Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology- Part- 1

Module-37

By
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Hello and welcome to this manufacturing process technology part-1 module 37

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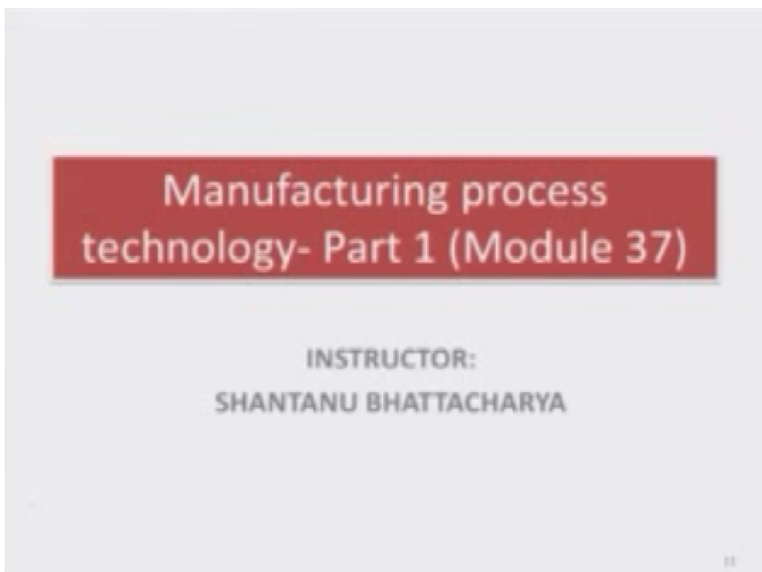

A brief recap of what we did in the last lecture we were talking about the different geometrical aspects of machining particularly in the machining zone where you could actually correlate between the uncut chip thickness and chip thickness with respect to the various angles that were formulated particularly the shear plane angle the friction angle the rake angle of the tool that the tool makes with the vertical etcetera.

Today we are going to look at again the force analysis aspect and for that we had just started covering the dynamics of the chip formation process particularly as the chip sort of comes out of the material and separates from the primary work piece material it is treated as a rigid body and there are a lot of forces acting over it particularly from the rake face of the tool or from the shear plane or from let us say the tool to the work piece and all these kind of balance together as a common resultant. So I am just going to recap that portion before starting again.

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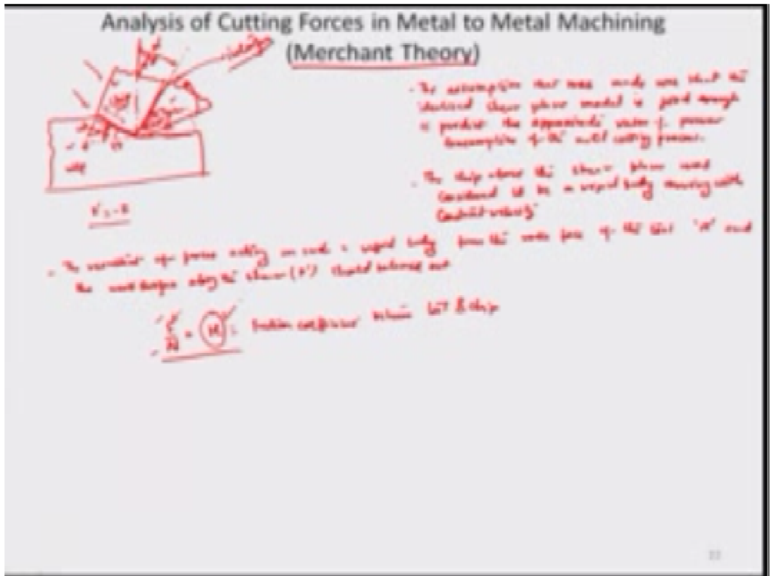

So the assumptions that we may have been brought forward as I earlier mentioned by theory proposed by Ernst and Merchants and the assumption that was made was that idealize the shear plane model is good enough to predict the approximate value of power consumption of the metal cutting process or the metal chipping process whatever you may called it as and the assumptions also were that the chip above the shear plane was considered to be a rigid body moving with constant velocity and in this respect.

We had actually drawn a diagram which talks about the chip formulation process. let us say this is the cutting area the cutting zone and there is a chipping action which happens over this particular plane let us say this particular plane is formulating or is responsible for formulating the chip or this is the shear plane this is the chip the work piece and the tool makes an angle α with respect to the vertical axis here and which is also known as the rake angle which is going to separately show the tool face.

Just in case you know although they are sort of meeting with respect to the chip but we are showing it separately because of for the sake of convenience of the force analysis that would be projecting so this angle right here that the tool face makes with respect to the vertical is the angle α and we also know that this plane angle here right here is Φ and basically if we consider the chip to be a rigid body meaning thereby that two different points on this body will not have a positional variation with respect to each other as a function of time.

So it should not do any deformation etcetera so chip should be in force equilibrium conditions and for that the resultant of the forces acting on such a rigid body and let us just write this down here that the resultant of forces acting on such a rigid body from the rake face of the tool and the work surface along the shear plane should balance out so I call this R' for example should balance out so only if there is a force balance it can be treated as a rigid body.

And basically we are also talking about a constant velocity case that means the chip velocity here V is treated to be in variable with time so there should not be any acceleration component involved and the forces should be in just in equilibrium with respect to each other also we assume the cut velocity in this case to be constant so therefore the force that the tool applies on the work piece and that whatever the work piece applies back as a resultant they should also be equal and opposite to each other.

So these are some of the presumptions which are made in order to analyze the Merchant's circle or the force circle that comes in this three components that is the chip the work piece and the tool so the total of the forces acting on the chip by the tool is basically also a function of the normal reaction that the chip would have by virtue of its curl by virtue of its pressure that it imposes on the top of the tool surface and the frictional force which happens because the chip is moving in a certain direction.

Let us say the chip is moving out in this direction V and so therefore there has to be an opposite frictional force F which acts on this particular chip opposite to the direction of its motion over the rake face okay so informal force N which is because the chip has applied certain pressure on the top of the rake face obviously you are trying to scribe it out meaning there by that you are trying to take it to a position along the shear plane.

So that earlier whatever component it had is now deformed and because of the deformation process so there is a resultant force which acts because of both these forces and this can be treated as the resultant force R because of the friction that the friction and the normal reaction provided by the tool face on the chip surface the other hand on the contrary you have a resisting force opposite to the again the shear direction of the chip so the shear is along this plane particularly.

So obviously the resistance that would come to the work piece R or the resistance that would come as a result you know the resistance force from the work piece to the chip that would come as a result of the chip fragmenting from the work piece will have FS shear force in the direction of the shear plane and also it will have a normal force FN which is actually opposing the force that the chip is facing on its mating face with the tool surface.

So there is a normal reaction and there is again a shear force and the resultant of these two I consider to be R' where R' can be said equivalent to be -R that means it is equal and opposite to the resultant reaction of the chip by the tool face so the chip being a rigid body now you have these two kind of forces one generating from the shear plane right about here and one generating from the tool face right about here.

And it is a constant velocity situation there is no accelerated component which is there so we can consider the summation of all these forces to be equal and opposite to each other and the chip exists as a rigid body we are not assuming deformation in this particular case because at least you know just after the formation process or after the chip has started to peel off that is the case that we are evaluating obviously there would be deformation because the chip was earlier the work piece which was extended by this dotted line here.
Which is actually rotated in this direction to formulate what you call this chip but we are not talking about that instance we are talking about an instance when this formulation has taken place already and the chip has started to formulate and come out and there we are trying to do the rigid body assumption okay so in that even the R'and R are equal and opposite to each other and the total force F and N which is acting as a result of the frictional and the normal reaction on the chip from the tool surface.

They can also be correlated by putting coefficient of friction μ between the tool chip interface as a ratio between both the forces μ is the friction coefficient between tool and ship and again we are just assuming a average friction coefficient and an average friction force obviously the force distribution would vary quite a bit at this interface because the chip may not be curling equally on the top or the chip may not be putting equal pressure on the top of the tool face.

Obviously the pressure would be more towards the cutting zone and lesser so there is a distribution lesser in the outward zone so there is a distribution and basically the idea that we are having here is that we report an average value of this frictional force and therefore this coefficient here is an average friction coefficient between the tool and chip surface so having said that now we want to sort of do a force balance between whatever forces we have now outlined and for doing that we would like to again draw this or redraw this diagram of the force various forces which are acting on the surface of the work piece and the chip.

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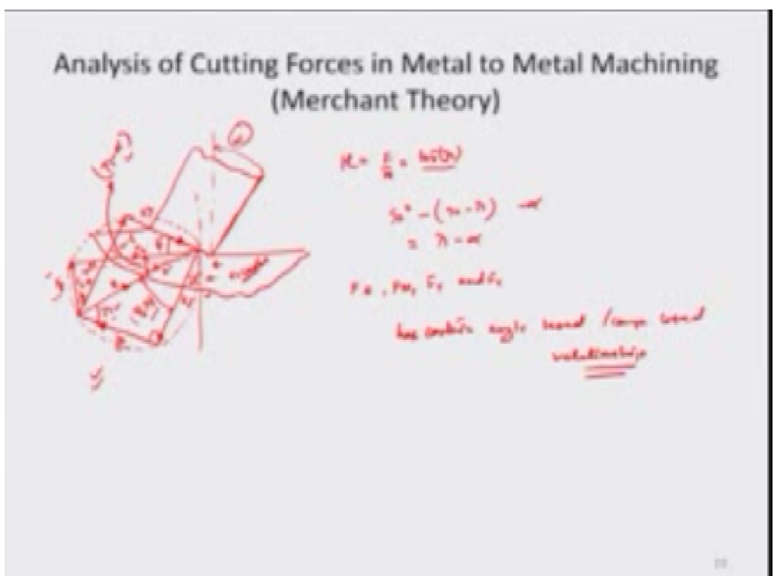

Let us say this is the chip being formulated and the shear plane is represented here we have remaining portion of the work piece and let us say this is all connected so this is the same work piece that we are talking about and here we have the tool so obviously if we look at the tool angle so the tool angle is between this vertical line and the tool face right about here I would call this alpha rake angle and what we want to do is to just slightly offset the point of intersection to the point where there action would obviously come.

So I am going to have a parallel axis just off shifted a little bit just to address conveniences and then again another plane and across this we would like to find out what goes on in terms of all the forces so you have a shear force component between this and this okay so this is FS we can write this FS here maybe I will just make the FS magnitude a little bigger all the way up to here so this is FS and similarly we also have a normal reaction component which is going somewhere here so we call this FN.

Let me just clear this a little more so that it is convenient to understand so here we just extending this component all the way here the angle here should be 90 º . I am just going to make this a little look like orthogonal to each other so this right here is FN and there is because of these two forces resultant reaction which would be applied to this particular point right about here and this we consider to be the reaction R similarly we have a component of the friction which is parallel to the rake face.

So this component of friction is in this direction parallel to the rake face we call this force F frictional force and we again have another component which is just perpendicular to the rake face of the tool and we call this the normal reaction N just for sake of convenience I am going to just shift this term FN to its vector component here okay so this is FN so this is kind of the force diagram which gets generated because of the two resultant being equal and opposite to one another.

So having said that now so obviously the R' was talking about would come in some direction here which is exactly opposite to the direction of the R which is result of the summation of you know the forces of friction and the normal reaction of the tool face so by the by this particular angle then would be equal to α obviously because it is the same as this particular tool angle the tool angle alpha that has been represented earlier.

And I would again like to just mention here that the velocity of motion of the point of engagement of the tool which is again opposite to the velocity of the work piece with respect to the tool the feed velocity that velocity also being constant we can say that the forces that the work piece exerts on the tool should be equal and opposite to the forces that the tool exerts on the work piece.

So that the accelerative component is zero now and there is a constant velocity case this point and up moves forward at V feed velocity equal to constant and so here in that event what I would assume is that the total forces that are given by the cutting zone on to the tool are one in the perpendicular direction and another in the direction parallel to the coordinate axis system that has been shown here.

So one is obviously in this direction right about here okay and I call this the cutting force FC which the tool exerts on the work piece or the work piece gives back as a reaction to the tool surface and this can actually be measured by putting a small dynamometer on the top of the tool surface and then there is another force right about here which is actually called the tangential force we call it F tangential okay.

Which is perpendicular to the direction of the tool movement okay and it comes by virtue of the fact that the tool actually is grazing and pushing into the work piece surface and this resultant should also be the same R and R' so that there is equilibrium and this V can be considered to be constant so having said that now so obviously at a constant feed velocity you would ensure that you provide a force equal to this F_T and F_C so that this tip moves at a constant velocity with respect to the surface but in any event the reaction force that comes out should be balanced.

So that this reaction force is in a way able to have a situation where the point of engagement moves at a constant velocity so this is actually overall the force diagram I can actually draw a circle around this force diagram and such a circle drawn is also known as the Merchant's circle and this force diagram under this circle is called the Merchant.s circle diagram so having said that let us now figure out some of the angles the angle between the shear plane.

And the horizontal here happens to be Φ and the angle which is actually between the frictional force and the normal reaction mind you μ is actually F/N which is also equal to the friction angle the tan of the friction angle tan λ it can be represented here so λ is this particular angle between F and N, $F/N = \tan \lambda$ and having said that we have this angle right about here which we find out as $\pi/2 - \lambda$ because obviously the you know the total sum of the total angles here.

In this particular triangle where you know which comprises of the friction force F and N and the resultant reaction are basically is 180 and this angle being λ obviously makes this other angle 90-λ and so basically the total angle this right here can be represented at 90º- (90 – λ)- α which is actually represented again as λ -α so this angle right here can be represented by λ- α and you have Φ , you have λ-α you have α you have λ all these different angles.

Now defined obviously if this is Φ then this should be 90 – Φ and same this should be 90 - Φ so this angle must be Φ then okay so you have more or less all the angles defined now and having said that now the force vectors F_S, F_N, F_T and F_C has certain angle based component based relationship and what I am now going to do is to sort of put together what are the different kind of relationships which exist in this kind of a case so this we will actually continue in the next module in the interest of time I am going to close on this module thank you very much you.

<u>Acknowledgement</u>

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