Product Engineering and Design Thinking
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Module - 05
Embodiment Design and Eco-design
Lecture - 21
Embodiment, Architectural, Configuration, and Parametric Design

Welcome back to our course on Product Engineering and Design Thinking. We are now in Module 5; the Lecture number 21 that is first one in this module is on Embodiment Design and Eco-design. And, the today's lecture would be on Embodiment design, Product Architecture, Configuration Design and Parametric Design.

In fact, the rest 3 that parametric the product architecture configuration design and parametric design those three actually are part of embodiment design. That we will discuss.

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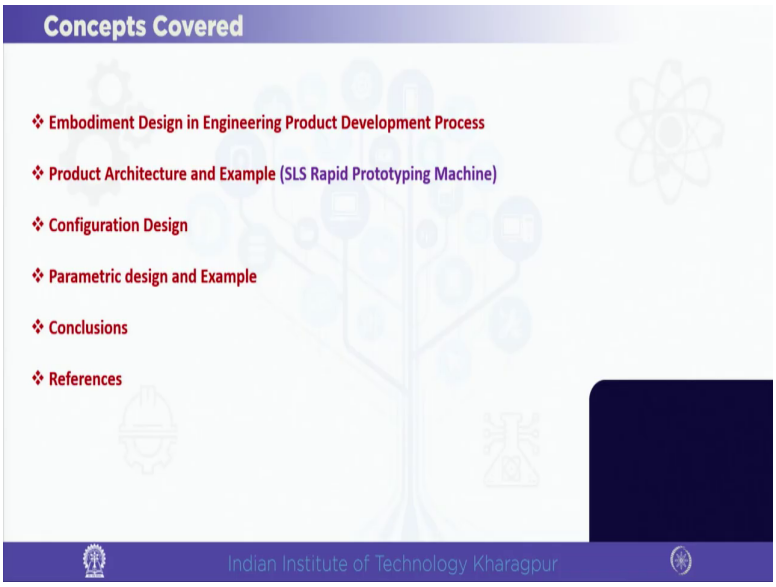

Now, in this session the lectures that will be covered is embodiment design in engineering product development process and also is applicable in general product development process as well. Then we will talk about those three major stages in embodiment design that is product architecture with an example. We will take an example of laser sintering rapid prototyping machine, it is development architecture development.

Then we will talk about the configuration engineering, configuration design that is what will be the size, shape, etcetera we will talk about that and finally, the parametric design most importantly like say for example, where the dimensioning and tolerances etcetera are finalized and that also will come with an example.

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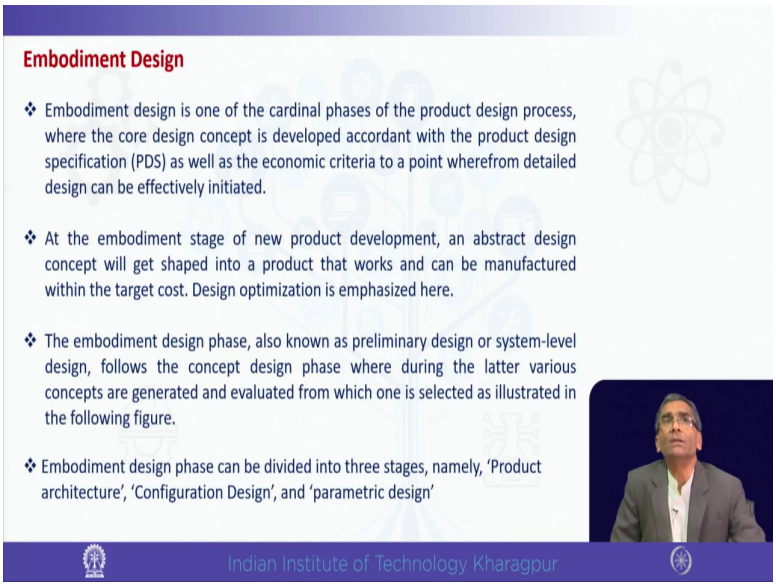

Now, as we proceed, first let us have the broad idea of what embodiment design is, then it is components like say product architecture, configuration design and parametric design will be discussed. It is one of the cardinal phases in product design as you would recall that we had functional design and conceptual design, then embodiment design.

And, then we will proceed to the detail design, but for now you would be going up to the parametric design in this session. And, it is developed according in accordant with the product design specification that is PDS as well as economic criteria that is what will be the cost constraints etcetera and what will be pricing on the target cost. So, accordingly it has to be developed.

The target cost the what that I have just now used is very important in product development because when we set a price or see a price that the product is being sold at, we need to know

at what cost it is actually to be manufactured so that the product remains competitive and viable because normally a product that is produced be it a TV, be it a refrigerator, be it an air conditioner or be it an aircraft, any item that normally what we procured from the market those are sold through certain supply chain points.

Like say first it goes to distributor, then maybe to dealer or retailer depending on the supply chain it might go directly to the retailer or it may go via dealer to the retailer and finally, it reaches there. See even for certain engineering goods that you have seen that there are dealers for particular regions where from you buy your machines and all.

So, what happens in the process every you know stage say be it the distributor be it retailer they retain their profit margins. So, finally, what add gets added up is the price. So, when we are producing because the company also will have to make it is own profit and that margin is to be kept.

So, target cost is when we deduct all these profits at different stages and what is the factory cost that is called the target cost and the product is to be built within that. So, that economic so, when we are selling economic criteria those are important to be kept in mind and. So, that is how the one of the design constraints.

Here what happens the abstract design concept get shaped picks up shape into product that functions, that works and can be manufactured within the target cost. Now, the target cost what I have used and I have explained it just now. Design optimization is emphasized here. Different components are being used and. So, naturally what will be their sizes etcetera we will discuss that, but we will discuss under different stages like as I have already said those three stages.

The embodiment design phase, is also known as preliminary design or system design or system-level design, it follows the concept design phase. After the concept design it starts in fact, where in the concept design the last part of it is the concept selection. So, just after

concept selection the embodiment design begins. Embodiment design phase can be divided into three stages which I have already mentioned.

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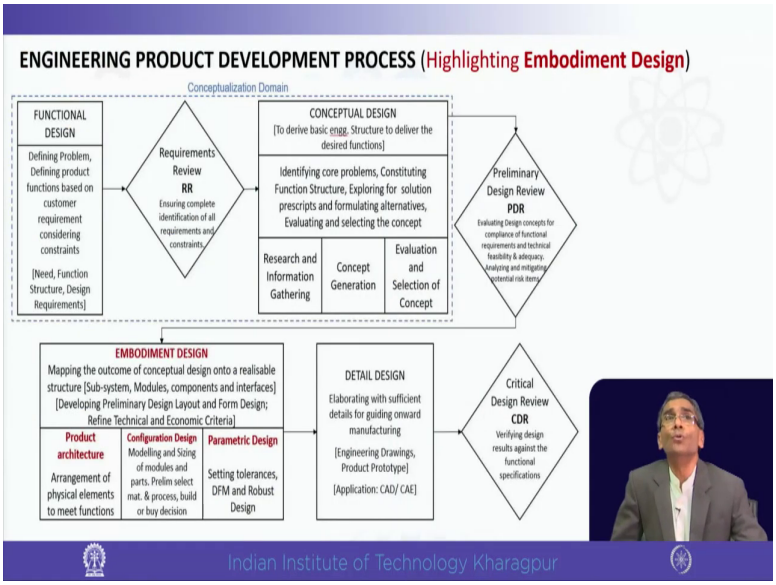

So, we will go to the individual parts. Here I am placing a slide which possibly is difficult for you to read. Now, the question is that this reading here is not necessary at all. It is only to understand that already we have discussed in the block diagrams which you can read is that functional design.

Then the review that is requirements review, then it is conceptual design and in conceptual design we have already discussed a number of things and their stages like research and information gathering, concept generation, evaluation selection of concept which just I had have said and after that conceptual design there is a review which is called preliminary design review.

Then our focus today's session is the next part which is written in red font or maroon font rather which is embodiment design. And, here below that you can see that there are three words in red in three compartments one is the product architecture, there is a configuration design, a parametric design. This is the this block is of interest for today's session. So, we do not have to study the whole thing now because already the first part more or less we have covered.

Now, we are into this phase and then from here it goes to detailed design. And after detailed design there is a critical design review or it sometimes is also called detailed design review. Now, so, why this diagram is placed? This diagram which I have created for convenience of all students who would like to see the entire design process including the review stages in one page, in one canvas, it is not frequently available. So, you please later on look at this diagram which will clarify several points.

But, now instead of focusing on this we will go to the embodiment design and first part is the product architecture.

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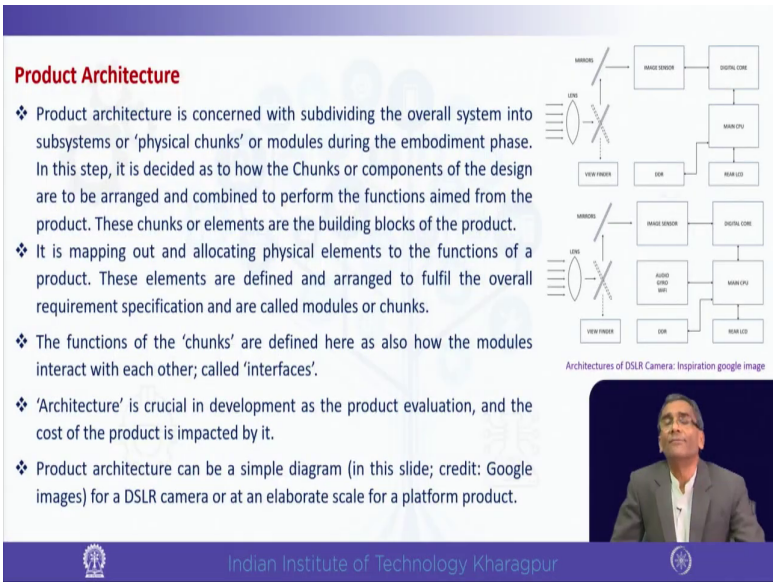

So, what is product architecture? Product architecture is concerned with subdividing the overall system into subsystems or which are called physical chunks, a camera for example, which you can see on the right hand side the block diagram. It is a DSLR camera block diagram. So, closely if you look at later, I am just explaining now because this is not which I would be explaining here, but a in a larger image you will be describing it later.

But, here just to show that there are different blocks like say lens, mirrors, event sensors, digital core, main CPU, LCD, DDR etcetera all these things are there. So, these are the chunks. I will tell you what chunks are – that is the module or subsystem of a big product which is you know divided subdivided into elements or chunks.

It is mapping out and allocating physical elements to the functions of a product. So, we first you will you remember we did the function analysis. So, the functions will be allocated to the

requirement and then those functions will have to be addressed through these physical components.

Like say if something is to be rotated, we will have to use the motor. Now, what kind of motor that will be decided subsequently whether it is a DC motor, a induction motor or BLDC motor or servo motor or stepper motor whatever it is. Now, so, that mapping is to be done here. We will see the example.

The functions of the chunks are defined here as also how the modules interact with each other called interface. So, when there are different modules, the modules should be able to interact between them. Say like when I am pushing the shutter, the flash should work so, in a camera.

So, those are the interfaces or interconnections and they the components therefore, interact through these interfaces. So, that is also a part of architecture; breaking down in modules and how the modules are connected or related or interfaced that is also to be same. Architecture is crucial in development as the product evaluation that is done and the cost of the product is impacted by it.

I just discussed about the cost aspect of it. Product architecture can be a simple diagram or it may be a complex diagram depending on a product. If it is a car or if it is a platform product, then the complexity increases and the and it becomes a you know big canvas architecture.

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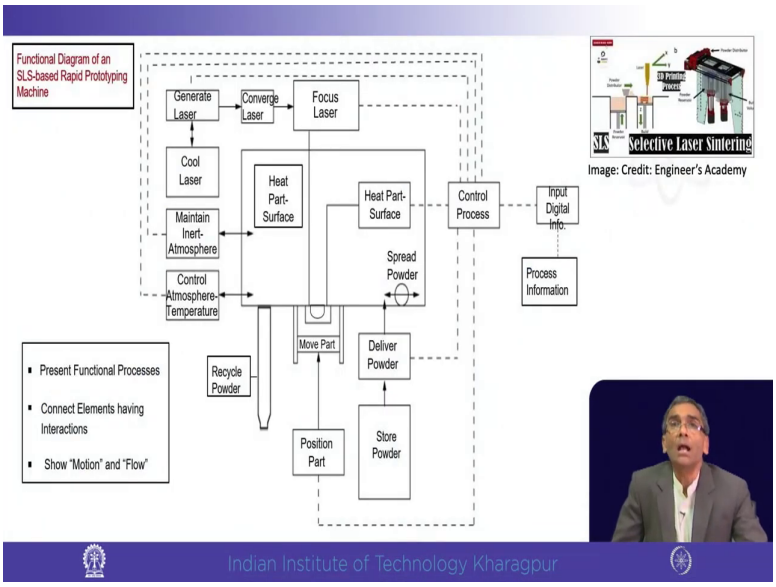

Now, whatever we have discussed, now let us examine and see with an example. The example is for rapid prototyping machine which works on laser sintering principle of powder, polymer powders. So, what happens? The process is first it is a laser process I said.

So, laser is generated through certain lasing methodology, maybe it is a CO 2 laser and then the laser is converged laser converged and then that converged ray is focused onto the job or onto the rather here job means the powder that is getting accumulated on the top surface and which is selectively being sent sintered to solidify it.

So, what happens is when is focused on the powder and it is a laser ray is applied on it, it gets melted and it gets solidified and layer by layer therefore, it builds up. Powder comes to the next layer then it is solidified another layer is built up. Again, power powder is with a roller is

put in, again it is solidified builds up. So, this is how layer by layer this is built up and that is that is it is built it gets built up through addition. So, it is known as additive manufacturing.

But here we will discuss only the you know the process. So, after the focusing laser on the job the laser part laser part of the work is explained. But then where will it work? It will work within the chamber where the heat is to be retained and maintained. So, that is the preheating also is done.

Now, what happens that when this is happening then the roller in the chamber moves and the powder the that is delivered into the chamber that gets spread. Now, when it gets spread only that portion where laser will be applied that will get solidified rest of the powder will be recycled back, alright. Now, when we said laser so, the laser also needs a cooling unit.

So, here now you might have noticed by now as we discussed when we discussed functions we said the functions are referred in the form of a verb and noun. So, here you find the what is our generate laser, converge laser, focus laser. Similarly, when the laser is unit is to be cooled, it is writen cool laser; cool is the verb, laser is the noun. Maintain is the verb, maintain inert atmosphere; then control atmosphere temperature.

Similarly, move part, deliver powder, store powder etcetera are there and then it is controlled which is therefore, again a verb and noun control process then, in input digital info, but from where this work will happen. So, it has to be a file a CAD file which is given as input and this processing happens and the process information which ultimately is a computer. So, this is the function functional diagram of a rapid prototyping machine working on the principle of laser sintering.

Now, we will see this diagram when we are allocating the physical elements to this function or in other words if I loosely may say if the elements are being super imposed on the functions, we will see first how the blocks happen and what the physical components goes there. We are presenting it in one and in the next diagram.

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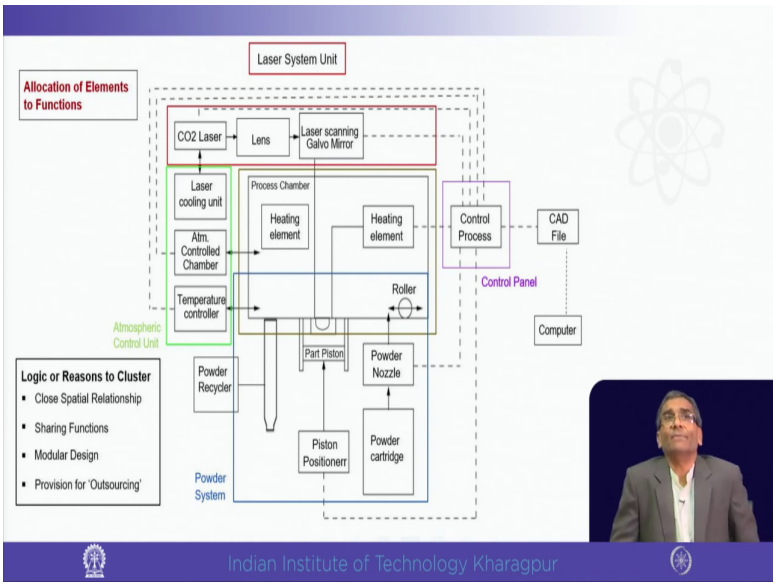

The next this diagram therefore, shows that we is in earlier case we said generate laser. Now, here we are saying CO 2 laser that is CO 2 laser process source is being used that is converged; that means, converging through a lens and then we said the focus the laser. Now, the laser how it is focused?

That physical element is laser scanning galvanometer which uses the galvanometer and the works on that principle of turning to adjust the focus to the point which is very common. You can check in on the internet to see if you are interested, but it is for the focusing purpose.

And, similarly the it becomes the physical component become laser unit, atmosphere control chamber, temperature controller, part piston, the powder delivery is the powder nozzle, the it the storage is powder cartridge that powder cartridge is put in the machine and the control

process is the control panel now or control cabinet whatever we call it. And then the CAD file comes from the computer.

So, in this you can see the functions in the earlier slide which was the functions I will go back to the function slide just for a second. Here you see it was the functions it was only you were talking about the functions and now the physical components are allocated from those functions and it has become the physical chunks or physical elements which are in that block.

Say if the red outline one is that laser block laser system unit. The green block you see where which is the atmospheric control unit. Similarly, if you see that there is a brown box which talks about the process chamber. Then below that with a blue outline all the parts are related to the powder system and then on the right is the control system or control panel.

Basically, so, these are having 5 major chunks or subsystems or modules. So, you we can we have just now seen how the function is transformed into the physical elements or you know allocated through physical by the physical elements. The functions are allocated to the physical elements and they are placed like this.

So, logic or reasons to cluster is close special relationship that they should be close to each other sharing functions, modular design because these are modular – each are module we will talk about the modular architecture little later. Then provision for outsourcing. Some of the chunks or modules may not be produced in house they are procured from outside.

So, this module, this modularization or the architecture will help us to find out which can be prepared from outside and which will be made in house.

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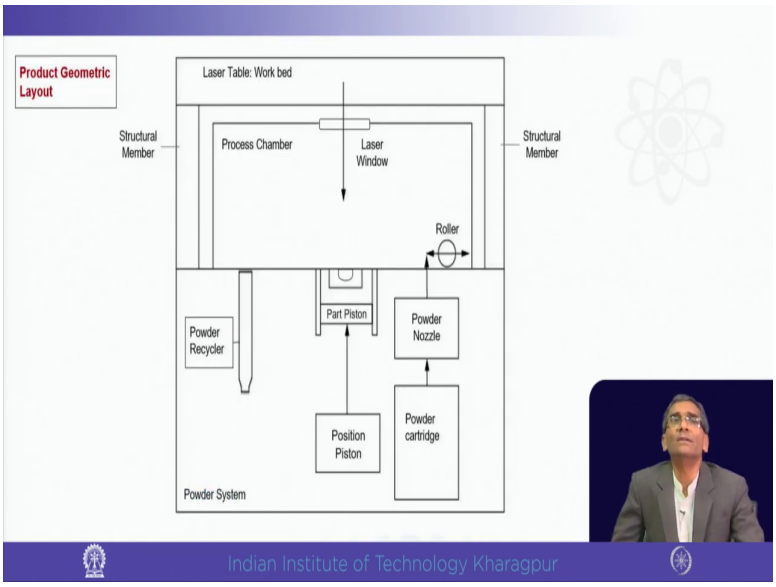

Now, this is the product geometrically out based on that architecture. On top it is the laser table, the structural member on both sides that process chamber, laser window all these things that we had seen. Now, this power recycler and power system all together is there this is the construction or geometric layout of the product.

So, from the function we have gone to the element allocation and from the element allocation we have arrived at the product geometric layout.

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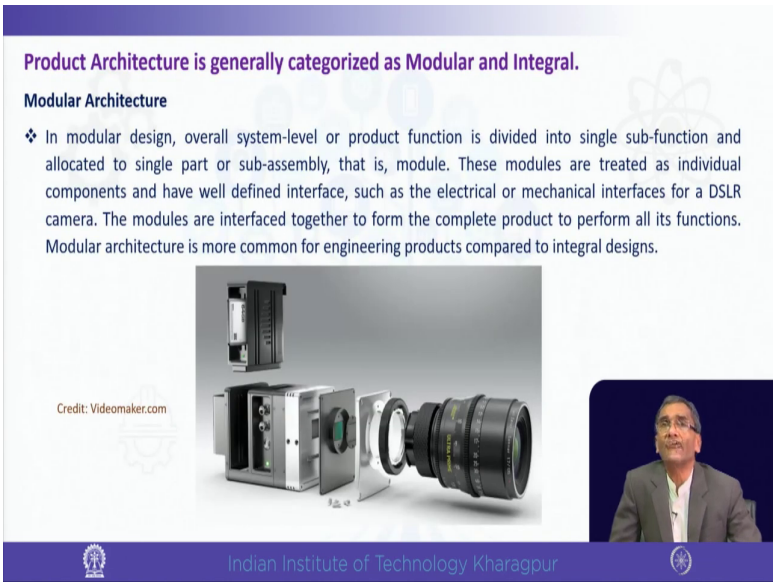

Now, we have touched on the modular and integral. There are two types of architecture one is modular, the other one is called integral. Modular that we have just understood from the earlier drawing, but here it is the image from which it is quite clear to you that how different modules are put together where the overall system level product function is divided into single sub function and allocated to a single part or sub assembly that is the module. We have already described that.

Like say in DSLR there are this mechanical and electrical interfaces in the camera the modules are interfaced together to form the complete product. So, interfaces are there and the modules are there. So, the camera works. We will talk about the characteristics later.

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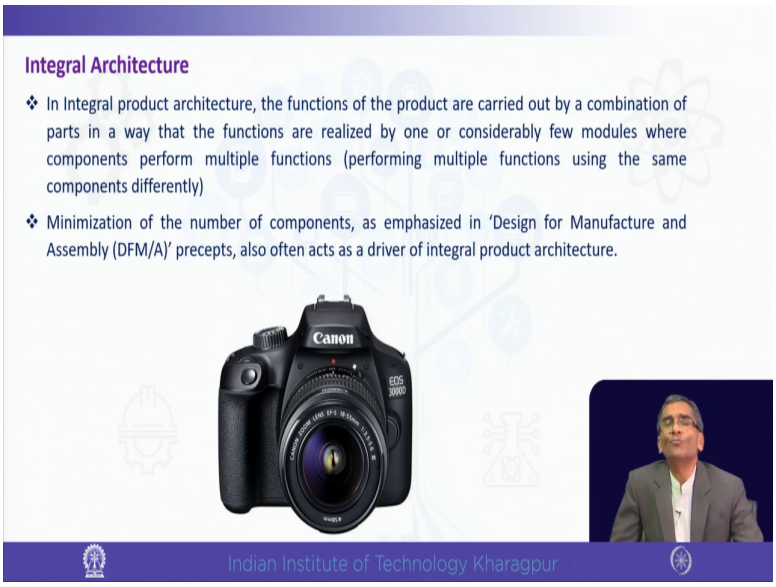

And, this is one example of a integral architecture where the functions of the product are carried out by combination of parts in a way that the functions are realized by one or considerably few modules. So, it is rather more compact and number of modules are either one or very few.

And, the it actually minimizes the number of parts and also the cost due to that, but it uses out on certain flexibility the advantage you will discuss just now of the modular design. But both has both have some advantages I mean here or there. So, these are some advantage on the performance and cost, but in modular design the flexibility is there.

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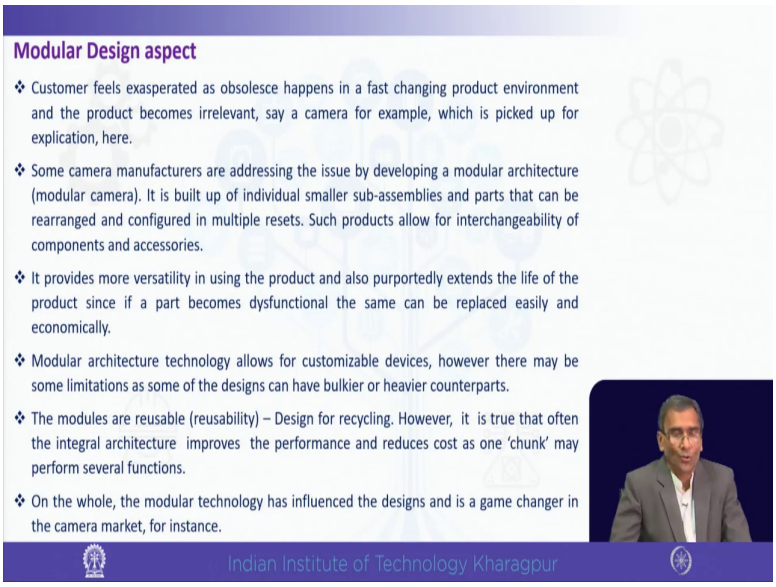

So, in the modular design aspect it is the very easy because another thing is the obsolescence. See if the if a particular module or the function gets obsolete, then it is in for an integrated product the entire product is to be changed, but here only if that module is changed then this product remains functionable. As since we have taken the example of camera, if we take that example forward then.

So, many manufacturers including the camera manufacturers or many others are in fact, the car manufacturers also they are using the modular design now. It provides versatility using the product and also purportedly extends the life of the product since if a part becomes dysfunctional the same can be replaced easily and economically.

Modular architecture technology allows the customizable devices. However, some limitations are there it becomes a little bulkier or heavier in configuration compared to the integral ones.

Reusability we have already discussed and it is therefore, helpful for recycling when in the modern time the people are talking about the how the recycling of a product can be done.

We will discuss much in the subsequent discussions, but reusability is an important recycling just keep that in mind we will discuss it in detail later. On the whole the modular technology has influenced the designs.

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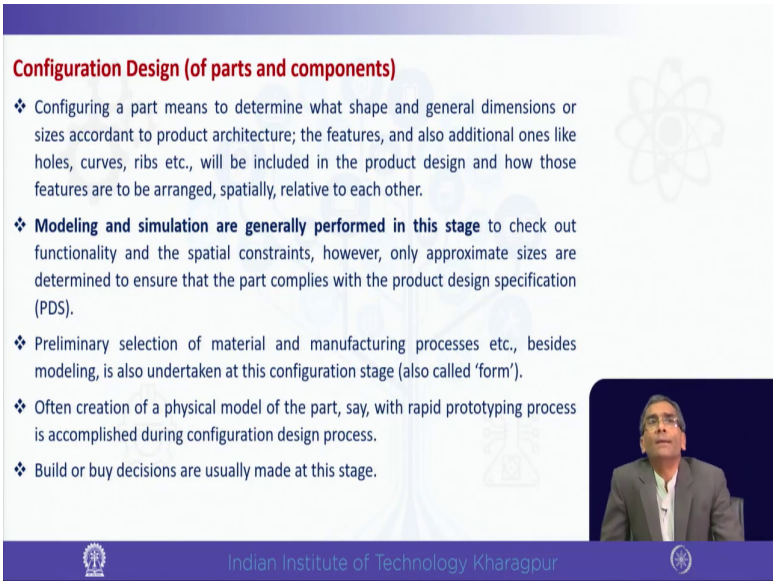

Now, after the architecture product architecture it is the configuration design of parts and components that is configuring a part means to determine what shape and general dimensions or sizes according to product architecture shape sizes the features there are different features also like say ribs, curves, holes etcetera are to be also provided.

So, those are to be included in the product design beside the shape and size and how the features are arranged in space or specially related to each other that also is discussed here. Here very importantly we will discuss that the modelling and simulation is done at this stage. Reasonably fairly using various software which perhaps you have already know or you have heard about and maybe you have studied like say some CAD software.

I do not know whether you have used CIE software like say Ansys or, but definitely I am sure you have heard the name there are many such software which are not very difficult to pick up. So, if you choose to work in this lane, it is a very exciting area to work. So, along with CAD you can learn some in the CAD in fact, not only Ansys many software CAD software now are having those features like say solid works etcetera.

Now, they are having those features built in so, the simulation can also be to some extent done. So, here we decide the approximate size of the products etcetera, shape of the product and all, according to the PDS – Product Design Specification that we had settled earlier, determined earlier, established earlier. The materials and manufacturing process also is generally addressed and selected this configuration often also known as form. What will be the form? What will be the form of a clock or a wristwatch or television set?

Often creation of a physical model of the part say with rapid prototyping process is also done at this stage. Very importantly here I would like to mention that make or buy decision or build or by decision is done at this stage. Some components as I was telling to be procured from outside or bought out components which are called they those are items to be decided.

And, in product design it is always to be remembered to contain the cost it is always preferable if we can use standard parts as much as possible like say bearings or some V beds or various other you know gadgets say for you know for electronic components it may be some sensors or actuators which are available in the market.

So, the standard ones would be very helpful. Say let us say, stepper motor or servo motor or those kind of thing those are standard things that do not know one has to design, but those can

be procured and fitted in the product that would help in two ways. One is that the cost will be counted and two because the technology or production is proven then it is reliability also will be high. So, that is the prescription to be followed.

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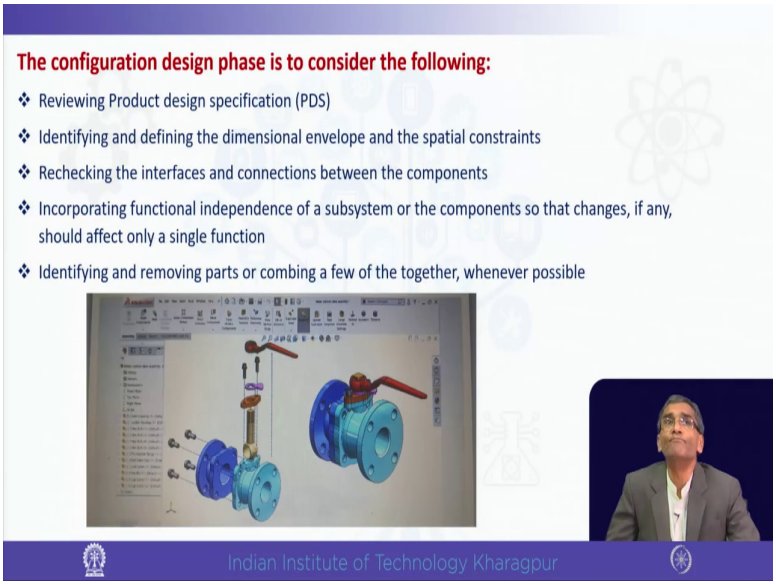

This is the example of configuration design how it is you know dimensions are provided etcetera that are done here. Reviewing product design specifications is done at this stage. Identifying and defining the dimensional envelope that is the within which space it would have to be manufactured total length, height, width kind of a thing like in I just I was talking about the rapid prototyping machine which has been called envelop within which it has to be produced.

So, that is another constant. Rechecking the interfaces and connections, so, all these things are reviewed at this stage.

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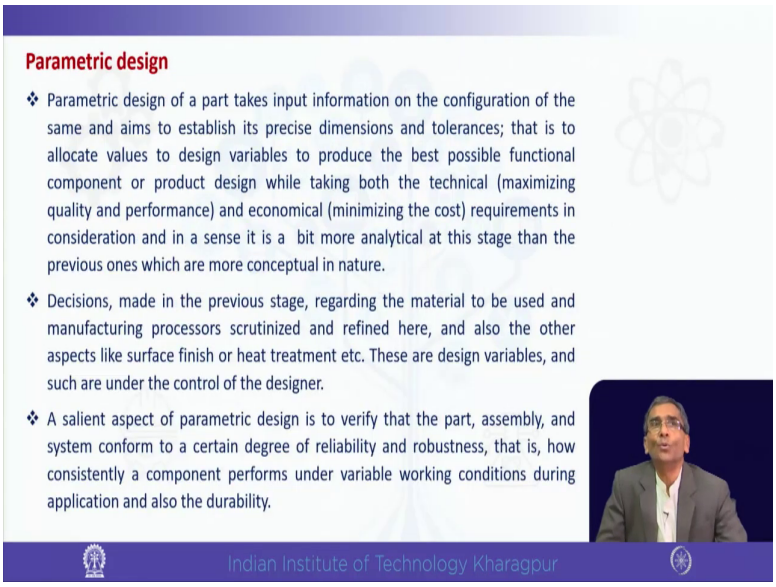

Finally, we will go to the last phase of the discussion that is the parametric design. Parametric design of a part takes input or information from the configuration design where it was selling more or less roughly the shape and size. Here the dimensioning and tolerancing are done to finalize the final specification. And, where the objective is to maximize the technical performance that is quality etcetera quality, reliability, durability etcetera and also economical that is minimizing the cost.

So, decisions, made in the configuration design stage or the previous stage rather regarding the material to be used and manufacturing processes are verified, scrutinized and finalized. Say if we are talking about steel say what grade of steel what tolerance etcetera to be finalized. So, these are then also the surface finish the heat treatment these are design variables. So, design variables are to be decided by the designer done here.

A salient aspect of parametric design is to verify that the part, assembly and system conforms to certain degree of reliability and robustness, that I have just now said. And that is how consistently a component performs under variable working conditions during application and also the durability say it is a repetitive load or high temperature application. So, those should be able to withstand those variations.

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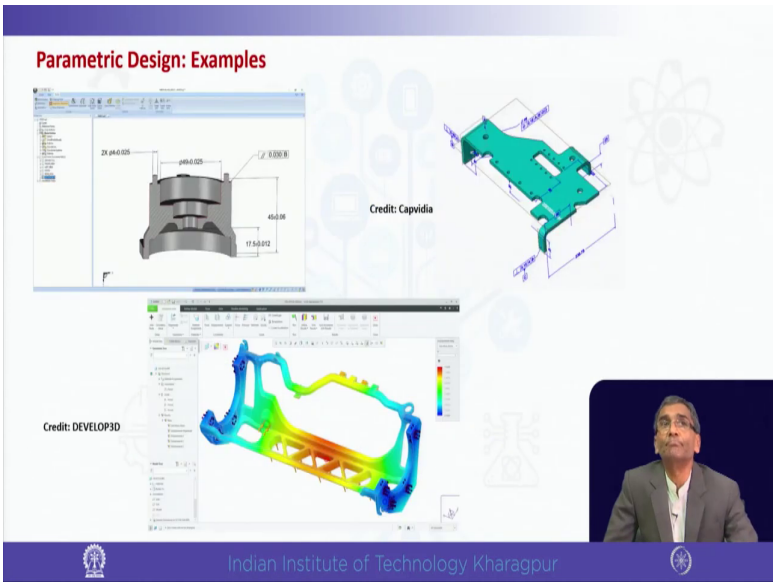

These are certain examples of parametric design which you perhaps have seen several times in your system either you have done it or you have seen the images which are the CAD images or CAE images that is where the stress analysis is done the dimensioning is done in the CAD. So, these are certain images taken from the particular source and the source have been named here these are done in the parametric design.

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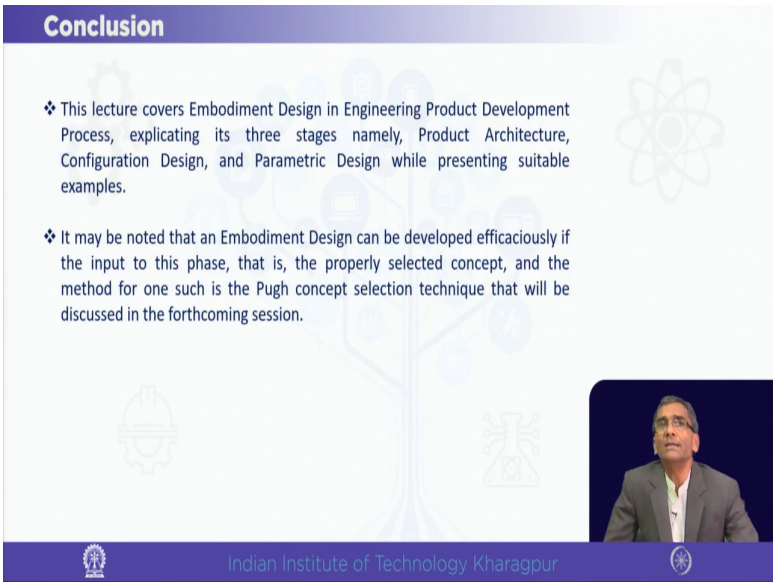

So, we discussed the three aspects of embodiment design that is product architecture, configuration design and parametric design here. It is important to know that to make the embodiment design this phase effective the correct selection of the concept is very important because that is the input.

So, what we will do is one of these concept selection process is Pugh method that we will be discussing in the next lecture that will help to understand and apply rather the embodiment design phase much better.

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Here is the reading list which you can refer to and so, this is what is about the today's session and I hope you would be you know looking at different products and try and decipher their architecture and configurations.

Thank you very much. Thank you for attending the session.