Rapid Manufacturing
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Lecture - 35
Product costing for Rapid Manufacturing (Part 1 of 2)

Good morning. Welcome back to the course Rapid Manufacturing. We have discussed multiple modules in this course regarding design of the product, different rapid manufacturing processes, and we had been through the laboratory demonstrations. In this lecture, I will discuss about the Product costing for Rapid Manufacturing.

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Product costing when I take say product costing, cost is the most accessible and it universally understood measure of resource of consumption, so cost is very important. Any manufacturing enterprise exist just to unprofit. The way is to satisfy the customers then to unprofit out of that. So, goals of any design activities are to create products that satisfy customers. So, cost can be readily used as an important metric on which to base engineering decisions are made.

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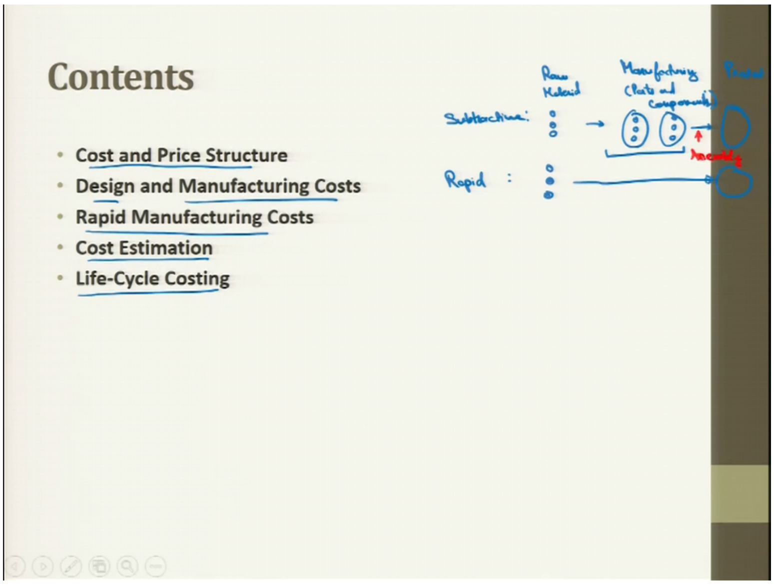

So, first I will discuss, cost and price structure. Then we will see what are design and manufacturing costs, then we will see what are the cost in specifically rapid manufacturing. Then I will come up with cost estimation model, then we will see what is life cycle costing. Now, when we talk about cost; in traditional manufacturing what happens the subtractive manufacturing and rapid manufacturing. What happens in this? We have the materials I would say a raw material, raw material suppliers, a multiple suppliers constants they are three suppliers here and three suppliers here. And in between of in subtractive manufacturing, we have manufacturing; this is parts and components.

The point I am trying to make here is that you have a middleman who convert the raw materials into parts and components this is component 1, this is component 2, and these components and then combined to get the final product. We get the final product here, where out of this component. But in rapid manufacturing the raw material is directly converted into final product in general, we do not need this components and here we can also have assembly which is not required in rapid manufacturing.

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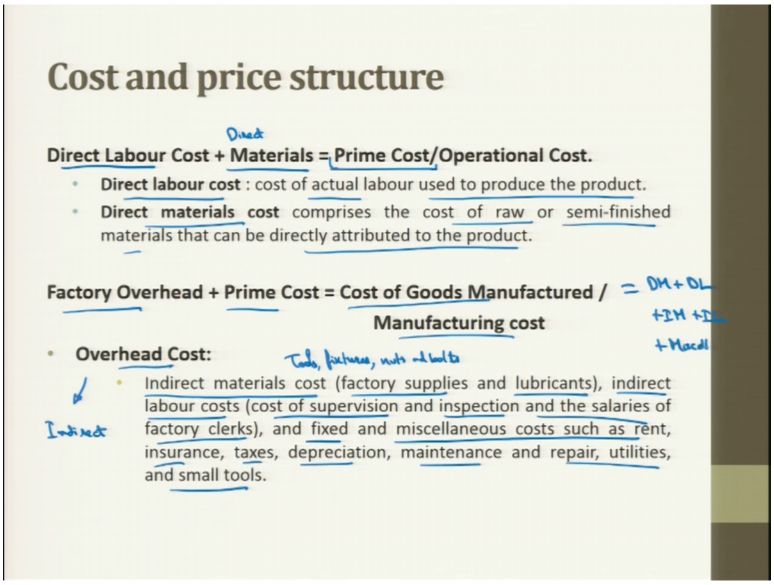

Let us first see, what are the cost and price structures. Very first cost let us like to discuss is prime cost. Total cost is the cost of the product, cost of the product has certain components like prime cost, then factory cost. So, what is prime cost? Direct labour plus direct material cost is prime cost, this is direct material is known as prime cost or operational cost.

Direct material is material that you can see in the product itself. In additive manufacturing, most of the medium is direct, because we are having negligible waste in additive manufacturing. And in subtractive manufacturing, the direct material is lower than in additive. What happens? While manufacturing anything, for instance while manufacturing any product say this bangle, it is manufacture through a subtractive process, this material has to be removed.

So, direct material is that we can see, sometimes that is indirect material. There is tool that is used to make to machining on this that tool is also deteriorative, tool where happens, tool where is the indirect material that can be see directly. So, prime cost is direct material plus direct labour. So, direct labour cost is cost of actual labour used to produce the product. Direct material cost is the cost of raw or semi-finished material that can be directly attributed to the product. In rapid manufacturing, we will see cost for indirect material is very less.

Now, factory overhead plus this prime cost makes the cost of the goods manufacture or manufacturing cost. So, when I say factory overhead, it is the overhead cost. Over cost is the indirect material cost like I said tools, then fixtures, then nuts and bolts which are used that is indirect material cost.

So, factory supplies and lubricant it is said, lubricants is very important. Indirect labour cost, indirect labour cost is direct labour is the labour, who is directly working on the product. Indirect labour is the workers, who have not work directly to produce this product, but the people who are there, who have design the product, who are doing supervision, and who did infection to those that is indirect cost.

And salaries of factory clerks, this is indirect cost. Factory clerks are never related directly to the manufacturing, but the salaries have to be paid that comes in the indirect cost. So, overhead is generally indirect, and fixed and miscellaneous costs such as rent, insurance, taxes, depreciation, maintenance, and repair, utilities, and small tools, this is overhead cost. So, the product cost is prime cost plus factory overhead that is in a way product cost is equal to direct material plus direct labour plus indirect material plus indirect labour plus miscellaneous.

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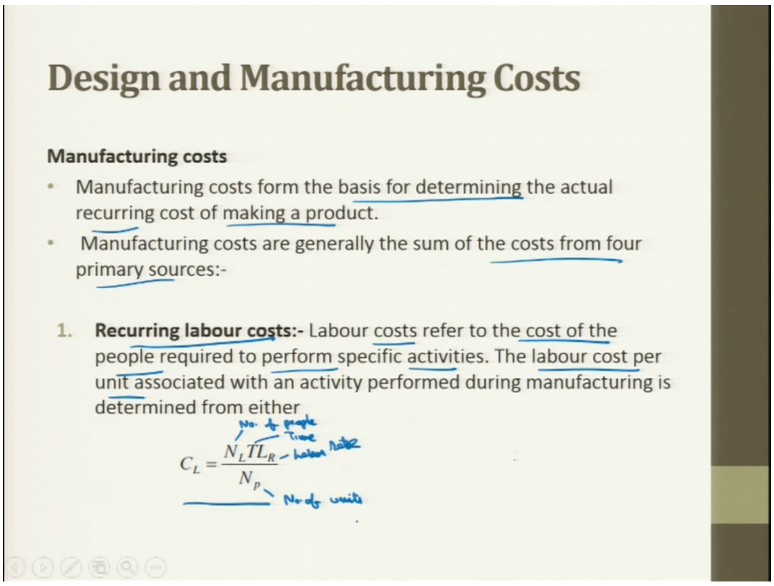

Now, design and manufacturing costs. Design manufacturing costs, first is manufacturing cost. Manufacturing cost form the basis for determining the actual recurring cost of making a product. Actual cost that is there to make a product is manufacturing cost that we have just discussed here, this is manufacturing cost. Manufacturing costs are generally the some of the cost from four prime resources.

So, what are those prime resources? Number 1 is recurring labour cost. Mainly two things required to determine that labour cost. The time that it takes for the person to did the job, and the wage rate. For instance, if he is paid rupees 500 per hour, and it takes 2 hours to complete a job, so 500 into 2 1000 rupee the cost of completing one part. So, it is time taken by the labour or the skill labour to complete a specific job and the wage rate of that person, so that is direct labour.

So, labour costs refer to the cost of the people required to perform specific activities. The labour cost per unit associated with an activity performed during manufacturing is determined from C L is equal to N L T L R by N P. So, what are is abbreviations here? This N L is number of people, T is time as I said, and N P is the number of units, so that produced here, L R is the labour rate. So, these are the components of the recurring labour cost, recurring means variable.

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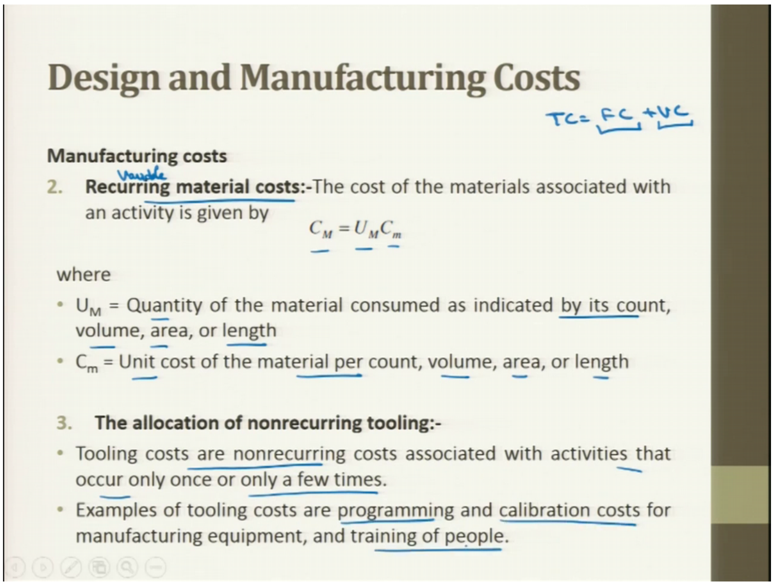

In manufacturing costs, as I said they are four components. First component is recurring labour cost the second component is recurring material cost. The cost of materials associated with an activities given by C M is equal to U M into C m small c small m. So, what is U M? U M is the quantity of the material consumed as indicated by its count, volume area or length.

So, quantitative of material in the terms of laminated sheets can be the number of rolls of the sheet of the consumed. For the very small components, it can be for filament, it can be length, the length of the frame, filament that is consumed or the weight of the filament or the specific volume. If I say volume of the powders or weight of the powder, those are consumed; so that is the quantity. So, this is unit cost of the material per count, volume, per area, per length; so this gives us recurring material cost.

The cost can be divided into two other major components; one of the quantification is total cost is equal to fixed cost plus variable cost. The fixed cost is the cost of the equipment cost of machines. Additive manufacturing machines, those we have purchased, the cost of the software, those we have purchased. And sometimes, the new one new versions of the software have to be updated, so that might coming variable cost. So, labour cost because that is proportional to the number of units produced that is a variable cost, material is also a variable cost. So, these are recurring or variable cost, recurring means variable.

So, the allocation of non-recurring tooling is the 3rd number here. Tooling costs are non-recurring, costs associated with activities that occur only once or only a few times. Examples of tooling costs are programming, calibration costs for manufacturing equipment, training of the people; these are all known as tooling costs. So, this is the third factor.

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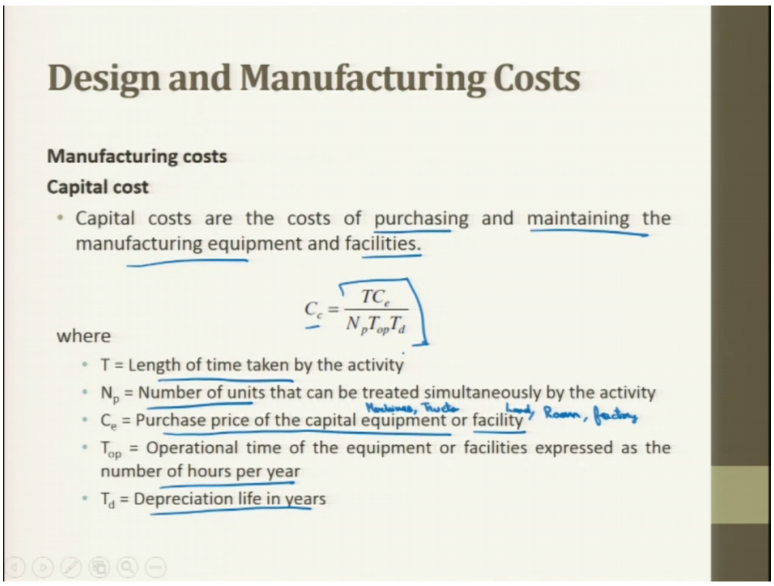

And next is capital costs; capital cost is what I called here as fixed cost, this is capital. Capital cost are the cost of purchasing and maintaining the manufacturing equipment and facilities. So, this capital cost can be given by this relation TC e by N T into T op and T d. What is T here? T is length of time again the same thing. N p is the number of units; again we had it before C e is a purchase price of capital equipment or facility. Facility means, it can be land, it can be factory room or a factory, so this is facility calculate equipment can be the machines ok. The transport units for instance may be trucks.

So, T op is the operational time of the equipment or facilities expressed as the number of hours per year. T d is depreciation life in years, because we are talking about the capital cost, this always life cycle cost associated with anything that we purchase life cycle cost that I will discuss in the end of this presentation of brief introduction to that would be given. Always the things are deuterating with time, and there is always a replacement value.

For example, if one equipment is purchased today, after 5 years that equipment might not be of use and that has to be sold, so that is the replacement price. We have to replace that equipment with some other. So, salvage value of that equipment in 5 years that has to be seen, so that is also taken into consideration the appreciation you can say. The appreciation life in years has come in a denominator here. So, these are the major components of the total cost.

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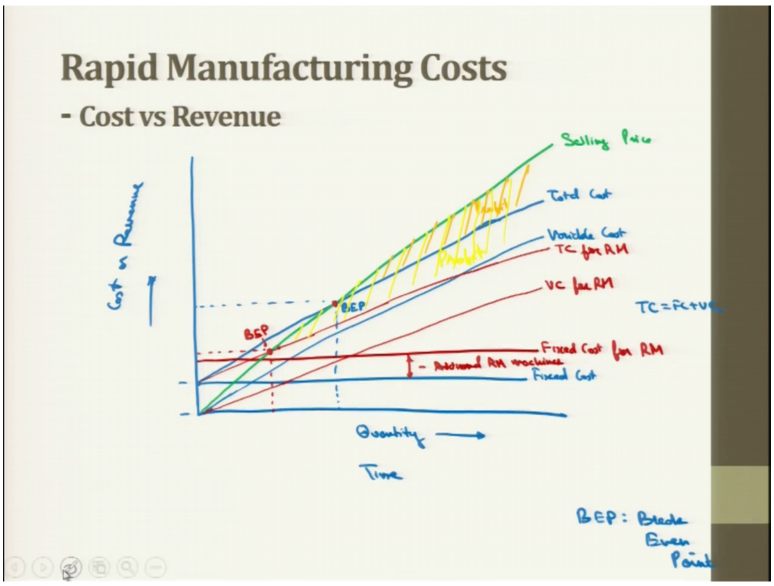

Now, cost versus revenue. In general or traditional manufacturing what we say, it is something like this. We have fixed cost here, this is fixed cost that is fixed, when we start this is the total cost or revenue. So, it we have the general fixed cost here, and the variable cost is depending upon the number of units. So, this is the quantity here, so this is quantity here, so variable cost is something like this that varies with quantity; this is variable cost.

If I add, variable cost that is total cost is equal to fixed cost plus variable cost, if I add these two the fixed cost, it becomes a line parallel to this one, but an intercept with it. The intercept value is this one, this is fixed cost. So, this is total cost when we sell the product, the slope of selling per quantity would be little higher than the variable cost is something like this, so this is selling price. So, this point at which the total cost that is incurred, if you see this total cost is the cost that is incurred selling price is that we have getting back from the market, so this point is known as breakeven point. This is known as BEP, where BEP is breakeven point.

Now, this is generally in traditional manufacturing. What if I try to draw this for rapid manufacturing? Rapid manufacturing may be the fixed cost. If we try to inculcate rapid manufacturing in the present scenario, for instance a factory has traditional setup. And rapid manufacturing or additive manufacturing is something most of the companies have to adapt in the recent times. So, in that case, what happens, the fixed cost of purchasing some more equipment wide would rise; so that fixed cost would come here something like.

Let me change the colour of the pen here, it would be something like this. So, this is fixed cost for rapid manufacturing, because this difference is additional RM machines ok. But, in this case, this is the fixed cost; but in this case, the variable cost would be lower. Variable cost would start from here, because now we are talking about additive manufacturing variable cost would be little lower, this is variable cost for rapid manufacturing. If I add this to the total cost, so this will be something like this, this is the total cost for rapid manufacturing.

Now, we get a I will put selling price in a very different colour let me say, this is the selling price. So, in maroon colour, we had a new breakeven point here that is this is again a BEP, this is BEP, and this is BEP ok. Now, the breaking point is lower, now when we see this, this is the profit this is profit ok. Now, in additive manufacturing for some component, where it is beneficial the profit would be here. Now, this is new profit, this is profit for additive manufacturing.

So, this is how the cost and revenue are related to each other in any manufacturing concern, breakeven analysis of breakeven chart is very commonly used, but this is the very common model. It has certain assumptions that any product that would be produced would be solved. So, we are considering that any product is that is produced here, it has variable cost, those (Refer Time: 16:57) sold to the market number 1.

Number 2, the variable cost is almost a constant; it is a straight line here. In reality the variable cost also varies, they are certain factors those (Refer Time: 17:08) whenever this is the very simplified model, and this is still used to have the overall field that, when would the breakeven point come or what would the payback period, at what time we can also say with quantity, it can also be time here, sometimes time can also be factor. So, at what time would our investment be recovered, so that is breakeven analysis.

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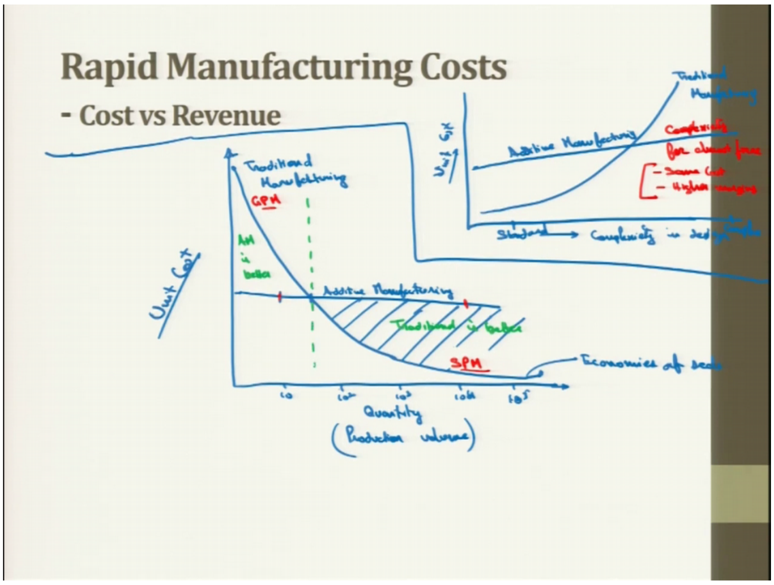

Now, if I put a little deterrent to this regarding, additive manufacturing and regarding production volume, so let me try to view it from a different angle, the same graph it is here, we have cost here, and we have quantity here. So, quantity in this case is production volume. Production volume if we know that types of production, we have job production, we have batch production job production is only one type of product come.

And we do work on that job, and that is delivered to the person to the customer.

Then they we have batch production, different batch is come for instance, the first batch is to produce specific kinds of the pens. So, those kind of pens are produce a second 10,000 PCs of that ok. Then second batches again a 10,000 PCs of second kind of pen in a pen manufacturing company. Third is mass production in which a large number may be 10 lakh PCs or more than that or very large quantity is produced.

So, depending upon the production volume in traditional manufacturing what happens, the cost is something like this. If we need to produce small number, the cost is very high. If we need to produce the large number, the cost is lower. So, this is known as economies of scale, it is something like this ok. When large quantities produced, one can say in ordering when we order the material in this case, it is economies of scale ok, this is traditional manufacturing.

In additive manufacturing, it is does not hold good. Though there is small change with the volume, but the slope is too low, it is something like this. This is additive manufacturing. So, this is additive manufacturing, where the volume of the production does not play a big role in reducing the cost per unit. So, this is actually unit cost, I would better say, the cost per unit is reduced here.

So, additive manufacturing does not play a great role in reducing the cost per unit. Let me put a logarithmic scale here. Let me say these are 10 PCs, these are 10 power 2 100 PCs, this is 10 power 3 1000 PCs, then 10,000 PCs, 10 power 4 100,000 PCs and so on. So, if we produce either 10 PCs or we produce 10,000 PCs, additive manufacturing cost per unit is almost same, because setup is already fixed for that.

But, in traditional manufacturing the setup can be made specifically, because we have the special purpose machines here. Here we have special purpose machines, here we have general purpose machines. General purpose machines are like lathe, milling, drilling that (Refer Time: 20:56), which is general that can be used to do specific operation on the job, and the job can be produced. Special purpose machine is like bolt maker. In bolt maker what happens, the billet goes in. And it just do forming operation first, the hexagonal bar is produced, then that is cut threading happens, and that is produced in one go. So, we use special purpose machines here. So, the cost per unit cost is reduced.

However, the fixed cost is higher for special purpose machines, but the overall cost is reduced per unit. If we consider the complexity of the parts, so let me draw another curve here, this is one. In this case, I am calling this is again unit cost, and this is complexity in design. In traditional manufacturing, more complex the design is higher is the cost, so this is traditional manufacturing.

In additive manufacturing again the line is like this a little change, but the slope is too low, with high complexity, because we have additive manufacturing system the cost would rise only a little. And we can either say the complexity is almost for free, we can say for almost free. So, in this case, the same costs are there. We have same costs almost same costs, then we have higher margins because of that, and therefore higher profits.

So, this is when traditional cost and additive manufacturing are plotted in the terms of complexity, so this is additive manufacturing, and this is again additive manufacturing here. So, conventional manufacturing technologies would have a higher cost. Here in general if I put scale here, this is a standard product, this is the geometric complexity, this is a very complex product, this is the role played by rapid manufacturing in the terms of costs these days. And in the coming time, this traditional machines would we taken over by additive manufacturing completely, additive machines would be left for post processing and preprocessing areas. The main processing would happen with additive manufacturing.

So, many software's like (Refer Time: 24:02) works, NX, Siemens NX, Evoga systems, they have come up with the additive manufacturing modules now. The analysis those who are being done on the product those are to be produced, and those are to be designed in the software's are now additive manufacturing analysis. We have material libraries for additive manufacturing separately all kinds of materials, and there are properties are already there. The properties of polymers, the certain models are being developed. So, these things are taking their place in a very high place.

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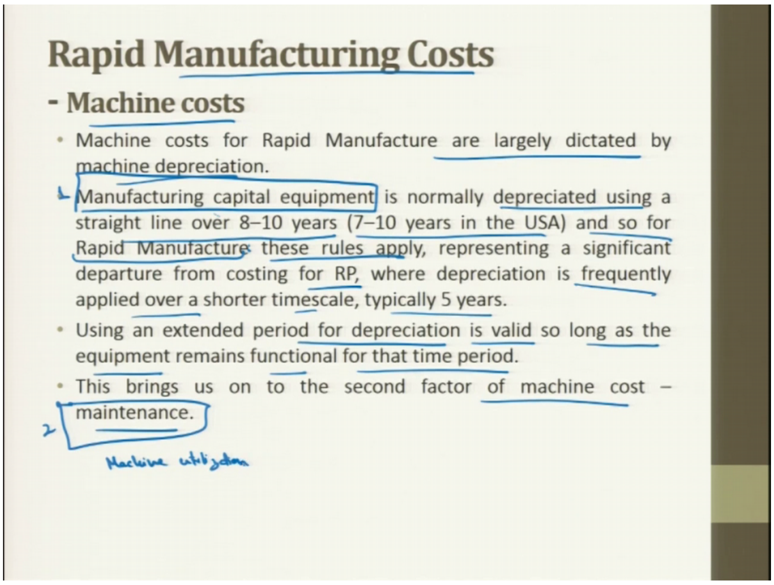

Rapid manufacturing costs. First cost in rapid manufacturing, we can call it machine cost. Machine cost is the equipment cost; machine costs for rapid manufacturing are largely dictated by machine depreciation. Manufacturing capital equipment is normally depreciated using a straight line over 8 to 10 years, 7 to 10 years in US, and so far in rapid manufacturing also these rules apply, representing a significant departure from costing for rapid prototyping, where deprecation is frequently applied over a shorter timescales, this is 5 years typically.

Using an extended period of depreciation, it is valid so long as the equipment remains functional for that time period. So, this brings us on the second factor of machine cost, it is maintenance. So, machine cost is one is capital equipment manufacturing capital ok, this is one. Second one is maintenance, this is 2. For example, in selective laser sintering machine, the equipment when general remain functional over an extended time scale, only some of the parts for instance lasers, those are to be replaced. So, there certain things rapid manufacturing costs need to be factored in a full maintenance package including the replacement of the lasers. So, machine utilization is another area of discrepancy between cost and rapid manufacture, we can say machine utilization to what factored are we utilizing the machines.

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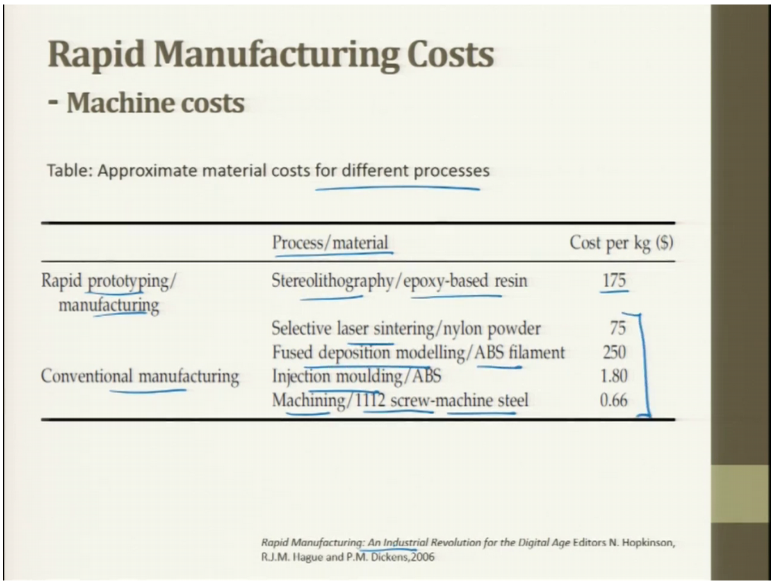

For this chart represents the cost for different processes taken from a study from this book. These are the processes and materials, this is rapid prototyping, rapid manufacturing, this is conventional manufacturing. For rapid prototyping, stereolithography and epoxy resin was taken as materials stereo lithography is the process, it tooks 175 dollars. And for conventional manufacturing again the machining happen, and this 1112 screw-machines steel was taken, injection moulding was taken, fused deposition modeling, ABS filament was taken, so these were the costs per kg.

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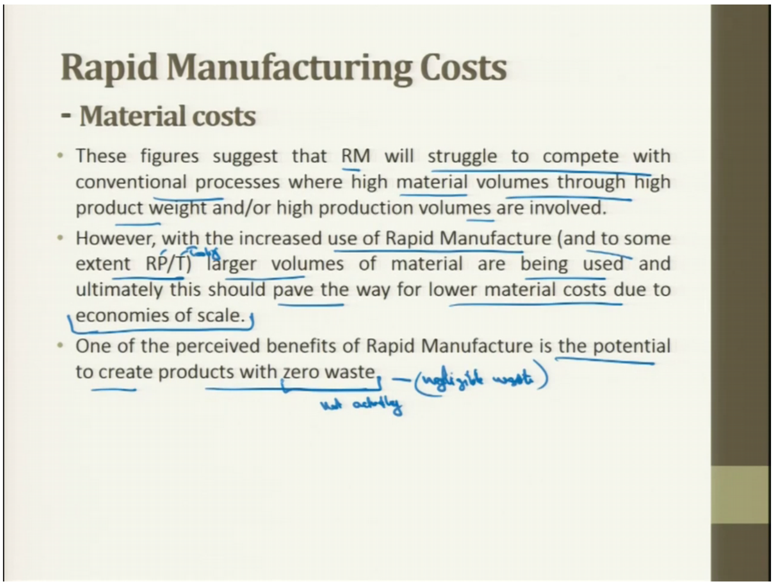

So, these figures suggest that rapid manufacturing will struggle to compete with conventional processes, where high material volumes through the high product weight or high production volumes are involved. As we see here when the volume is higher, the unit cost is higher here rate. At this point additive manufacturing is higher. So, in this case, we can say traditional is better. And here if volume is lesser than this, here additive manufacturing is better. So, this is the dividing line that point I am trying to make here is that where high way material volumes, and high product weight or high production volumes are involved rapid manufacturing has to struggle.

So, with the increase use of rapid manufacture and to some extent rapid prototyping and rapid tooling larger volumes of material are being used, and ultimately this should pave the way for lower material costs due to economies of scale, this is what I just discussed. One of the perceived benefits of rapid manufacturing is the potential to create products with zero waste. This is not zero waste, not actually this is negligible waste; zero waste is never possible. There always supports and some other things, those are wasted.

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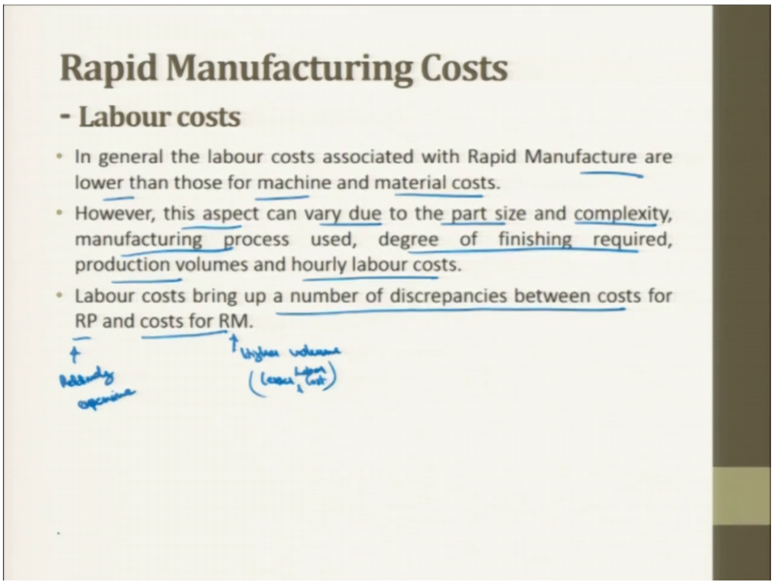

Next is labour costs. Now, labour costs those are associated with rapid manufacture are lower than for machine and material costs. However, this aspect can vary due to part size complexity, manufacturing process used, degree of finishing required, production volumes and hourly labour costs. Labour costs bring up a number of discrepancies between cost for rapid prototyping and cost for rapid manufacturing.

Firstly, setting up a build on a rapid prototyping machine is a highly skilled requirement, and it is relatively slow process. So, it is relatively expensive, rapid prototyping is relatively expensive right. So, this expensive process needs to be repeated for each part that is manufacturing rapid prototyping, this cost is include only once the multitude of bills, when series of production of rapid manufacture is produced.

So, when rapid manufacturing comes, we have higher volume, therefore it is a little less expensive. I am just talking about the labour cost, lesser cost, lesser labour cost specifically. With this I would like to have a break here, and we will meet in the next part of this lecture, where I will discuss the cost models for rapid manufacturing, and we will talk more about the costing in rapid manufacturing.

Thank you.