Product Design and Manufacturing
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Lecture – 19
Design for Manufacturing

The next topic of discussion is going to be design for manufacturing. Any product you design, if it is not maturable or if it is not manufacturable, then the product does not play any sense. So, when a product is designed or developed, the basic thing what a designer should keep in his mind is design for manufacturing. A simple example is when somebody says a hole immediately what comes to our mind is a circular one, and we give a depth to it. Why nobody is thinking of making a square one, why do not there be a square hole why do not there be an oblong hole, why do not there be a hole of star shape cannot be there because from the process of manufacturing, the simplest process which can be used for hole making is drilling. In drilling there is a relative motion between the tool and the work piece, so the tool rotates the work piece is kept stationery and then you start giving a feed you generate a hole.

So, now when you have a square profile to be made in a hole, as a hole then what happens is the tool has to is not cannot be cylindrical. And if it cannot be cylindrical and if it rotates, so it is going to create more of wobbling and it is going to have an impact on the whole geometry. So, that is why people always try to keep this idea of manufacturing at the first stage itself. After getting customer, voice from the conceptual ideas are getting developed, then and there itself people start putting this design for manufacturing also parallely and start tweaking their concept keeping this manufacturing us primary source.

In fact, when we talk about manufacturing it is not only material, it not only helps in processing, it also helps in material choice. And it also helps in moving towards the concept of modularity. Moment modularity comes into existence; it also tries to pushes you towards subcontracting. So, many things are attached with this manufacture. So, this is the next topic of discussion.

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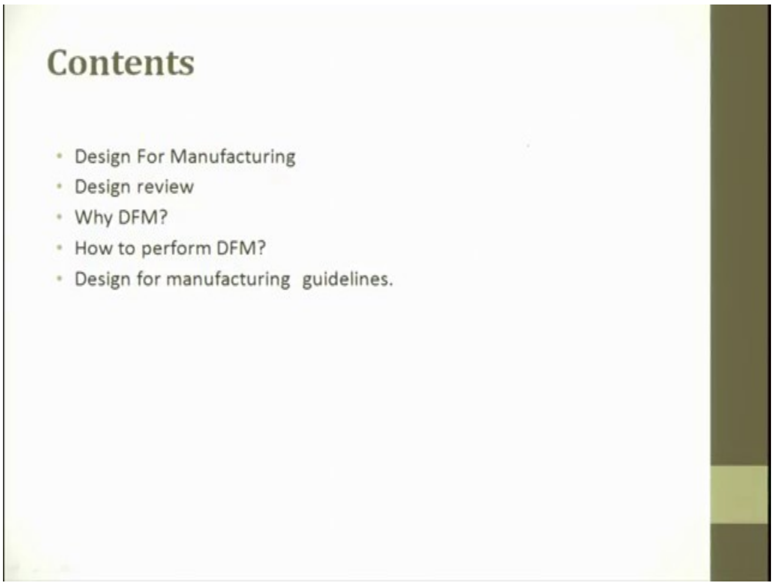

So, we will try to understand what is designed for manufacturing then design review, then, why design for manufacturing, how to perform design for manufacturing, then design for manufacturing some basic guidelines which has been drafted over a period of time. Today, design for manufacturing is followed by every automotive company follows it, in fact, food industries have started following design for manufacturing.

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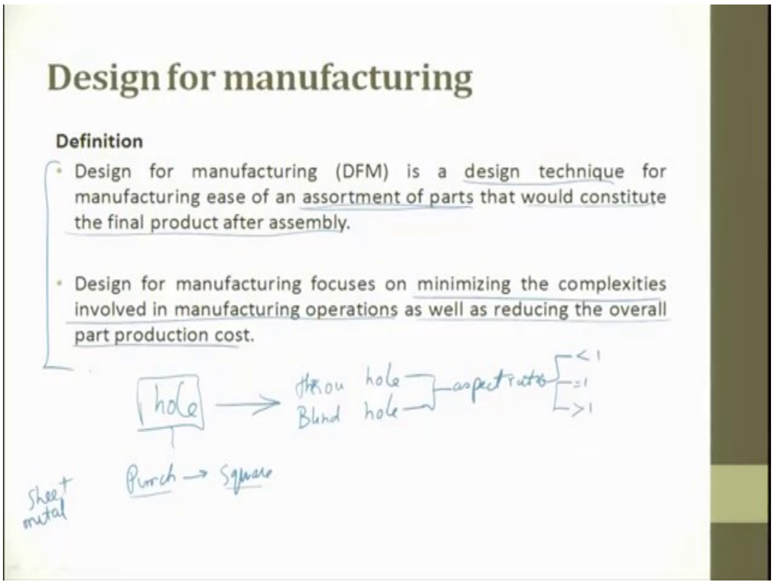

Definition for design for manufacturing is a design technique for manufacturing ease of an assortment of parts that would constitute the final product after assembly. So, it is not only for a single part for assortment of parts. For example, when I try to talk about a hole you can have through hole ok, you can have blind hole, you can have blind hole and through hole for varying aspect ratios, where the aspect ratio can be less than 1, equal to 1 or it can be greater than 1. So, you see here a hole, just a hole and then if the thickness of the material is very less, then this hole can be created by a punch. When you talk about a punch, we also have square punches, a square hole can be made right, but the process is different ok.

Depending upon the sheet metal for example, sheet metal when you use it for desktop you see on the size of the cover of the desktops, you see lot of holes are there, these holes are basically air belt holes to remove the heat which is getting generated during the working of a computer. So, you can also have punched holes, where square holes can be made or perforations can be made. If you want a larger fit, then hole can be of two classifications here.

So, what am I trying to say is I am trying to say about this assortment of parts that could constitute the final product after assembly. So, we are not talking about a single part becoming a product DFM cannot be used in a big way, you cannot enjoy more of DFM. If you have several parts put together as sub-assembly, several subassemblies put together and assembly, so assembly means a product then you can think of enjoying the advantage of using DFM.

DFM for manufacturing focuses on minimising the complexity involved in manufacturing operation as well as reducing the overall part production cost. Here when I try to say minimising the complexity, so but maintaining variety that means, to say any part I do or any assembly I do, sub-assembly I do, I would like to make it modular. In this modular, I would like to add variants such that I can meet out to several requirements. So, this is what minimising the complexity means if I minimise the complexity, I make it as modular. So, I use more of standard parts and then start using it.

For example, the mixer whatever I was talking to in the in the last lectures, so I was talking to you about a mixer it has a motor which is separate, which is which is a standard part. And then you have three or four jars for various applications. One would 1, 1 liter, you can have 1.5 liter, you can have 1.5 liter, you can have 0.25 liter and then you can have a separate jar for juice. So, if I do this for jars along with the mixer, it caters to all demands of a kitchen. So, this is a modular concept where and which the complexity of having of the parts are reduced. And once the complexity of the parts are reduced the manufacturing operation is reduced moment you make the manufacturing operation simpler the cost is going to fall down, so that is what we try to convey through here. So, when you try to follow design for manufacturing we try to group the operations. And once you try to group those operations, we try to generalise a machine. Once you start generalising the machine, then we start generalising or producing parts in a standard manner.

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So, design for manufacturing is also the process of proactively designing products to optimise all the manufacturing functions like fabrication, assembly, testing, procurement, shipping, delivery, service and repair. When we t,alk about design for manufacturing it is interesting to know shipping is also part of manufacturability. So, delivery service, and repair, so here we are trying to talk about manufacturability, design for manufacturability.

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Design for manufacturability is also the process of proactively designing products to assure the best cost, quality, reliability, reliability and repeatability are two different terminologies, you should understand that. I repetitively do a job that is different. Whenever I try to start for example, a cell phone which are not used it for 3 months, when I when I start operating it after 3 months, I put everything battery back and then I just press on button it starts working that is a reliability. I put a key in the keyhole of a car and I start cranking it, it starts cranking that is reliability ok. Repeatability is a different story. I try to produce a same part I get consistency is this repeatability.

Then regulatory compliance so that means to say it is energy efficient it does not produce fumes, it does not use any by product which has hazardous which are hazardous in nature. So, all those things are regulatory compliance safety time to market which we have already dealt when we do the initial design itself. What is the time it is going to take from understanding the customer voice to giving it to the customer as a finished product is called a time to cost, ok. Then completely customer satisfaction, all these things are assured when we follow this design for manufacturability. Design for manufacturability is a process of proactively designing products to meet out all these things.

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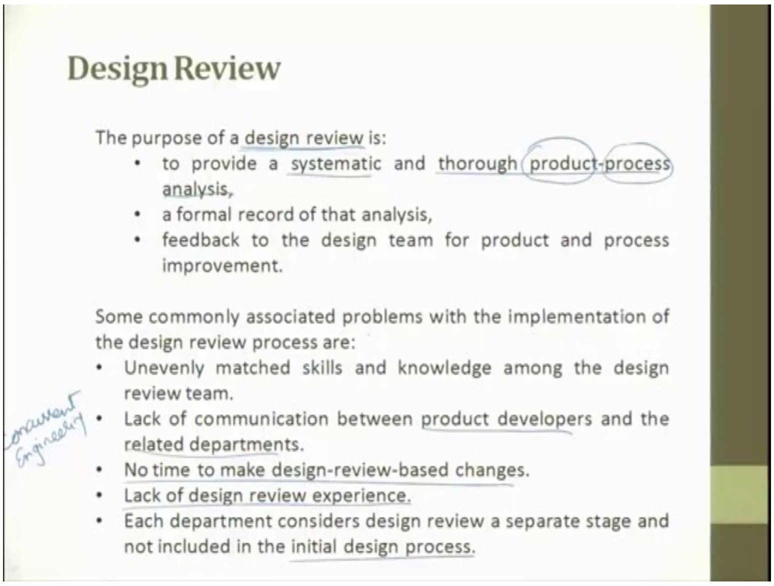

The purpose of a design review is existing see design for manufacturing can be done for a new product, for a existing product. Existing product again you take the existing product go to the customer asked what is the problem, comeback start sorting it out. Maybe it is cost, maybe it is the performance; maybe it is even appearance. So, you come back get the feedback comeback, sit on your desk and design desk and start working on how do I redo it such that I can meet the customer's satisfaction. So, design for manufacturing can be done for existing product, can also be done for the new product which is getting evolve.

The purpose of a design review is to provide a systematic and thorough product process analysis product and process; please note it down. Product is a chair; product is a table; process can be carpentry; process can be injection moulding; process can be even machining, sheet metal process, so through product process analysis ok. The next one is a formal record of that analysis. The third one is feedback of the design team for products and process improvement. So, the process of a design review has these three points. So, you try to provide a systematic and a thorough product process analysis, then you try to look at a formal record of that analysis whatever you have done. And then you try to give a feedback to the design team from the product process analysis and improvement what has to be done.

Some common associated problems with the implementation of design review process are unevenly matched skill and knowledge among the design review team. Your team is not good, the skill of the team is not so great, so then what happens is you try to land up land up with a team where it is not providing a good output. Then lack of communication between the product developer and the related departments. So, this is why we try to push for concurrent engineering. In concurrent engineering is it is a discussion and in the discussion we have team members who participate from different departments, different expertise sits together communicate together and then start evolving the product. So, lack of communication can also be a problem in implementing the design review process.

No time to make design-review-based changes people just keep working on let us make a cosmetic change, just change the colour, just change the texture, just change the material, so that is what is called as, no time to make design review, based changes; lack of design review experience each department considers design review a separate stage and not includes in the initial designs process. So, these are some of the problems which are associated and which always makes this design review of failure. So, please make a note you should have a strong team, you should have a team with multiple skills, you should not give a cosmetic change, you should look at changes which is a very fundamental completely relook into it then get into the market. So, and when you try to do it, every department should understand that the design process is the initial process compared to rest.

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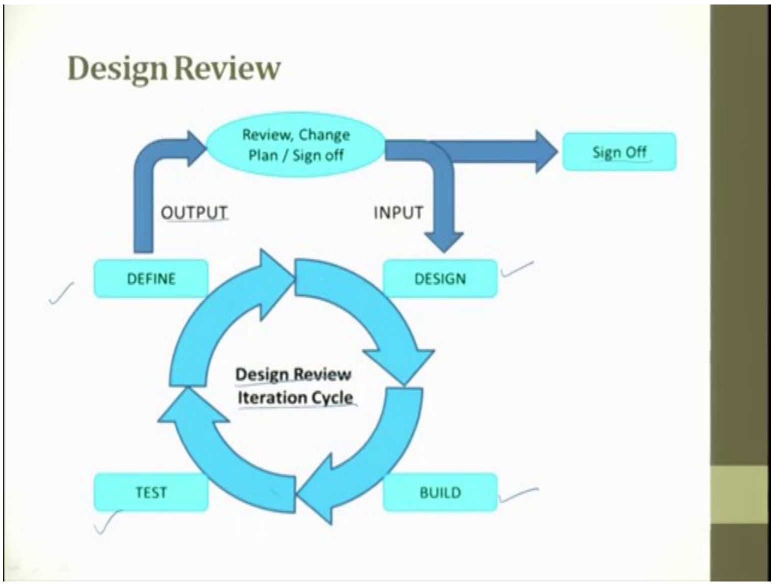

So, if you want to put it in a very pictorial view, you have defined the problem, and then you design, then you try to build and then you try to text. It is not one cycle circuit; the cycle keeps on repeating. So, this is the design review iteration cycle. So, this keeps going. After testing once again you look it into relook into the definition you redefine, then what you do is you try to design, build, then test. Suppose you feel it is ok, so output is good then fine you go for the output. Then review changes and plan and then sign it off, the sign off happens here, but no company goes to the sign off mode. They keep on going to this vicious cycle. So, they always try to come up with innovative product you take a typical software, they have releases, they have versions.

So, why do they have these two they can come up with the first stage itself the best product, but please do understand the companies get feedback from the customers try to improve, and then they also wanted to have a market. So, every time when they release a version or when they try to release a release, so they make a new branding and they get into the market. So, this keeps going on. And this is what I am talking about only for a software product. The same thing is also used for games videogames. The same thing is also used for automobile, the same thing is also used for domestic appliances. No product enters the market the best way; that needs to say there is always a chance or a scope for improvement, so that is what is this design review iteration cycle keeps going on.

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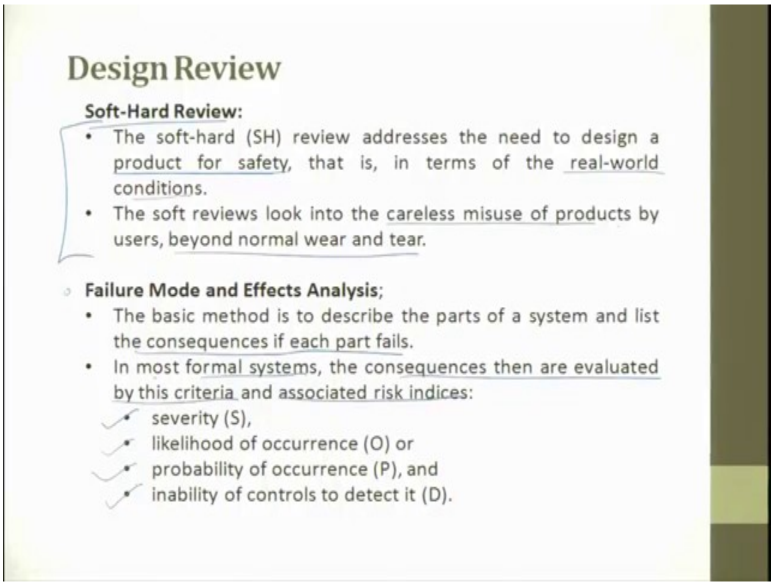

So, there are soft-hard reviews. So, what are the soft-hard reviews the soft-hard review addresses the need to design a product for safety that is in turn in terms of the real-world conditions, so that is called a soft-hard review. It is only predominantly looking for safety. The soft reviews look into the careless misuse of products by user, beyond normal wear and tear, very crude, very speaking people many a times use their pen to clean their ears, it is just a careless misuse of the product ok. And then what they do they dig their ears and then come back and start writing on a piece of paper, the ball gets stuck from rotates and then they start cursing the product that it does not perform what it is supposed to perform. So, these two are called a soft and hard review. So, soft-hard review is for addressing the product for safety.

Soft reviews look at the careless misuse of the product. Then there is another tool which is very effectively used which is called as FMEA; failure mode and effective analysis, this is used when the product is getting designed itself to evaluate what can be the possible failure of this particular product. And if this product or if this part fails in the entire product, what is that going to have on the complete performance of the product.

So, one failure here in the product, what is the performance in decline that is what they do. And the performance declined can be safety, can be efficiency, can be even look ok. So, the failure mode effective analysis, the basic method is to describe the part of a system, and the list of consequences if each part is failing. Suppose there are ten parts, a, b, c, d, e, f, g, and if a fails what is the impact on the performance.

Now, what you have you have weightages. Now, you what you do is you try to fix out which part can fail more, and start going to that particular part start looking at improvising the design. And once you improve the design again go back and see the efficiency is the still weightage maintaining the same. If the weightages are shifted to another part you keep improvising the second part, when you keep doing you also have to fix the first part design. So, like this you keep on iterating. And finally, what happens you try to reduce the failure, failures whatever it can happen and then you try to improve the product itself.

So, in most formal system, the consequences then are evaluated by these criterias and associated risk in indices, severity likely for of occurrence probability of occurrence, and inability of control to detect. For example, if there is a crack growth on a ceramic material we do not have any tool to measure the crack growth as and when the it is in the when the part is getting used or when you put the part for a service condition. And the failure is trying to grow, it is very difficult for you to find out the crack growth on a ceramic material that is what I say inability of control to detect.

Then the next thing is likely to occur likely to occur is you are pretty confident. Probability of occurrence, so you look at the data, and you look at 100 pieces what is the performance and then you come up with the probability because I am not pretty sure whether it is going to. So, these two are completely different likely of occurrence, probability of occurrence. And then severity of occurrence is very important. If this part fails, how severe it is with respect to the output.

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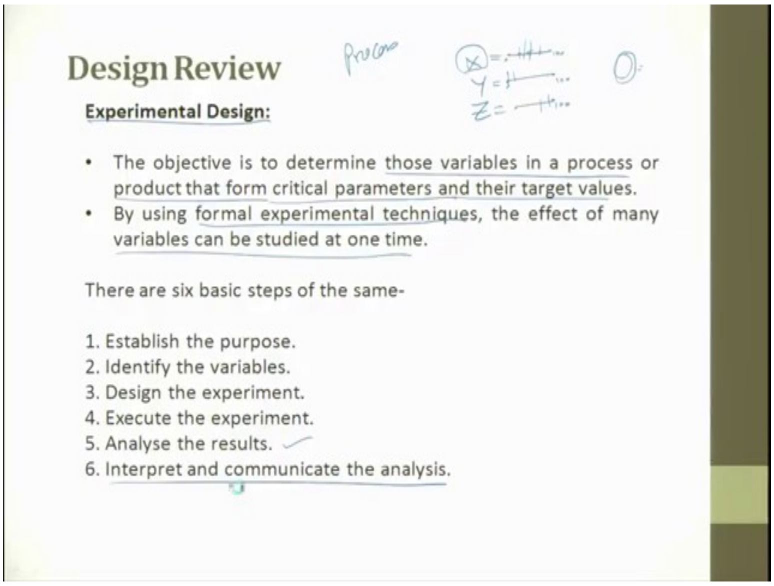

Next is experimental design. So, here what we do is we try to do experiments and then try to figure out what is the optimum parameter. For example, you try to take variable x, variable y, variable z. We have experimental design in experimental design you have three parameters x, y and z and let us take an output O; experimental design. In experimental design, what we have is we take a process wherein which in the process you will have three variables x, y and z are input variables; output is O which is one variable you have.

So, now, you have to find out what is the best process parameter I should choose in each of these such that I get the best output. So, for this if I start doing experiments may be x can vary from 0 to 100, I am just giving a range, y can vary from 0 to 100, z can vary from 0 to 100. And now if I start doing experiments fixing y and keep on changing each individual value for x, I have to do so many number of experiments to find out what is this fellow is influence. So, in the same way, I will fix x and z and then try to vary y; same way I will fix x and y and vary z. So, you see there are so many experiments which have to be conducted and conducting experiments means it is going to be costly. You have to have so much of raw materials or machines to conduct and evaluate.

So, what we do is we try to talk about why do not we have a structured way of doing it. So, the structured way of doing is nothing but designing proper experiments. So, the objective is to determine those variables in the process or the product that form critical parameters and their target value. So, there are three parameters. So, first of all what we do using the design of experiments, we try to do only one factor of a time try to find out the variable ranges, and then what we do is we try to do experiments a choosing discrete levels in each range, and this interval must be almost equal. So, we do that.

And then with minimum experiments rather than doing continuously all points we do a discrete points and then we try to find out which is the significant parameter and what is the target, what is the optimum parameter in each such that you get the best target out of it. The target can be higher the better; the target can be lower the better; the target can be mean the better ok, so that is what you structurally do the experiments and try to figure out the best parameter, so that you get the good output.

The objective is to determine those variables in a process and or a product that forms critical parameters and their target values. By using this formal experimental techniques, the effect of many variables can be studied at one time ok. So, here there are six steps to be followed, one is establishing the purpose, identifying the variables, design of experiments, I said the logical way of doing experiments, evaluate each experiment with respect to the output, analyse the result and then interpret and communicate the analysis.

So, when I try to do experiments at various process parameters, I try to get the output. And once I get the output, I analyse the result. So, here I plan for experiments then I do the experiments then from this experiment, I try to get the output, so that is what is analyses of output and from this analysis I try to give my own interpretation and communicate the analysis back to the system such that the product performance can be enhance.

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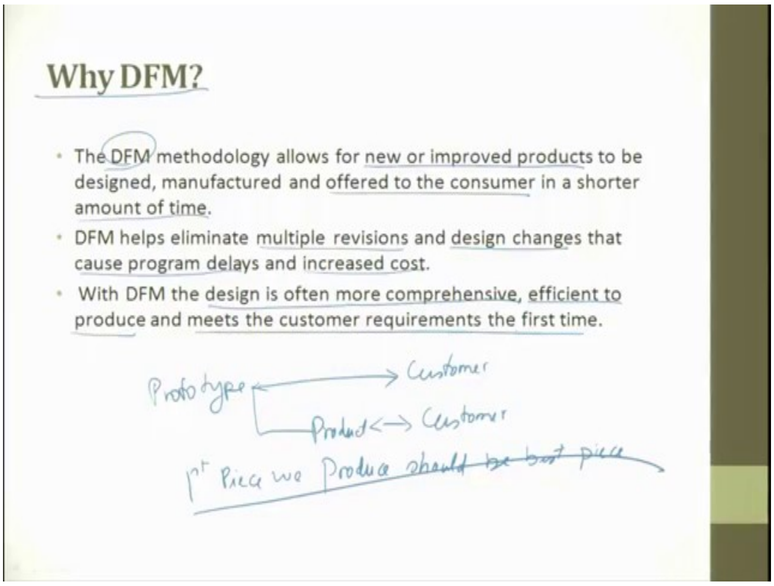

Then why DFM? DFM methodology allows for new or improved products to be designed, manufactured and offered to the consumer in a short amount of time. So, the time from the design state to go to the customer state is very important. When you follow DFM, you will try to reduce that time. DFM helps in eliminating multiple revisions and design changes that can cost program delays and increased cost.

So, when NASA was trying to work on improving our enhancing the productivity, they followed design for manufacturing as a concept and they try to standardise so many parts, and they were also standardised certain subassemblies, and their assembly was made very fast the productivity of men making a launch became very fast. With a design for manufacturing, the design is often more comprehensive efficient to produce and need the customer requirement the first time itself. So, earlier people were talking about let us make prototypes, and then show it to the customer and then start to prototype to customer. Then they say prototype to product, then we will show to customer. And then when the customer says then there will be a feedback which will go back and forth. Today what we say is we say with the first piece we produce should be the best piece. So, the customer requirements are met the first time itself.

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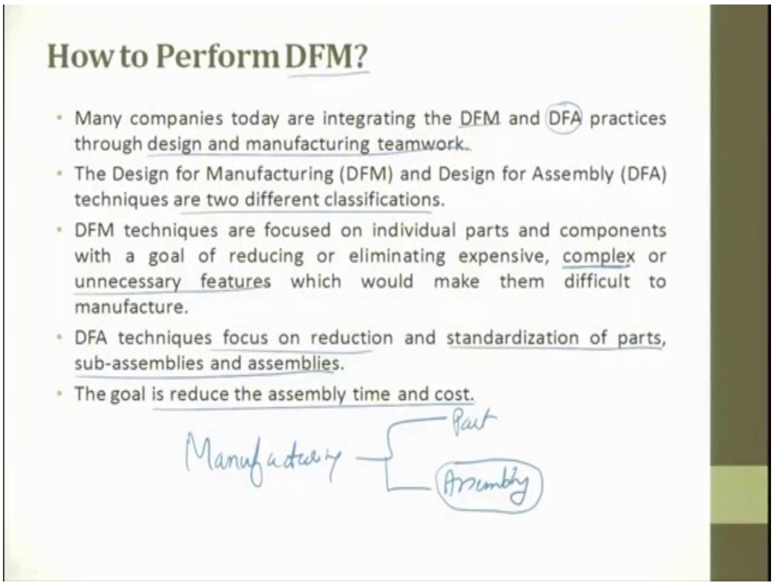

How to perform DFM? Many companies today are integrating the DFM and DFA practices. DFM is design for manufacturing, DFA is a subset of a design for assembly. So, now they are integrating see assembly is a separate job. When you talk about manufacturing, manufacturing, there are two approaches I have told earlier also. It is part producing and then assembly. So, assembly is a subset of manufacturing.

So, today what has happened is people have started blending this assembly into manufacturing practice, so that the design and manufacturing team can work together in developing new this DFM concepts in the or implemented DFM concepts in the product development. Design for manufacturing and design for assembly techniques are two different classifications. Design for manufacturing techniques are focused on individual parts and components with the goal of reducing or eliminating expenses, complexity or unnecessary features ok; complexity and unnecessary features which would make them difficult for manufacturing.

So, what we are trying to talk about here is try to make the geometry as simple as possible, and try to remove unnecessary features such that you can quickly produce the part and meet out the requirement. DFA technique focus on reduction and standardising of parts and subassemblies and assemblies. So, DFA is only from the assembly point of view. The goal basic goal is to reduce the assembly time and costing, so moment you are doing manual assembly if you standardise it then comes the conveyor belt.

So, in a conveyor belt, the parts move from machine to machine to machine and the assembly keeps happening. For example, in terms of a car, automobile, automobile they put the lower part of the car and then they put it on the skid, it tries to move from place to place to place to place, from station to station, station to station, and then slowly at every station parts are getting add up and finally, these skids are removed and then you will have tires fixed and then you try to go

So, first people did manual, then people started using conveyor belt for part moment alone. Today what they have done is the conveyors are used and the human is replaced by robots, these robots does see events sequentially when the car comes and stands in the station. So, if you want to go towards automation, so first the easiest thing which you can do is automate the assembly line. Part producing, yes, it is ok, but assembly line takes lot of time, assembly line takes lot of here is where lot of defects can happen. So, if you automated, then you get the best product out of it.

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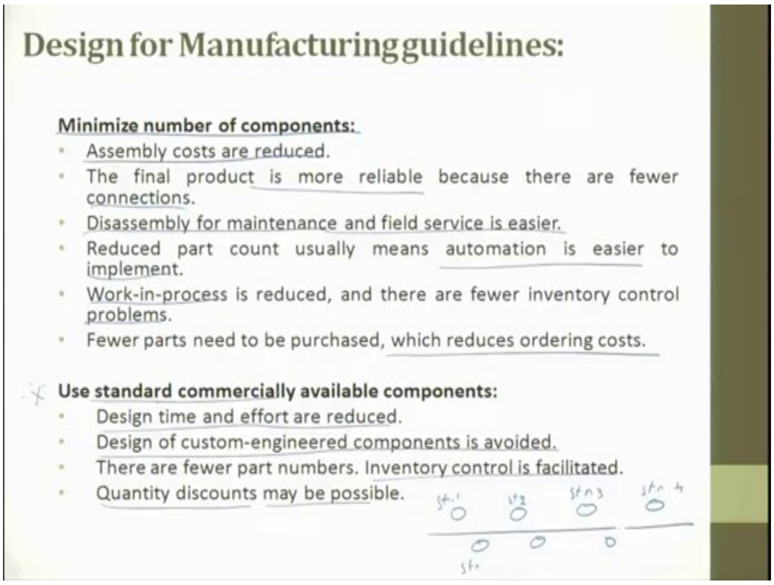

So, DFM, DFA, so the first guideline is, minimise the number of components in the product. So, when you try to take a PCB or when you try to take even a RAM or you take a mobile phone, in a mobile phone the only moving part is the vibrator. So, rest all parts are all static, all the moving parts are removed. Moment you have moving parts first assembly becomes a challenge then there is a wear and tear concept which also comes into existence. So, in order to avoid this wear and tear and manufacturing lot of defects in the assembly line, so what people suggested is trying to reduce as much as assembly operations as possible then it boiled down to reducing the number of parts. So, assembly cost can be completely reduced.

So, today I earlier told an example people make furnitures wherein which they do not do assembly they just shift the individual parts to the customer and give a manual ask the customer to go through the manual, and they do assembly. Why one the shipment cost when you have a large volume occupying objects, so shipment becomes expensive. So, what they do is they pack it individual parts, move it and no, no company or no customer will try to pay money to a product saying that this product is assemble. So, assembly costs are reduced.

Today, you buy computer wherein is there you has modular concept you have a hardware separately. You have battery separate, you have RAM separate, you have hard disk separate, all the you have you have so many processors separate you buy the best and then you start assembling assembly costs are reduced. The final product is more reliable because there are few connections only. Disassembly for maintenance and field service is easier ok. If we have so many screws nuts and all coming into existence which it is very hard for you to maintain. So, if it is a clip assembly or if it is like shirring fit or it is like circlip fit, so there is only one part you just put it fix it and then get it done or like what is there in transition fit in RAM getting fixed on the slots. So, disassembly for maintenance and field service is easy.

Reduced part counting usually means automation is easier and it is implementable. The work in progress is reduced and there are fewer inventory control problems. So, work in progress, suppose you have you have an assembly line you have several stations. So, in each station, there will be material which are stored. So, work in progress is reduced and there are a fewer inventory control problems. When you have a conveyor belt, so all across the conveyor belt you have several stations. Each station, we will try to have its own inventory of parts. So, when you have each station has its own inventory, then the inventory in each one summing up leads to lot of work in progress.

So, work in progress means there is a product which is existing or a part which is existing which is which I cannot sell it at that point of time. So, until I work more, I converted into some usable form, so I cannot sell it. So, till I can the time I can sell it whatever happens is going to be an inventory record in my factory. So, every company fights to reduce the WIP that is nothing but work in progress. So, if you follow number of parts to be minimised, so I do not need to have. So, many stations fewer parts need to be purchased which will reduce the ordering cost also.

Next one is the very interesting thing and very important use standard components for the for manufacturing the product. For example, screws, nuts, springs, ok. So, please use the standard which are already available that will be economical for you and easily available for you. So, the design time and the efforts can be reduced. Design for customer engineering components are avoided that means, to say the customisation cannot be thought in a very big way that is what we are trying to say that is what is followed in your shoe company like they put all the issues into several boxes, 6, 7, 8, 9, 10 numbered and then kept. So, there are fewer number of parts inventory control is facilitated, and then quality discount may be possible if you have standard commercial parts as parts as parts used for your product.

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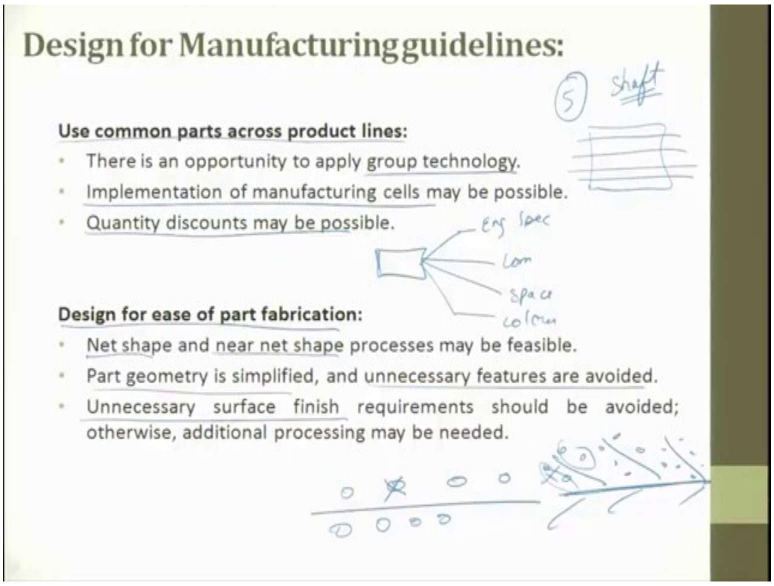

Use common parts across the product line. So, if there are 10 places or 5 places where the shaft has to be used at several layers, assuming this is a product. Here is a shaft, here is a shaft, here is a shaft, here is a shaft, here is a shaft, so use the shaft which is getting assembled at across different product lines at. So, I am taking one product, you have multiple places where a same shaft is used at different places or what I am trying to say is the I am trying to say I have a car, and then I have several different models of the same car. For example, I can change the engine spec, I can give more comfort, I can give more space inside the car. I can give you different colours. So, these are all different varieties wherein which a single product can be given. So, I have multiple lines. So, I try to make the parts which is used in every line to be almost the same.

So, predominantly what I do is I try to use a technology called group technology while doing this. So, what is group technology, group technology means you try to group you try to group different parts almost having the same features into one group, so that you can start manufacturing it at an economical price. Implementation of manufacturing cell may be possible. This we have gone one step into deep into it. When you apply group technology, I can start grouping the machines. And once I start grouping the machines, each group I call it as a cell, so I can have more number of cell. The idea is rather than having a single conveyor and having so many machines around. What I do is I do clustering, I have individual lines may be all these lines are trying to produce the same part, but I have several lines which goes in parallel and produce the output which come to the main conveyor.

So, here if this machine comes up or if this station comes up, the conveyor comes to stand still, but here I have different, different manufacturing cells. So, if one cell fails only this conveyor fails, but rest all will start producing. So, that is what while implementation of manufacturing cell may be possible when I start using this point, and quality quantity discount is possible. So, you produce more you get a discount.

Designed for ease of part fabrication. So, today there is the big concept or a big talk which is going on. Let us start producing parts to the near to the net shape and the near net shape processors are feasible. For example, earlier days they used to make a wheel drum by casting and then what they do is they used to machine it to the requirement. Today what they do is they directly make it through pressure die casting you can have aluminium, you can have magnesium, you can have titanium you can have steel whatever you want. And what they produce is the shape and the size is exactly what matches for the requirement in the real time situation or the product dimensions are made. So, this is what is designed for ease for part fabrication. Choose processors such that you can try to produce to the near net shape. The part geometry is simplified, unnecessary features are avoided, unnecessary surface finish requirements are also avoided. So, this makes the ease in part fabrication.

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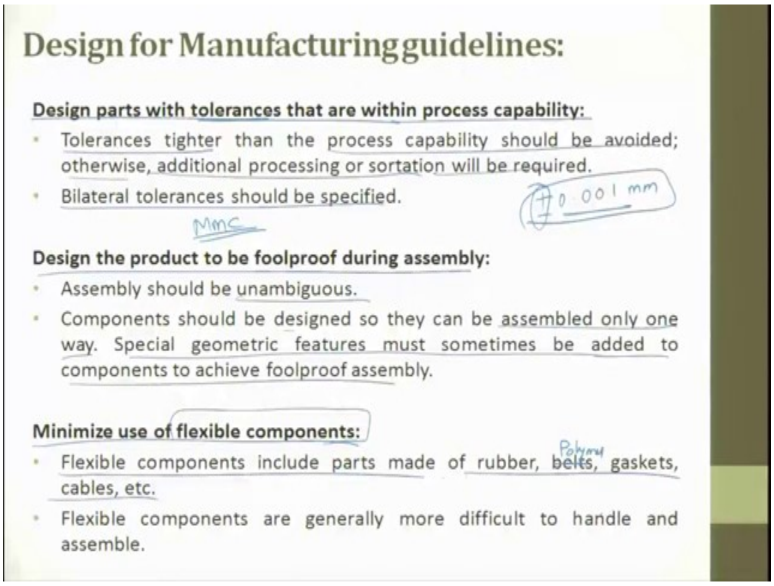

Next one is design parts with tolerances that are within the process capability. Do not try to just demand here is a part which mates with another part a male part and the female part. Let us ask a tolerance of 0.001 millimetre. Why did you ask I thought this is good but can your machine make, no it cannot make? So, what are you doing? Since you get this dimension, I am going to add one more process while producing the shaft for a whole and pass the process through that.

So, what we are trying to say in this design for manufacture is knowing the capability of the process, you try to change your design such that these high type tolerances you do not give. Moment you do not give type tolerances, then the process which is trying to make becomes easier, and the process capability of that process is also higher. So, tolerance tighter than the process capability should be avoided; otherwise additional process or short stations will be required.

Bilateral tolerance should be specified. So, this is the bilateral tolerance, because when you talk about assembly, you have a maximum material condition assembly. So, you try to take a shaft, you try to take a hole the maximum material condition of the shaft, maximum material condition of the hole then you try to understand what fit you want. So, the tolerances play an important role. Try to make tolerances as liberal as possible when you do that you should make sure that you do not sacrifice the performance of the product,

Then design the product should be foolproof during assembly. Many a times today you see in electronic industry, when you try to place a battery, it does not give you a possibility you to place it in the wrong direction. The fixtures are made in such a way such that whatever mistake you do, the design itself shows it to the customer that you have not place it in the right direction. So, the product or the battery will not get into the slot.

So, what we are trying to say is try to make fixtures or slots wherein which the product or the part has to go assemble unambiguous. So, I should place it only in one direction and see for example, in battery the positive and negative, you have a small projection on the top of flat, but at the bottom. So, the flat portion; the top portion with the head, you always say it is positive right. By looking at the design itself you try to say that, so that is what it is if you do not have that top, but which is projecting. So, both sides will be can be considered as positive and negative. So, this is unambiguous design.

The components should be designed, so that they can be assembled only in one way or in one direction. Special geometrical features must sometimes we added to the component to achieve foolproof assembly. Foolproof assembly means even an unskilled labour should place the part in only one direction which is the right for the assembly. Minimise the use of flexible components. These flexible components giving the pressure, it can expand or contract or this ‘flexible components’ always have a lifetime which is which is lower than the metals.

So, the flexible components including rubber, belt, gasket cables must be avoided, because these flexible components are proven for failure. In automobile also earlier days, the belt whatever was done we did not get proper choice of material. So, it used to fail frequently because of the belt failure a car stops moving. So, now, the belt technology has improved. So, you do not see the such belt failure. So, composite belt comes that is what we say flexible components include part made of rubber, polymer, gaskets and cables have to be avoided. The flexible components are generally more difficult to handle an assembly because when you try to the automatic assembly and this flexible components the shape size and all gets deformed when the assembly happens.

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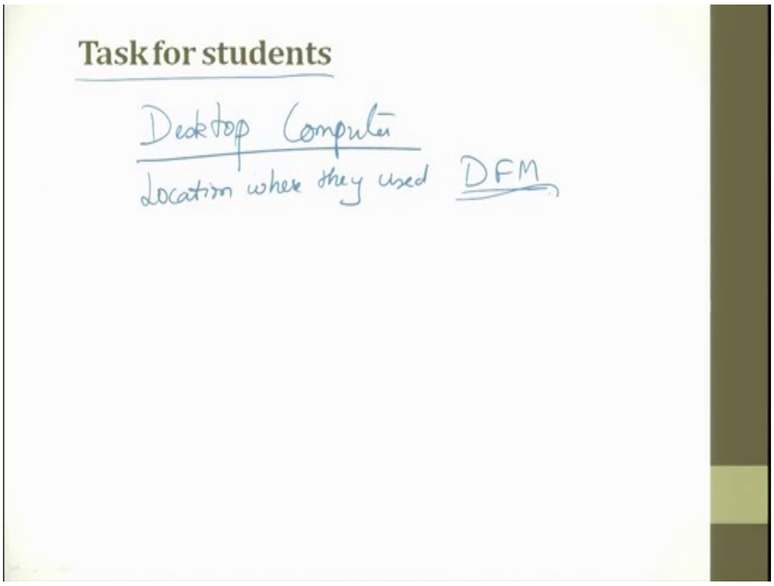

So, we have a task. So, try to look at your desktop computer and then try to find out locations where they have used DFM. This will try to give you when you start doing this cross-sectional analysis of the desktop, so you will try to appreciate how DFM is followed in electronic industry.

Thank you very much.