Rapid Manufacturing

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Lecture - 9
Design for Modularity (Part 3 of 4; Design for Assembly)

So, welcome to the lecture on Design for Assembly.

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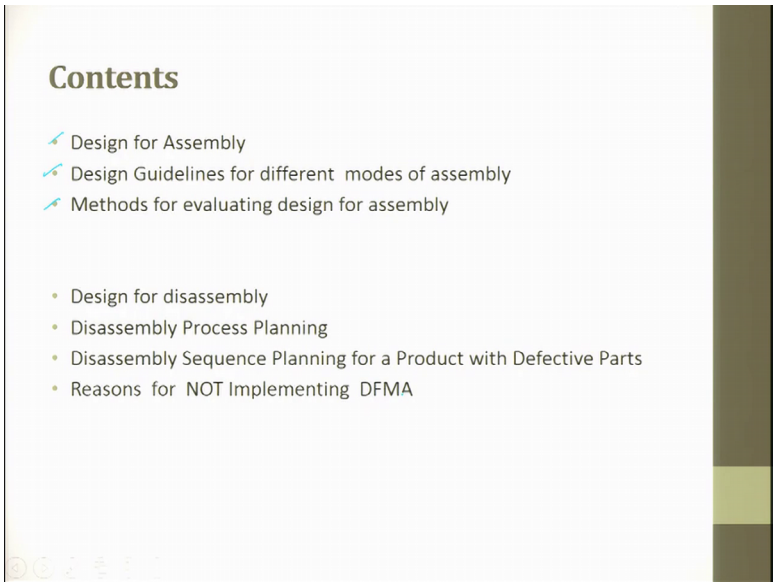

We initially saw design for assembly, design guidelines for different modes of assembly, then methods for evaluating design for assembly. In this lecture we will be more focused towards designed for disassembly, disassembly process, planning disassembly sequence planning for your product with defective parts, reasons for not implementing DFMA.

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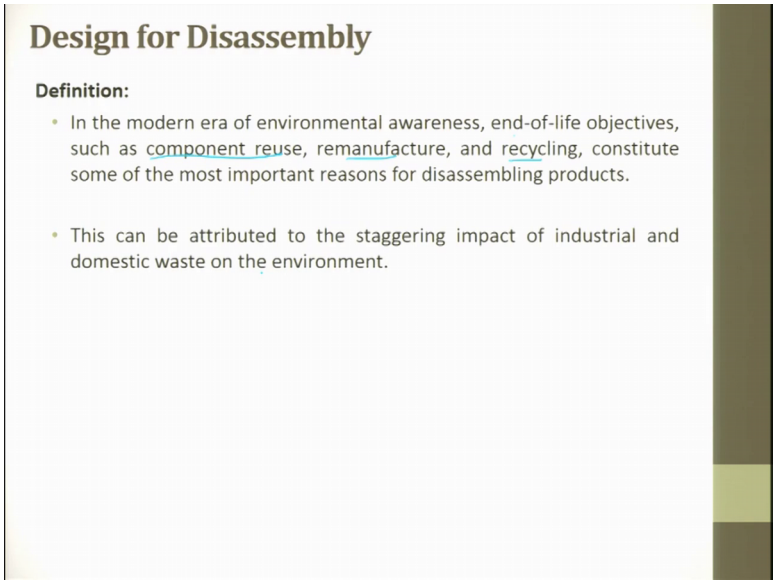

The definition for disassembly: in the modern era of environmental awareness, end of life objectives such as component reuse, remanufacture, recycle constitutes some of the most important reasons for disassembling products. So, earlier it was thought of only from the maintenance point of view; today we are more focus towards component reuse, remanufacture and recycle.

So, in order to optimize the utility of the material or the products or components we are more focus towards reuse, remanufacturer and recycle because, the entire manufacturing domain moves towards our eyes talking towards sustainable manufacturing. This can be attributed to a staggering impact of industrial and domestic waste on the environment.

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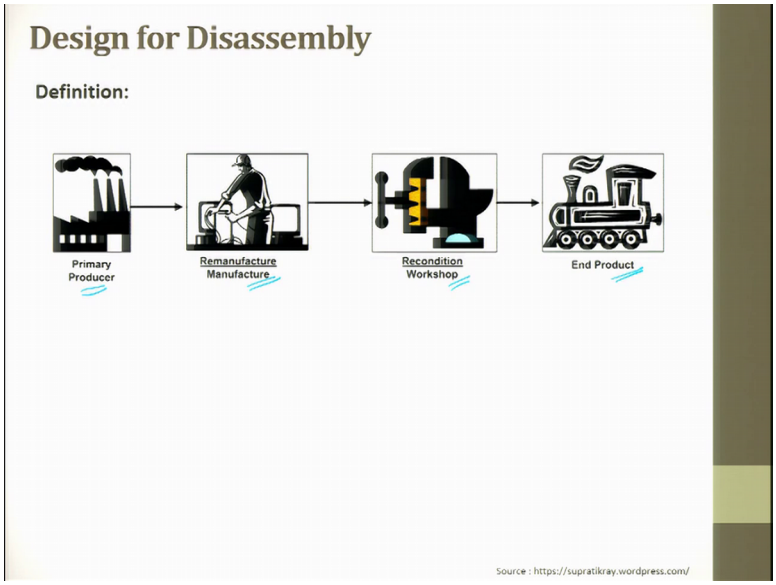

If you go ahead with a same definition, if you want to pictorially represent you can have it as primary producer then you have remanufacture, where in which we try to manufacture and then we do reconditioning in the workshop and then finally, it goes to the end of the product. So, we use all these things to try to reuse the material which can be salvaged and we go towards the end product.

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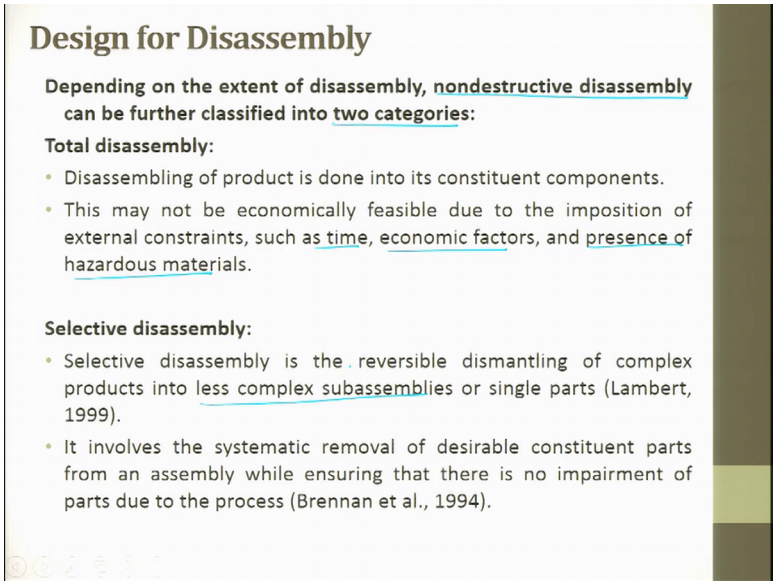

So, depending for disassembly; depending on the extent of disassembly nondestructive disassembly can be further classified into two categories. Please understand nondestructive disassembly, destructive disassembly means you dominates the part and then you do or re-melting or smelting. So, total disassembly: disassembling of a product is done into its constituent components. This may not be economically feasible due to the imposition of external constraints such as time, economy factor and presence of hazardous material. So, disassembling of a product is done into its constituent components. This may not be economically feasible due to the imposition of external constraints, this is total disassembly.

Selective disassembly: selective disassembly is a reversible dismantling of complex product into less complex subassemblies or a single part. So, I tried to remove parts of the entire component is the reversible dismantling of complex product into less complex subassemblies or simple parts. For example, removing a tire from a car; selectively I removed, remove it from one car put it in the other. It involves the systematic removal of

desirable constituent part from an assembly, the example which I gave you is a tire getting removed from a automobile.

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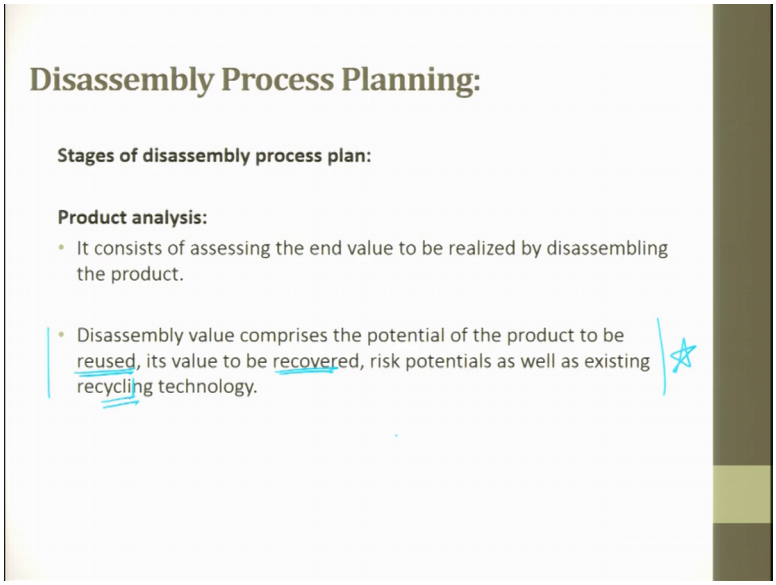

The stages of dismantling process plan, the product analysis: it consists of assessing the end value to be realized by dismantling the product. So, product analysis it consists of assessing the end value to be realized by dismantling the product. Disassembly value comprises the potential of a product to be reused, its value to be recovered, risk potential as well as existing recycling technology.

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

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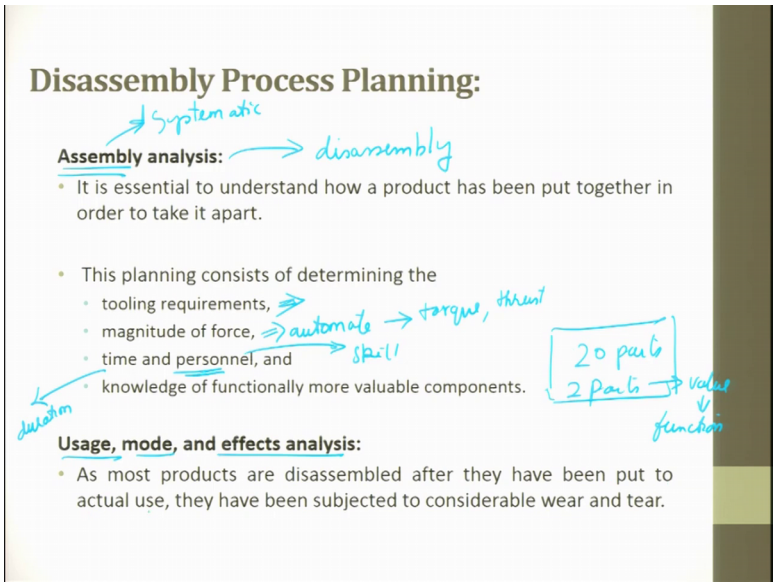

So, when you try to make an assembly analysis it is essential to understand how a product has been put together in order to take it apart. Until, I know how the product is assembled I cannot think of disassembly because, assembly would have been done in a systematic manner. So, the disassembly also should follow a very systematic manner. In fact, when I was travelling abroad I was completely fascinated by looking at the way people try to dismantle a complete product and then assemble it back.

So, they have a best procedure. So, if there are 20 screws they say this screw has to be done first, they have given even numbering for it. So, systematically they go and then remove all the parts, then they do whatever maintenance back and then they follow a reverse of it in a systematic manner they assemble. So, if disassembly has to be efficiently done, the assembly has to be systematically done. It is essential to understand how your product has been put together in order to take it apart.

This planning consists of determining the tooling requirements very important. See many a times we try to damage a very good part or a very good product because, we do not have the tools. Then magnitude of force today, what is happening is many of the assemblies which is done it is all automated. So, when you try to automated it clearly says this is the torque you have to use or this is the thrust you have to use for assembling this part into the product; then time and personnel. So, the skill is very important and the time is what does the duration spend to get the output. The knowledge of functional more

value components is also required, knowledge of functionally more valuable components.

Suppose, you have a subassembly in this subassembly you have 20 parts out of which 2 parts are going to be very much value added part as far as function is concern and not the cost. So, you should know this, pick up this, handle this fellow in a very proper fashion such that you can try to do the disassembly process. Usage mode and effective analysis, Failure Mode Effective Analysis we saw earlier which is nothing, but FMEA. Now, what you are trying to learn is usage mode and effective analysis. As most products are disassembled after they have been put to actual use, they have been subjected to considerable wear and tear.

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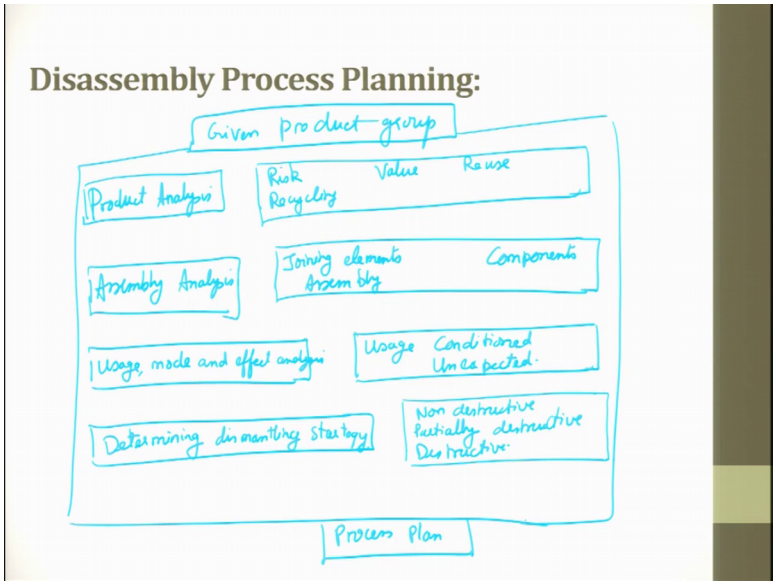

So, the disassembly process plan the schematic diagram goes like this. So, given product group ok so, you have you have product analysis, you have assembly analysis, you have usage mode and effect analysis. And, then you have determining dismantling strategy. So, here when we talk about product analysis we try to see the risk, value reuse and then we say see the recycling ok.

We see the risk, we see what is a value when we are trying to dismantle the part is that we are going to do, what is the reuse components and what is the recycle component. Then when we talk about assembly level analysis we have joining elements, we have

components and then we have assembly. Then we have usage condition and we have unexpected usage condition and unexpected.

And when we talk about this dismantling strategies, we have non-destructive, we have partially destructive and we have destructive. So, these are all the process plans which we do from the dismantling point of view. So, we try to look at given group product we take and then we try to do product analysis, assembly analysis, usage mode effect analysis and determining dismantling strategy. So, these are all the components which are involved when we try to do dismantling process plan right, process plan for fabrication, we have process plan for assembly, we have also process plan for disassembly. When we try to do disassembly risk, reuse, value and recycle are very important components.

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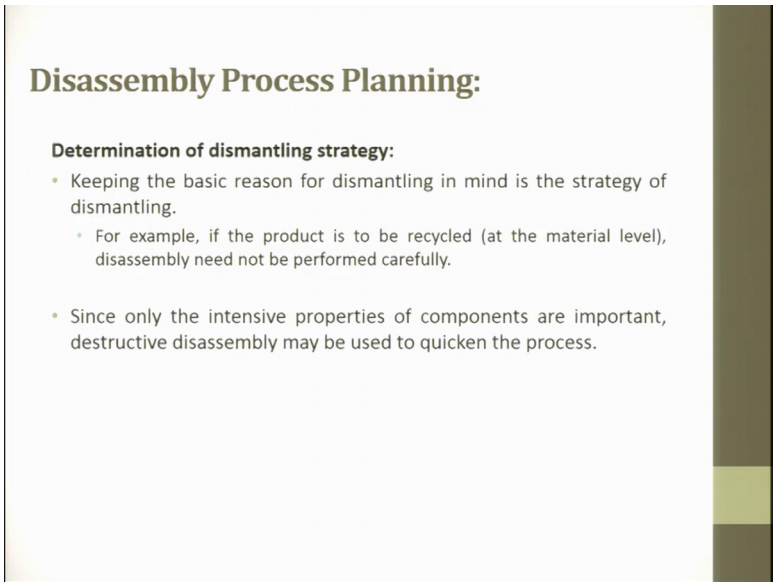

Determination of dismantling strategy: keeping basic reason for dismantling in mind is the strategy of dismantling. For example, if the product is to be recycled at the material level disassembly need not be performed carefully. For example, I am trying to completely take the iron box or iron hollow box and inside a hollow box I have a shaft and a gear. So, if I decided that I am going to recycle it completely at the material level. So, I am going to melt it and then try to make a fresh a billet or a bar whatever it is.

So, then I do not have to spend lot of time in dismantling the shaft and the gear. So, that I spend lot of time and then I try to extract it to material level. Since, only the intensive

properties of the component are important, destructive disassembly may be used to quicken the process. So, here what I do is I try to shear it, hammer it, break it and break it into small pieces such, that when I do casting the surface area to volume ratio is minimized or maximized I start getting the output.

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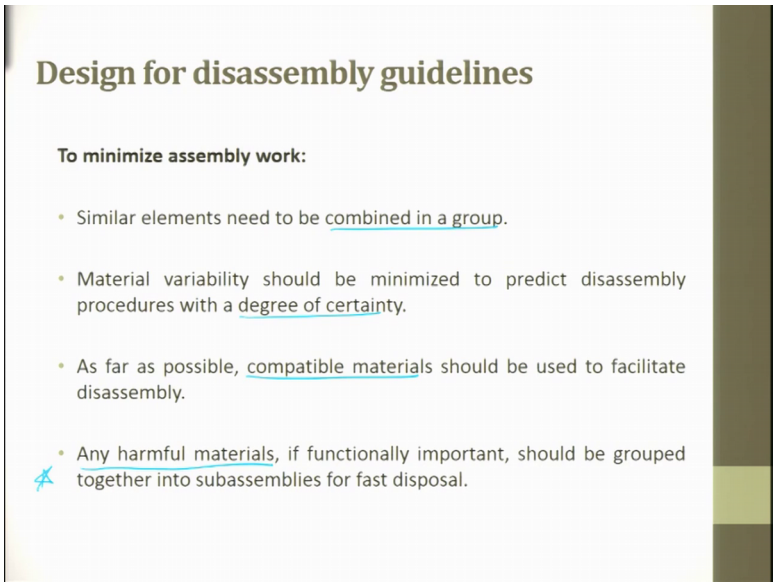

So, to minimize assembly work: so, similar elements need to be combined in a group which we saw earlier also this will try to reduce the assembly work. Material variability should be minimized to predict disassembly procedures with a degree of certainty. As far as the possible, compatible materials should be used to facilitate disassembly compatible materials. So, materials when we try to apply force it should shear. Any harm full material if functionally important should be grouped together into subassemblies for fast disposal. Any harmful material it can be polymer, it can be radioactive material, if functionally important should be grouped together into subassemblies for fast disposal. So, this is also very important when we look at dismantling.

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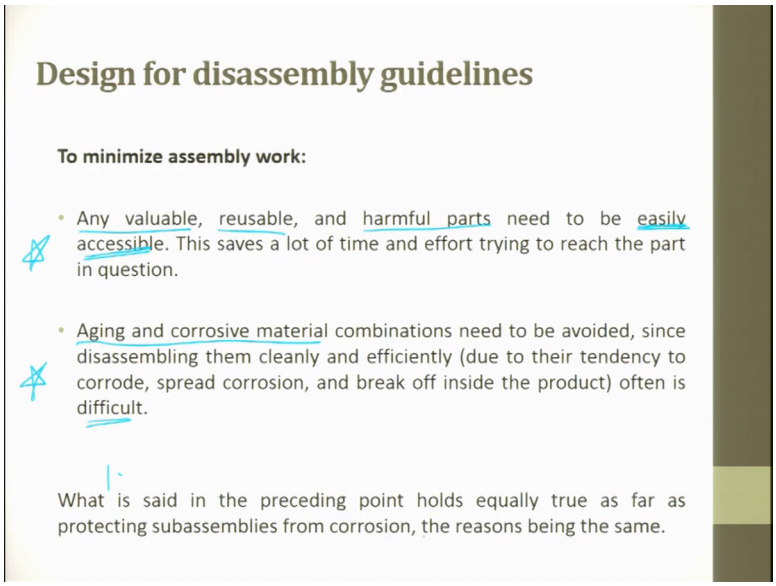

Any valuable, reusable and harmful parts need to be easily accessible; keep this in mind any valuable, reusable and harmful parts should be easily accessible. So, it should be something like a container I pick the container, throw the container I am done with a job. This saves you a lot of time and efforts for trying to reach the part in questions. Aging and corrosive material combination need to be avoided. So, if a material undergoes both the cycles simultaneously it is going to be deadly influence.

So, ageing and corrosive material combination need to be avoided, since disassembling them clearly and efficiently is a big challenge, often is difficult. These two are very very important points please keep it in mind. When we talk about assembling we should also think of product architecture. Product architecture means placing of the subassemblies at spaces such that it can be accessed and it can be replaced very fast ok. What is said in the preceding point holds equally true as far as the protecting subassemblies from corrosion, the reasons being the same.

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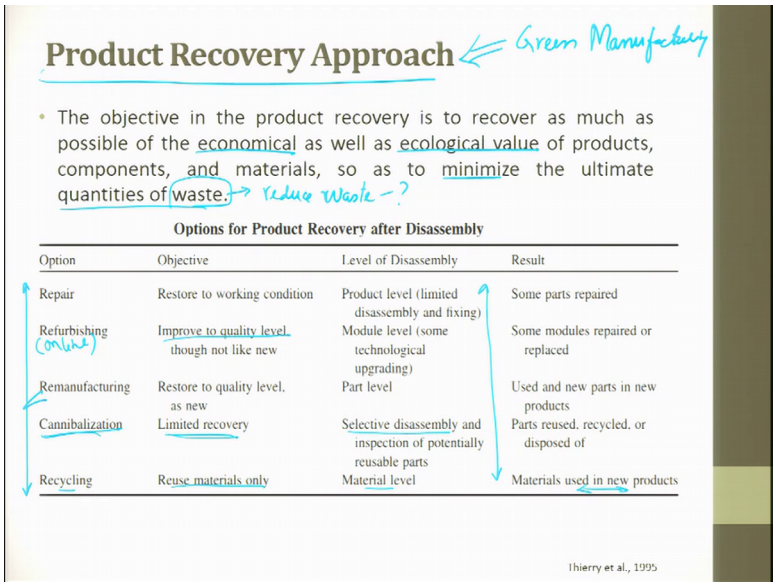

The product recovery approach: the objective in the product recovery is to recover as much as possible of the economical as well as ecological values, economical and ecological; today we are talking about green manufacturing, damage to mother earth. So, economical as well as ecological value of the product, component and material so that to minimize the ultimate quantities of waste. So, the biggest challenges how to reduce waste is a big challenge. So, options for product recovery after disassembly: option 1 is repair, the objective of repair is to restore the working condition, level of disassembly, product level limited disassembly and fixing results some parts are repaired.

Cycle repair restoring to the working condition, product left that remove a nut, put a nut, axle has to be removed, spokes has to be replaced, the bearing has to be replaced, bell has to be replaced. It is all just working on one part, repair the part, put the part into action and then you can start using it. Refurbishing which is very commonly used in online purchase if you see cell phones, they say refurbished cell phones, refurbished products.

Improve to quality level though not like new, improved to quality level this generally happens while producing the part. If there is a small scrap involved or if there is a small damage which is involved or you have used a series of batteries of in a sense battery series means a number, batch number you have used and you have found out that while quality checking they all have given some problems then the entire product is quarantine.

So, now what the company does is take those parts products and then replace those batteries and then start selling it once again and they put stamp saying that it is a refurbished part. So, improve to quality level though not like new, modular level I said battery is a modular, some technological upgrading may be a software upgrading so refurbishment. So, some modules repair or replaced. Remanufacturing: restoring to quality level where the part level we try to do it and then we try to replace, used and new parts in new product will be done when you try to do remanufacturing. The next one is cannibalization: limited recovery cannibalization is limited recovery, selective disassembly and inspect of potential reusable parts; parts reuse, recycled or dispersed off.

Cannibalization means selective disassembly and once you disassemble you have a module and then look at those module or subassembly and look at part level and see what all can be reused, recover it from there and then put it back and start using it and see cannibalization many a times happens. Say in hostels what happens you have lot of furnitures which are to be re-worked some with goes beyond the condition of rework. So, what we do is we extract material from each part, from each table, from each chair and try to assemble it and make one more chair. So, this is cannibalization. So, cannibalization means limited recovery and 100 percent cannot be done.

So, we only recover from 10 parts and then we make 1 product. Then recycling is reusable material only, material level it is done. So, if you look at it product level, module level, part level, selective disassembly and material level look at the level how it goes. Recycling works on material level, materials used in new products for example, we try to take a plastic bottle, shred it we go back to the platform then make platform and then you can make one more bottle. So, that is shredding and making one more bottle.

So, these are the different options which are available as far as product recovery approach is concerned. Now when we talk about green manufacturing this is all major component or major concepts or technology which is used. So, these are some of the options for recovery, repair, refurbishing, remanufacturing, cannibalization and recycling.

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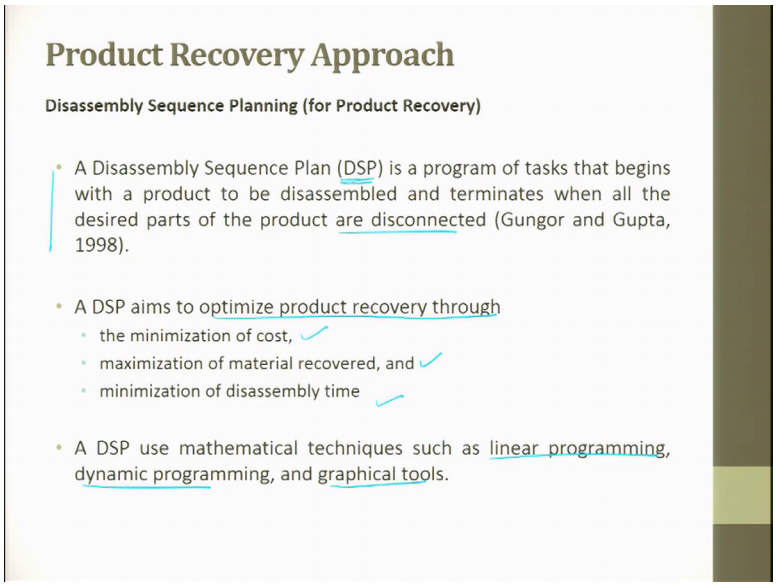

So, disassembly sequence planning for a product recovery, that Disassembly Sequence Plan: DSP is your program of tasks that begins with your product to be disassembled and terminates when all the desired parts of the products are disconnected. So, this is the definition for disassembly sequence plan. You buy a car, remove that car part by part by part by part that is called as disassembled and terminates when all the desired parts of the product are disconnected, part by part by part. DSP aims to optimize product recovery through the minimization of cost, maximization of metal recovery and minimization of disassembly time. One is cost, time and material recovery.

This are the optimized product recovery through these are the optimization techniques which we use or the constraints, we use not the techniques constraints we use. One is cost, other one is material and then maximize metal recovery and minimize disassembly time. A DSP uses mathematical techniques such as linear programming, dynamic programming and graphical tool for doing it. For example, I have been working with a problem of recovering or recycling lead acid batteries; lead acid batteries are more used in UPS that is Uninterrupted Power Supply, it is used in cars. So, all these batteries are 90 percent or even people claim 99 percent recoverable. So, we try to look into the cycle, how is this entire cycle working on.

So, when a customer buys he uses it, when he tries to sell the used batteries what is the costing he get, what is a policy which is there for the entire recovery of the lead acid

battery parts is a big challenge. And, people have started working on it because, the policy decision has to be made. What percentage of discount has to be given to the customer when he tries to buy a new product. When he gives the old battery to me and buys a new battery for me, what is a discount and when it is getting into recycling what will be the cost recycling person gets from the manufacturer. So, it is a very very interesting problem.

Product recovery approach is very much talked today. For example, when you have trying to discard your automobile, bus, truck, car. So, what happens to the overall recovery for example, if a car is to be salvaged, if a car is to be sent for recycling. So, how much percentage of parts come for recycling, what is a recycling procedure, what is the energy we apply at every level, what should be the costing who gets this costing. And, at last from the product what is the amount of waste getting generated. So, it is very interesting and government is pushing to do lot of study on this recovery.

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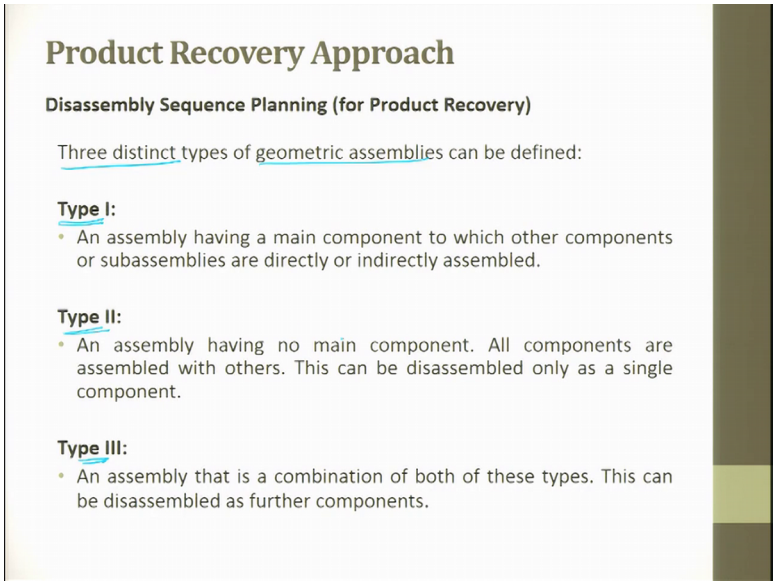

So, the dismantling disassembly sequence planning for product recovery three distinct types of geometric assemblies can be defined. So, first is type I: any assembly having a main component to which other components are subassemblies are directly or indirectly assembled they are called as type I. Type II is any assembly having no main components. All components are assembled with others. This can be disassembled only as a single

component is called as type II. Type III: an assembly that is a combination of both of these types, this is called as type III.

This can be disassembled as further components, this is called as type III. So, type I let us take an example of a car and assembly having a main component to which other components or subassemblies are directly or indirectly assembled for example, engine ok. And, assembly having no main components all components are assembled with others. This can be disassembled only as a single component or tire and rim. So, when you have a mixture of these both it is type III.

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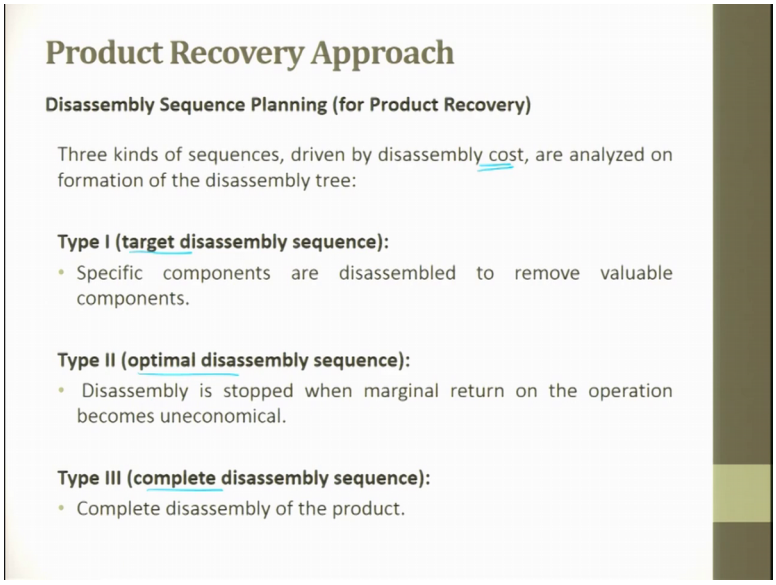

Three kinds of sequences driven by disassembly cost are analyzed on formation of the disassembly tree. Type I target disassembly sequence: specific components are disassembled to remove valuable components. For example, you try to remove some 10 bolts and nuts and you recover a complete engine. So, target disassemble sequence; optional disassembly sequence: disassembly is stopped when marginal returns on the operation becomes uneconomical. You keep removing, removing, removing till that time that you know that these are the parts when you try to dismantle you are not going to make a money out of it stop there.

So, that is disassembly is stopped when marginal returns on the operation becomes uneconomical. That type III is a complete disassembly of a product is complete disassembly sequence. So, you have target disassembly, optimum disassembly and

complete disassembly all these things are disassembled keeping the optimization parameter has caused or time. So, cost and time can be linked.

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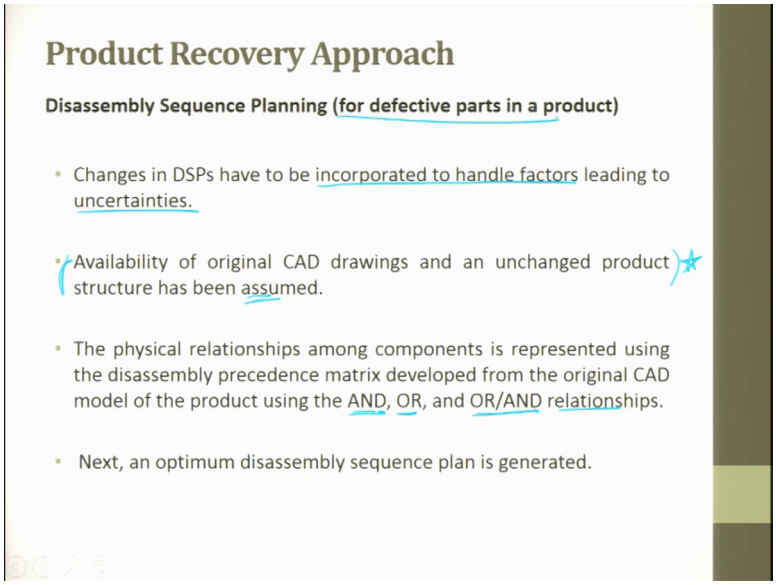

Disassembly sequence planning for defective parts in your product: changes in disassembly sequential planning have to be incorporated to handle factors leading to uncertainty. So, incorporating to handle factors leading to uncertainties. Availability of original CAD drawing and an unchanged product structure has been assumed. So, these are all for defective parts, these are all for defective parts. Please note it down.

Availability of original drawing and an unchanged product structure has been assumed. Next is the physical relationship among components is represented using the disassembly precedence matrix develop from the original CAD model of a product using AND, OR, OR and AND relationship. Next, an optimum disassembly sequence planning is generated. So, this is all for a defective parts in a product.

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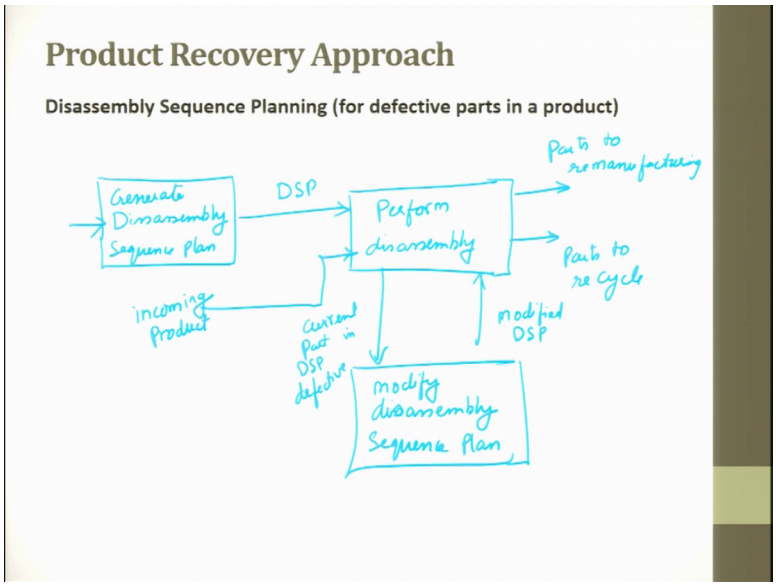

So, when we try to draw a schematic diagram for disassembly sequence planning for defective products; first what we do is we generate disassembly sequence plan. How are we going to remove, next it is going to be DSP: Disassembly Sequence Plan for perform disassembly. Then it is going to be parts to remanufacture. When you want to understand what is remanufacture, please go and see the options which we went through now cannibalization, recycling, remanufacturing so those things. So, parts to recycle. So, these are all performance disassembly. So, here we modify disassembly sequence plan.

And, this is the incoming products and this is the current part in DSP defective ok. This is modified DSP, DSP is Disassemble Sequence Plan ok. So, it is generating disassembly sequence plan. So, then the plan is given here, performance disassembly is carried out. So, you tried to separate out remanufacturing, recycling and then it is modified disassembly sequence plan is done. So, this is given back. So, again this gets reiterated and we start doing it. So, here is directly from the incoming product where disassemble parts can be or products can be put for.

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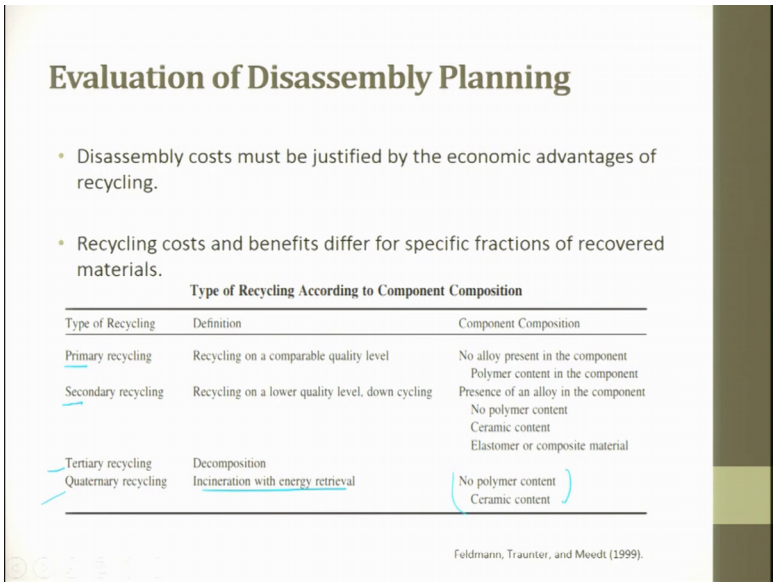

So, evaluation of disassembling plan. Disassembly cost must be justified by the economic advantage of recycling. Recycling costs and benefits differ for specific fractions of recovered material. Recycling costs and benefits differ for specific fractions of recovered material. So, type of recycling according to the component composition we have primary recycling, secondary recycling, tertiary recycling and quaternary recycling. So, primary recycling is defined as recycling on your comparable quality level.

No alloy present in the component, polymer content in the component is taken care. So, secondary recovery: recycling on your lower quality level, down cycling, presence of an alloy in the component, low polymer content, ceramic content, elastomers and composite materials. So, these are all the component composition right. Then ternary recycling: complete decomposition, low polymer content of ceramic and quaternary recycling is incineration with energy retrieval. So, this is like biomass, incineration with energy retrieval again the component composition will be low polymer or ceramic content in it.

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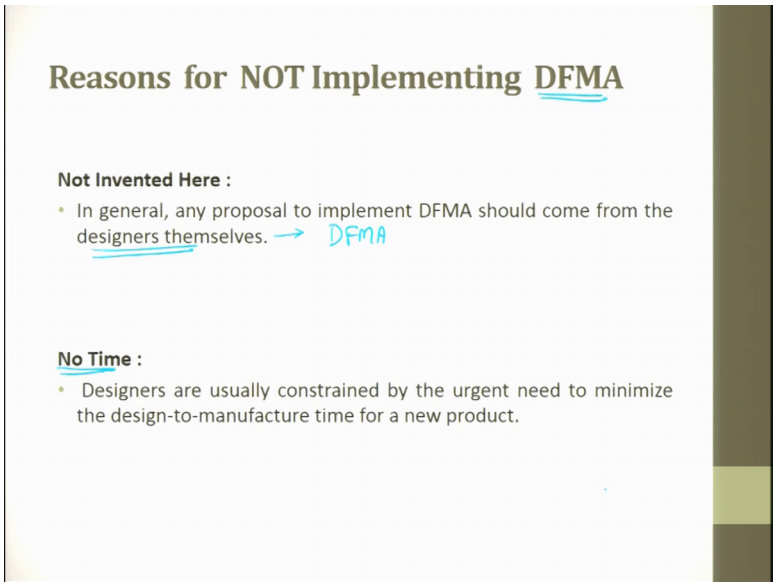

So, reasons for not implementing DFMA: Design for Manufacturing and Assembly not invented here. In general, any proposal to implement DFMA should come from the designers themselves. If the designers do not come then it is good for DFMA it is going to be very very difficult. Next is no time: designers are usually constrained by the urgent need to minimize the design to manufacturing time for a new product. So, that is why no time. So, this tries to put a major restriction for implementing for DFMA.

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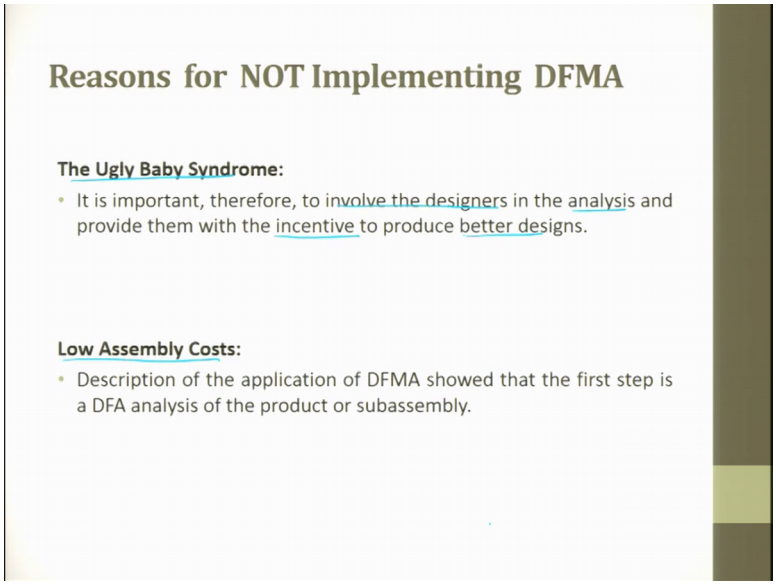

So, the ugly baby syndrome is: involve the designers in the analysis and provide them with the incentive to produce better design. So, designers getting involved in the analysis. So, while analysis they know where the failure is, how the failure is, how to retrieve the failure or how to improve the product and other things. Low assembly cost: description of the application of DFMA shows that the first step is a DFA analysis of a product or subassembly. So, the low assembly cost also tries to put a restriction from going to DFMA.

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If the production volume is low then also people do not prefer for going for DFMA because, DFMA needs a critical batch size in terms of numbers. When the product is manufactured in large quantities only then DFMA is worthwhile. The database does not apply to our product: in need of unique database everyone seems to think that their own company is unique. So, this is the other thing which companies do not apply DFMA.

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We have been doing it for years. So, this is a typical mind set which is there amongst industries that they do not look for implementation of design for manufacturing an assembly. When this claim is made, it usually means that some procedures for "design for producibility" has been in used in the company ok; design for producibility is used in the company its only value analysis. It is true that the objective of DFMA and value analysis are the same. So, this also puts a restriction of implementing DFMA.

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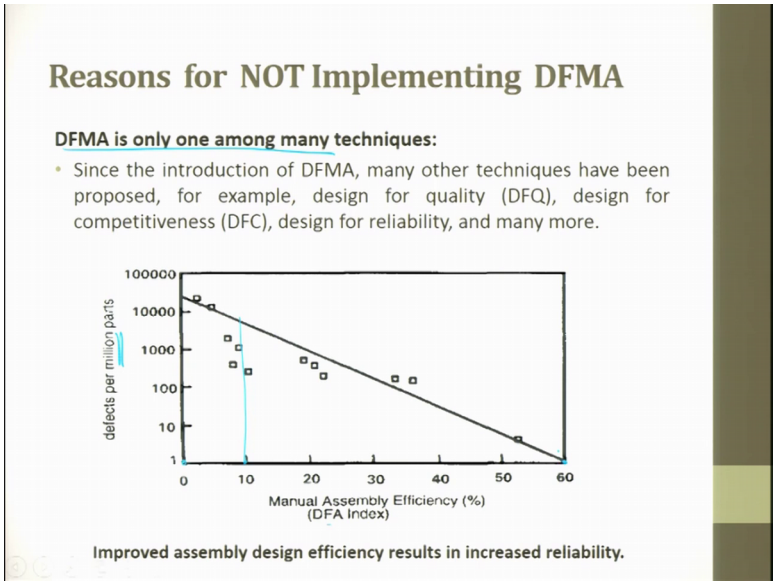

The reasons for not implementing DFMA. DFMA is only one among the many techniques which are available. So, since the introduction of DFMA many other techniques have been proposed. For example, design for quality, design for competitiveness, design for reliability, design for repeatability and many more. If you look at it defects per million parts ok. So, these are in million parts. These are the manual assembly efficiency.

DFMA index you see that when the efficiency is very high 60 percent, when the parts defects part is produced is 1 when the manual efficiency is such 60 percent, then the manual efficiency goes down so; that means, to say there are many mistakes done. So, many defective parts are produced per million ok. So, this is an index which clearly says why we should go from manual assembly to automatic assembly. So, if it is 1 defect the manual efficiency is 60 percent so, per million.

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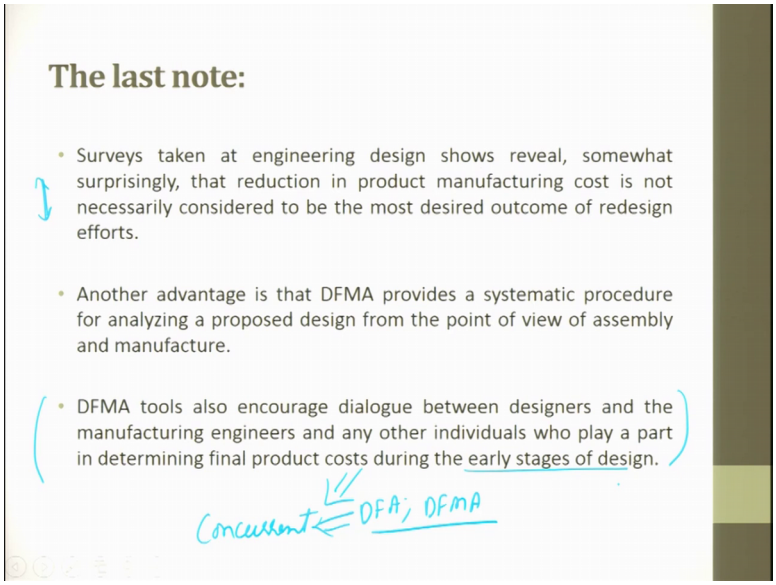

So, the last note: survey taken at engineering design shows reveal somewhat surprisingly, that reduction in product manufacturing cost is not necessarily considered to be the most desired outcome of redesigning efforts. This is what I understand and this is what I have collected from several literatures. Another advantage he is that DFMA provides your systematic procedure for analyzing a proposed design from the point of view of assembly and manufacturing.

DFMA tools also encourages dialogue between designers and the manufacturing engineers and any other individuals who play your part in determining final product cost during the early stage of design. This point is very important, this is why in concurrent engineering we try to in the discussion whatever it is DFA, DFMA is all used ok. So, determining the final cost of product cost during the early design stage is done if DFMA is implemented.

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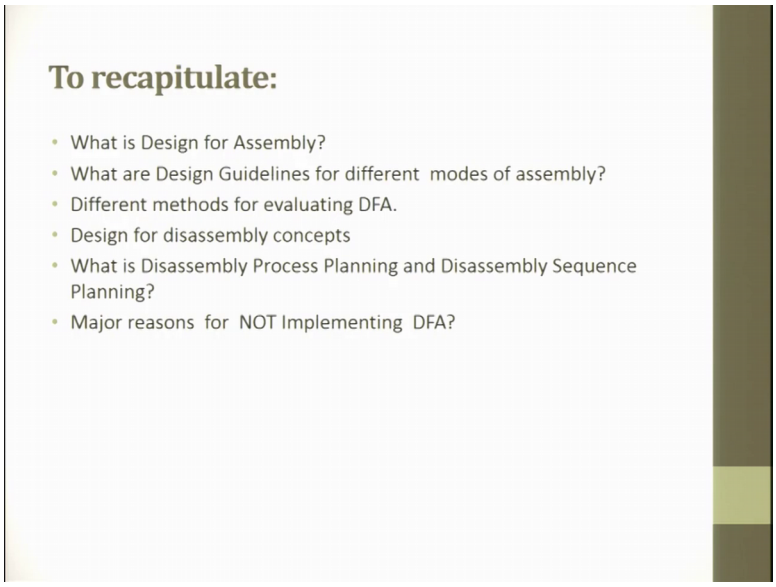

So, to recapitulate what we saw in this particular lecture: series of design for assembly and disassembly. What is a design for assembly? What are design guidelines for different modes of assembly? Different methods for evaluating DFA: Design For Assembly. Design for disassembly concepts. What is disassembly process plan and different types in it, disassembly sequential planning? Major reason for not implementing DFA? These are some of the titles are topics or contents we saw in this lecture.

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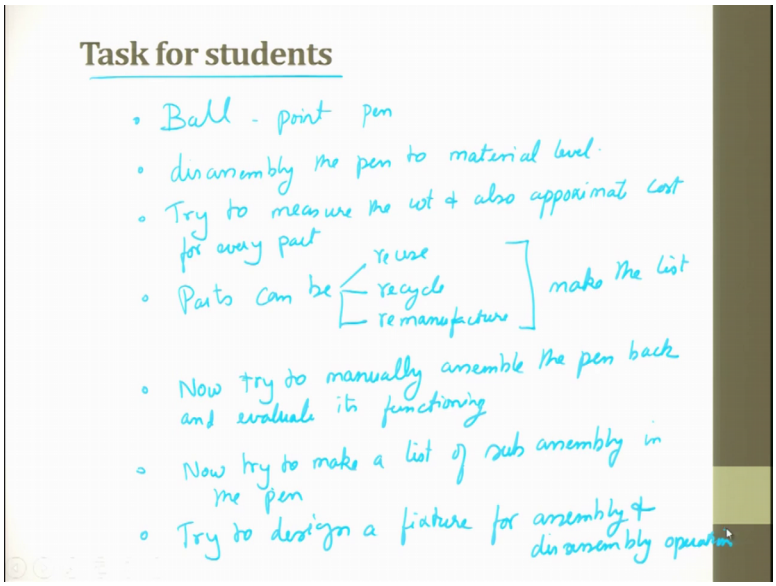

So, tasks to students: take a ballpoint pen ok. Try to disassemble the pen to material level, try to measure the weight and also approximate cost for every part. Certain parts can be reused, can be recycled, can be remanufactured. Please make the list ok. After doing all these studies, now try to manually assemble the pen back and evaluate its functioning. You will see lot of challenges will be there and it will be very surprising to see, many a times it will not even function.

Then on top of it when we have made parts that can be recycled; so, now you are to the last mile right to the material level. Now, you will try to make a list of subassembly technique used in the parts or now try to make a list of subassemblies in the pen. Try to design a fixture for assembly and disassembly operation. You can take ink pen or I have said ball point you can also take ink pen.

So, if your more conversion with ink pen please do it. Try to disassemble, then assemble, try to make a fixture first that you exactly make it to the requirements. So, once you start doing this complete exercise you will start realizing what is assembly, what is systematic assembly, what is disassembly, what is the systematic disassembly, what is the economical viability level till where we can go disassemble parts and see. And, after you do that how is the concept of recycling, reuse and remanufacturing applied in the pen as a product so.

Thank you very much.