Functional and Conceptual Design
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Lecture No. 15
Functional Decomposition

So, in the last few classes we discussed about how do you identify the product specifications or basically how do you convert the customer needs into objective values or specifications, that is what, that is what we discussed and then we saw how do we actually put together all the information, what you get from the customer requirements, from the benchmarking and then looking at the benchmarking values, how do you identify the conflicts in the design as well as how do you get the target values for the products.

So, that is what we saw in the last few classes and we saw how to develop a House of Quality based on the requirement, customer needs and metrics and the values. So, all of you are comfortable with the House of Quality now? You have done it for the lab also. So, today also you will be doing one House of Quality for another product so we will be thorough with the House of Quality and how you develop the house of quality.

So, now once you identify the product requirements and the specification, the next question is how do you satisfy those requirements? So, what you need to provide in the product in order to satisfy the customer is the next stage where we look at the product functions, how do you provide the functions in the product? That is the next step in developing a new concept for a product.

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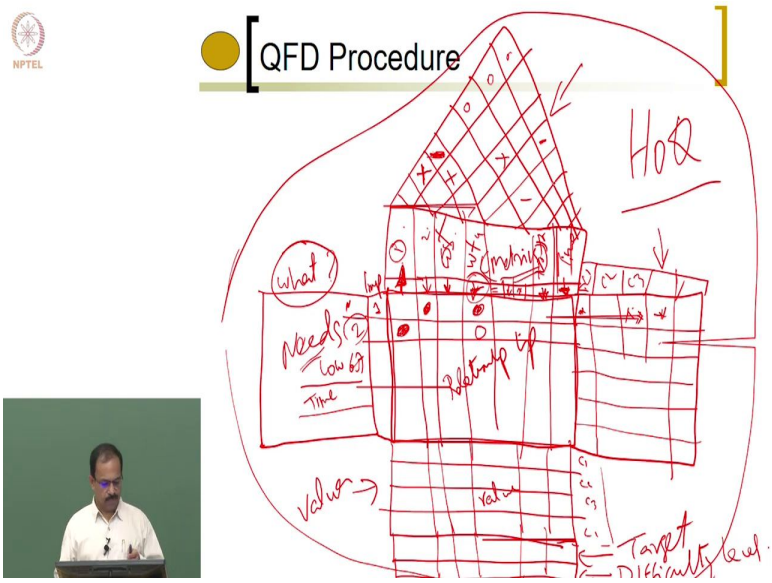

For example, establishing a product function is one of the important aspects so, you have many requirements when it comes from the customer, for example, the customer says, you want this product to be low cost and somebody says it is comfortable, it should be comfortable to use. So, these are 2 customer requirements and we know how to fix the metric for this and we can find the value also.

Now, somebody says low cost and then we say that the metric is the cost of the product should be less than or equal to say 1000, so this is what we specify in the product design specification or product specifications but for comfortable we identify some metrics and then say that the vibration should be less or it should, you should not feel the discomfort, you should not feel any jerk, these are the things which you will say that the vibration level or some other metrics we identify.

So, if you, when you start designing the product you cannot really say that, how can I satisfy the cost constraint, cost? So, cost can be satisfied by saying that it is a constraint in the design, I mean you cannot go more than this value, that means only you can say, but for comfort we can say how to provide comfort in the products. So, we can provide something called function in the products in order to satisfy the customer requirements

but in the place of a cost you cannot say something like a function in the product which will reduce the cost.

So, this is known as the constraint in the design, so some of the things in the customer requirements, some of the customer requirements can be satisfied only as a constraint in the design. We will say that, 'this cannot be more than, this is a constraint.' So, whatever you do in the product make sure that the cost is less than 100, there is nothing much to do with the function of the product itself because any particular function is not going to affect the cost or control the cost.

So, any customer requirement in the product can be achieved either by providing a function in the products or saying that this is a constraint in the development of the products. So, are those customer requirement whatever you saw, we classify them into two categories, some of the we say, they are the constraints in the design as a designer I had nothing else to do with that, as a designer I cannot control it by providing a function in a product to reduce the cost or increase the cost.

But comfort I can say that by providing a particular function in a product, in the product I will be able to improve the comfort. So, this is the importance of functions in a product because we provide a function in a product to satisfy the customer requirement, customer has got specific requirement, easy to use or nice to have or easy to carry, these are all the functional requirements which we can provide in the product.

So, any customer requirement can be addressed either using a product function or using a constraint. So, we will not worry about the constraint work for the time being, we will see how we can provide functions in the product in order to satisfy the customers requirement.

So, this is what we are going to look at, we identified many customer requirements and identified the metrics, we will see how we actually provide that in the product to satisfy the customer, that is going to be the discussion we are having.

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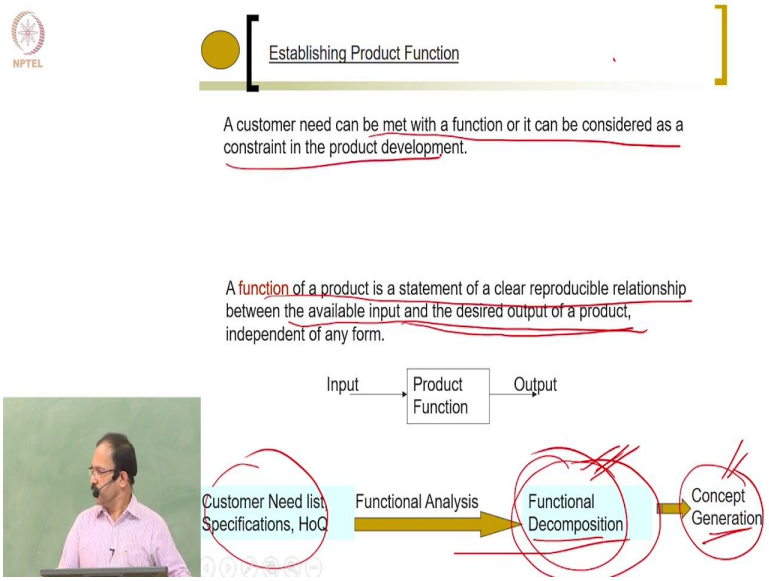

Now, see that reducing the vibration is when you can provide a function in the products so that that can be addressed by a function, it can be either adding a part or doing something else, that may affect the cost of the product. So, we are saying that 'I can address that requirement of the customer by providing a function in it that works, but somebody says that the it should be low cost, so low cost I cannot have a function in the product to make the, reduce the low cost low cost low or high, it is not a products function it is more of a constraint you put in the product saying that whatever you do the cost would be this much.

So, it is not a function of the product per say, it is more on the, as a designer I do not have, I cannot provide a function in the product to control the cost, overall cost can actually be restricted to this and I can work out on that point but I cannot provide a function in a product to reduce the cost, that is what we are trying to explain. That is why, when you, that function if it is increasing the cost it should identify another function which reduced the cost, cost can be reduced, they are not independent. But what I am saying is that this function we are adding or deducting is not controlling the cost.

If the function you are adding is to control the vibration, that is the focus of adding the function, you are not adding a function to control cost. So, cost cannot be controlled by adding a function or it is not a functional requirement but more of a design constraint from the customer's point of view. So, that is, so what we will do is identify a few methods by which vibration can be reduced, suppose I identify 4 methods to do, when I look at these four methods and then see which one is most feasible, where actually my cost is not going to be raised.

So, I will take that one on so, my requirement is not, primary requirement of providing the function is not to control the cost but when I use a function and identify a method to do that function I keep this in mind saying that 'I have a constraint of cost so, when I choose a particular function, I need to make sure that it is not adding to the cost.' So, that comes as a constraint from the design point of view.

Cost actually, cost all the things will affect the cost, I mean if I add additional function it will raise the cost but then I need to make that requirement also, I mean so, if somebody says the vibration to be reduced, I cannot say that because the cost is increasing I do not want to reduce vibration. So, then I need to have a compromise on it, what is the best way to address both the requirements.

So, we actually discussed during the lab also, I used to ask you 'what is the function of these, what is the function of these?' So, function can actually be defined as a statement of relationship between the input and the output of a product that is the overall definition of a function. So, if I ask you what is the function of a fan? What will be the function of the fan? What is the function of the fan? Reduce temperature?

No, it is not going to reduce temperature, what is it going to do? It circulates air, basically the primary function of the fan is to circulate air, so like that you see take any product you will be able to identify a function, the top level function of the products. So, that is defined as a relationship between the input and output of the product, you provide

electricity, you get air circulation. So, the relationship in between is known as the function of a product.

So, that is what is given here, a function of a product is a statement of clear reproducible relationship between the available input and the desired output of the product. So, any product we will be able to find an overall function like this. So, now what we are trying to do is, from the customers' needs list in the House of Quality, we try to do a functional decomposition of the product to identify what are the things needed in the product to provide that function.

For example, if you take the fan, the fan is to provide air circulation, how does it provide air circulation? It needs multiple sub functions, first of all you need to convert the electricity to mechanical energy then, you need to rotate the blades and you have to rotate the blades you have to hold the blade and you have to keep your distance so all those things actually lead to the final function.

So, an analysis of a function into its sub elements which basically we call it as the functional decomposition of a product. So, the overall function of the product needs to be decomposed to identify what are the small, small things needed in the product, so that it requires the final output. So, that is basically known as the functional decomposition.

And when we have these small, small elements then we can understand or we can identify what way we can generate the concept to provide that function then, you get new products, for example, you have a fan here, the fan is having a particular structure, a particular function and specification. Now, I want to redesign and I want to make a new fan, so I need to know how the fan is actually providing air circulation.

I looked at each one every function inside the product and then see can I modify the way the blades are attached to it or can I change the way the blades positioned in a particular, oriented in a particular way so, which one if I change in a different way I can get a better product and it is basically I develop new concept to developing a new product.

So, in order to develop new concepts, I need to know what is happening inside the products and we will be doing this function decomposition to understand what is happening in a product, so that we will be able to redesign the product in a better way. So, that is what we are going to do in the next few classes. So, this one I already told you the customer needs can be met with the function or it can be considered as constraint as a product development.

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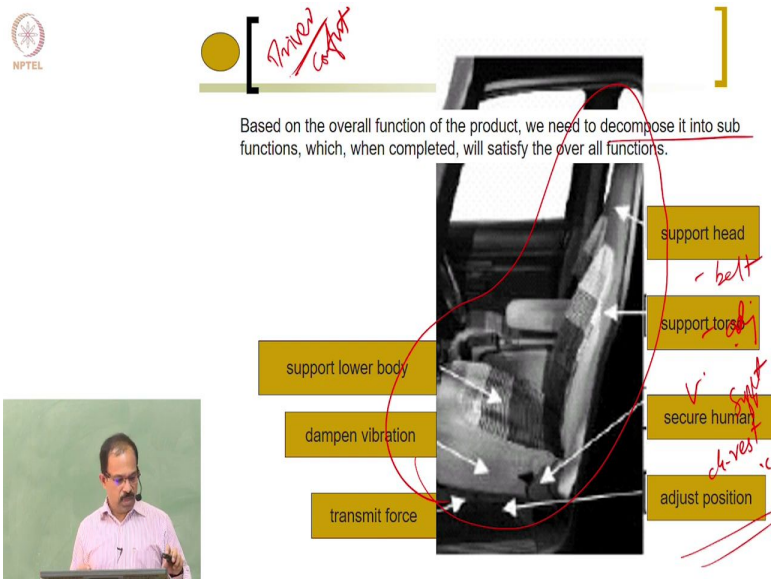

So, for example, you take this product, how many of you have done these products? Most of you have done this product. So, what is this product? This is a blender, right not a blunder there is any difference? No difference, blender and a blunder no difference, so what is the function of this? Overall function of this is to blend materials, you can blend solid and liquid or both solid and liquid.

Now, if you look at this product, finally you have provided electricity you provide electricity outside and then you get that blending at the outside and this is what actually happened so, it provides blending. Now, if you look at this you will see if I open out this

you will do something like this, so what is the function of this particular part, is there any particular function for this?

So, basically you have a rotation here, that rotation needs to be transmitted to the blade so, the blade, the transmission is then through this but then you could have connected the blade here itself, why not connect the blade here itself? Because we need an access point, holding point and distance from here to here so that you can put it into a jar, so if you look at this way, you can see each and every element in this product has got some function.

So, if you take this shaft this is a shaft, there is a shaft inside, this is a shaft if I hold you can see so, if I take this individually what is the function of the shaft? First is transmitting the torque, any other function you can see? So, it provides you access to the narrow jar then, anything very obvious from this, what is another function of this shaft, who is holding the blade? The shaft has multiple functions, transmits the torque, provides you an elongation for which you can put a narrow jar and it holds the blade also, then what is this part doing?

It converts electricity to torque or mechanical energy and then that energy is converted and transmitted to the blade, so any parts if you look at in a product, it has got some functions. Now suppose, this blade is not held by the shaft, how will you hold it? Is there another way you can do this? Can you think of any other way to do this? So, this is not actually the new design that comes into picture, so we try to understand how the whole thing happens and go through each and every stage and see if there is a way I can redesign this so that the blade can be removed.

Now, this blade cannot be removed, it is actually fixed to this so it is not a replaceable one, now there is a requirement that the customer says that this blade often becomes blunt so it cannot be used then, you have to throw this. Now, the requirement is that you need to have some kind of a method by which either it should not become blunt or when it will become blunt, we have to replace it.

So, to do that we need to have a design where the blade can be in a different way or different arrangement, that is why we need to look at the internal construction and how it is actually providing the overall function then, you can develop a new concept to hold the blades then, it becomes in new product and understanding that which one to be more, which one will change is the job of a designer and therefore you need to understand what is happening inside the product and to do that we do something, we do something called as a functional decomposition of a products so, that is what we call this the functional decomposition.

We composed the product in terms of its functions so, what do you do in the lab is you decompose or you do the product, you make it into parts but more from the physical construction point of view, from the, where the product is assembled but here we look at from the functional point of view and then try to decompose the product into multiple functions and then check which function can be improved to get that desired customer requirements because customer requirement be achieved through functions.

So, we decompose the product into multiple functions and then see which can be modified so that is basically known as the functional decomposition, for example, take this, what is this one? It is a car seat; it is a simple car seat. Now, somebody is designing a car and then there was a customer requirement saying that there should be more comfort for the driver, so driver comfort was a customer requirement.

And we all know that driver comfort comes from the seat, that is where he seats and then by changing the seat or adjusting the seat or modifying the seat, there is a way to improve the driver comfort so, to see that which, what to be change in the seat or what actually happens in the seat, we need to find out what is the seat doing in the car or what are the functions that provides comfort to the car, comfort to the driver.

So, we look into the seat and then see what are the major sub functions in the product, that seat and then see which could be modified so that you can improve the comfort and to do that we try to decompose these functions into many sub functions. Now, you look at

the car, you can actually see there are many things and can you tell me what are the main functions of the car seats?

Main function is to provide support to the driver, right and in addition to that what other things it is doing or comfortable seat if the driver is in the seat? What are the functions you can identify there? Everybody is saying but I am not able to hear, motion, adjustable seat, what is that you have to adjust the seat, seat adjustment is one requirement, then I have to reduce the vibration, so you have to control the seat vibration, what else?

Head support, Angle adjustment, backrest adjustment, backrest adjustment you have, and that is basically the ergonomics, they call these ergonomic, seat adjustment, height also, sometimes you can adjust the heights, what else? Seat belts, yes what else? Seatbelt, seatbelt so now you know that a seat is not just for seating, it actually provides you multiple things, so these are the multiple functions it actually provides in order to give comfort.

Now, if you are thinking of improving the comfort, you can actually look at any of these functions and then see which function can be improved to increase the comfort, you can come up with a new way to do the head support or a new way to the backrest or it can be anything so, you go through the whole product and then try to decompose into sub functions and then see which function can be modified or added so, that you will get improved the performance.

This is the way how you try to satisfy the customer requirement by looking at the product. So, you can see there are multiple adjust positions, support lower body, dampen vibration, transmit force, so, like this, you will be able to see multiple functions.

So, any products you should take, if I take this product, I can actually decompose into multiple sub functions, so that I know which function to be modified to get a better performance, that is the whole idea of decomposition. Any product you take will be able to see this as an outcome.

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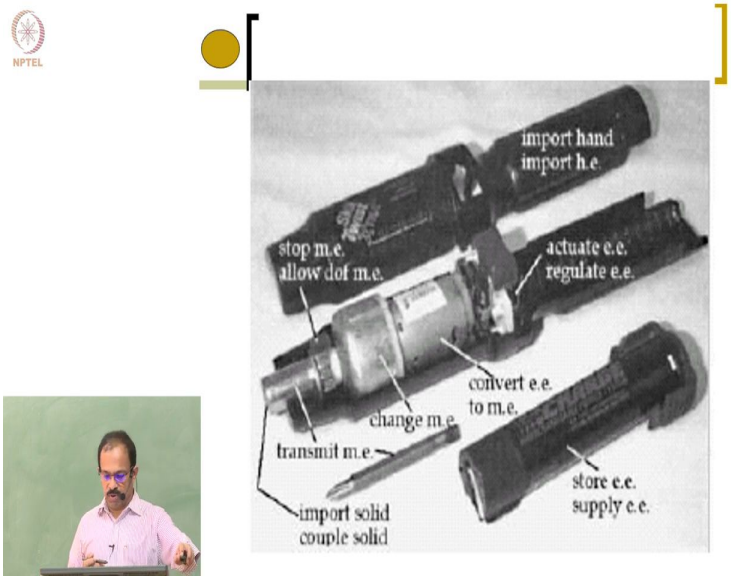

So, for example, you might have seen this product or you take the fan or you take that drilling machine, you will be able to decompose this, how to do this in a systematic way is the question, how can we have a systematic way of decomposing the product? We will see some standard methods by which we can decompose the products.

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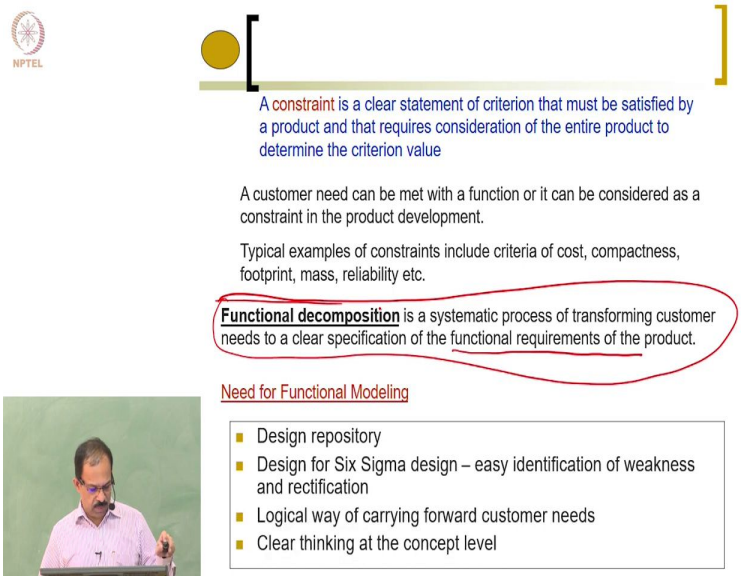

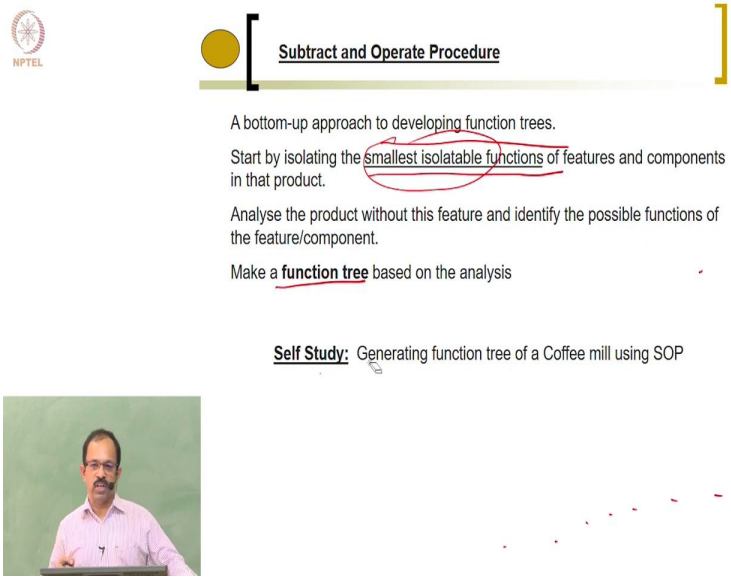

So, functional decomposition is the systematic process of transforming customer needs to a clear specification of the functional requirement of the products. So, what are the functional requirements needed in order to satisfy the customer is basically the functional decomposition, for an existing product we can do this but for a new product we can identify all the functions that are needed in order to get the customer requirements, so, this is what we are going to see.

Let me skip this, that is not an important one so, to do this we actually go by different methods so, there are 2 simple methods which we call it as making function trees and then we have another one called function structure so, first method, first we will look at the SOP which is known as Subtract and Operate procedure, SOP is subtract and operate procedure so, this is to identify all the functions needed in a products, for existing products we can actually use SOP and identify all the functions in the products.

Suppose, you have a table fan which you are seeing in the lab now, substrate and operate procedure says that you remove one part of the products, you remove one part of the products and then try to operate it and then see if it is functioning, what is missing in that product, when this product is not, this part is not there what will be missing in the

products or in the performance of the product, what is missing and that missing element is the function of the products.

For example, if I remove this shaft from here suppose I remove this shaft from here and then try to operate this, what will happen? You do not get the blades rotating so, the rotation of the blades and transmission of torque you do not get then, you know what is the role of this shaft, like this if I remove this cable and then try to operate it, what will happen? It would not operate because it cannot provide electricity.

So, this way you can operate a product by removing the parts and then or logically try to understand what is the, what is missing in the products by using that you will be able to get all the functions that are known as subtract and to operate procedure to get the functional decomposition. Start by isolating the smallest isolatable functions of features and then prepare a function tree. So, what is a function tree?

A function tree is you write the top level function of the products like in your assembly charge you write the top level assembly so, here write the top function and then see what are the sub functions providing this top function and then try to decompose each one into small functions and if there is further you divide this so, this is known as the function tree.

So, by subtracting and operating you will identify, you will be able to identify the smallest functions and those smallest functions will add up here and you will be getting it as a function tree. So, this is known as the subtract and operate procedure for identifying sub functions. So, now whenever you take out the product from the part from the product in the lab, you should be able to see what the product is, this part doing so, in the chart what you used to prepare in the lab you used to prepare a chart of the part, the part name.

Now, in the next one you need to add a column for that, what is the function of that part, each part when you take out whether it is a screw or it is a shaft or it is a blade you see what is it actually doing in the product and write down that as a function and when you writing a function you need to keep in mind that the function should be written as a noun

and a verb, for example, transmit torque so, transmit torque is a function, hold blade so, hold blade is noun and a verb so, like this you should be able to write the functions here, whatever may be the function try to write it with a simple noun and a simple verb then you are getting the functions identified in the products.

That is what you will be doing in today's lab class. When you do the product tear down you note down the part and its function also along with the other things like material and everything that you write. Add this also, that is the one thing which you need to do. So, let us look at how you actually find out the SOP.

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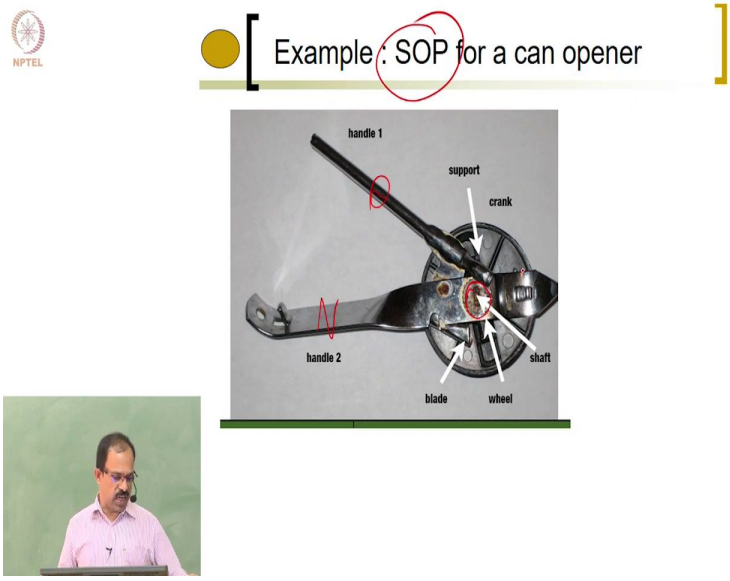

So, we will then do a simple example for a can opener, all of you hope, all of you know about this can opener, all of you seen this and actually you are, this Milkmaid and all if you want to cut open the can you will be using this and then you will be rotating it so that it will actually cut the top cover of the can that is known as the can opener. Nowadays it is all pulled out, so old one there was no pull out so you have to cut it open so that is the one which we are shown here.

If you have not seen I will show you later, but just to give an example, how do you operate this, do SOP for a can opener so, each one you try to understand suppose, you remove these parts and then see whether you can operate it or if you remove this part whether you can operate it or you remove this blade, cutting blade whether you can operate it so, this wheel. So, like this we try to see what each one is doing and then write down it in the chart and that is known as the operate, subtract and operate procedure.

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Component Name	Form	Function
handle 1	x	import human force, transmit human force, magnify human force, convert human force to rotation, guide rotation, stop rotation
handle 2	x	import human force, transmit human force, magnify human force, convert human force to rotation, guide rotation, stop rotation
support	x	stabilize can
blade	x	magnify rotational force, remove lid
crank	x	import human force, magnify human force, convert human force to rotation
wheel	x	stabilize can, transmit rotation
shaft	x	transmit rotation
rivet	x	allow rotation

So, we will take each one, handle one and then try to find out what its function, handle two, support, blade, crank, wheel, shaft etc. So, this is the subtract and operate procedure and finally you will see these kinds of functions. So, you can see it is like an import force, transmit force, magnify force, convert force to rotation, guide rotation, stop rotation, everything you can see is a noun and a verb. So, whenever you write the function you have to use a noun and a verb. Stabilized can, transmit rotation, allow rotation.

So, this way you should be able to identify the function in each product, each parts by writing it as a noun and a verb, that is the subtract and operate procedure which is applicable only to existing products but it is not existing normally you cannot do this and therefore we do something called a better method called FAST methods.

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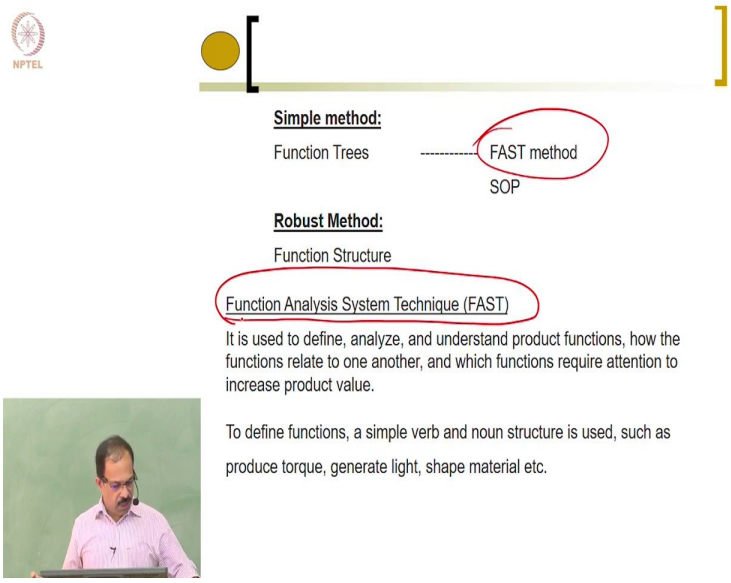

So, the FAST method stands for Function Analysis System Technique. How do you analyze the function of a product and that technique is known as Function Analysis System Technique? So, it is used to define and analyze product functions and how the products relate to one another. So, it is a very simple process, so we do this in a very systematic and simple way by looking at the product and then trying to understand how it works.

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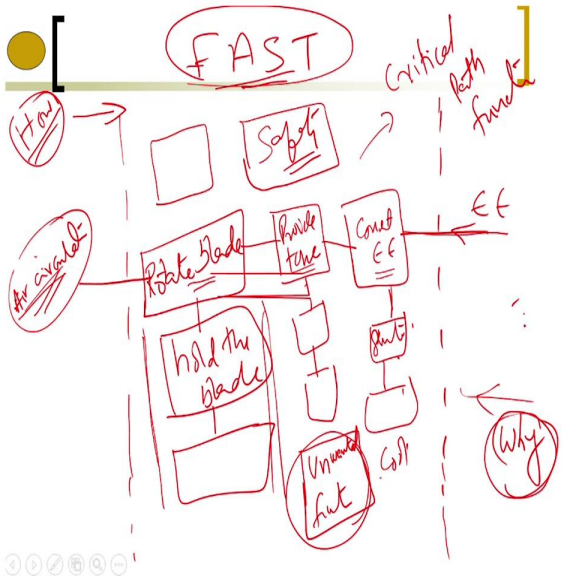

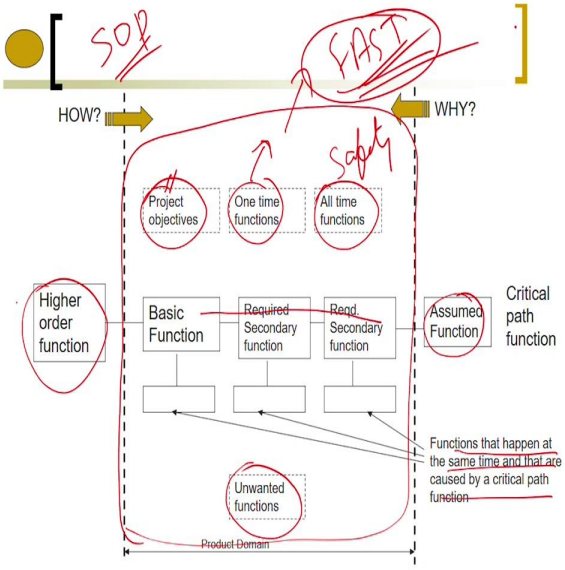

So, I will give you a brief idea how it works, so we will see what are FAST methods known as Function Analysis System Technique, not very fast it is slow. So, what we do is, we actually draw two lines and say that this is what actually happens in the product, you give an input to the product and you get the output of the product. So, this is the function analysis system technique so, we draw two lines and say that this is what you are giving as an inputs and input is an assumed function which say for example, you give

electricity, electrical energy here and then you get air circulation, air circulation here so that is the output, this is the inputs and this is the output.

So, what is happening inside is known as the product function so, all this what is happening between these two lines we call it as the function of the products. Now, we want to know what is happening to this electricity and how this electricity is converted to air circulation at the other end and whatever happens inside is because of the products and the product is doing something inside to get these converted, all this things needed in order to convert this electrical energy to air circulation is the function of the product.

So, what we do here to understand the function is to assume that this air circulation is the output and then I will ask the question how air circulation is happening, simply ask a question how are you getting air circulation, how are you getting air circulation in this fan? Simple looking at the products can you say how the air circulation is happening? Blades are rotating, right so simply by rotating the blade you are getting air circulation.

So, basically how, you rotate the blade? The next question is how to rotate the blade? You convert you convert electricity or you provide torque, you can rotate by providing torque to the blade and how do you provide torque? You convert electrical energy, right. How do you convert electrical energy? Using a motor right. So, now we have an answer for the product so we do not need to go further ask the question then, we say you provide electricity.

So, that is the input so, now we have come to a path where we can say what is happening, how we are getting air circulation by rotating blade, how we are rotating blade, you provide toque, how are you providing torque, you convert electricity in to torque and how do you do this by providing electricity, electrical energy.

So, now we know what is happening inside the fan so this is the method by which we try to identify the main functions of a product or the main line function or the critical path function, so this one we call it as the critical path function. So, this is the first step now, you can actually do it from the other side also, we can ask the question from here, why,

why you provide electricity? Because you want to convert the electrical energy, why do you want to convert the electrical energy?

Because you want to create torque, why do you want to create torque? Because you want to rotate the blades, why do you want to rotate the blades? Because we want air circulation, this method of identifying the functions using asking questions how and why is known as the FAST method of functional decomposition. That is the Functional Analysis and System Technique.

Now, this is only the critical path, we need to have many other functions for this because if you want to rotate the blades, what are the things you need to rotate the blades? Blade should be there then, someone should hold the blade, so who will hold the blade? So, holding the blade is a function. Now, just holding the blade is not enough, so in order to hold the blade you need to do something, you need to change the blade, so, you may have to accept the blades and then if you have to change the blades you may have to release the blade and the blade should be locked.

So, there will be many functions coming there, also when you see that it has to connect electrical energy there will be many functions associated with that, you have to accept electricity, you need to regulate electricity. Similarly, when you provide torque you need to convert electrical energy to torque, there will be many other sub functions like there may be some vibrations or there may be some noise so you need to overcome those things.

So, there will be many unwanted functions associated with the sub functions so, whatever maybe the critical path function, along the critical path function you will be able to identify some required functions and sometimes these required functions will lead to some unwanted functions also, so these unwanted functions need to be compensated by adding an additional function.

For example, if there is something like an unwanted function of generating heat, when you convert electricity you will see that there is a need to reduce the heat, so you cool the

system. It will be a required function then. Similarly, if for every system there will be some all-time functions, anytime this function should be available in the product for example, safety of the, electrical safety is an all-time function so, this should be always there the product is, as long as the product is in use we need to have this safety.

Similarly, there will be some design objective, so that when we write it as another function and design objectives may be to reduce noise, maybe a design objective. So, this is the way how you actually develop the FAST method.

So, to summarize this so, you can look at the method of FAST so, you have these two lines between these two lines are the functions and then you write, you ask the question how and why and then by answering these questions you will be getting the critical path function, that is you have the higher-order function and ask how it is happening, you will get the critical path function or you assume the critical path function at the other end and assume the function and then ask the question while you will be getting the critical path functions.

And functions that happen at the same time and that are caused by a critical path function they are basically the additional sub functions that you can associate with every critical path function and as I mentioned there will be some unwanted functions which you need to overcome or you need to addition, add some functions to compensate for these unwanted functions.

And there will be an all-time function which is safe and there may be some other function like one-time function, these one-time functions may be like you need to have a proper packaging in order to withstand the transport problems or if it gets transported it should not get damaged. So, these are basically one-time functions and of course, the product objective should be written at the top left-hand corner, so that that becomes the core of the design process.

So, this is the way how you get the FAST decomposition so, by following this procedure you will be able to identify all those sub functions either in a product so, we look at other methods available for decomposition in the next class thank you.