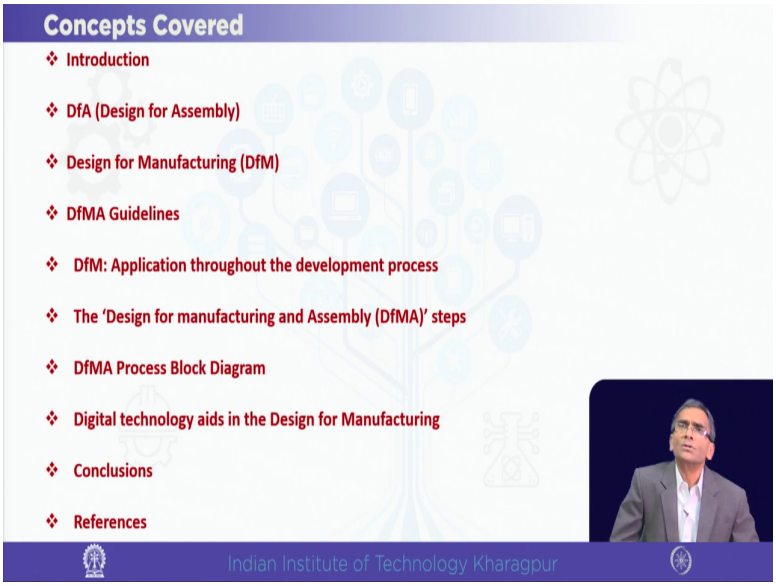
Product Engineering and Design Thinking
Prof. Pranab Kumar Dan
Rajendra Mishra School of Engineering Entrepreneurship
Indian Institute of Technology, Kharagpur

Module - 06
DFM, Rapid Prototyping and Affordability Engineering
Lecture - 28
Introduction to Design for Manufacturing (DFM) and Assembly (DFA)

Welcome back to our course on Product Engineering and Design thinking. Today we are starting a new module number 6 which is Design for Manufacturing or in short DFM Rapid Prototyping and Affordability Engineering. Today the 1st lecture in this module will be on Design for Manufacturing and Assembly, Design for Assembly.

(Refer Slide Time: 01:00)



So, now we will first see the concepts covered in this session or will be covered in the session is that with the brief introduction we will go into the design for assembly and design for manufacturing. Though very commonly it is called usually design for manufacturing and assembly, the word manufacturing comes first then the word assembly comes. It is natural because after all when we consider a sector ah, we consider as a manufacturing sector.

So, there assembly is another activity of overall manufacturing. So, that is why popularly it started with the concept of design for manufacturing, but it has been from the you know product design perspective, besides the sector naming another requirement came up is that which is slightly different in nature though there are many things in common is that the assembly basically deals with the larger sub assemblies or modules and then it is broken down to its sub parts or components.

So, the characteristics of assembly is that first the assembly configurations are to be settled and then under the constraint of those settlements the individual components are to be accommodated or designed. So, that is why we have kept design for assembly purposefully before design for manufacturing and then we will be discussing the DfMA guidelines.

And of course, it is applicable throughout the product development cycle because at new point in time we cannot spare this because at every point in time the translation of whatever design or whatever design stage or whatever considerations are being made would be ultimately to be taken into account and therefore, manufacturing considerations are indispensable.

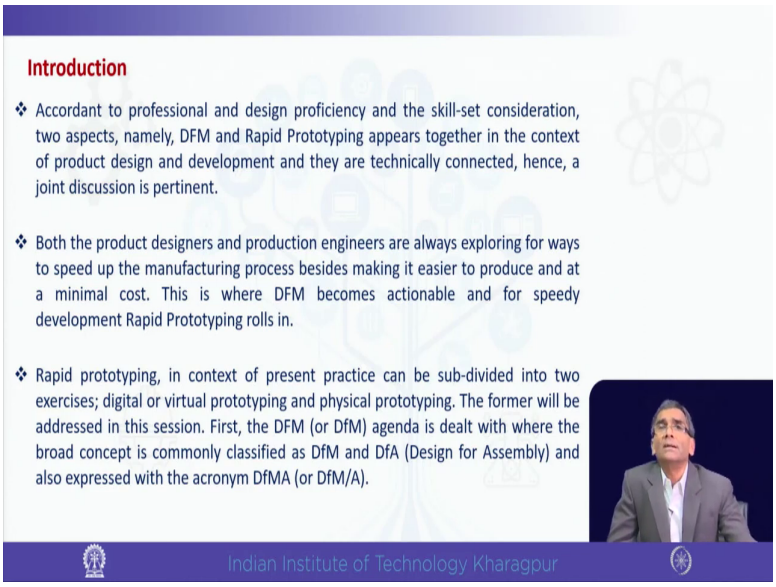
Therefore, it is across the entire development process design for manufacturing assembly steps will be discussed and then we will talk briefly on modern technology that is actually it is basically says CAD. Now, CAD you already have some exposure about maybe AutoCAD maybe SolidWorks maybe SolidAge maybe Creole maybe NX Simmons (Refer Time: 03:51) graphics or whatever the softwares are similarly maybe some exposure or you have heard the name of ANSI's or some simulation software etcetera.

But here specifically for design for manufacturing the software's are also available now and very conveniently those can be used when the mating parts are particularly configuration which is really useful to or suitable to manufacture those would be decided and we will talk about that and that would also help in explaining one point that DfM is actually helping the rapid prototyping.

I will talk about rapid prototyping little later, but then here in the beginning I would just like to touch upon a point that when we hear about rapid prototyping some notion, I am not saying for everyone, but some notion is there as if it is a rapid prototyping machine or 3D printer machine or something like that or some other machine. But or say maybe it is a hybrid manufacturing machine where additive and subtractive both are happening and besides our regular equipment for prototyping like CNC machines and others.

The question is that now it is increasingly being felt that this before any such prototyping it is always good to have its digital version or virtual version or digital or virtual prototyping is necessary. We will through this address the beginning of this discussion in rapid prototyping and that we will take up at a later stage in an elaborative manner.

(Refer Slide Time: 05:48)



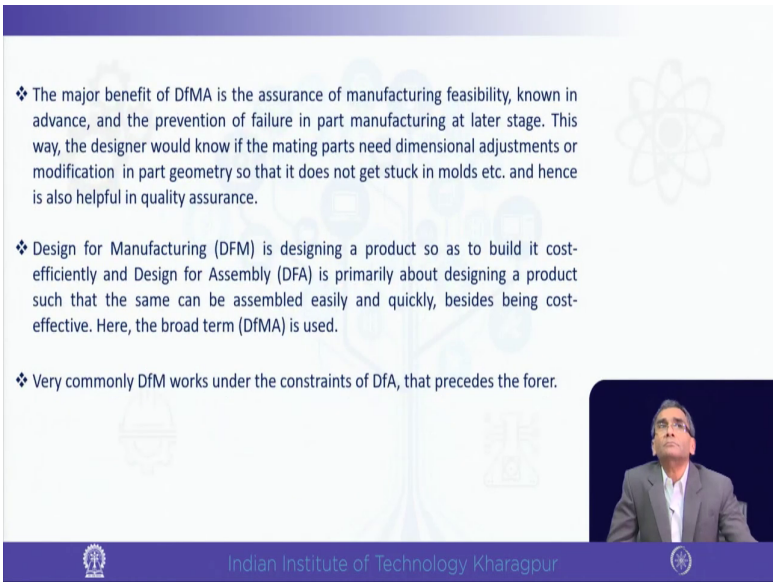
So, here we go discussing that since when it comes to professional proficiency in job advertisements and other recruitment time or when the interview people are asking people generally ask whether they know I mean similar things like say if they know CAD, then if someone can tell them that they also know that design for manufacturing software that would be certainly of advantage and because that is where the need comes.

So, from the industry need perspective we have kept these two things together. Industry need as well as the technical logic also because the two things are technically also aligned. Both the product designers and product engineers are always exploring four ways to speed up manufacturing process besides making it easier to produce and as it is easier to produce and quick to manufacture rapid prototyping or rapid manufacturing role set and this creates a avenues for that discussion.

So, technically you can now see and logically how they are connecting. A rapid prototyping in the context of present practice can be subdivided into two as I have said the digital part and then the physical part. First it is a digital simulation or digital solution is created from a CAD design say whatever is to be checked say how much stress or force is coming on to the product etcetera.

So, all these assessments are made and then if those are satisfactory then physical prototype is justified and will be convenient. Otherwise, a physical prototype in a 3D printer will be made which will collapse. There is no use because the stress was not assessed through a digital system earlier. Therefore, we would discuss the DfMA aspect in that rapid prototyping and assembly.

(Refer Slide Time: 08:12)



The major benefit of DfMA is the assurance of manufacturing feasibility that whatever is being designed whether actually it is feasible. Suppose someone is designing a whole very small in diameter, but pretty long in length.

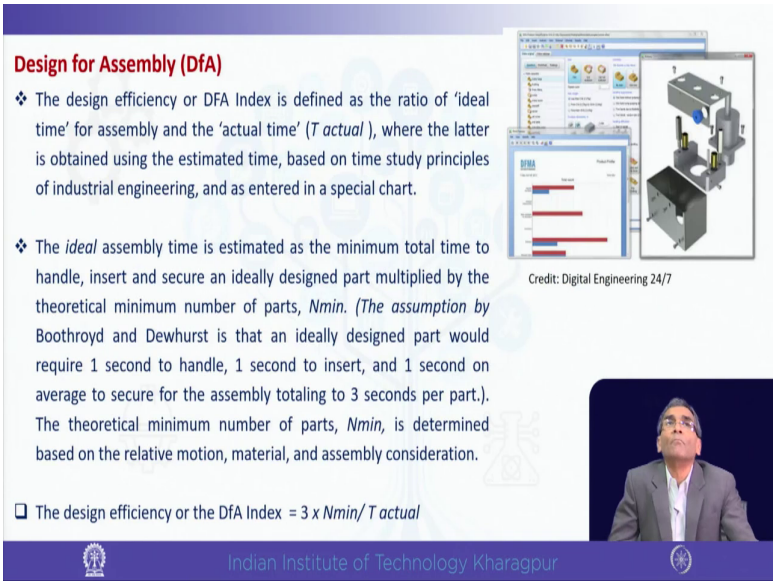
So, I mean one has to be careful in noting that this drill can be only machined with a very long drill and so whatever the care because long drills has a propensity of breaking. I am just an example. So, those are the things. Similarly, if a product is being made where a thin section is generating which is likely to break.

So, those are the things that can be checked whether that is possible through this design for manufacturing approach the feasibility is known or two parts are cannot meet or the mating parts are not of right dimensions. So, they need adjustments. So, those are the things considered say or say a mold may get stuck in the component may get stuck in the mold in a system alright.

Design for manufacturing is designing a product which is actually to be built cost effectively cost efficiently. And that is what we normally here for design for x; x is that variable where we when we talk about design for reliability it is DfR when we talk about design for environment it is DfE when we talk about design for quality it is DfQ. Similarly, when we are designing for manufacturing it is DfM when is designing for assembly it is DfA.

DfM and DfA primarily are targeted to cost containment or reduction that gives the competitive age of course, besides easiness and proper quality. Now, very commonly as I said that DfM works under the constraints of DfA. When DFA is tested and if the major components broadly fit in then the sub components or the detailed analysis of the components are further carried out in DfM.

(Refer Slide Time: 11:05)



So, design for assembly, it is basically can be evaluated with an index or it is also known as design efficiency. But DFA index would be a more proper term for possibly good design efficiency is a broader term though it is used in this context often.

And it is considered to be a ratio of the ideal time of a product assembly possible ideal that is possible that is actually not happening in reality divided by the actual time. So, what is possible? That is a big question that while designing there is a way to find out what is possible. So, and divide by actual will be actual the number of parts from the estimate how much a component requires to be assembled etcetera that we can figure out. How can we figure out?

If the product is still not ready if the physical assembly is not possible, how can we figure out? Here there is a method called industrial engineering time study method or time

assessment method where or it is also called work measurement. So, from there one can find out what is the time required for a particular assembly is based on estimation.

There are methods of estimation I am not going into that there are also charts from there one can find out or one can try with similar components to check whether you know kind of time that is coming is acceptable.

So, somehow understand there is a chart to be established for that particular operation. Now, based on that chart with the estimated time the actual time is derived adding all the individual assembly times. Now, how the ideal time will be found out? Here two things; one is how much time per assembly it will take and what will be the minimum number of components that would be assembled.

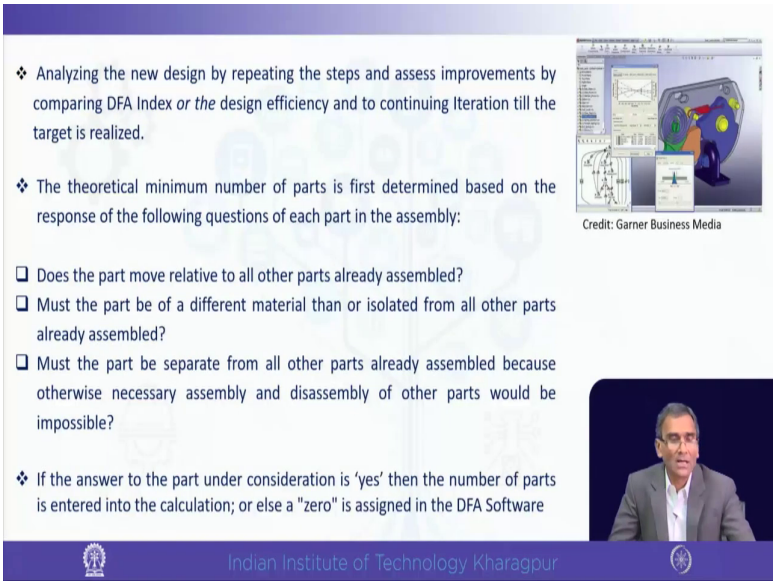
So, if we can reduce the number to a minimal then it will become ideal because then the then they you know this will be up. Hence, what we do is that there are. So, number of parts how it can be determined is a study that we will just now do. That how what is the criteria based on which the number of parts can be decided optimally or minimally here ok we will come to that. But before that what is the time per assembly? Here one very popular assumption made by Boothroyd-and Dewhurst they contained that a 3 seconds time is to be considered for each to be minimal.

So, that is that first is 1 second to handle, 1 second to insert and 1 second to secure. So, 1 plus 1 plus 1, 3 is a second that the ideally it should take, but if it takes more than that; that means, it is not very efficient. Now, ideal means what? Ideal means say if you are putting a square pig in a square hole, though one has to look it that where is the square edge and all alright.

So, one has to position etcetera. But if this spin is cylindrical then that requirement is not there, but still positioning is necessary at the hole which should take lesser time in assembly I am just giving you an example. Actual assemblies are more complicated. Now, even if the position is eliminated then if it is a sphere spherical ball then if I put it then that requirement will completely go a blindly one can put it in the whole and it will go in.

So, you understand when the ideality is considered it is considered with that kind of a frame of mind. So, here the 3 multiplied by n minimum by actual time gives the indication as to where it is. Now, with the actual assembly the current assembly the actual time will go down and the efficiency will increase that is the objective.

(Refer Slide Time: 16:35)



Analyzing the new design by repeating the steps whatever has been discussed that would be repeatedly done till the perfection is reached. Theoretical number of parts as I said that is to be discussed what is this? Now, a part if it is not one separate if it is if it can be combined to one then that is the advantage, so that we can bring it to minimum.

So, if there are two three parts big machine and fabricated added instead if we can mould it through a casting process and in one part multiple configurations can be brought in. So, it will

become one part like you see moulded chairs in one part the whole chair comes legs seat backrest armrest everything will come in just one mould.

So, it instead of 5 6 components it becomes one component. This concept I will tell you it is also two some extent related and connected to value engineering which will briefly touch because we have already discussed first diagram a component of value engineering, but we will address that later on in a different context in a way.

So, what are the criteria by which it is to be identified? So, if a part has to move in relation with another say bearing has to the shaft will rotate with respect to the housing. So, that is in relation there is a movement, but if the shaft had to be fixed to that body, then it could have been one part, but since these are moving relatively moving motion then these are two parts one consideration.

Second is if the material is not the same then it has to be two different parts if something is made of aluminium and something made of steel then it cannot be one part. And third for maintenance or repair purpose if they are to be separated then they cannot be one part.

So, other than that rest all are becoming the candidate for consideration for a single part. Then that design for manufacturing principle would be applied and finally, one would have to see whether truly design for manufacturing is can support or is supporting that one part for that particular in that particular case. If the if it is yes then it is yes otherwise it is no zero.

(Refer Slide Time: 19:18)

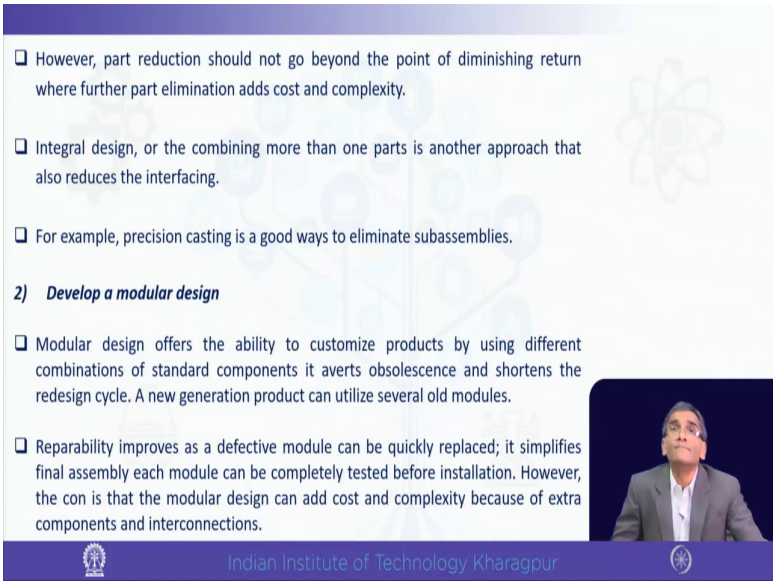
Design for manufacturing, I would if this is written in a very elaborate manner in the slides. So, you have every opportunity to go through the slides and read those I just would describe here briefly for each one of them is that designers need to recognize the significance of processibility. Obviously, we have said because if it is not assessed if designers is designing at his own fancy and wins then at some point in time it will be stuck when this realization or conversion or translation has to happen.

So, it has to be checked beforehand before it actually is sent to the factory floor. Here are certain guidelines, which has been provided by Henry Stole which are considered to be representative though they are at the outset. Let me tell you that I have already named Boothroyd and Dewhurst and now I am talking about Henry Stole and I would like to tell you there are other guidelines also or other principles also.

Companies are coming up with this. However, we have to start with something and something which is widely accepted and referred. So, I will be discussing those. But one can always add or improve this. As I have already said minimize the total number of parts because less number of parts reduces many things, less number of inventory, inspection, procurement, processing equipment, machinery, everything.

So, I have already discussed the next four points how why a part how a part can be eliminated. If they do not fulfil those already stated criteria that whether relative motion these and that which is written here, they can be eliminated. So, part counts can part count can be reduced based on that.

(Refer Slide Time: 21:21)



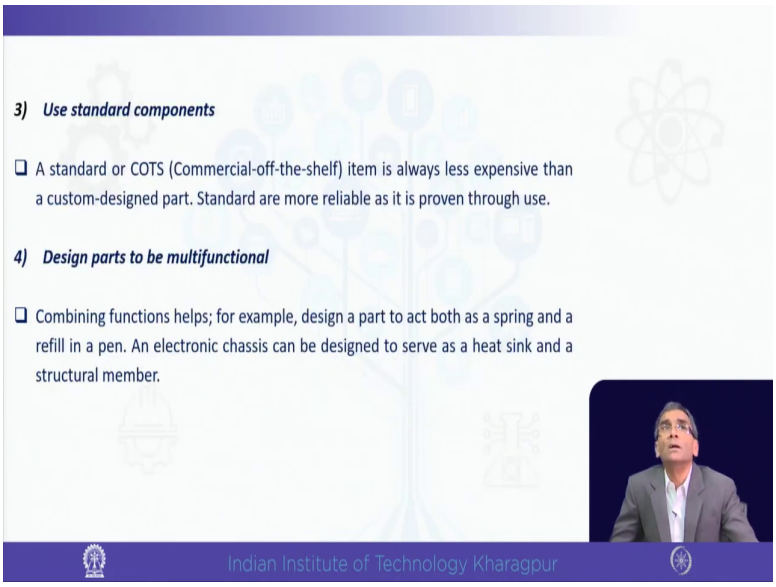
Then, however, one thing here I would like to tell you is that while part count is to be reduced, but there will be a some point beyond which if we try to reduce then the cost may

not be actually listen it will go up say then it would be complete integrated heavy part. And so, it is based on say integral design and sometimes there are certain disadvantage for which we have already in the product architecture has discussed the modular design versus integral design.

So, those principles will apply. So, naturally in the course of discussion come the developer modular design I do not have to discuss anything further which has been discussed elaborately in the architectural design discussion say the lecture where we have said what are the you know modular design what are the integral design etcetera.

So, only to bear in mind the modular design is not always the solution when particularly the compactness or cost is to be considered then possibly in some cases integral design is also preferred. So, those are the consideration however, for design for manufacturing to be kept in mind.

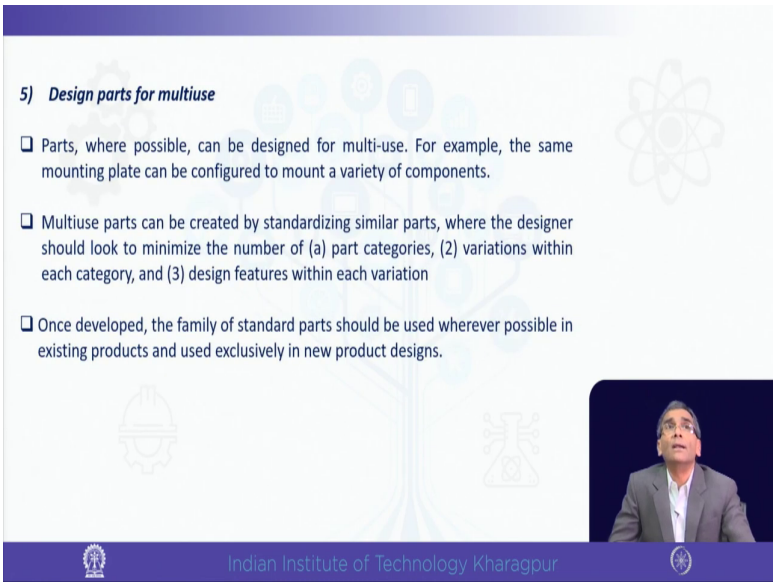
(Refer Slide Time: 22:39)



Use standard components or cost called commercial of the shelf say first runs, nuts, bolts, bearings, certain switches and all those kind of things which is standard available the market is no point designing. If they are used in that product that is better because for two reasons one is that since they are those are being mass produced by some company their cost will be less and two because of the ongoing manufacturing for several years their designs are proven and is established.

Also, to make design parts to be multifunctional that is a say for example, in a heat sink may also be used as a structural member. So, in an electronic chassis so, that can be one product can serve multiple functions so, that will be also a consideration.

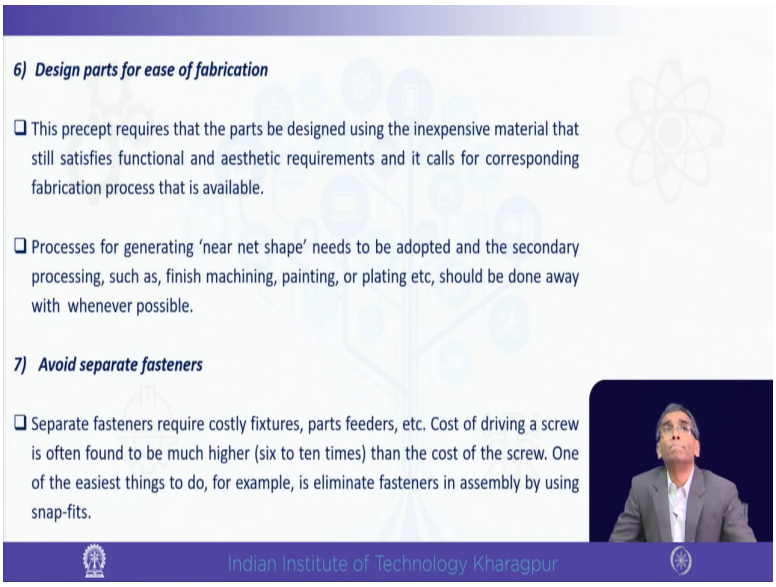
(Refer Slide Time: 23:50)



I will tell you design parts for multi use parts where possible can be designed multi use the same mounting plate can be used for multiple folding. Like say I can give you an example for multipurpose or multi functions which I discussed a little while earlier also that there are certain pens ball pens where you would find springs and in some pens, you will not find that spring where the refill is built a little longer and it actually using its plastic bending ability a kind of springing force that is acting as a spring.

So, the refill is a spring as well. So, multifunctional is an example of that, which you can see open your pen and you will find. So, so similarly so, therefore, it is always to bring some kind of standardization different sizes if possible, can be brought into one kind of size unless it creates some other problem it is good for inventory control also. So, standardization is important.

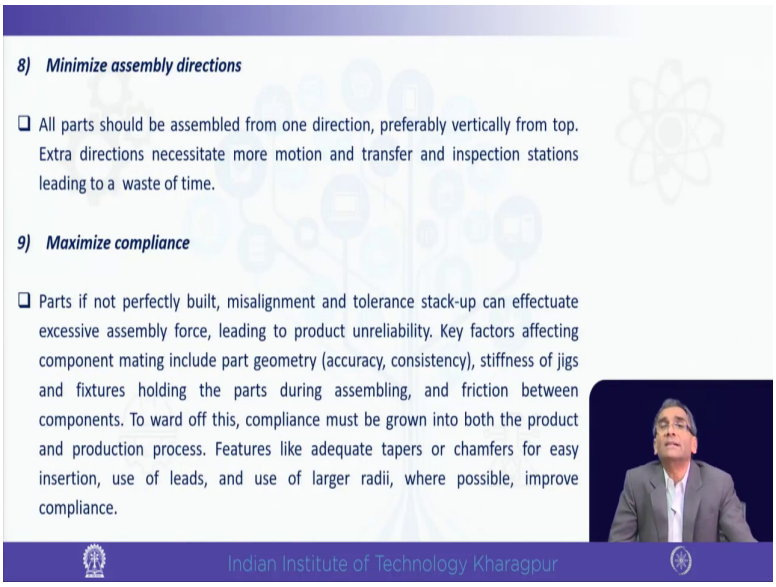
(Refer Slide Time: 25:16)



Design parts for easy fabrication of course, I mean near net shape that even close to the final product if we can make then it is easier. So, then we can avoid some secondary finishing, machining, polishing these are that can be avoided etcetera. Avoid separate fasteners are costly and fasteners are assembly of fasteners are costly because it takes a labor and say screw may be very small and may be very inexpensive, but actually if we look at the labor cost of driving it through, then we will see that involves cost.

So, instead if we can use snap fits or something like that like I say the mobile phones back cover it is not fitted with the screw like other electronic gadgets it is a snap fit that you can just press that back cover is fitted. So, fasteners are removed and when components are removed that it is coming from the moulding itself.

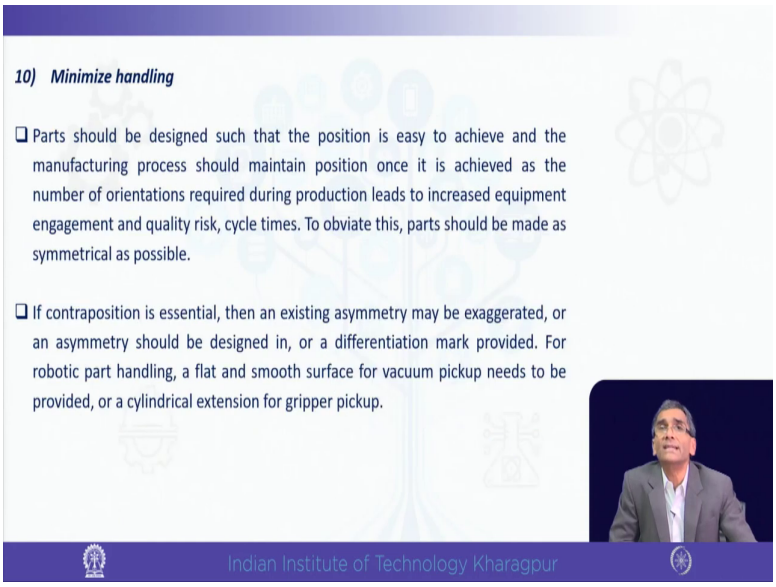
(Refer Slide Time: 26:23)



Minimize assembly direction cities to be an not upside down left right preferably it should be done vertically something is kept and on top everything is been put in assembly is complete because the more we are upturning, down turning etcetera is happening the more the time is wasted and it does not hail.

Maximize compliance: So, the tolerance or alignment should be such that the assembly becomes easier and so unnecessarily stacking up tolerance or to be done and the also the jigs etcetera fixtures should be tough enough stiff enough. So, that the bending etcetera does not happen and so the compliance explains.

(Refer Slide Time: 27:18)



The details are written you can always read them, but I am giving you the essence and which is close to what is written there and minimize handling. So, this is the last item of the design for manufacturing parts would be designed such way that it is designed say a robot is it is gripping. So, something may have may require a cylindrical part. So, that the robo arm can grip or say a vacuum pump needs a flat surface. So, that the this can be picked up from there.

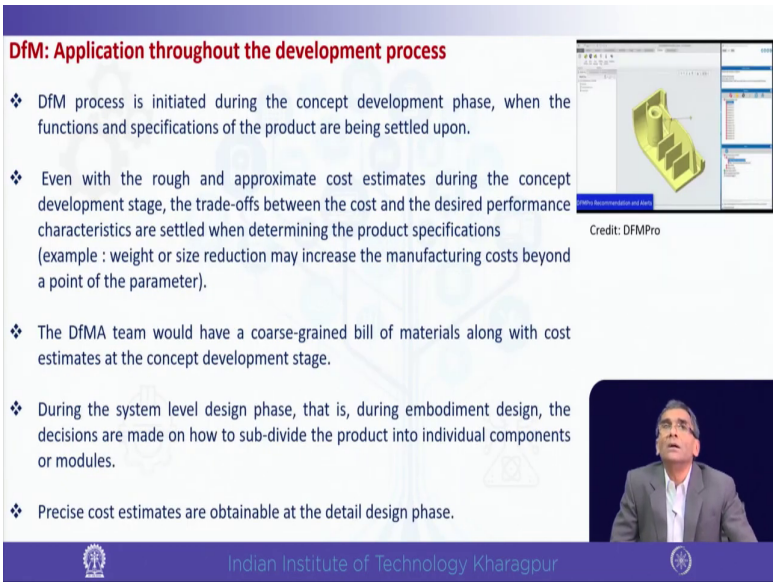
So, those are certain the features to be put in the product that helps in a material handling. So, it is a part feature being incorporated for the convenience of material handling, which otherwise would become expensive. So, these are helpful tips for design for manufacturing.

(Refer Slide Time: 28:08)

It is normally done in a cross functional team I have already discussed about the team earlier that say design, manufacturing, quality, procurement and costing so all. It starts with the sketches, drawings, product specification also mock-ups, reasonable detailed understanding of assembly and manufacturing process are necessary and estimate of manufacturing costs would be essential and also the production volumes mainly before the pilot run and timing.

Production volume is very important because it depends if one has to produce one component, then naturally the process may be something else, but for months. Say for example, if one needs 10 pieces one may go for machining, but when millions of pieces to be produced then people might go for costing otherwise the machining would mean wastage of material and time both.

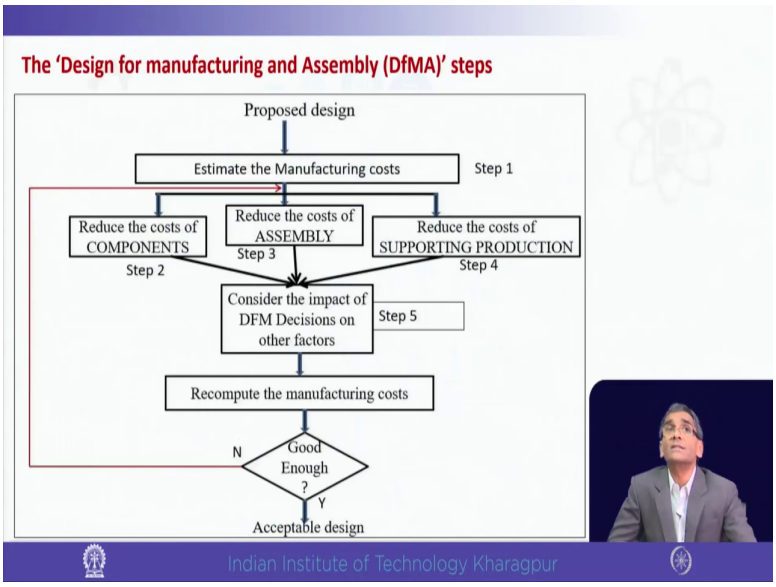
(Refer Slide Time: 29:15)



Design for manufacturing is application throughout the development process I have already dealt with this and therefore, I just would tell you that at this stage the concept generation stage here the where it begins the rough and approximate cost estimates are done.

But that is a no a close grant estimate and bill of materials are also a little bit coarse-grant and so bill of material may which are the materials how many would be required etcetera. And during the system level design that is a embodiment design level it is broken down into sub parts or subdivided. Precise cost estimations are available in detail design process.

(Refer Slide Time: 30:03)



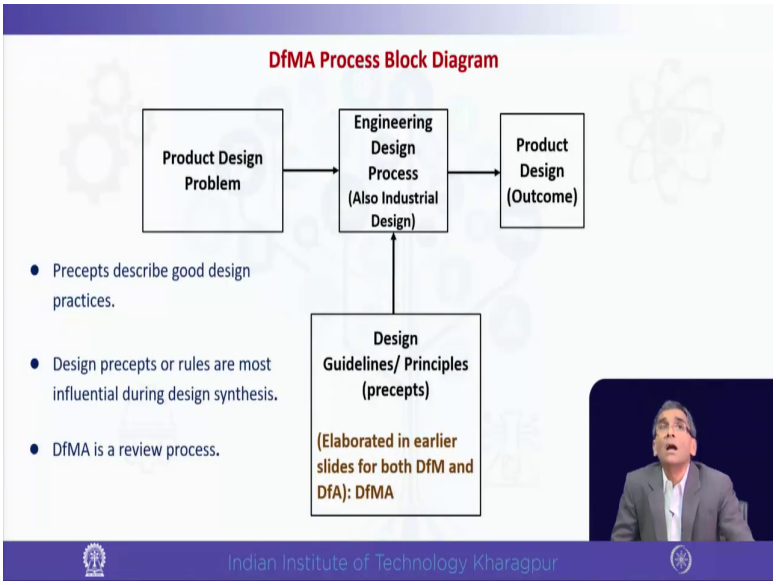
Here you see in one diagram we are bringing all the components. So, that you know the process the can be understood just in one page. A proposed design whatever is being conceived then that is a estimate the manufacturing cost that is step 1, step 2, 3 and 4 are parallel that is a component cost, assembly cost and support production cost.

Where support means all kinds of support starting from its maintenance equipment maintenance to quality control everything and a procurement of material etcetera and assembly and component making components are goes into assembly. So, the attempt should be made to reduce cost at every stage as I said just now for assembly for manufacturing. And now I am talking about the supporting production the manufacturing support system that (Refer Time: 31:12) fixture equipment material handling system everything.

So, but one has to see here consider the impact of DfM division on other factors like say when you are doing while doing that whether the it is impacting the cost or it is impacting environmental conditions whether by doing that the it is becoming un environment friendly, it is creating greenhouse gas or pollution that is not acceptable.

So, if that happens then it cannot be done otherwise re compute the manufacturing cost then if it is good enough that is target cost if it is meeting target cost then accept it otherwise repeat the process once again in the next iteration reduce the cost for each aspects component assembly support system.

(Refer Slide Time: 32:11)



This is a process block which gives us the idea the product design problem to engineering design process also it is industrial design process included. So, I have mentioned that in particular where, which considers the aesthetics and agronomic part of it and environmental

eco design part of it and then the outcome is product design where which is big fulfilled through design guidelines and principles which we have just now discussed both for DfMA and DfA.

(Refer Slide Time: 32:47)

Now, we are towards the end of the discussions I would just tell you that there are various software available now that perform DfM and DfA. This digital aids make sure that the designs design is suitable and ready for manufacturing quickly and accurately and quite importantly by providing opportunity for visualization that one can see through these 3D imaging, modeling etcetera one can see.

That how the parts are coming and how the drill holes are closer to each other what is the center distance everything now visually can be seen with the help of a software 2D and 3D

both and so with the corrections can be made there and then in the digital form which is very interesting.

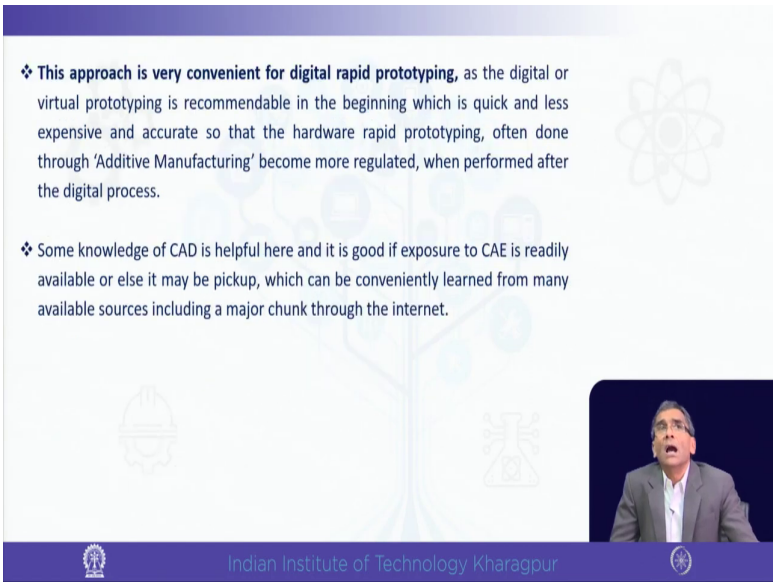
As you already have learned CAD or if you have forgotten in just weeks recapitulation will be help and then with that knowledge if you try even some open source software it would be very interesting activity and this interesting activity actually will help you to gain proficiency and what do I say the skill set which is immensely valuable in industry.

So, those are simple things, but it needs interest. So, if someone is interested in engineering design or becoming a designer etcetera. So, for them it is very important and. So, here certain links are provided also, but by no means that links are the only links where we can look for these software's there are plenty of others. In fact, in the slides I have presented some views from various other software manufacturer or applications and below that you would get the name as a credit.

So, it is a Siemens PLM it is digital 2747 some are of course, from DFM Pro all these are. So, once you get into this it is a very interesting world design is a very interesting world and you would love to do using all these in this digital system computer system. So, it is a digital design and manufacturing system you also have had hard CAD CAM.

So, CAM is the part of computerized manufacturing Siem is computer integrated manufacturing here our initial parties CAD and CAE that is computer engineering and finally, it will be final draft will be prepared or it is called CADD computer aided that is automated drafting.

(Refer Slide Time: 35:56)

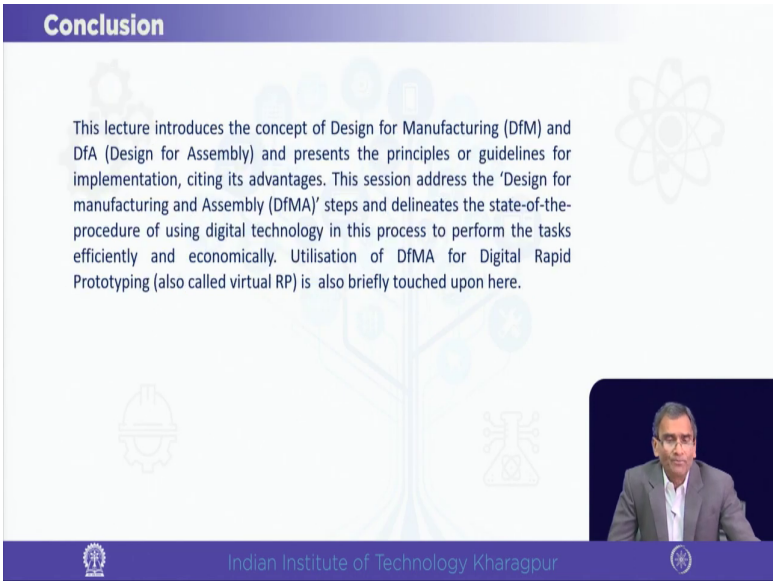


This approach is very convenient for digital rapid prototyping which I said I will come to because rapid prototyping is absolutely essential ultimately to chart out to bring out the final product and coming back to the initial discussion that we had that it has two parts. One is that the digital form simulation on screen we can see how the product is created, what is the shape size, how it moves, how it fits with each other and then physical assembly or component fitting can be made or component building can be made.

But before that if the simulation says that no it is not working, fine then there is no purpose of making it through hardware be it additive manufacturing or some other process which commonly is used. But therefore, we emphasize always that first in modern times and that the companies the industries are wanting that first it should be done digitally it saves huge cost on prototyping.

So, some knowledge of CAD is helpful here, which I am sure you have say some auto cad or something you had and it is very easy to learn weeks time if you spend then it and you can learn also CAE, then it would give a great skill set which is market worthy industry worthy alright.

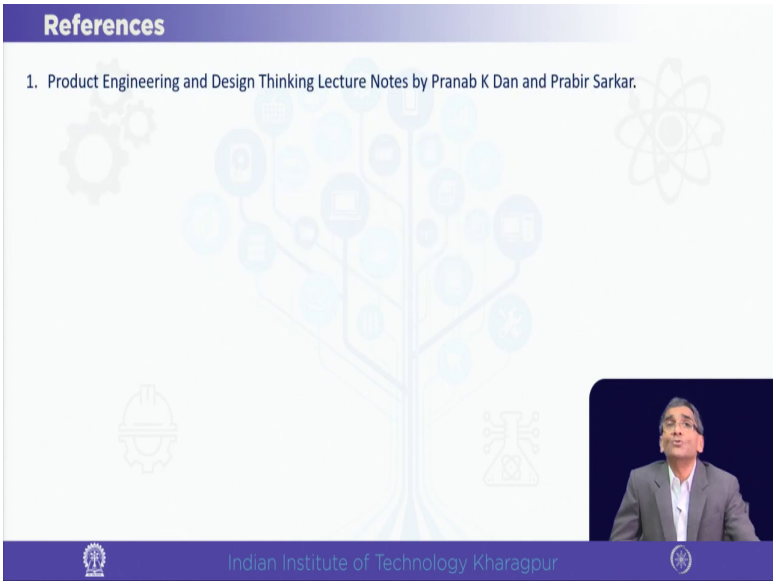
(Refer Slide Time: 37:28)



So, in conclusion I would like to say that this session introduces the concept of DfMA and DfA and present the principles or guidelines for implementation citing its advantages. This session address the design for manufacturing assembly DfMA and last part is very important that it relates to the digital rapid prototyping aspect which actually we will be discussing in with more elaboration in subsequent sessions.

And I am sure that way this session has helped you or will help you if you when you read it further again because it is presented in elaborate textual form for your convenience on the slides you can read this letter and get benefit extract benefit from it.

(Refer Slide Time: 38:29)



I would like to show the reference that this reference can be read and of course, nowadays as I have already given the reading references say basically you can go to those links and check the software and from the software you can learn things.

So, I thank you for attending the session and I am sure you will benefit if you study those aspects what has been discussed today.

Thank you very much once again.