Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology – Part -1

Module – 38

By
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Hello and welcome to this manufacturing process technology part one module 38.

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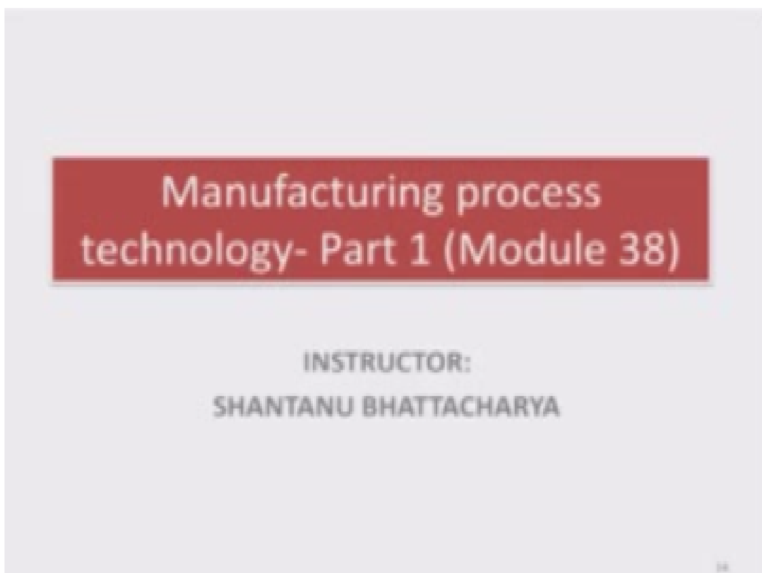

We were talking about the force circle diagram.

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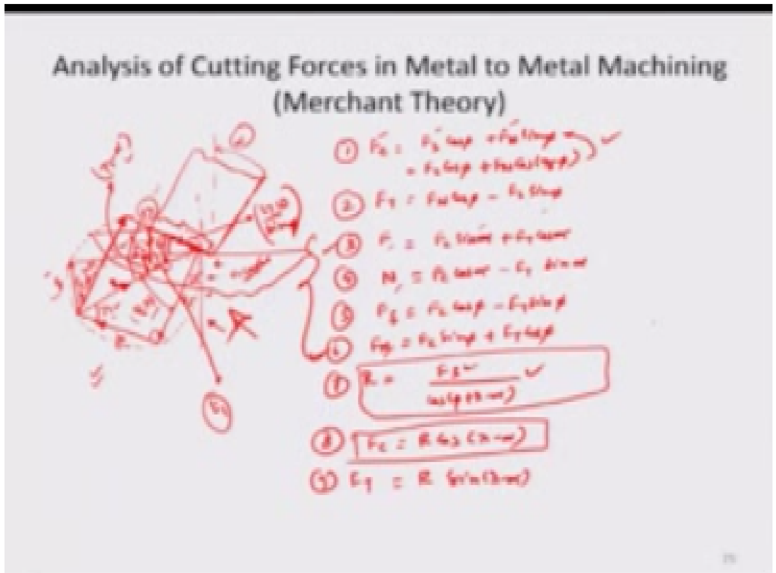

$$F_C = F_S \cos\varnothing + F_N \sin\varnothing$$
$$F_T = F_N \cos\varnothing - F_S \sin\varnothing$$
$$F = F_C\, sin\alpha + F_T\, cos\alpha$$
$$N = F_C\, cos\alpha - F_T\, sin\alpha$$
$$F_S = F_C \cos\varnothing - F_T \sin\varnothing$$
$$F_N = F_C \sin\varnothing + F_T \cos\varnothing$$
$$R = \frac{F_S}{\cos\left(\varnothing + \lambda - \alpha\right)}$$
$$F_C = R\cos\left(\lambda - \alpha\right)$$
$$F_T = R\sin\left(\lambda - \alpha\right)$$
$$\mu = \frac{F}{N} = \frac{F_C\, sin\alpha + F_T\, cos\alpha}{F_C \cos\varnothing - F_T\, sin\alpha}$$

Or the merchants circle diagram and we had drawn this particular diagram in the last module and tried to correlate the various angles and the forces which are involved in chip formation process I am going to now today write the different components of the forces and the force balance equations which would involve from this first equation I write here is that $F_C = F_S \cos\varnothing + F_N \sin\varnothing$.

Let us see in the diagram how I have formulated that, so F_S cos of φ is basically this right here and cos of φ is the component towards the F_C direction and again you know the Fn which is actually this particular force right about here has a you know same kind of a 90 - φ direction when we when we talk about the normal vector so along the F_C direction the component of F and that will work is Fn cos of (90 – φ) that is F_N sine φ.

So basically we have F_S cos φ + F_n cos of (90 – φ) which is actually written down again as F_S cos φ + F_N sine φ. So I am NOT going to get into the sort of you know how these really I mean only this one relationship from this one relationship it is clear why we are recording FC in terms of FS and F_N or how we are recording F_C in terms of F_S and F_N in terms of the angle so there are many other angular relationships available in this diagram I am simply going to write down all the force balance equations.

So the second equation then would be F_T equals $F_T = F_N \cos\varnothing - F_S \sin\varnothing$ please be very careful about the directions so just in case of F_C you had seen that the component of the force FS is in the same direction along the F_C is along is the same direction as the component of the force F_N along the F_C. So in some cases it may be opposing in nature and so you have to either you have to be very careful about this signs of the force balanced by the various components which would be indifferent dimensions directions.

We can also calculate the friction force F in terms of $F = F_C sin\alpha + F_T cos\alpha$ we can calculate the normal reaction N as $N = F_C cos\alpha - F_T sin\alpha$. we can calculate F_S as $F_S = F_C \cos\varnothing - F_T \sin\varnothing$. calculate F_N in terms of $F_N = F_C \sin\varnothing + F_T \cos\varnothing$. so on so forth

the resultant reaction R can be recorded as $R = \frac{F_S}{\cos(\varnothing + \lambda - \alpha)}$. if you can see here this right here is λ - α and you have an angle φ here + λ - α as this total angle and what you are doing is essentially you are resolving the R cos of φ + λ - α R being this particular vector.

So you are resolving this vector in this direction FS direction and that is the F_S okay, so here is where you have a relationship between R and FS we can also derive a relationship between F_C = R cos (λ – α) we can derive a relationship between F_T which is equal to $F_T = R \sin(\lambda - \alpha)$. so please look again carefully at the various angles which have been illustrated in this figure and try to figure out from 1 to 9. I have already told you about 1. I have already told you about 7 the remaining I would like you to actually figure out how these angular relationships are, so having said that the measurement.

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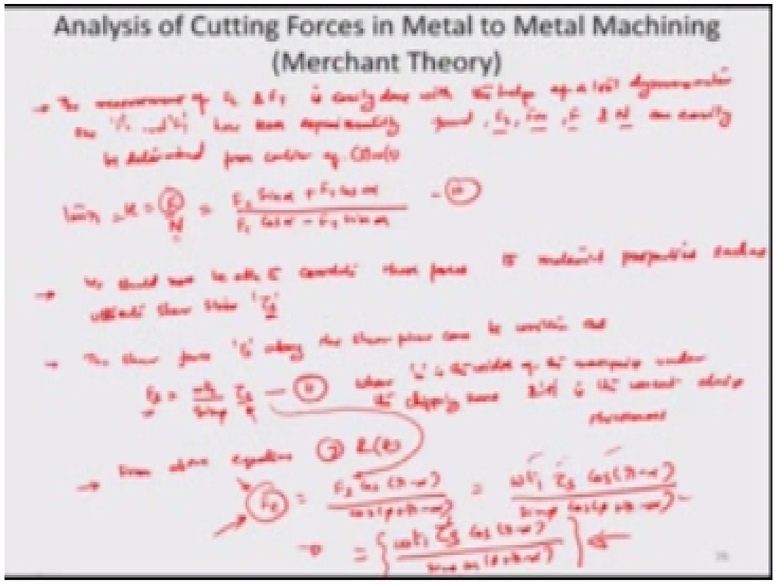

$$\mu = \frac{F}{N} = \frac{F_C sin\alpha + F_T cos\alpha}{F_C \cos\varnothing - F_T sin\alpha}$$

$$F_S = \frac{w t_1 \tau_s}{\sin\varnothing}$$

$$F_C = \frac{F_S \cos(\lambda - \alpha)}{\cos(\phi + \lambda - \alpha)}$$

$$F_C = w t_1 \tau_s \cos(\lambda - \alpha) \frac{1}{\sin\phi \cos(\phi + \lambda - \alpha)}$$

$$W = F_C v = v w t_1 \tau_s \cos(\lambda - \alpha) \frac{1}{\sin\phi \cos(\phi + \lambda - \alpha)}$$

Of F_C and F_T is easily done with the help of a tool dynamometer, so typically you can actually either embed the dynamometer onto the surface of the tool or you can just mount the tool over the dynamometer okay. So that way you can have an average data of the total amount of cutting forces and the tangential forces in the cutting zone obviously there are the small you know micro sensors or micro dynamometers which can actually be able to gauge what is the kind of distribution of the forces at the cutting zone by just embedding the system just below the rake face.

So that you can have a real measurement of the forces along the rake face, so once F_C and F_T that is the cutting force and the tangential force have been experimentally found F_S, F_N, F and N that is the shear force the normal force along the shear plane the force of friction and the normal reaction along the tool rake face can easily be determined from earlier equations 3 to 6 which is represented here you can see this equation 3 into equation 6 and so these are all the relationships between the various cutting forces and the tangential forces with respect to the angles that they formulate in the direction of the friction forced action of the normal reaction of the shear force and of the normal force along the shear plane okay.

So having said that the μ friction angle which is F by N and you can also write it by the tan λ is actually equal to the relationship between F_C sine α + F_T cosα which is actually how the F is described the friction force is described divided by F_C cos of α - F_T sine of α in the way that normal reaction along the rake faces define the tool. So let us call this equation 10. and basically the idea is that if we want to really estimate everything in terms of cutting power I should be able to also involve a material property aspect here.

$$\mu = \frac{F}{N} = \frac{F_C sin\alpha + F_T cos\alpha}{F_C \cos\varnothing - F_T sin\alpha}$$

Because obviously the material is now taken to the yield stress value for it to start you know the flow of the material okay. So therefore we have to see what is the ultimate yield strength of the material is somehow plug that is a material property into this whole modeling so that I can get the power consumption of the cutting as an estimate of the various material you know components which are there or material properties which are there of the work piece or the tool and also as a function of the various geometries like the uncut thickness, the cut thickness which defines the shear plane angle and the rake angle of the tool which are thereby important for all the machining processes.

So we should now be able to correlate these forces to material properties such as ultimate shear stress call this tau s. obviously once this value is reached the chipping information or chipping process will start to happen and the chip will start to plastically or to separate from the work piece the shear force FS along the shear plane can be written as the amount of area of the cutting zone which is actually the width of the work piece times of the uncut chip thickness t1 . let us look back and see what we mean by that so there is a shear plane formulated in this particular direction and we are having a uncut chip thickness which is round about this thickness right here.

So this is t_1 that is this point how much away it is from the zone of machining on the vertical axis so obviously the total area that this particular plane would have multiplied by the ultimate yield shear stress would actually define the amount of shear force that is necessary to separate the chip from the work piece material, so the component of this t_1 here this particular thing here along the shear plane okay.

It is basically t_1/ sine φ so this is t_1 / sine φ and if I assume the width of the cutting zone of this particular zone as coming out of the page or going into the page as W so this is the total area that this particular face would have. So t_1 sine φ *w by sine Φ is the total area that this face would have and we will be left with the total shear force necessary W*t_1 / sine φ that is the area of the shear plane times of the ultimate shear yield stress of the material which is a property of the material and it defines the extent of cutting forces that has to be applied for the material to start machining off or peeling off from that area.

$$F_S = \frac{w t_1 \tau_s}{\sin \varnothing}$$

So this is how you define the total shear force okay, so I will just mention this that here the W is the width of the work piece under the chipping zone you can say and t_1 is the uncut chip thickness. So from earlier equations 7 and 8 as you can see right here 7 was related to how the resultant varies with respect to shear force and 8 was how the cutting force varies with respect to the resultant we can write the total amount of cutting force F_C as F_S cos (λ – α) / cos (λ + φ - α).

$$F_C = \frac{F_S \cos(\lambda - \alpha)}{\cos(\phi + \lambda - \alpha)}$$

So obviously you have to put the value of R here, so F_C becomes equal to F_S times of cos λ – α / this whole term cos φ + λ – α, so once this F_S is now defined by the earlier process here with the material property and the geometry I just plug this value here so that it's completely independent of the forces. So let us see how F_C then varies as, so we have W* t_1*τ_s times of cos λ – α / sine of φ times of sine cos of φ + λ – α or in other words I can write the F_C it is completely independent of all the other forces and only related to the material properties as W* t_1*τ_s *cos of λ - α and this term right here can be written as sine φ cos of φ + λ – α.

$$F_C = w t_1 \tau_s \cos(\lambda - \alpha) \frac{1}{\sin\phi \cos(\phi + \lambda - \alpha)}$$

$$W = F_C v = v w t_1 \tau_s \cos(\lambda - \alpha) \frac{1}{\sin\phi \cos(\phi + \lambda - \alpha)}$$

So we will now perform an optimization here because obviously the power that is consumed is also the force velocity product and the cutting force that the tool is applying on the work piece or the work piece is applying back on the tool is given by this F_C which is now related to all the material properties and geometry properties. So we are going to now do some kind of an optimization in the next module where we will talk about how power consumption minimum criteria could actually result in the relationship of the various geometries that we have considered corresponding to which you feel operating power would be optimum. So with this I would like to end on this particular module and in the next module we will do this optimization of power of cutting, thank you so much.

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