Operations Management
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Lecture - 08
Design for X (DFX)

[FL] friends, welcome to session 8 in our course on Operations Management. So, currently we are in the week 2 of our course on Operations Management and in week 2 our major focus area is product design and development. So, we are not going through the run of the mill type of sessions on product design and development because there is lot of literature, lot of good books available on product design and the steps have been outline in a very clear and precise manner. So, all of us know that when we have to design a product, what we must take care of or what are the steps that we must follow, but we are trying to acquaint ourselves with the tools that may help us during the product design process.

So, within the broad gambit of Operations Management, we have seen in week 1, what Operation Managements is, what are the functions and scopes and strategies of operations management. Then we focused on what we should make in order to make our organisation or our factory or our enterprise successful; what means what product we must make. And there we have seen that in product design and development, we are able to identify the products that will that may make a successful. Now in week 2, our focus broadly from Operations Management point of view is that what we should make to be successful in the market. Within product design and development, if we see, we are going to have 5 sessions; in first session we discussed about product life cycle. So, what we could what can be the take home point from that product life cycle session. We have seen that how the sales vary over the lifetime of the product, how the profits vary over the life time of the product.

So, we were able to establish that, no there is no product which can continue on and on and on and on. There has to be a period when the sales or the profits of the product will start to decline. And as soon as the sales or the profits start to decline, the company either has to come up with a improvised version of the product or has to come up with the completely new product. First session gave us this I think understanding that product

design has to be done regularly by every organisation either to sustain in the market or to capture additional market share. So, product design is important which was established by the product life cycle session. In second session we focussed our attention on value engineering, that once we have decided that we are going to come up with the improvised version of our product or we are going to come up with a completely new product, what we need to do. We will try to understand the needs and wants or the requirements of the customer.

We will try to see what are the functions the customer wants from our product, we will focus on those functions, we will identify those functions, we will break down those functions into individual functions of the components and then we will try to achieve those functions at the minimum possible cost either by redesigning the product or by changing the material of the product or by changing the manufacturing processes that are used to fabricate or manufacture that product. Once we have made our design, we have finalized our design, then we will go to the next stage that is we have to look for the manufacturability. We have to look for the assembly of the various components into the product. So, we have already conceptualized our product, but during the design stage only, we have to see that how this product will be manufactured, how this product would be assembled and for that we need to understand a completely new aspect that is design for X.

Now, X here is variable and may depend upon the particular situation or environment where we are going to use this concept. There is a term called design for manufacturing and assembly where there are guidelines that, if we follow those guidelines, we will come up with the product which is definitely going to be successful in the market, if we follow these guidelines. But still, there are failures of the product. The failure may not be because of the d f m a guidelines, but because of the design that we have made or we may not have been able to address all the needs requirements wants of the customer. So, if the product is not accepted by the market, not accepted by the customers, the guidelines may not be blamed for that reason; the reason can be that the mapping between the wants and the functions that the designer has designed into the product is not accurate; the mapping is incorrect.

So, today in our section we will try to understand that once the functions have been identified, a conceptual design has been purposed; what are the other guidelines, rules,

regulations that we must follow during the design process so that our design is successful. And we are going to understand this important aspect of Design for X. Many times you will hear the word design for manufacturing, design for assembly; so, all these are subsets of the concept of Design for X and that we are going to cover in today's session. Then once we understand that Design for X, there is another important aspect that is ergonomics, because every product mostly will be used by human being. So, this man machine interaction also has to be taken into account and we have to take into account the concept of ergonomics also during the design process of a product. So, we will see in the next session the concept of ergonomics.

So, let us today try to understand the concept of Design for X and we will just rush through the presentation and see with examples that how this can be helpful to us or to the product designers.

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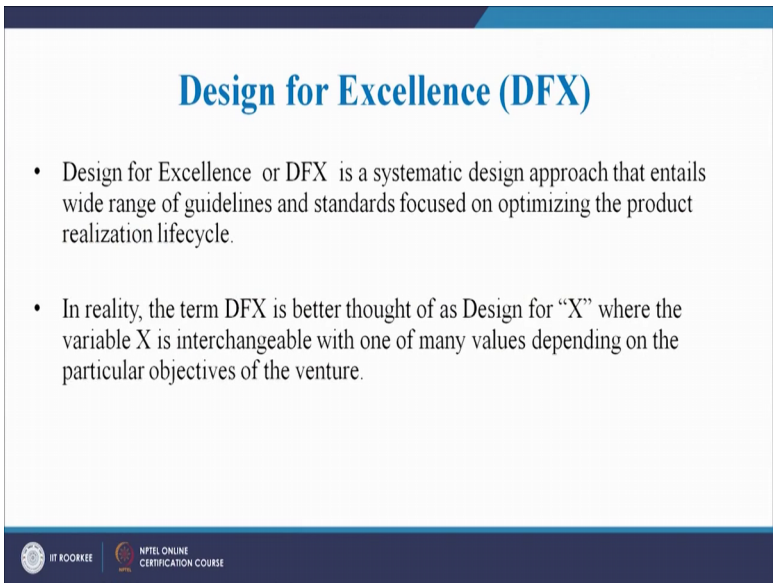

So, on your screen, you have a very fundamental definition for Design for Excellence or design for x. So, design for excellence or DFX is a systematic design approach that entails wide range of guidelines and standards.

Now, this is the design approach which is comprising of or which incorporates a long list of guidelines. Now guidelines can be, the you can say rules of thumb which can help us in easy manufacturing of our product. This can be guidelines, which can help us for ensuring the easy assembly of the various components into the final product. So, DFX is

something which is systematic in nature and it entails guidelines and standards which optimise the product realisation life cycle.

Now, we have seen from the product life cycle, we have seen that new products are the need of the our. Every company comes out with innovative and creative products with passage of time; if they want to sustain in the market or if they want to build themselves in the market. So, new product design is inevitable for every company which is well established. Then value engineering concepts help us to map the functions that the customer want with the product design. Now ones our concept is ready, we take into account these guidelines; we take into account these standards which help us in further fine tuning our conceptual design into a tangible design, which can then be sent for manufacturing.

So, during the design process we must take into account all these guidelines. So, in reality the term DFX is better thought of as Design for X, where the variable X is interchangeable with one of the many values depending upon the particular objectives of the venture. Now objectives of the venture can be that, there can be a product which is may be which has 5 different subcomponents or subassemblies. Now these subassemblies have to be assembled together in the form of a tangible product.

Now, the X here can be assembly that we have to follow the guidelines already established for design for assembly and we have to develop the assembly sequence in such a way that it is easy to assemble these 5 sub components together. It may take minimum time, minimum cost, minimum effort to ensure the assembly of the 5 subcomponents into the final product. So, X will take the; we can say value assembly there. So, the; our guidelines which guidelines we have to follow, we have to follow design for assembly guidelines. So, we will see one case study today and try to understand the d f a DFA, how DFA is beneficial to us.

Now these guidelines, whatever design for manufacturability, design for assembly guidelines and shows the issues related to manufacturing, cost, quality, assembly and serviceability are addressed at the design stage only.

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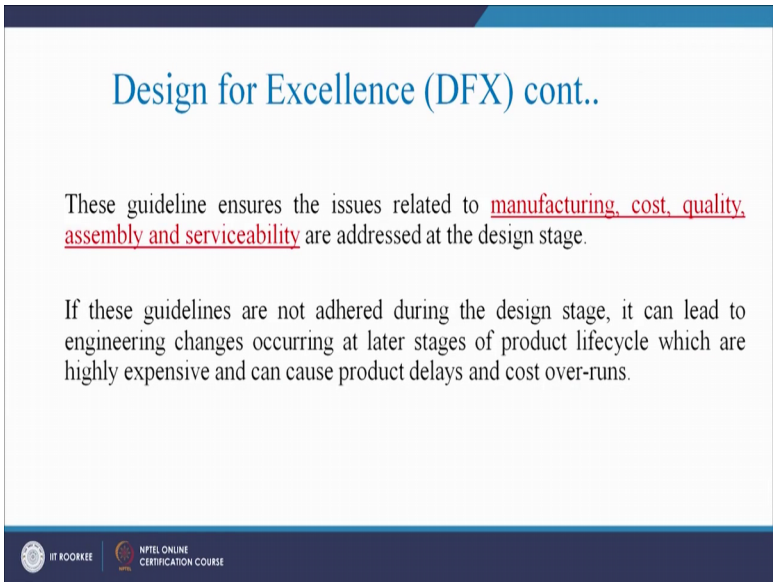

Why I am emphasizing on design stage only because, the most of the cost associated with the product is locked, l o c k e d, locked at the design stage only. So, we should follow we must follow all these guidelines at the design stage to ensure that our product is of good quality, our product is easy to manufacture, our product is easy to assemble, our product is easy to service. So, if we follow all these guidelines at the designs stage only, we are ensuring the success of our product in the long run. So, if these guidelines are not added, then what is going to happen. So, if we do not follow these guidelines, it can lead to engineering changes occurring at later stages of the product life cycle. The latter stages can be during the manufacturing of the product which are highly expensive and can cause product delays and cost overruns. Very simple examples of this point can be making up of a building or construction of a house. So, we architect has designed the house; during the design many things have been overlooked.

Now, you make the foundation and you erect the walls and you leather roof and do the plastering and later stage if you identify that oh this thing is missing, we must have incorporated this thing; what you need to do you need to change the complete things physically, but at the design stage only, if you find out that, yes this thing is missing this thing can be incorporated in the building, in the design stage only on your system, you have to only make changes. Only the cad file or the soft file only or the computer based file only, you need to change you need not physically demolish walls or may be roof of the house to make the changes. Therefore, if we follow all these guidelines at early stage

of the product life cycle that is during that designs stage, our life becomes much easier during the manufacturing phase; why because, everything is locked at the design stage and if you have followed all the guidelines we need not make any changes towards the manufacturing stage of the product life cycle. So, it is important, again and again I am emphasising that there can be a question somebody may asked you that when we must follow these guidelines of DFA, DFM, DFM AND DFQ; immediately you must be able to answer that we must follow these guidelines during the design stage of the product.

Now, some of the common substitutes for X I have already in the previous slide highlighted that DFX, X can be a variable in which X can take different values. So, some examples are given here Design for manufacturing, Design for Assembly.

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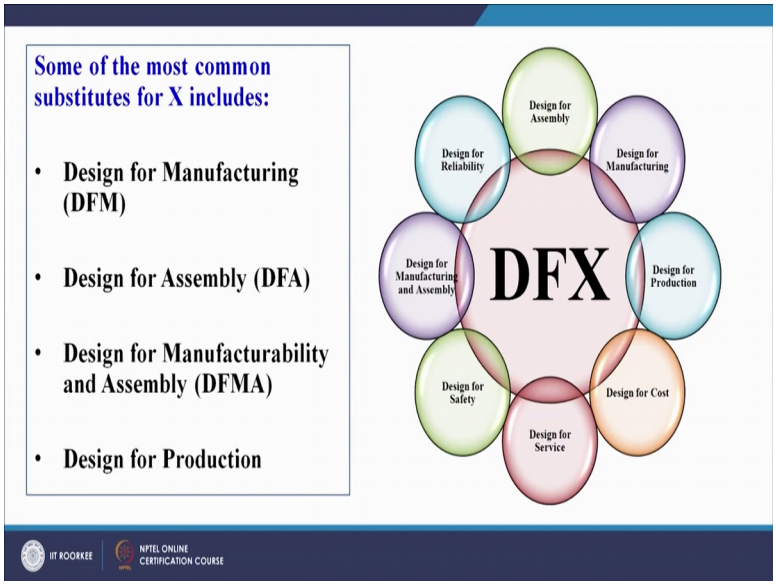

So, X can be Manufacturing, X can be Assembly, X can be Manufacturability and Assembly, X can be Production, even X can be Quality also, X can be Safety also. So, on the right hand side you can see a figure DFX; Design for Manufacturing, Design for Production, Design for Cost, Design for Service, Design for Safety similarly Design for Reliability, Design for Assembly, should X can take any value. So, we must ensure that when we are designing a particular product, we must follow these guidelines religiously and judiciously. Otherwise what is going to happen, in most of the companies there is a design centre or a design cell, there is a manufacturing plant; note the design centre can be in city a, manufacturing plant can be in city b, now the design people without having

much knowledge about the manufacturing versatility or the manufacturing and ability of a company they will design the product.

Now, the design will be sent to the manufacturing plant and there may be iterations in the design based on the availability of machines in the manufacturing plant and that may lead to time wastage. So, these days this DFM, DFA concepts are very helpful and a product team or a project team is appointed which has different members. Now members can be definitely from the design stage design team; means people will be from the design, people will be from the manufacturing, experts of manufacturing will always be there in the product design team or product development team as per the basic principles of DFM and DFA, then there will be people from the legal department, there will be people from the sales department, there will be people from the marketing department, there will be people from the finance department.

So, a complete multifunctional product team will be formed or will be constituted to take this product from the conceptualization stage to the final launch in the market and there the concept of DFM, DFA will be well adapted. Why? Because, as soon as the designer will come up with a suppose a particular shape of a product the manufacturing expert who is there in that product team will be easily able to establish there or will be easily able to tell at that point of time that whether the company has that particular capability to make that shape or whether some design changes are required in the shape to map or to match with the manufacturing facilities available with the company. So, this will save a lot of time and this is the basic fundamental concept of DFX that is Design for Manufacturing or Design for Assembly. So, at design stage only, we will take into account all this aspects, the aspect of safety is also at covered during the design stage only.

Now, let us take 2 examples. Now example number 1 is Design for Manufacturing.

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Now, DFM is the method of design for ease of manufacturing. Ease of manufacturing means that once we are, we have conceptualized our idea we need to take into account that once this product will go to the shop floor, once this product will go to the factory, it should be easy to manufacture this product. It should not be too complicated a product that it is difficult to produce it our difficult to manufacture it. So, DFM will ensure the ease of manufacturing of the collection of parts that will form the product after assembly. So, further it goes 1 level down

So, we are saying ease of manufacturing of the product. For example, the camera that is recording this lecture; there are so many parts components small parts that I can see in this camera. Ease of manufacturing says that the different parts that had been assembled to make this structure or make this camera must be easy to manufacture. There maybe probably I can just make a wild guess that maybe more than 50 to 60 parts that have been used to assemble this camera. So, ease of manufacturing means or Design for Manufacturing means that each and every part should be easy to manufacture and what should be our objective. Our objective is to minimize the manufacturing costs. So, that is one broad bottom line that we have to ensure that the cost of the product or cost of the individual component is minimized.

So, what we, what is our focus optimization of the manufacturing process at the design stage only. We are not going to first design and then on the shop floor we are not

optimizing the process, we are optimizing it during the design stage only. So, that is the beauty of this concept of Design for Manufacturing. Now, Design for Manufacturing is a development practice. So, during the design only we have to take into account these guidelines emphasising manufacturing issues throughout the product development process. Usually this used to happen towards the end of the product development process, but now with the invention or with the development of concepts like DFM and DFA, this is this has become a routine or this has becomes you can say long process or a continuous process I must say, not a long, I must say a continuous process from the conceptualization of the idea to the final launch in the market the manufacturing concepts have to be considered or the manufacturing issues have to be considered. Successful DFM results in lower production cost without sacrificing the product quality.

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So we can say, we have studied in the last session value engineering. In value engineering also we are not compromising the quality, but we are still focusing on minimizing the cost. So, here also our focus is to minimise the production cost without sacrificing the qualities. So, the concepts are overlapping, here also we are doing value engineering.

So, this is just overview of what the manufacturing system is overall made up of; our target is the red colour here, the finished goods.

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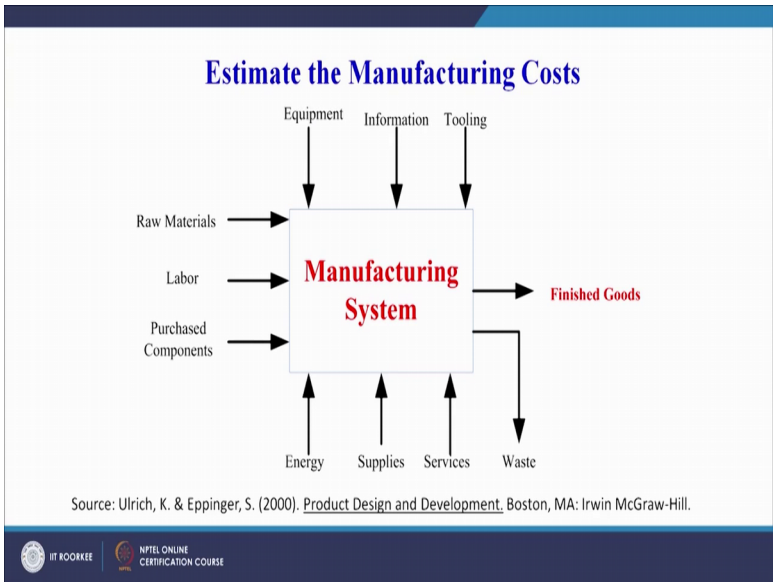

What are the various inputs; raw materials, labour, purchased components, for sub assemblies, equipment, information, tooling, energy, supplies, services and then sometimes we have some rejected parts that go as waste. So, our final product are the finished goods only. So, we have to focus on each and every element, each and every component of this system in order to overall optimise the manufacturing process

Now, in DFM method we can see here.

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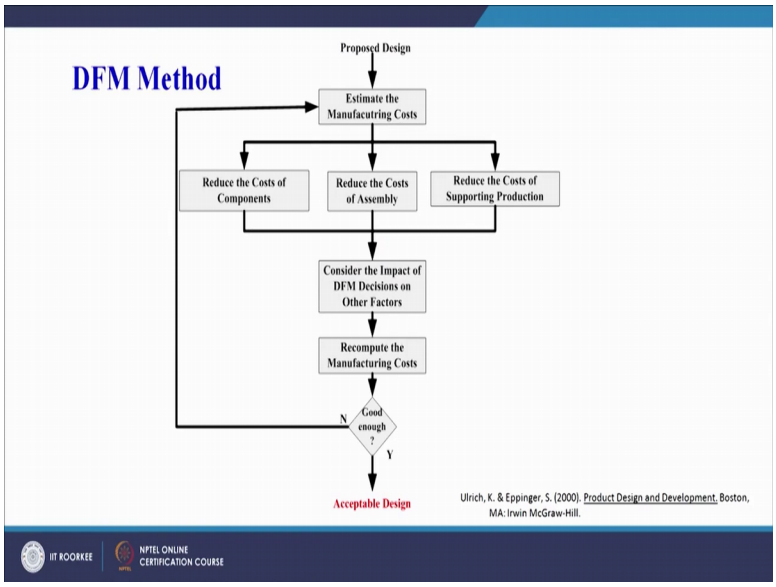

There is a proposed design which already has taken into account the concepts of value engineering, it is satisfying all the functions as specified by the customer. So, we have a input that is a product design or a concept design. We will see, as per DFM, what are the manufacturing cost. So, in the previous slide we have seen that the manufacturing system is made up of so many inputs.

So, we will establish the manufacturing cost based on all these things, raw material, labour, information, tooling, services and electricity and other part other things whatever was mentioned in the previous slide. So, we will estimate the manufacturing cost. Now that is our benchmark, that for this design, this is the cost. Then we apply the guidelines of DFM. So, we will see we will try to reduce the cost of the components as I have given an example of this camera, we will focus on reducing the cost of the individual components, but without sacrificing the quality. So, we will try to reduce the cost of the component, we may in some cases combine the 2 parts together. So, they can achieve all the functions for which there were 2 parts earlier.

Now, we can combine them into a single part and then we can re-design that part in such a way that the cost is reduced, but the quality is not sacrificed. Similarly, we can reduce the cost of assembly. So, if we are combining the 2 parts together achieving the desired function without sacrificing the quality, we are saving 1 assembly operation. So, we can reduce the cost of assembly similarly, we can reduce the cost of supporting production. So, we will focus on all these areas and then we will consider the impact of DFM decisions on other factor. So, these 3 steps we will follow 1 step, second step or these 3 things we will follow as per the guidelines of DFM. And finally, we will see what impact this guideline has on the cost. So, consider the impact of DFM decisions on the other factor recompute the manufacturing cost.

So, other factors can be the overall look of the, suppose we are minimizing some parts we are combining certain functions. So, how the product is looking now; what is the effect on the safety, what is the effect on the aesthetics of the product, what is the effect on the legal aspects of the product. So, we will see what this changes, how these changes are effecting the other factor. So, if there is not much change in the other factors we will recomputed manufacturing cost. And if it is good enough, we will say we can accept the design modified design as per the guidelines of DFM, but suppose we feel that no there are certain issues, there are certain safety issues related to the re design, we will a go and

go back and we will follow the iterative process of design until and unless we are satisfied that our new design is giving us all the functions it is satisfying the design requirements, the specification at a lower cost. So, we will say let us now fix the or let us now freeze the final design.

Now, this is an example, very simple example we have taken.

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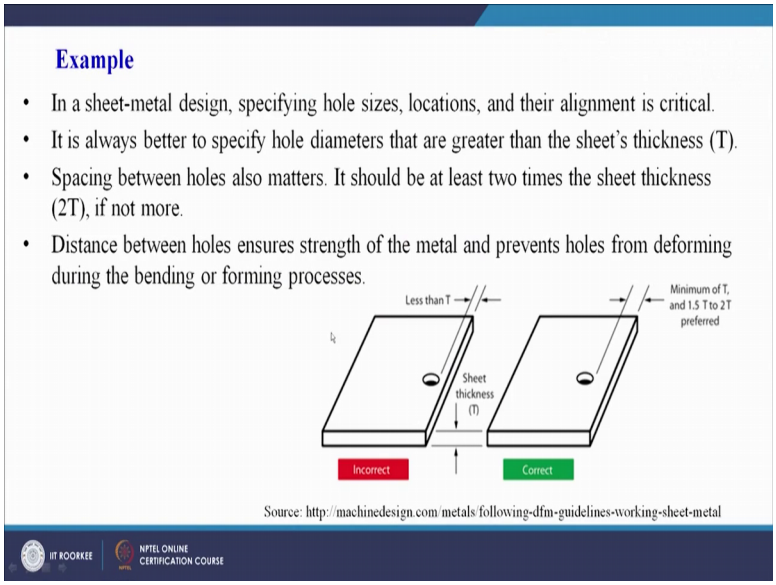

So, I will just read it for you. In a sheet-metal design, specifying hole sizes, locations and their alignment is critical. So, we can see here, there are holes in this sheet metal. It is always better to specify hole diameter that are greater than the sheets thickness T. So, it is always better that the diameter should be greater than the sheets thickness. Spacing between 2 holes also is important, it should be at least 2 times the sheet thickness if not more. So, the spacing between the 2 holes is also important. Distance between the holes ensures strength of the metal and prevents holes form from deforming during the bending of bending or forming processes. These are the Design for Manufacturing guidelines, DFM guideline, for sheet metal with or the design of the sheet metal with holes.

So, once you need to have holes in the sheet metal, it is always better it is always judicious to follow these guidelines in order to make a good design. So, these guidelines will be considered during the design stage of the product development cycle. Now coming on to Design for Assembly, let us have a quick discussion on DFA. DFA is a method of design of the product for ease of assembly. So, I am not going to explain DFM

ease of manufacturing, DFA ease of assembly; optimization of the part or system assembly.

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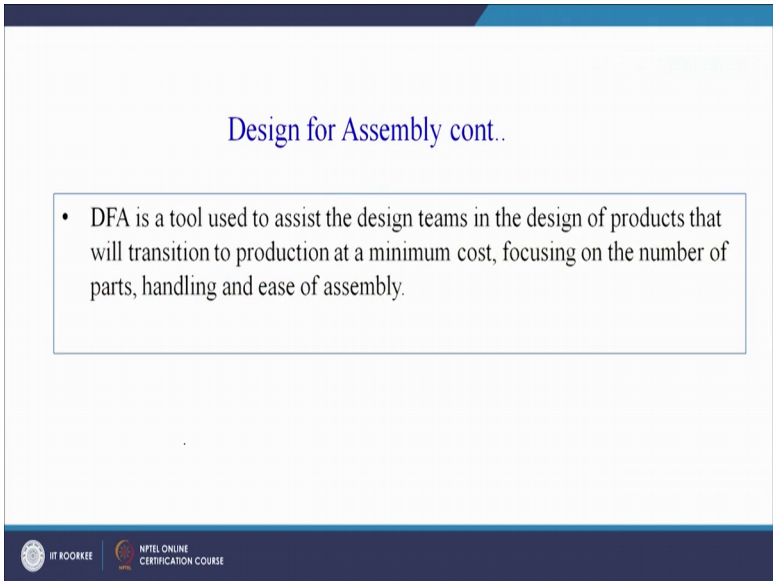

Now, DFA is a tool used to assist the design teams in the design of products that will transition to production at a minimum cost focusing on the number of parts handling and ease of assembly.

Now, 3 things are important here. First is, what is the total number of parts? So, as per DFA, Design for Assembly, we will focus on reducing the number of parts in the product. How to handle these parts? It should be easy to handle and finally, they should be easy to assemble. So, these are the 3 things that we have to take into account. First thing is number of parts should be less, this part should be easy to handle while assembling and the assembly operations should themselves be simpler. Now this is Design for Assembly principles, quickly I will read.

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I have already highlighted some of them. Minimise the part count; number of parts should be less. Design parts with self-locating features; so, part should be so designed that they locate a one above the other easily.

Design parts with self-fastening features; so, self-fastening concept should also be there. Minimise reorientation of parts during assembly; so, we must avoid the reorientation of part. Design parts for retrieval, handling and insertion. Emphasize Top-Down assemblies; so, Top-Down assembly, means that the heaviest part we should keep at the bottom and on that we should assemble the smaller parts. So, standardized parts, minimum use of fasteners should be ensured encourage modular design which is again we can say is related to the first point that is minimise the part count. So, number of parts should be less, modular design must be ensured. For example, one example can be, 3 wires going independently into a electric switch or the other thing can be 3 wires fixed into a 1 modular design and only 1 we can say switch is being fixed.

So, that is the kind of modular design that we need to use the concept of modularity in the design. Design for a base part to locate the other component which is again related to the top down assembly approach, design for component symmetry for insertion; if 2 parts have to be joined together, we must ensure that the orientation should be such that there is symmetry and the 2 parts can be combined together easily. So, these are design guidelines. Since we have paucity of time you can just go through these guidelines and

search for DFA, you will get so many good examples in which you will see that this is a modular design, this is not a modular design, this is a poor design, this is a good design, this is a top down approach, design related to top-down approach, this is not related to top down approach, this is poor assembly operation, this is good assembly operation. So, all these points must be taken into account when we are designing a product that when the different parts will be assembled together, these guidelines if we are following our assembly will become very easy and therefore, we can easily say that after following the DFA or Design for Assembly guidelines, the assembly was easier.

Let us take very quickly one example and then we will wind up the today's session.

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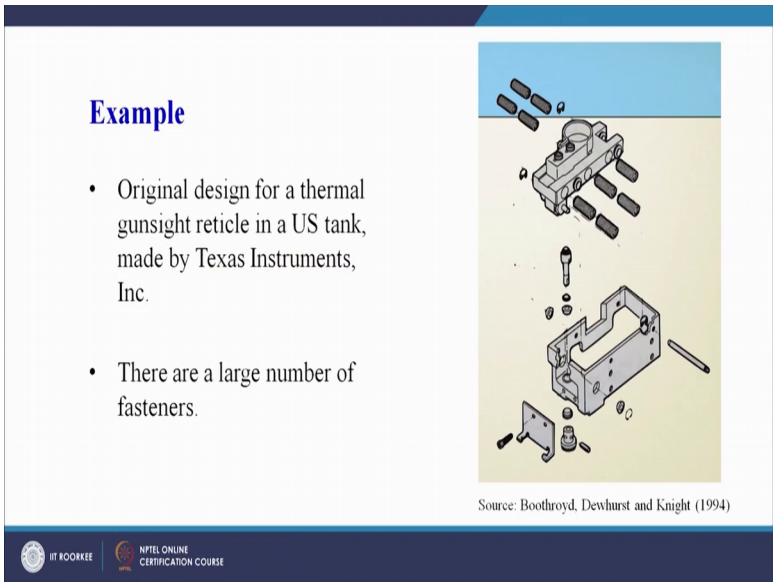

This is one, source is Boothroyd, Dewhurst and Knight dewhurst and knight sorry. So, this is a good book on product design, Design for Manufacturing and assembly guidelines are given. So, this is Boothroyd, Dewhurst and knights book. So, the example has been taken from there. So, the original design for a thermal gunsight reticle in the US tank made by Texas instrumenting, there are large number of fasteners here we can see, redesigned thermal gun sight reticle simpler to assemble and less to go wrong. So, you can see the previous again there are number of fastener designed here.

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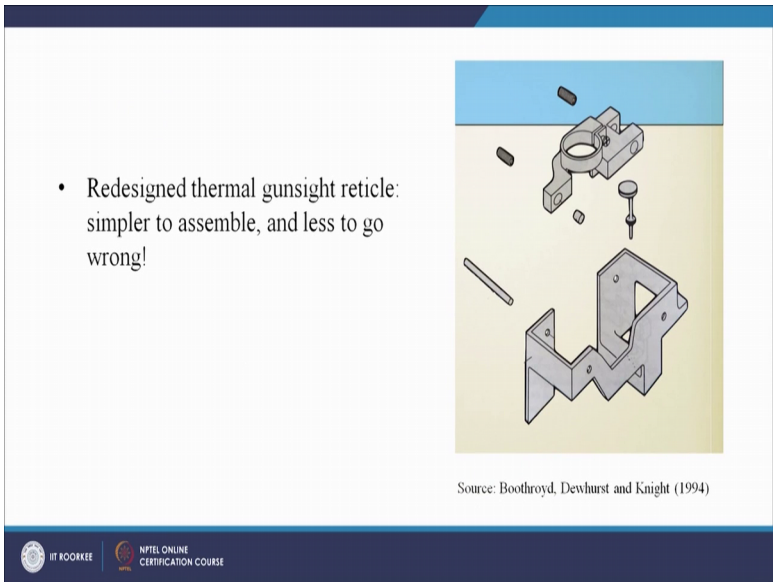

And this is a redesign it is going the redesigned part or the product is going to achieve the desired function as was being done by the previous design, but here you see, far less number of fasteners and the parts have been redesigned in such a way that they are easy to assemble. Now what are the advantages or improvements noted, assembly time improvement is 84 percent, number of different parts original design had 24 parts.

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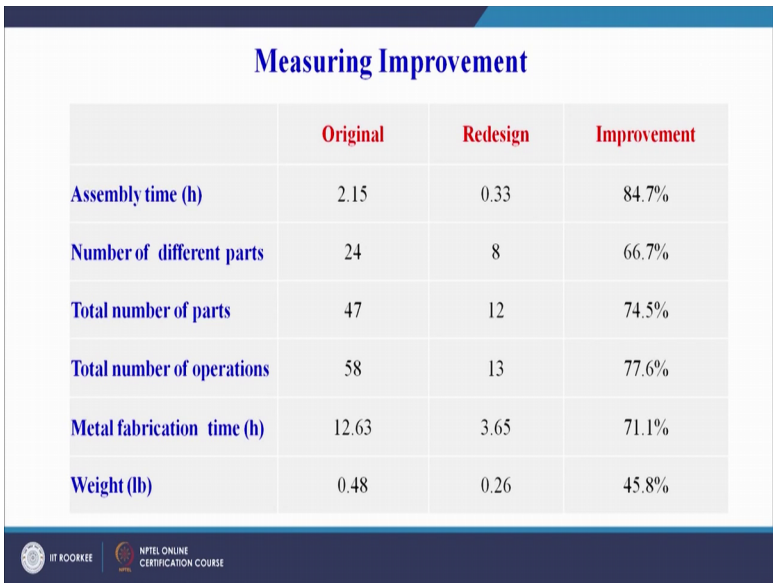

	Original	Redesign	Improvement
Assembly time (h)	2.15	0.33	84.7%
Number of different parts	24	8	66.7%
Total number of parts	47	12	74.5%
Total number of operations	58	13	77.6%
Metal fabrication time (h)	12.63	3.65	71.1%
Weight (lb)	0.48	0.26	45.8%

Redesigned part has only 8 sub component. Total number of parts were 47 and in redesigned there are only 12 number of parts.

So, some of you may be wondering number of different parts and total number of parts how they are different. So, different parts means 24 different designs are there. And total number of parts can be 47, may be there are there is a type of a fastener which is 4 fasteners of same type are used. Therefore, the total number of parts are more, because different parts are 24, but total number of parts are 47 , but they have been reduced finally to 12. So, total number of operations are also reduced because there are less number of parts to be assembled from original 58 operations, now redesigned part as only 30 operation, 13 sorry 13 operation.

So, that is basically you can see that, if you apply the design for assembly guidelines you get lot of improvement which saves your time as well as effort without compromising or without sacrificing the functionality of the product design. So, with this we come to the end of today's session and if you have, if will go through this session again if you will go through those guidelines, definitely you will get certain examples in various books where you will be better able to appreciate the concept of Design for Manufacturing and Assembly. In our next session we will focus on the concept of ergonomics and how ergonomics can help us to design a better product.

Thank you.