulic extrusion, this is the hydraulics and here is the hydraulic oil giving pressure, this is the piston which moves down and this piston moves the punch and this punch tries to do it. So, here you apply force and then you try to extrude material and then for example, all the steel rods, steel rods of diameter little smaller they are extruded they are extruded and slightly larger diameters are rolled. So, you can also do rolling.

So, what happens just rolling when you do you have to reduce the diameter in several steps you get it down and in here also you should take a you should keep one thing in mind if you want to reduce the diameter drastically it is not advisable. So, it is better to do it; step wise, but here what we do is we try to play with the geometry and try to get what best we want, but these are some of the tricks which we have to first understand the process and then try to produce, where ever you want to use extrusion or metal forming operations you should have a volume large.

In casting, you do not have to have you can have from number one to maybe even 10 numbers of production, you can have a batch size parts can be produce 10 or even 100 can be produced, but when you are talk about metal forming it has to be large we all generally talk in terms of 1,000, 100 to 1,000 again these numbers are not sanctity depending upon the cast depending upon the material you keep changing with the processes.