Science and Technology of Weft and Warp Knitting
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Module - 6
Lecture - 26
Knitting Calculation - Production (Circular)

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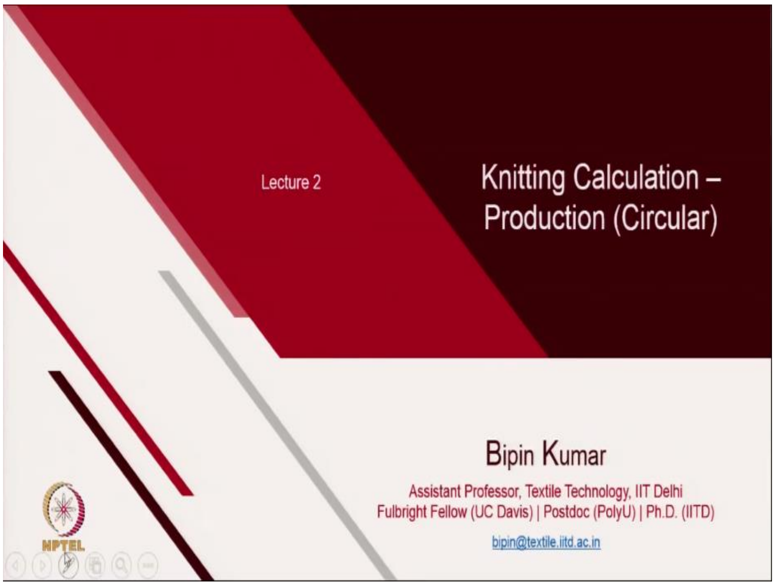

Welcome participants. Now, we are moving to lecture number two in knitting calculation category. So, today the topic is the production, the fabric production in circular knitting machines. Just a quick recap, what we have covered in the last lecture.

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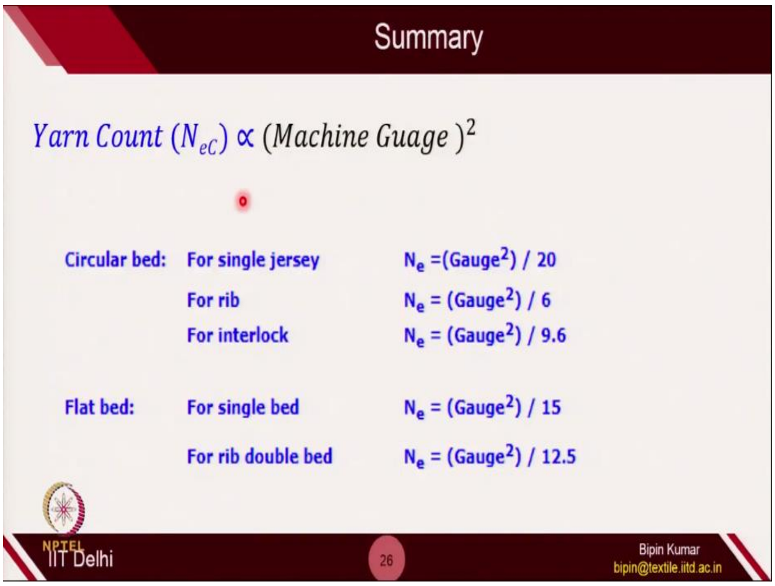

We have seen like, the yarn count that could run on the machine is directly proportional to machine gauge square. So, this is the relationship we derived in the last class. We have also seen like, for different types of technologies in circular bed and in flat bed, the proportionality constant can be different. For example, in single jersey, the proportionality constant is 1 / 20. For rib, it is 1 / 6.

Again, these type of proportionality constant, it is empirical in nature. It again comes from the knitter experience. So, they have given this useful relationship, so that, when you have a particular machine and when you have a particular yarn count, you can cross check using this formula that can, whether that yarn is suitable to run on the machine; yes or no. So, this useful relationship, we have covered in the last lecture.

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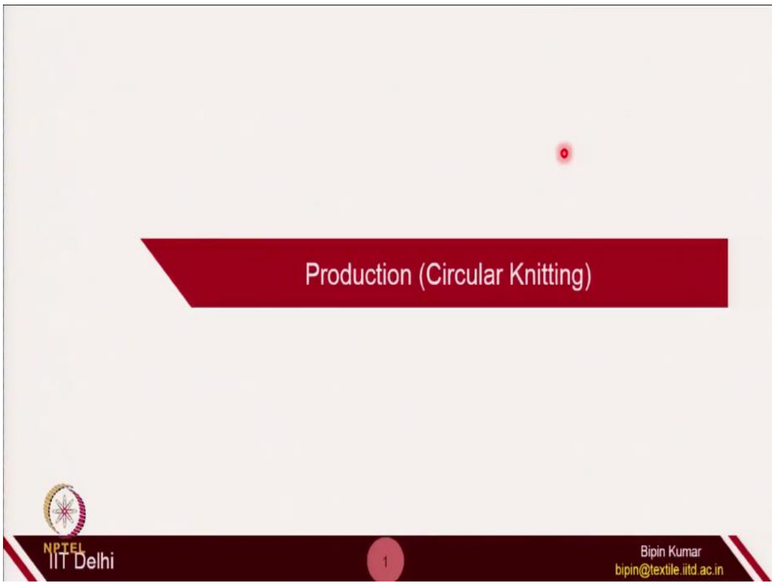

Let's move to the next lecture, which is production on circular knitting. So, production is no doubt, is the key thing from a manufacturer point of view. Because, no matter whatever technologies you are using, they will be mainly focusing on the production in terms of meter or in terms of weight. Because, they have to sell the fabric; so, they want to exploit the full whatever technologies that is available in their arena.

So, in circular knitting, you have seen so many technologies are available. So, in this section, we will see how we represent the production in circular knitting and what are the machine parameters that are used to calculate the production directly.

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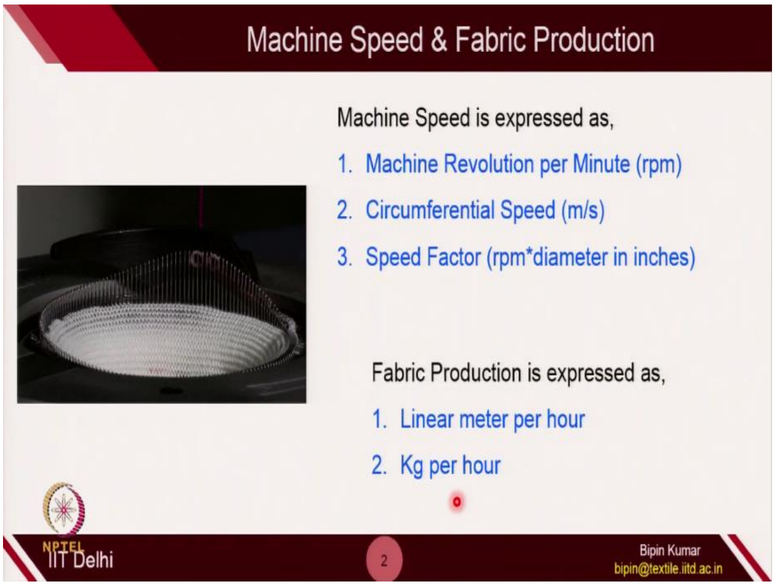

In case of circular knitting, **(Video Starts: 02:28)** you have seen the demo also. So, this is how the cam was rotating and the cylinder was stationary here. So, the production is no doubt, it will depend on how fast the cam is rotating here. Because, if it is rotating at very fast speed, the loops will be formed faster. You can see here, it is rotating in a very slow speed. **(Video Ends: 02:52)** So, naturally the production will be lower.

So, in production, we, there are 2 categories where we generally connect each other. One is speed, because whenever we are looking to any of these circular machine, speed is very, very important. And the speed can be expressed by 3 parameters. One is machine revolution per minute, which is, in nominal terms it is denoted as rpm. So, any circular motion, this term is quite useful.

The second is circumferential speed, how fast it is rotating around the circumference. It is expressed in meter per second. And the third is speed factor, which is the relation of rpm and diameter. So, if you multiply the diameter of the machine especially the cylinder and the rpm of the machine, you get a speed factor. This is also sometimes very, very useful. And in terms of production, again, depending on the capacity of the machine, either it’s rpm or speed; we can relate the fabric production, which can be expressed in linear meter per hour.

So, how many meter of the fabric which is being winded from the bottom side or kg per hour. So, how many weight of the fabric is produced per hour. So, especially depending on the speed, you can connect production. So, there are, I am going to derive some useful relationship where you can connect speed with the production. And there are some other machine parameters if you give, there is a very useful relationship through which you can calculate the production. And then, you can confirm with the actual production. So, this relationship is very, very useful.

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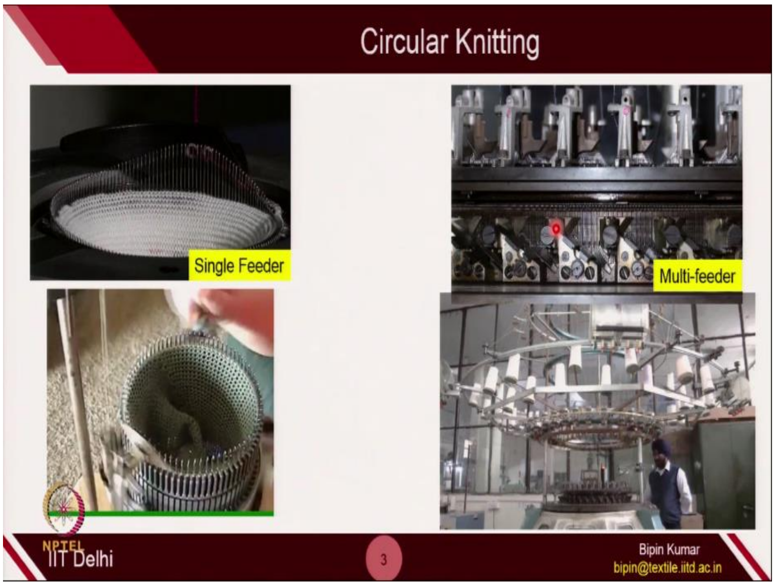

In circular knitting, you might have seen both single feeder machine and multi-feeder machine. So, **(Video Starts: 04:58)** in single feeder machines you can see, just there is 1 feeder. And the cam is taking that feeder across the circumference and needle is catching that feeder. So, in 1 rotation, here, only 1 needle is making 1 loop. But again, to increase the production, we can go for multi-feeder machine, **(Video Ends: 05:23)** here you can see, there are so many bobbins attached here.

And each; and there is a separate feeder zone. And you can see here, these are the feeders: 1, 2, 3, 4. So, along the circumference, there are multiple feeders are present on the machine. This is again for very fast productions. Because, when the machine rotates, the needle can catch feeder from one cam position to second cam position. So, in same rotation, each needle will be making multiple number of loops, in case of multi-feeder machines.

So, you can see here, **(Video Starts: 06:02)** this, again this is rotating. Here the cylinder is rotating and the cam are fixed. **(Video Ends: 06:08)** So, whenever one needle is moving from one cam position to other cam position it will be catching yarn. So, within the same circumference, it can makes multiple number of loops, which will depend on the number of feeders.

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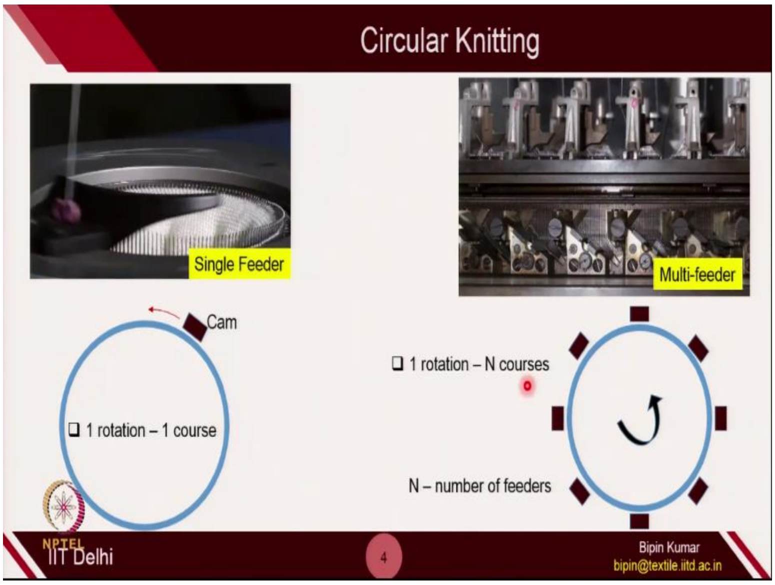

So, this is just a summary. So, in single feeder machine, in 1 rotation, especially in this machine, 1 rotation, 1 course will be generated. But in multi-feeder machines, in 1 rotations, the needle can do, each needle can do N times knitting action. So, N course can be formed. So, N is the number of feeders. So, again, the number of feeders will be equals to number of cams as well.

So, this is how the, we will be looking at the 2 different technologies and we will try to calculate the production in both of the case. So, the key take point is: in 1 rotation, here you can make just 1 course; but here you can make N courses. So, the production naturally will be very, very faster. So, let’s see what are the machine parameters that is useful in deriving this production relationship. We have, we will look to each of these machines separately. So, let’s focus on first single feeder machine.

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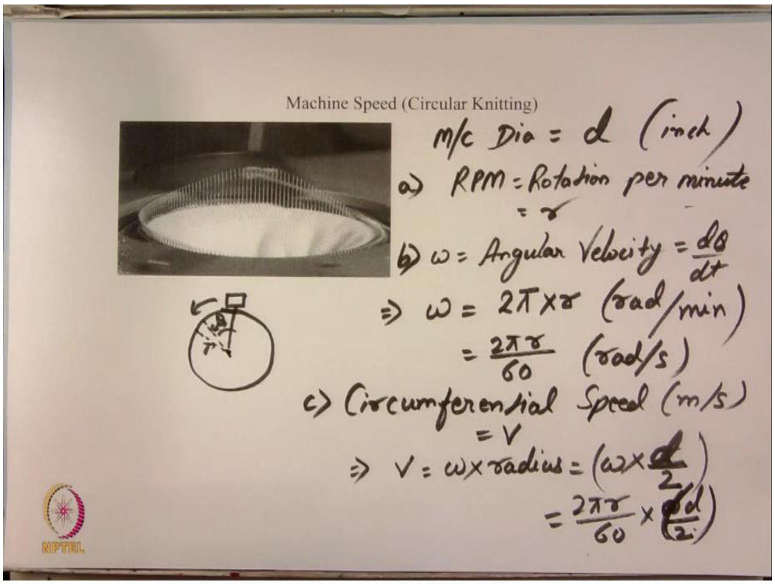

So, this is the single feeder machine. And, we need to first learn how we can express the speed. So, in reality, whenever you go to any manufacturer, you will usually get the diameter of the machine. So, whenever manufacturer machine manufacturer sells the machine, it will give you the diameter value. So, the machine diameter will be always known to you. So, let's suppose this diameter is d, okay; and it is expressed in inches. Okay.

So, the unit of diameter is inch. The second thing which is quite the value which is given by the machine manufacturer is the machine rpm. So, it is rotation per minute. So, this is the circle and the cam will be rotating around the circle. So, it means, how many rotation, full rotation it is doing in 1 minute. So, that's the rotation part. So, this is, let's suppose, this is given in r.

So, with, using these 2, we can calculate other speed for this machine is, the one speed which you, which is also related to in circular motion is **ω**, which is known as angular velocity. So, if you see this class twelfth standard book, you will be knowing your **ω**. **ω=angular velocity**. It means, rate of change of angles per second. So, because if you sit somewhere at the center and if the carrier is moving; so, every second, the carrier will be changing the θ.

So, the **angular rotation = dθ/dt**; rate of change of theta. So, that is angular velocity. And this angular velocity and r are connected. So, in 1 rotation, you know there are 360°. So, if you know the value of r, you can connect w. So, the angular's velocity is, **ω=2π*r**. Because, in 1 rotation, you will be moving **2π*r**. Okay. So, this will be **radian/minute**.

If you want to express per second, then you can simply divide by 60, radian per second. So, one speed which is used is rpm. The second speed is angular velocity. And the third speed is circumferential speed, which is generally expressed in meter per second. So, this is V. It is expressed in meter per second. So, if you want to connect velocity, diameter and rotation, rpm, the relation is **V = ω*radius**.

And radius is nothing but **V = ω*d/2**, because the diameter is known to us. **V = ω*d/2**. And omega, if you want to connect velocity and rpm, the circumferential velocity, the unit is meter per second. You can simply substitute here. If the omega is in meter per second, **V=2π*r*(d/2)/60.** So, this is the relation of circumferential speed.

So, in reality, the most commonly used is rpm. With the help of rpm, we can find out the angular velocity as well as circumferential speed. Let's see one of the simple example. So, find the machine speed. For example, if you see here, find the machine speed in meter per second.

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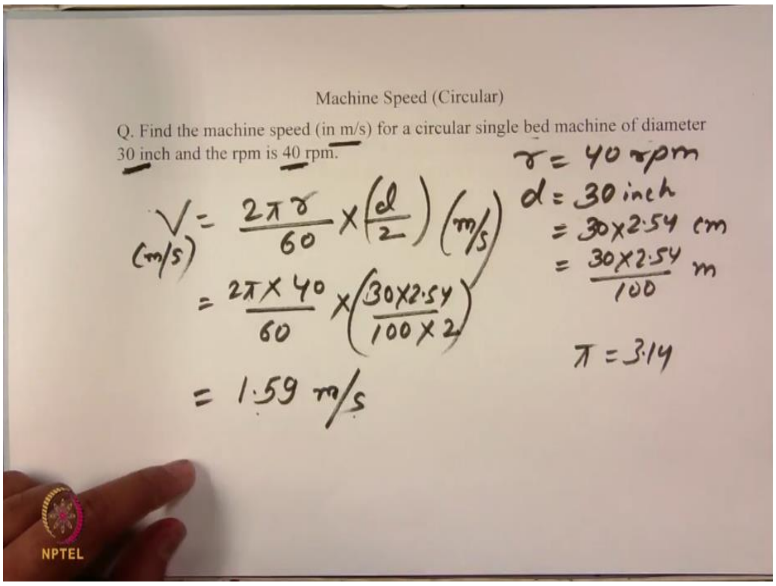

So, unit is very, very important. So, I suggest you, always focus on the unit properly, because this is very, very important. Find the machine speed for a circular single bed machine of diameter 30. So, diameter is given and rpm is 40 rpm. Okay. So, if this is the value, you can simply use this formula, **V=2π*r*(d/2)/60**. So, **V=2π*r*(d/2)/60**. Okay. So, you have to be very careful with the unit.

Because the, here the velocity is asked in meter per second and your rpm is given is 40 rpm. So, r = 40 rpm. d = 30 inch. Okay. So, you can convert inch into meter. So, **30*2.54**. This is in centimeter. **30*2.54/100** meter. So, this is the d. So, you can simply put everything here. And then, you will get meter per second. Okay. This is the unit in meter per second.

So, **$2\pi*40*30/60$**. You can, we are putting d directly in meter. So, **30 * 2.54/(100*2)**. Okay. So, **$2\pi*40*30*2.54/(60*100*2)$**. So this, if we will solve it, this diameter is in meter. Radian r is in rotation per minute. So, the, so we have converted this into second. Minute has already been converted into second. So, that’s why, meter per second.

So, once you solve this, **π=3.14**. So, **π=3.14**. So, if you simply solve this, you will get 1.59 meter/second. The speed is 1.5; so in 1 second, it is traveling 1.59 meter on the machine. So, if you know the machine gauge, you can be able to find how many needles it is traveling in 1 second or it is interacting with 1 second. So, in 1 second, if you know the machine gauge, you can count number of needles, because the length is given.

Then you can say how many loops that can be formed in 1 second. So, this is the simple example which I wanted to show to you. Now, let’s move to the production part. So, this was speed. So, this is all related to speed. This is machine speed. Now, we want to see how much fabric that can be formed on this machine, in terms of meter or in terms of kg. So, for that, we need to first define certain symbols.

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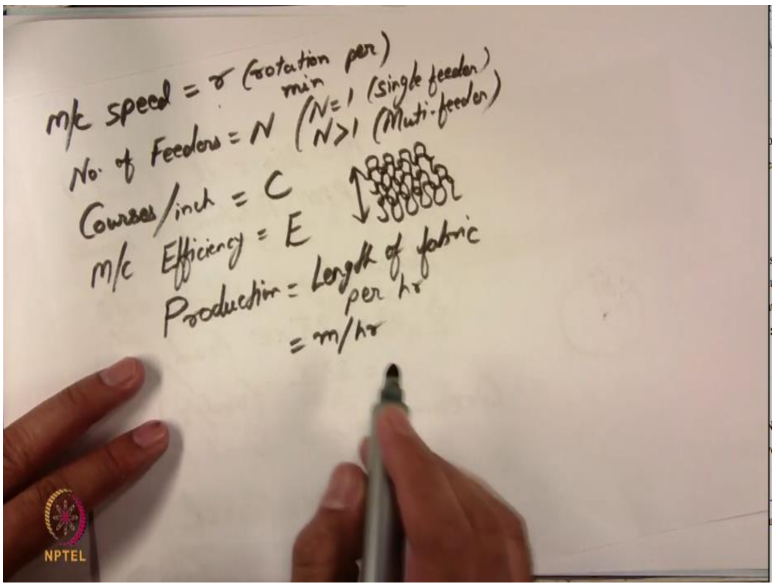

So, machine speed, we are representing in rpm, which is in rotation per minute. Okay. Number of feeders is N. **N = 1**, it means single feeder; single feeder machine which we have, I have already shown you. **N > 1**, then it is multi-feeder. Okay. So, in single feeder machine, 1 rotation, only 1 course will be formed. In multi-feeder machines, more number of course will be formed in 1 rotation.

So, number of feeders is known. The fabric produced, we can measure its course per inch, course density which is C. So, number of courses per inch. So, if you have the fabric; for example, this is the fabric. You can measure the number of loops per unit length. So, that is course per inch. So, if you remember the first lab demo, I have shown you in the first week also, we have described this thread density.

So, course per inch is C. And machine efficiency, because when you start running on the machines, you have seen, we use the machine by hand. And sometimes, computerized machine is also used. But not all the time, the machine will be used. There will be some downtime means, like for example, if the labor goes for tea, then he has to stop the machine. So, in that case, you are not actually 100% all the time you are using the machine.

You are also under producing or the potential of the machine. Or maybe, let's suppose, while running the machine, if the thread breaks. So, again joining the yarn on the machine, it will take some time. So, some part of the productivity will be loss. So, machine efficiency is E. So, we denote, it could be like 80%, 90% of the time it is running perfectly. It is very rare that the machine will be running 100% of the time.
Because, there will be always break. It may be tea break. There may be also some problem with the fabric productions; the yarn may break. And there could be a number of, other possibilities can happen. Because of that, the efficiency will always be less than 100%. So, if you know this, these are the very common practical values which you can always find. So, machine speed already given by the manufacturer, you know that.

Number of feeders, you can easily count. Course per inch, the fabric which is being formed; anyways, you will do the analysis, so you can find out the course per inch. And the efficiency, you can expect. If it is more, it is good for the company; if it is less, this need to be improved. So, once you have all these 4 parameters, you can find out how much fabric that you can produced per hour.

So, fabric production which we can describe in length of fabric per hour; so, length of fabric per hour. So, it can be expressed in meter per hour. Okay. So, if you carefully see the machine, if you go and see the lab demo, we have shown you.

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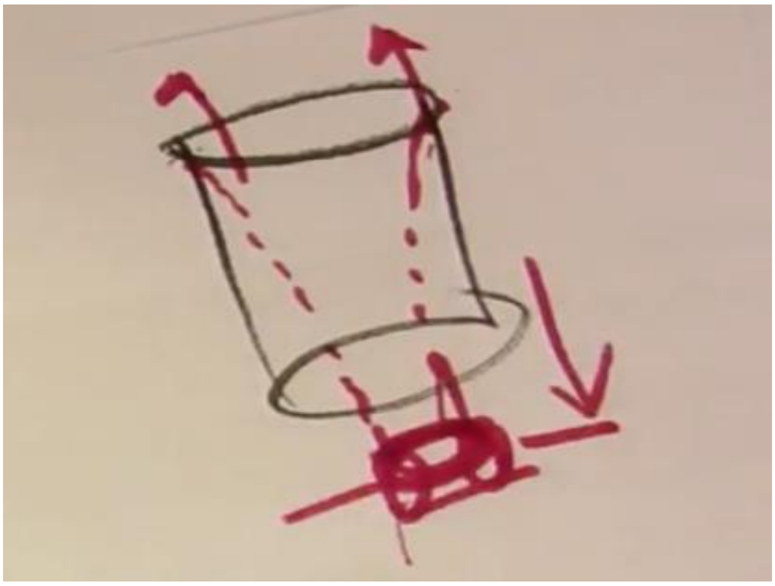

So, this was the cylinder. And the fabric was being formed like this. So, this is the length direction. And it was wrapped at the, on the spool. So, this is the length direction. So, the fabric was formed on the, from, on the knitting zone. So, here the needles was performing. And after the knitting zone, the fabric was being formed and pulled by dead weight. And you roll the, sometimes you roll the fabric on a cylinder.

So, this is how you produce the fabric. So, this is the length of the fabric which we are talking of. So, we can relate this production, length of fabric per hour, with all of these variables. So, if you want to find out, what is the, how much the fabric length can be produced in an hour, you need to find out how many courses that it is producing in 1 hour. So, we have seen machine speed is r.

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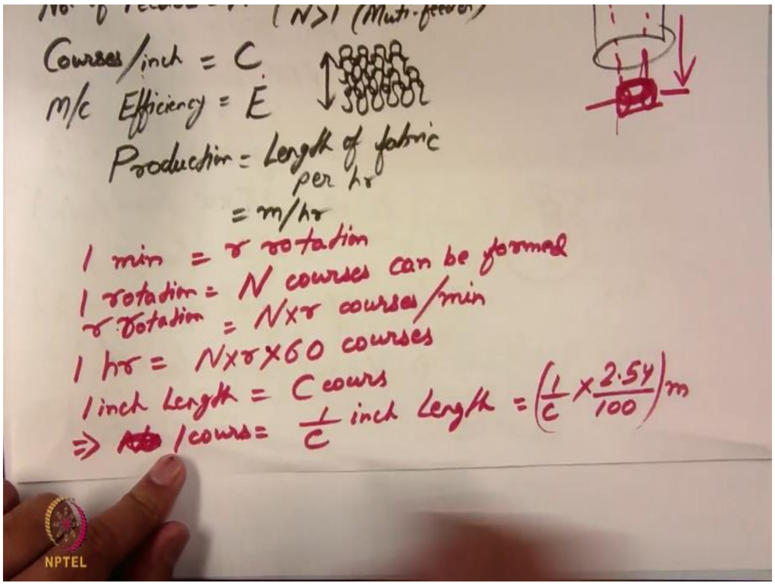

So, in 1 minute, r rotation is done by the machine. Okay. And we have seen, in 1 rotation, N courses can be formed. Okay. So, 1 rotation, N courses can be formed. So, in r rotation, because in 1 minute r rotation is happening. So, in 1 minute, r rotation is happening. So, it means, **N*r** courses are formed per minute. So, in 1 minute, **N*r** courses has been formed. So, you can find out how many courses can be formed in an hour.

So, in 1 hour, because **N*r** courses are being formed in 1 minute. So, in 1 hour, **N*r*60**, okay, courses. In 1 hour, **N*r*60** courses is being formed by the machine. So, you know the total number of courses. You know the course per inch. So, in 1 inch length of the fabric had C course. So, if you have this number of courses, you can find out the fabric length.

So, 1 inch length has C courses. So, C courses has 1 inch length. So naturally, so 1 courses will consume 1/C inch length. So, you can convert 1/C inch into meter. So, this is **=(1/C)*2.54/100 meter**. So, 1 course is consuming this much length of the fabric. So, you have produced **N*r*60**. 1 courses has **1/C inch** length. This is this much.

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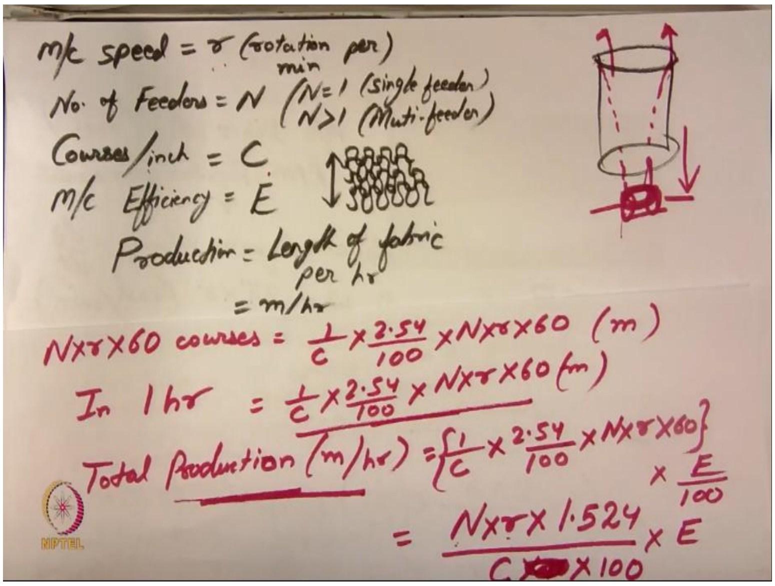

So, **N*r*60 courses/hr, = (1/C) *(2.54/100) *N*r*60 meter**. Okay. This much meter. So, how much time we are taking to make this much courses? 1 hour. So, in 1 hour, we are producing **(1/C) *(2.54/100) *N*r*60**. Okay. So, this is the production. So, we can; so, this is the actual production. We are assuming that the machine is running for entire 1 hour.

But, since we know we have the efficiency E. Not, in 1 hour there must be some downtime. So, you can simply multiply, So, total production is in meter per hour. Is equals to, we can simply multiply this by efficiency. So, **(1/C)*(2.54/100)*N*r*60*(E/100)**. Because efficiency is given in percentage. So, 95 means, 95/100.

So, we can simply get; if we solve all of these. So, this will be, **N*r*1.524*E/(C*100)**. So, this is the formula. So, you can see, how production, how the production is connected; how the production, if you see this, the production, the total production is connected with N. You can see here, this is N. Machine speed, rpm. This is some constant. C is the courses per inch.

And E is the efficiency. And all of these downs, you can find out experimentally. And, with this we can, you can find out the productivity of the machine. So, this is the meter per hour. Now, sometimes we can also express the production.

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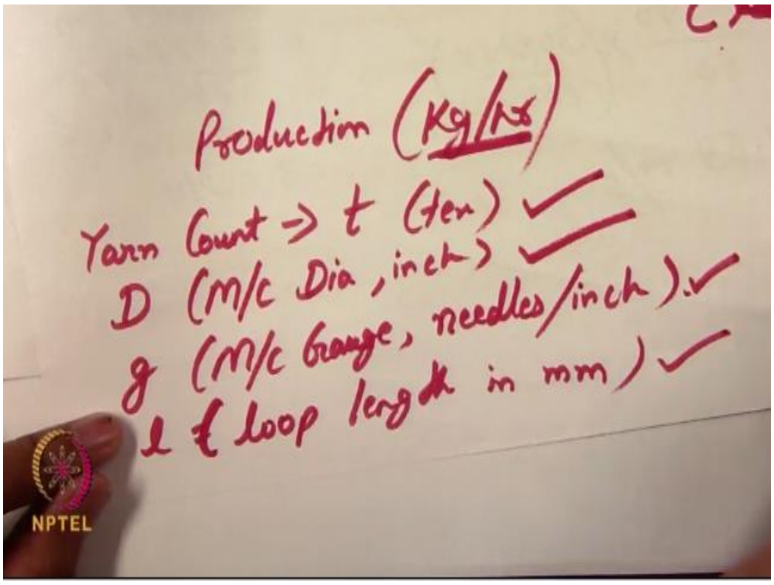

We want to express production in kg per hour. Okay. So, sometimes we can express the production in kg per hour. So, for that, to find out the production in kg per hour, we need other variables. For example, because we want mass; so, definitely yarn tex should be known. So, yarn count, it should be t in tex. If it is known to you, you can convert this meter per hour into kg per hour.

You also want to know machine diameter in inch. And g is the machine gauge, needles per inch. And l is the loop length in mm. So, if you have additional 4 values. So, because, this will be known to you. You will be knowing what count you are using; you will be knowing machine diameter; machine gauge and loop length, which you can measure. So, with this, you can also find out the production in kg per hour. Let me derive for you.

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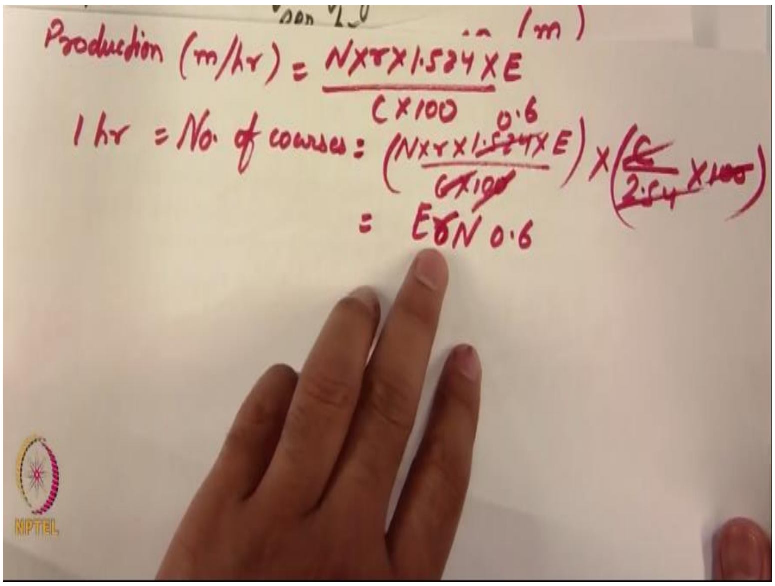

So, you know the **production (meter/hour) = N*r*1.524*E/(C*100)**. So, in 1 hour, this much meter of the fabric has been produced. So, if we need to find out how many loops are being produced. So, this much meter is known to you. So, in 1 hour, number of courses. You can find out **N*r*1.524*E/(C*100)**. Number of courses, this is the length of the fabric.

And, if you multiply by C; because, this is the length of the fabric and you know the course per inch. So, number of courses can be simply calculated by the length into courses per inch. So, you can convert into centimeter **2.54*100**. Okay. So, this, in that case, C and C will be cancel out. This and this will be again cancel out, 0.6. And this and this, 100. So, this will be, you have, you can see in 1 hour, E r 60.

So, here, **E*r*N**. And E is the efficiency, we have just multiplied **E/100**. So, that's why, and this is exactly same. So, here we have used the efficiency in the beginning itself. So, we know the number of courses. And we need to count how many loops are there in 1 course.

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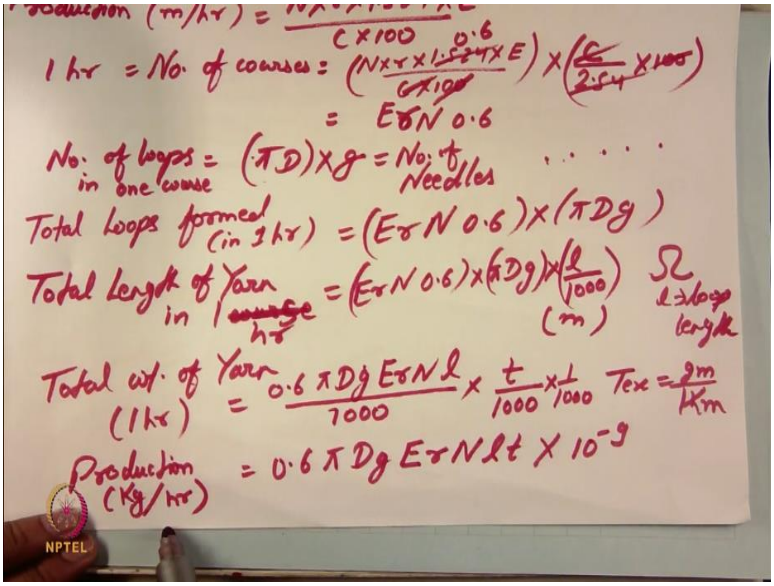

So, number of loops, you can find out if you know the machine diameter. And if you know the machine gauge, you can find out the number of loops. Because, number of loops in 1 course will be equals to the number of wales. And each wale is made by 1 needle. So, each needle will be making 1 wale. So, in 1 course, if you count the number of needles, that will be equals to number of loops in 1 course.

So, this will be **πD**. This is the circumference of the machine into machine gauge (**πDg**); g is the machine gauge. So, this is the number of loops in 1 course. So, total loops formed in 1 hour, you know how many courses has been formed. And this is the number of loops in 1 course, multiplying the circumference into gauge, because this will give you number of needles. And each needle will be making 1 loop.

So, if you count the number of needles along the circumference, they will be making number of loops in 1 course. So, if you multiply this **E*r*N*0.6*πD*g**. So, we multiply this and this. So, we get it here. So, total length of yarn. So, if you know the loop length, you can say what is the length of the yarn used in making 1 loop. So, total length of the yarn in 1 hour, because in 1 hour you are making so many loops.

So, you can simply multiply by l. And l is the loop length; l is loop length. So**, total length of yarn in 1 hour= E*r*N*0.6*πD*g*loop length**. This was in mm. So, you can convert into meter. So, here 1000 is for meter. So, you have the total length of the yarn. You know the tex of the yarn, you can get the weight. Because, this is the total length of the yarn which is used in 1 hour.

So, you, if you know the total, you can weight, you can find out the total weight of yarn used in 1 hour. This will be the production actually, because this is the total weight of the fabric. For that, so this will be **(0.6πD*g*E*r*N*l)/1000**. And if you know the yarn tex. So, **tex=gram/kilometer**. So, total, this is the total length in meter. So, we can simply multiply this tex.

Tex is in gram. So, t is the tex**, tex/1000 meter**. 1000 meter has this much gram. So, you can convert this gram again into kg. So, if you just multiply with this, you can get the production in; so, **0.6πD*g*E*r*N*l*t*10^{-9}**; so, production. This is nothing but the production in kg per hour. Although it looks very complicated, but if you simply follow the process, you can easily get the values. Okay.

So, here you can see how many parameters do you need to find the fabric production in kg per hour. Now, let’s do a very simple example.

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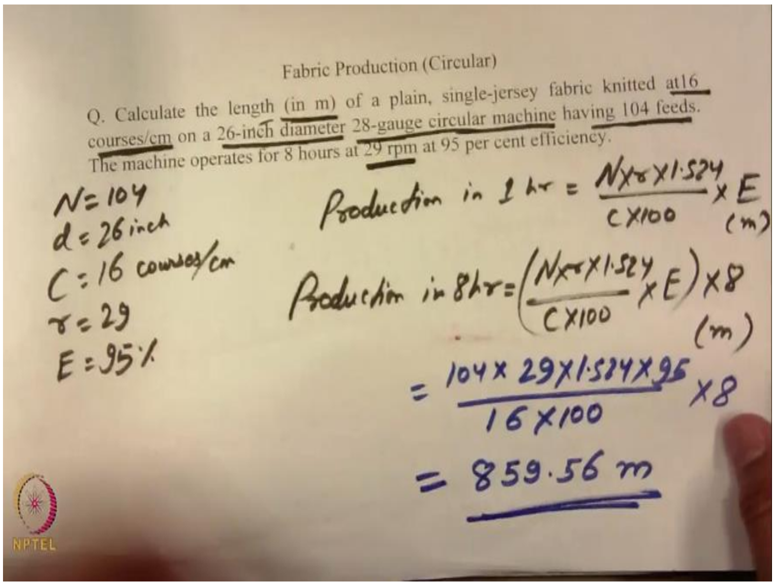

And then, we will finish it here. For example, if you see this, calculate the length in meter, of a plain single jersey fabric knitted at 16 courses per inch and 26 inch diameter, 28 gauge circular machine having 104 feeds. So, **N=104. Diameter = 26inch. C=16 courses/centimeter. Machine rpm =29. Efficiency = 95%**. These are the values given to you. You can directly use the formula.

This is the formula. So, production in 1 hour, this is the formula, this is the total **production in meter 1 hour = N*r*1.524*E/(C*100)**. Okay. So, **production in 8 hour= N*r*1.524*E*8/(C*100)**. Okay. This one in meter. So, all are in meter. So, you can simply get these values. So, N is 104; r is 29 into 1.524; E is 95; C is the your 16. If you know, C is 16 into 100 into 8. Okay.

104*29*1.524*95*8/(16*100)=859.56 meter

So, if you simply get, this will give you 859.56 meter. So, this is the. With this, you can actually find out the productivity. Since other values are also given, except yarn tex; so, if you know the yarn tex, D machine gauge and l, then you can also calculate the production in kg per hour. So, depending on the questions or depending on the requirement, you can use this useful relationship and match with the reality.

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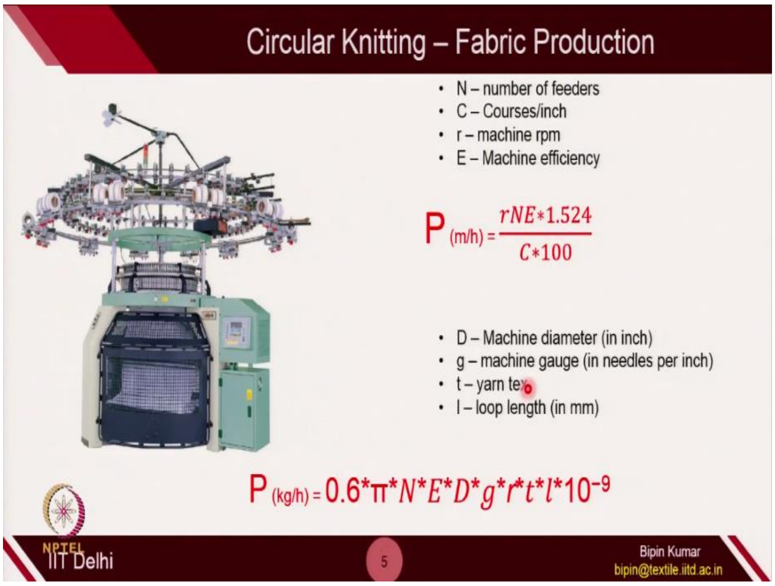

So, with this, I want to summarize this lecture. So, these 2 formula is very, very important. So, one is production in meter per hour. So, this is the key parameters from machine and the fabric. And you can find out the production in meter per hour. And also you can find the production in kg per hour. So, we have derived this. I expect you to do this derivation by yourself. You don't have to remember this formula. If you have understood the concept, you can easily find out by yourself.

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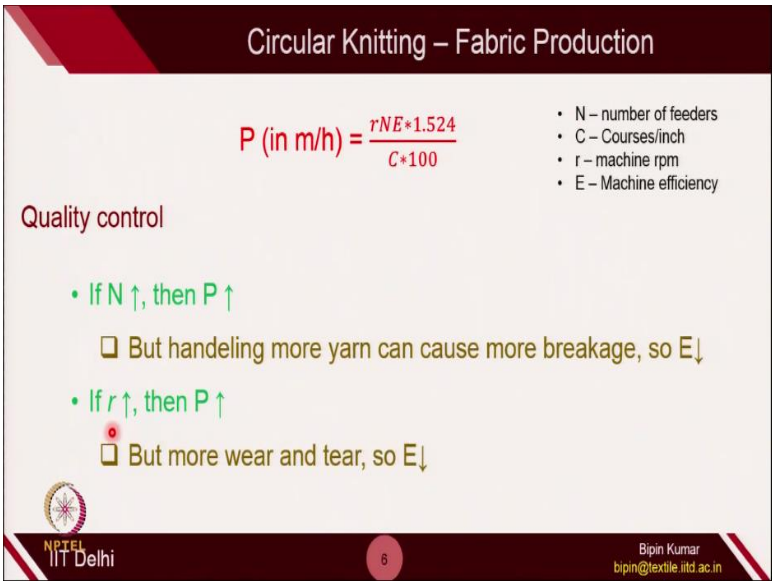

Production, somehow very, very important. Because, from the manufacturing point of view, you can anytime, you can increase the rpm. And you can also select for higher number of feeders. But, in terms of quality control there are some glitches. If you increase number of feeders, then there are obviously you are controlling more number of yarns. So, but handling more number of yarn can cause breakages.

But, so, efficiency will go down. So, the machine will be stopping very, very frequently. If you see the rpm; if you increase rpm, P will also increase, production will increase. But since if you are increasing the rpm more and more, it will be hitting the butt and the cam frequently, so, more and wear and tear of the machine. So, there may be chances of butt breakages or needle breakages.

So, E can decrease. So, you have to play with the feeders as well as rpm, so that you can run the machine smoothly. So, in reality, the highest speed which has achieved is around 2 meter per second for circular knitting machine, single feeder machine. And the average speed is around 1 to 5 meter per second. So, now you have seen how these small equations can give you so much information about machine productivity. And you can, in the assignments you can do more practice for exploring these equations. So, with this, I am ending here. Catch you in next class. Thank you very much.