Rapid Manufacturing

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Lecture - 36
Product costing for Rapid Manufacturing (Part 2 of 2)

Good morning. Welcome back to the lecture on Rapid Manufacturing costs or costing in rapid manufacturing.

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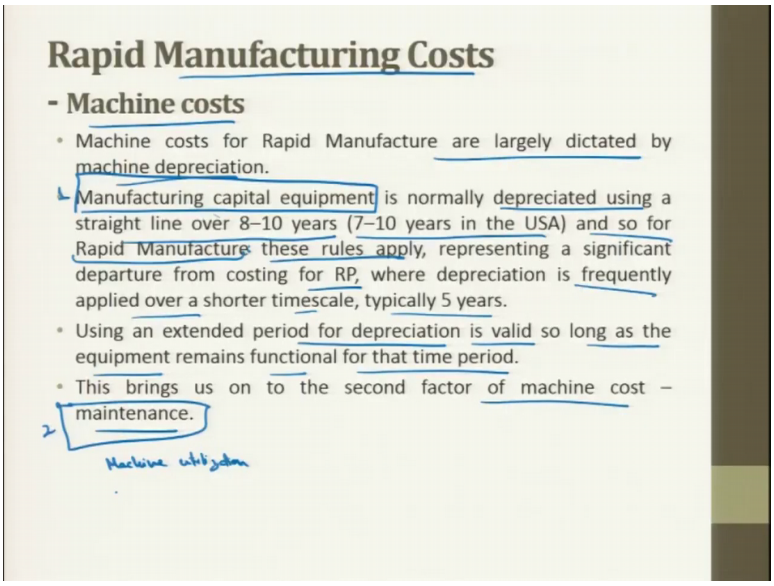

So, we have discussed the machine labour and material costs in the previous lecture. So, machine cost was discussed machine is capital equipment of the cost of purchasing the machine and cost of maintenance.

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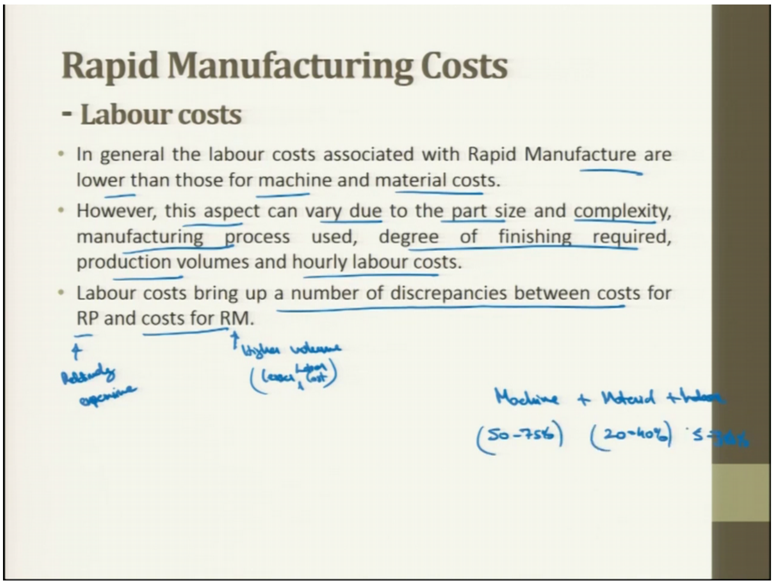

Then we had material costs, then we had labour cost. Typically, when I say machine plus material plus labour is the total cost of the product. So, in general, these ranges can be broken down into certain percentages, I can say machine cost is from 50 to 75 percent, the cost of the equipment, then material cost is from 20 to 40 percent, and labour cost is from 5 to 30 percent. It all depends upon the type of application and the type of skill that is required and the kind of material that we are using. So, this is the typical breakdown.

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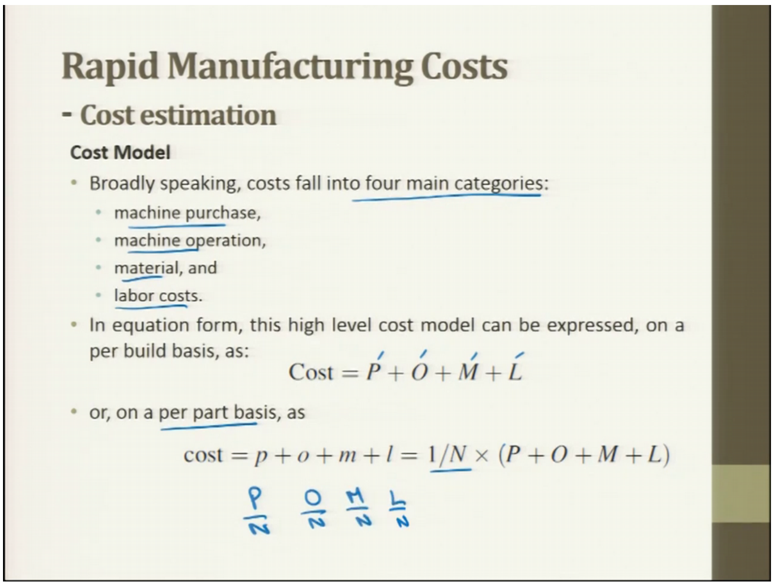

So, next we have cost estimation models. The cost model, broadly speaking costs fall into four main categories that we have discussed. Number one is machine purchase; second is machine operation; third is material; fourth one is labour costs. The total cost is purchase cost plus operation cost plus material cost plus labour cost, and also cost per unit per part basis for which we had the illustration that I showed you in the previous slide.

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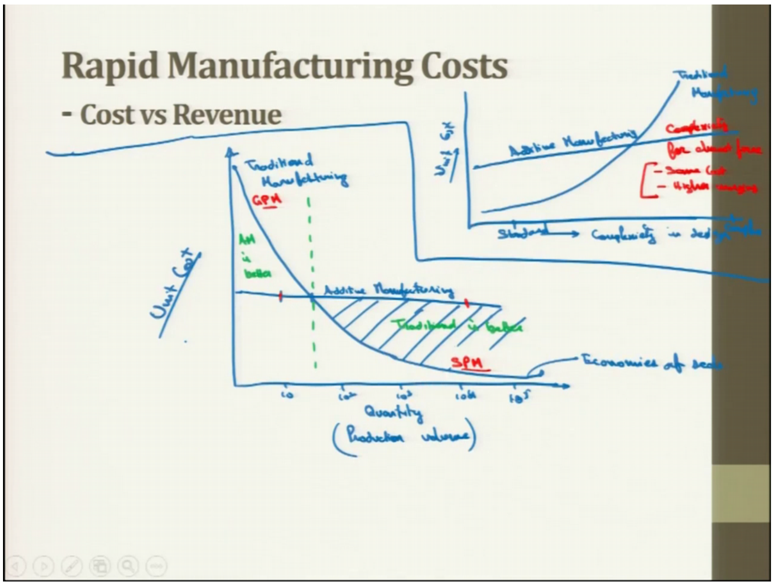

This is per unit cost. So, this is calculated by dividing by the number of parts, the total cost by number of parts by n. So, this p is actually P by N, this is O by N, this lower case letters are the capital case letters divided by the number of parts, this is equal to L by N.

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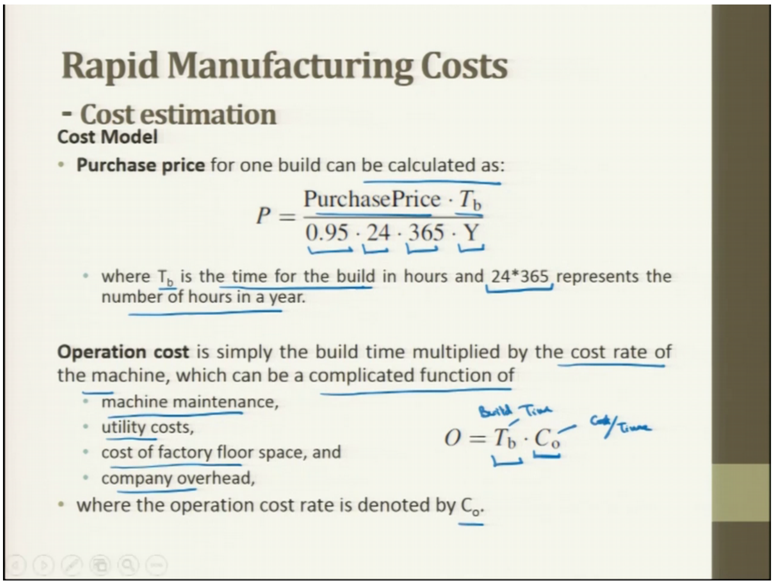

What is purchase price? This is one of the models. There is certain models which are developed by additive manufacturing people, who those are working in the analytics or the calculation of the cost in additive manufacturing. This is only one of those models that I am discussing here. However, certain complex models are there in the market, but to understand the basics or the simple model of additive manufacturing, this is well enough.

So, purchase price for one build can be calculated using this formula that is purchase price, I am talking about one unit (Refer Time: 02:46) that is the total purchase price into T b by 0.95 into 24 into 365 into Y, Y is years, this 24 into 365 represents the number of hours in an year. And T b is a time that is taken to make a build; you might recall the time that we took to manufacture the 3D print was around 4 hours in the laboratory demonstration. So, this is that time, time for the build in hours.

Then operation cost is simply the build time multiplied the cost rate of the machine, which can be complicated function of machine maintenance, utility cost, cost of factory floor space, company overhead, where operation cost is related by C o. So, this operation cost is the build time into the operation cost rate per unit time, C o is cost per unit time and this is time it is build time.

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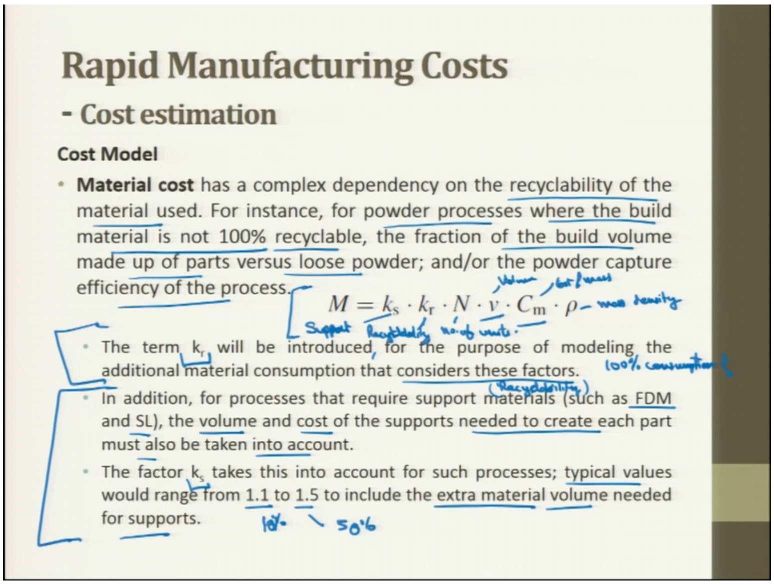

So, next is material cost. Material cost is conceptually simple to determine, it is the volume v of the part multiply the cost of the material per unit mass, this is cost per unit mass, this is volume, this is cost per unit mass, this is density or specific gravity or mass density, N is the number of units.

What is k r and k? This we will discuss. So, this material cost has a complex dependency on the recyclability of the material used. For instance, for powder processes where the build material is not 100 percent recyclable, the fraction of the build volume made up of parts versus loose powder; and the powder capture the efficiency of the process.

Now, the term k r will be introduced for the purpose of modeling the additional material consumption that consider these factors, what are these factors the recyclability or 100 percent consumption, this is questioned ok. In addition, for processes that require support material such as fused deposition modeling and stereolithography, the volume and the cost of the support need to create each part also must be taken into account.

Set of k s takes into account the such processes, typical values of k s varies from 1.1 to 1.5 to include extra material, extra material volume that is needed for supports. For this is for supports, this is for recyclability or the utilization of the material or the consumption of the material. We have this factor k s, s is for support and this is k r, r is for recyclability right. So, this gives us the material cost.

So, it is simple to the domain, if we just use this factors that is around 10 percent of extra material would be taken around this means around 50 percent of extra material will be taken for supports, but exact measurement or exact model or exact factor values are to be determined using some experimentation or from past experience or from the experts those can be known.

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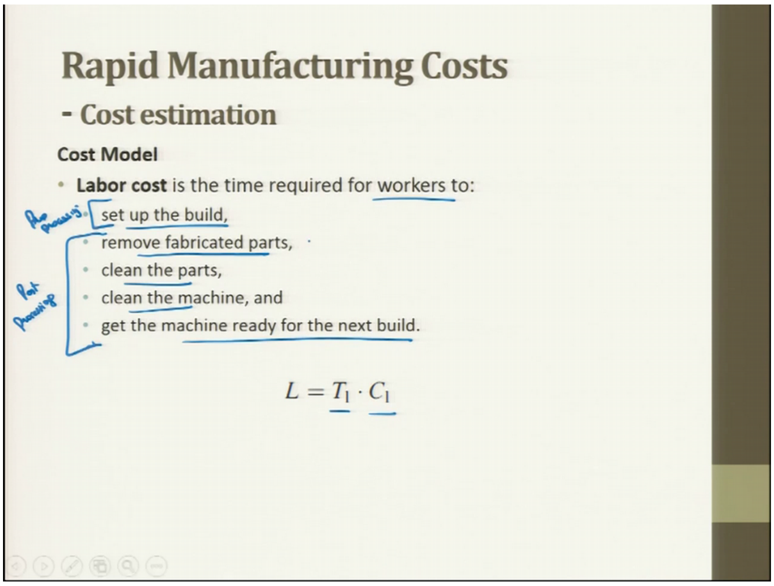

Next is labour cost. Labour cost is time required for the workers to set up the build, remove fabricated parts, clean the parts, clean the machine, get the machine ready for next build, this is the total labour cost. So, setting up then removing and taking the part of this is preprocessing, this is post processing. So, labour cost is directly T 1 into C 1 the time taken and the cost that is the wage rate for the specific work.

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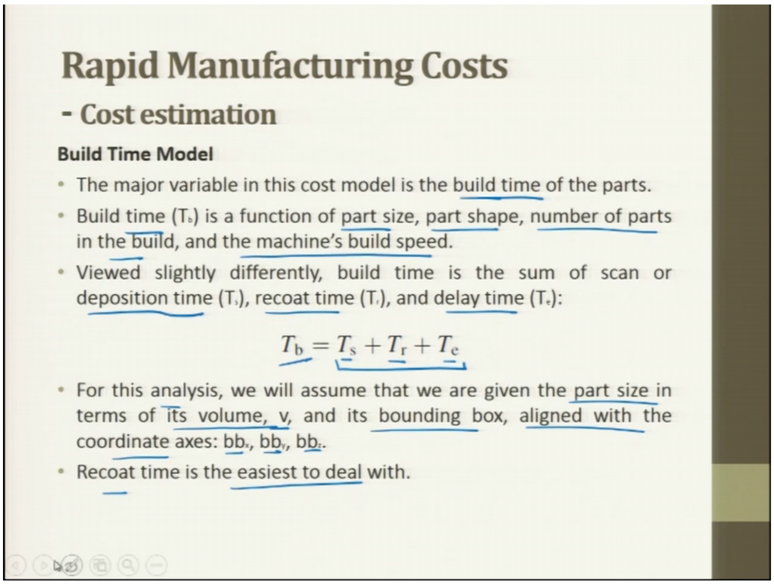

Next is build time model that is T b. You might have seen that we have all the factors here, purchase price is the price that is spent T b is one of the factors that is coming in purchase and operation cost. Labour and material cost are can be determined from these models, M model and L model. So, the P and O model P and O has this factor build time T b.

Now, what is this T b dependent upon? So, it is an additive function of three factors, T s, T r and T e; T s is deposition time, T r is recoat time, and T e is delay time. The major variable in this cost model is the build time of the parts, built time is the function of part size, part shape, number of parts in the build, in the machines build speed. These three different times are added to get the total built time, deposition time, recoat time and delay time. For this analysis, we will assumed that the part size is in the term of its in its volume and its bounding box aligned with the coordinate axis that is bb x, bb y and bb z 3 different axis, recoat time is easiest to deal with.

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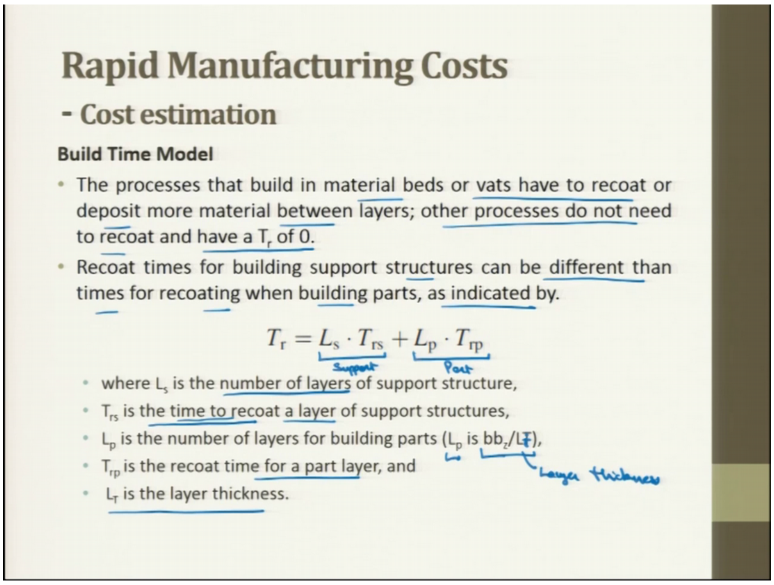

What is recoat time? The process that build in material beds or vats have to recoat or deposit more material between layers; other process do not need the recoat or they have T r is equal to 0. So, recoat time for building support structures can be different than time for recoating when building parts, as indicated by. This recoat time, recoat time T r is equal to L s T rs plus this second factor here L p into T rp.

So, what is L s? L s is the number of layers, T rs is the time to recoat a layer or support structures. So, this is number of layers and time to recoat a layer. L p is the number of layers for building part that is L p is equal to bb z direction by LT. T rp is the recoat time for a part layer, for a part layer now the specific layer. So, T rs is the time to recoat a layer. So, essentially this L T is the layer thickness, this is L small t, this is layer thickness; it is mentioned here.

So, this is essentially telling us that recoat time is divided into two factors, one is support recoat, a second is part recoat. L s and L p are the thicknesses of the support and the part respectively and T rs and T rp are the time taken to recoat the layers of the support and the part respectively. So, this is T r that is one of the element in build time model.

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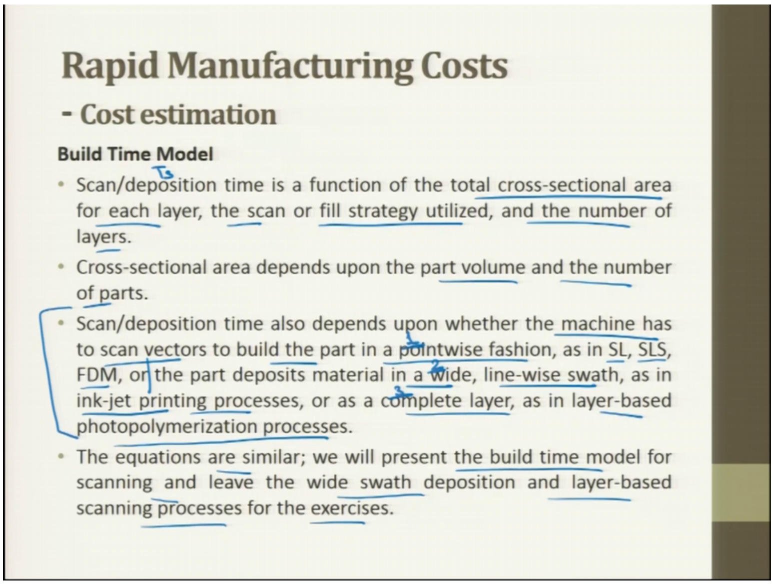

Now, scan deposition time is a function of total cross-section area for each layer, the scan or fill strategy utilized, and the number of layers. Cross-section area depends upon the part volume and the number of parts. Scan deposition time that is T s also depends upon whether the machine has to scan vectors to build a part in the point wise fashion, as in stereolithography and selective laser sintering, fused deposition modeling, or the part deposits material in a wide, line-wise swath, as in ink-jet printing processes; as a complete layer, as a layer based photopolymerization processes.

So, the three ways, number 1 is point wise fashion; number 2 is in a wide or likewise fashion, number 3 is complete layer. Equations are similar for this, so we will present the build time model for scanning and leave wide swath deposition and layer-based scanning processes for the exercises or it is a little complex model for we cannot build models for all these three processes. So, scan this deposition time is depending upon the different applications or different way in which this scanned vector work.

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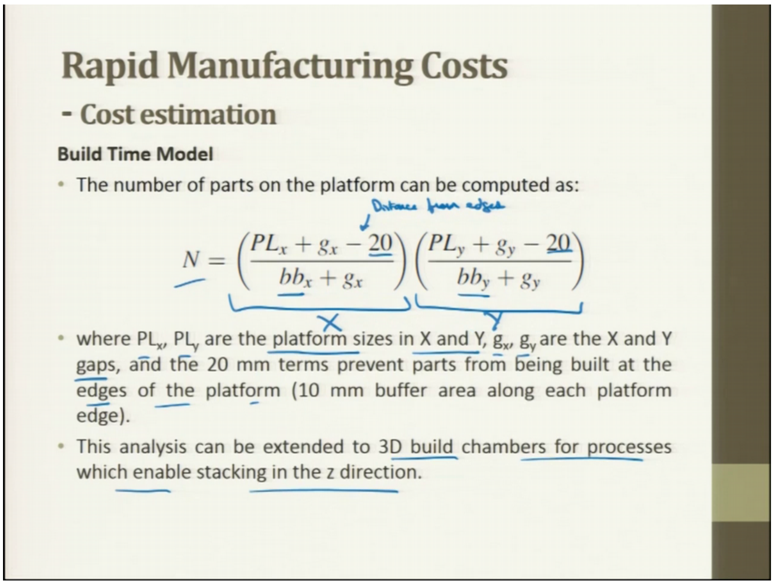

But the point wise or line wise or layer wise may be. And number of parts can also be computed using this relation, where these two factors are here in the direction x direction y, we have bb x and bb y with PL x and PL y are the platform sizes and in X and Y directions, g s and g y are the gaps and 20 mm terms prevent the parts from being built at the edges, this is 20 mm is distance from edges ok, this term tell distance from edges.

This analysis can be extended to 3D build chambers for the processes which enable stacking in z direction; this is only in X and Y directions. And z direction it is taking it is making layer by layer, it is going in z direction. So, this is we determine the number of parts.

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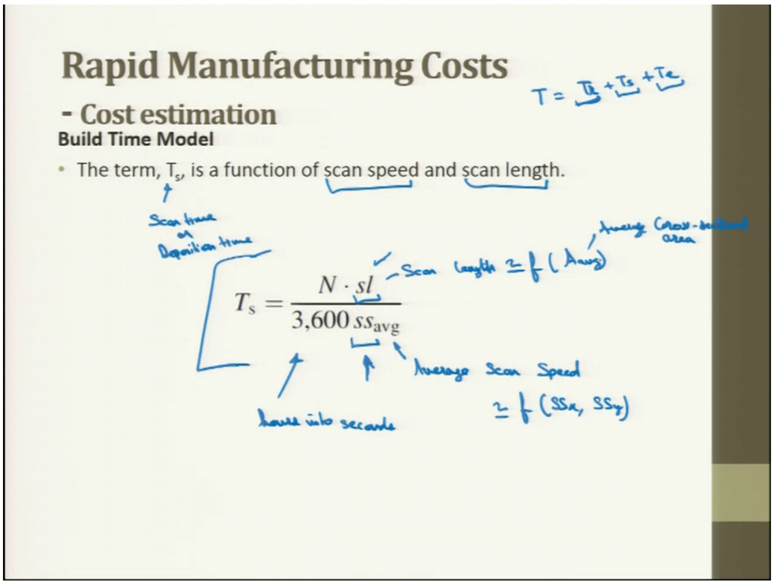

Next term T s. T s is the scan time, scan time or deposition time, deposition time. This is a function of scan speed and scan length. So, this is scan speed, this is scan length s l is scan length, s s average is this is average scan speed, average scan speed which is a function of scan speed in x direction and scan speed in y direction. This is scan length, s l is scan length, which is a function of function of I put a average, average surface area or average cross-sectional area, cross-sectional area. So, these are certain models to determine these scan length and average scan speed.

So, I am not go going to that detail, just we need to know that total time is equal to time for r recoat time for scan plus time for delay. So, we have determine what is T r, we have seen what is T s this 3600 is the factor that converge hours into seconds, this is that factor.

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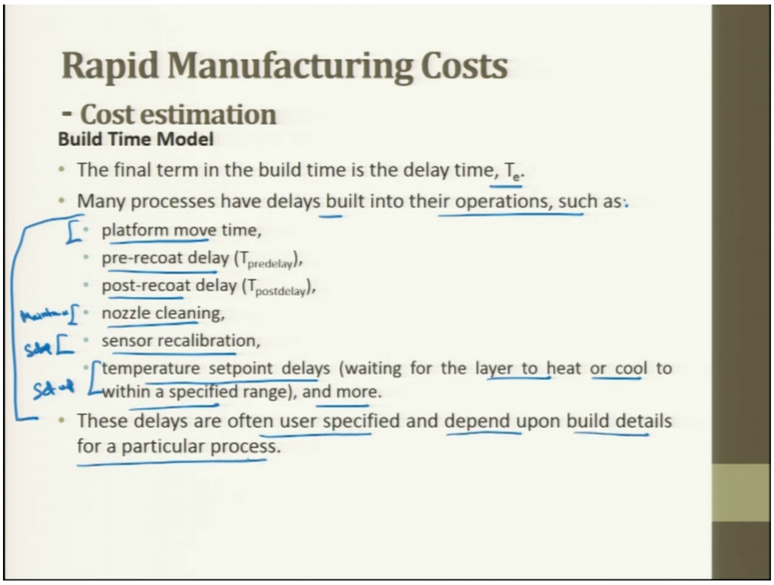

So, next we have with us is final term that is T e delay time. Many processes have delays built into the operations such as platform move time pre-recoat delay, post-recoat delay, nozzle cleaning, sensor calibration, temperature set point delays that is waiting for the layer to heat or cool within a specific range and so on. And this is actually setup time that this is again set up, this is maintenance. So, pre so this all is non-productive time, but this cannot be ignored and it is there and we need to minimize this, these delays are often user specified and depend upon the built details for a particular process.

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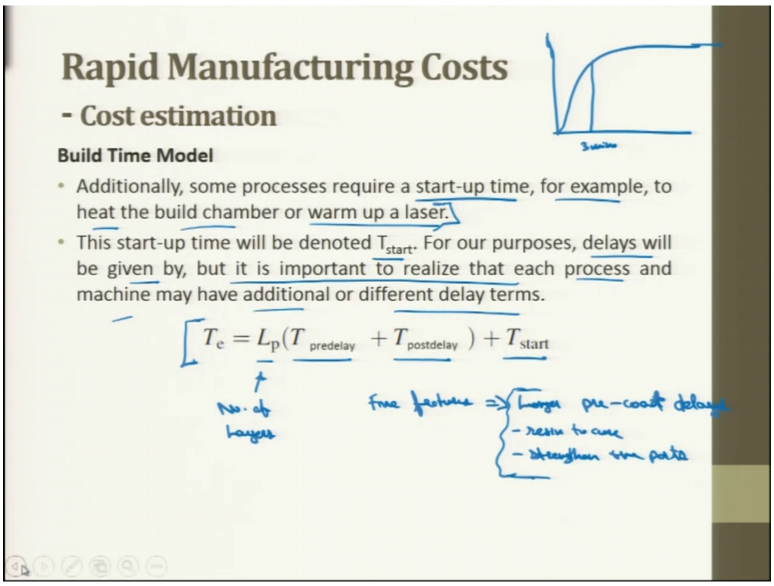

So, the delay time is given by this relation, L p into time for pre delay and time for post day plus time for start, additionally some processes required a startup time. For example, for to heat the build chamber or to warm up a laser, this we also explained when we discussed about 3D printing, and also 3D scanning. 3D scanning this scanners also need some start up time and also I showed you the graph, at what time thus the scanner is heated up to work, it was around 3 minutes if you remember for (Refer Time: 17:02) scanner, so after that it can work properly.

So, this startup time will be denoted by T start for a purposes delays will be given by, but it is important to be realize that each process and machine may have additional or different delay times. So, this is a generic term, but delay terms would be very different for the different processes. For example, it can be different in a way, if parts have many fine features, longer pre-coat delays may be used. If I say fine features implies longer pre-coat, longer pre-coat delays. So, this is in the case of stereolithography in general. So, this longer pre coat delays may be used to allow the resin to cure further or to strengthen the part for resin to cure to strengthen the parts, because the features are very fine.

So, before subjecting the fragile features to recoating stresses, this is important. These terms can have other factors or other elements that can be included this, this is now a generic built time that is T s plus T r plus T e first we talked about, T r that is the recoat time that is the recoat for support and recoat for part. Then we had our scanning or deposition time that is the function of scan length and average speed. Then we have the delay, delay is pre-delay plus post-delay into L p plus T start, L p you know it is the number of layers.

So, this is the cost estimation model we have picked a simple model to explain how the cost in additive manufacturing calculated. There is certain model as I said which are being developed and the complex models, there are even stochastic models which are coming and we can go in to at a detail, but to understand that what does cost estimation in rapid manufacturing has it has machine costs, labour costs and material costs and operation costs, so four costs are there.

Then we had the time, build a time that is very important factor in that how to manufacturing buildup time, it is having three elements in it. Directly one is scanning time, then is recoat time, then is delay time. So, these all are the factors that we have seen now.

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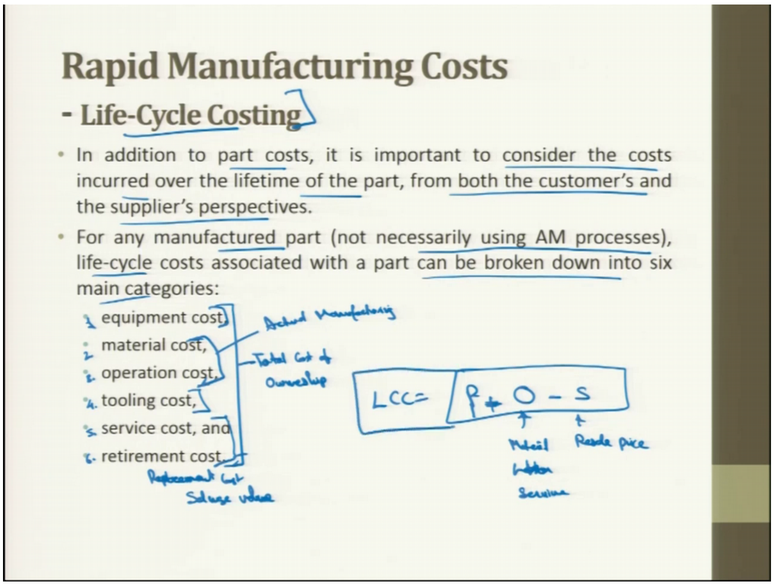

One important point in rapid manufacturing, I will have to touch is life-cycle costing. In addition to part cost, it is important to consider the costs incurred over the lifetime of the part from both the customers and the suppliers perspectives. For any manufactured part, not necessarily only additive manufacturing process is life-cycle costs associated with the part can broken down into six main categories; number 1 is equipment cost, number 2 is material costs, number 3 is operation cost, number 4 is tooling cost, number 5 is service cost, number 6 is retirement cost, this is the total cost of ownership.

One has to purchase equipment and material, then operation has to be done while operating the cost are incurred, electricity, etcetera. Then tooling is the servicing has to happen, then retirement machine has to be replaced, this is also known as replacement cost. The equipment cost include the cost to purchase the machines that are used to manufacture of the part, material and operation cost they are related to the actual manufacturing, this is the actual manufacturing right.

And for the most conventional rapid processes tooling is required for part fabrication, in this case the tooling can be the tools to clean the part, to clean the machine, to take the part off, to the small tools ok, so those tools are there. So, this may include an injection mould, stamping dies, machining pictures, in case of post processing, the other two elements are service and retirement cost.

Service cost typically include the cost that are associated with repairing or replacing a part, which can include cost related to taking the product out of service, disassembling the product, to gain access to the part, repairing or replacing the part, reassembling, testing of the part, inspection, preventive maintenance, all those things come in service. Then design for service guidelines indicate that parts needing, frequent service should be easy to access and easy to repair and replace. So, these costs are also important.

Retirement cost is the final salvage value can say. So, the life cycle costing is also important, because only the cost of purchase and operation if it is considered and retirement costs and service costs is not considered, sometimes it is a little expensive. Life life-cycle costing is the method to think about the material or the equipment or anything in which we are investing for its whole life, for its life for which would work.

For instance, the life equipment that I am going to purchase is may be 2 years. And after 2 years, I have to sell that the overall cost the cost of purchasing plus the material costs that is cost of operation that would we incur in that I am not considering now, labour, etcetera here that is all in operation here. Operation is everything, it is material, labour, service, I am considering all these things. So, purchasing cost of the operation minus salvage cost I am putting that is the resale price. So, this is the total cost, total life-cycle cost.

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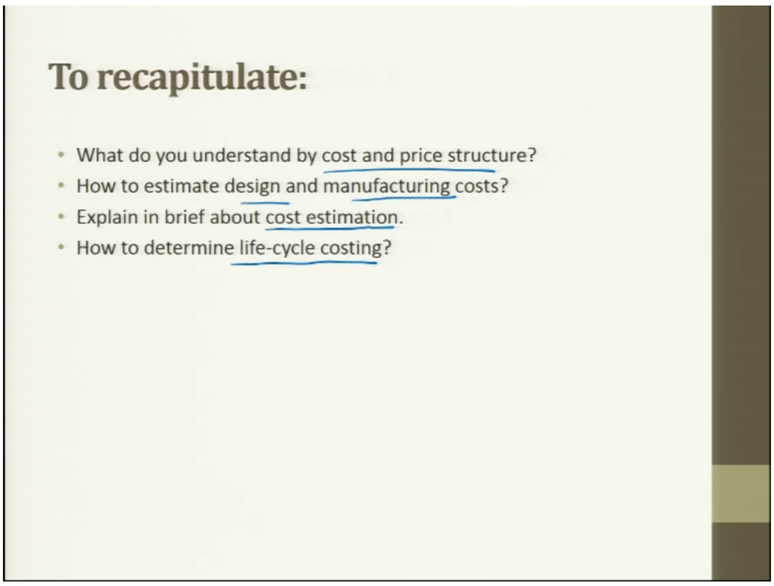

So, with this we have completed this presentation of life-cycle costing and the costing on the rapid manufacturing parts. So, what questions now you can address or you can understand from this presentation, you can answer why do you understand the cost and price structure, this you now know. Then you can tell how to estimate design and manufacturing costs. You can talk about a model of cost estimation in rapid manufacturing, you can say how to determine life-cycle costing and what are the various elements in this. So, product costing part is over with this lecture.

So, we will meet in the next lecture, where we will discuss rapid product development.

Thank you.