Design for Quality, Manufacturing and Assembly
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Lecture - 28
Accounting for Manufacturability and Assembly in Design - An Overview

So, we will step one step backward and take a look at the design process itself.

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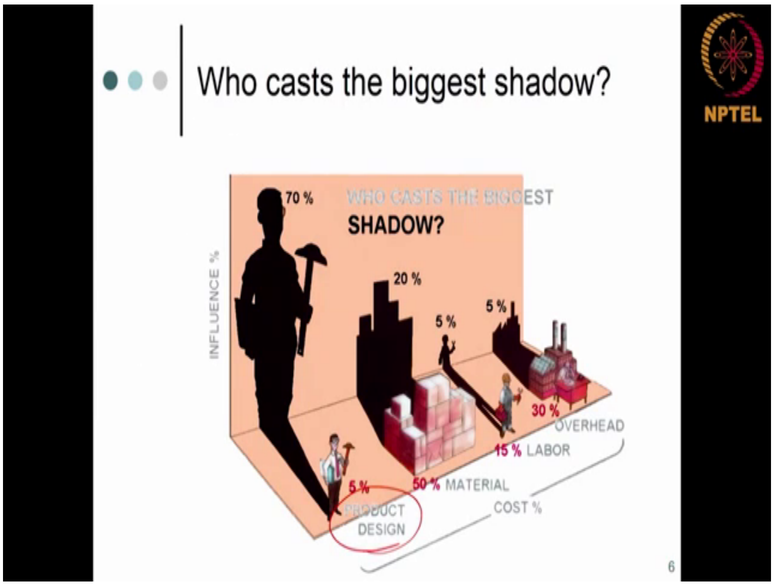

This particular chart is borrowed from the internet actually. There is someone called the Munro associates. It is borrowed from their website. So, if you look at it, these are the 4 different major heads that you would have costs they give a costs percentage. Product design, material cost, labor cost overhead. This is the slightly outdated picture from the fact that it was generated at least the couple of decades ago. So, the number of percentage might vary the cost perspective today, labor is sometimes larger than the material depending on the field that you are looking at depending on the application that you are looking at.

And the overhead also might accordingly decrease or increase. The y axis here is the influence who impacts which particular silo has the huge impact is an important prospect. The impact is being shown by the shadow here. That is all the item says who casts the biggest shadow. The biggest means who has the biggest impact. So, interestingly product design has the highest impact of 70 percent. And the amount of time that we spend on that is only 5 percent. There is you go into the material, the moment you go into the material you cannot change your design anymore.

So, it is only the cost perspective. It says the cost it says the material cost that you have that is it and the labor of course, for fixing for fitting those stuff. As a matter of fact, you can actually reduce this by increasing your time here, if you intelligently design, it you can reduce your labor time and hence the overhead. If you for see they are all there could be issues with the overhead, then you can actually reduce the overhead by spending more time in the design stage. So, this is a very powerful chart if you look at it, because it very clearly tells you that people should be spending more time in the product design during the design lifecycle rather than worrying about the other stuff, because that has the highest impact.

So, we will build based on this motivations and foundation on design for assembly.

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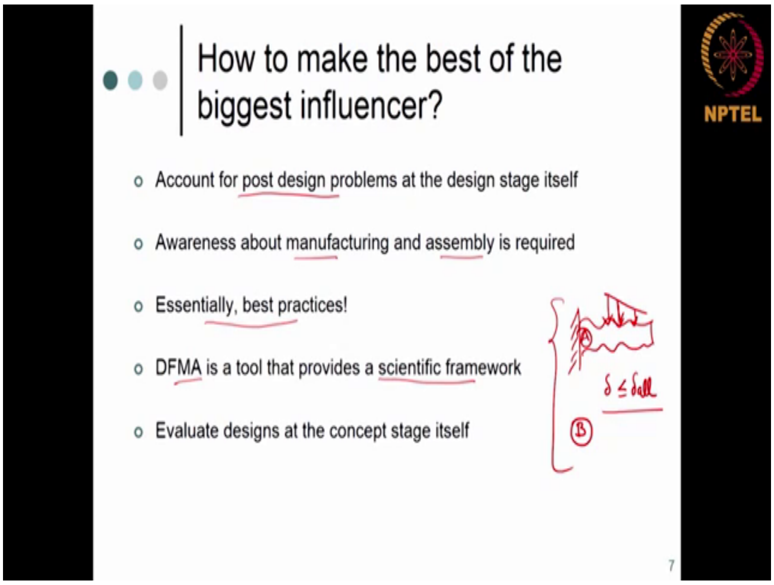

How to make the best of the biggest influencer? This particular slide tells you that product design has the biggest influence. But how can you make use of it? You understand and your tomorrow you are starting a company, you remember this particular lecture that I told you. And then you say that I am going to take advantage of the product design part. What will you do or how will you do with that? So, that see end of the day it is all 100 percent, it has to sum up 100 percent right. If you are going to increase your product design here from 5 to 25 percentage, you should reduce the other guys correct.

Because this is 50 plus 30 is 80, 95 and 100. So, if you have going to increase this 5 percent to 25 percent, you have to adjust the 20 percent in these guys.

So, how will you make use of this impact gain? And at the same time reduce the impacts of these? Can you imagine a situation? You get the question? So, how can you make use of the biggest influence? The biggest influence here is the product design. Design of experiment is a tool that enables you to do that. My question is straight forward. You know very simple question I will ask. If you were to increase your time or cost in the product design part of your design life cycle, instead of 5 days, you will going to increase it to 25 days, but overall I have only 100 days for you. So, my question is if you increase 20 days in the design part, you have to go and adjust that in the labor or in the material or in the overhead part. And you give me one instance how will be able to do that?

Student: (Refer Time: 05:06).

But then you have to well, that is bit all due respects the answer is fine. But then you will have to provided you have a robotic assembly line then it is fine. Otherwise, the robotic assembly line is follow cost is probably a fortune than the 15 percent labor. Yes, but that is a correct one. Because you cannot just design something that can be manually assemble and use the same idea for a robotic assembly. he That is not a that is not a great way to do it. But of course, the robots can assemble at I do not know 100 times faster than us. So, that that makes a lot of yes, then?

Student: (Refer Time: 05:50).

Ok.

Student: (Refer Time: 06:13).

Alright, so, you have to have an idea about the materials of the different parts that going to. You cannot just model an assembly; I guess you would have done computer visualization and some kind of a modelling course right. So, there if you ask you to make an assembly you would have made an assembly, it has multiple component that mean, you made an assembly. There you would not have worried; I do not know, did you give material property as well, you give material property that is well ok. But I guess let us say that you gave material property let us not worry about ok.

But the computer would let you give a material property of a steel and aluminum and a plastic. There are 3 components in an assembly. Meaning parts there are 3 parts in an assembly, and each part is of a different material. And I would say fine, I do not think that computer is going to stop you from doing that it will allow you. The best it could do probably with nice a algorithm is that box you are putting a plastic on this and you might have a problem. That is exactly what we want the DFA to do ok. So, what I am trying to tell is, when you are trying to design you really do not worry whether a particular plastic material is going to go sit on that.

Because as design the word design see now is you do not you do not worry about the performance part yet. You only look at the assembly part, you do a 3-D modelling and then you give. But now design a slowly encompassing the performance also. You are also responsible for analyzing. So, when you analyze what happen is you will have to give a material property you apply load you apply boundary condition and then when you analyze you would know there is a problem.

But still it does not take the manufacturing or it does not take the assembly into picture. It just assumes that you know how to put these different materials together. It does not bring that into a picture. It just let us you assign different properties. It does not care how you can assemble a plastic material over a steel material. It does not care about that. If you put a fastener, it will simulate a fastener. If you put a glue, it will simulate a glue, if you give a gap element, it will simulate a gap element. It does not care how you are actually going to do that ok. Today one of the major challenges for finalement companies are the ones commercial finalement court companies are how to include the manufacturability constraint.

Today the optimization community tries to do something called a topology optimization; which comes up with very nice structures ok. Like what we call the tree kind of a spread kind of structures. They are not manufacturable using the classical technique, but today using laser sintering or using 3-D manufacturing you are able to do such structures. But the problem is not necessarily all those structures are manufacturable. So, the question is then why do I because this takes significant amount of my computational time to come up to that structure.

And after that I realize that I cannot actually re manufacture the structure. So, the question is can I be wise to begin with and put a constraint on that optimization saying that, these are my only options, can you come up with the structure such that it can be manufactured using one of these constraints? I mean, by one of these methods subject to those constraints. So, that will be the best you know it might not be the best optima, but it will be an optimal design for that particular manufacturing technology. So, it is not it is still not very clear to them how to incorporate this in a mathematical form into a finite element software.

This is one of the major challenges ok. So, as he pointed out you to even if you try to do an analysis, the analysis only accept what you say. It still does not comment anything about your manufacturability of that particular assembly or how it can be assemble that is also there. How heavy this is how light it is? It does not give you any idea on how it is assembled, or what are the difficulties in such an assembly. What else? This is a nice thing. What else?

Student: (Refer Time: 10:40).

Overhead could be anything for instance got to do with a very intricate design let us say. You have a very sharp edge or a very nice turn that is not easy to measure.

So, what happens is your tune needs to be always sharp to my cut. Then what happens is in such kind of designs. You will have more rejections compared to a simple stamping process and giving it to you. So, if you came up with a such a nice design or tool that is usually used for 20 machine 20 components can be used only for machine 10 components. But in order to reduce the tool cost, I might up end up doing 13 or 14 components.

And those 2 or 3 components needs to be rejected. That can be taken care in the design stage, provided I have the vision of manufacturing, I had the 4 side of manufacturing. Or from an assembly perspective will becomes a very difficult assembly, will becomes a very difficult assembly that these screws are in a in accessible coefficient.

Or there is no proper light to do that. Then those assemblies need not work better. In that sense, even before it goes to the field they are rejected. So, this could be the over head or what we call the technology readiness level in the sense a particular technology which is not ready if you want to use that. Then comes with it is own strings attached. There might be a larger rejection. It if you remember I told you about one tier example; like, call back, there will one Indian car company which sold lot of tier to the European markets. And then figure out one batch of the tiers that was shipped at problems, but then the clause said that if you have such problem you will have to call back all the tiers.

So, if you look at the cost that is involved in a call back and supplying new tires, the kind of pretty much how did the profit they made out of selling to the European market. So, that is an overhead. So, what you need to do is you need to up front spend more time on your reliability and durability, just to make sure that you do not have a call back situation ok. So, we will see some cases here one is something that what he pointed out the first thing is a very generic statement here account for post design problems at the design stage itself. This is like asking how do I know it is how it is going to perform on feet that is why an engineer is required.

You need to be able to predict failure, you need to be able to forecast the performance. So, what becomes important is you spend more time in the design stage, and then you look for post design problems and try to account for them in the design stage that is one thing. This is something that I have already emphasized awareness about manufacturing and assembly is required at the design stage. It is not going to happen overnight, but if even today some designer wants to know you can hear she can do it, but it is going to take little bit more time.

So, that is the time that is going to get added up in the design stage, but you can always cut it down in the overhead stuff. This essentially is nothing but best practices. If you go by any company today, any company which has a legacy that is something called best practices. If they face a problem ones they would document, it. And they will say here after words. This is how we do it. I will just give you a simple example.

I once visited at earth moving equipment company. I was taken to feed to understand a particular test that they did. When we went there are some simple security stuff that I need to do to begin with which I did. And then just before I enter, they gave me a 2 metal pieces which had criss cross elastic bands around it, they were like a c shaped cups, they were like c shaped cup, and metal cups. And then it had like a cross band, they gave, I had no clue they gave that. Then I asked why. They said this is for your toe protection. I said, why? I mean why is it particular that it is only the toes? Why do not you give me a entire shoe like a leather shoe that I can wear, you know and he said yeah.

So, if you see they used to wear this nice, the ones were can nice heeled. And then he said actually our shoes have this metal casing inside. There is the reason for that, 2 things; one is this particular industry has a history of toe injury. When a documented all their injuries in their foot, they figured out that most of their injuries happened in the toe. So, whatever reason they were all different modes of injuries ok. Someone fell, someone went and dashed on something, for someone rolled something rolled over their foot. But the injury was recorded on the toe that is one example that they told, the toe had a higher probability of injury in your foot that is one thing.

And the second is it is also an electrical insulator, but they will have a electrical lines at a pre place and it was an electrical insulator; that is I guess that is one of the most important stuff. And second is this is specific to that experimental set up meaning like it is a field test place.

So, they said we have issue with toe injuries ok. So now, that is the best practice for that particular industry. For instance, we went to I do not know whether you guys came with me to Saint Gobain. Did you guys come to Saint Gobain, Saint Gobain industry?

Student: Yes.

So, that particular group I took to the Saint Gobain industry ok. They insisted that they have to wear shoes, they also said leather shoes if I am not wrong, but there were people like yes, at least the couple of them who did not wear shoes and they did not have they were wearing slipper. I do not recall exactly probably they were export shoes and, but they said it is fine ok, they you were suppose to wear.

But it is ok, we are going to keep you know we were really not going to get into that machining area. So, it is still fine ok. So, they whereas, the other company there was lot of loss already recorded, and they mandated that you have to have, so, it is a best practice. In a similar fashion, there are certain things, if you go to the company where they assemble products ok; where they manufactures stuff there are some best practices. Maybe they are not a 6 sigma manufacturing company. They do not manufacture for an OEM, you go to our Ekattangal facility.

They know this is the best way to accomplish success of. That is the best practice for them. In my class I have certain best practices right. After 2 years I learnt if I am going to let people after 9 o clock, if the class is going to start at 9 o clock, if I am going to let people in after 9 o clock, it is going to be a never ending process. Because it is always 1 minute before the after the last guy entered ok, someone comes at 9:11 and then says the previous guy just came in that is right 9 10. And then that guys says no, this guy came just before me. So, it is a never ending process. So, I put a best practice saying 9 is 9, and no one gets attendance after I enter the class. So, that is the best practice for my class.

So, you learn out of the mistakes ok. So, essentially this assembly or manufacturing is nothing but the best practice. So, they have a list of best practice for designers these days in industry if you go. They pay if you are going to have a cut like this, if you are going to have fillet like this. You need to check with the manufacturing team to see if this is doable. They have a best practice now, for specific designs you need to check. Or they will have a tree; this kind of a design is likely to cost you x factor. This kind of a design is going to cost you 1.2 x factor. So, unless you necessarily need this design do not do it.

So, those kind of best practices are coming to picture of it. DFMA manufacturing and assembly is what usually axis call, but today axis getting extended for everything ok; is a tool that provides scientific framework to do this. So, you go to Ekattangal, you have a different best practice for the same type of work. You go to a bearing company ok, you go to an automobile company, they have for more or less a similar type of an assembly, was they have a different set of best practices. So, if you want to make sure that I am a new company how do I do that? They provide you a scientific framework to do, they generalize, they formalize their understanding that they had over the years and that is the interesting part.

Today anyone on computer this is the interesting part, you do not need to have a manufacturing facility as a designer on computer you can evaluate a design from the manufacturing perspective or from an assembly perspective. This is the beauty because you are already exposed to the performance perspective. I have a design, I have a cantilever beam and then usually when we say cantilever beam we actually usually give you a tip load, and you know how to solve it. But the moment I give a different type of load you do not know how the equation gets modified. So, what you might do is you might end up going to fundamental analysis and do this, correct?

So, I give you another design, and then I ask you which design is better from a performance perspective. My deflection is allowed. So can you tell me whether this design is A and there is a another design B, which design is a better design from a weight perspective and this is your criteria. You know how to do this by using finite element or back of the envelope calculation. However, if I show you 2 designs like this, same performance, same type of product, giving you the same performance, but this has 5 components and this has 3 components. It does the same thing, this product also does it in 2 minutes, this product also does it in 2 minutes.

There is no they are comparable, that is why I am keeping them in the same frame. The only difference is this has 5 components and this has 3 components. Can you tell or a designer is interested in knowing which design I should go with? Currently, in a performance sense yes you can go and perform you can find out the deflection this that and all that. But from an assembly perspective or I have 2 different designs, can you commented from the manufacturability perspective? I need to understand both of them are competing from a design perspective their weight reduced weights. But from a manufacturing perspective which one is easier to manufacture?

Hence, it will give me lesser cost, or there could be something from a performance perspective this been in not be a better design. But from a manufacturing perspective this is far better, it is easier to manufacture, and from 1 to 100,000 of these then I would rather go with this design and not this design. So, there is a need for people to understand at the design stage. Please understand one thing that you need to clarify or get it out of your mind is this is not after you manufacture you see ok, so, this took 10 minutes to assemble and this took only 8 minutes to assemble.

I should be able to do that in the design stage, because otherwise what happens you spend so many months on design, then you go to manufacture, then you go to test, and then you find this is better and then you come back and you will have to change your entire design. No, I do not want do that, I want to spend more time during my design stage; when I say in the design stage I am still not going to manufacture.

Today design is predominantly done on computers. So, I want to be able to figure out whether design A or design B is better on computer. So now, not only from a performance perspective from a manufacturing perspective from an assembly perspective I should be able to do that. In order for you to be able to do that you need a scientific framework which is common, you cannot say with respect to my experience of 10 years I know this is better. You cannot say this component is slightly heavier than this components, so, I think this is a better.

Now you cannot do that you will have to scientifically evaluate it, you cannot say this is painted blue and this is painted red, so, I like this design. No you cannot say that it should be scientifically backed up. And it should be common; should be common, it should be a best practice because you would be a third level vendor who supplying to an OEM. But the OEM is an international player. You need to be able to subscribe. See, today 6 sigma is 6 sigma. It does not matter whether you are in India, you are in China, you are in US; 6 sigma is the concept and it is adopted across the world.

Similarly, assembly is assembly does not matter. Today, some small vendor in Ekkaduthangal might be supplying someone in China or Hong Kong, but you need to align that is important. So, such a framework is what DFMS is about. That is what we are one going to talk about. We are only going to touch upon that, what are the basic elements of it, how do you go about quantifying, see what is important is this is the base of engineering right.

So, there is some basic physics that you want to qualify, we are all engineers. So, it is not enough if you know the physics. You also need to quantify it. We are we can only compare numbers, you cannot compare A verses B, you need to compare numbers, you need to give a rank for A you need to give a number for B and then only you can compare. So, you need to quantify, the word be uses you need to quantify. Let it be performance, let it be weight. In similar fashion, you need to be able to quantify assembly. How did we quantify quality? The same thing we discuss right, quality how did we quantify quality?

Student: (Refer Time: 26:47).

Sorry.

Quality loss function exactly. So, we defined I mean we measured it or rather we quantify reducing of quality loss function. We actually achieved quality by concepts of robustness. How do we quantify robustness?

Student: S n ration.

You use S n ratio, it is just a metric. In a similar fashion, I give you 2 design and I ask you which design is more robust? I might not I have given you 2 designs, in the same function, I would have asked you which locations are more robust. So, what you look for? You look for minimum deviation or you look for the S n ratio of the different design combination, then you picked up the ones with the better S n ratio. In a similar sense, if I give you multiple designs, can you evaluated from an assembly perspective? Can you evaluated from a manufacturing prospective? I have design A, B, C, D, can you tell me which design is good from a manufacturing perspective? In order for you to be able to do that, you need to be able to quantify it.

Now, can you imagine what could be a quantifying element or a metric for me from an assembly perspective? I accidentally told something when I was explained, other than that you can say, but even that if you say I will be happy, when you want to evaluate multiple designs from an assembly perspective. All of them from a performance perspective all of them are the same. They all will perform the job for you that is not a problem.

Do not worry about the material part, material, also let us say cost wise they are the same material wise.

Student: Number of component (Refer Time: 28:34).

Number of component should 1?

Student: It could be one (Refer Time: 28:37) possible.

Number of components could be 1, then?

Student: (Refer Time: 28:41).

But why number of components?

Student: I was created out it.

Yeah, then?

Student: We can take number of component (Refer Time: 28:51) was required for every (Refer Time: 28:52) assembly process. The assembly process which is governed by how would you say which process is better?

Student: Process equal to time taken.

The time taken could be 1, and the another could be?

Student: (Refer Time: 29:07) average.

The yields of doing it, then?

Student: Cost (Refer Time: 29:11).

So cost is kind of related to the time.

Student: Time.

It is kind of related to the time. But then there is also another perspective to the cost. Not everyone's time is the same cost. Not everyone's one hour is the same costs. So, what does that mean?

Student: Quality of the labor.

The quality of the labor, but do we go with the quality of the labor, what do we call it? You are right, it is not the quality per say. But what is it? It is a skill level, it is the skill level. Sometimes it is also quality everyone does it, but there are few people who does it better. So, there is a cost that is there is a higher cost that is associated.

So, this is the very nice breakup of stuff that you saw right. So, it could be the time taken for a particular assembly. But that is an interesting criteria because it is not necessarily directly proportional to the number of components. Just because I had 5 components and 3 components, it does not mean that the one with 5 components is going to take a longer time to assemble compared to the one with 3 components. I could actually have an intricate complex assembly in the 3 component stuff ok. And it could take longer than the 5 components stuff. So, the number of components still is a particular thing because it does have cost effects from a manufacturing perspective. You have to manufacture 5 different components. But again, that could be a simple design. So, it might be easier for you to do, rather than having 2 levels of design components to be manufactured together.

So, as you see there is I would not say complexity, but there are levels of difficulty in being able to do this. And this is what people have been doing for years, and they have come up with the scientific framework to analyze this. So, that is one, what else? How else can you compare 2 different or not 2 different, n different designs from an assembly perspective?

Student: Tooling component.

Sorry?

Student: Tool, tools; tooling component.

Yeah, but that is manufactured, your answer is right, but that is from manufacturing perspective, from an assembly perspective I am asking. You can answer this when I ask the question in manufacture.

Student: Components required services, so we need (Refer Time: 31:48) state will also how much time they should use it.

Yeah so, de-assemble becomes an important stuff ok. Today especially with the electric vehicles and all that people talking about design for disassembly. It is not only disassembly, but it is also design for recycling reuse. So, what are you going to do with the batteries? That becomes an important question. So, during the performance it is green, but the process of manufacturing the battery itself need not be green.

So, that is there are famous articles on how green is your green energy, you can go and read such articles ok. So, we recently looked that sustainability of composite materials, and it turns out that it is better to use aluminum in aircraft components compared to composites. Though the weight reduction is significant in composites, hence you are going to save fuel, but when you look at the greenhouse gas emission in not being able to recycle composites. It out weights all the benefits that composite gave someone. So, it seems like it is better to use aluminum you know.

Anyway, so, in a from this kind of perspectives it becomes important to understand and appreciate the assembly, and the manufacturing limitations from a designer at the design stage itself for a designer at the design stage itself. And since we are engineers, we need to be able to quantify; either the difficulties or the advantages it does not matter. Whichever way it is we need to be able to in order to compare 2 designs, you need to be able to quantify them. You cannot compare A versus B, you can compare 9 verses 10. That is all engineers now to do right.

So, you in order to compare 2 different or n different designs, I need to be able to quantify it. So, from an assembly perspective one of the things that we pointed out was the time taken for the assembly that could also translate to the number of components that are there. But that again also relates to the manufacturing part of it, how you are going to manufacture them, and what are the costs that are assemble, but purely from an assembly perspective which is going to be dependent on number of components, the time taken to assemble ok.