Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology – Part- 1

Module- 45

by
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Hello and welcome to this manufacturing processes technology part 1 module 45, A brief recall of what we did in the last module, we were actually talking about the.

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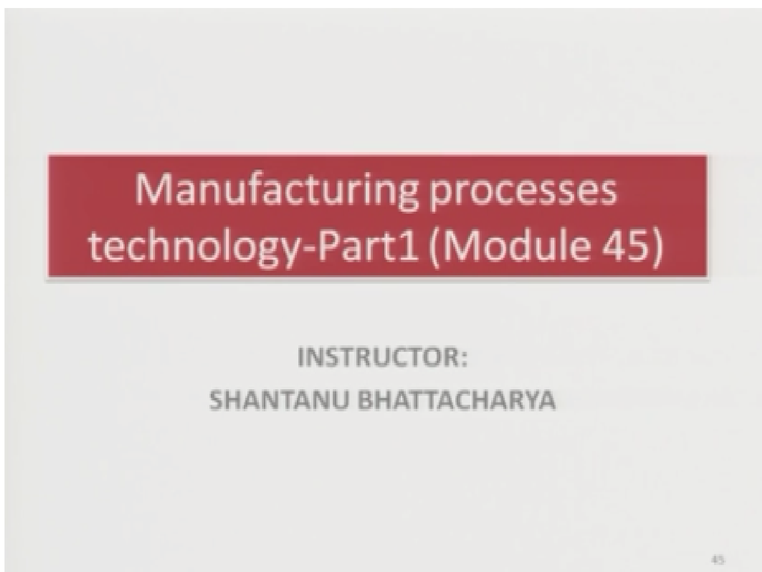

Optimum machining conditions by cost minimization, where we discussed about the various productive and non-productive costs, the times which are used for loading and loading which are otherwise non-productive times and then productive times based on which there would be actual machining operation and then we tried to optimize the cost and based on that optimum cost we had a velocity for minimum cost and to life or minimum costs, as again related through the Taylor's tool life equation. Today we are going to look at just an identical model but it will be the minimum time or maximum production rate model, which is really assuming that you have the time per piece of manufacturer to be minimum or the manufacturing time manufacturing rate or production rate goes to the maximum level as a manufacturing time per pieces low value, so let us now look at this model for just you.

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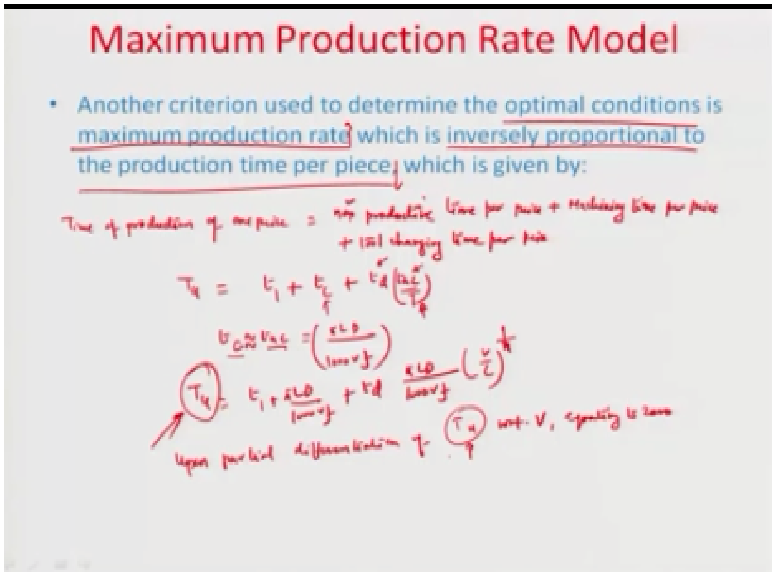

It is kind of an alternate criterion used for determining the optimum conditions of machining corresponding to the maximum production rate okay, which is inversely proportional obviously to the production time per piece, so as this time reduces the rate should increase and that is the fundamental assumption here that we make for determining what is going to be the optimum parameter.

So the time of production of one piece we will be defined as the non-productive time and a piece plus the machining time per piece plus tool training time piece. So if we want to express this mathematically the total time of production per piece tu can be defined as t_1 which really was the non-productive time for the tool changing the work piece loading and loading so on and so forth plus the actual time of machining which was t_c plus again the tool changing time per piece which was t_d times of the number of times that the tool would be changed.

Which is actual cutting time divided by the two live T okay, so there is the frequency at which the tool would change per unit work piece times of t_d which is the time every time there is a new cutting edge, which needs to be deployed in the system, so if I substitute again the value of t_c and t_{ac} which are more under similar to each other again assuming the situation, where you know all these different machining centers have hardly any relaxation time or idle time as designed because of the optimum path of the controller and the rapid feed etc. So this is again I written as π L_D divided / 1000 vf and therefore T_U can be defined as t_1 + πLD / 1000 vf which is t_c + t_d times of π LD / 1,000 vf times of 1 /T which is V / C 1/ n okay.

$$T_u = t_1 + t_c + t_d\left(\frac{t_{ac}}{T}\right)$$

$$T_u = t_1 + \frac{\pi LD}{1000Vf} + t_d\frac{\pi LD}{1000Vf}\left(\frac{V}{C}\right)^{1/n}$$

So that is how you define Tu and I want to just optimize this time per unit component minimize this, so that the production rate goes to the maximum so upon partial differentiation of T_u with respect to V and equating to 0. You get that condition of optimum Tu corresponding to maximum production rate. So let us now do that derivative derivation here.

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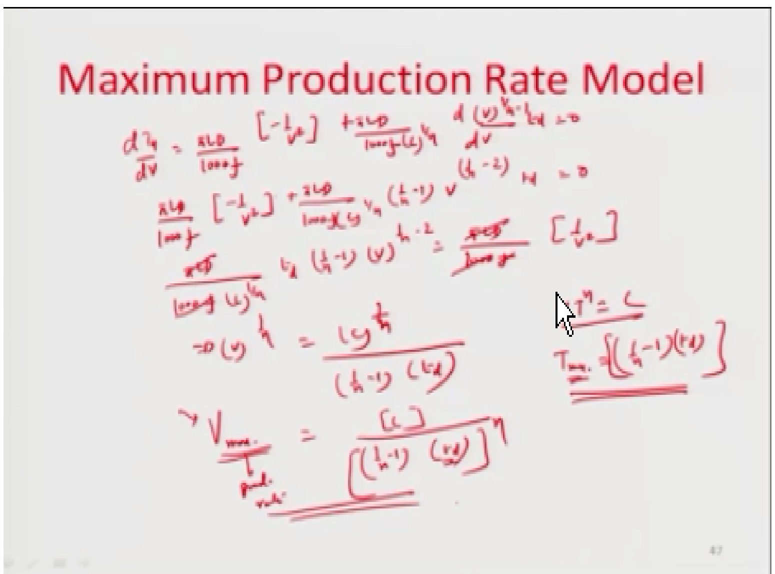

$$\frac{dT_u}{dV} = \frac{\pi LD}{1000f}\left(\frac{-1}{V^2}\right) + \frac{\pi LD t_d}{1000f(C)^{1/n}}\frac{d}{dV}\left[V^{\frac{1}{n}-1}\right] = 0$$

$$\frac{\pi LD}{1000f}\left(\frac{1}{V^2}\right) = \frac{\pi LD t_d}{1000f(C)^{1/n}}\left(\frac{1}{n}-1\right)\left[V^{\frac{1}{n}-2}\right]$$

$$V^{\frac{1}{n}} = \frac{(C)^{1/n}}{\left(\frac{1}{n}-1\right)t_d}$$

$$V_{max} = \frac{C}{\left\{\left(\frac{1}{n} - 1\right) t_d\right\}^n}$$

$$T_{min} = \left(\frac{1}{n} - 1\right) t_d$$

dTu /d_V which is actually = π LD /1,000 f times of - 1 / v^2 + πl_D / 1,000 F C $^{1/n}$ dV to the $^{n-}$ / dv T $_D$ = 0 and obviously from that equation again let us just modify this a little bit and so therefore this π LD / 1000 F times of - 1 / v ^{2}+ πL_D / again 1000F C to the power of 1 / n times of 1 / n - 1 V $^{1/n-1/n-2}$ t_d =0 linked to us a condition I_{LD} / 1000 f C 1/n times t_d times 1 / n - 1 v $^{n-2}$ equals π L_D / 1000 F times of 1/ v^2 so these guys cancel each other and we are left with the condition $V^{1/n}$ equals C $^{1/m}$ divided / 1 / n -1 times of t_d in other words the velocity of cut corresponding to the maximum production rate condition okay.

That is why this subscript V max equals C divided 1/ n - 1 times of the total number of times needed to change one cutting edge to the power of n and just substituting this value in the Taylor's equation V T^n=C. I can always find out what is the time corresponding to the maximum production rate.

So the minimum time what the maximum production rate and that that = 1 / n - 1 times of t_d okay, so that is how you define the optimum criteria for the maximum production rate model just as we did in the earlier case for the minimum production cost model. So let us actually now work on a problem where similar kind of a situation is the risen.

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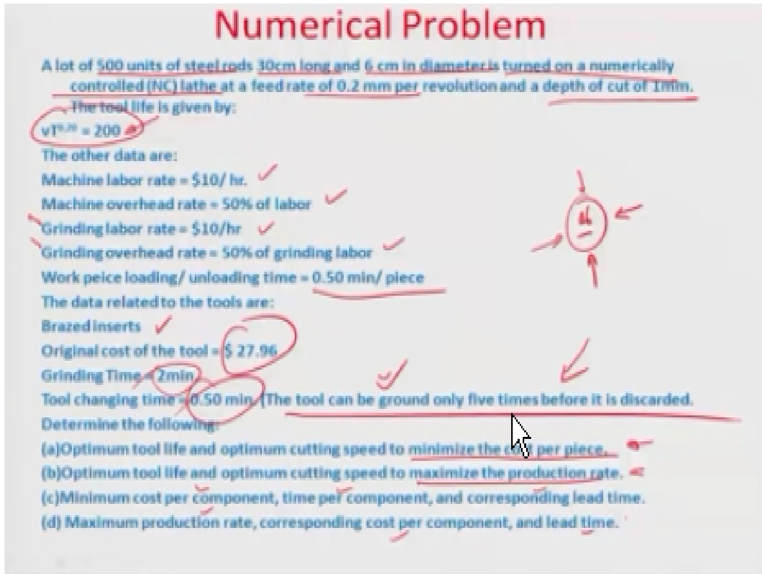

And for that we would like to consider a lot of about 500 units of steel rods 30 centimeter long 6 centimeters in diameter turned on a numerically controlled lathe at a feed rate of 0.2 mm per revolution and a depth of cut of about 1 mm, these things are fixed for the cutting process only thing which probably can vary is the speed and if we look at the tool life equation is given by V $T^{0.20}$ is 200. it is the machining constant for the Taylors tool life equation. T is the tool life minutes; V is the meter per minute cutting speed or cutting velocity.

The other data which are needed or given here as machine labor rate is about 10 units of currency per hour machine overhead rate is 50 % of the labor rate , grinding labor rate is similar 10 units of currency per hour and the machine overhead rates are about 50% of the grinding labor. Now the work piece loading unloading time is given to be 0.50 minutes per piece and all the data related to the tools are provided these are brazed inserts, original cost of the tools are about 27.96 units of currency and the grinding time is about 2 minutes to changing time is about 0.5 minutes.

And it has also been given that the tool can be ground only 5 times before it is discarded. So basically we are talking about just using the tool edge for 6 times okay, so 5 times it is used after regrinding and 1 time it's used as is when it was original and was the first cut that goes executing okay. So there are about 6 such processes which could be or 6 times the process machining process could be carried out with one brazed insert with a little bit of again labor cost as you see here, the dining labor rates and overheads have been mentioned here and we need to now determine the optimum to life optimum cutting speed, so that it works on a minimum cost model or maximum production rate model.

And then also the minimum cost and maximum production rate which are the obtained from the you know the conditions, as given earlier and also estimate time per component and the lead time and similarly in the production rate model estimate the corresponding cost per component of the time. So we start sort of using the formulation that we had learnt earlier in this particular case and the first thing we need to.

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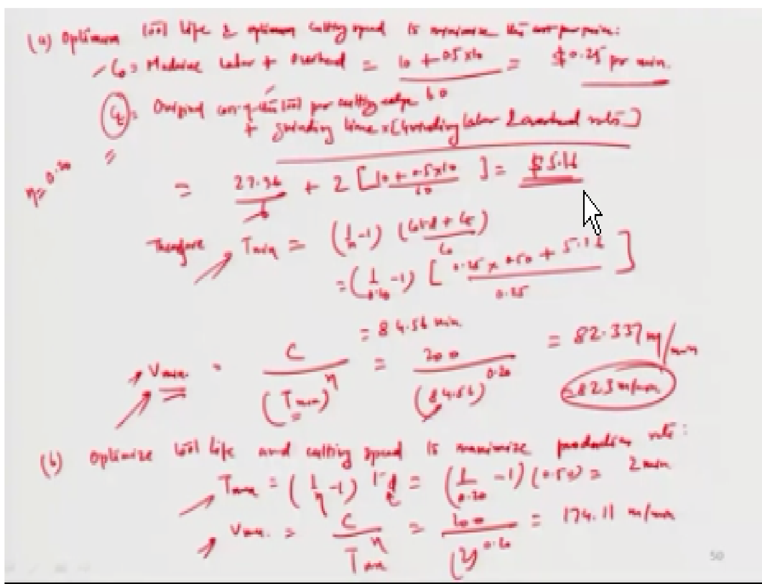

$$C_u = C_0 t_1 + C_0 t_c + C_0 t_d \left(\frac{t_{ac}}{T}\right) + C_1 \left(\frac{t_{ac}}{T}\right)$$

$$V_{max} = \frac{C}{\left\{\left(\frac{1}{n} - 1\right)\left[\frac{C_0 t_d + C_1}{C_0}\right]\right\}^n}$$

$$T_{min} = \left(\frac{1}{n} - 1\right)\frac{C_0 t_d + C_1}{C_0}$$

Get here is the optimum tool life and optimum cutting speed, to minimize the cost per piece. So Co here is the machine labor + the machining overhead cost and as we know here the total cost is 10 units of currency per unit time given in hours + again 50% of the labor rate which is again 5 units of currency and because its per hour per minute conversion can be made by dividing through 60, so this comes out to be 0.25 minutes of currency per minute.

So let us also try to estimate the C_t which is the actual tooling cost and here the original cost of the tool per cutting edge would be important. added to that would be the total amount of grinding effort that is grinding time times of the grinding labor and overhead rates which is paid for the grinding is to be added on to this original cost of the tool per cutting edge.

So the original cost per cutting edge obviously is the total cost of the tool as has been given in the question earlier is about 27.96 units of currency and we have already said that this tool can be used for 6 times so per cut or pert cutting per cutting edge. The total original cost would be divided or split up by 6 and then we add the grinding overhead and labor rate to it, so the total grinding time is given to be about 2minutes and the total grinding labor and overhead rates are calculated as 10 + 0.5 times of 10 again in the same manner divided by 60, so this comes out to be = 5.16 units of currency as the C_t value or the value of the original value of the tool per you know for one particular machining operation.

So we simply apply the minimum cost model so we obtained earlier the total tool life for this minimum cost model is 1 / n - 1 times of C_0 t_d + C_t / C_0 so we record the n value from the Taylor's tool life equation as given in the question to be 0.20 and therefore this is 1 / 0.20 - 1 times of 0.25 which is the C_0 value * T_D which was given as the tool changing time which is 0.50 minutes + the total amount of C_t value 5.1 6 units of currency divided / the total co value 0.25. So this becomes = 84.56 minutes and. if we similarly calculate the minimum cost criteria the velocity add the minimum cost per piece can come out to be the machining constant tailor to life divided by the time for the minimum cost model to the power of n.

So in this particular case it will come out as 200 divided by 84.56 minutes corresponding to the optimum to life to the power 0.20 and this comes out to be 82.337 m/min or 82.3m/ minute so this is how you estimate the velocity corresponding to the optimum cost model and this is how you estimate the time corresponding to the optimum cost model.

So we also now use the or trying to solve the second part of the problem which is about you know the maximum production rate model so optimized to life and cutting speed to maximize production rate here obviously T_{max} could be obtained as one by *eta* - 1 times of t_d refer back to the derivation that has been just made in the earlier module and similarly this can again be written as 0.20 inverse minus1 times of 0.5 0the t_d value and that becomes = 2 minutes.

Similarly the velocity corresponding to the maximum production rate condition has obtained from the equation Tmax ^{n} inverse times C so this is 200 divided / 2 $^{0.20}$ makes it 174.11 meter per minute. So that is how you estimate the T_{max} and the V_{max} corresponding to a maximum production rate model. We also want to determine the minimum cost per component time per component and corresponding lead time so let us look at that.

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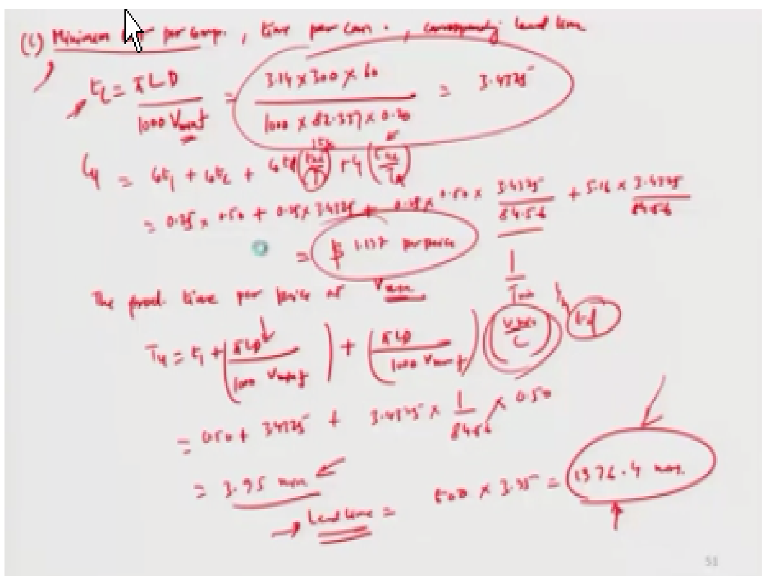

Extent. so minimum cost per component time per component and corresponding lead time, so let us first calculate what is the total amount of cutting time in this particular case t_c and t_c has been as you already know provided through the formulation P_I L_D times of thousand Vf and the V value that we are using is corresponding to the minimum cost per component model, so it's V n and Vn has been borrowed from step a of the earlier parts, where V mean was it remind us 82.337m/m.

And we can write this here as 3.14 value of π times of the total length of machining which is about three 100mm, 30 centimeter long, that is how the question recorded in terms of the diameter of the in terms of the length of the work piece the diameter was 6cm in this case you can record it as 60mm divided /1000 times of the velocity corresponding to the minimum cost model 82.337 times of again, the feed which is 0.20.

And this comes out to be = 343.4325, so if we want to determine the minimum cost in this particular case per component this would be recorded as again the $C_0\, t_l$ which is actually the non-productive cost per piece + $C_0 t_c$ what is the machining time cost per piece + the $C_0\, t_d$ tac / T which is the tool changing cost per piece + finally the tuning cost actual $C_1\, t_{ac}$ / T. So in this particular case we calculate the C_0 as 0.25, which is the Machine labor and overhead rate corresponding to the situation that has been described here times of the t_l which is actually the non-productive time consisting of loading and unloading of the part in minutes. So in this case that is given to be 0.50 minutes per piece the work piece loading and unloading.

Time refer back to the question times off or + C_0 again 0.25 times of t_c which was obtained from this minimum cost criteria, as 3.4325 + 0.25 times of t_d which is actually = 0.50 minutes again the time to change one cutting edge times of t_{ac}, which can be treated 50 as t_c so times of 3.4325 / $T_{minimum}$ which came out to be in the last part a solution 84.56 minutes and then finally this is added on to the cooling cost that is used which is about 5.16 times of the total t_c value 3.4325 divided / again the T minimum value here 84.56. Hence the price per component comes out to be 1.197 units of currency per piece.

Similarly the production time per piece which is equal to the maximum production time per piece at the velocity which is corresponding to the minimum cost condition and that is given by $T_u = t_l + \pi\, L_D$ divided by 1000 V minimum F + $\pi\, L_D$ divided by 1000 V minimum F times of V minimum / $C^{1/N}{}_{TD}$ and this becomes = 0.5 0 + again 3.43 which is this value here right about here as obtained earlier in this step + again the same value 3. 4325 times of V minimum which was also obtained as 1 / T minimum.

So T minimum was obtained as 84.56 so I will just substitute that value here1 divided by 84.56 times of the t_d value which was again 0.50 the time to cut onetime to replace one cutting edge for the drilling operation. So this is calculated as 3.95 minutes and therefore if we include the major setup time which is you know a part of the major setup time which is a major part of sometimes the total lead time.

The total life time is really in the time needed to make the 500 pieces at the rate of 3.95 minutes per piece which makes it about 1976.4 minutes in totality. So with the Taylor's tool life we are able to estimate that corresponding to the minimum cost per component criteria and optimizing the tool life we have a lead time which is about 1976 minutes and a total cost per component which is about close to 1.2 units of current the piece. In a similar manner we can do the same for the maximum production model.

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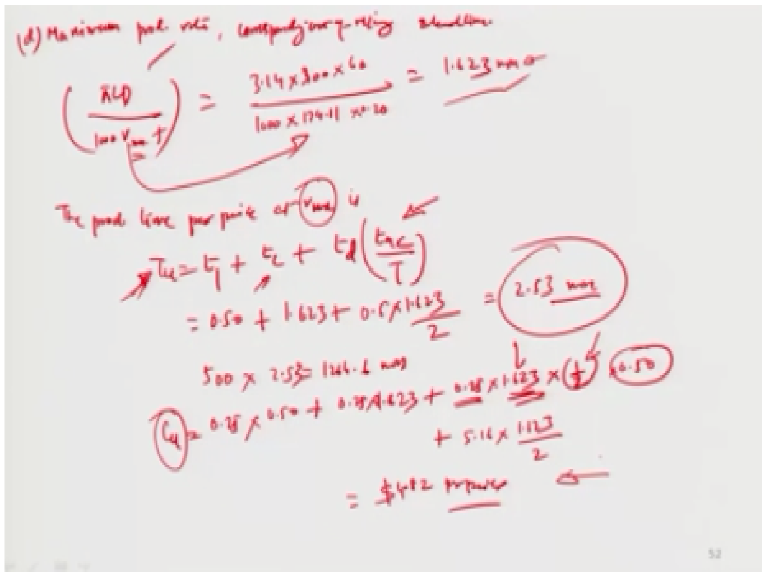

So let us actually now do this for Part d, Part d asks about the parameters you know including I mean the production time per piece or let us say the cost at the maximum production rate, so maximum production rate model you have to find out the corresponding rate the corresponding cost of machining and lead time in this particular case.

So we have the again the first part is to sort of estimate what is the actual cutting time, so considering the V_{max} now that means the velocity corresponding to maximum production rate the total cutting town comes out to be = 3.14 times of 300 times of 60, the various length and diameter parameters of the work piece divided by 1000 times of 174.11, which is the velocity corresponding velocity cutting velocity corresponding to the maximum production rate kinds of 0.20 the feed.

And this comes out to be 1.623 minutes of time and. similarly the production time per piece at Vmax can be recorded as the total amount of non-productive time per piece t_1 + the total cutting time of the corresponding work piece on the machine t_c + t_d which is the tool changing time per cutting edge divided / the number of times it is needed for changing the cutting edge of the tool in a particular work piece recorded as t_{ac} / T.

So in this particular case I can put all these or plug all these values here this t_l happens to be 0.50 minutes the non-productive time this happens to be t_c which has been calculated as 1.623 minutes, just about the last step time + t_d which is one point which is 0.5 0 times of t_{ac} again t_c 1.623 divided by Tmax which is actually in this particular case two minutes has calculated earlier.

So divided by 2 and this is recorded as 2.53 min per component okay, so if you consider the maximum production rate model then the total time per component which comes out is only about 2.53 minutes and therefore if I wanted to look at the lead time again without really considering the major set-up time of the machinery it is just the time per component times the number of compounds to be produced that is 2.53 times of 500 and this corresponds to about 1264.6 min. And similarly the total cost and the maximum production rate model comes out to be = again the non-productive cost 0.25 times of 0.50 + the total amount of cutting time which is again 0.2 or total cost because of the cutting time actual cutting time which is 0.25 times.

Then you know time of machining individual component which is in this case 1.623 + the total amount of time for tool changing, so in this particular case the tool changing time can be recorded as again 0.25 times of 1.623 times of 1/2 times of 0.50. This happens to be the optimum cutting time t_{ac} or t_c 1 / 2 because this 2 right here is the optimum tool life which is 2 minutes in this particular case.

And this 0.25 again happens to be the 0.25, which happens to be the Machine labor head labor and overhead cost plus the cost because of the tool changing operation and the total amount of tooling cost. Which is involved here and this is 5.16 times of the total time of cut divided by the time corresponding to the maximum production rate which is two minutes and this comes out to be equal to 4.82 units of currency per piece.

So you can see here that corresponding to the maximum production rate model we have been able to determine the optimum time of cutting and then from that predicted the total time per component corresponding to the maximum production rate, and the total cost per component corresponding to the maximum production rate.

So this is how Taylor's tool life equation can be suitably used to optimize some of the cutting conditions particularly in high speed machining etc and it is a very useful equation as such for predicting some of these production rates or you know the costs of the components given some particular condition of Optima, so having said that now I think we should look into.

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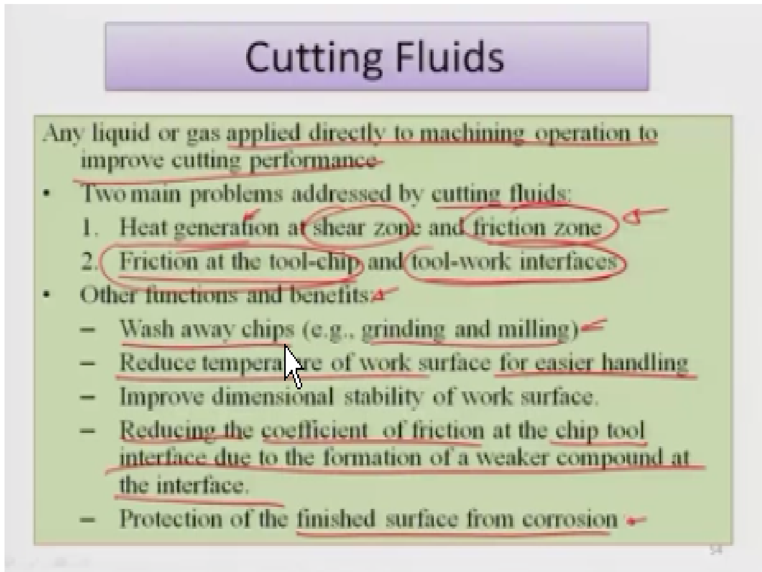

Some aspects regarding cutting fluids and why they are used, so as you may recall that any liquid or gas applied directly to machining operation is generally done to improve the cutting performance. The two main problems which are addressed by the cutting fluids include the heat generation and you know particularly because of machining you know that there is a shear zone and a friction zone where there is a lot of heat which is generated, so this is one of the problems which are addressed and the other problem is obviously the friction at the tool chip and the tool work interfaces which again causes abnormal rise of temperatures in the cutting zone and somehow by putting cutting fluids.

You ensure that machining operations become smoother, so some of the other functions and benefits that the coolants or cutting fluids would provide would be to wash away the chips which are generated from the machining zone, particularly in grinding milling operations, you can also reduce temperatures of the work surface and this important for easier handling particularly with manual handling components are involved and then obviously you reduce the coefficient of friction at the chip tool interface.

Due to the formation of a weaker compound at the interface due to some kind of you know chemistry between the cutting fluid and the tool surface the tool surface as well as the work piece surface. And finally you protect the finished surfaces from corrosion by putting a layer of this cutting fluid, which always flows into the finished surface from the working zone while it is being applied.

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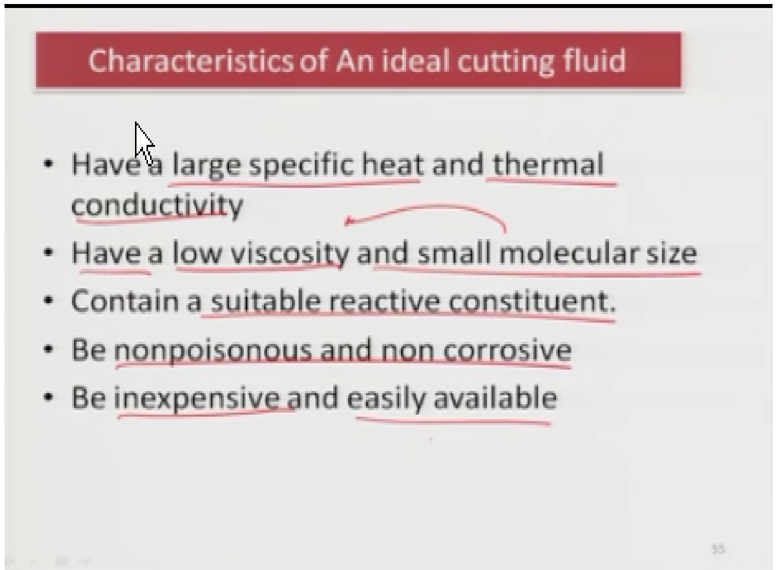

So what is some of the characteristics associated with an ideal cutting fluid? So they have they should have a large specific heat and thermal conductivity, so that they can easily carry away the heat thus lowering the temperature in the cutting zone, they should have a low viscosity. So that they are easily flowable and may be small molecular size these are probably they go hand in hand contain a suitable reactive constituent be non poisonous and non corrosive and also should be inexpensive and easily available and having said that now.

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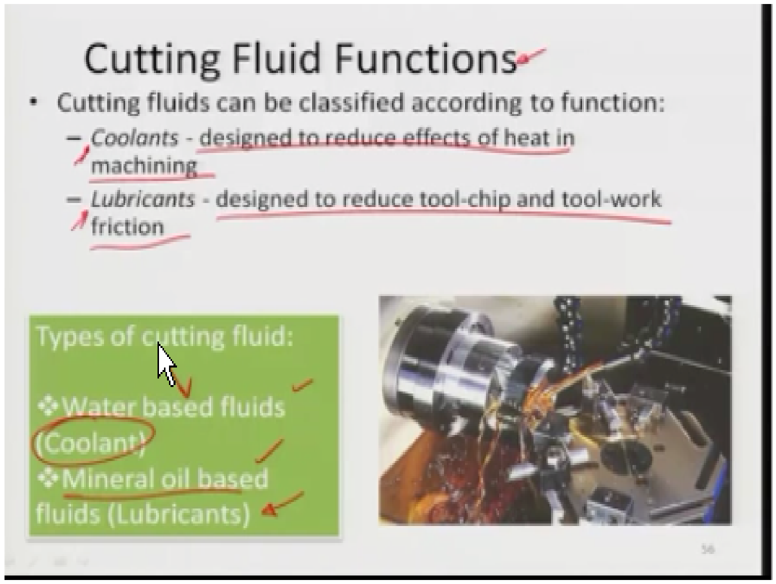

The cutting fluids can be classified really according to the functions, that they are used in or they are put to some of the cutting fluids can be used as coolants, which are typically designed to reduce effects of heat in the machining zone and some of them can be used as a lubricant where it is designed to reduce the tool chip and tool work friction.

The many types of cutting fluids typically water-based or oil-based mineral oil based, the coolants are typically the water-based fluids which would have a again higher thermal conductivity high specific heat. Again the lubricants you know they would have more slightly more viscous kind of fluid and also they would typically be mineral oil based fluids.

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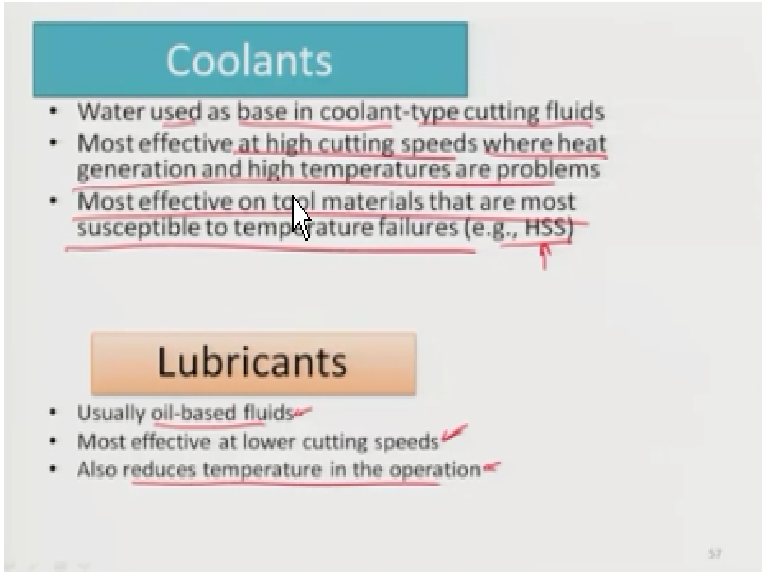

If we look at coolants whatever is used as a base in the coolant? Type cutting fluids and most effective of operation range is basically at high cutting speeds, where heat generation and high temperatures are very prominent problems and these coolants are most effective on tool materials that are most susceptible to temperature failures example, let us say high speed steel etc.

On the other hand lubricants usually are oil based as I earlier pointed out based out of mineral oil they are more effective at lower cutting speeds and they also help in reducing temperature in the operation, but they are slightly more viscous in comparison to the coolants because they typically have to workout layer of film which would form which would which would really necessarily provide the lubrication between the tool and the work piece surface.

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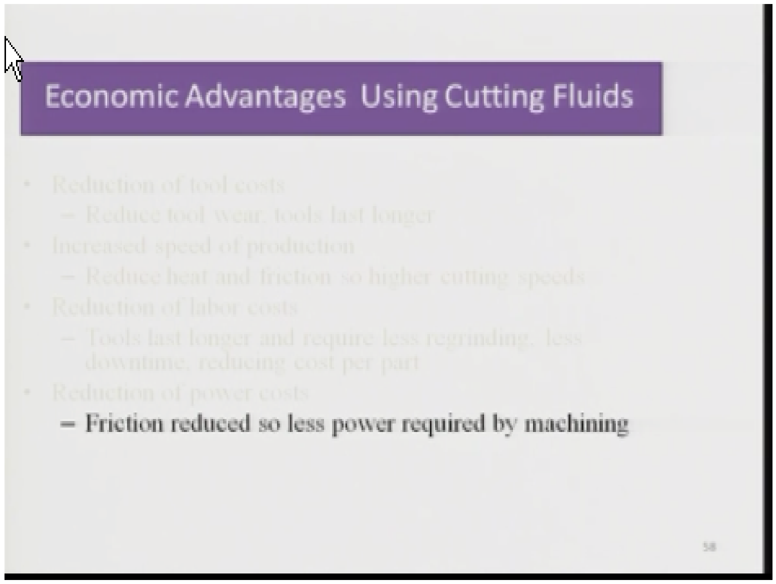

So there are many advantages particularly economic advantages of using cutting fluids, one is the reduction of the tool cost, another is the increased speed of production again reduced heat and friction, so high higher cutting speeds can be obtained and probably maximum production rate conditions could be arrived at.

Obviously reduction in labour cost if you have a uniform or uniform surface finish then finishing costs come down drastically tools may be able to last longer and may require less regrinding or less down time in or reduce cost per part and, then finally you know production of power costs because of the additional advantage of formulating you know a zone, which either acts as a lubricant or as a sort of a coolant or reduces the temperature so that you need not.

So reduction of power costs typically the cutting fluids ensure if they are used as a lubricant they ensure that there is a small layer between the tool and the work piece and obviously in that case the frictional effects are reduced quite a bit, so the frictional dissipation would also be subsequently reduced and then finally because of that reduce friction less power could be required for machining.

So with this I would like to sort of close on the machining module and obviously the next step would be that once we have learned how to do the primary fabrication process in terms of casting and then probably you know trying to machine them machine the components so that they can come into an assembly.

The obvious secondary manufacturing process which comes into your mind is how to join things together? So that there can be a positional relationship between different components and they can work out into machines or assemblies, where there can be an input side which could be in terms of power or velocity and there could simultaneously be an output side.

So now the focus that we will have on this course from next module onwards would be typically on joining processes and this would constitute for another three or four modules beyond which we will like to end this course. So thank you so much for listening I would look forward to talk about welding in the next module thanks.

Acknowledgement

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