Product Design and Manufacturing
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Lecture - 20
Design for Assembly (and disassembly)

So, welcome to the next lecture which is more focused on design for assembly. Last lecture we studied about design for manufacturing. This lecture is more focused towards design for assembly and disassembly.

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As I told last class, manufacturing has two components; one is producing the part, then other one is assembly. Again, an assembly there are two type; one is permanent assembly and temporary assembly. So, assembly place a very important role. So, now we will see more about design for assembly.

So, design for manufacturability we saw last class some information, then this time we will start looking into design for assembly, some guidelines for different modes of assembly, methods for evaluating design for assembly, design for assembly method based on MTM standards, design for disassembly, design disassembly process planning, design for disassembly guidelines, optimal disassembly sequence planning for product

recovery, disassembly sequence planning for your product with defective parts, evaluation of disassembly planning based on economic criteria. We have proactive design for disassembly method based on MTM standard, reasons for not implementing DFMA, advantages of applying DFMA during product design and then finally, will see design for environment

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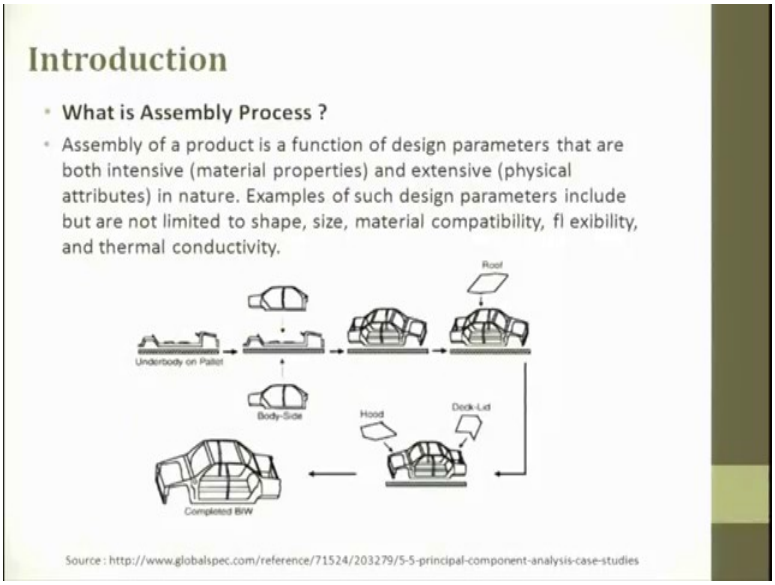

What is assembly it is a process, where in which we try to join or we try to consolidate number of parts and make a single product or make a part of a single product; such that it can meet out to some requirements. So, assembly of a product is a function of design parameters that are both intensive and extensive. Intensive is material property, extensive is physical attributes.

Example, for such a design parameter includes, not only limiting to shape, size, material compatibility, flexibility and even thermal conductivity is considered. So, assembly of a product is a function of design parameter that are both intensive and extensive in nature.

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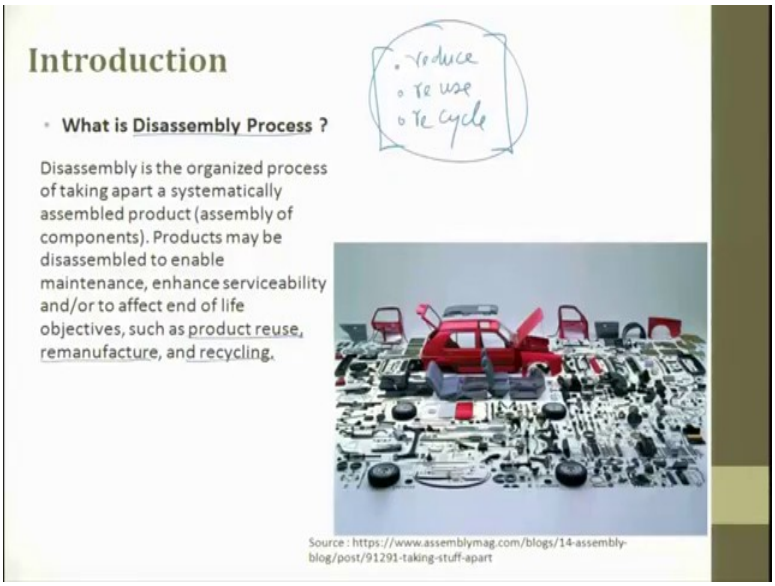

What is disassembly process? Disassembly is the organised process to of taking apart us a systematically assembled product. So, disassembly means, it is not like breaking, when you try to remove parts from a product without damaging the parts in the product; that is what is disassembly? Disassembly is the organised process of taking apart, a systematically assembled product and it need not follow the same sequence. Assembly took over from 1 2 3 4 5 to 10 and disassembly need not start from 10 to 1, it can follow some other route also.

The product may be disassembled to enable maintenance, enhanced serviceability and or to affect end of the life objectives; such as product reuse, remanufacturing and recycling. So, today when we talk about manufacturing, we try to say reduce, reuse and recycle. We use these three parameters exhaustively in manufacturing; that means, to say you reduce as much as possible material usage of machines or usage of other secondary items which are used in producing. So, you reduce them.

Next you try to reuse the part produced or finally, nothing happens then you try to recycle, but in which the chip whatever comes out and manufacturing or even you try to produce a defective part it is corrupt, it is re-casted and then it comes back to the manufacturing. So, we always have to follow these 3 R's in manufacturing exhaustively. So, here if you see the products may be disassembled to enable maintenance, enhance serviceability and or to affect the end of life objectives; such as product reuse,

remanufacture and recycle. So, whatever I have said it is given here

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So, addressing common manufacturing process, injection moulding process, sheet metal process, in a casting process assembly and machining; so, these are examples of common manufacturing process. So, we try to produce parts through form injection moulding, sheet metal, casting, machining. And then finally, what we do is we try to put integrate everything and then we try to do an assembly operation

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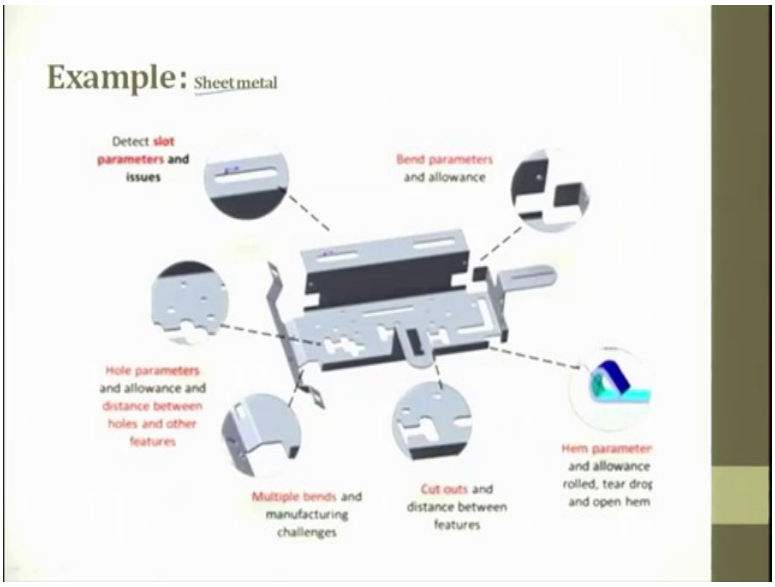

Sheet metal example; so, detects slot parameters and issues. So, here this is a slot which

is there on a sheet metal part it. To a large extent it looks something like a bracket or what you see used in the in the desktop computer in recover. So, detect, detect slot parameters and issues and here bend parameters and allowances, then hole parameters and allowances and distance between the hole and the feature.

This plays a very important role and then multiple bends; you can see multiple bends and manufacturing challenges, cut-off and distance between the features. Then Hem parameters, Hem is nothing, but bending, bending of it and allowances rolled tear dog and open hem. So, these are some of the parameter or issues, which are attached to a sheet metal part. And here we have put multiple bending, we have put hemming parts the, we have put bending parameters et cetera.

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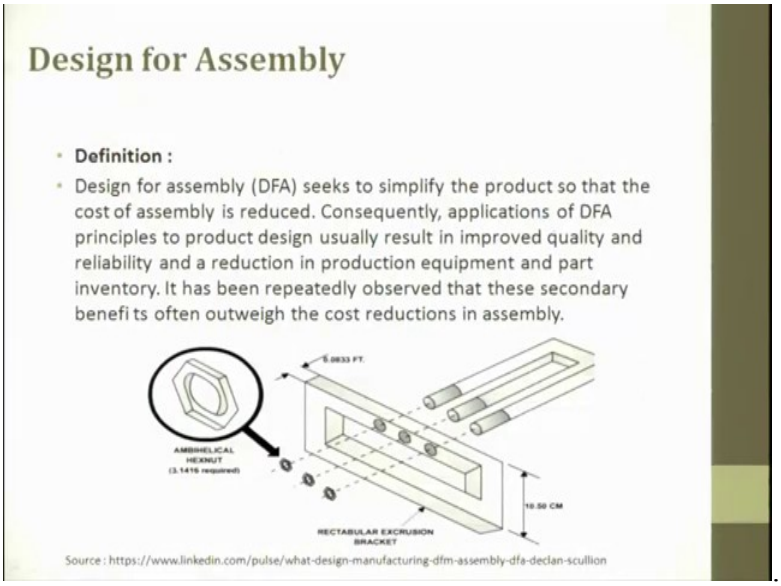

When we talk about design for assembly definition DFA seeks to simplify the product, so that the cost of the assembly is reduced ok. Consequently, application of DFA principle to product design, usually result in improved quality and reliability and reduction in production equipment and part inventory. So, when you try to follow design for assembly, you will see the part inventory level goes down. Like I said in the last class you WIP goes down, it has been repeatedly observed that these secondary benefits often outweigh the cost reduction in assembly

For example, you will have a nut, which is there and then you will have a clip which comes and attaches to it, here is a nut. So, this is pushed and then here you come and

then you will have nuts. Suppose in case let us assume that how do you want to follow DFA here. So, what I will do is, instead of having these screws, this hexagonal nuts, see this hexagonal nuts are always prone for, prone for failure; that means to say it can get unbound and it can fall down when it is put on dynamic load.

So, now what people are suggesting is, try to remove all these hexagonal nuts, try to make a thread here and then thread or whatever. So, here there is a thread. So, you pushing the thread into the hole and then start putting it or you just do a press fit and get a done do not try to go for the next one.

So, here the pins are attached to a bracket or this is a lead which is attached to a bracket. So, you do a press fit this is attached to it and then we have now removed it. So, this is this is how when we try to do design for assembly or design for manufacturing. So, we try to remove the number of parts. So, when you follow design for assembly you will have a improved quality and reliability product.

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So, there are different ways of assembly. So, one is manual assembly the other one is automatic assembly. Manual assembly you can see that there are a series of operators or there are many operators sitting one besides each other and trying to do a job. So, here the product can move from the first person to the last person, a sequence of operation can be done and they can produce a finished part at the last or individual operator tries to produce parts which are very similar

So, here we try to use vision base; that means, to say we use our hand and we use our eyes and then we start doing the assembly. So, all the sensor; vision sensor, tactile sensor what is there, it is all controlled by man. So, it involves parts that are transferred to work bench, so this is called as a workbench. Workbench is nothing, but a place where something happens. If we talk to an electrical guy he says the work bench wherein which he puts his breadboard and he assembles all the electronics gadgets into it

So, it involves parts that are transferred to workbenches, wherein which the assembly of individual components into a final product takes place. Hand tools generally are used to aid the worker to for easy in assembly. So, everything is done by hand. So, the tactile sensor which is there or the 4 sensor, is all human being only.

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So, the other way around I do not want to have man. Why I do not want have man? One decade there is a possibility that defects can happen, because of fatigue reasons and second thing sometimes, because of wrong judgement they could have done an assembly

So, and then the forces what they apply in fixing, there can be variation from human to human. So, these are some of the possibilities for error to happen when you do assembly by manual way, in order to avoid we try to use automatic assembly. This method is used either synchronous, synchronous indexing machines and a part reader or a non-synchronous machines, where parts are handled by a free transfer device is used.

So, synchronous and asynchronous machines, we have said synchronous machines are. Suppose if there are three machines, so all the three machines if they transfer, say the cycle time for each station 1, station 2, station 3, if it is all balance 3 minutes, 3 minutes and 3 minutes. So, then what is happening is, when I move from one station to the other station, others station to the other station, there is a synchronous motion or there is a synchronous indexing machines.

So, what this is, suppose you have 5 stations around, and then you have an indexing table. So, every time when it index. So, and the new job or the part to the machine comes in contact with the work piece ok. So, that is synchronous and you can also have a nonsynchronous machine; like a cycle time can vary. The entire line can wait till station of having a highest time is fulfilled and then it moves possible

So, here and then the part feeding in the previous system, the part feeding was done by hand many a times, when the components are very small, manual part feeding is very difficult and if you want to automated and do it in a high speed, again manual feeding is a problem. So, here what we do is, we try to have part feeders which are automatically controlled. So, a Robot does it, so this is what is shown in this figure

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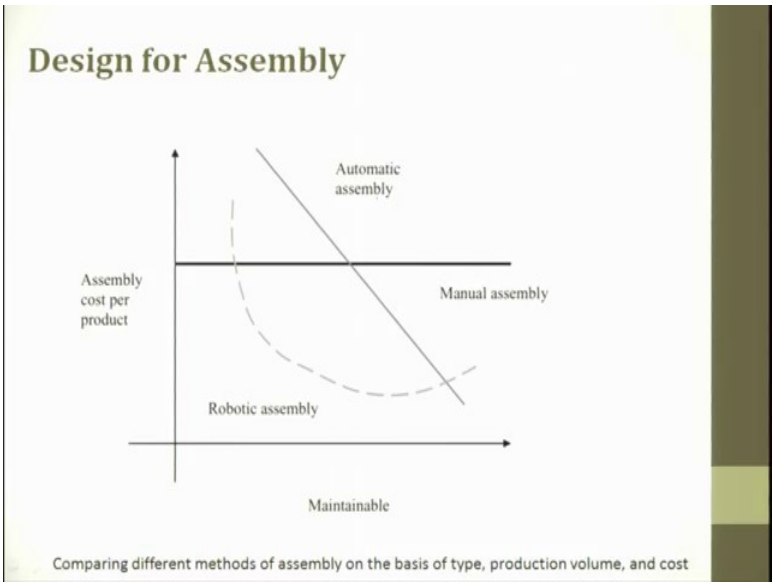

So, when you try to plot assembly cost per product was is maintainability. So, you can see there this is manual assembly, which is a straight line, the automatic assembly, the assembly cost per product, initially will be very high and slowly after a period of time it

goes very low. So, maintainability or you can put it as time. So, and then if you see Robo assembly, it starts from here, it is very interesting graphic, you see it goes from here to here.

So; that means, to say it comes very close with respect to casting assembly to casting and all becomes very cheap, and then a very economical and then it starts slowly rising with respect to maintainability. And here what we talk about is, assembly cost per product. So, depending upon the type, depending upon the production volume and the cost this curve is given.

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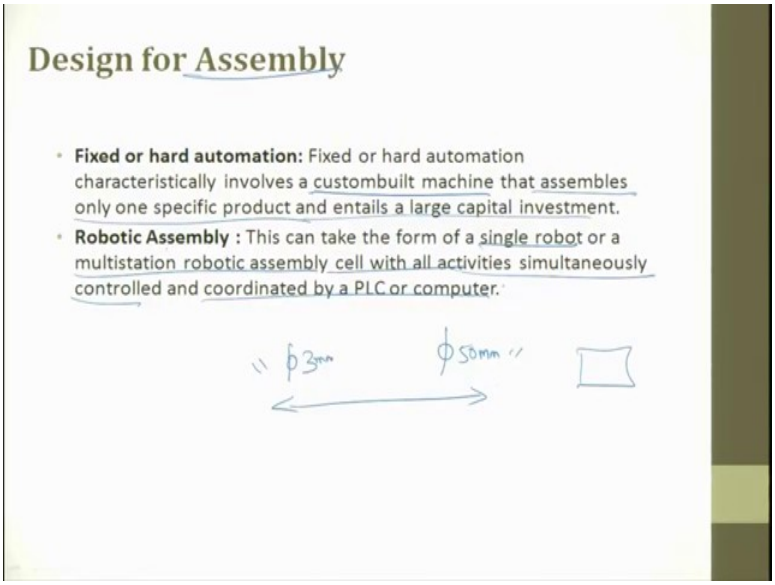

When you talk about assembly, there are two types of assembly; one is manual and I said automatic assembly, then you have fixed automation and Robotic automation. Fixed automation, see the difference between Robo and the other automation is Robo, it gives you a freedom of reprogramming ability. So; that means, to say multiple tasks can be done, when you do hard automation the operation, what you can do is, within the fixed bracket you can do. For example, the diameter of the shaft can be 3 millimetre, the diameter of the shaft can be 50 millimetre.

So, it can handle cylindrical shafts within this diameter ok. So, within the given spectrum, and suppose if it is only handling a shaft without doing anything, then hard automation is very good. So, fixed or hard automation characteristically involves your custom-built machine that assembles only one specific product and entails a large capital

investment; that means, to say day in and day out, it will try to produce only one part and that part, there can be a very small variations happening, but it is capital intensive, but the production rate is very high in fixed or hard automation

When you talk about Robotic assembly, this can be taken in the form of a single Robo. The biggest advantages as I said earlier it is reprogrammability or a multistation Robotic assembly cell with all activities, simultaneously controlled and coordinated by a PLC or a computer, this gives the flexibility of reprogramming. So; that means, to say I can handle shafts, I can handle prismatic jobs, I can do painting, I can do die-casting, I can do sheet metal operation, I can do machining. So, all these things are possible by Robotic assembly

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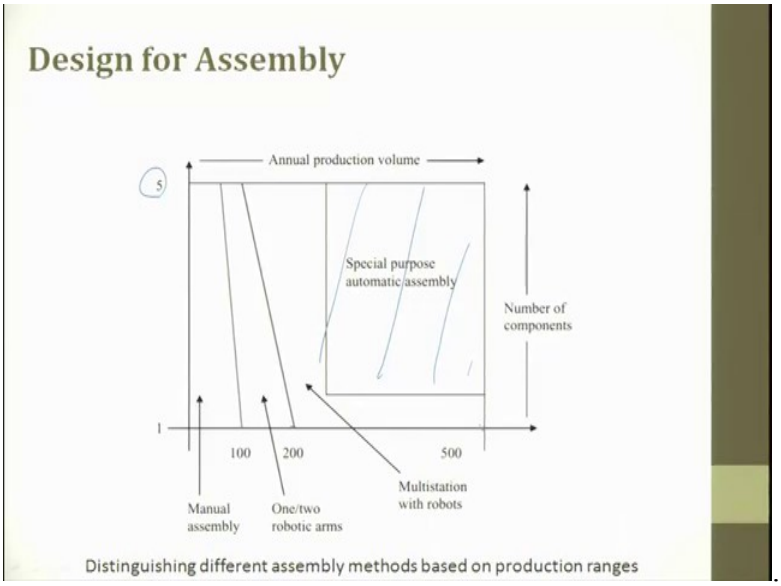

When we talk for design for assembly, here we have said 1 to 5 and then here are these numbers are given. Please these numbers are not sanctity numbers, these numbers are just taken for representation. So, here in this graph we clearly distinguish between assembly methods based on the production range. So, if you want to do manual assembly, you can the number of parts which you produces very less or the variety is very less and the production rate is also somewhere close to 100.

If you want to do with Robotic arm, you can touch 200. If you have a multiple station Robotic you can do up to 500. If you have a special purpose automatic assembly lines; then you can do varieties more and the production volume also, can be high and the

number of components, this is number of components 5. So, you can produce that and the product here you can also see the volume. So, manual the volume is less by automatic, when multiple station the volume is large. So, this is what you have to understand

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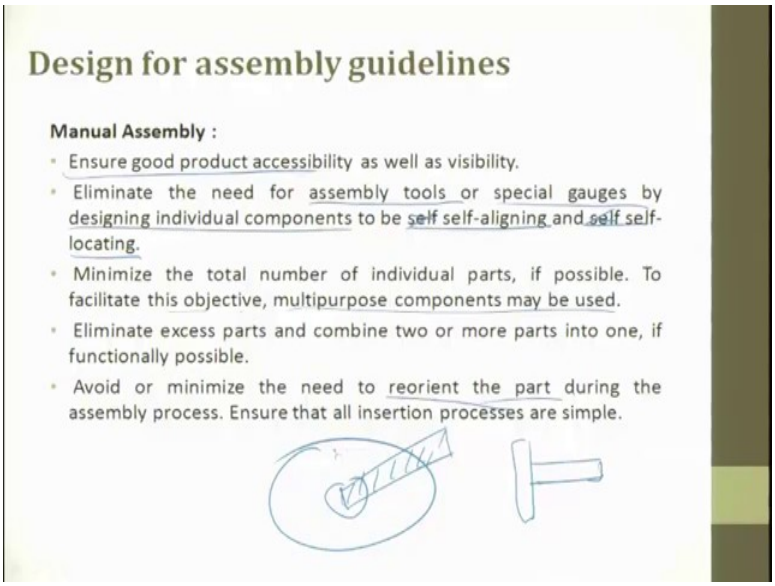

So, the next one is manual assembly; ensure good product accessibility, as well as visibility is there. This is the assembly guidelines eliminate the number of assembly tools or a special gauge by designing individual components to the self-alignment and self-locating principles. So, it should have self-alignment and self-locating alignment and locating are different different things, self-aligning me locating is where there is a hole gets located. Aligning means it gets adjusted. So, these two are different

Minimising the total number of individual parts is possible to facilitate this objective multipurpose components can be used. So, eliminate excess parts and combine two or more parts in one, if the functional responsibility, if functionally possible. So, here what do they say, is instead of having a shaft, then you have a hole, then you have a projecting shaft.

So, first of all you try to see whether these two materials can be made of a single material and if these two has, there is nothing big, it is going to bring a difference when it is made of a single part, then they say please go for a single part. So, eliminate excess parts. So, these two parts and then now what you do. You try to make this; you try to make this

assemble. So, now, if you make it as a single piece injection moulding, you want to make it. So, if I draw the side view, it will be something like this. So, for this, here the excess parts and combine two or more parts into one give the functional, if functionally possible then avoid or minimise the number of reorienting the parts.

See if you look at PCB all the assembly of IC, other things happen only in one direction why, because all assembly happening in one direction is much more easier and faster, you can always do bi-directional both sides. So, then what happens, all the all the assembly components have to be, the PCB has to be held vertical and the components will be fixed on both sides, but it might fall down, when it is starts moving.

If you do it only on one side, the number of approach of placement of IC or whatever it electronic components is, only one direction, then the gravity is used as an advantage and also the welding can happen, the accept the, the soldering can happen only at the bottom side rather than on the top side. So, here what we are trying to say is, if at all you want to do an assembly, the design for assembly when you think about, we try to have one directional approach, or you try to minimise reorientation of the part during the assembly operation.

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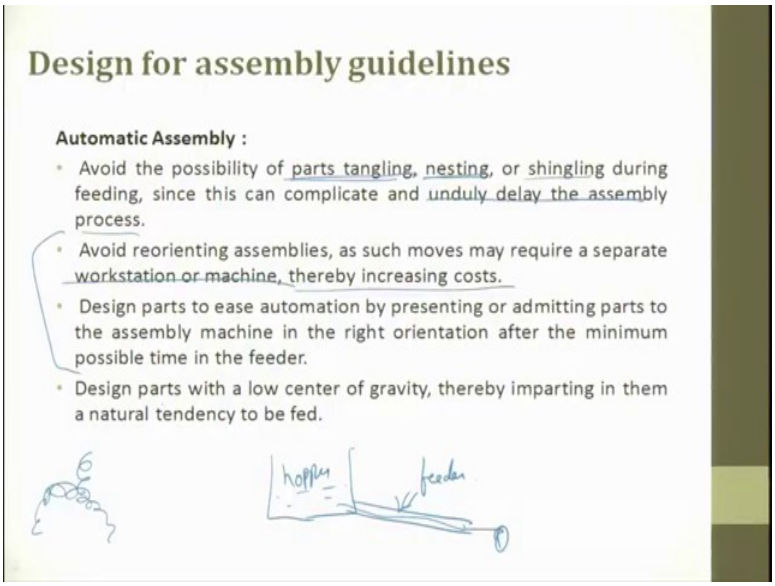

The automatic assembly guidelines, avoid the possibility of part tangling, nesting and shingling during the feeding. So, when you say automatic, automatic you will always have a hopper, then you will have a feeder. So, this is hopper, wherein which you put all

the parts, then you will have a feeder. So, this is a feeder and then you get one piece at a time, whatever it is ok; one piece, one piece you get. So, what we have to do is, when we are trying to do it from the hopper and then pushing it, the parts might get tangled, the springs might get tangled

So, now that you try to make sure that the parts are not getting tangled, nesting does not happen, shingling does not happen during the feeding. Since it can complicate and unduly delay the assembly process, avoid reorienting assembly as such moves, we are require a separate workstation or a machine.

Thereby increasing the cost, I have discussed about, it design parts to ease automation by presenting or admitting parts to the assembly machines in the right orientation, after minimising in the possible time in the feeder. So, these two points are just a small difference. I have already told you about the example of the design parts with a low centre of gravity. Thereby imparting the natural tendency to feed

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So, here you see the Robotic assembly, in many Robo manipulators have poor repeatability. Therefore, the features such as lip lead chamfer assumed a great deal of importance. So, these are lips leads and chamfer, all these things are some of the features of the Robo ok, a great deal of importance. So, that has to be taken care the design components; such that all can be gripped and inserted using the same Robo gripper. So, when we do this, this is a Robo end arm and this is a gripper. So, the gripper must be

made universal; such that it can be used both for insertion and removal

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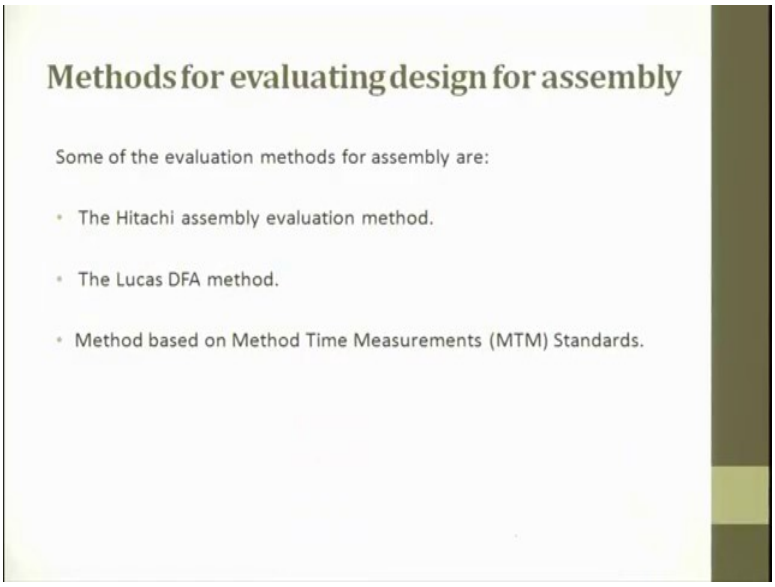

Some of the methods for evaluating design for assembly. So, one is Hitachi assembly evaluation, next is Lucas DFA method, the third one is Methods Time Measurement Standards.

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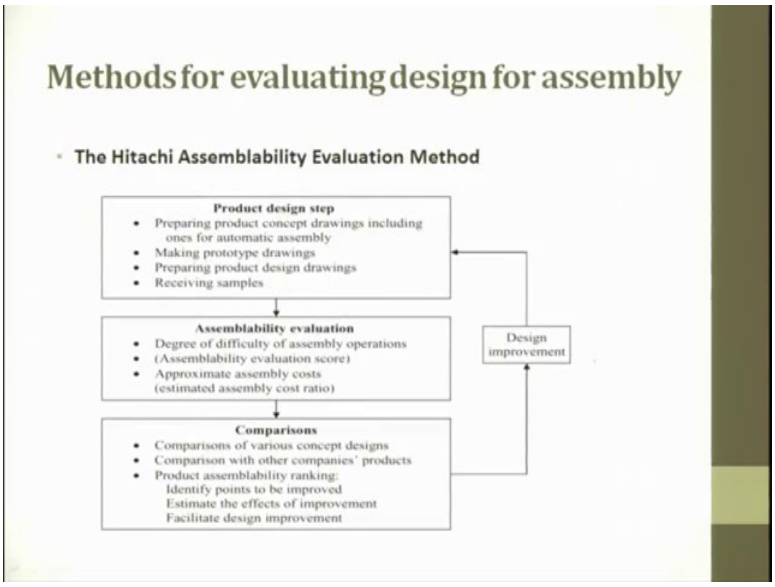

So, the Hitachi Assimilability Evaluation Method goes like this, product design step, prepare product concept drawing including ones for automatic assembly, making prototype drawings, preparing product design drawings, receiving samples. Then

assimilability evaluation, degree of difficulty of assembling operation and then approximate assembling costs. So, these two comes here.

Then the next one is comparison of various concept designs, comparisons with other company products, product assimilability ranking. So, it identifies the point to be improved, estimates the affect of improvement and facility design improvement. So, this is, design is an iterative process, so it keeps going back and forth.

So, comparison us, evaluation and then design step. So, once you make the design, then you start assembly evaluation is done. Then once evaluation done it is compared, then once again the product design is reiterated and it starts going. So, this method is called as Hitachi method of design for assembly

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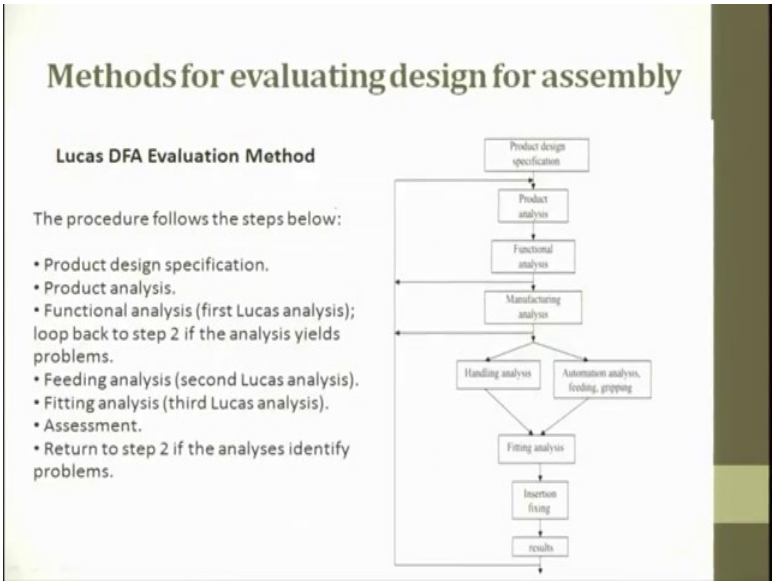

The next method is Lucas DFA evaluation method. So, here the product design specification, product analysis, functional analysis. So, functional analysis is the first. This is the first time people started talking about functional analysis, then they talked about manufacturing analysis. So, the functional analysis loop back to step 2, if the analysis yields problem and then what you do you reiterate and then come back. Then you get into manufacturing analysis. After manufacturing there are two steps; one is handling the other one is feeding.

So, handling analysis, automation analysis, feeding and gripping and then what you do

is, if the both are put together we do a fitting analysis, then insertion fixing and then finally, you get results. So, here if you have a problem after manufacturing analysis again we go to loop 2. And then here if you have a problem after the results, once again we go to step 2 and then start reiterating. So, here interestingly functional analysis, manufacturing analysis, handling analysis and feeding analysis, all are talked about in Lucas method.

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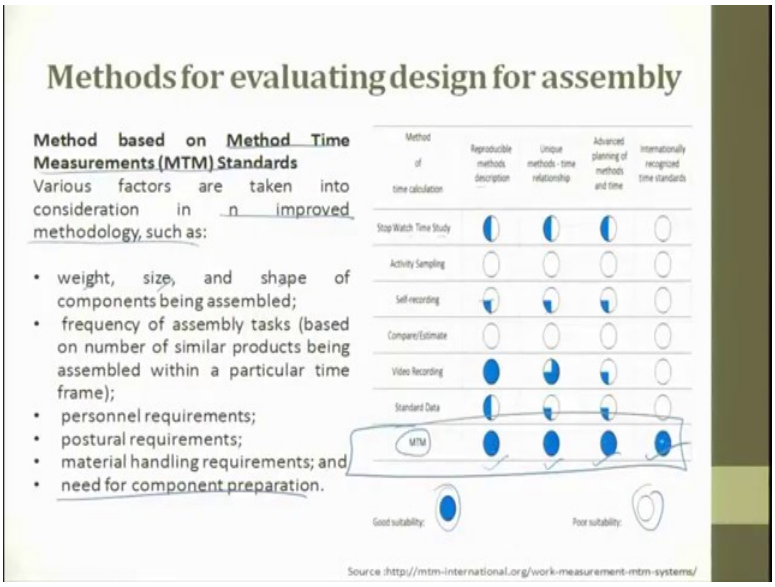

In method based on method time measurement standards, various factors are taken into consideration in n improvement methodologies; such as weight, size, shape of the component being assembled; Frequency of assembly task, personal requirements, postural requirements, sitting down.

So, see when you are trying to do assembly, if you try to sit on a very bad posture or if I try to take some element which is backside to me and then if I want to take it out and then keep it here, it is not going to be easy task. So, the posture or the location plays a very important role where the parts are kept, then material handling requirement and the need for the component preparation. These are the various factors which are considered.

So, method for time, time calculation, stopwatch time study, the reproducibility method description; This shows good suitability, this shows poor suitability, it is 50-50, then unique method time relationship it is also 50-50. Advance planning of method and time, stopwatch time study method is also 50-50. Then you look at self-recoding, it is only one

quarter and self-recoding unique method time relationship is 40 45 percent ok

So, when we talk about MTM you see, all the reproducibility method description is is 100 percent, unique method time relationship is 100 percent, advance planning in method and time is 100 percent, internationally recognised time standard is 100 percent. So, here what are we trying to say, whatever method, see, when we use MTM method, this is a standard method which is used to evaluate design for assembly and here this is internationally also accepted

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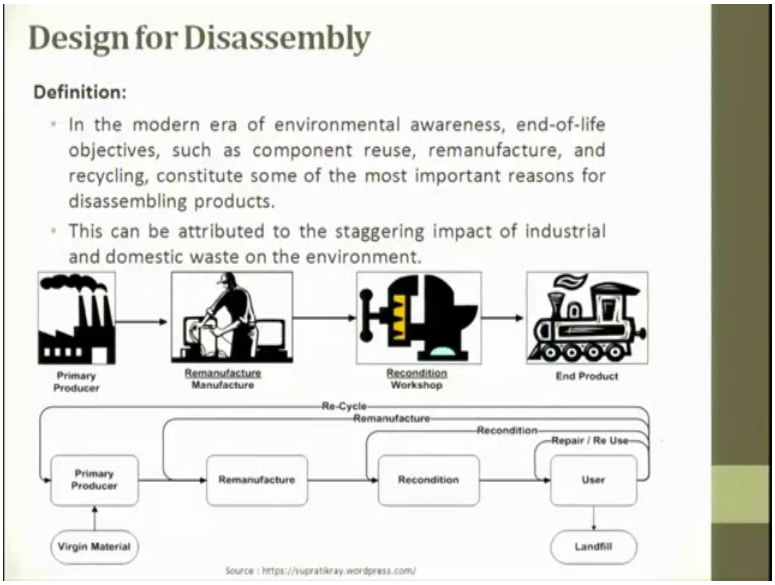

So, design for disassembly definition. In the modern era of environmental awareness, end of life objective; such as component reuse, remanufacture and recycle constitutes some of the most important reasons for disassembly products. For example, I try to buy a refrigerator and the refrigerator they say, the compressor is used to for. I give a warranty for the compressor for 14 years; the refrigerator life time is only 10 years. So, once I throw the refrigerator what do I do, the compressor which is already working.

Now they come and say let us try to apply disassembly, try to remove the compressor, either you try to refill it with gas or what they say, they try to take the entire compressor, place it in the new machine and start using it, or place at the lower machine and start using. This can be attributed to the strategic impact of industrial and domestic waste of environment; So, primary producer, remanufacturing, reconditioning and the end product. So, primary producer, we try to. This is primary producer, we remanufacture,

primary producer we remanufacture. After remanufacture we also try to do reconditioning, remanufacture, reconditioning and then we give it to the user.

The user starts using it back and if there is a problem he repairs. If the user gives it back and then it can be reconditioning and use. If the user gives it back it can be remanufacturing and it can come. If the user gives it back, it is a recycle and it can come to primary producer. So, here you will also have virgin material, here user finally, developing comes out it goes to landfill. So, this is what we try to say. So, user just a repair can be done, reconditioned can be done, remanufacturing can be done, recycle can be done. So, this is all part of design for disassembly

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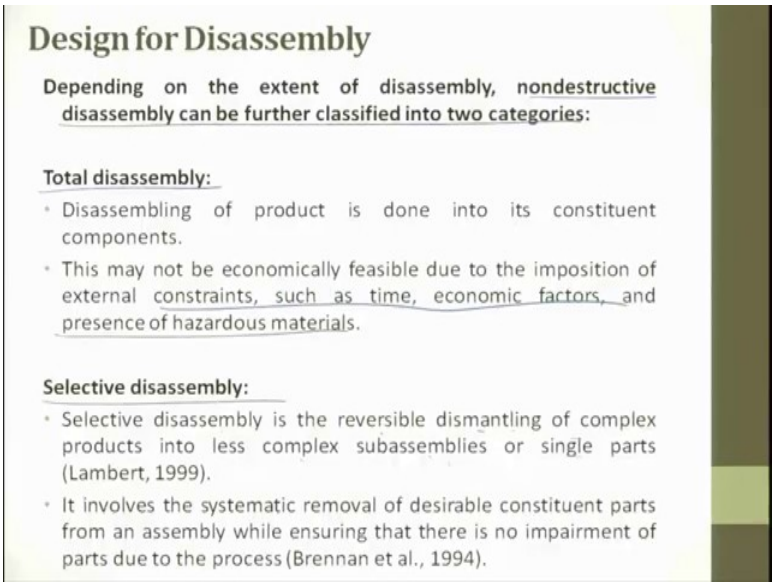

So, depending on the extent of disassembly, non-destructive disassembly can be further classified into two categories; one is total disassembly, the other one is selective disassembly. Total disassembly means our product is done into its constituent components. So, you try to take a car strip of every part of the car total disassembly. This may not be economical feasible, due to the imposition of external constraints; such as time, economic factors and presence of hazardous material

If you want to repair a car, it is you try to take only fixed location or fixed parts which is not functioning, rather than doing it if you remove the entire car, yes it is good you do over oiling and then place it back, but while placing, many a time in the time consuming and many a times it is also difficult.

What is selective disassembly? Selective disassembly is the reversible dismantling of complex products into less complex subassemblies or single parts. Selective disassembly is the reversible dismantling of complex products into less complex subassemblies or single part. It involves the systemic removal of desired constituent part from an assembly, while ensuring that there is no impairment of parts due to the process.

So, what we do is, one of the part you try to remove and the rest you do not even touch, and while ensuring that there is no impairment of the part due to the process. So, exactly remove one replacement and the machine goes. The first one is completely you try to dismantle

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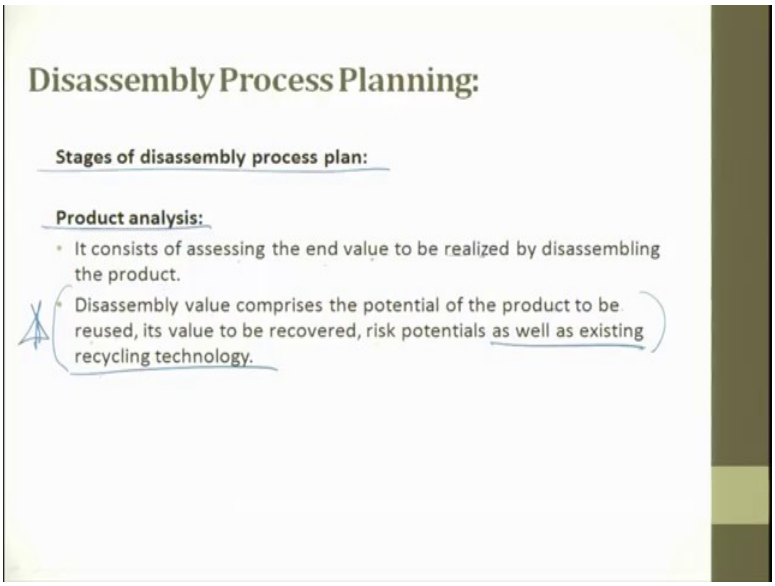

The stages of dismantling process plan, you have product analysis, functional analysis product analysis, it consists of assessing the end value to be realised by disassembling the product ok, it consists of assessing the end value to be realised by disassembling the product.

So, that is product analysis. Disassembly value comprises the potential of the product to be reused, its value to be recovered, risk potential as well as existing recycling technology. So, this point is very very important. So, all these things are thought of as product analysis.

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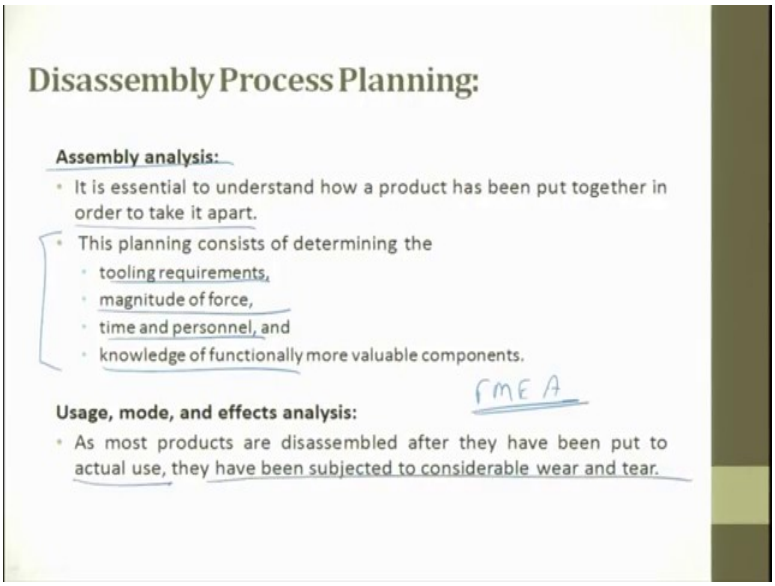

Assembly analysis, it is essential to understand how a product has been put together in order to make it a part. This planning consists of tool requirement, magnitude of force, time and personnel and knowledge of the functional, more valuable components. So, these are important things which we have to plan.

Usage, mode and effective analysis, we studied FMEA; failure mode effective analysis last class we studied. So, usage mode effective analysis are very important. So, first we saw about product analysis, assembly analysis, then we see all these usage, mode effective analysis. As most of the products are disassembled after they have been put to actual use, they have been subjected to considerable wear and tear, which is called as usage mode and effective analysis.

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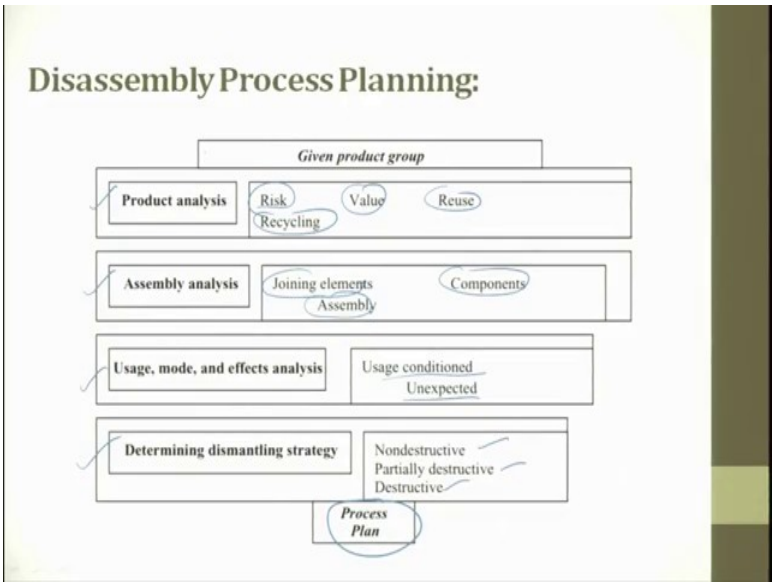

Disassembly process plan has product analysis; assembly analysis, usage mode effective analysis and determining dismantle strategy. So, here given the group products, risk value reuse recycles, assembly joining elements, assembly and components. When you trying to talk about usage mode effective analysis, where wear and tear is an usage condition unexpected.

So, here determining dismantling strategy, non-destructive way, partially destructive and destructive way, and finally, what we do is the process plan. So, here design for disassembly process plan is product analysis, assembly analysis, usage mode effective analysis, determining dismantle strategy. So, all these things put together comes.

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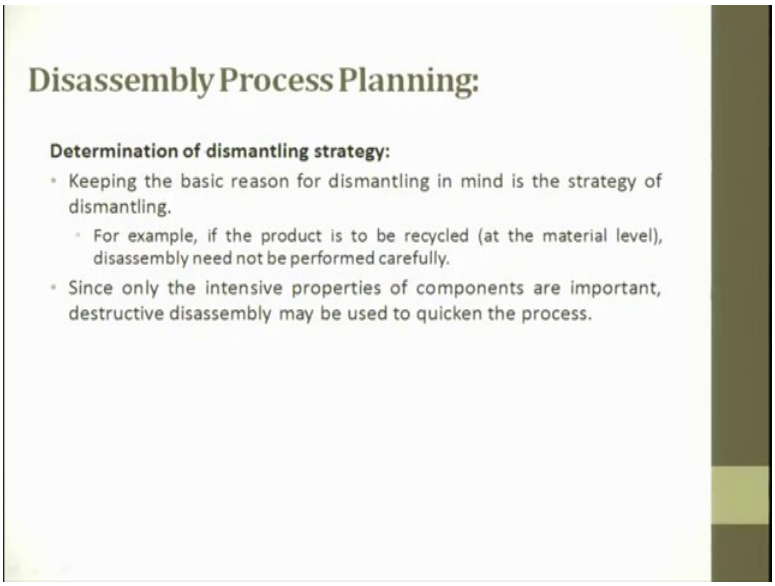

And decide for process analysis; Disassembly process planning, determination of dismantling strategy. So, we have seen the first three points here; product analysis, assembly analysis, usage analysis and then we are trying to see the determination of dismantling strategy. So, keeping the basic reason for dismantling in mind, the strategy for dismantling is. For example, if a product is to be recycle at the material level, disassembly need not be performed carefully.

So; that means, to say anyhow you have decided that you are going to recycle the material. Now, do not spend enough of time and do it. For example, what happens in the in developed countries, once the car and it what they do is they try to discard the car. When they try to discard the car, they try to discard it in a very crude manner why, because they know very clearly the entire thing is going to get melted and then it is going to be remanufacture. So, that is what they do

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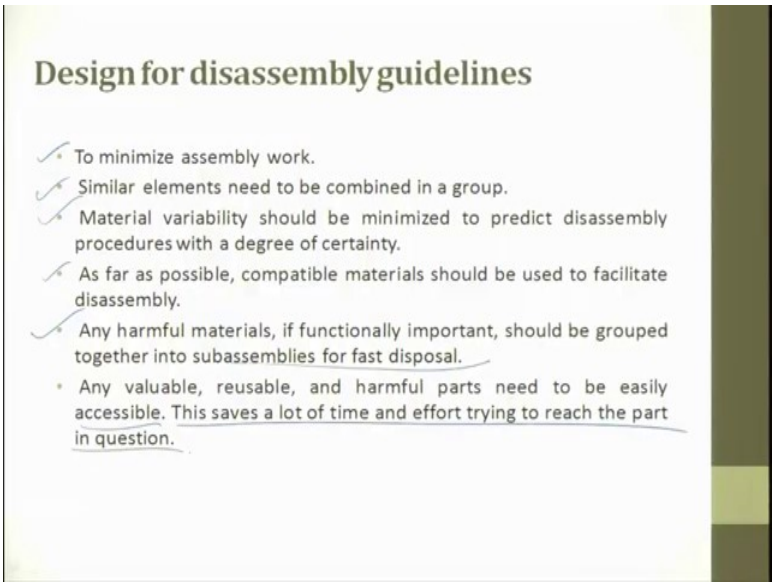

Since, only the intensive property of the components are important, destructive disassembly can be used to quicker the process. So, the design for disassembly guidelines, to minimise the assembly work, similar elements need to be combined together, it is just a repeat, material variability should be minimised. So, as far as possible compatible material should be used, any harmful material, if functional important should be grouped together into subassembly for fast disposal.

For example you take PCB, when you take PCB or when you take a smart phone, there are about, there are about 25 to 30 rare earth material which are used, which are highly toxic. So, that is what we say any harmful material, if functionality, if functionally important, should be grouped together into subassemblies for fast disposal. any value valuable reusable harmful parts need to be easily accessible, this saves a lot of time and effort during reaching out as part in the question

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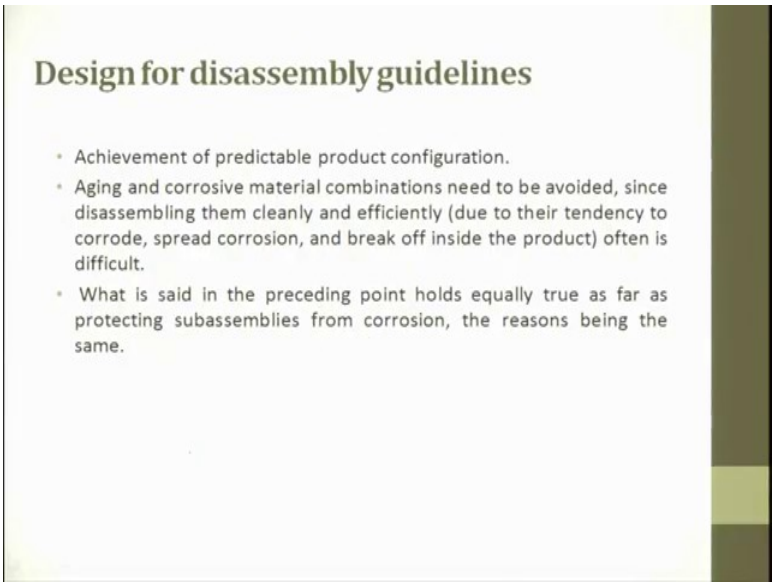

So, what they say is, they say if at all there is some part, wherein which you have used rare earth materials or it is going to be an explosive. So, those parts should be easily accessible while disassembly; the achievement of predictable product configuration, aging and corrosion material combination need to be avoided. What is said in the preceding point holds equally true, as far as protecting subassembly from corrosion. So, these are some of the design for disassembly guidelines which is talked about.

So, minimise assembly work, similar element should be joined together, material variability should be reduced, as far as possible compatible material should be should be used for disassembly. Then harmful material should be avoided, then if you are still having a harmful material it should be easily accessible to remove. Then achievement of predictable product configuration should be there, ageing and corrosion is also talked about.

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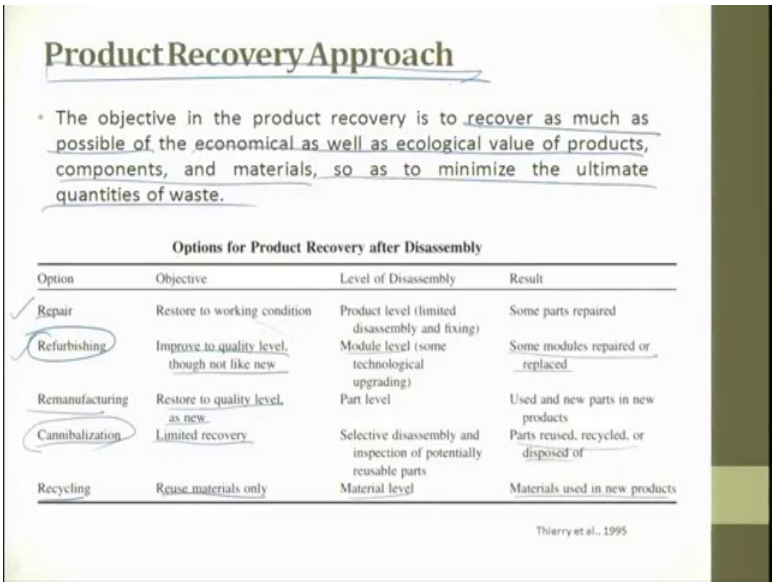

So, product recovery approach. So, I have a product for example, I have a desktop computer and this desktop computer has finished it life or it has become slow or it has become inefficient in its performance. So, then what we do is, we try to apply a product recovery approach, try to extract whatever material is good for us and try to replace those, and then certain things are not use for as, you scrap it.

The objective in the product recovery is to recover as much as possible of the economical, as well as ecological value product components and materials, so that to minimise the ultimate quantity of waste.

So, when you try to see options for product recovery after disassembly, it can be repair option, refurbishing option. This is a very common phenomena in the electronics electronic products today. Refurbishment is, there is a defect in the product, the company pulls back the product, tries to work on the product and then the company itself tries to come and give it to the market. So, those things are called as refurbished products.

So, refurbished products are generally economical. So, here they try to improve the quality level through, though not like new one, but they try to improve. Here module levels they do, some modules are repaired and replace. When you try to talk about repair, they restore the working condition, remanufacture, restore of to the quality level as new.

Then cannibalization; So, cannibalization is limited recovery. I cannot use major, I use

only a very small, so that is called a cannibalisation. So, selective disassembly and inspection of potential reusable parts falls in this cannibalisation. The parts reused, recycled or disposed of. Recycling is reuse material only, so it happens at material level, the material used in the new products in, the material it can be used in the new products. So, this approach is called as product recovery approach. Today what has happened in order to fix the customer, the companies are coming up to the strategy.

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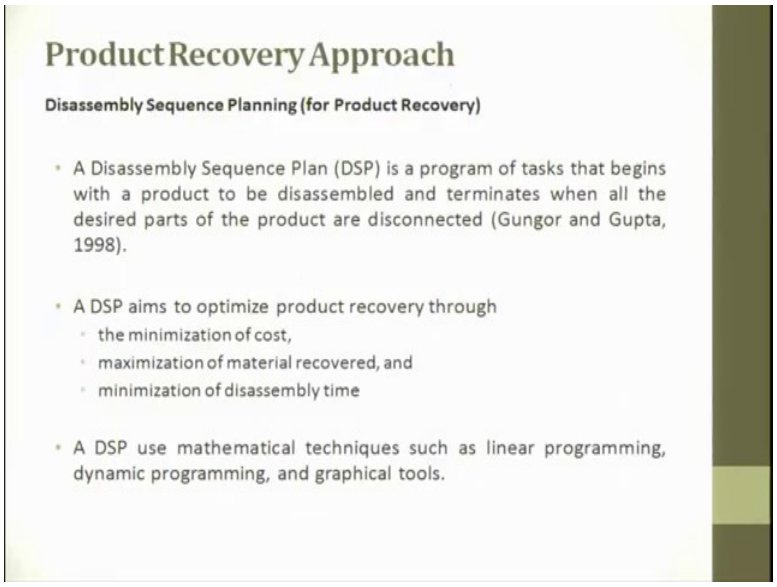

That they will say that after 10 years if you come back to me, I will try to put a better value for the product, and then I will try to give a discount for the product what you are giving it back to me; So, the disassembly sequential plan for product recovery. The disassembly sequential plan which is otherwise called as DSP, is a program of task that begins with the product to be disassembled and terminates when all the desired parts of the product are disconnected.

So, disassembly sequence plan is a program of task that begins with the product to be disassembled, take a car disassembled and terminates when all the desired parts of the product are discontinued, disconnected.

So, the DSP aim is to optimise product recovery through minimisation of cost, maximisation of material recovery, minimisation of disassembly time. So, this is what very, this is also very important point. I should not spend a lot of, lot of money to disassemble, then I should try to recover maximum material whichever is unavailable

with me, and I shall try to do it in faster time. The DSP uses mathematical technique; such as linear programming, dynamic programming and graphical tools for solving this, or this can be used as a product recovery approach; that is.

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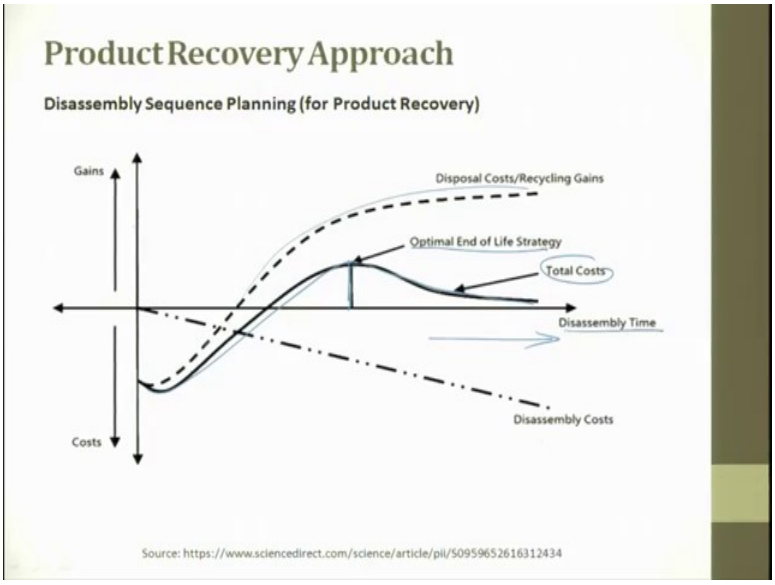

Disassemble sequence planning for product recovery, if you see gain and costs and then if you see here, this is the disassembly time we do. So, if you try to take this disposal costs and recycling costs, it gains over a period of time, disassembly time.

The optimal, optimal end of life strategy, it comes in this zone. So, this is falls under the gain region. This is the total cost, this is the total cost, optimal end of life strategy and this one is the disassembly cost. So, this is disposable cost, this is disassembly cost, this is the optimum end of life strategy and this is the total cost which is spent, and along this direction you have disassembly time and here is gain and here is the cost.

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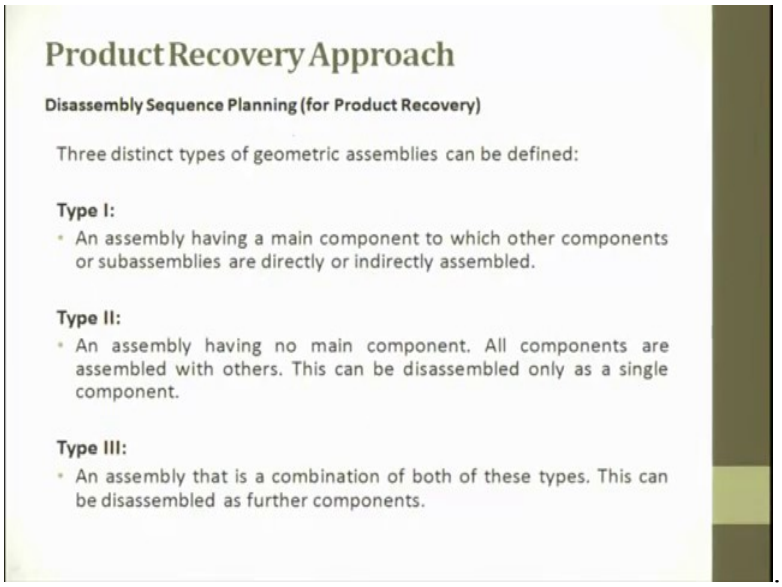

So, the disassembly sequence plan for product recovery has three distinct type of geometric assembly can be defined; Type 1, type 2, type 3. Type 1; an assembly having a main component to which other components or disassemblies are directly or indirectly assembled; for example, breadboard, PCB. Type 2, an assembly having low main components or components are assembled with each other, this may can be disassembled only as a single component.

So, this is something like which is used in toy. An assembly having no main competent, so there is no, there is no base. All components are assembled with each other there all like, like a wheel or a nut or whatever it is, this can be disassembled only as a single, single can be can be disassembled only as a single component when you try to remove type 3, an assembly that is a combination of both the types, this can be disassembled as further as further components.

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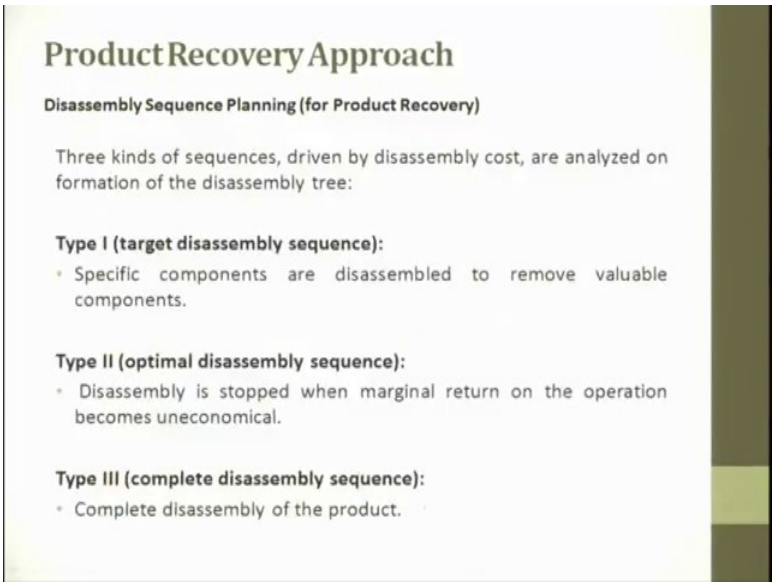

So, the three kinds of sequences driven by disassembly cost are analysed on formation of disassembly tree. So, here type one is target disassembly sequence, the special components are disassembled to remove valuable components. Type 2 is optimal disassembly sequence, disassembly stops when marginal return on the operation becomes uneconomical. Complete disassembly sequences, complete disassembly of the product.

So, these are the three kinds of types which are involved in the product recovery, target disassembly sequence; that means, to say you try to remove valuable components alone; that means, to say in the car, I find that the engine is pretty expensive or it is the heart, so I wanted take it. So, that is called target disassembly sequence. Optimal is you try to keep on the removing till a level; such that it is you do anything more.

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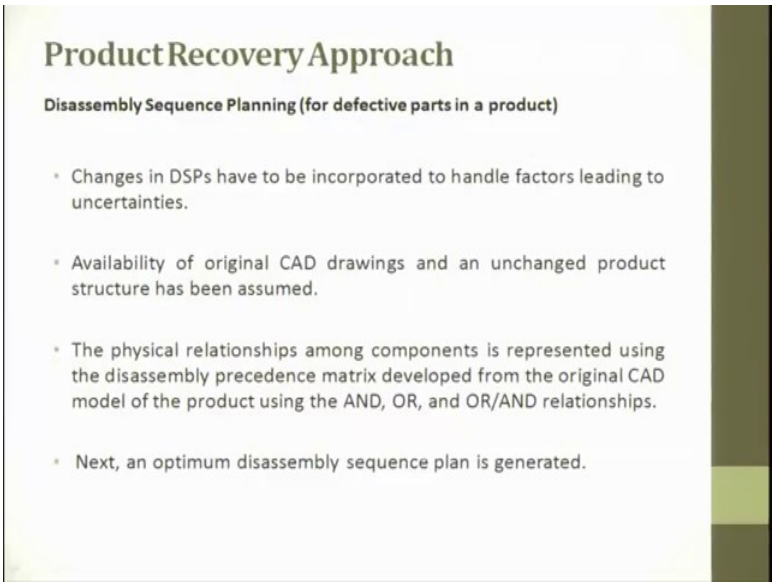

It is going to be uneconomical, so that is optimal disassembly level and complete completely disassemble all these things into small small parts. The disassembly level planning for defective parts in the product, for defective; Till now what we were talking about is, we were talking about original new parts, now for defective parts in a product we are trying to talk; Changes in DSP, what is this DSP? DSP is disassembly sequential planning, have to be incorporated to handle factors leading to uncertainty, uncertainty happens leads to defective

Availability of original CAD drawing and unchanged product structure has to be, has been assumed. The tip, the physical relationship among components is respected using the disassembly precedence matrix, developed from the original CAD model for the product using the AND, OR, OR AND relationship. These are some of the Boolean relationship what we have used. So, I am using this relationship, having a drawing I am trying to use it for design for disassembly.

So, the next, an optimum disassembly sequence is generated by using this, by using from the CAD itself you start and then you try to do Boolean operations.

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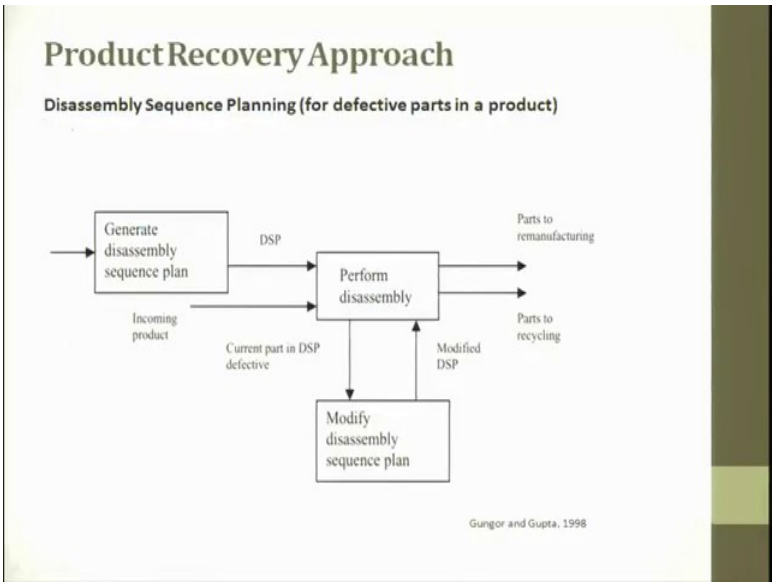

So, here you can see generated disassembly sequential planning. So, generate disassembly sequential planning, then this is sequential planning, it is disassembling sequential planning. So, here you try to look at performance and then here incoming product.

So, you see if there is anything we try to performance of disassembly we see and then parts to be remanufactured, parts to be a recycle, modify DSP, disassembly sequential planning and then modified disassembly sequential planning. So, this goes back and forth and it tries to enhance the performance disability

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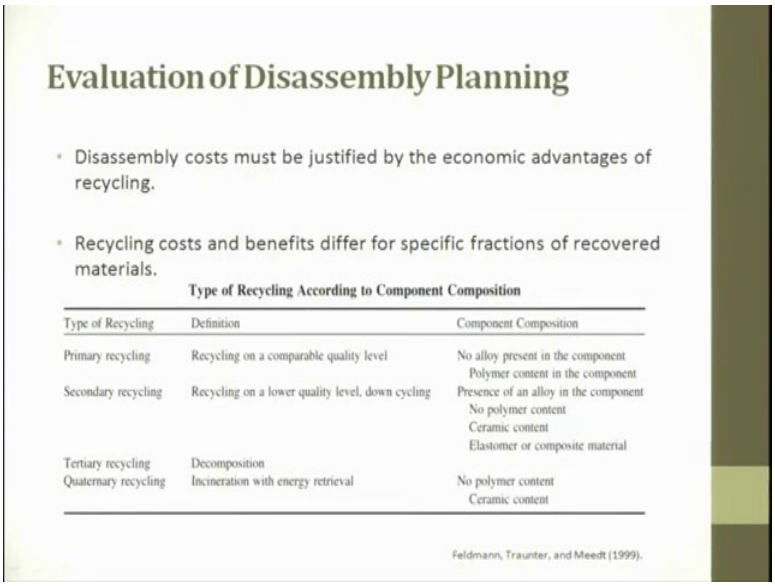

The disassembly cost must be justified by the economical advantage of recycling. The recycle cost and benefit differs from the, for specific fraction of recovery material. So, there are three types of recovery; primary recovery recycling, secondary recycling, tertiary recycling. Primary recycling is nothing, but cycling, recycling of a compatible quality level. Secondary recycling is at lower level quality, so and the tertiary level is decomposition

So, here no alloy present in the component, polymer content in the component, present of an alloy in the components. So, you can see a recycle order comparable quality level; recycle on a lower quality level, decomposition and incineration with energy retrieval. So, there are three types of recycling, so this very important.

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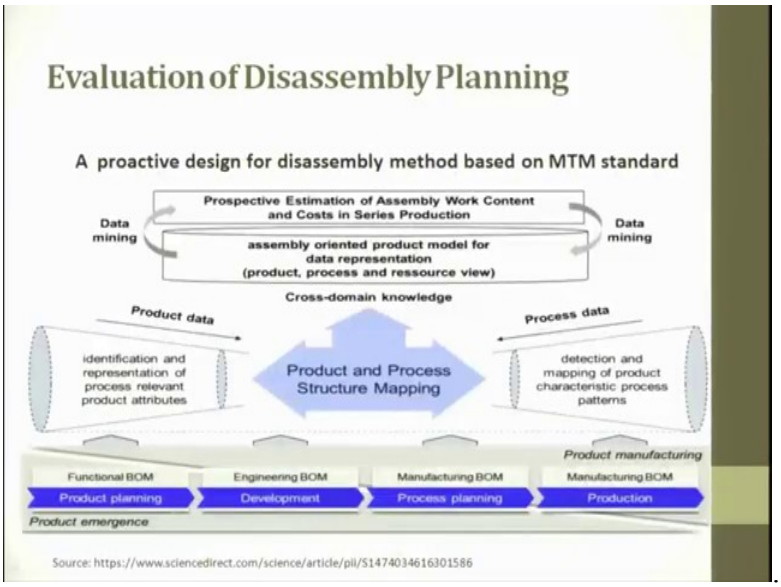

So, the evaluation of disassembly planning; So, a proactive design for disassembly method based on MTM study motion time method study. So, first what the prospective estimation of assembly work content and cost in series, cost in series production. Then what we do is assembly orientation product model for data representation. So, we do a back-and-forth data mining and then what we do is, we try to generate something called the cross domain knowledge. So, here we have product data, here we have process data.

So, this is something like a funnel which comes here. So, identification representation, process relevance and product attributes. So, here reduction and mapping of the product characteristics process pattern, it is here. So, the cross domain knowledge is product and process structure mapping.

So, you see here functional BOM, engineering BOM, manufacturing BOM and manufacturing BOM we have two things. So, here process planning, development engineering BOM we have development, so then we have process planning. Here it is product planning, here it processes planning and here it is production. So, this is all evaluation of disassembly planning

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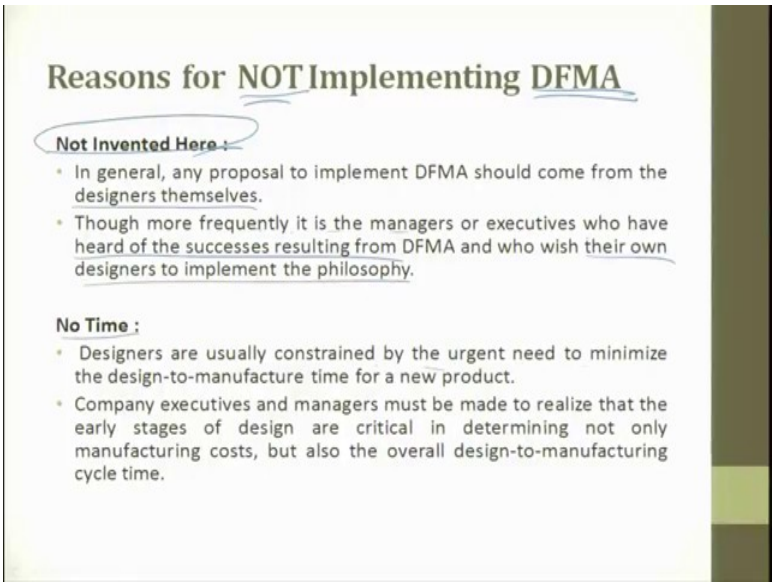

The reasons for not implementing DFM; So, not inventor here; In general, any proposal to implement DFM should come from the designers themselves. It cannot be top to bottom; it has to be bottom to top. Though many, if, though more frequently it is the manager or executers who have heard of the successful, successes resulting from DFM, who wishes their own designer to implement the philosophy, so not invented here.

So, this is why are, we not implementing DFM. So, the one is no time. So, designers are usually constrained by the urgent need to minimise the design to manufacturing time, because of that they do not follow DFM, so not invented here. So, the designer themselves do not have any big proposal

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So, then Ugly Baby Syndrome, it is important, therefore, to involve the designer in the analysis and provide them with the incentive to produce better design. So, you have to keep the designer in the concurrent engineering loop and start doing it. Telling a designer that this design cannot be improved is much like telling a mother that the baby is ugly. So, its, this is what is the Ugly Baby Syndrome.

So, here, because of the Ugly Baby Syndrome they do not implement, then low assembly costs. So, description of the application of the DFM showed that the first step is a DFA analysis of the product of, or the disassembly. Quite frequently it is suggested that since assembly cost for a particular product form only a part proportion to the total manufacturing costs, there is no point in following DFA. So, that is what this is. So, they say that assembly cost is too low, why do you follow DFM.

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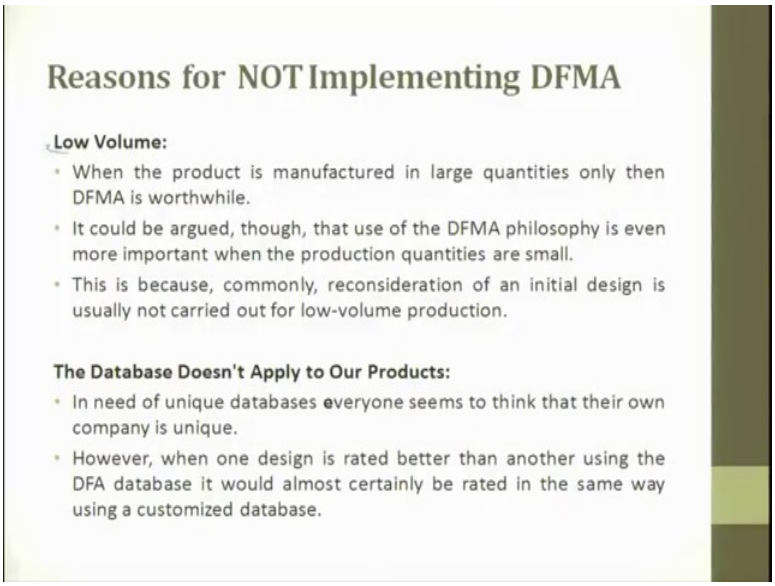

So, the production volume is too low. The database does not apply to our products, so that is what is the other thing.

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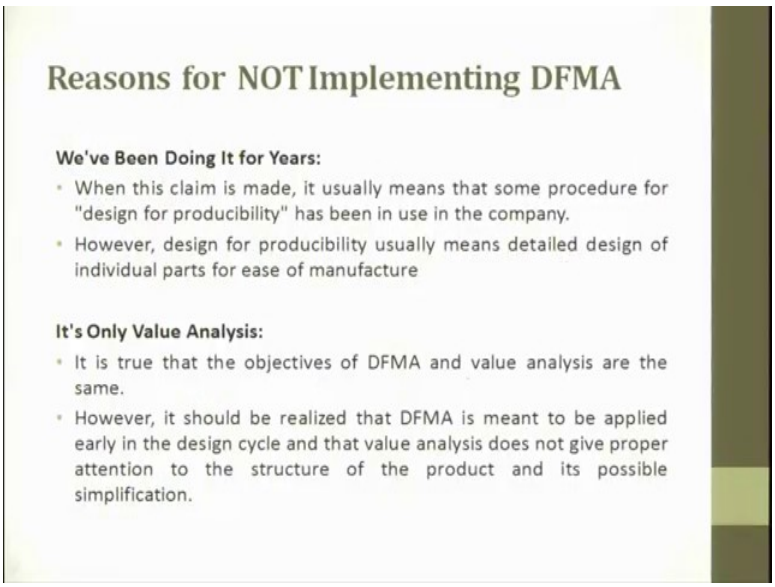

We have been doing it for several years. So, please do not try to teach us, it is only a value analysis, it does not come into reality.

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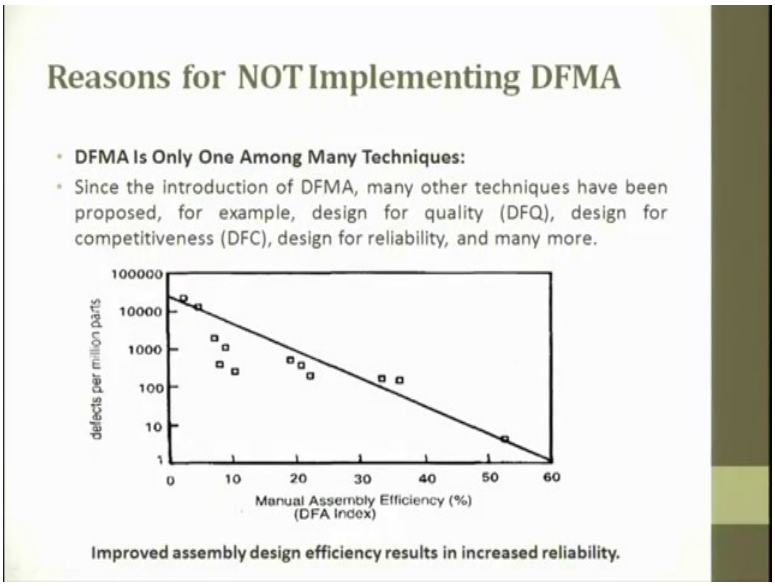

So, these are some of the reasons why people do not implement DFMA. So, DFMA is only one among many techniques, since the introduction of DFMA many other techniques have been proposed like design for quality, design for competitiveness, design for reality and many reliability and many more. So, here are defective parts and here are manual assembly efficiency you can see that.

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The efficiency for the manual is 60 percent, major advantage of applying DFMA during product design. So, this has many advantages, this survey take taken at engineering

design shows reveal somewhat surprisingly the reduction in the manufacturing cost, product manufacturing costs is very high, is not necessarily considered to be the most desirable outcome for redesign efforts. The other advantage is that the DFM produces a systematic procedure for analysing a proposed design DFMA tools also encourages dialogue between the designer and the manufacturing engineer.

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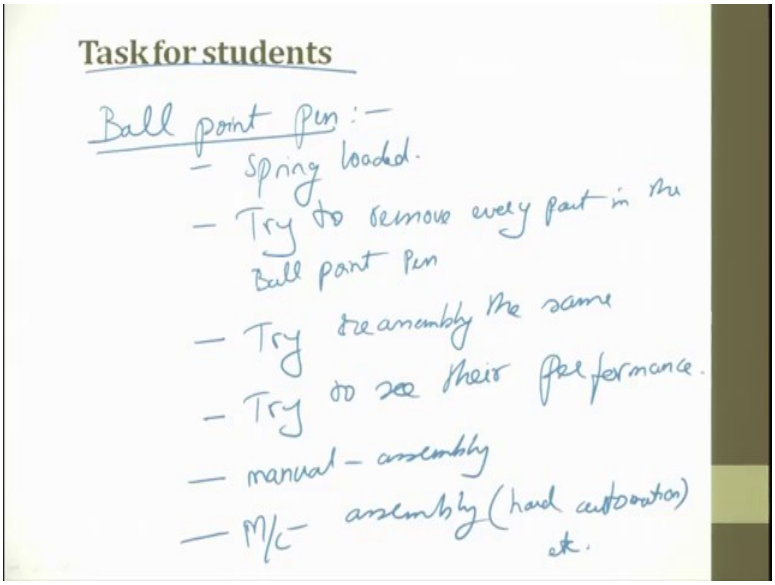

So, this is what is done. So, now what we will do is, you will try to take task for the students, you will try to take ball point pen and then it has to be spring loaded that try to remove every part in the ball point pen. Try reassembling the same, try to see their performance. This will clearly distinguishably say what is the difference between manual assembly and we will try to talk about machine assembly, manual assembly, machine assembly. Machine assembly can be hard soft hard automation etc etc ok.

With that we come to an end for this lecture. In this lecture we were more focused towards design for assembly, design for disassembly. So, we have seen several factors and then we have also seen different levels of disassembly to be executed keeping costs as one of the prime criteria

Thank you.