Design for Quality, Manufacturing and Assembly
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Lecture – 40
DFA software

Welcome to this over view of Design for Manufacturing Assembly. As a company we d-ESPAT are engaged with in a supporting DFMA for Indian Southeast Asia we help academy and engineering service outfits to deploy DFMA in a meaningful manner in the new product initiatives alright.

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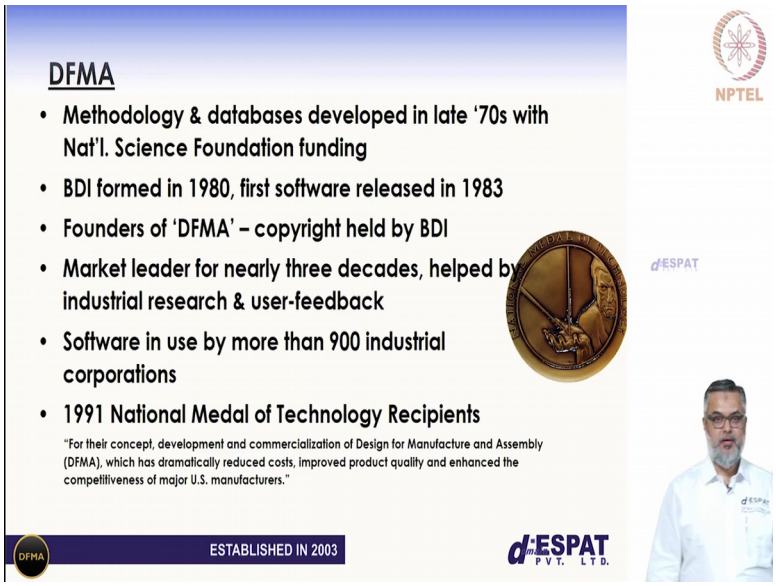

So, as a methodology DFMA was introduced in the early 1970s to help Automotive and aerospace organisations to have a way of measuring design cost of the design stage. And that said since 1983 it is also available in the form of a computing tool. And today we have version 10 of the DFA, DFM software this tool was also what did the national medal of technology in the year 1991 which is highest honour given to innovators in the United States.

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So, let us just have quick introduce to this concept of DFMA. If I were ask you to guess what this is? And if I probably give you about a few seconds you think through it you probably come out with different points of view of what you perceive of what this product is. And let us say if I give another prospective of the same product. Probably you are getting a figure going to figure out what this product is probably intended to do well of course, yes it is it is probably a peeler used to shave off and peel vegetables.

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Now, the question is when there are So many such peelers in the market why develop another new peeler? Well new product development is ongoing process and always this is quest for man to look at a better way of doing things.

And DFMA is that process of exploring that another way and finding out the meaning through it by way of identifying that a new process or product.

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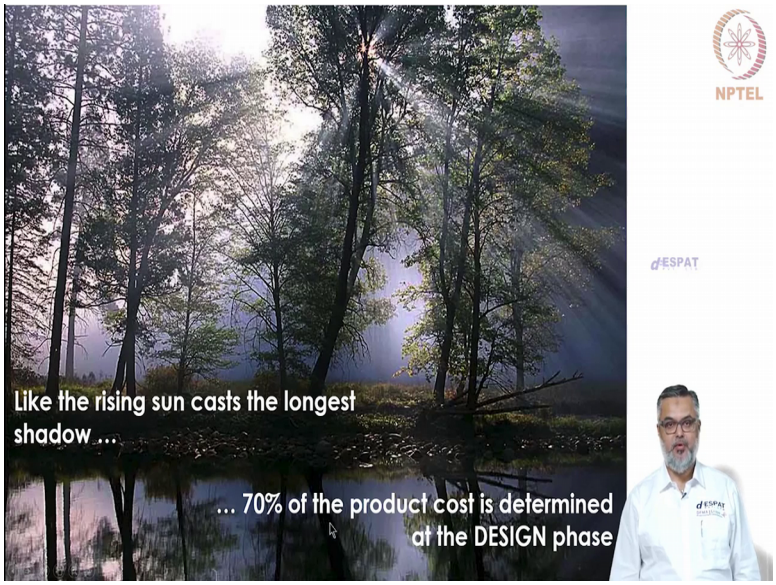

In a competitive manner by saying whether your cost is much better at building the product or not. I am show you the probably grew with this philosophy that they say this; the early morning sun that casts the longest shadow.

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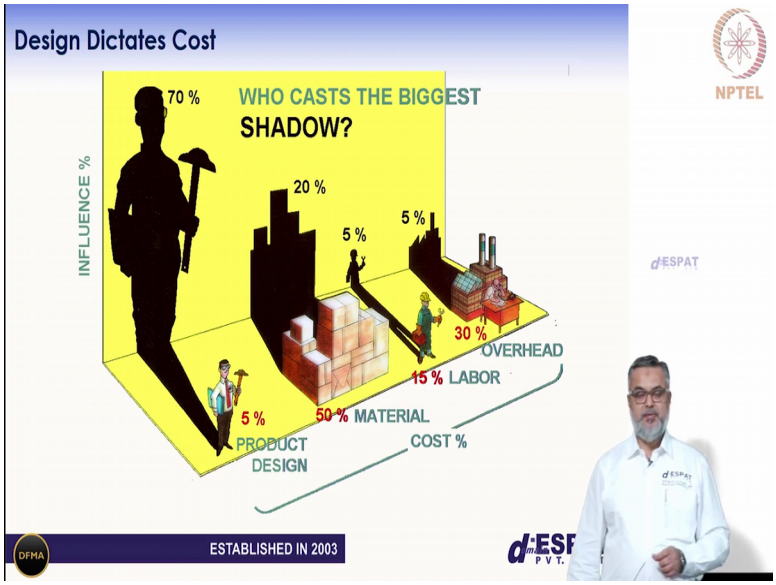

Similarly, in the product design world it is been proven for hundreds of industrial case studies that by the decisions taken at the initial stages of the product design has the

largest influence on the total cost of the product. It is a designer's intend that reflects on what material he chooses to produce this product.

And the material requires certain kind of equipment or tools in order to process the material and skills in order to use equipment to process the material. So, this there is a snowball effect of this design decisions that reflect which is shown on the y axis here, but is overall intend reflection the total cost of the product and that is why we would say that design actually in a way it takes the cost of a product build.

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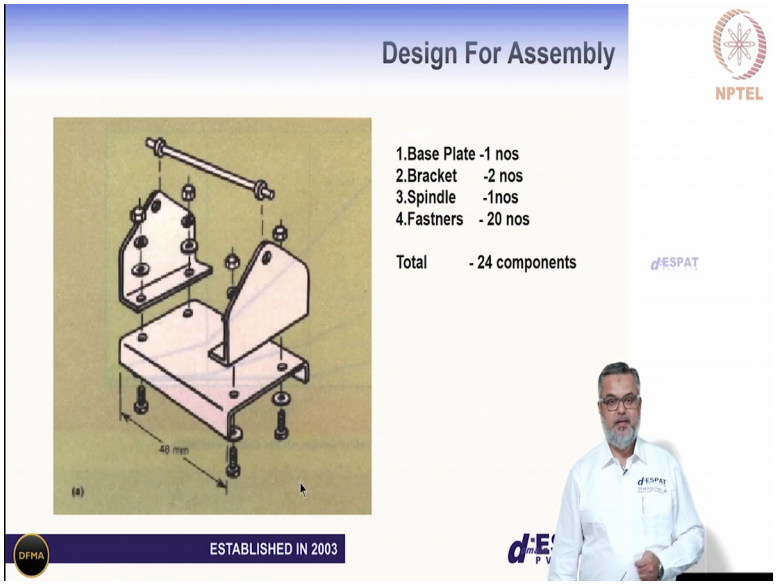

That is a DFMA has two module that look at this aspect of a product design the first of which is called the design for assembly. The design for assembly for software has two module one is called the design for assembly module and the other one is called the design for manufacture.

To highlight the design for assembly module I show casing the simple subassembly here. Now if you get analyse this for product simplification there will be several idea that would come out as a part of the process, but in the design for assembly we have a particular way in which we look at analysing. So, we would say what is this product or sub assembly look like when it is fully assembled and what are these components doing there? For example, what is this base part doing there it is of foundation on which this whole sub assembly is built what is the next components in the brackets? Why are they there this holding is suspended in the position.

So, who is the functional part the spindle why because this is providing some sort of rotational movement? So, as we analyse these importance of the parts we also do what we call as a part count and so, this 24 part component could probably be simplified in this following steps for example, the first of which is shown here.

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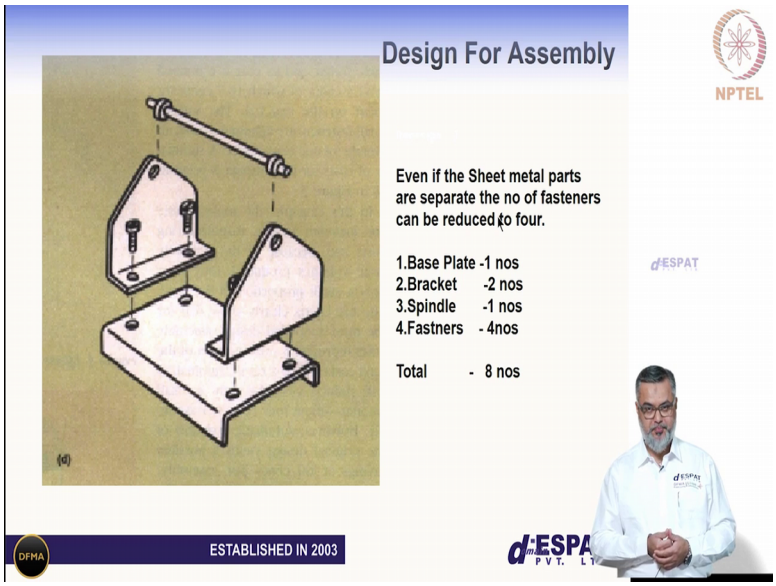

It is quite evident that if you were to integrate the threading as a part of the base you would probably be able to save so, many of these fasteners components. So, 24 part product would probably be 8 part candidate.

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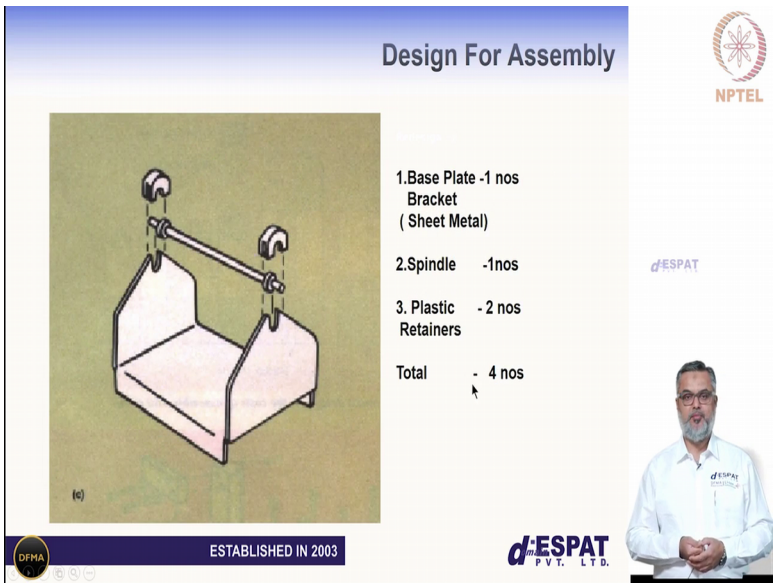

Little more improvised design would probably look something like this have a single part which going to probably a sheet metal or plastic component. And hold that spindle in position by means of plastic or metal or rubber retainers 4 part candidator.

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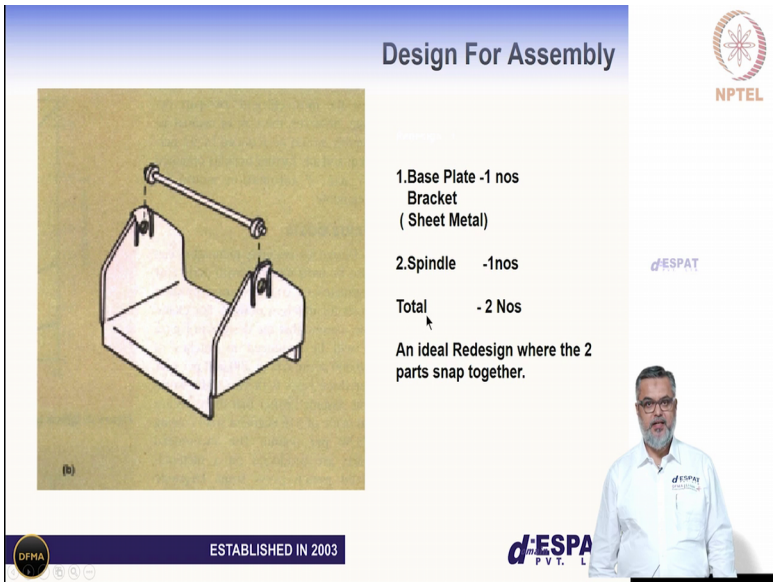

And a further much more ideal design would look something like this sheet metal base and probably snapped with the spindle in the position from a 24 part component you have a potential 2 part candidate, but they are what we given advocate is not let us bow build cheap products.

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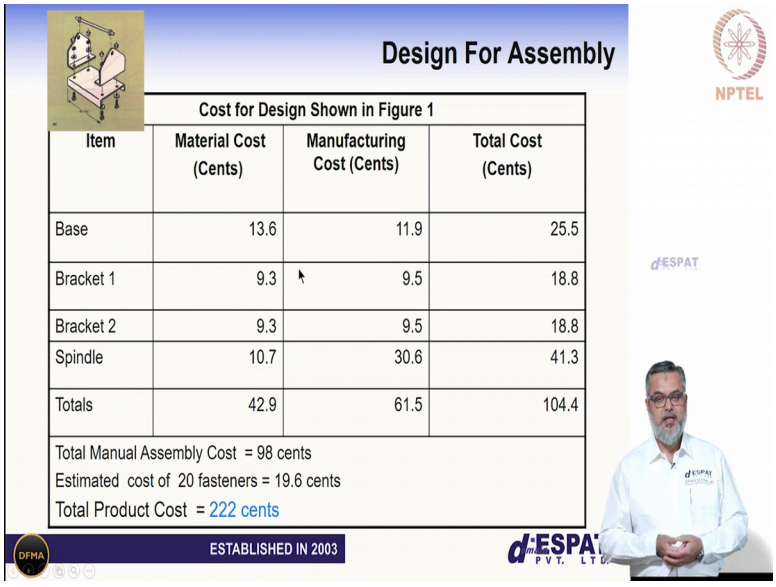

What we are trying to say through this mechanism is you have a tool that can help you to break down your original design intent under the companies are going to it and identifying the cost of material and manufacturing that goes individually and then collectively.

Well we also have to spend on in assembling this components on your shop floor or your manufacturing table. So the cost of tools and tackles that go into the assembly and like in this case we have purchased components like fasteners in this example shown here. So, all of the totals to net estimate what this product is going to cost you. That said imagine applying the same method for all of these new ideas that one would come out with and you have a way of comprising how good or bad your current design ideas are in comparison to the original intent and that is what the design for assembly module is intended to do.

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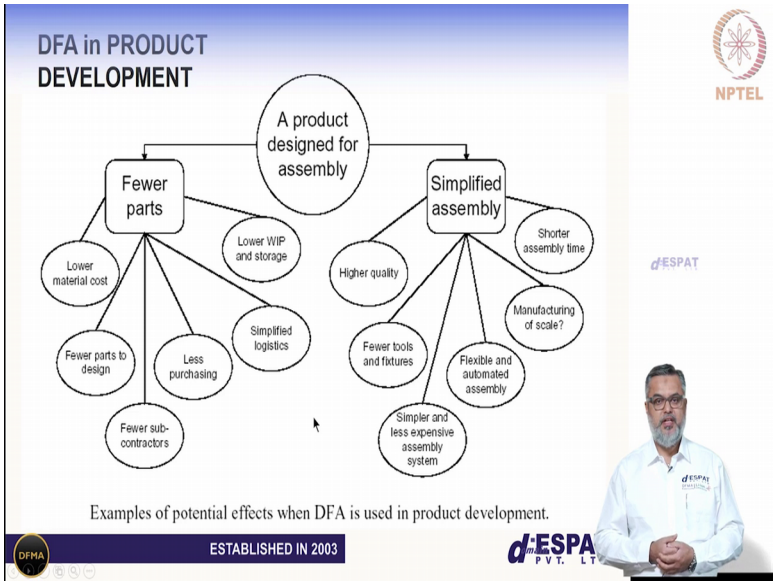

So, why would one want to do DFA as a part of the design process well they are two main benefits one is to have a product which is having fever parts that can achieve the functionality that you can original intended.

The other one is having a simplified assembly a fewer parts means lesser inventory lesser process lesser drawings to verify lesser subcontractors to work in. So, the snowball effect of that is endless on the left hand side. And the other one is your simplified assembly is intended to look at the product from maintenance repair warranty service point of view.

So, simplified assembly facilitates all of these requirements that may be part of the products life cycle.

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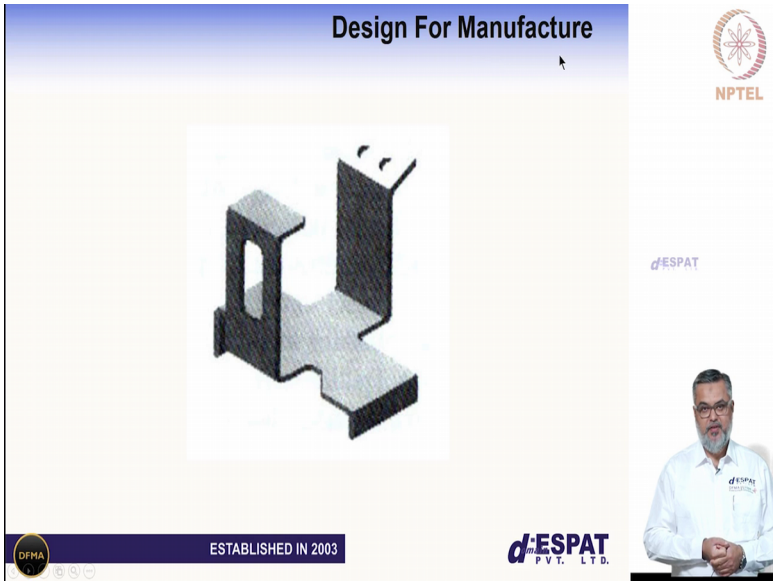

The other module that we have in you know software is called the design for manufacturing module so in order to explain that I have taken a simple example of sheet metal component here.

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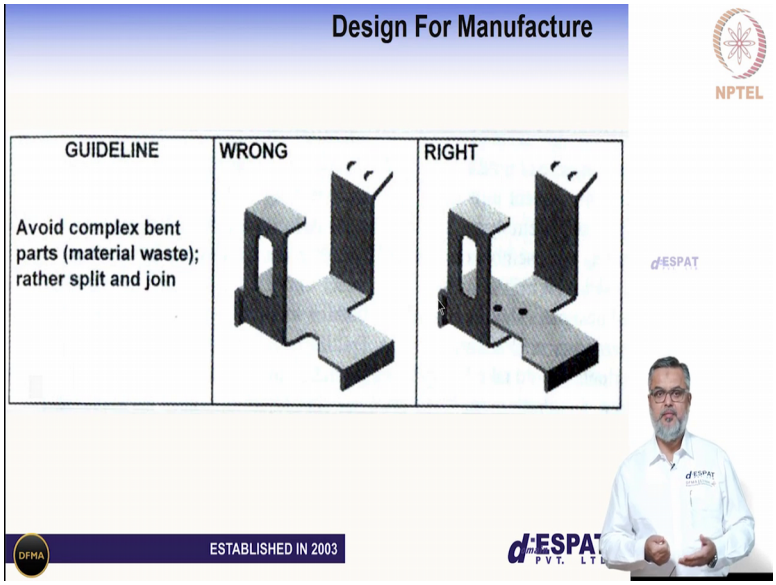

Let us say as a company we do not need to make some 10000 parts. And if you look at the guidelines of sheet metal and if you compare it says that it is a bad idea to have a complex bent parts it is a better opportunity to say one material if you have simpler parts.

So, that is what a shown on the right side of the screen which has the right design and one on the left side it is probably not. So, good a design because you definitely going to waste material from the blank.

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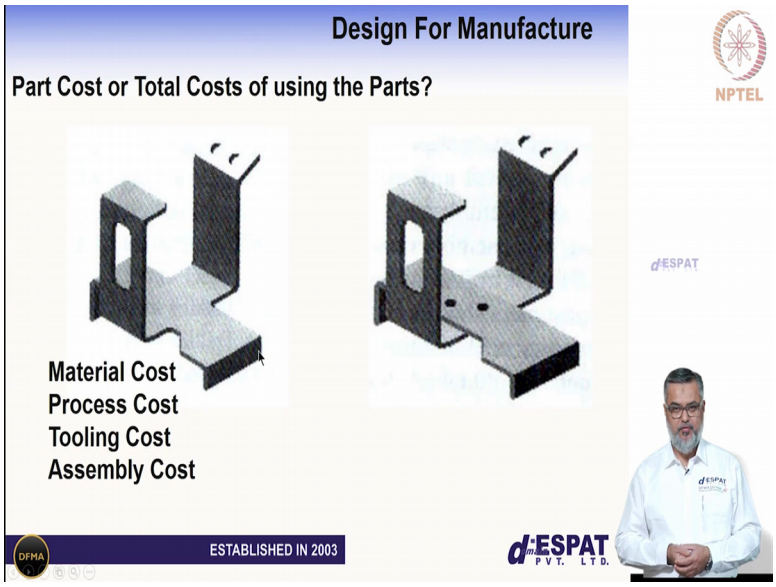

Now, if you were to compare these two designs and have a way of measuring the contribution in terms of material process setup tooling rejection that goes into each of these complaint builds what do you think is going to be the candidate that wins as most economical component to be built that is said I have another question for you to think through which is what you think is a important for a broad design is it cost of the individual part or the total cost of using parts to achieve a functionality as you think through it let us go to the remaining slide.

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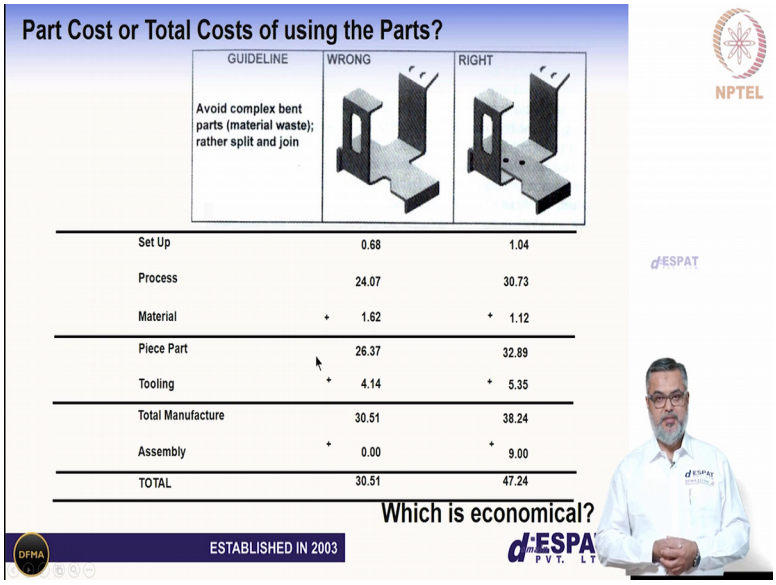

So, if you do a scientific analysis of these two parts using the design for manufacturing method. You will be surprised to see that at one aspect we were probably right. Which is the cost of material in the one that is marked is wrong being higher, but it wins out and the other attributes that contribute to the cost of manufacturing the part which is in terms of the setup the process in one tool you could probably stamp the part.

And once the part is formed you have a completed component. While in the other case on the right hand side which is not as right you will see that the components requires further assembly and that adds to the total cost of the product. And we can figure out yourself from the table that is highlighted that which is more economical design. So, I will be rephrase the question which is on the top left hand corner of the screen. So, what is important of product design is not individual cost of parts, but the total cost of using parts that is to achieve the functionality originally intended for the product.

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Let us look at one more example of published case study for one of our customers. If you would see most of the automotive world uses casting as the process for manufacturing brake shoes and the in the process of looking at newer ways of manufacturing our we have explode; let us say a make manufacturing the same part through sheet metal.

Now, previous example we saw 2 parts were more expensive than 1. Here if I let say we want to make 20000 trucks worth of brake shoes. It is very evident if I ask you gut field question what you think is going to be more expensive while I leave you the thing through this what you will get as a surprising result from the DFM is though you have 5 sheet metal parts on the left hand on the which is which is showed as a welded assembly in the slide here Which evidently requires 5 parts to be made.

They have to be held in the procession check and welded while on the right hand side the sand cast component probably this has to be casted in a few secondary tertiary machining steps and the component is ready to go.

Further the sand cast has been around for quite some time in the automotive world as a compliment for brake shoes, but what comes out evidently when you do a scientific analysis using DFM is at the cross sectional thickness in sand casting adds quite a large contribution to the total cost of the product and that leads to the substantial saving that you could probably get if you were to invest in a welded assembly.

And this again is a published case study and it is got a meaningful ROI Return on investment. which leads the group of engineers or the company to investigate whether a welded assembly would actually make meaning in building a product more efficiently.

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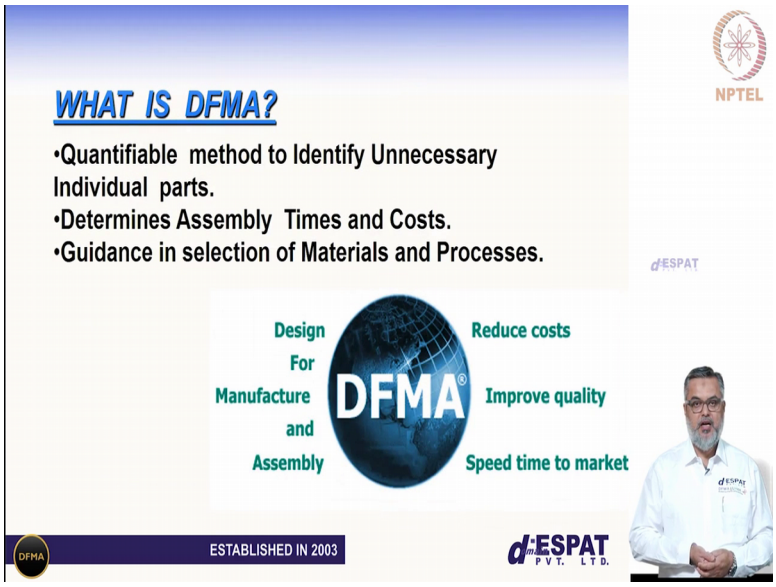

So, having said quick overview of the two tools that we have what we like to emphasize is that the DFMA is a procedure to systematically analyse and quantify product design. And it has to important modules one is the design for assembly module the objective of which is to help to determine assembly time and cost and other one is the design for manufacturing module which helps as a guide to help you select as user what is the aped process and material combination that can go in to manufacturing your singular parts.

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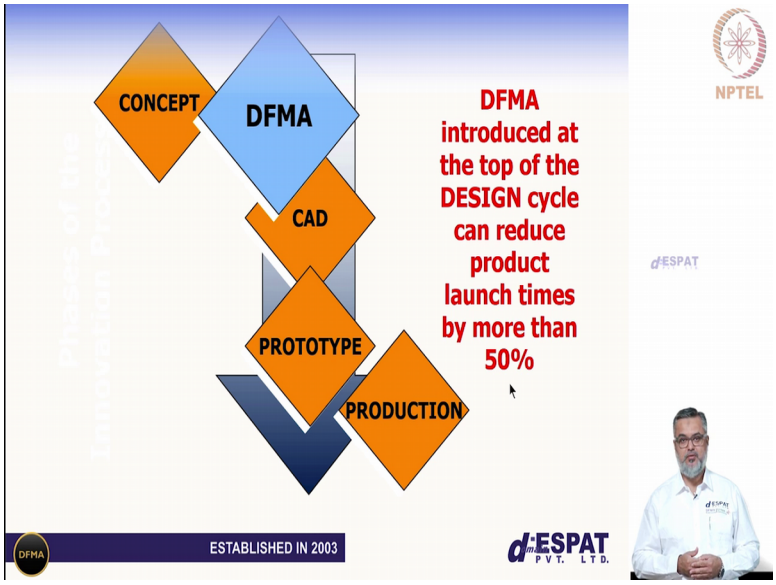

Further if you look at what is happening in the industry and generally the design process starts with the coming out with the idea of the product and going through the engineering of it.

Most cases that we have seen and it has been documented from several hundreds of case studies that till the prototyping stage everything is nice and beautiful, but most of the bottle necks arise when it comes to production. Introducing DFMA at the initial stages of the product design cycle in largely reduced launch time upto 50 percent so, what I am saying is if you doing your vehicle and development in 2 years if you probably do it in 1 year really how DFMA helps will probably try to show you as we go through the overview of the two modules.

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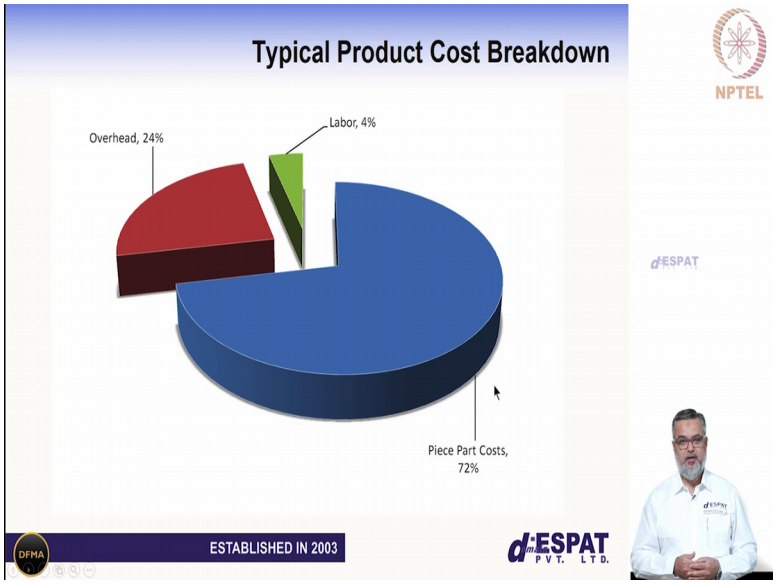

DFMA is a product centric tool and so, be the DFMA people focus on this big blue pi segment of the product which is the d-ESPAT per cost and we will show you how has been show you the as we go through the overview demonstration.

I will come back to the slide they will eventually let us get into the DFA software. So, in order to have a have a quick look at the two modules of our software let us start with design for assembly we will do the whole presentation based on the sample subassembly that we show in this design for assembly module.

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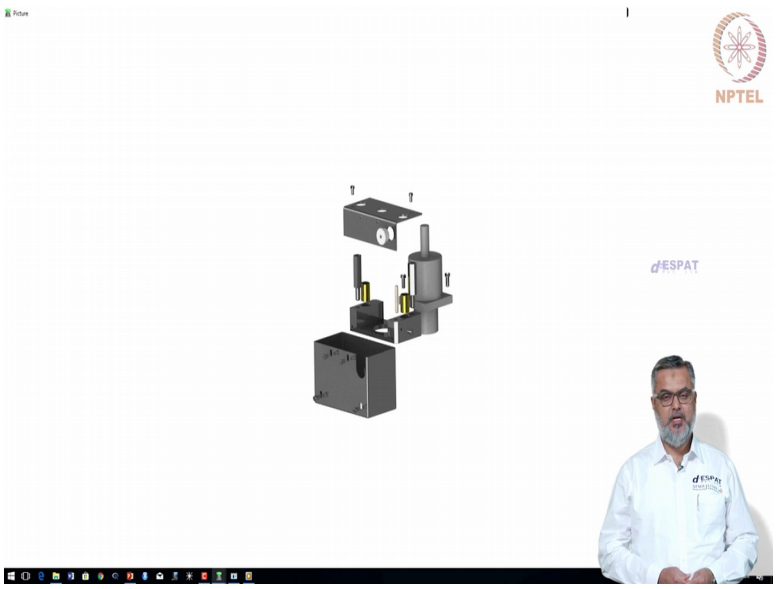

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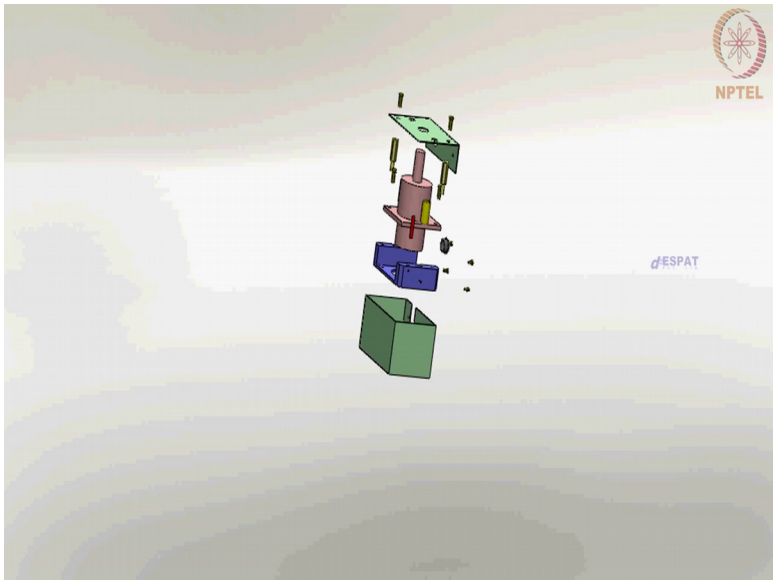

This is the image of what the subassembly we should analyse today and let us have a quick look at what the sub assembly would look like from an assembly standpoint quick video that captures this.

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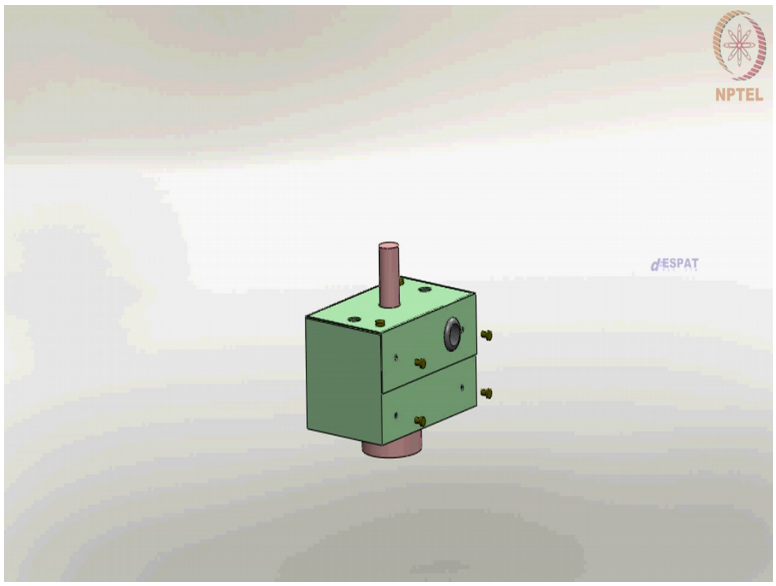

So, you see that the base is a first part that is going to be assembled followed by a sequence of components the one that look like a cylindrical component is a motor that is supplied by vendor. And let us assume the rest of the parts are made in house where for this product to be fabricated.

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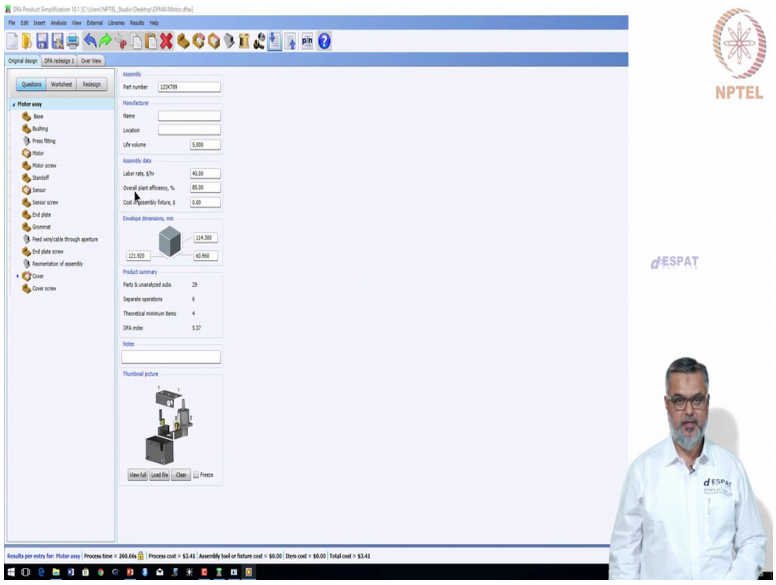

So, this product we got analysed using the design for assembly two. So, what is see on the as a graphic user interface of the design for assembly software as a as a three part window the one on the left hand side is called the product structure chart it is the sequence of the below materials.

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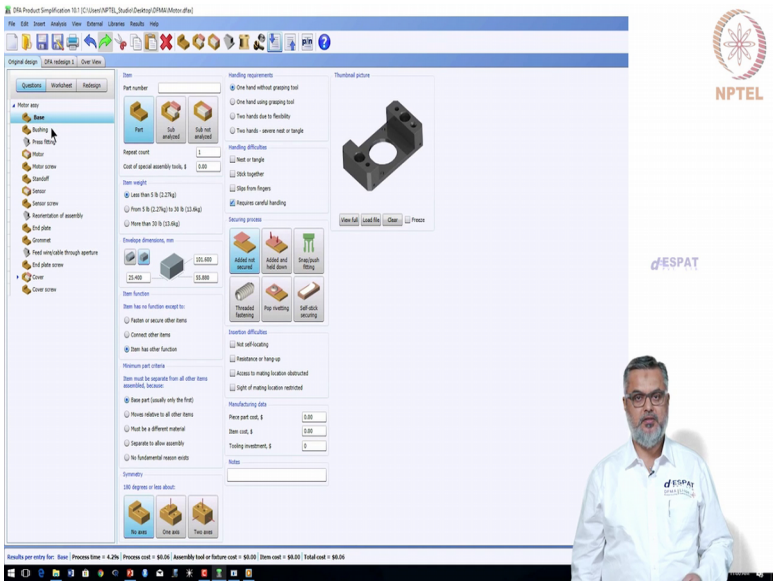

But as one would visualise it to be assemble on the shop floor to form the complete product. And for each component in the bill of materials on the on the product structure chart you have a detailed question and answers panel on the right hand side which is the inputs given by the user.

As what is force is to be the importance of the attributes related to this part component probably even operations which is standard or non standard. As we investigate and clicks on these options for answers you going to get a rapid feedback of a intend on the bottom which includes the cost of the process time the process cost. And if we as also familiar with the cost of individual components you could probably go and look at the manufacturing data which says input the value of the part cost item of these items and you also get the total cost of the product as we build this analysis.

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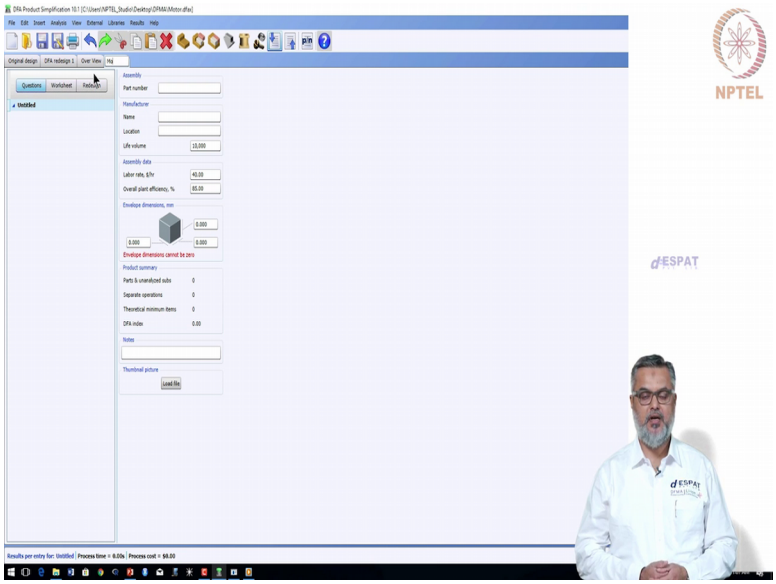

So, let us do a simple overview demonstration of this product that we just now saw few steps just to highlight the kind of questions that are asked for the review of your product. And how does it translate in terms of give me your feedback based on your intend.

So, let us say we start of this overview and the first window. So, the most important entry that you want here is probably the number of products that you like to make and we would call it life volume it just reflects.

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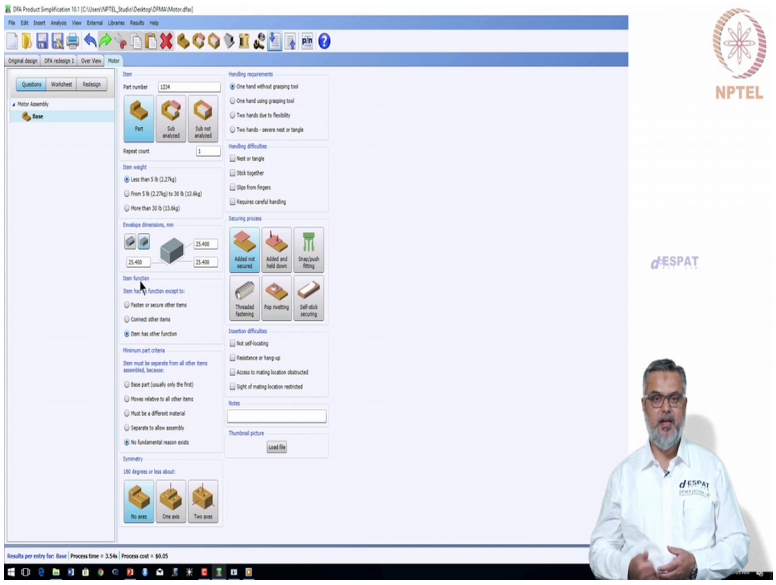

What is our designed with what is the idea that we have of how many number of products that you like to make of this particular design. And the rest of the components that are there in the questionnaire include what is your labour cost what is your problem plant efficiency. Let us go add a first component here and we will call it the base as you saw in the assembly video and start with that component the question on the right hand side you see our range very nicely in group boxes.

So, first of the question is what kind of a component is it. So, this is a part I will go select there the next few questions ask you to visualise what does the overall weight profile of this product. So, this is a component which has less than 2.27 kilograms of weight. So, I will select that I will go and say what is envelope dimensions of this part one thing that comes to mind here is hey I have complicated part I have want to sell the multiple features.

So, why envelop dimension while the matter of complicated geometry is. What would do I ask you to visualize is? What is the actual space of the component occupies and which is important in transportation storage handling and how the operator interacts with the part.

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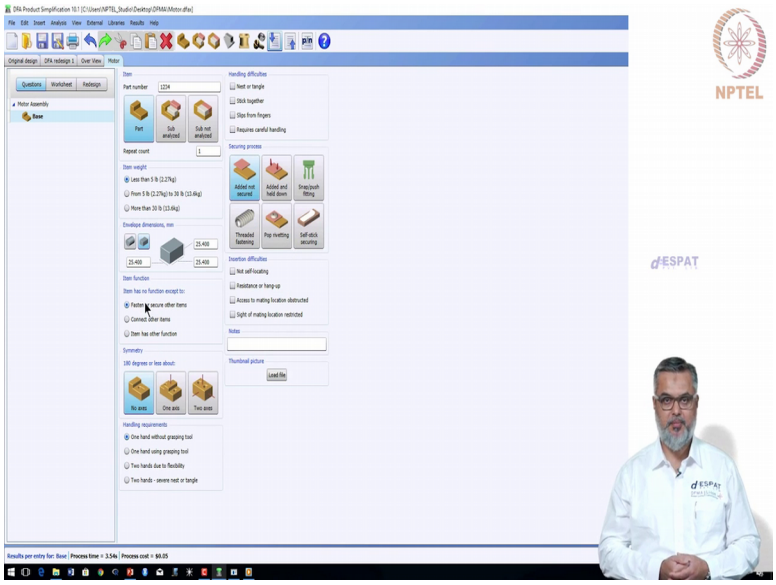

So, that is why we with the (Refer Time: 16:26) our overview of the component as these are cuboidal shape giving x y z dimensions or a cylindrical shape giving a circle diameter and height. Then next question that is ask is; what is importance of this part or how do you classify this part? Is it a fashioner nuts bolts weights washers is it a connector tubes conduits cables wires ropes or is it a part which has some function.

So, under the category of functions which is the main definition of which the design assembly module or the walls around in giving you a indication of your design through an efficiency measure is this question call minimum part criteria. Basically what was the question there says which we highlighting here means what you think is the importance of this part is it there because it is a base part well in this case it is.

So, I will select this option first I will answer the other questions as we go through the presentation the next question that it wants knows how symmetric is this component. Is it symmetric about all the three axis is it symmetric about one axis. So, easy for the user to pick and place or it has no symmetry at all. Which means when this component based on a symmetry the time penalty for the operated pick and place a component sort of multiplies depending upon how symmetric or asymmetric the component is. And the next question that set of question that is asked is how does the operator interact with the part.

So, if you can visualise somebody assembly of product two things happen. One is going to handle the product to bring it to the point of assembly the other thing is how does insert the product into the product structure to form the complete assembly. So, that two

question are asked there what is the handling difficulties what are the handling requirements, what is the securing process and what is the securing or insertion difficulties? So, we will go through these questions as we try to answer some of the questions for this part, but in this case this is a component is fairly easy to handle does not have handling requirements it is the first part. So, we will say it is going to be secured later and from insertion difficulty stand point it does not have any difficulties.

So, let us go at the next part and this one is the set of brass bushings the first component was an aluminium base and the second one is a brass bushing. So, we have two such parts and it is less than 2.27 kilograms in width it is very small component of 15 mm dia and about 20 mm height and the envelope shape is fairly it is a cylindrical components so, we going to select that. Now the question that is the answer is what is important of this part of course, it is not a fashioner or a connector. So, definitely is the part of some function. So, we look at the function part; is it a base part? Obviously not; is it there does it revolver move out does this part move in response to the other components in the design? No.

Is it made of the different material? Let us fond a for a moment yes it is made of a different material it is made of brass and other based components made of aluminium, but that is not the critical reason why this component should be there this product can work even we did not have the bushings. So, we will say though it is there at a part of this design it is probably a redundant component. So, I am gonna give a criteria of this part has a component that has no important fundamental reason to exist then I go ahead and answer the other questions which is how do I handle it there is no handling difficulties that could handle it with one hand.

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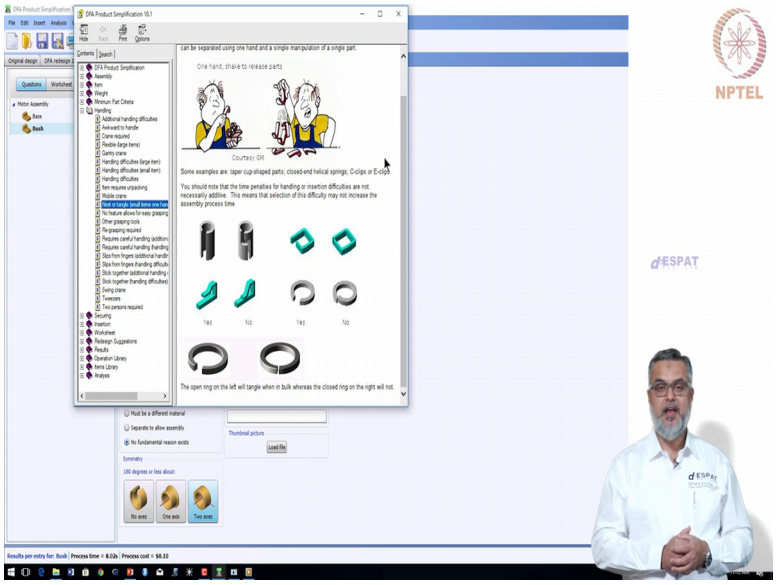

As I am showing it you right now and there is no handling difficulties the other part beautiful part about a software. If you do not understand what this question means for example, I do not know what next a triangle means I can click on it I can click on the on context self we have very nice dictionary which has all these questions mean.

And we have detailed explanations through this on context help that is a part of our tool and this has been documentary over the last 3 4 decades. So, it is easier and self explanatory in most cases the next question that I ask this how do secure it. So, let us visualise this is a bush I am going to place it I am going to probably use the press fitting tool. So, I will say I am going to secure it later. So, will select that option I will go and select what I call in our library and operations library.

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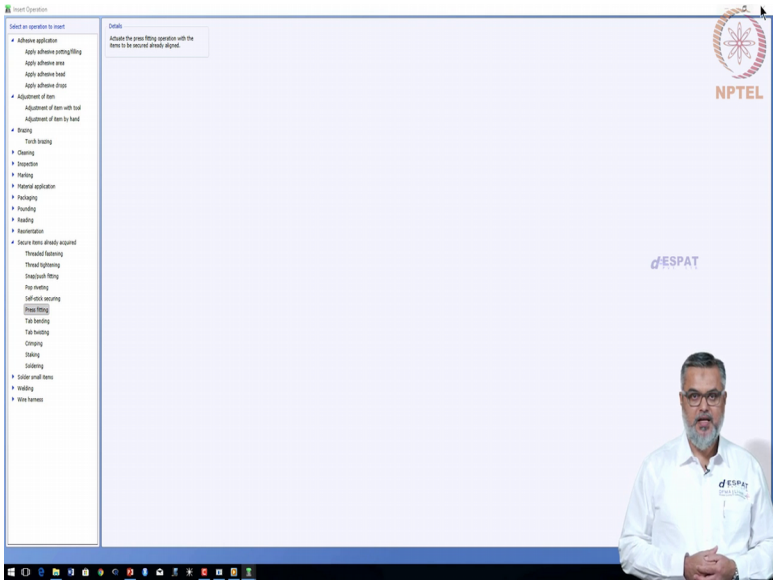

So, we have a standard of which is available as a part for our library. So, we have a library of operations that has been documented of the lasts few decades. Commonly used in the industry world and it is available at your disposal to pick and user as a part of your analysis.

So, I am going to pick this option for securing a part that is already been selected.

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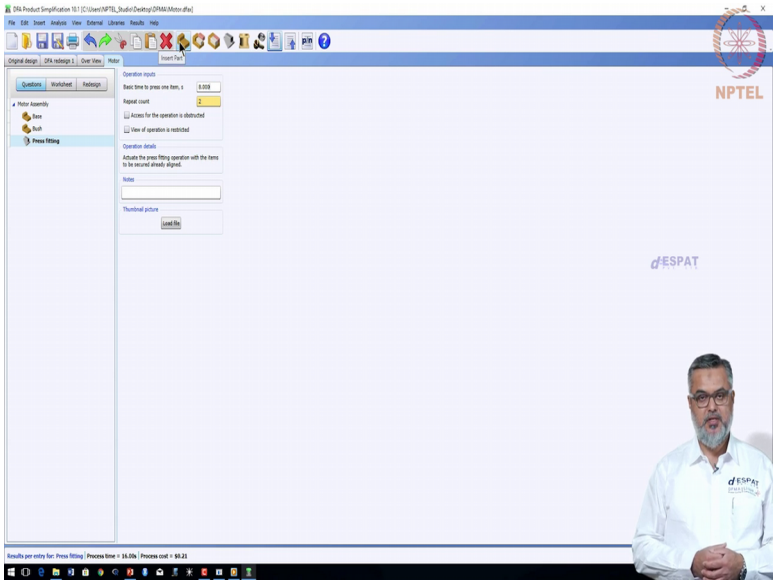

And uses press fitting operation and bring it into my analysis. So, I will double click on that get it into the analysis and I just going to say that the number of reputation that I have here I have 2 bushes I will select 2. So, the time for a default press operation is a

part of our data base, but you may agree or disagree with this because of what your actual practices on the shop floor and use that as a input for this entry here for the time value in case there are other issues associated with this assembly that this is the difficulty that also can be accessed by clicking on this questionnaires that are there as the part of the press fit operation.

So, let us go add the third component which is probably in our case motor and let us assume for this presentation that the motor is supplied by vendor. So, the motor if you see what is the definition of a motor; is their part it is subassembly or is it. So, it is a sub assembly so, I will click on the and subassembly option you will see that one I do that on the product structure I get the ability to rebuild the components under this sub assembly that I have as a part of my original design, but I choose not to do the analysis of the parts inside the motor. So, I will treat this motor as a sub assembly, but I am not going to analyse the parts of the motor. So, that is the third option that I have under the parts nomenclature which says subassembly not analysed.

So, again the next question is; what is the width profile? Less than 2.27 kilo grams; what is the overall envelope dimensions? It is fairly cube bottles I am going to select the cube bottle dimension shape I will also give the envelope dimensions. Actually with each of these entries that you were the user keys in the kind of question and answers panel profile would probably change on the right hand side. And that is why our tool is called design for assembly product simplification which means it does not bother the user with all the questions that the same one go it probably allows him to answer subsequent questions if a previous questions warrant that some more details have to be provided. We will see as we how that happened as we go through this presentation.

So, I will give the next question which is related to the symmetry of the motor so, this motor is has a fairly square base. So, I probably rotated about one access you will notice that if the symmetry is high if this more symmetric the lesser is the time as you can see in the bottom left hand corner of the process chart. So, an symmetric part will have taken obviously, little more time for assembly and added to that it will complicate the assembly time if you have more difficulties in handling which add to the penalty of handling and I also in terms of insertion of the product.

So, coming to the motor I have a base I have this bush which have been infected now I have his motor if you visualise I am going to align the motor to such that thus the motor screws slots align with the slots for the screw on the base. So, I am going to do this alignment and then pick screws and fascinate. So, now, I come to the questions where I have to answer the handling requirement is easy to handle how do I secure it normally I would say I am going to secure the part and hold it down. So, that this holding down allows me to align the screw for fastening the motor which means I have two issues here one is the holding down and fairly because in the handling difficulty I have it is a not self locating component.

So, this kind of visualisation of what your assembly steps are either yourself as a designer or with the operations people who actually facilitate the assembly leads you a good understanding of what are the issues related to how you should probably answer these questions in this q and a panel. Let us answer one more question before we move on which what is the minimum part criteria for this motor; this is the base part of course, not does it move relate to other parts. Well we have taken a sub assembly is not analysed well the motor is there because one of the compressor is the spindle rotates and that is important for this motor to subassembly to work. So, technically it is this capability of who relate to other parts which we have writing here is the importance of this motor being functional part and this design.

So, what is the importance of this minimum part criteria question here altogether let us go to the main motor assembly you see on this column here we have a the opportunity which says design for assembly index. So, Boothroyd's method has way of documenting or design and comparing to the world's best practices and coming out with an efficiency measure. So, you can say how good or bad my current design is compared to the world's best practices.

So, this actually empirical formula we could probably discuss this as we eventually, but this is just for you to know that the intent actually gets captured in these attributes also the get a measure of comparable comparison of the design again this practices and get you a number which is how good or bad your design is. Now that you have the motor let us just do one more component before we move on to the attributes of this tool we have the motor screw. So, this motor screws are the once that I am going to hold into the base by fastening the motor to the base part.

So, what is the motor screw it is a part how many motors use we have two numbers what is the overall weight less than 2.27 kilogram envelop dimensions and envelop weight that said what is important of the part? Fairly a motor screw is a fastener. So, once I select fastener you will notice that the minimum part criteria questions are no longer there which means fastener no matter what is just used to hold two components together and there is no other criteria for it to be important.

So, let us go and look at the other attributes which is the handling difficulty fairly easy to handle how you are going to secure it.

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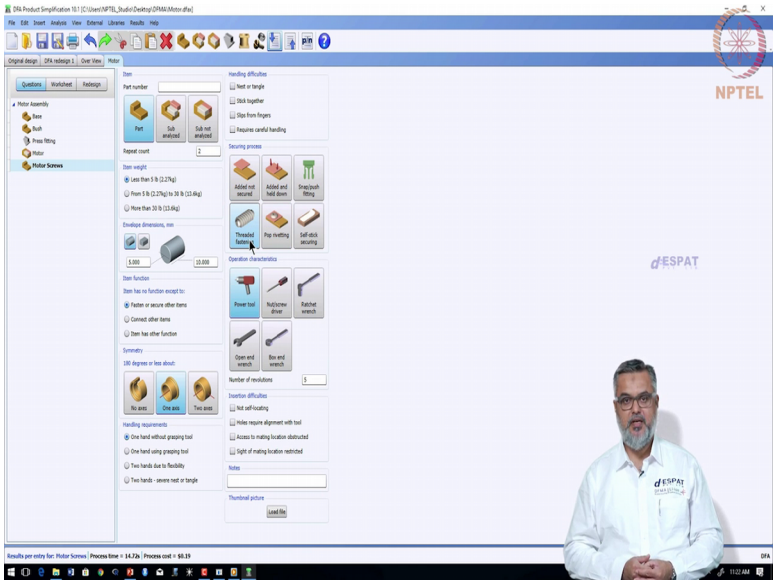

So, the security method obviously, the choice you would probably be to select as the threaded fastener. So, when I select the threaded fastener you see you one other question pops up which says; hey how are you going fasten this using power tool, screw drivers so on and so forth. Like I said earlier the question and answers panel are so, designed that you come up with subsequent questions based on a previous question and that you have answered.

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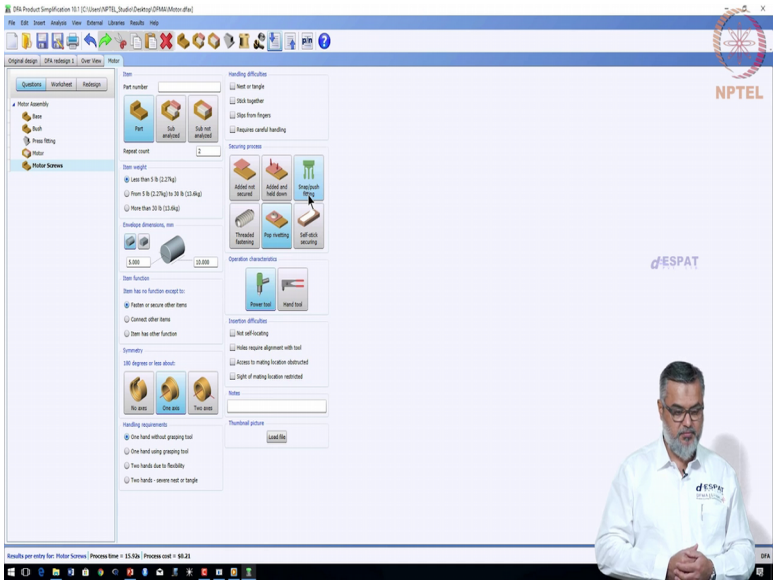

If you for example, if this was not threaded fastener, but if it was a snap fit it would select the characteristic for snap fitting we (Refer Time: 27:16) the rivet it would riveting of the operation characteristics for refitting right, but right now it is a threaded fastener. So, let us click on it let us say it is going to use a screwdriver. As I am going to select these options you will see the implication of this selection on the bottom left hand corner which is how much process time it takes to fasten the screw two numbers with the 5 revolutions with the screwdriver. So, the question is what is this was not 5 revolution what if this was 10 revolutions and I just change your ten you will see the implications of that highlighted there.

Now, this beings are through a create of question that I was design as we tend to just meet the functionality of a part you want to put two parts together we take this depth we take standard screw and probably inserted it as a part of your analysis, but do you know what is the implication of selecting this screw which has say 5 revolutions in order to get itself fasten and hold these two parts together (Refer Time: 28:12) more number of fastening action. And this is how this tool helps to sort of brainstorm around these kind of final aspects of a product to help you to see what assist in reducing the assembly time.

We will see the integration of this fastener.

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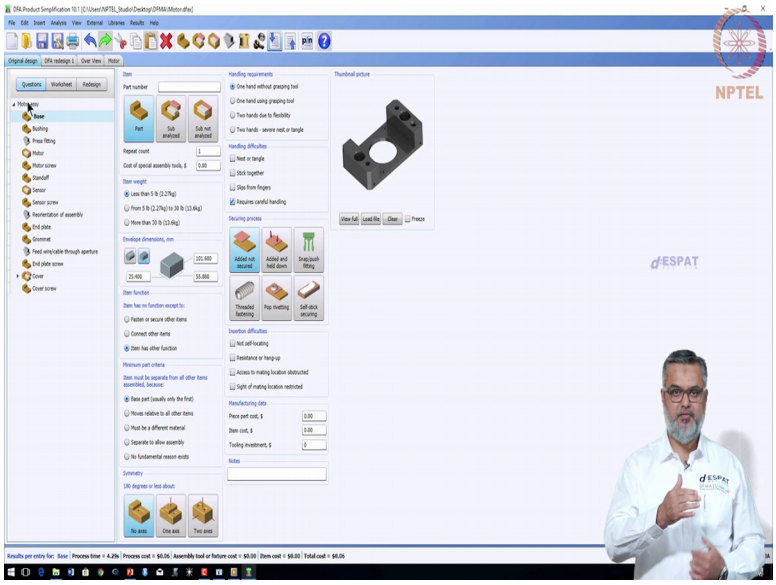

So, in this manner like we have showed you in this few steps we can go on building the product structure. And what would probably be of the full assembled product would look something like this.

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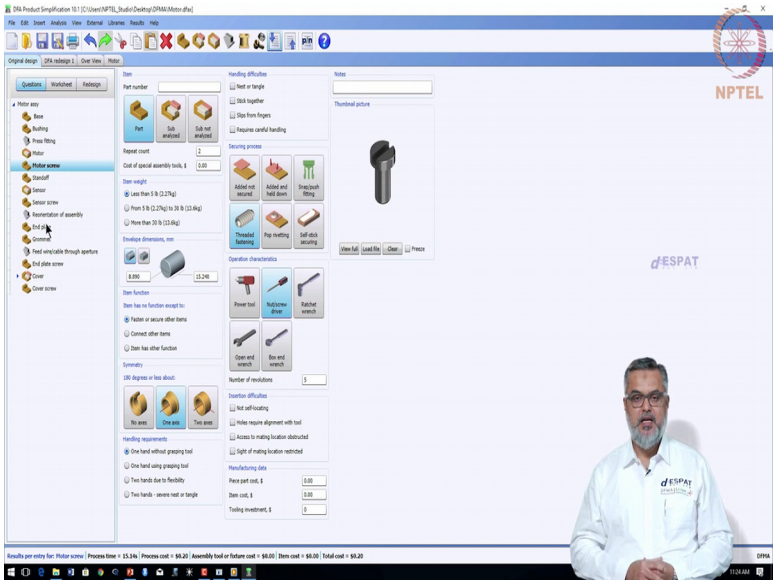

The only difference between what we showed in the initial demo is we enact this pictures or of what the part looks like which is a good way of documenting up your design. So, what I have on the left hand side is the full product structure of this product that I intended to assemble. And I can review this design by spreading it out as a worksheet which is most industrial engineering analysis would do.

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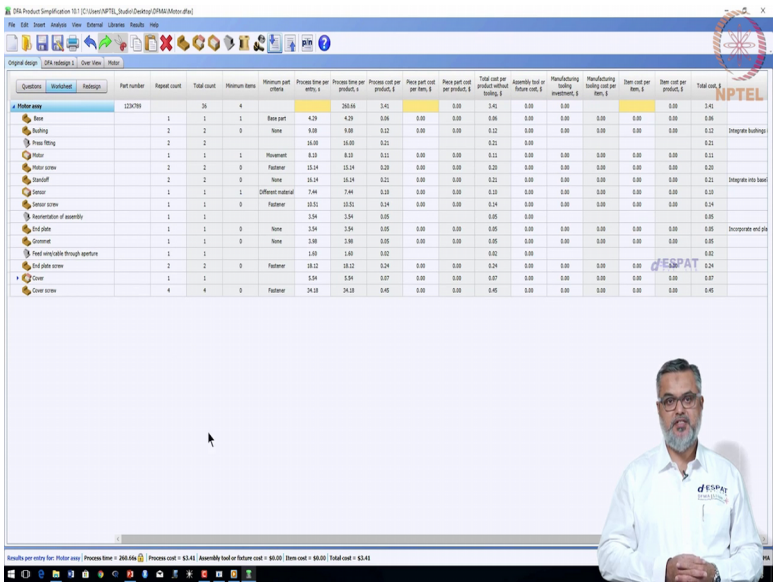

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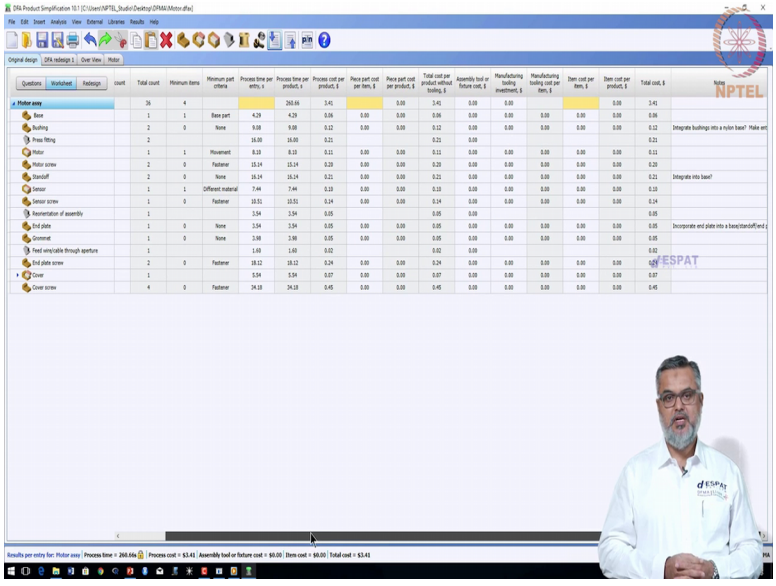

But that is not only the scope over the tool is capable over doing this the importance of this defect tool to assess the engineer is with his intelligent very useful feature called suggestions for redesign.

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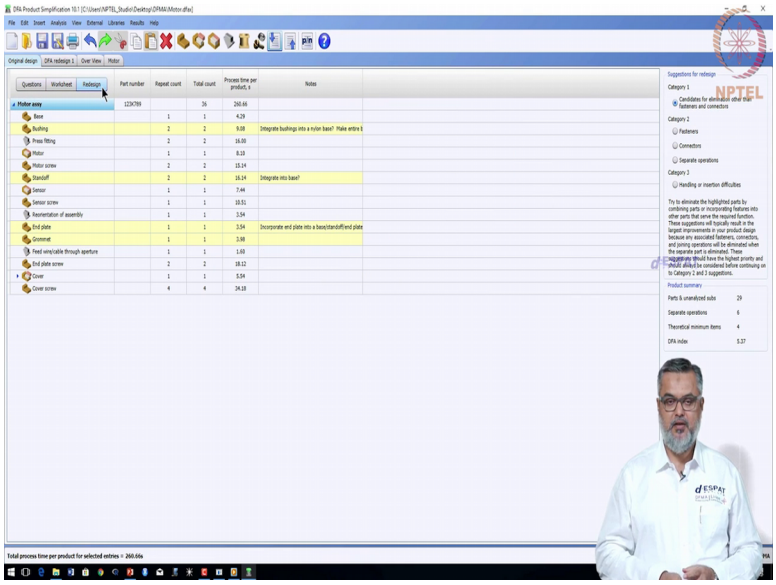

So, what is popping up here is your list of parts and on the right hand corner is the opportunity to improvise the product. So, it lists out the category for improvements under these three headers the first which is called candidates for elimination other than fasteners and connectors and category two is fasteners connectors and separate operations.

So, let us look at fasteners with this design we have four different types of fasteners and that is highlighted there when I look at a product like this and breakdown of our inputs it becomes easy for us to identify and questioned the importance or relevance of the parts in the design and quickly go about doing creative brainstorming of how we would probably reduce the parts for example, if I see cover screws here there are four cover screws and if you recollect the video that we will be played the role four cover screws are finally, come together assemble the cover and position hypothetically.

Let us say if we where we do something like this instead of four cover screws if there was a way if there was a way of assembling the product that cover with two screws what would happen ok. Let us do this let us make a quick copy of this current analysis that we have we will call it new idea with two screws. So, we will make a copy and we will rename this and say cover screws two number for the filename and we will go to questions panel and go to the cover screws if you see there are four cover screws there I am going to change it to two and (Refer Time: 31:04).

Well I am going to look at the quick review these two ideas by doing a comparison of these files by picking up the current design.

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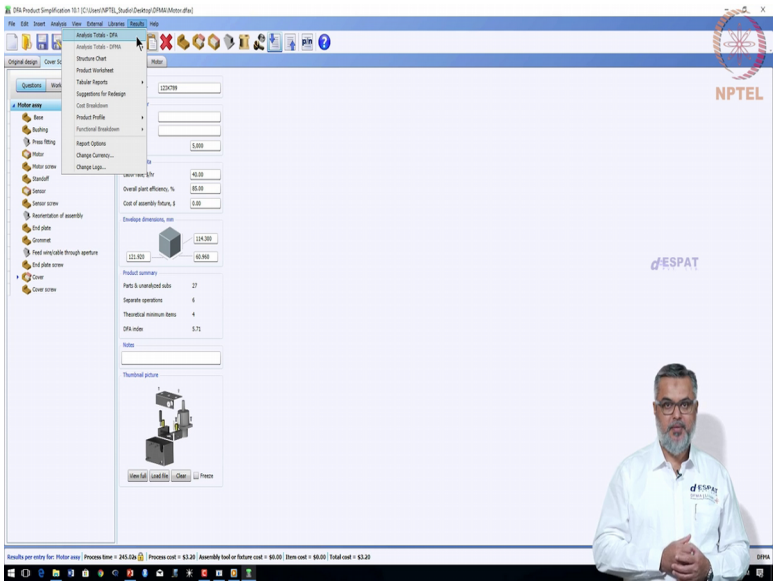

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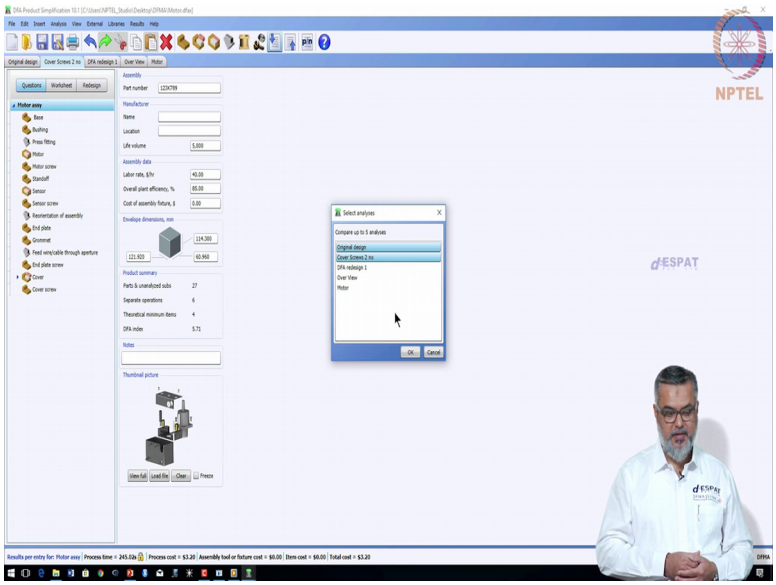

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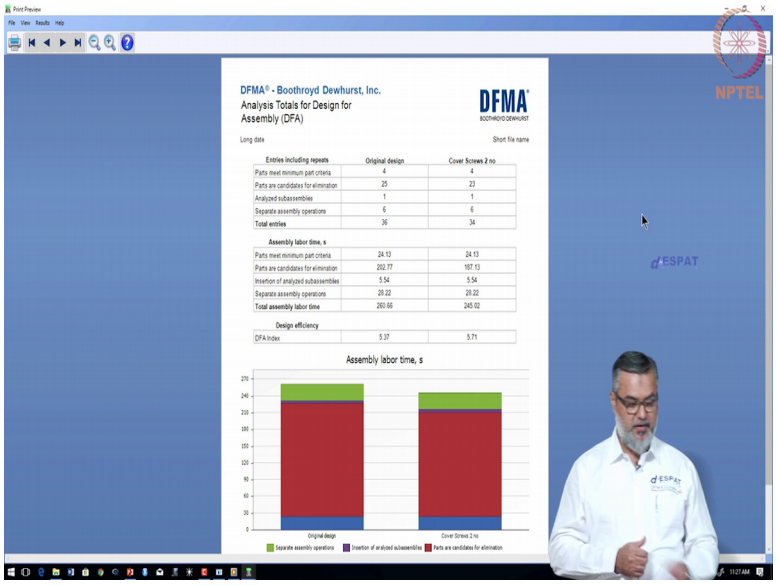

And my propose new design which I just now did and comparing them and saying we would probably get rapid feedback of your design intense. So, what you see there is the time for assembly the number of parts reduced and so on and so forth.

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Let us say if we have quick look again of the fully assembled cover all right if I just bringing up the three CAD image that part. So, I am going to another view of what the. So, if you maximize this is what our cover looks like. If I am going to actually quickly sketch what this final cover assembly looks like there is a potential opportunity. If I just move the exploded view video a few steps back you will see in order to the act of covering I have two separate sheet metal parts which are highlighted in green colour.

So, upon assembly they look like one enveloped cuboid. So, the opportunity for me exist that I can make this as much more simpler design which probably looks something like this that is highlighted here ok. So, I will created a third file which says what if we instead of having a cover which is going to be help by two screws have a entirely different design which shows look something like this.

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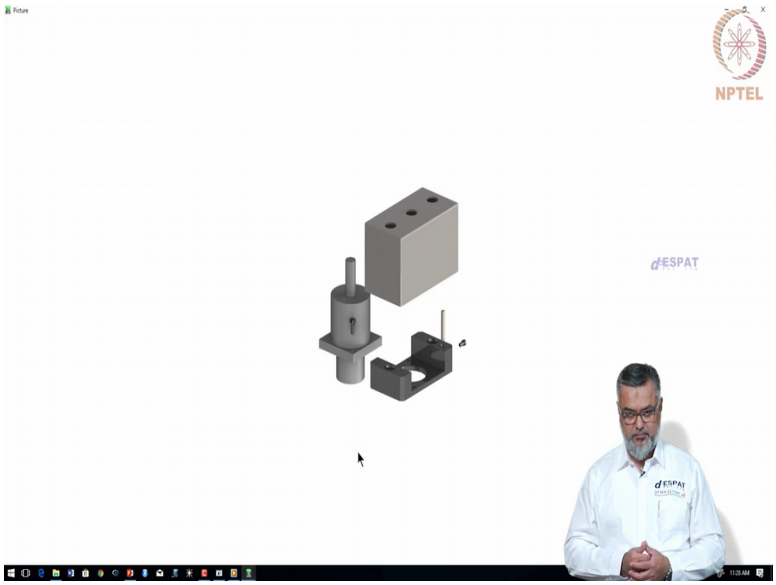

Where in the cover and then and plate is ones envelop part and instead of having those separate 6 or 8 fasteners. We have one envelope shape which could be which could be used to cover this whole motor assembly.

So, I have a third design that I had just now created. So, I am going to quick comparison of this I am going to take rapid feedback of my design intent.

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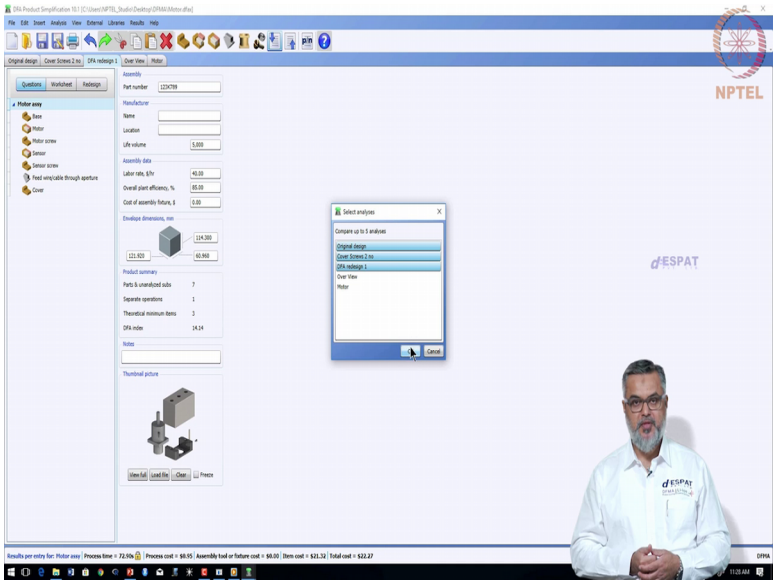

And I can break down into these three different attributes.

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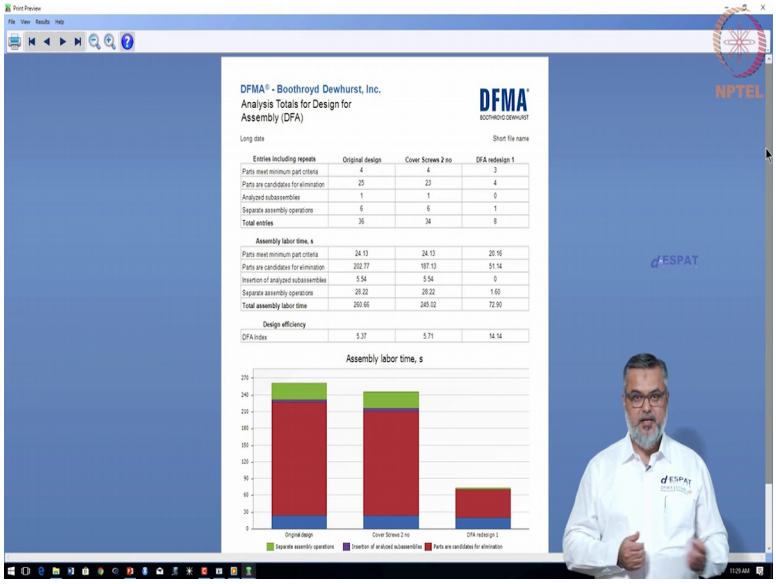

I can select these three different files and find out the implications of this design.

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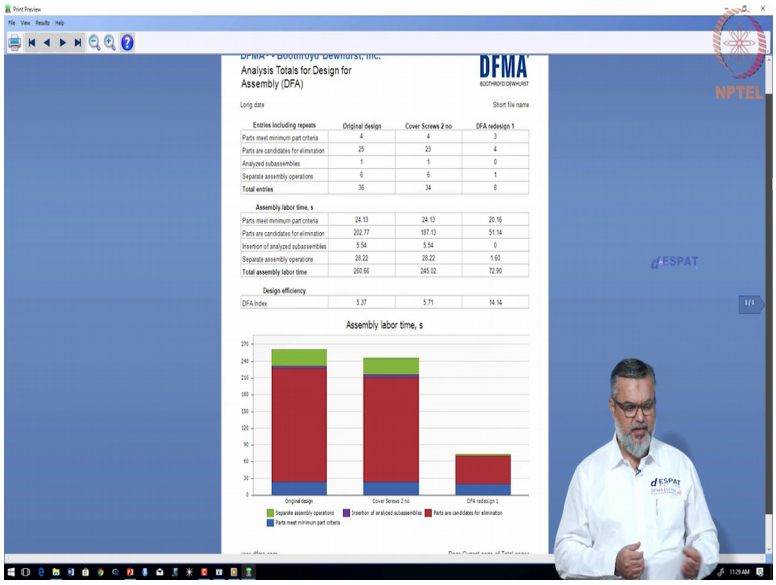

So, let us quickly look at sort of at this report that we have generated. So, the original the intent was about 36 parts when we reboot two screws it was about 34 and our direction in terms of the assembly time if you see from 260 seconds to about 245. And the overall efficiency that we can probably get as a better meant from this design is highlighted there as the DFA index, but if we have to get rid of those fasten is all together to form the part I have a fantastic new set of matrix and that is really very interesting and also achievable. So, usually this assembly level product design improvisation happens like this progressively as you create an ideate for different attributes.

The important thing I like to say here is under the results I can generate several different types of reports very instantaneously.

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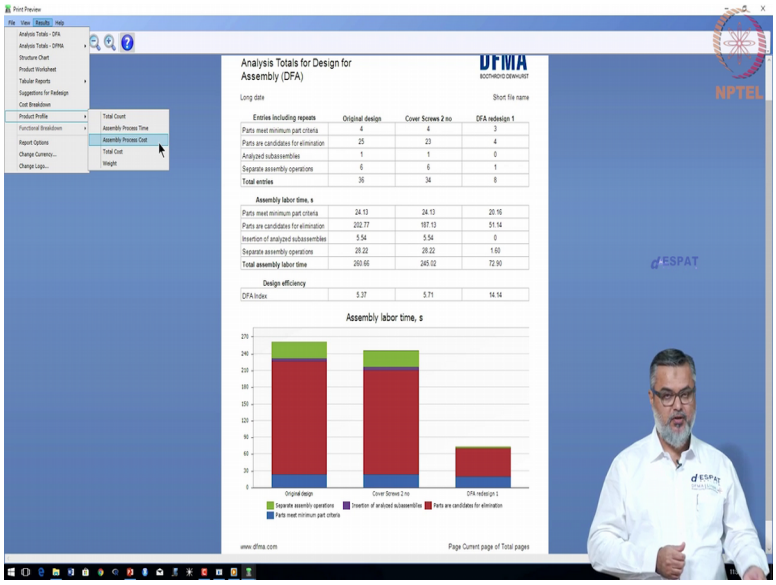

And that is how we are helping design companies or design designers to quickly have a rapid feedback of their design intent. So, I can look at probably the process time for these three different designs.

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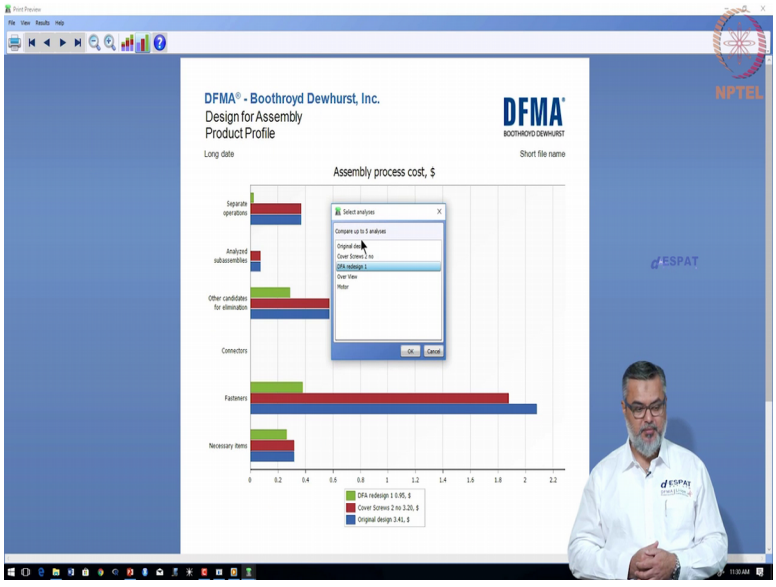

Then interesting attribute that you will probably come out and this attribute is very evident in most product builds which is the fastness as you can see here is taking about close to 160 seconds of assembly time out of a total of 260 seconds of the products assembly.

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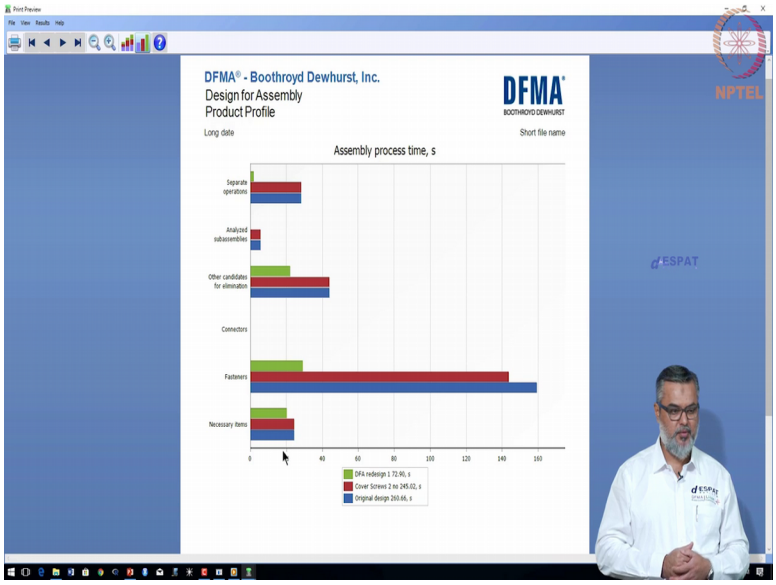

And look at what is there on the left hand side on the y axis necessary items just contribute about 20 plus seconds. In most products this fasteners and fastening elements contribute of large chunk of the assembly time was a actual functioning necessary parts from a fraction of the total assembly and as good designers this intention is always to see how we could probably reduce this requirement for fasteners and fastening elements. So, these are several different capability measures you could do with the kind of reports we can generate through a tool there are probably about in different types of reports that you can generate.

So, let us pause for a moment here and then let us say now that I have a new intent of a component ok. Which as we are writing now this is the proposed new design can which looks like this is need not necessarily be a CAD model because most people when you would visualise they are able to sort of they want to have a history realisation of what their product looks like through a CAD tool it need not necessarily be a CAD model it could just be a sketch or drawing that you came out with as you are having coffee with your friend and you want investigated. DFA DFM allows you to do that you without having necessarily engineered model of your design intent. So, I have this overview of that the envelope shape I am going to take that intent from my design for assembly tool; bring it into design for manufacture.