New Spinning Technologies
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Lecture - 10
Production and Energy Consumption Calculation

So, today's topic is Production and Energy Consumption Calculations.

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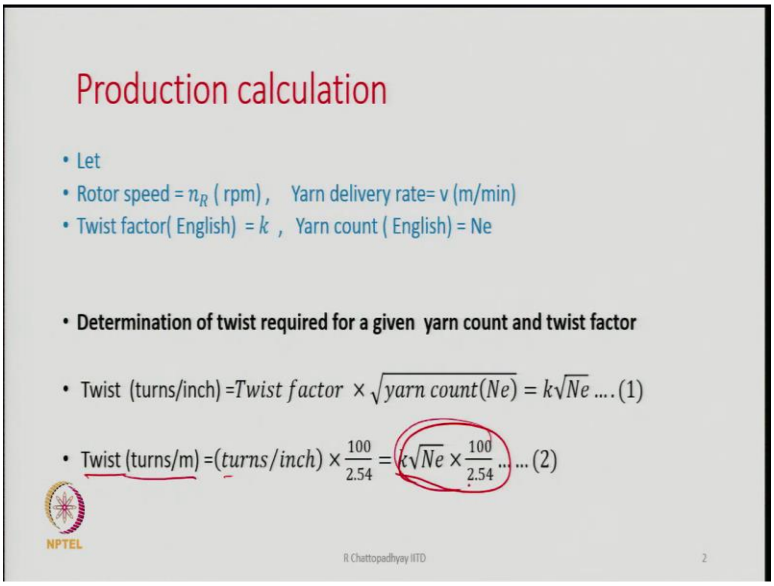

Let us see how do we calculate production in rotor spinning machine. Let rotor speed be 'n_R' in terms of rpm, revolution per minute. The yarn delivery rate let us say is 'v' meters per minute. The twist factor English is 'k' and the yarn count also in English system is 'Ne'. Suppose, these are the parameters which are given. Now, we need to calculate the production that a particular rotor unit is producing or generating per unit time.

So, unit time will fix, it could be per hour, or per shift as the case may be. Now, first of all determination of twist required for a given yarn count and twist factor. Suppose we the count of the yarn and the twist factors are given we need to determine how much twist I have to impart. That we need to calculate first.

So, this is what is already probably known to most of you that twist in terms of turns per inch is,

$$\text{Twist (turns/inch)} = Twist\ factor \times \sqrt{yarn\ count(Ne)}$$

This formula is a very classical formula and this is generally taught when our ring spinning is taught. So, twist factor and root over yarn count these two are related to the twist that we require in a yarn. So, twist factor represented by small '*k*' and yarn count by 'Ne'. So, twist in terms of turns per inch will be,

$$= k\sqrt{Ne}$$

And twist in terms of turns per meter is going to be,

$$\text{Twist (turns/m)} = (turns/inch) \times \frac{100}{2.54}$$

This will give you the twist in terms of turns per meter. So,

$$= k\sqrt{Ne} \times \frac{100}{2.54}$$

Per inch if we divided by 2.54 we get twist in terms of turns per m, and then turns per cm, if we multiply by 100 we get twist per m. That is why 100 is coming on the numerator and 2.54 is coming in the denominator.

So, this is how we can calculate the twist that is required in a yarn of a given count and the twist factor stated either in terms of twist per inch or twist per meter whatever we need.

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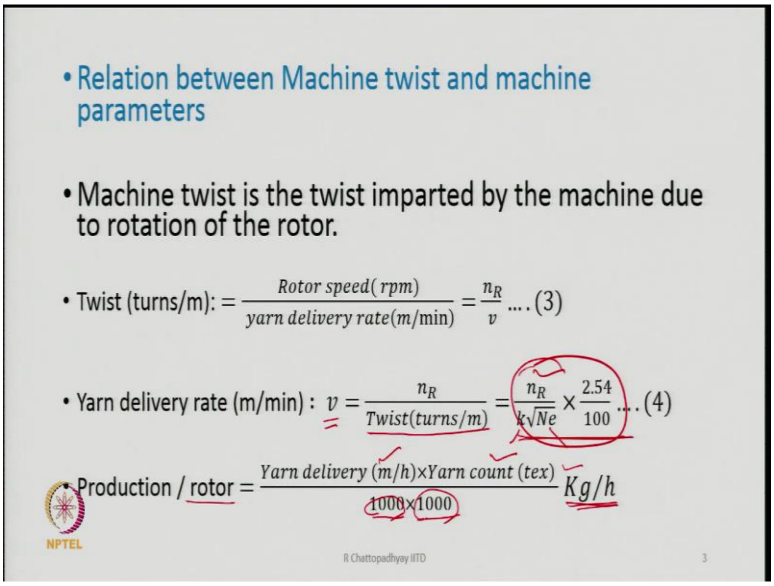

Now, the relationship between machine twist and machine parameters. So, that is what basically gives you how much twist you required in the yarn. Now, the machine we have to set the twist on the machine. So, the relationship between the machine twist and machine parameter. So, twist that is generated by the machine is called machine twist. So, machine twist is the twist imparted by the machine due to rotation of the rotor.

Now, this is a new term that is machine twist which comes in the case of rotor spinning, but this is not there in the case of ring spinning. Because we will also discuss that the twist that we impart on the rotor spinning machines in a yarn. If we try to determine the twist by untwisting the yarn then we will find there is a mismatch between these two.

That is twist in the yarn and twist imparted by the machines not necessarily are same. The reason is the structure of the yarn. The rotor spun yarn has a differential twist structure. We will discuss about them in coming lectures on the lecture, which results in finding out the twist accurately in a rotor spun yarn.

Therefore the term machine twist has come that is the twist that is imparted by the machine due to rotation of the rotor. Now, when it comes to the machine the twist that the machine is going to generate in turns per meter is,

$$\text{Twist (turns/m)} = \frac{Rotor\ speed(rpm)}{yarn\ delivery\ rate(m/min)}$$

So, rpm stands for revolution per minute and yarn delivery rate is also meters per minute. So, if we, in this ratio is the twist that is generated by the machine.

So, this is ‘n_R/v’; where n_R, ‘R’ stands for the rotor. So, rotor rotational speed divided by the delivery rate. Now, yarn delivery rate ‘v’ therefore becomes,

$$\text{Yarn delivery rate (m/min)} = \frac{n_R}{Twist(turns/m)}$$

So, now what comes in the turns per m the twist is related to the twist if we express in terms of no turns per inch or if we want to express in terms of twist factor. We have already seen earlier that twist per m is actually if we go back to the previous slide it is written there we are basically substituting this value.

This is what it is that is this twist turns is ‘k’ sqrt(Ne)×(100/2.54). So, this value actually we are trying to substitute. So, if we go back to the slide that we are looking at. So, we have just replaced this. If you do that we get this is the equation number 4 that is yarn delivery rate ‘*v*’ becomes rotor speed and twist factor and this is yarn count in ‘*Ne*’.

So, therefore, production by a rotor, by a single rotor will be yarn delivery rate it could be meters per hour if they want the production to be per hour basis then delivery has to be calculated how much yarn is delivered per hour. That multiplied by the yarn count if it is given in tex, which will give you the amount of the weight of the yarn if we want to calculate in terms of kg and you have to divide this by ‘1000×1000’.

Because if you want to count in ‘tex’ if you go by the definition of ‘tex’ it is gram per 1000 meter. Therefore, yarn delivery per hour has to be converted into how many 1000 meters it is. So, therefore, we divide it by the 1000, first 1000 is giving in terms of kilometer of yarn you can say. Because total yarn delivered divided by 1000 will give you how much yarn is delivered in terms of kilometre. And then that if it is multiplied by yarn count given in text it will give you the weight of yarn in gram.

Now, gram is then has to be converted into kg therefore, another 1000 will be coming. So, divided by another 1000 that means, the denominator become 10^6. That will give you the production in terms of kg/h. So, here we are writing the yarn count in terms of ‘tex’, because that makes the calculation easy and then if we want it to be written in terms of ‘*Ne*’ that also can be done.

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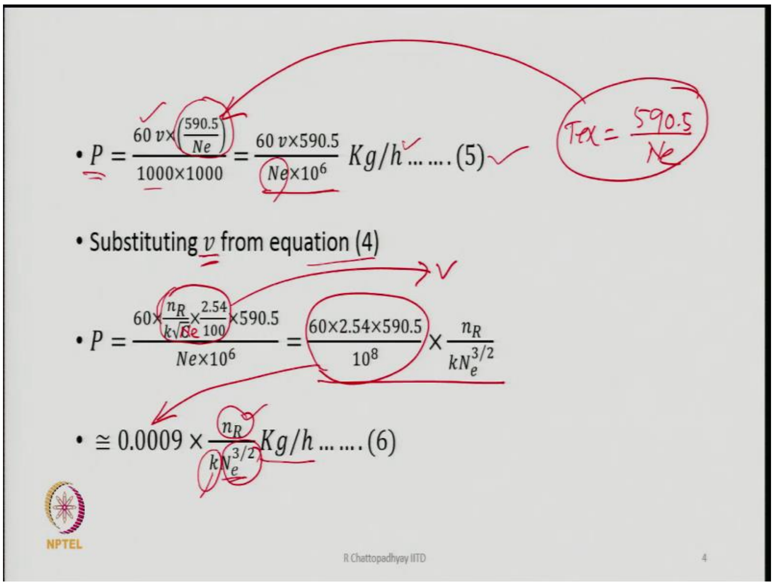

Because we need to know the conversion formula between ‘Ne’ and ‘tex’. So, the easy way out is that you first know it first consider the yarn count in ‘tex’ do the calculation, it will be faster, it will be easier. Otherwise one can also do the calculation using ‘Ne’ value of the yarn. So, if we do that suppose you want to find out the production same production instead of ‘tex’; we want to know it in terms of ‘Ne’ then I am what we are doing we changing the ‘tex’ into ‘Ne’.

And the relationship between these two is takes value is always ‘590.5/Count of yarn expressed in Ne’. So, this is what we are placing here, everything remains same as it was shown in the previous slide. And then we simplify this and we get ‘60×*v*’. 60 is coming because per hour; ‘*v*’ is given in terms of generally meters per minute. So, if I want to calculate per hour because the time unit is hour therefore, we multiplied by 60.

So, it is

$$P = \frac{60v \times 590.5}{Ne \times 10^6} K\, g/h$$

that gives you the production in terms of kg per hour if the yarn count is expressed in terms of ‘Ne’. Most of the time in the Indian texture industry the counts are expressed generally in ‘Ne’. Therefore, we need to know the formula when the count is expressed in terms of ‘Ne’. Now, substituting the value of ‘*v*’; So, equation 5 also is a formula to calculate production.

Now, if I want to replace ‘*v*’ by rotor speed then we can get another formula to calculate the value of the production that is we are what we are doing here? Substituting ‘*v*’ from equation 4. So, the equation 4 the value of ‘*v*’ was stated that is what we are bringing it here now.

So, it is this part is actually ‘*v*’ where,

$$\frac{60 \times \frac{n_R}{k\sqrt{Ne}} \times \frac{2.54}{100} \times 590.5}{Ne \times 10^6}$$

So, this whole this is what is basically ‘*v*’. Now let us look at the equation 4 again, let us go back and see what is equation 4. This ‘*v*’ is here. So, this ‘*v*’ is stated,

$$v = \frac{n_R}{k\sqrt{Ne}} \times \frac{2.54}{100}$$

So, same ‘*v*’ we are basically substituting here.

So, this is basically 'v' and if you simplify it, we end up with this formula. And if we these are all constant and this value will be 0.0009. And the other parameters are 'n_R' that is the speed of the rotor, 'k' is the twist factor and 'Ne' is the yarn count in English system. So, equation 6 also gives you production in terms of kg per hour. So, either 5 or 6 anyone can be used depending upon which are the parameters which are given.

So, equation 6 gives you production figure in terms of rotor speed, twist factor and the yarn count. These are the 3 unknown parameters in this equations this 3.

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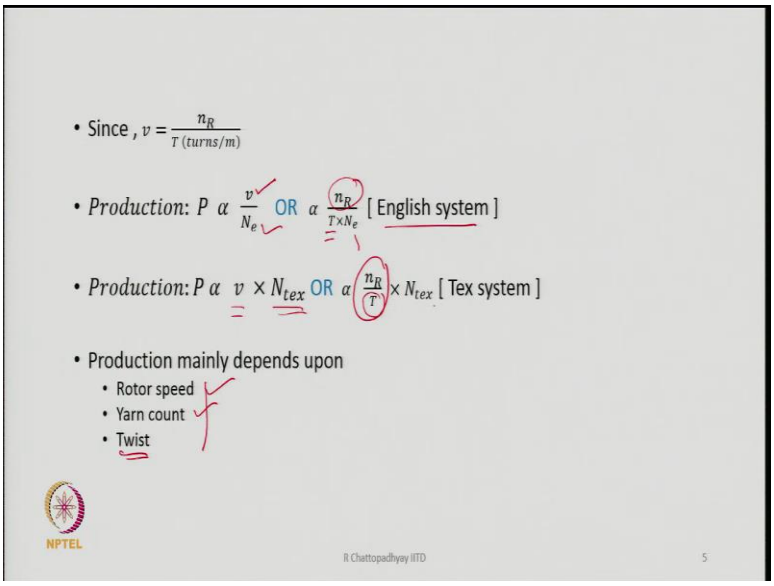

So, therefore, we can say that the production rate is proportionally to what is proportional to 'v' and inversely proportional to the yarn count expressed in 'Ne' or it is proportional to

$$P \propto \frac{n_R}{T \times Ne}$$

That is inversely proportional to twist and inversely proportional to the English count. So, you can say this is one when the count is expressed in English system.

If we want to express the count in 'tex' system, in that case the production figure will be proportional to 'v' directly proportional and also directly proportional to the yarn count expressed in 'tex'. Or if I replace 'v' by the rotor speed and twist. Because 'v', rotor speed and twist are interconnected there; twist is a function of rotor speed divided by delivery. So, they are all connected together.

So, ‘v’ can be replaced by ‘n_R/T’. And therefore, we can write P is proportional to either ‘n_R’ rotor speed or proportional to count of the yarn expressed in ‘tex’ system and inversely proportional to twist. So, we can generally say production therefore, mainly depends upon the rotor speed more the rotor speed we can expect more will be the production.

It will also depend upon the yarn count, but whether it will dependent on it inversely proportional to the count or directly proportional to the count all depends upon the counting system in which we express the yarn count. And it also depends upon the twist. So, if we increase twist keeping other thing constant what will happen to the production? Production should increase or decrease? Production should decrease is very obvious. Because ‘T’ is in the denominator and if we increase the rotor speed keeping other parameter constant, the production should increase immediately. See if we want to increase production rate, you have to go for higher speed of the rotor or you have to decrease the twist in the yarn; we have two options, either you increase the rotor speed or you decrease the amount of twist that you require to spin the yarn.

The other thing is the course of the yarn the model with the productions. So, if it is in ‘tex’ system then it is directly proportional and in the case of indirect systems of yarn counting it will be inversely proportional. But generally, we can say that one other things remains constant the course of the yarn model with the production. So, these are the you know three important parameters rotor speed, yarn count and twist these parameters affect the production rate.

Rotor speed generally can be changed to increase production, but there are certain other problem that we face when you try to increase production by increasing rotor speed. That is what can happen if we try to increase production by raising rotor speed what could be the negative consequences of this?

What?

Student: Yarn breakage.

Yarn breakage, correct. It could be yarn breakage. Because the tension is going to increase simultaneously. So, generally rotor speeds are optimized first and that optimization is done keeping in mind the tolerable level of end breakage. If the end breakage frequency goes very high then will not; that means, the efficiency of the machine will go down and therefore, the whole operation becomes very very commercially not successful.

So, there is a tolerable limit of the end breakage rate in rotor spinning machine as this is also true for ring spinning machine for that matter any spinning machines. And the most sensitive parameter that affects end breakage rate is the speed of the rotor in this case. So, therefore, once the rotor speed is optimized for a given type of fiber and for a given type of count of the yarn then we do not change the speed much we try to then change other parameters.

Count is also a parameter that cannot be changed at will. Because you have to produce a yarn of a certain count only. You cannot say I want to change production therefore; I want to make the count coarser or make it finer to reduce production that is not acceptable, because count is decided by some other requirement.

So, that cannot be touched. So, only the two parameters that can play a role is rotor speed and twist. By rotor speed as I said is not really always may not lead to a higher production rate because it can increase your end breakage rate. And thereby can reduce the efficiency. The twist is other parameter, ok. The twist if we reduce the production is going to increase, but what is the negative fallout of increasing or decreasing twist?

Student: If the twist will less, again the yarn breakage will be more, because gripping will not be that much, and.

If the twist is less then what will happen? The strength of the yarn may go down.

Student: Yes.

And that can also lead to breakage. That could be other thing also if we reduce twist that is the flow of torque in the band of fiber which is pressed against the rotor wall that also can get interrupted. If there is not sufficient torque available in the yarn arm within the rotor then also the twist cannot flow into the band of fibers which are pressed against the rotor wall then also it can lead to breakage.

So, therefore, too much reduction of twist may lead to breakage due to two different reasons. One is because of the yarn is becoming weak and the other one is you may not have sufficient torque available in the yarn arm. And therefore, the fibers may not get twisted properly especially a bundle of fibers which are pressed against the rotor wall.

As I think we have already discussed in the previous lecture. So, these are the you know phenomena which we should keep in mind and accordingly we should try to increase or decrease production. So, other effects could be there. The other effects could also which I have not discussed is that the rate of injection of dust particles in the rotor. The moment we try to increase production rate especially with cotton; that means, my sliver feed rate is going to increase simultaneously.

So, per unit time I will be feeding more dust in the rotor. And these dust are going to accumulate some of the dust may be escape or may be taken out by the yarn itself. But some dust particles also will be accumulating within the rotor groove and we all have also I think I have discussed earlier that a dust particle keeps accumulating within the groove a time comes in the thickness of the dust layer is such that it leads to breakage of the yarn.

The fibers cannot get packed tightly now. Because the corner of those groove is already loaded with lot of dust particles. So, higher production rate means to a more dust will also enter and therefore, frequent breakages can also happen. So, these things we have to keep in mind. Now, we will take a simple examples to solve some problems. There very straightforward simple problems calculate production from the following data.

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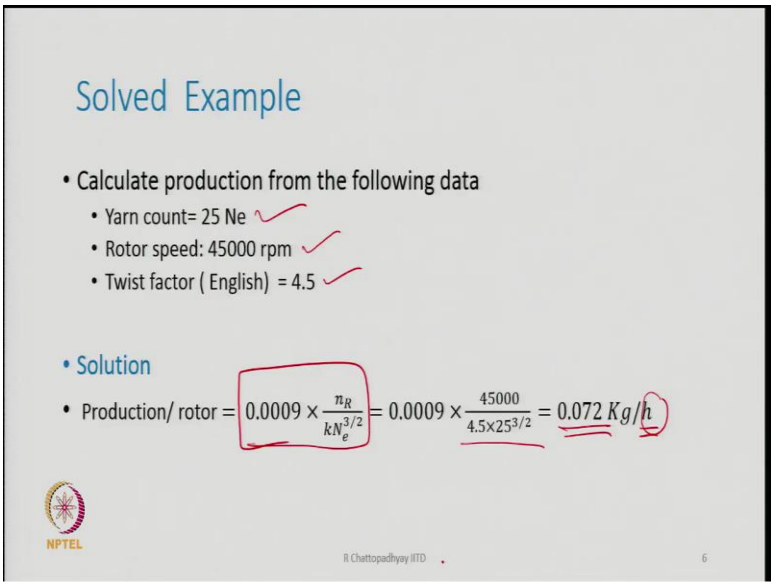

So, what data are given? One is the count of yarn which is 25 Ne, the rotor speed given is 45000 rpm and the twist factor (English) is 4.5. So, from these three data you are supposed to calculate the production rate of the machine not the machine probably per rotor. If we can calculate the production per rotor we can also calculate the production for the entire machine for that we need to know how many rotors are there in the machine.

Generally the number of rotors are close to 200. The solution is we are using directly the formula that we have I have shown you earlier. So, this is the formula. Sometimes remembering the formula is difficult. So, if you do not remember the formula how to solve it that way or so you should know. Then you should go by the simple logic that how much yarn I am producing per unit time. Here the production is to be calculated per hour. So, the unit is per hour.

So, you can find out also that how much yarn I deliver or I produce per hour and what is the weight of that yarn? This is what you require to know. What length of yarn I am producing? And now if I know the count of the yarn what is the weight of the at yarn? That will give you production. Only assumption is that the efficiency is 100% there is there is no breakage. So, that is the assumption.

Sometimes these some efficiency figure may be given also. Now, here in this case we are directly using the formula that we have developed and in that formula the parameters are 3; speed of the rotor, the twist factor and the count of yarn. So, these 3 are given in the example. We simply substitute. If we substitute, we get this figure 0.072 kg/h. If it is to be shown in terms of g/h we have to multiply it by 1000 that will give you g/h. So, in that calculation see efficiency figure has not come.

That means we are not considering the efficiency part or we can say that efficiency is 100% in that case. So, much of kg of yarn will be produced if it is producing 25 Ne yarn.

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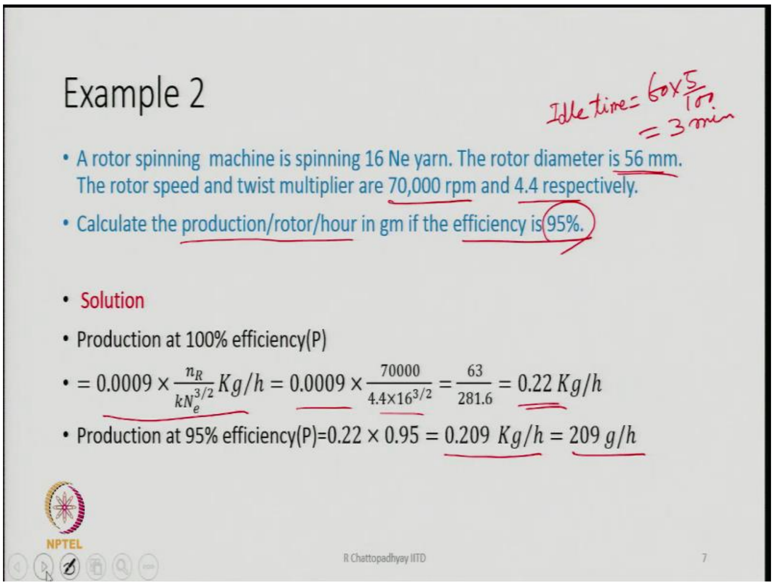

Now, one more example. A rotor spinning machine is spinning 16 Ne yarn. The rotor diameter is 56 mm, rotor speed and twist multiplier are 70000 rpm and 4.4 respectively. This is what is given. Calculate the production per rotor per hour in gram if the efficiency is 95%. So, here the efficiency figure is given.

That means first of 5% of the time the rotor did not work, did not produce; 95% of the time the rotor was running. So, if I say in an hour how many minutes the rotor did not run? What will be the value? In one hour how many minutes the rotor did not produce any yarn? What will be that figure? Take some time and calculate. Per hour how many minutes the rotor was idle? Though that question has not been given in this example well that is a additional simple question we can put.

So, ideal time is 5%; that means, (5/100)×60 minutes. So, ideal time if we want to find it out it will be how much? ‘60×5% (5/100); that means it is basically 3 minutes. 3 minutes the rotor did not work it was idle, 57 minutes it has worked. And if we want now to calculate the production again first of all we calculate production with 100 percent efficiency.

Again we are using the previous formula directly putting these values and we get a figure 0.22 kg/hour this will be close to this. And with 95% efficiency simply multiplied by 0.95 or ‘95/100’ this will give you 0.209 kg/h. If I want g/h we multiplied it by 1000, it will be 209 g/h, this will be approximately, these are the figures. The figures might little change depending upon how many decimal points you have considered in the calculations. So,

Student: Sir, here rotor diameter is given. But there is no need of rotor diameter?

Yes, there is no need of rotor diameter this has been given. So, that you get confused. So, no use of rotor diameter in this particular example. So, this kind of the problems are quite simple in nature. So, now, difficulty is not there in calculation part.

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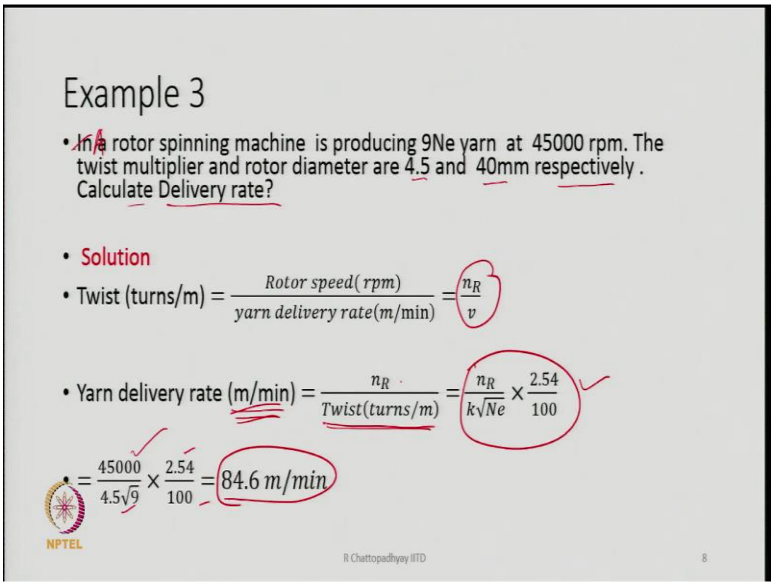

Another example, example number 3; a rotor speeding machine is producing 9 Ne yarn at 45000 rpm, the twist multiplier, rotor diameter are 4.5 and 40 mm respectively. Calculate the delivery rate, calculate the delivery rate. So, the steps are already shown. Now sometimes we may need to know what is the delivery rate.

So, delivery rate twist and rotor speed are interrelated as shown in this. Twist is 'n_R/v' where 'v' is the delivery rate. So, this is what we have to make use of this formula. So, yarn delivery rate 'v' will be 'n_R/twist' and twist in terms of meter because if we know the delivery rate in m/min and I have to know the twist also in terms of turns/m.

So, many times people you know generally forget and they put the figure of twist in terms of turns/inch and they make a mistake. If the delivery rate where we are you know we try to find out in m/min, the twist also has to be in the same unit that is turns/m not turns/inch. And we need to know the relationship.

So, this entire formula has to be used, that is the deduction of this already has been shown earlier. So, one can go step by step instead of using the last formula, if you cannot remember the formula then you go step by step that is you first find out the twist in terms of twist/inch, if we know the twist factor and the count. Then twist/inch you convert into twist/cm and twist/m and then use that.

So, not necessarily that you have to remember the final formula always. But you should know the logical steps that you have to follow in order to solve a simple problem. Here we are using the formula directly and therefore, it becomes just a matter of substitutions. So, all the figures are given the parameters are given we are putting those values and getting a value 84.6 m/min. So, in this case we expect the delivery rate to be 84.6 m/min.

So, different you know types of example could be there sometimes you calculate the production rate, sometimes the delivery rate, sometimes you may be asked to calculate the efficiency figures, sometimes the stoppage data may be given and you have to calculate the production. So, various ways the problem may come, but the solution is not difficult only thing that you have to be logical in your approach you will be able to solve the problems.

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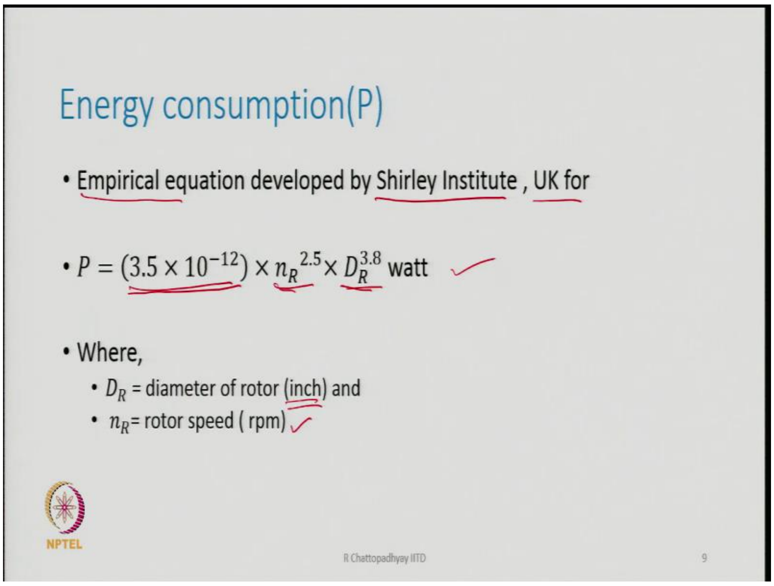

Next one is the energy consumptions or power consumptions. Rotors are made to run at very very high speed. So, we all know the higher the speed more will be the energy consumption that is electrical energy. So, there is a formula, its empirical formula which has been developed by Shirley Institute, UK long ago. And this formula states that the power consumption in terms of what is,

$$P = (3.5 \times 10^{-12}) \times {n_R}^{2.5} \times {D_R}^{3.8} \text{ watt}$$

This is an empirical equation based on basically empirical equation means that it is based on data. By collecting large number of data these values such kind of regression equations can be found out. So, if this is the formula which is given then using this formula we can find out the energy consumption; at least some idea will get how much energy is consumed when you run a rotor at a certain speed.

So, in this formula there are two parameters one is ‘n_R’ which is rotor speed in rpm and the other one is ‘D_R’ the diameter of the rotor in ‘inch’ you have to remember the unit. The unit has been given in terms of inch. It is not that we will not be able to change it to cm or mm, we can do that also.

So, inch can be easily converted to mm and then the formula therefore, will be get little modified the constant term will then change. If I want ‘D_R’ to be changed to suppose mm, and the formula as suggested by the Shirley Institute is given here. So, this formula can be used directly to calculate the power consumption.

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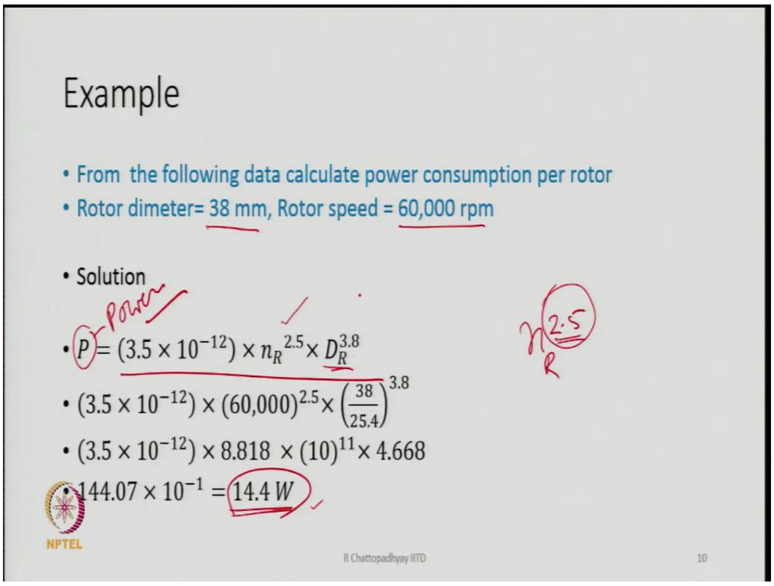

Like an example is given here. From the following data calculate power consumption per rotor. Rotor diameter is 38 mm a typical rotor diameter to be 38 could be 50, could be

65. A rotor speed is 60000 rpm, rotor speed can go up to 100000 rpm nowadays, it can go to 110000 rpm also. And the rotor diameter can go on the lower side to 28 mm the minimum diameter. So, that is the range.

There the diameter can vary from 28 mm to almost 65 mm and rotor speed can vary from 450000 to 120000 rpm depending upon the type of yarn we want to produce. Now, for this if we want to find out what is the power consumption. So, we make use of that previous formula that was given in the previous slide this formula we make use of it.

So, values are given and you substitute them such calculation would need; obviously, the help of a calculator. If I do this if I just go by substitution and then we will get a figure like this and the last figure which is coming here is 14.4 W. That is to run a rotor it is consuming 14.4 watt of electricity electrical energy one single rotor.

So, we are simply using this formula and. The point is what is to be noted here that the power consumption increases disproportionately and the power of to the power 2.5; between 2 to 3 actually it is somewhere it lies. So, this increase in speed the power consumption goes very very high with increase in speed rotor, the production rate will increase linearly.

Suppose if I express the count becomes coarser the production rate will increase linearly or if I increase the rotor speed then the production rate will increase linearly. This 'P' stands for not production, but for power. And the power, the $(\text{rotor speed})^{2.5}$; So, with engaging rotor speed the power consumption will go very very high.

So, per kg the production rate; of the per kg the power consumption is going to increase and it can also increase at a very faster rate with increase in rotor diameter. So, if you in going to increase rotor speed in order to increase productivity then we can decrease the rotor diameter simultaneously to keep the power consumption may be at a constant level. Because if I increase 'n_R' and decrease 'D_R' we will find a place where probably the power consumption may not change much.

Otherwise if the rotor diameter remain fixed with increase in rotor speed the power consumption will be very very high or if we just keep increasing the rotor diameter keeping the rotor speed same then also the power consumption is going to increase at a very faster rate because it is almost $(\text{diameter})^{3.8}$, a very high figure.

That means the power consumption in the rotor spinning is very very sensitive to these two important one important you can say factor one is related to the machine factor that is diameter of the rotor and the other is related to the process factor or process parameter, that is the speed of the rotor.

So, one is machine parameter the other one is process parameter both of them are very very sensitive as far as the power consumption is concerned. With this we close this session of production calculation and some energy related also calculations. So, what we see here the basic you know methodology that we follow to calculate production actually remains same for all types of machines.

Ultimately what we need to know how much we are delivering in terms of length per unit time and then convert it into how much kg per unit time. Whether it is a draw frame producing sliver or roving frame producing roving or ring spinning machine producing yarn or rotor spinning machines or other spinning machines that we will see. So, the basic you know methodology is all same it does not change ok with this we close this session.

Thank you.