Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology – Part – 1

Module – 36

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Hello and welcome to this manufacturing processes technology-part I (Module 36).

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In the last module we had looked at some of the geometrical relationships which are available between the various dimensions like the uncut and cut chip thickness on the angles and tool formulates with respect to the work piece as well as to the vertical plane. Now we are going to look into the force analysis aspect and this actually comes from a theory which is also popularly known as Merchant theory.

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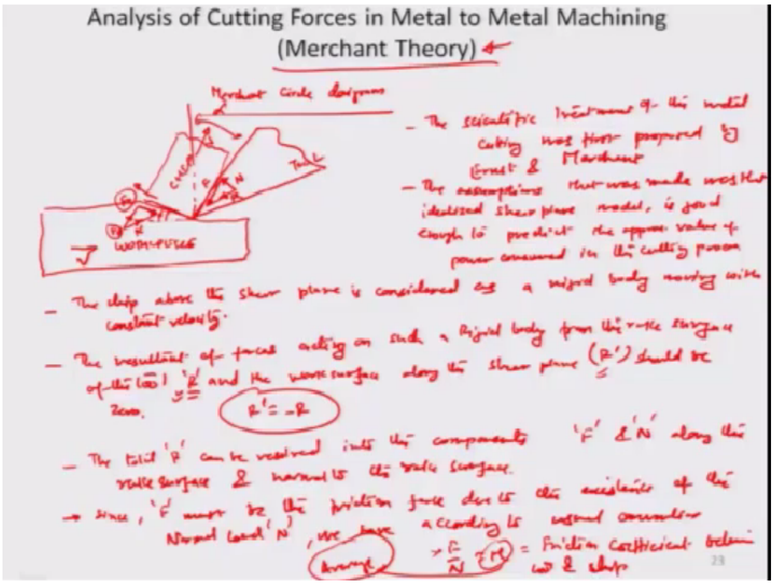

Where it talks about a sort of universal diagram which associates all the forces with various angles in the other geometrical parameters that we have seen in that cutting zone be a turning beet, drilling any other machining metal to metal operation would definitely in necessitate to involve such a cutting force and symbol, so that the equilibrium conditions could be obtained and then you know you should treat that chip as a rigid body than there can be some supposition which comes in if you do not treat it as a rigid body, it makes it slightly change because of that.

So this all comes into one account called earns ton Merchant theory and I would like to start this with looking at the Merchant circle diagram. So far understanding this diagram let us actually see part by part what goes into this, so the scientific treatment of the metal cutting was first proposed by Ernst and Merchant. The exemption that was made was that idealized shear plane model is good enough to predict, the approximate value of the power consumption of the cutting power.

So approximate value of power consumed in the cutting process and so let us now look at how the chipping process as happening here let us say this is the work piece that we considering and there is some kind of a chip formulation which takes place somewhere here you know this chip actually comes out from this particular plane and you have the chip travelling in this particular direction, so this is actually the chip.

The work piece from which the chipping process as happened. So you also have the tool component here which is actually had an angle α the rake angle with respect to the chips surface, so this is the tool component which is there this angle being the rake angle α and we have the various issues related to what are the forces total amount of forces in the cutting tool or what are the total amount of forces in the chip which would and also on the work piece which would be in equilibrium with each other given the dynamic condition that the work pieces moving against the tool at relative velocity of V with respected to the tool.

So let us see what are the assumptions involved in modelling this for the chip above the shear plane, this being the shear plane you well aware of the plane along which the chip gets basically sheared off from the surface of the metal of the chips above the shear plane is considered as a rigid body moving with constant velocity. The resultant force acting on such a rigid body from the rake surface of the tool the resultant force on the rake surfaces 'R' let us say there is a perpendicular force that is given by the tool surface to move the chip away from it is rake surface and then there is frictional force which is going to come against to the direction of movement of the chip.

So either chip actually moves forward with the velocity we here the frictional force will exactly come in the opposite direction as illustrated by this arrow right here and the resultant component of this force is actually obtained by something of summation of these two forces one of them we call the normal reaction of the tool face, another we call the frictional force F of the chip on the tool as it moves along the rake face, and so the resultant component is R and then simultaneously component should also we generated by the work piece, because obviously when the chip is moving against to the work piece is going to have a shear force which is going to be in the direction opposite to the chipping action.

So the chipping action is happening in this direction, so obviously there is going to be shear force in this particular direction opposite to the direction of the chipping action and then there is going to also be a normal force which the work piece would provide to the owing to the ploughing motion of the tool with respect to the work piece and this two forces together generate a resultant component R dash and the presumption here is that the total amount of forces on the chips or chip is always assumed as a rigid body in this particular theory and Ernst and Merchant theory and in the rigid body as you know the lots of physical and it is no deformable.

So it is solid body where distance between two points as a function of time remains fixed actually, so in this particular case also the total amount of forces are which are result of the forces from the tool to the chip on one side and the total amount of forces because of the work piece on to the chip on the other side. They should have a resultant of a zero and what it means is that R and R' are really equal and opposite to each other and R' = –R for that rigid body condition to be valid. Otherwise the chip will deform the distances between it will change; it will not be treated as a solid body anymore.

So the total R can be resolved into the components F and N along the rake surface and normal to the rake surfaces as such, since F must be the friction force due to the existence of the normal load N and we have according to usual conventions F /N = μ i.e. friction coefficient between tool & chip. This μ is actually more like an average μ which is based on the fact that the average frictional force coming in the chip, as a result of the normal reaction.

However if you would like to look at the sectional profile of the way that the chip curls around. The chip actually as varied distribution of the normal loads on the contact that it has chip comes off from the tool rake surface like this, so obviously that would be some point which will be more loaded in comparison to the other and if you consider that distribution than you will have a real friction from area to area of the chip tool interface, but in this particular case, we have consider only an averaging effect and an averaging friction force in the Ernst and Merchant theory as assumed in the earns ton merchant theory in this chipping case.

So having set that now I can actually utilize this Merchant theory to the lay out all the forces together in a circular manner in a circle diagram which are also known as a Merchant circle diagram let us see how.

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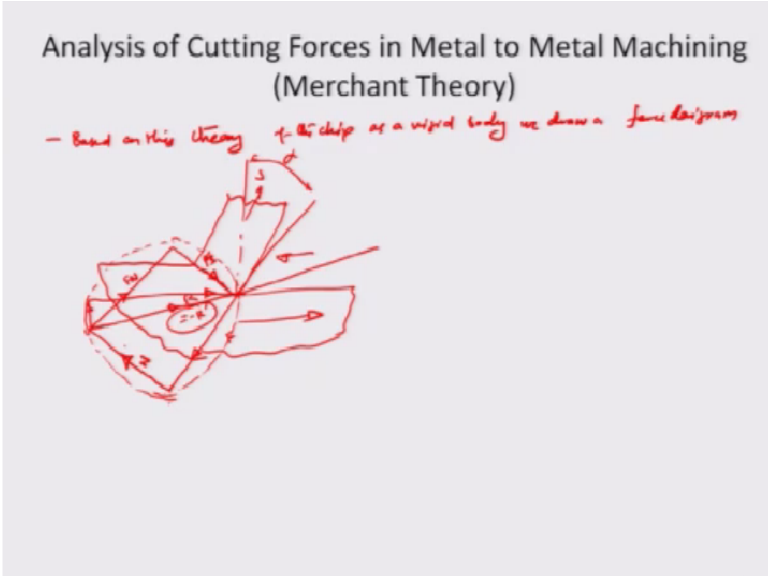

So based on this theory of the chip as a rigid body we draw a force diagram. here we have a section of the part as the normal work piece. There is a chipping action happening, because of which there is a shear plane is formulated with respect a tool which as present right about here and you can say that you know this is how the work piece actually would look like this is the direction of the chip velocity. This is the rake angle, that the rake face would make with respect to the vertical and we have the shear force component if you draw on the shear plane, this is the shear force component.

Let us call it FS given by the work piece on to the chip, similarly we have another component which is the normal force component we call this FN which is given by the again the work piece on to the chip, let us draw it little properly which appears to be like exactly like perpendicular. Something like this, so we call this component FN. So I already explain to you what this mean and the resultant of this two would actually be a normal reaction in some direction let us say this is the direction of the total resultant reaction force.

I am sorry not the normal reaction but resultant reaction force and the similarly we have now the similar kind of situation because of the frictional force and the normal force, so we would like to draw the frictional force parallel to the chip surface, the tool surface and opposite to the direction of the velocity of the chip. So this we call the frictional force F and we also draw a normal force which would actually mean to generate a resultant that is equal and opposite to the direction of the resultant that we have just generated because of the shear force and the normal force.

So we obtain this right here as the direction of the normal force and that would result in a resultant R dash which is actually exactly hole an opposite to the direction of the resultant R and further there would be a situation where we have a cutting force which of the tool gives on to the work piece, so this is although not on the chip, but again there is a chipping process which is happening of the chip from the work piece.

So whatever forces are there on the work piece in a way before the chipping has completely happen would also influence the process and so therefore these forces are also of at most considerations so obviously the amount of force that the tool would give to the work piece would be recorded as a cutting force, so I would like to call this force to be in a direction opposite to the direction of ploughing of tools.

So let us say the work piece goes in this direction of the tool travels in this direction. This force cutting force should be exactly opposite to the directions of traverse of the tool. And then we have another tangential force that the work piece would offer, because of the cutting process. You already saw that in case of milling where each component would be offering a force in the perpendicular directions.

So all these forces together would result in a common resultant R and I can actually make these forces over the diameter R meaning there by the draw a circle, it would be able to connect all these forces together and these therefore becomes the common diameter R you know which all these forces are connected. So that is why we call it Merchant circle diagram.

Obviously this angle that the shear plane makes with respect to the direction of velocity of the tool with respect to the work pieces Φ and so we have a verity of different other angles which are there in this the diagram that we have finally obtained. I am going to now discontinue this part here because the module is going to be over now in the interest of time, but what I am actually now going to do is to sort of take this circle and take the various other angles like for example the friction angle or for example the rake angle and the shear angle and then correlate all this different forces that we have put together is a single circle.

So that there is relationship between the various forces which come off and from there we can see if we can do some energy minimization in terms of cutting power minimization, etc., through which we can arrive at an optimum situation of the cutting. So having set that I would like to close this module here and looking forward to talk to the next module. Thank you so much.

<u>Acknowledgement</u>

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