Design Practice
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Lecture – 34 and 35
Axiomatic Design

Welcome to the course Design Practice, lecture module 34 and 35. In this module I will start a new topic that is called Axiomatic Design.

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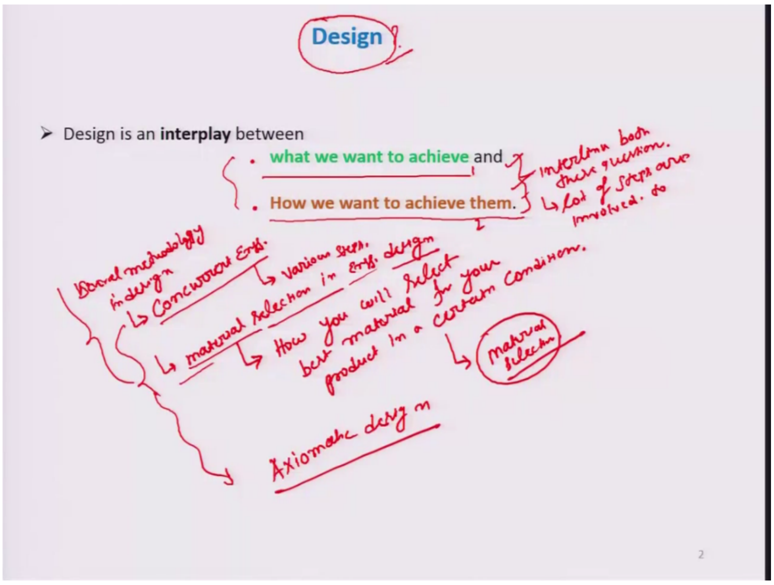

So, first I will discuss what is the design. So, design is interplay between what we want to achieve and how we want to achieve them. So, first what you are saying there, there is you will have to interlink both this questions in a design. So, although they have only two point you are targeting, but in between there are lot of steps are involved to jump from one to two.

So, we have already discussed variety of several methodologies in design, you have already learned concurrent engineering. In this approach you will have already learned how you convert your idea into product, through various steps. Another methodology you have learned material selection in engineering design. So, in this topic what you have learned how you will select best material for your product in a certain condition.

So, in these models you have already learnt how in metal selection in any both questions were involved there ok. So, first you initiated the idea which product you want to fabricate then you went through the various process and after that to a final material selection. So, now in continuation with that I will start a new topic that is called axiomatic design.

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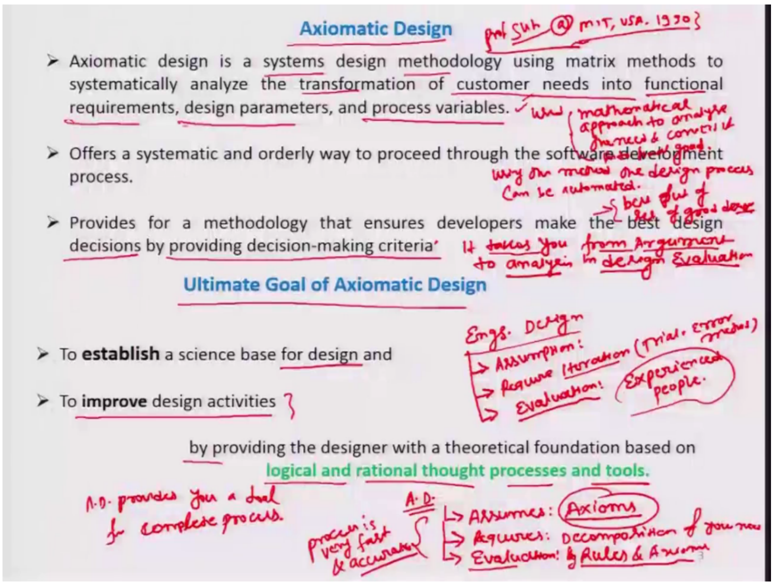

This design this method was by professor Suh at in MIT USA in 1990, he proposed approach that is a basic more about a design framework rather than any principle. So, he proposed a new technique that is called axiomatic design.

So, it is a system design methodology using matrix method systematically analyse the transformation of customer need into functional requirement design parameters and process variables here in this approach what he proposed he just used mathematical approach, to analyse the need and convert it into final goal.

So, for that he used four domains that was the functional requirement design parameter sorry first was customer need second was functional requirement third was design parameter and last one was process variable, I will discuss each element in detail in next slides ok.

Also axiomatic design offers a systematic and orderly way to proceed through the software development process ok. So, using this method design process can be automated. So, basically axiomatic design provides you an identification of a good design and how to pick the best out of a set of good design suppose that you are going to make something some product and you have a set of good design available.

So, which 1 will be best for you that you, you can find the solution in that axiomatic design best out of set of good design also axiomatic design provides for a methodology that ensures developer make the best design decision by providing decision making criteria. So, it takes you from argument to analysis in design evaluation and this methodology is very simple and based on mathematical approach.

So, ultimate goal of the axiomatic design is to establish a science base for design and to improve, design activity existing what about existing design you have you can improve using this method axiomatic design and, and how you will improve this activity by providing the designer with a theoretical foundation based on logical and rational thought process and tools. It means axiomatic design provides you a tool for complete process, you can compare it with engineering design in engineering design first you make assumption which process will be correct and or not.

So, you are making assumption first then after it requires iteration trial and error method like and finally, evaluation and general evaluation is make by experienced people in department. So, like engineering design axiomatic design also have several steps, first it assumes you will have to also make an assumption here in a form of axiom I will explain you what is the axiom later then it requires decomposition of your need and then evaluation that is the most critical parameter and it is done by rules and axioms.

So, here unlike engineering design here experienced people is involved in evolution process, but in this process there is an already rules are available for that. So, process is very fast and accurate.

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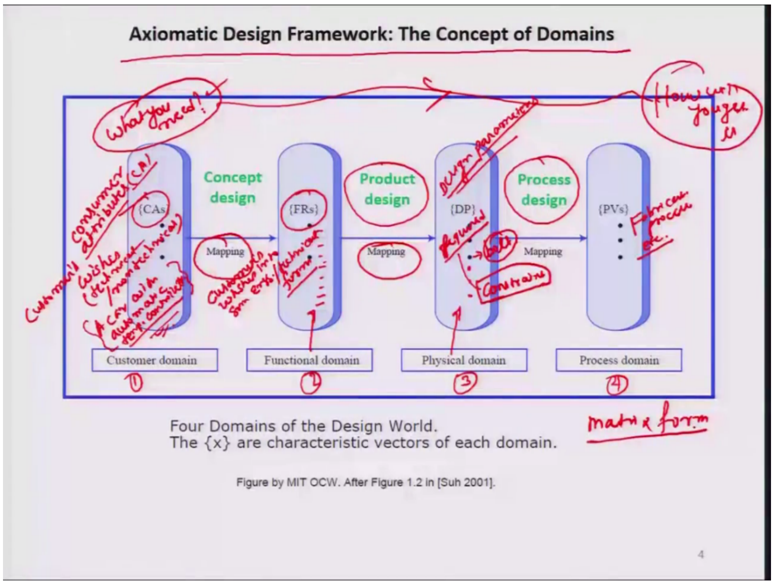

Now, so what is the axiomatic design framework here you can see that it has a general in general axiomatic design framework consist of four domains first one is customer domain second one is functional domain, third one is physical domain, fourth one is process domain ok. So, what I will explain you each one in brief.

So, customer domain in this domain it relates to consumer attributes, it categorise the design in a consumer domain and what is the consumer attributes it is in a generally in a form of wishes customers wishes. And it may be technical or non technical suppose that if someone wants to buy a car with automatic temperature controller. So, he makes customer makes a wishes, he wants some automatic controller in his car.

So, first what you will have to do this is the customer domain, and these are the attributes of a customer then you will have what you will have to do first you will have to map it in a functional requirement that is called a functional domain. In functional domain what does functional requirement does it is a minimum set of independent requirements that completely characterize the functional needs of the product.

So, that means, you have to convert customers wishes into some engineering or technical form. So, there may be a for one need, one wishes you have a several it may be possible that you have a several functional requirements for that.

After that again this functional requirement will have to mapped again for a designing of a product. And this comes into a physical domain in this is DP is for design parameter, how you will how your requirements will have fulfilled, so you will have to select design parameters for that. So, it describes the design in a physical solution space and design parameters are the physical characteristics of a particular design that has been specified through the design process.

So, whatever requirements you have, so you have to choose accordingly designing parameters required, after that and as well as here you will have to also select constraint for that what is the limitation for customers wishes. So, after that after choosing a designing parameters for your functional requirements then again you will have to map into a process domain.

So, that is called a process design suppose that you have a parameter to make a bolt, so which machine will be available for fabrication of bolt. So, that machine is comes into a process, process parameters process variables here it comes fabrication process etcetera.

So, you can see that here customers need what you need here in a left side that is the customers need and it is finally, converted in a how you will get it. So, this from this to this one is converted in an it is decomposed in four steps. So, now and all domain is in an axiomatic design it is represented in a matrix form.

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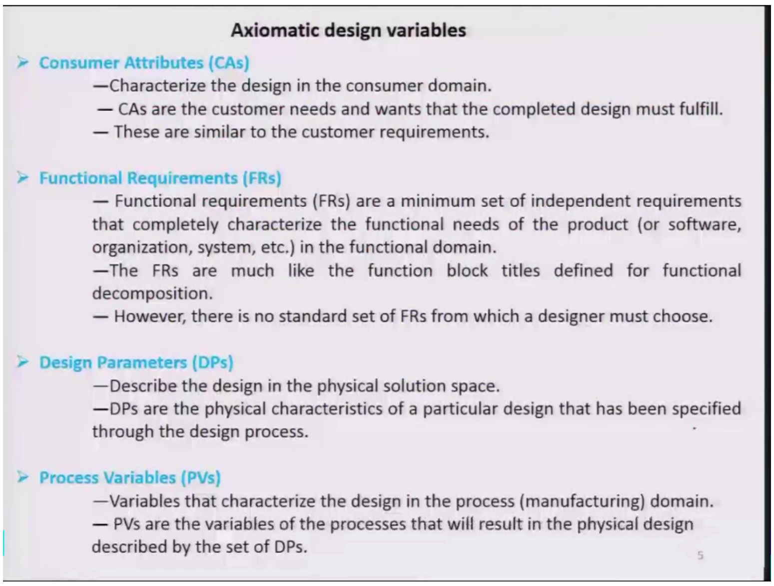

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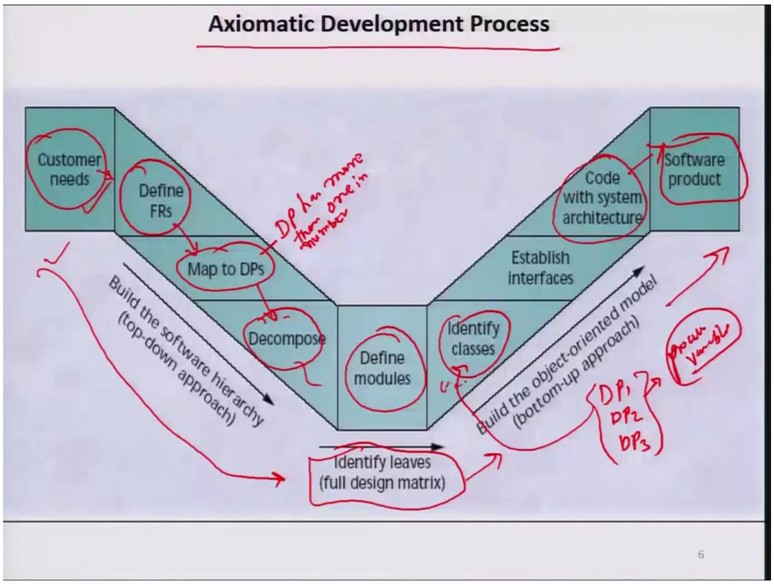

So, you have four domains for an axiomatic design, so how it works. So, first customer need what I said that in earlier slide then again after getting your needs from your customer then convert his wishes into your functional requirement then again it you have to map it in a designing parameter then it if suppose that say more than if DP has more than one in a number then you will have to decompose it.

So, that each parameter effect of each parameter should be taken into account of solving your customers need ok. After that after decomposition of designing parameters you just define models for each one, so that. So, that you can make a full design matrix for that after that just divide it in a classes.

So, class one, class two class three, so that parameter can be ranked. So, DP 1 DP 2 DP 2, in such a way you will have to make a classification of designing parameters after that you will have to make an interface between your parameter functional requirement and what is the process variables are available for that, will be required to achieve your customers need ok.

After that if you can convert it in a coding system then you can automate your system designing process. So, it will come it as a software product. So, this is the way to do how you will do axiomatic design step by step.

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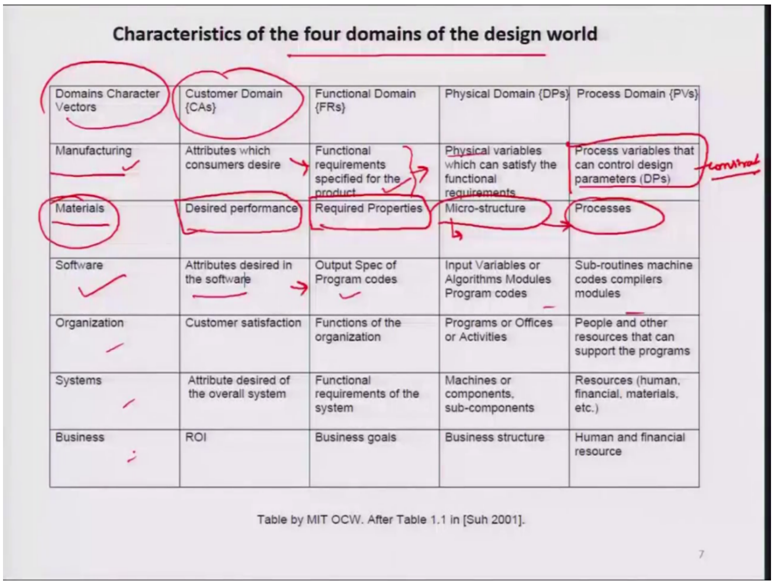

Characteristics of the four domains of the design world

Domains Character Vectors	Customer Domain {CAs}	Functional Domain {FRs}	Physical Domain {DPs}	Process Domain {PVs}
Manufacturing	Attributes which consumers desire	Functional requirements specified for the product	Physical variables which can satisfy the functional requirements	Process variables that can control design parameters (DPs)
Materials	Desired performance	Required Properties	Micro-structure	Processes
Software	Attributes desired in the software	Output Spec of Program codes	Input Variables or Algorithms Modules Program codes	Sub-routines machine codes compilers modules
Organization	Customer satisfaction	Functions of the organization	Programs or Offices or Activities	People and other resources that can support the programs
Systems	Attribute desired of the overall system	Functional requirements of the system	Machines or components, sub-components	Resources (human, financial, materials, etc.)
Business	ROI	Business goals	Business structure	Human and financial resource

Table by MIT OCW. After Table 1.1 in [Suh 2001].

So, here characteristics of the four domain of design world, so here you can see here variety of process are available here domain character vectors are manufacturing. So, for in a customer domain what is the attributes which consumer desire, after that what is the need is converted into functional requirement that is specified for the product after that this functional requirement is mapped into a physical variable which can satisfy the functional requirement.

Again process variable that can control design parameters this is the constraint ok. So, for material if you are doing an axiomatic design for material then what you will have to do first desired performance ok, suppose that a customer need a lightweight cycle. So, so you will have to make a selection accordingly light weight cycle is a functional requirement.

So, you have to require some properties for that how you will make it then what would be the macro structure for that or other parameters like some mechanical properties, chemical properties, and electrical properties etcetera, then and by which process you will be going to make it ok. So, again in case of software there is an attributes desired in a software again you will have to convert in a functional require domain output specs of program codes and like that.

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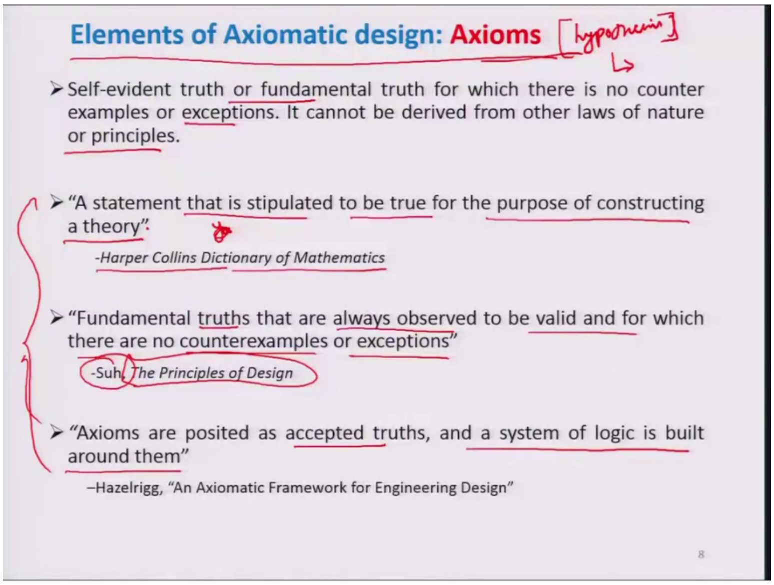

So, so I will discuss what are the elements of axiomatic design ok. So, that is called axioms is the self-evidence truth or fundamental truth for which there is no counter examples or exception. It cannot be derived from other law of nature or principles it is just a hypothesis axiom is a hypothesis, and it cannot be supported by any law or you cannot validate this hypothesis ok, so it is based on hypothesis.

So, various statements are available regarding axioms and these are first a statement that is stipulated to be true for the purpose of constructing a theory. So, this statement was given by Harper Collins in a dictionary of mathematics.

So, what is what this statement said that, so there is a you will have to make a statement for a particular design process and there would have an only that will be only hypothesis only then another statement is that fundamental truth axiom are the fundamental truths that are always observed to be valid and for which there are no counterexamples or exceptions. And these were given by professor Suh in a department of mechanical engineering MIT, USA and in a book principle of design.

And third one axiom are posited as accepted truth and a system of logic that is built around them ok. So, you can see that these are the only hypothesis only. So, they have no any base and support of technical support. So, axioms you will have to make an axiom for your design process.

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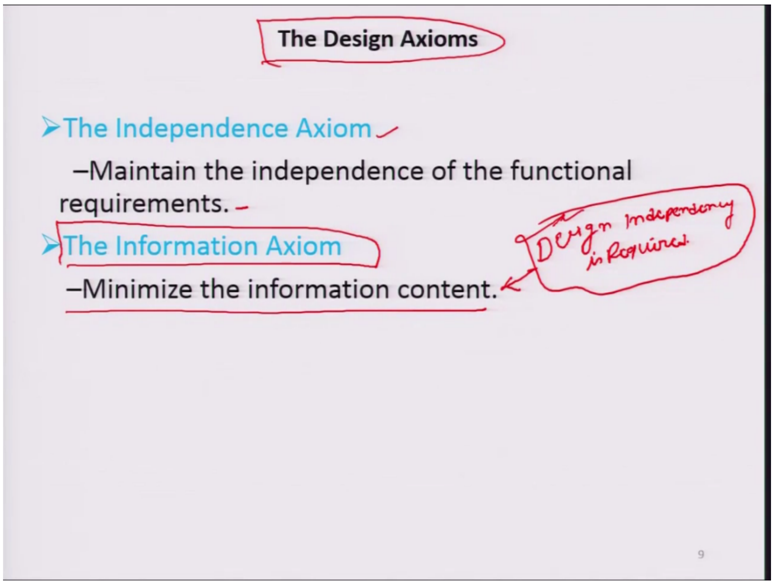

So, in a broad way the design axioms can be classified into two parts first one is the independence axiom, and what is the independence axiom. It maintains the independence of a functional requirement, it indicates that the aspect in the proceeding domain should be independently satisfied by the choices carried out in the next domain, and second one is the information axiom here the primary purpose of this axiom is that minimize the information content; so that you can make the design independent.

Design independency is required and you can achieve by minimizing the information content. So, that your matrix will be uncoupled and all parameters design parameters will be independent with each other for a particular function functional requirements here.

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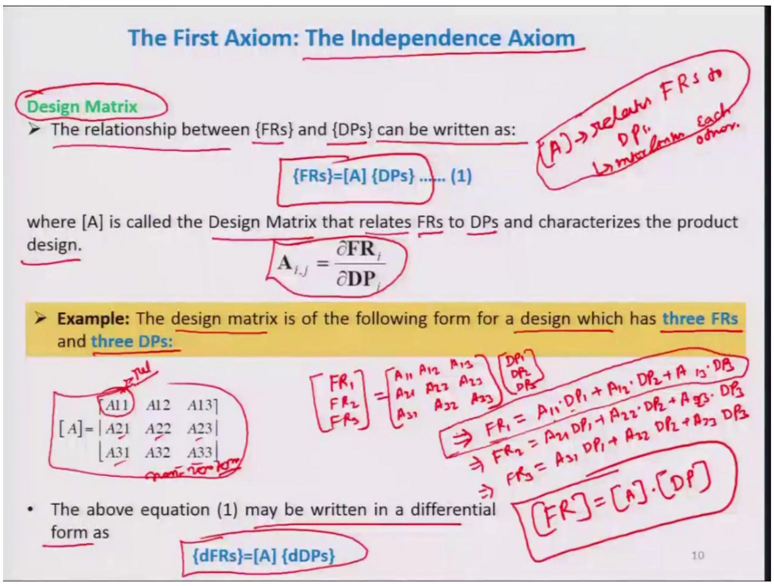

So, first I will explain the first axiom the independence axiom here. So, for your any axiomatic design process first you have to make a design matrix formation of design matrix.

So, here what is the design matrix it is the relationship between your functional requirements and design parameters and that can be written as in a matrix form FRs is equal to A into DPs, where A is called a design matrix that relates to functional requirements and design parameters here A relates functional requirements to designing parameters.

$$A_{ij} = \frac{\partial FR_i}{\partial DP_i}$$

So, it is an interlinking it interlinks each other and characterise the product design in a another term you can write it in A ratio term that is the differential functional requirement in differential form divided by partial differentiation of design parameters.

So, here I will take an example how you will write a design matrix for a particular problem ok, here design matrix is of the following form suppose that we are giving a design which has a 3 functional requirements and three designing parameters for that. Here that is the design matrix for that here A 11, A 12, A 13, A 21, A22, A23 these are the non-zero term and each has some significance and it has it relates with it makes relationship between functional requirements and designing parameters.

So, if you want to write in a matrix form for a this one. So, how you will write it because you have three functional requirement FR 1, FR 2, and FR 3; so according to equation 1 we can write it A 11, A 12, A 13, A 22, A 23, A 31, A 32, A 33, and we have also 3 design parameters that is DP 1 DP 2 DP 3.

So, if you write in a standard form, so what will be FR1 is equal to A1 1 into DP 1 plus a 1 2 into DP 2 plus A 13 DP 3. Similarly, you can write FR 2 is equal to A 21, A 22 into DP 2 plus A 32 3 into DP 3, and again for third functional requirement A 31 DP 1 plus A 32 DP 2 plus A 33 DP 3. So, here you can see that all functional requirements are there is a relationship between functional requirements and designing parameters with the help of this design matrix. So, the above equation can be written in a differential form as DFR is equal to A into DPs. So, in a broad way in a functional requirement is equal to design matrix into matrix of designing parameters.

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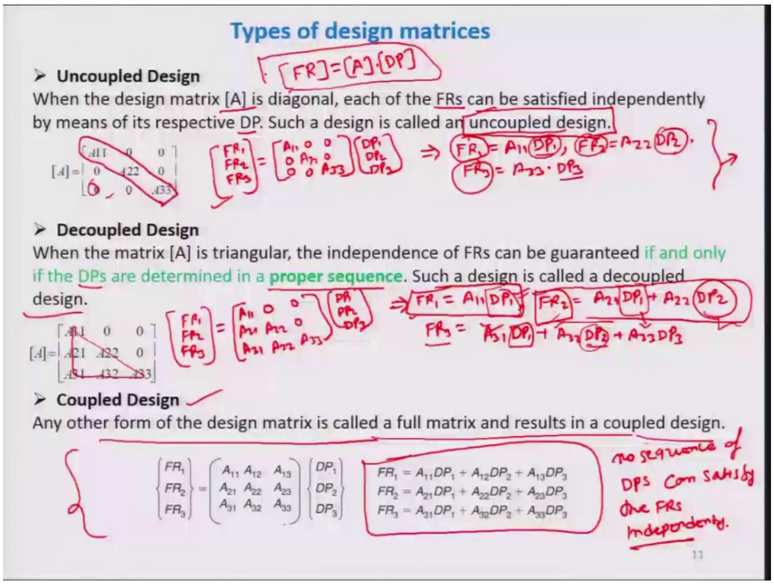

Now, types of design matrix here a in a broad way there are three types of design matrices first one is uncoupled design when the design matrix a is diagonal each of the FR functional requirements can be satisfied independently by means of it respective designing parameter such a design is called uncoupled design. So, for the independent axiom what was the equation FR is equal to design matrix into designing parameter.

So, here you can see that if design matrix a diagonal matrix only in a there is a null 0 term in diagonal only and rest of the elements are 0 term ok. So, and if you are making a matrix for that suppose that FR 1 FR 2 FR 3 3 functional requirement is equal to A 11, 0, 0, 0,A 22 , 0, 0, 0, A 33 into you have A 3 designing parameters, then you can write it FR 1 is equal to A 11 DP 1, FR 2 is equal to A 22 DP 2 and FR 3 is equal to A 33 into DP 3.

So, here you can see that all the designed parameters are independent ok, this parameters are related only with the functional requirement 1 DP 2 is only related with the functional requirement 2 and it has a no effect on functional requirement 3. So, this is called independent design.

So, for a better good design their matrix should always should be uncoupled. So, each parameter will be independent with each other second one is decoupled design second type when the matrix is triangular and the independence of functional requirement can be guaranteed if and only if the DP designing parameters are determined in a proper sequence, such a design is called decoupled design here you can see that this is the triangular matrix triangular matrix, and if you will write again similar to this matrix FR 1 FR 2 FR 3 here A 1 1, A 2 1, A 3 1, 0 ,0 ,A 2 2, 0, A 3 2, A 3 3, and DP 1 DP 2 DP 3.

So, after solving what you will get FR 1 is equal to A 11 DP 1, FR 2 is equal to A 21 DP 1 plus A 22 DP 2, so similarly you can write for FR 3 also.

Here you can see that suppose that first in a functional requirement 1 here DP 1 is related to functional requirement 1 here, first and if you have determined functional requirement 1 with the help of DP 1. Now you will you have to make it fixed DP 1 fixed then in a second step the FR 2 is satisfied only if that DP 2 will be DP 2 will be satisfied by FR 2 and DP 1 is already fixed.

So, here you can see that if design parameters are in a proper sequence than your functional requirement will be independent ok, so here because here DP 1 is fixed and you are moving only varying only DP 2. So, and DP 1 is fixed ok. So, it means although it includes DP is included in this equation, but it has a no effect only if DP 1 is you have make a fixed here for functional requirement 1, so similarly FR 3 if you will write here.

So, what will happen for FR 3. So, all parameters will be included FR 3 A 3 1 DP 1 plus A 3 2 DP 2 plus A 3 3 DP 3 here DP 3 will satisfy only FR 3 only if only DP 2 and DP 1 will be fixed ok. So, although this is the decoupled design, but here parameters are independent now third part is couple design.

Any other form of the design matrix apart from diagonal and triangular, so that will be a that will make you full matrix and result in a couple design. So, here you can see that there is a full matrix A 11 is there no zero parameters.

So, there is a final equation is that like this one and this is the no sequence of designing parameters can satisfy the functional requirements independently. So, couple design falls under the bad design and uncoupled design falls into a good design. So, always you will have to focus to make a matrix such that it is an uncoupled design.

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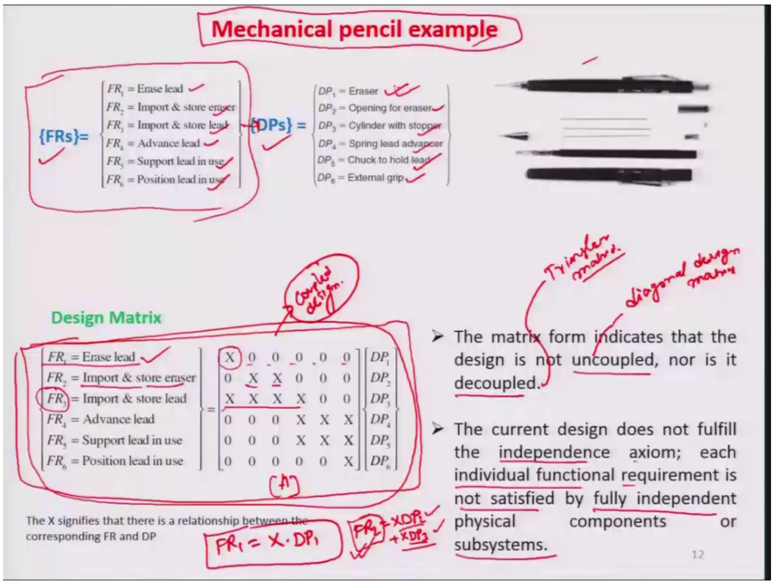

Now, I am taking one example to explain how you will formulate design equation and I am giving you one example of mechanical pencil, suppose that you want to make a pencil and there is a customer need after your you have make a questionnaire from customer and those needs is converted into functional requirement and what are the functional requirement first one is erase lead.

So, it should have a facility to that lead will we get erased import and store eraser they have a storage facility of eraser import and store lead can be changed in that pencil advanced lead support lead in use and position lead in use that is a for ecstatic part, they are the functional requirements for your fabrication of your pencil.

So, here your functional requirements will have to mapped in a designing parameter. So, what are the designing parameters first one is eraser you will have to make use of eraser. So, that lead can be erased opening for eraser cylinder with stopper spring lead advancer. So, that they will be a much smoother writing chuck to hold lead and external grip to hold pencil bit in a better way.

So, if you are going to make a matrix using your functional requirements and designing parameters. So, what be designing matrix here you can see that this is the design metrics. A design matrix and these are the design this is the design equation here you can see that in this equation lead can be erased only with eraser.

So, here other parameters are 0 and only x is there that is the non zero parameter will you. So, if you will write FR 1 is equal to what will be FR 1 is equal to x into DP 1.

And this is true because lead can be erased only using eraser similarly import and store eraser here you can see that there is a 2 non zero value ok if you write equation for that FR 2 what it will be x DP 2 plus x DP 3.

So, here two designing parameters which is required for that your functional requirement 2. And so again here you can see that there is a four non zero parameters and in a form the previous slide you can see that in this matrix this matrix not a neither a triangular matrix and nor a diagonal matrix. So, it will be a just couple design. So, whatever you have made a matrix.

And this is a not a good for your fabrication of pencil, the matrix form indicates that the design is not uncoupled and nor is it decoupled because for uncoupled you will have a you should have diagonal matrix, diagonal design matrix.

And for decoupled you should have triangular matrix, matrix the current does not fulfil the independence axiom each individual functional requirement is not satisfied by fully independent physical components or subsystem here for example, you can see that here for function to satisfy the functional requirement two, there is a two designing parameter is involved similarly in a case of FR 3 there 4 designing parameter is involved to satisfy one requirement. So, this makes a very complex I increase complexity of your problem, so that is why it is a bad design.

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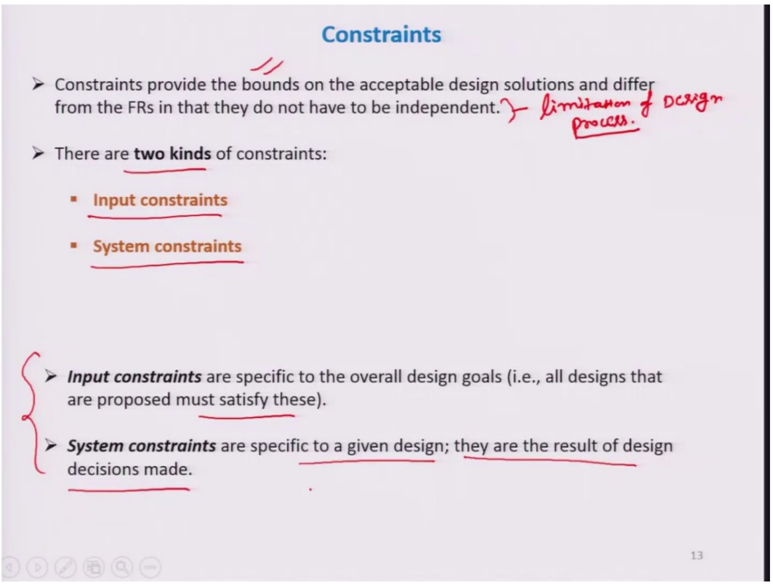

Now, I am talking I will talk about constraints. So, after your functional requirement and designing parameters you will have to consider take consideration of constraint, what are the constraints are available for your design constraint provide the bounds it is a limitation it provide it will provide you limitation on the acceptable design solution and differ from the functional requirements in that they do not have to be independent.

So, that is the limitation of your design process. So, there are variety of constraints in a, but in a broad way you we can divide it into a kind of constraints input constraint and system constraint, what is the input constraint? Input maybe input are specific to overall design goals all designs that are proposed must satisfy these it may be in form of current voltage for a designing of a transformer system constraint, that are the specific to a given design they are result of design decision made.

So, they are the two basic constraint that is that is always available in a axiomatic design process.

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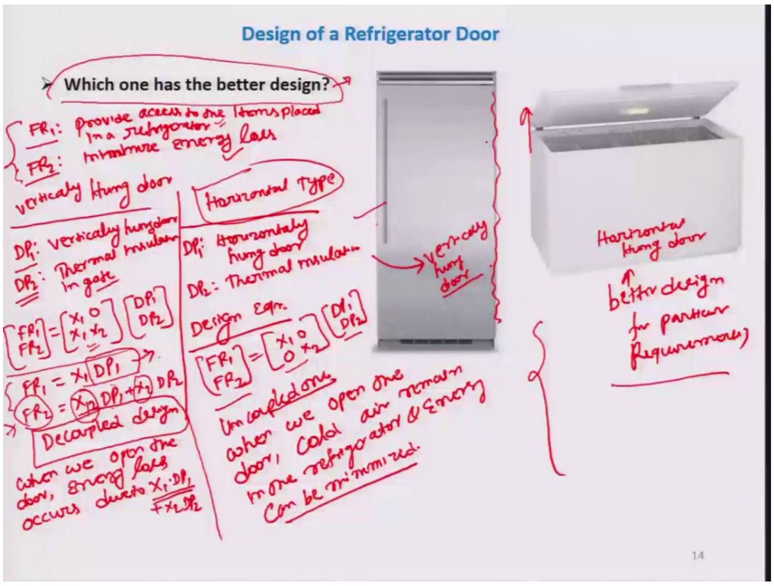

Now, I am taking giving you an another example design of a refrigerator door, here there is two kind of refrigerator is available here gate will open like this way and this case gate will open like this way. So, that is the horizontal hung door and it is vertically hung door.

So, we will have to decide which one has the better design, but design. So, you cannot say in a broad way which one is a better design always you will have to focus at what is your requirement a designer will ask you what is your requirement then only he can say which one will be better for your purpose.

So, first you will have to decide your functional requirements. So, what are the functional requirement functional requirements 1 is that provide, access to the items stored in a refrigerator and second requirement is that minimize energy loss. Here are only two requirements are available and on basis of that will have to select which one is better requirement, first requirement is that provide access to the items placed in a refrigerator and second one is a minimize energy loss.

So, first, I will analyse vertically hung door, here what is your design parameter for will be for that purpose. So, design parameter one will be vertically hung door and designing parameter two will be thermal insulation in a gate. So, that energy loss can be minimized if you will write in a matrix form then FR 1 FR 2 equal to x1, 0, x 1, x 2, DP 1, DP 2.

$$\begin{bmatrix} FR\,1 \\ FR\,2 \end{bmatrix} = \begin{bmatrix} X\,1 & 0 \\ 0 & X\,2 \end{bmatrix} \begin{bmatrix} DP\,1 \\ DP\,2 \end{bmatrix}$$

So, FR 1 is equal to x 1 DP 1 and FR 2 is equal to x 1 DP 1 plus x 2 DP 2. So, here you can see that there is a triangular matrix designing matrix. So, this design equation is decoupled one. here you will have to rely more than one parameter for a particular requirement.

Here you can see that for vertically hung door if you will open the you will make a horizontally hung door then your first requirement will get fulfilled, but if you will open the door at the same time energy will be get evicted from your fridge ok, so there will be energy loss. So, here x 1 and x 2 there are two non-zero design term in a design matrix and it involves in a to fulfil criteria of functional requirement two.

So; however, when we open the door, what will happen energy loss occurs due to x 1 into DP 1 plus x 2 DP 2 ok. So, for to fulfil functional requirement two and functional requirement simultaneously this 1 you will have to make a fixed then only your FR 1 and FR 2 will be get independent.

So, in case of now in case of horizontally hung door horizontal type, here designs requirement parameter 1 is horizontally hung door and parameter two is thermal insulation. So, for that design equation FR 1 FR 2 here this is the diagonal matrix and here you can see that you have a two design parameter and two requirements. So, that is the for ideal case and x 1 x 2 is a placed in a diagonal form, so it is an uncoupled one ok. So, you can here both parameter DP 1 and DP 2 is independent in each case for functional requirement one and functional requirement two why.

Because when we open the door, cold air will remain in the refrigerator and energy loss can be minimized ok. So, here in this case for that particular function requirement you can see that horizontal type is better than vertical type refrigerator, but this is always not fixed better design for particular requirement. So, for different requirement the design may be changed. So, it may be possible that for certain requirements vertically hung door will be better.

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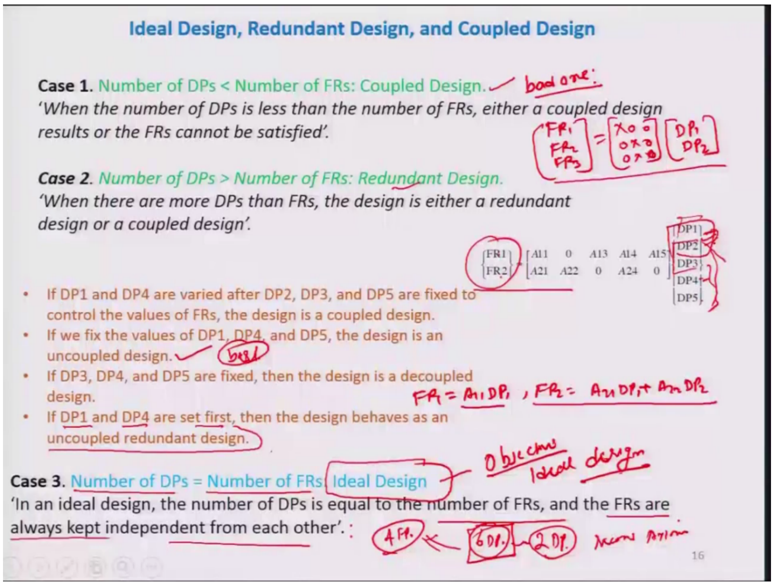

Now, what is the ideal design, redundant design and coupled design, again you can distinguish your design in an another form that is for case one if number of design parameter is less than number of functional requirements that is called coupled design that bad design bad one.

Here what is they are saying when the number of design parameters is less than the number of function requirements are there a coupled design result or the functional requirements cannot be satisfied, suppose that here you can write it FR 1 FR 2 FR 3 there are 3 requirements and you have a design matrix and you have only two design parameter.

$$\begin{bmatrix} FR1 \\ FR2 \\ FR3 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{bmatrix} DP1 \\ DP2 \end{bmatrix}$$

So, in that case the design matrix equation will be coupled design second one case two if number of design parameter is greater than the number of FRs functional requirements then it is called redundant design.

So, in you can see here if here if you have only two requirements and they are five parameters. If design parameter one and design parameter 4 are varied after DP 2, suppose that DP 1 and DP 4 is varied after DP 2. So, here they are talking about sequencing and DP 5 is fixed to control the value of functional requirements then design is a couple design ok, because here what are the how many variables are there 1, 2 ,3.

So, in second case if you fix the value of DP 1, DP 4, DP 5, DP 1, DP 4, DP 5, then there only two design parameter and two requirements. So, in that case it will make uncoupled design best one in that condition ok.

So, third condition if DP 3, DP 4 and DP 5, are fixed DP 3, DP 4 and 3 all are fixed than the design is called decoupled design, because here if you make an equation for that FR 1 FR 2 they are that in each requirements the involvement of both parameters will be there. So, here for that case if you will write FR 1 is equal to A 1 1 DP 1 and FR 2 is equal to A 21 DP 1 plus A 22 DP 2.

So, here you can see that this is the case of decoupled design. So, if last one if DP 1 and DP 4 are set first and then the design behaves as an uncoupled redundant design and in this case you are not neglecting anyone and you are taking consideration of all the things, but you are making DP 1 DP 4 before than the parameters. So, it is an uncoupled, but still it is a redundant design.

Now, in a case three that is the if number of design parameter is equal to number of functional requirement, so in that case that will be the ideal design. So, your objective should be always to make an ideal design.

In an ideal design the number of design parameters is equal to the number of functional requirements and it and benefit of that a functional requirement are always kept independent from the each other. So, suppose that if you have more than the you have supposed four functional requirements and you have a six design parameters for that. So, you will have to illuminate two design parameters using the second axiom. So, I will explain what is the second axiom later.

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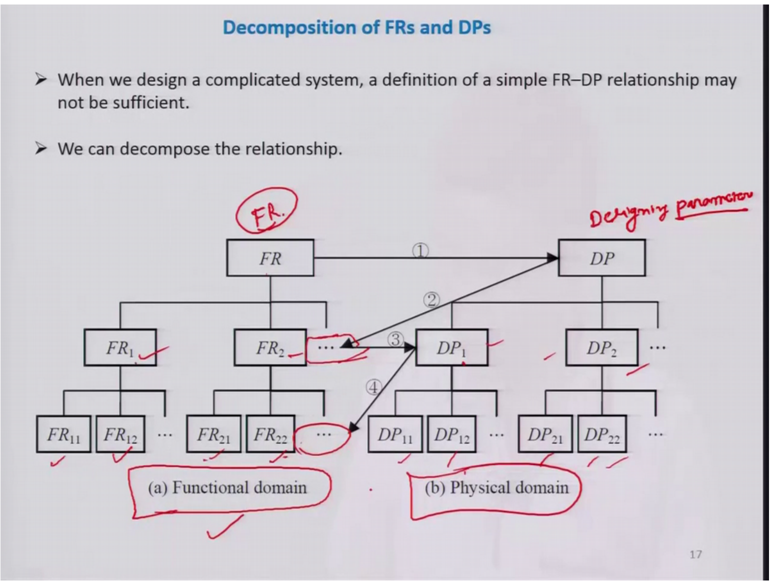

Now decomposition of functional requirements and parameters, so in an ideal condition functional requirements and parameters are a very few in numbers, but in actual condition there are a lot of requirement functional requirements involved there to in a fabrication of one product.

So, in that case you have to decompose your product in a variety of sub element. So, that you can make involvement you can take consideration of each elements in your design consideration, so I am giving you one example for how you will decompose your functional requirements as well as your designing parameters.

Now, here you can see that they are this is the decomposition of functional requirement and this is the designing parameter. Here you can see functional requirement is divided in a sub various sub element FR 1, FR 2, again FR 1 is subdivided in FR 11 FR 12 here similarly FR 21, FR 22.

And here also correspondingly design parameters is also divided in a various sub parameters and each parameter are linked to sub elements functional requirements here FR 21 FR 22, is linked to DP 1 you can see in example. So, here you can see that you have decomposed your functional domain and as well as physical domain so for example,

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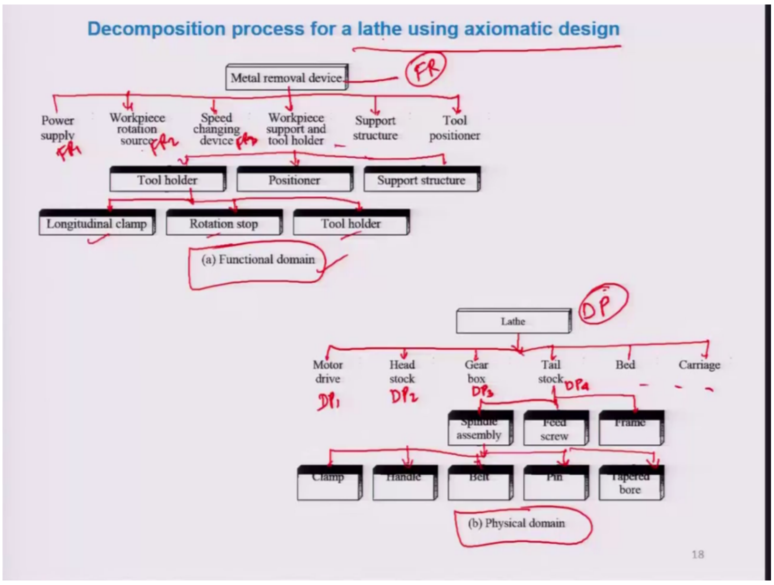

Decomposition process for a lathe using an axiomatic design. So, for lathe what you have to do for lathe what is the function of lathe it is a metal removal machine ok. So, for material removal device what are the functional requirements you have a functional requirement.

So, these are your functional requirements power supply, workpiece rotation source speed changing device workpiece support and tool holder support structure tool positioner and again here you can divide it a workpiece support in a various form, tool holder positioner support structure again you can divide in tool holder in a sub functions. So, tool holder maybe longitudinal clamp rotations stop and tool holder.

So, how in this way you can divide your functional requirements. now after your decomposition of functional domain will have to decompose your designing parameters accordingly here you can see that for a lathe there are lot of parameters are involved in a process motor drive, head stock, gear box tail stock, bed. Here also tails this one is divided into frame spindle feed, screw frame again your spindle assembly is subdivided into clamp, handle, belt, pin and tapered bore.

So, how what you are doing here, so you are dividing your main functional requirement this was your main functional requirements and you are dividing in a various requirements FR 1, FR 2, FR 3, like that and similarly here you are your first designing parameter to material removal process is the lathe machine ok.

So, this was the DP and for designing that lathe machine you have to divide it in a various parameter. So, each parameter is involved in a machining process. So, this is the how you can decompose your process.

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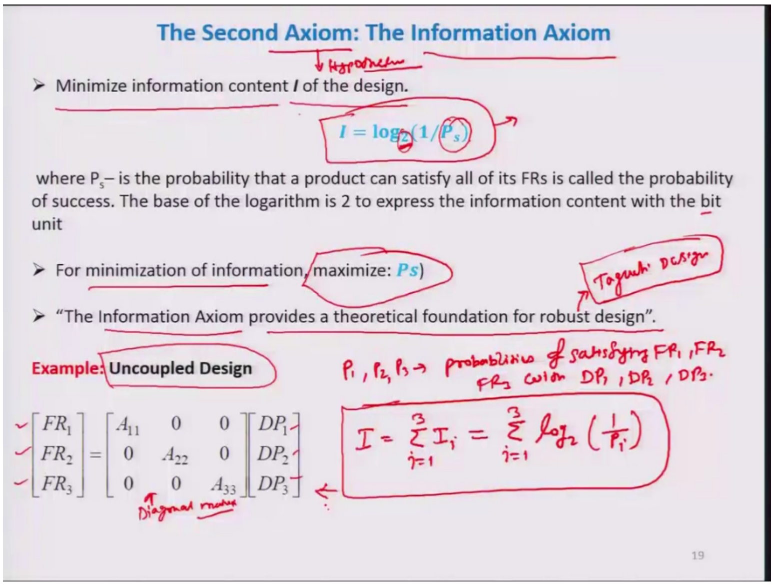

Now, earlier I said that if there is a more than number of designing parameter is more than functional requirement. So, you will have to reduce your designing parameters. So, that that design system will be a good design. So, what is that second axiom is a hypothesis ok.

So, here what is the goal of information axiom to minimize the information content of the design and it is mathematically it is represented as I is equal to log base 2, one by P s, here P s is the probability that a product can satisfy all the functional requirements that the is called probability of success and here, base two is only used to express the information content with the bed because your final goal is to convert it in a software for your designing process.

$$I=\sum_{i=1}^{3} I_i=\sum_{i=1}^{3}\log_2\left(\frac{1}{P_i}\right)$$

So, you will have to convert your mathematical value in a bit form. So, that, so that is why here two is taken. So, what will have to do for minimization of information here only one parameter is variable that is the probability. So, probability of success will have to maximize the probability of that success ok. So, that your information content will get minimized and this information axiom provides a theoretical foundation of your robust design, and one type of robust design that is called Taguchi design you have already learned in a concurrent engineering module.

Now, I am giving one example for that how information axiom is calculated mathematically, suppose that for a system design system you have a three functional requirements and as well as 3 designing parameters and it is a diagonal matrix.

So, it is that is fall into an uncoupled design diagonal matrix and let us supposed that P1, P2, P3 are the probability of satisfying FR 1, FR 2, FR 3 with the parameters respective parameters DP 1, DP 2 and DP 3.

So, so if you are going to calculate information content for that design. So, what it will be usually summation of you have a 3 parameter and 3 functional requirements. So, you can write in a way log 2 summation of 1 by Pi. So, this is the information content for this uncoupled design example.

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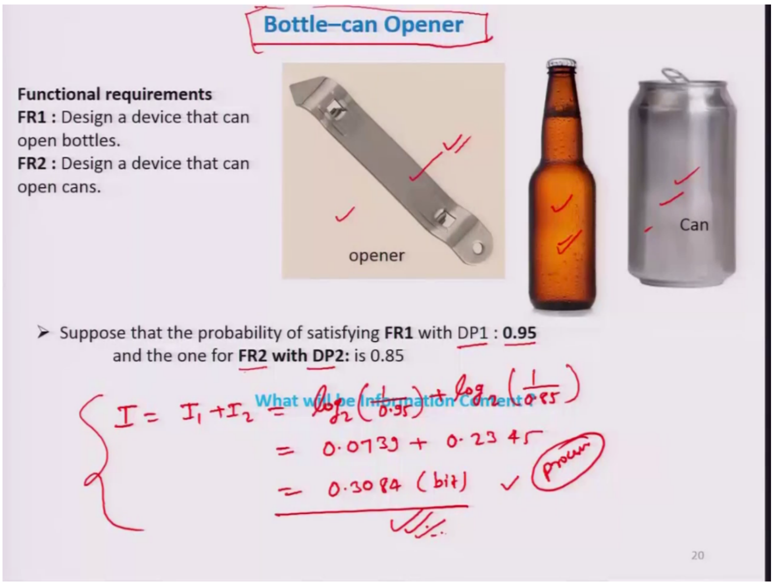

Now, I am giving you one real example that is the bottle can opener and we are going to calculate information matrix for that bottle can opener this is the bottle can opener using this you can open your bottle beverage bottle as well as your aluminium can. So, it has a more than two functionalities, so it is available to open both of these. So, what are the functional requirement for this problem design a device that can open bottles and design a device that can open cans ok.

So, you are making a one device which can which is capable of open a open either a beverages bottle or can. So, for that purpose suppose that for variety of satisfying functional requirement one with DP 1 is 0.95 and the one for FR 2 with DP designing parameter 2 is 0.85, then how you will calculate information contained.

$$I = I_1 + I_2 = \log_2\left(\frac{1}{0.95}\right) + \log_2\left(\frac{1}{0.85}\right) = 0.0739 + 0.2345 = 0.3084\,(bit)$$

So, I will be I 1 plus I 2 and we know that I is equal to log 21 divided by probability corresponding. So, we will take 0.95 and plus log 21 divided by 0.85 I you will solve it. So, will happen 0.0739 plus 0.2345. So, that will be equal to, so this is how you will calculate mathematically your information content ok. So, this is how you designing your process. So, this is your calculation for axiomatic second axiom.

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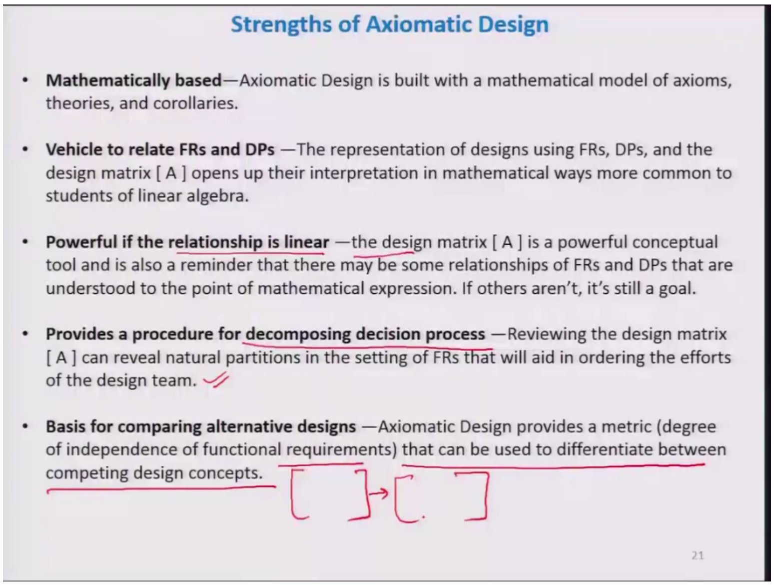

Now, what are the strengths of the axiomatic design. So, first you can there are variety of benefits are available for axiomatic design. So, what are the strength that first one is mathematically based, second one is vehicle to related functional requirements and designing parameters third one is the powerful if the relationship is linear.

So, if there is an equal number of functional requirements and designing parameters and both are the independent all physical requirements are independent with their corresponding designing parameters. So, that is the then relationship is very powerful and your design will be good very good design it provides a procedure for decomposing decision process.

So, your idea of thought can be decomposed in a mathematical way in this design. So, it is a very authenticate tool for a designing process. then last one in is the basis for comparing alternative design. So, it provides you a comparative study you can do with the other competing design concept. So, because whatever you are getting here in a mathematical form. So, that comparison is very easy with other designing process.

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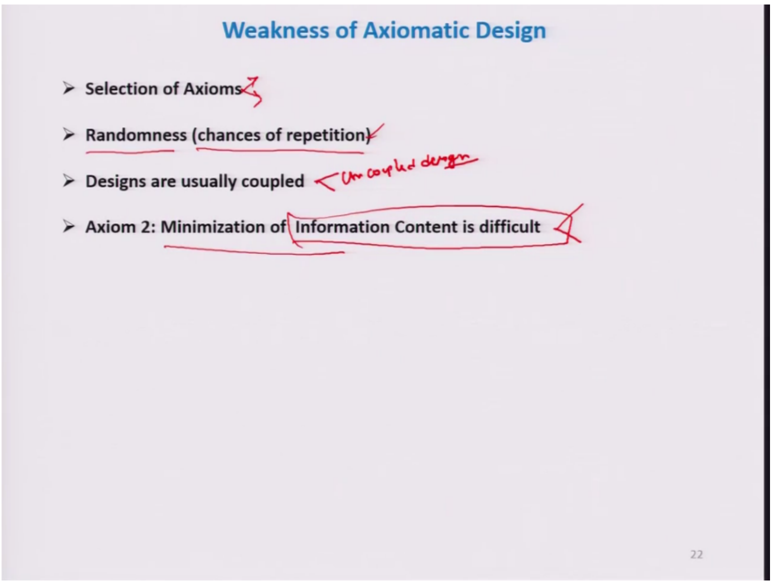

And there is also some weakness is associated with the axiomatic design first one itself axiom is a selection of axiom because it is a hypothesis. So, you cannot argue with that your axiom on the basis of your technical information.

So, always you will have to make a proper selection of axiom. So, that your you are designing your design will be a good design otherwise if you have selected wrong axiom. So, you might you may be may be possible that design is not good for that process.

Then second one randomness chances of repetition because there is variety of randomness is available in each domain. So, it may be possible that some very parameters get repeated in your matrix and it will increase your complexity in a design.

Third one is designs are usually coupled in a real practice you it is very difficult to find an uncoupled design. So, a designs are always related one requirements are related with the more than one designing parameters. So, you will have to always minimize your designing parameters and information content.

So, that your design will get converted into coupled design, so it is very tedious task and last one is a axiom two, that is the minimization of information content that is I have said earlier that information, it is a seems to be it is very easy looks very easy, but it is not a very easy process to reduce the information contained because when you will start doing designing process designing process then you will make find that some parameters are very difficult to remove in a from your process.

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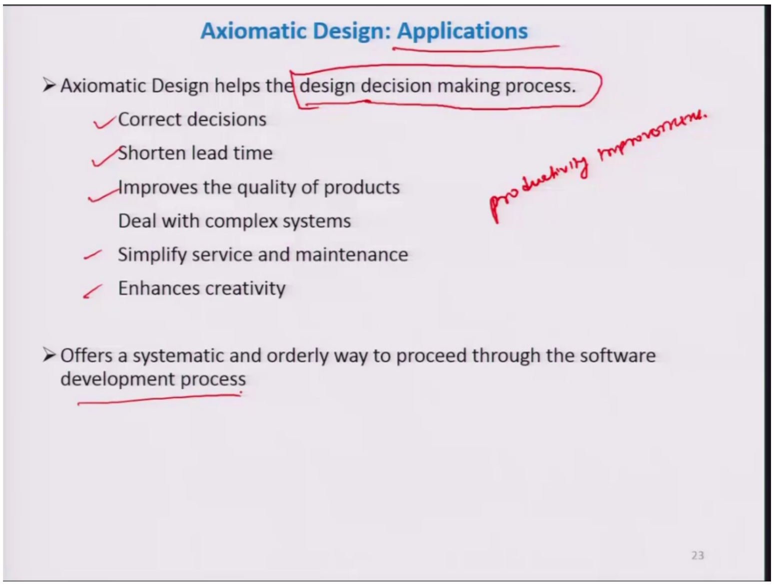

Now, axiomatic designs have a variety of applications are it helps in a decision mainly design decision making process, sometime it is called also called design decision making process. So, it helps in a correct decision shorten it shortens the lead time it improves the quality of product deal with complex systems, simplify service and maintenance and enhances creativity and as always as well as productivity improvement it offers a systematic and orderly way to proceed through the software development process.

So, in this process you have learned that in the axiomatic design it is a very convenient way to convert your hypothesis into mathematical form. So, that you can represent your idea in some standard formulation you can atomise for it and make a software for that.

So, that next time when you will be going to design new product then that software will help you to development of that new product. So, now, I am closing thus module and in the next module I will discuss some new topics.

Thank you very much.