Rapid Manufacturing

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Lecture –8
Design for Modularity (Part 2 of 4; Design for Assembly)

Welcome to the next lecture on Design for Assembly. As you know in manufacturing there are two important processes; one is fabrication the other one is assembly and people slowly have started realising that if you give more importance that to assembly then you will try to have more number of parts and there is a prone for defects also. So, now, people are looking for can we make a product which is assembly free or let us can we reduce the number of parts make it into small small subassemblies in each subassembly you have very minimum parts so that the assembly is perfect.

And the other things people have companies have also started realising that assembly process if I do nobody is going to pay me extra. So, slowly slowly the companies have started working on design for assembly and shifting the assembly process completely to the customer side. For example, when you buy a fan ceiling fan we buy it as parts and then we assemble to get the final product. Today when you buy when you are looking for a modular kitchen you buy it as parts and then you assemble.

When you buy a desktop computer you get it both version assembled version and unassembled version so you try to get everything and you start assembling it. So, slowly slowly and for example, when you talk about modular furniture so, that is the other thing which is also talked about. People are slowly started assembling the final product at the customer end rather than manufacturers end.

So, design for assembly is the next topic. There is lot of importance now company is giving towards this to make their product more reliable repeatable and they take care of logistics costing also.

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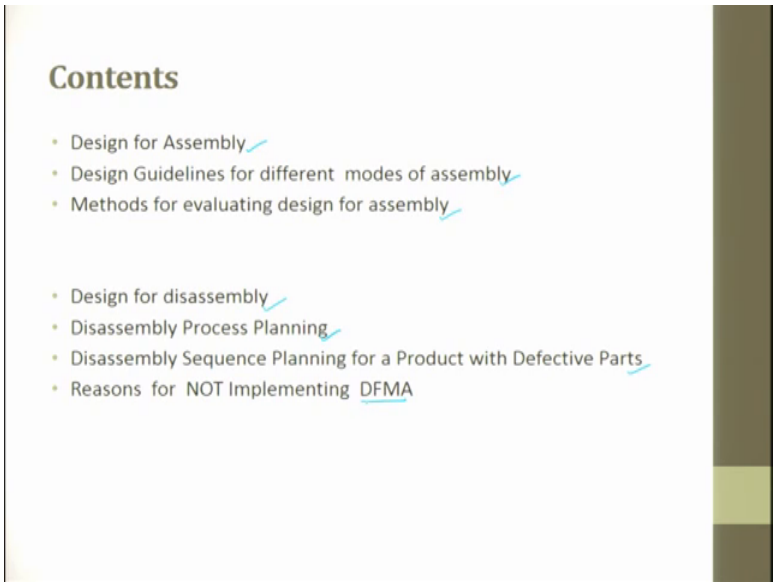

So, in this lecture we will go through design for assembly, then guidelines for different modes of assembly, then methods for evaluating design for assembly. Then design for disassembly assembly disassembly; disassembly process planning, disassembly sequence planning for a product with defective parts. And finally, reasons for not implementing DFMA design for manufacturing and assembly.

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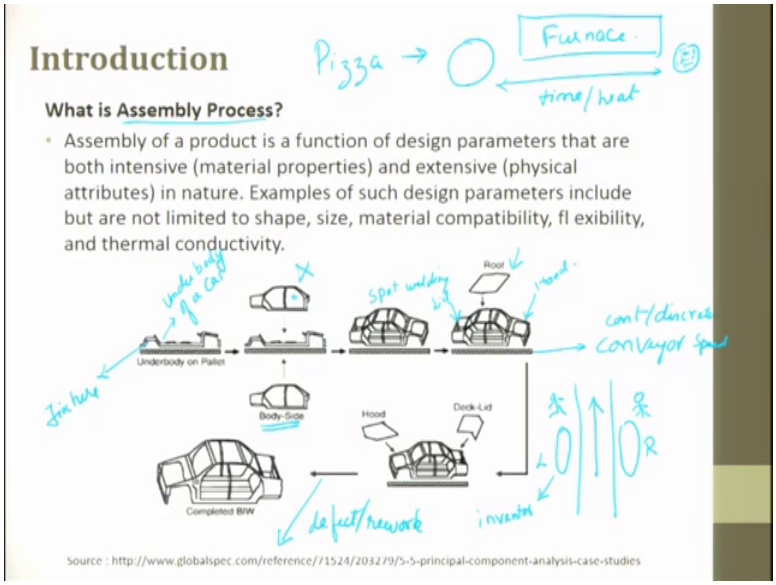

What is assembly process? Assembly of a product is a function of design parameters that are both intensive and extensive in nature. Example of such design parameters include,

but are not limited to shape size material compatibility, flexibility and thermal conductivity. This is what is definition or the meaning for assembly process. Assembly of a product is a function of design parameters that are both intensive and extensive in nature.

If you look at the complete assembly of a car you see that the under body is kept on your palate and this is moving in a conveyor. And interestingly in car assembly or in automobile assembly or in pizza assembly where ever your mass production rate is very high they look for automated assembly line. In automated assembly line in order to maintain the production rate they always move it on a conveyor. In this conveyor you put a fixture and hold your part.

So, your part is here nothing, but the under body or of your car. So, that is put on a pallet or fixture. Now this is placed in a fixture and this moves at a regular speed you can do two things continuous feeding or you can also have discrete conveyor moving speeds. So, when I said discreet it comes and stands at a station and it stays in that station for a limited time and then it starts moving to the next one.

So, when you do this the entire cycle time of all the stations have to be balanced. Both in terms of inventory and second in terms of the operations what is to be done. So, now, you see the body side one side that is left side and right side it is done. Interestingly, in car assembly what happens the conveyor most like this and you have a set of works happening in the left hand side as well as in the right inside.

So, you can have inventory here, you can have a operator here and you can have an operator here. So, he does all the right side work, he does all the left side work and conveyor keeps moving all along. So, here if you see this is the body side which is fixed to the under body of chasse right. So, now, it is done on both sides. So, then the conveyor keeps moving to the next stage where in which it gets assembled on the spot welding or welding happens here this only placing.

And next station you can have welding operations moment the welding is done. So, or the fixtures are put so, that you can do all the fasteners and then it was for the roof for the bonnet and for the hood. So, you can these three parts come and get filled up or here it is only roof and then the conveyor keeps going to the next station where in which you have deck lid which is put and you have the hood which comes on the top.

So hood comes here and then you have lid deck lid come here or this is called as dicky or decklid. So, in a very colloquial term in India we always call it as dicky so decklid is put your hand then you have a hood here so, this is assembled. And now what you see is you see only the shell of the car; shell of the car. And then what they do is you have to now start feeding engine and other components.

So, this can happen while the car is made or the entire white body assembly can happen and then you start fixing the engine and other working functional parts inside. And then comes your tyre fixing and other things so, this is a complete assembly line. If you look at the other way round when you look at Pizza corner or Pizza hut where in which the assembly is all done at a single station and then it is passed through a furnace ok. Where this furnace it passes through it there ISA time period and temperature heat time heat is set it is passed through.

And then what you get is a final assembly of parts. You can have single station assembly; you can have multiple station assembly depending upon your products. And the beauty of assembly line is the cycle time for every process is. And suppose if one station stops its production. The entire line stops it is production because the conveyor cannot move to the next station with the defective part or if there is a defect which is happening which you could not rectify and it is allowed to move.

And what happens is all further operations on this defective car will not happen and the car will be excited out as defective or rework. This is also possible, if in case it is only one defect and it is peculiar which is not going to get continuously repeated. So, then they say let it go and then will pull it out rework only on the car, but the rest of the car let it go on the fresh one. Suppose if there is a major defect on the metal working operation a hole is there or a dent is there then the entire cars pulled out reworked and then done. And rest of the assembly the car goes through every station it spends that time and no work will happen on the car.

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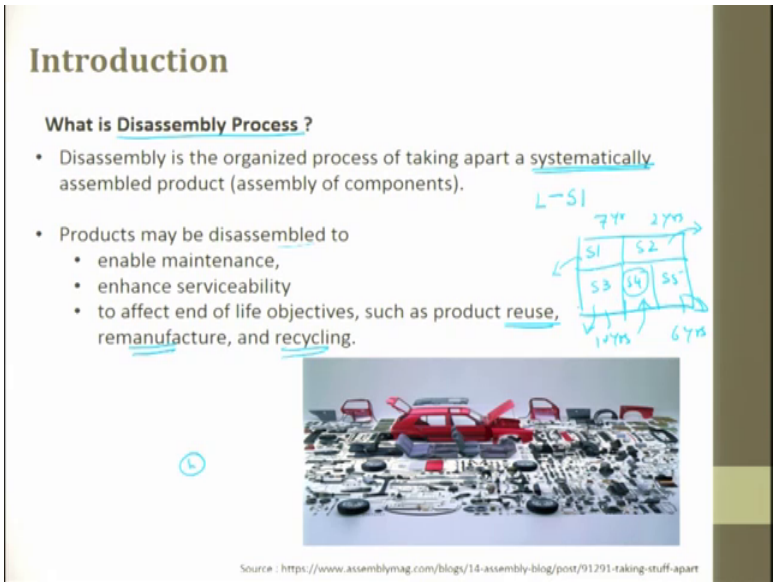

What is disassembly? Disassembly is the organised process to of taking a part here systematically assemble the product. So, is pretty interesting when you disassemble you should be very very systematic. I remember when I was young I dismantled a tape recorder id is mantled it completely with enthusiasm that I will be able to put it back, I did not realise that there are so many parts which are which have to go in the selective fashion.

That means, to save this screw can go only hear that screw can left hand it will go left hand right hand has to go right hand. So, I did not realise the importance I just removed all put it in a piece of paper and kept aside and then started assembling it then I realise the problem. My father taught me the systematic way and what you have to do if you have to take a paper, you have to take apart mark on the part L on the paper whatever you do keep that and mark it as L. So, then you place the path here.

So, that when you are assemble it is done one after the other after the other and in the same way he also told me that you should have the system assembly. For example, if the subsystem assembly is S1 please write it has left hand side S1. So, this is a systematic way of dismantling it or a systematically assembled part. Dismantling process is also very important. Today you can see the tyre in a car when it gets flattened the assembling and disassembling time has become very less.

There are quick fastening nuts which have come into action switch. So, all these things are designed for this assembly process. The products maybe disassemble to e enable maintenance enhance serviceability to affect end of life object such as product reuse remanufacture, recycle. So, many a times what happens you might have a product. So, in this product I will section this product into several assemblies so S1, S2, 3, 4 and 5.

So, if you look at it so all these subassemblies need not fail when the product is not functioning to the expectation there might be only S 4 a failure. So, one way of doing it is you service it replace this part and start using the same product. The other way around start dismantling remove those parts or subassemblies which are good and then try to salvage it put it into a next product and start using it ok.

This is what we are calling it reuse right reuse. Recycling means you take it out dismantle it and then you try to generate the raw material and from the raw material you process it to get the part. So, here the raw material is a material which is getting used or which is available in the market already in use that is recycle. Remanufacturing is what we do we try to change the path whatever it is there cut it into pieces or do some modifications and then start using it ok.

So, these are the three objectives in fact today when the product sold in the market entire sum of their subassemblies are given warranty 7 years warranty, 2 years warranty, 10 years warranty, 6 years it is given. So, the overall product is given a warranty of 2 years, but individual sub assemblies are given warranty of different different time.

So, now the company says if you come back within the warranty period and give me back the all the subassemblies to me. Now on the new product I will give a discount and I will give you a fresh product and the company tries to take these products for recycling or reuse ok. So, now the concept of assembling and disassembling is getting integrated heavily into costing also.

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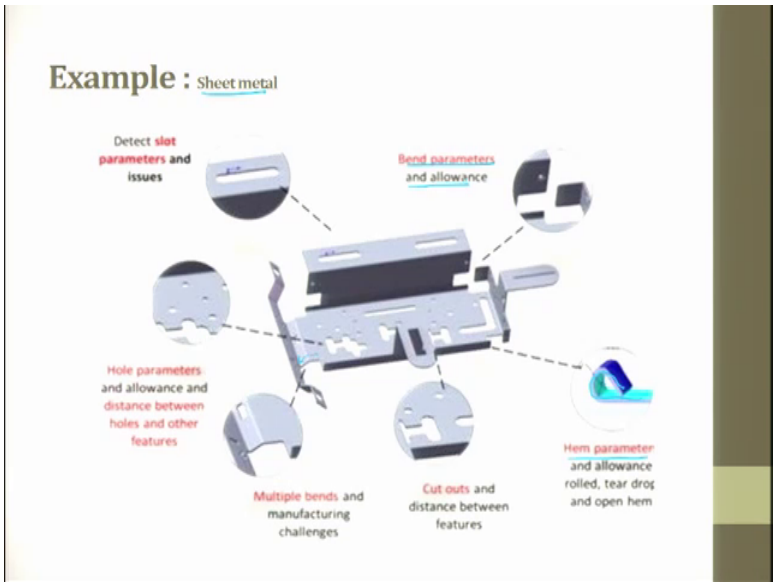

So, when we talk about a sheet metal part ok. So, you can see here deduct slot manufacture slot parameters and issues. And then we look at this we try to get those details then here it is all bend parameters and allowance. Then whole parameters and allowance and distance between the holes and other features, when we try to look at this part and then multiple bends and manufacturing challenges.

So, here if you see the entire part the entire part or maybe 1 2 3 4 5 6 parts are now getting integrated into one single part. And this is done by metal forming sheet. So, in metal forming first they might do all blanking operation then they might do all sharing operations then they might do all bending operations to get whatever it is. So, this can be done progressively or this can be done in next station the fixture can move one station to the other.

So, this is completely from the metal sheet metal point of you following design for assembly. So, you can see a multiple bends and manufacturing challenges this part is completely bent in different different things. And then cut off and distance between features so, the this is also there cut outs ok. Then here it is hem parameters this is nothing, but a bending parameter. So, where in which we use it for insertion or fixing.

So, you see design for assembly is used number of parts are reduced everything is got integrated into single part. The other way around what will be the alternative I do not want to do it in a complex way I tried to manufacture all these parts and then I do

welding operation and then I assemble it which sometimes leads to a failure when one part gives off.

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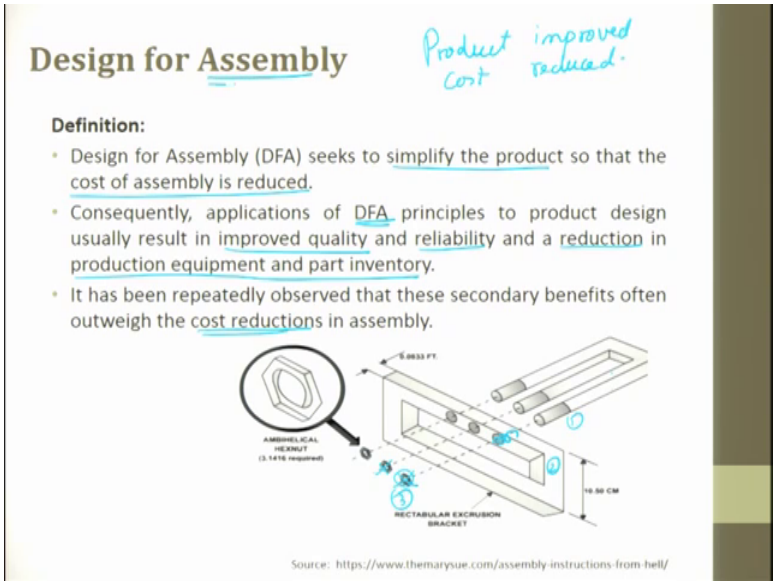

So, when we talk about the definition design for assembly seeks to simplify the product so, that the cost of assembly is reduced. Consequently applications of DFA principles to product design usually results in improved quality and reliability and a reduction in the production equipment and part inventory. For example, if you have here a screw to be mounted on to a bolt screw.

A screw or an or a bolt to be done to a nut and this is going to be used for assembling some operations. If you want to if you see here the fastening happens this fastening happens by 1 part you need the 2nd part and you need the 3rd part. If I wanted to apply design for assembly and try to eliminate the parts what I will do it I will eliminate these nuts and make the thread internally inside the part.

So, now what happen's? The bolt or whatever this part is getting fastened to this base without using the nut. So, we have reduced the part and this reduces the failure of the complete product. So, we can always think of making a thread inside the hole and try to fix this part with this part directly rather than using a fastener. So, when we try to follow a design for assembly the results in improved quality reliability and a reduction in the production equipment and part inventory all these things leads to a efficient product.

It has been repeatedly observed that these secondary benefits of an overweight the cost reduction in assembly cost reduction in assembly. So, we are trying to product is now getting improved and cost is getting reduced if you follow design for assembly.

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So, different methods of assembly these are called as manual assembly. So, in manual assembly what happens; you can have a conveyor belt. This conveyor belt can be moving from station to station to station and people are involved in doing assembly so. In fact, when the placing of parts and then they the hydraulic ramp to push the part inside or they just do assembly and do soldering along the assembly line.

So, manual assembly the operation is done by a man manual or it is done by a man operation is done by man but the conveyor keeps moving from station to station. So, it involves parts that are transformed to workbenches where the assembly of individual components into the final product takes place ok. Hand tools generally are used to aid the worker for ease assembly that is what I said you can use your press a small press to place the parts.

And then press it inside if you won't have a shrink fit you just do that and then try to give the output. Generally vast assembly is done like that if you want to do bearing assembly of very small bearings very small bearing they do it like that. And many of the ornamental works are done in this way manual assembly line this is a complete automatic assembly line.

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If you see incomplete automatic assembly lane the first thing what the following is they will follow unidirectional assembly. That means, to say the part will be locked at the bottom end and rest of all parts which are to be assembled happens only in one direction from the top. And this makes the assembly very easy this method uses either synchronous indexing machines and part feeders or non synchronous machine where parts are handled by a free transfer device. So, synchronous indexing machine means the parts are fed by feeder.

It is not manually fed you might have a shoot in that shoot all the parts are loaded. So, the parts are dropped one after other after the other it drops at the required place and then you can use a robo or man robot to assemble or you can also try to use some other automatic devices to get it done. Non synchronous machines are those were the cycle time for every operation is different. So, here you can feed the parts for free transfer and other things so this is automatic assembly.

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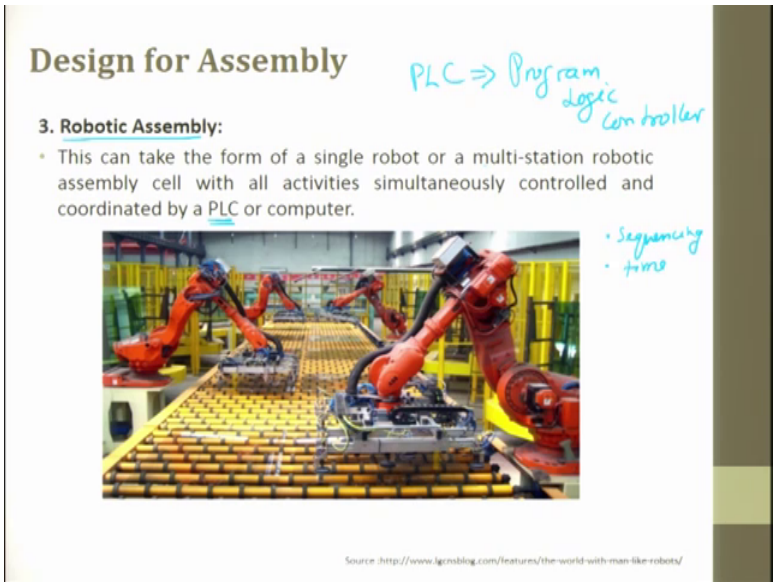

This is robotic assembly; so this can take the form of a single robo or a multiple station robotic assembly cell with all activities simultaneously control and coordinated by a PLC; PLC is Program Logic Controller. So, which tries to say first this operation to happen that operation to happen third operation forth operation fifth operation and if at all there is any problem in the first or second it goes to an emergency stop.

And then there you also try to do a sequencing with respect to time. So, I would say sequencing and then it also have sequencing with respect to time so, you can start doing it. So, this is a robotic assembly. So, the form of a single robo or multi station robotic assembly cells with all activities simultaneously control and coordinated by PLC or computer.

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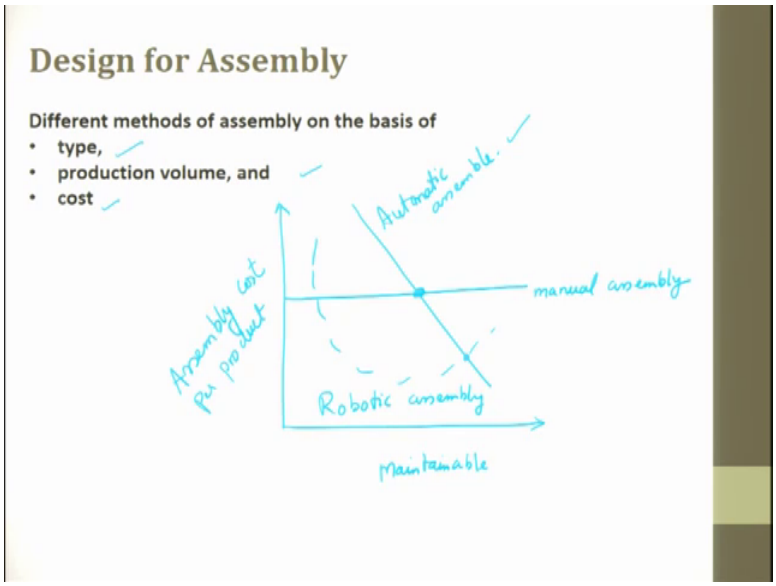

So, there are different methods of assembly on the basis of type production volume and cost we try to choose different method that is manual robotic automatic and other things. So, let us see how do you choose this? So, this is assembly cost per product ok. This is going to be the manual assembly this is maintainability.

This is how it is going to be for automatic assembly and for robotic assembly in the cost is going to be something like this. This is going to be for robotic assembly. For manual a constant cost when you try to automate; when you try to automate it is going to the price is going to fall down drastically. And when you try to do robotic if it is small parts it is going to be expensive and if the production rate is high then the cost is once again going to go high.

So, you have to see where is the breakeven point. And then start using for automatic assembly or manual assembly or robotic assembly. So, in automatic assembly synchronous nonsynchronous robotics plc and computers are used for the or for controlling and manual assembly you use a human being to do it. So, if you look at this the best part or quality parts are got from automatic assembly only.

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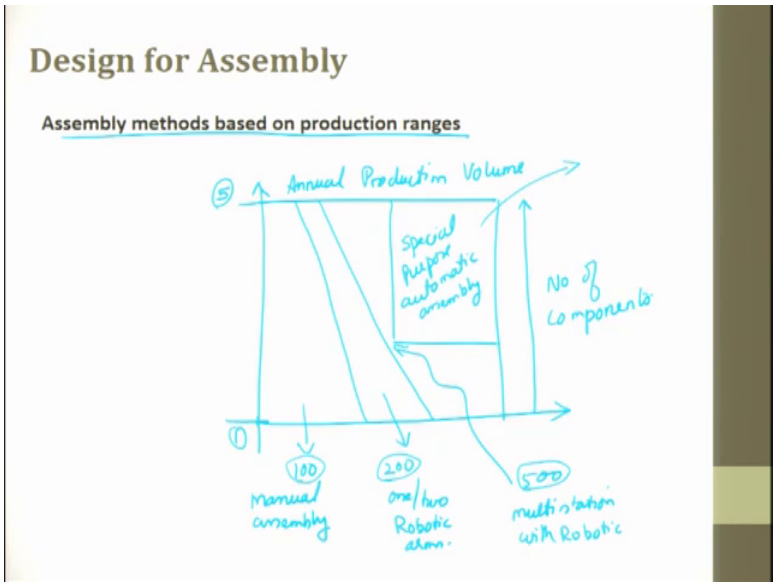

So, let us see the assembly methods based on production range, this is the annual production volume ok. This is going to be the number of components, these are special purpose automatic assembly going to be 1 and this is going to be 5. And here this is going to be for this is going to be for 100, this is going to be for 200 and somewhere here it is going to be for 500. So, this is going to be manual assembly, if the annual production volume is in terms of 100 it is manual.

So, we use 1 or 2 robots robotics robotic arms for doing it when the annual production rate is somewhere close to 200 and when it is close to 500 we try to use multi station with robotics. When their production rate is extremely high we go for special purpose automatic machines. These machines are custom build for doing only those operations for a required part or it is a customised assembly process so, where we use a special purpose machine ok. This manual is done by human being so you can try to do parts up to five and the total value annual production volume is 100.

When it is true or 1 or 2 robotic arms up to 200 annual production volume you can do that. When it is 500 you go for this when it is more than that you go for this. And please do not go by this number this numbers are just to give you a feel that what happens as and when the number of parts increases and what happens when the production rate increases how does it go right. This 100, 200, 500 are not a numbers these adjust for your understanding.

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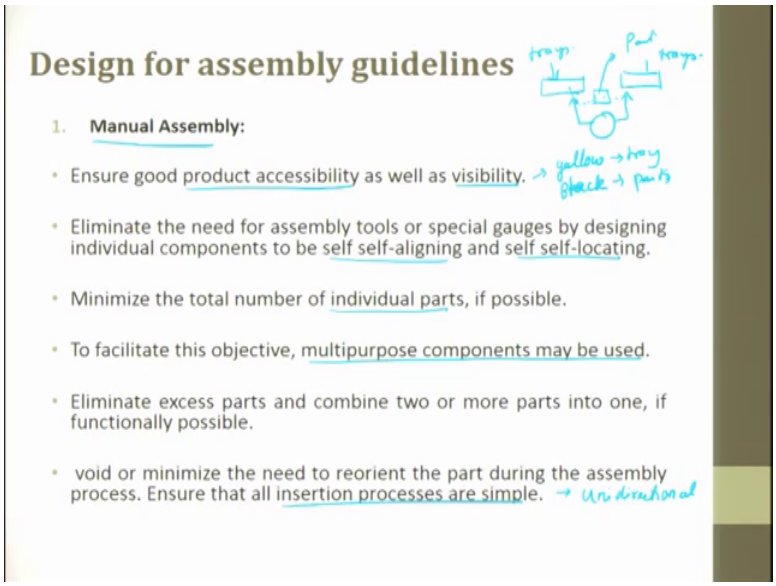

So, are some of the guidelines we will start discussing. When we talk about manual assembly ensure good products accessibility as well as visibility. So, product accessibility and visibility so, what are you trying to do is you have a human then he has a left hand and right hand. So, what you do is you try to keep the parts in a distance such that he can go pick it up and start putting it in his assembly this is your part these are trace.

So, he picks up and then he puts it here right. So, it the product has to be accessible within his limits while he is sitting in a sitting posture or standing posture he should not extend the full arm to pick the product. And second thing is the product should be placed in a tray or a container where it is clearly distinct. For example, the use a container which is yellow in colour and the parts this is a tray and the parts are black or black the parts are black in colour.

So, this is a contrast difference or they have a red tray, in the red tray they put the black parts. So, the parts are black so it is visible and second thing is it is also accessible. And then what we do if it is also made sure when you put a tray you inclined and keep the tray such that by gravity the parts keep moving down. So, the operator need not go to the extreme end stretch his arm so much generally the cycle time will be in 2 minutes 3 minutes.

So, in a shift close to 100 times the operator has two more his left and right arm so, which is going to be too expensive in terms of fatigue. So, the operator will not be able to work at his efficiency. Second thing is eliminate the need for assembly tools are special gauges by designing individual components to be self align and self locating ok. So, self aligning and self locating we have given.

So that means, to say when there is a slot there I drop apart the part has to get oriented itself aligned itself at exactly goes locates at the point where it has to be placed. We can always use another option of drop it anywhere in the part and use some small vibration the part moves and gets locked of it is own. So, eliminate the need for assembly tools right.

Rather than eliminate the assembly tools try to do it by gravity itself minimise the total number of individual parts if possible. For example, if there are 20 parts and this 20 parts for example, take part take a screw and then you have a nut you have to fix a nut to it and then this assembly gets into the product. Rather than doing it try to make the nut and the screw as an integral part.

So, two parts is reduced into one and if you can reduce the number of parts it is well and good. But still if you are forced to do it now try to assemble two parts and instead of having individual parts try to make subassembly. So, that these subassemblies can be exactly located at those parts and it can at those positions and you can make the part. To facilitate this objective multipurpose component may be used multipurpose component a single component which can do multiple jobs.

For example, you can use a apart for fastening as well as the same part to reinforce strength to it possible you can do that. Then eliminate excess parts and combine two or more parts in to one if functionally possible. This is what I was trying to explain in the second point also this is getting told here. So, here in second part we were talking about self aligning and self locating an individual parts. So, here they have send that individual parts make subassembly sub assembly; assembly or minimise the number of reorienting orient the parts during assembly process.

Ensure that all the insertion process is simple and it is unidirectional. For example, you can always do the assembly of a part in vertical face like what happens in a car. But when there are more number of parts and the parts are very small and it is manual

assembly we always prefer to have a horizontal type of assembly. For example, we place the product horizontal and then start putting all the parts in the product to get the final parts. So, assembly is done in the horizontal way and a single direction.

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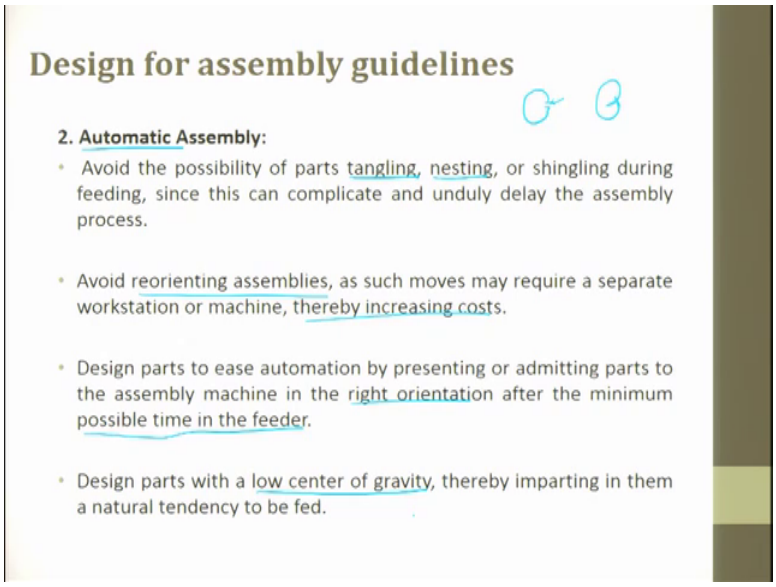

When we talk about automatic assembly line the first guidelines is avoid the possibility of parts tangling nesting and shingling during the feed. For example, when we try to feed it is said as automatic assembly. So, when we try to do automatic assembly you are replacing the man. So, when you replace the man the parts which is there in the tray which I was talking to you now has to come through a shoot or a conveyor.

So, it has to be continuously feed when you are continuously feeding it a individual man cannot drop one after the other after the other. So, what we do if we drop the entire parts very few 100 or few 1000 in hopper. And then from that hopper the through that shoot the parts keep moving. So, that is what we say when the parts move it should not get tangled it should not get nested. What is tangling and nesting? Locking with one another is tangling and nesting right.

So, once it angles then it becomes very difficult the part will not flow the assembly line will stop. So, now what you do is you try to make sure in the design itself such that the parts do not get locked. For example, you can have a spring like this or a washer like this. When you have a washer like this what happens the reason start points these are

endpoints. So, there is a possibility the entangling can happen here. So, now, what they suggest is please make a washer like this.

So, when you make it like this so this part touches the top of this part or this side of the face is touched at the bottom of this face. So, when it over lapse it makes sure that entangling cannot happen. So, these are some of the design changes which are made in the washer itself when we use it for automatic assembly. Avoid reorienting assemblies as much as such moves many require a separate workstation or machines thereby increasing the cost.

So, reorientation of assembly part of the assembly is done. So, then you try to do an another part of the assembly in another direction then in the third direction please try to avoid it. Design parts to is automation by presenting or admitting parts to the assembly machines in the right orientation after the minimum possible time from the feeder.

So, once the path drops from the feeder let your what assembly start immediately the design parts with a low centre of gravity thereby imparting in them a natural tendency to be fed is required. So, try to make the centre of gravity as low as possible so, it is stable and it exactly feeds on the location where it is to be fed and the assembly starts.

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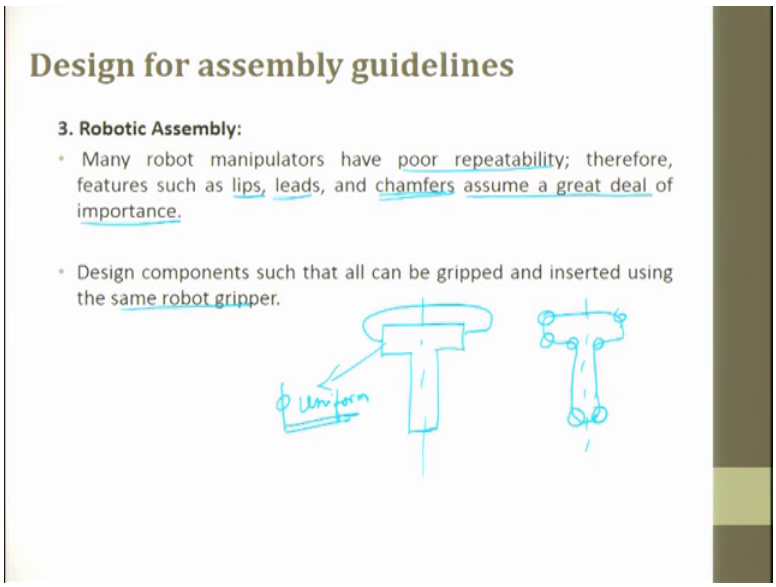

When we talk about robotic assembly many robo manipulators have poor repeatability. See robo manipulator is nothing, but your hand. You have three orientations one speech

ya and roll right. Our hand has lot of repeatability reliability and sensitivity that is our human hand. Because it has multiple sensors and every link is individually controlled by muscles. But when you try to mimic a human arm and try to make it in the form of a robo manipulator the repeatability is always a question.

Repeatability means to the exact location what it did in the first time the second time and the fifth time and nth time it has to go to the same location that is very difficult because it has it is attached to a series of motors ok. So, poor repeatability is a known advantage or disadvantage of robotic assembly. So, knowing this you have to do a controller or you add a controller and systematically fine tune the error whatever it is done for every time it has to be calibrated check with the calibrated status and then you give the error signal so it goes back to the original location.

So, poor repeatability therefore, the features such as lip leads and camper assembly assume a great deal of importance. That means, to say rather than having a sharp edge you try to have something like a rounded of edge. So, you see rounding happening here rounding and then chamfer happening here. So, the all these things are given such that it exactly goes and locate very easily. So, the path design has to be changed right, the design components such that all can be griped and inserted using the same griper. So, this portion has to be or the diameter has to be uniform for almost all parts so that the griper can easily hold and drop.

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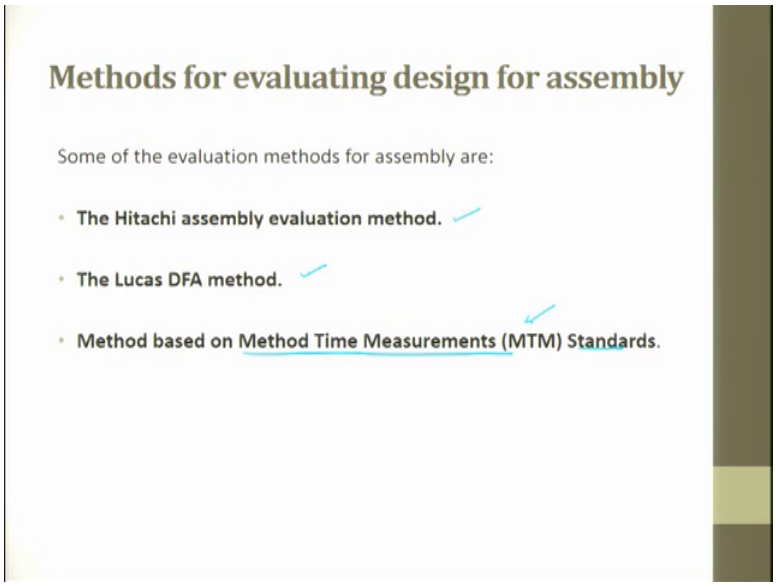

So, methods for evaluating design for assembly some of the evaluation methods for assembly are the Hitachi assembly valuation method with us from Japan Lucas DFA design for assembly method. And method based on method time measurement standard which is nothing, but MTM. So, there are several evaluation techniques in this course we are discussing only three which are very prominently used in industries.

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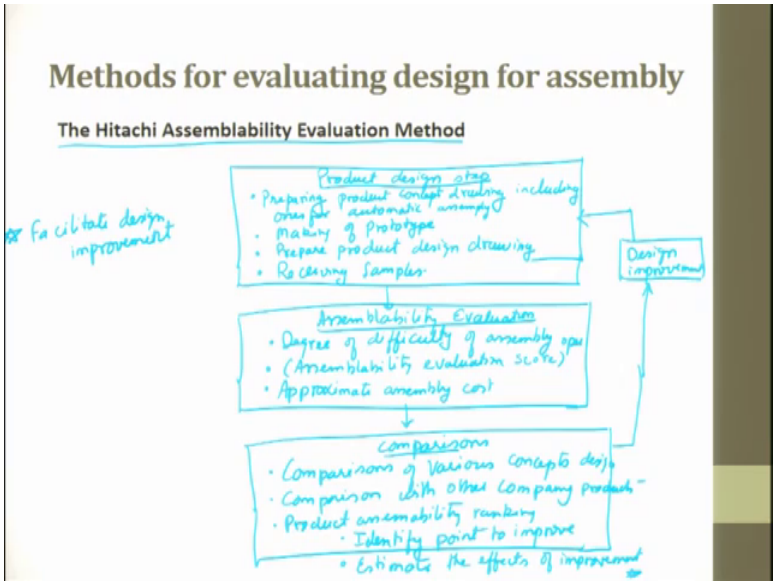

So, Hitachi assimilability evaluation method it has three blocks. So, this is product design step ok. So, here what we do if we prepare preparing product concept drawing including once for automatic assembly. This is done in the product design step then making of proto type, then we prepare part drawing prepare product design drawing.

And the last one is receiving samples then next assemblability evaluation assemblability evaluation what we do is here we see the degree of difficulty of assembly operation. Next we put scores assemblability evaluation score is done, then we will have approximate assembly cost.

So, this is assemblability evaluation and then what we do if we try to compare we try to comparisons so, we try to compare what and what compare comparison of various concept designs. This is after revaluation then what do you look for alternative solutions right then comparison with other company products. Then what we do if we look for product assemblability ranking.

So, first is identify 5 points to improve, then it is eliminate or estimate the effect of improvement effects of improvement. Then the last point you will have facilitate design improvement. And this process is an iterative process it goes like this design improvement. So, this is how the Hitachi assemblability evaluation method is done first we look at the product design step, then we go at assemblability evaluation, then we look at comparison. Comparison we are not only look at within the part within the product. What is that we also look at a similar product whatever is there or a similar way of fastening is there anything else and compare it with that. Do our ranking and then go back and re iterate our product design step and then keep going back and forth it is very TDS job and it involves lot of time and skill.

So, it you have to not only look at within your product you also have comparing with other products within the product and a similar one across the market and then try to pick up the best one. So, it is always something like benchmarking you have done something, you have ranked something like your rank 10 points. In this is critical, this is critical then after the ranking you look at similar assembly where ever it is happening.

In the same product in the business then after you have to also slightly expand your horizons. And look at can this how is it done in other material for example, plastic it is done. How is it done in ceramic? How it is done in metals? All those things and how is it done in other industries from aero you have to see in auto you have to see in commercially available or domestic. So, that is how you compare and reiterate re improve your design and go further.

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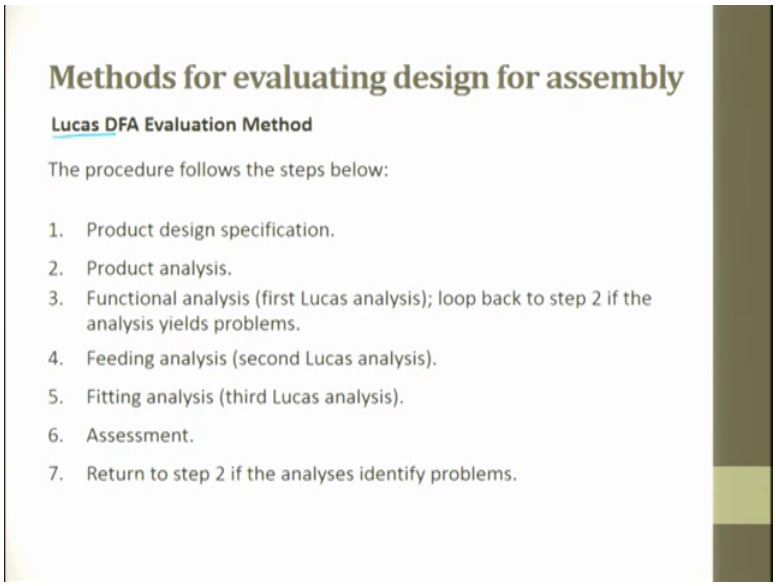

The procedure when you talk about Lucas DFA evaluation method the procedure follows the steps below; first the product design specification then product analysis functional analysis. First Lucas analysis loopback to step two product analysis from functional it goes to product. So, it goes back and forth if the analysis yields problem then feeding analysis, then you have fitting analysis, then assessment then return to step two if the analysis identifies a problem.

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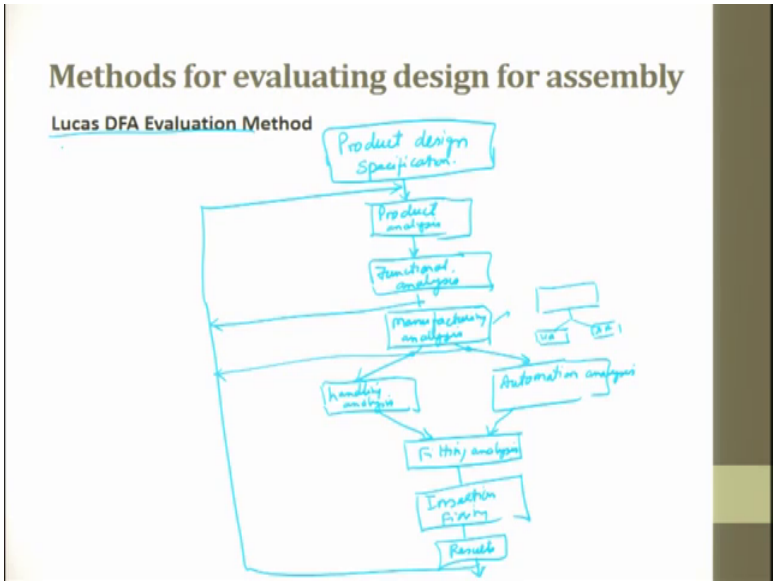

So, this is how product design in Lucas happens product design specification which comes from customer voice. I had an interesting question from your student who is undergoing this course he said. So, rather than calling it is customer voice can we call it as customer noise so I thought.

So, this is product design specification, then product analysis then what comes is functional analysis, then you do manufacturing analysis, then this gets split into handling analysis. How are you going to handle the part? And then it is going to be automated automatic or automation analysis ok.

Then we have fitting analysis this goes fitting analysis and then this goes into insertion fixing and then we have results ok. So, we have output coming from results from here which goes into product design then from manufacturing which also and links to it then from I would after manufacturing.

I can put like this same line goes here and here or I can replace this drawing I can make it like this and this. So, where you can have Hitch analysis and automation analysis we can do like this or the 2 points connect here. So, this is nothing, but Lucas DFA evaluation analysis.

First will be a product design specification product analysis, then we do functional analysis, product analysis how is the product performing how are the functions performing perform? Functions performing not of the entire product, but individual parts in the product then how is it getting manufactured.

What is the manufacture is? Then we can talk about handling and then we can also talk about automation we can talk about handling moving the part automation inserting then fixing inserting and then results. So, this is Lucas design for assembly evaluation method.

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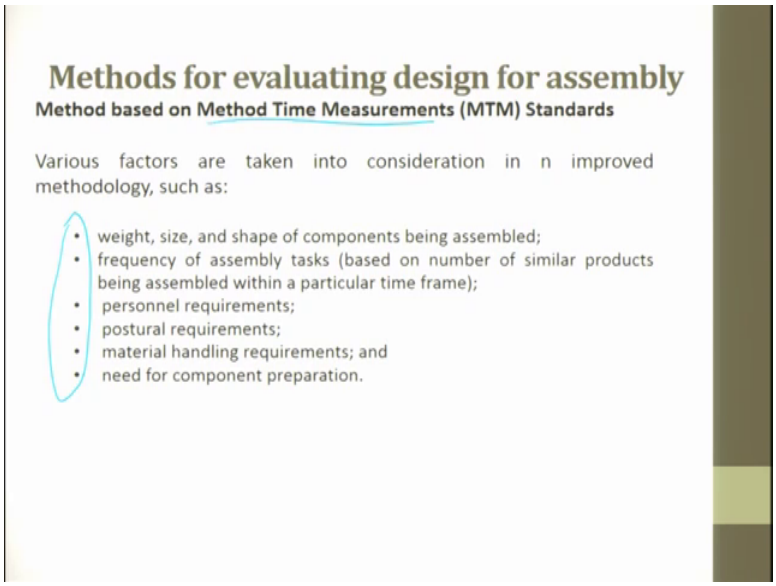

The method based on method time measurement standards. The various factors are taken into consideration in n improved methodology such as; weight, size, shape of the components being assembled, frequency of assembling task, based on the number of similar products, being assembled within a particular time frame, personal requirement, postural requirement, material handling requirement, need for component preparation.

So, all these things are evaluated first it is recorded and then what they do they try to split up into small small events. And then they try to accommodate all sorts of events and for each event they tried to calculate the cycle time and with that the method time measurement is done. And this is also an evaluation method for design for assembly.

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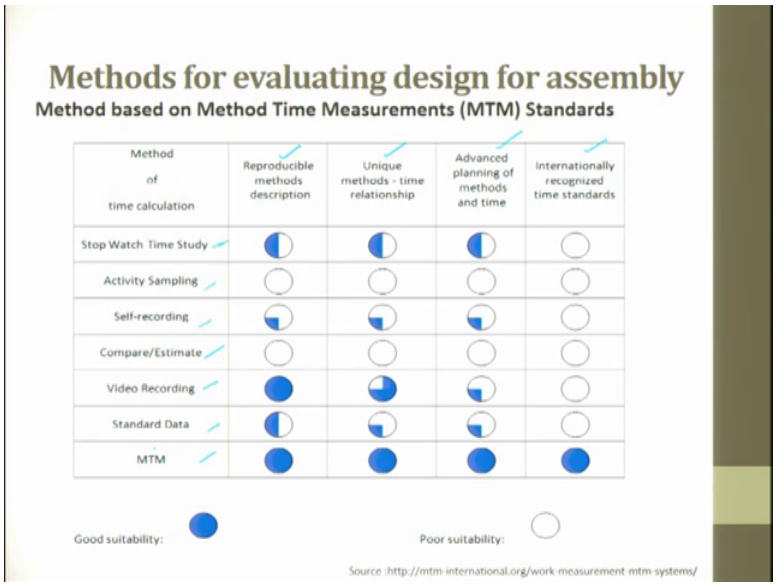

So, you can look at it. So, this is method based on method time measurement standards method of time calculation, stopwatch time study this reproducibility method description is 50 percent. Then unique method time relationship 50 percent, advance planning of method and time is 50 percent. Internationally recognised time standard it is not suitable for this it is not suitable at all.

So, you can say video recording producible method description it is good it is very well suited. And this process video recording for unique method time relationship it is 75 percent. Then advance planning for method study it can be used to 25 percent and international recognized times than that it has poor suitability.

So, this will try to tell different different ways in which the measurements are calculated stopwatch study, activity sampling, self recording. That means, to say on the helmet you can have a camera, then compare and estimate video recording, standard data which is available in the books, then MTM study method time measurement study here it tries to give good reproducibility.

It time relationship it is very good advance planning and methods it can help and it is internationally recognized as a time standard. So, this is what is the design for assembly another technique which we are using. So, we would stop here we will continue in the next class.

Thank you very much.