Experiment No. 1b

Analysis of Chip formation in orthogonal cutting

THEORY:

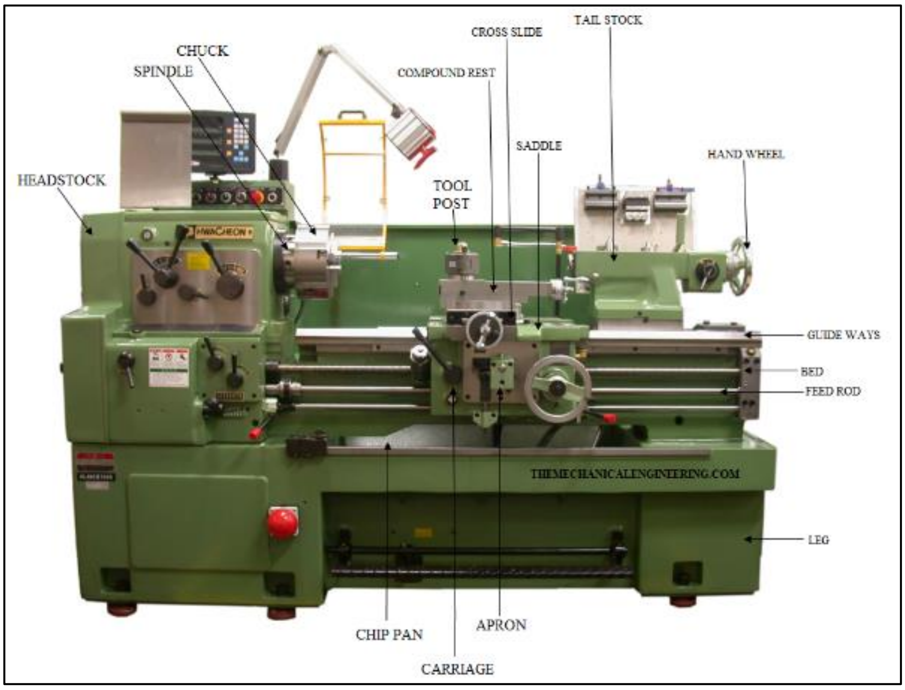

Figure 1: Lathe machine

Orthogonal cutting is a machining process used in metalworking and other industries to remove material from a workpiece using a cutting tool. In orthogonal cutting, the cutting edge of the tool is perpendicular (or nearly perpendicular) to the direction of the tool's travel and the motion of the workpiece. This results in a shearing action that removes material in the form of chips.

Here's a step-by-step description of the process:

1. **Setup:** Imagine a lathe or a milling machine setup where a workpiece is clamped securely, and a cutting tool is positioned to engage with the workpiece.

2. **Cutting Action:** In orthogonal cutting, the cutting edge of the tool is oriented at a right angle to the workpiece's surface. As the tool moves along the workpiece, it generates a shearing force that causes the material to deform and eventually separate in the form of chips.

3. **Shear Plane:** The shearing action occurs along a specific plane within the workpiece called the shear plane. This plane is where the separation of material takes place due to the shearing forces applied by the cutting tool.

4. **Chip Formation:** The material that is removed from the workpiece forms chips. These chips can vary in shape and size depending on factors such as cutting speed, feed rate, and tool geometry.

5. **Cutting Forces:** In orthogonal cutting, there are mainly two cutting forces: cutting force (Fc) and thrust force (Ft). Cutting force is directed along the cutting edge and is responsible for the

actual material removal. Thrust force is directed perpendicular to the cutting edge and helps advance the tool along the workpiece.

6. **Merchant's Circle**, is a graphical method used in metal cutting analysis to understand the forces involved in the cutting process. It is based on the assumption of orthogonal cutting, where the cutting tool's edge is perpendicular to the workpiece's surface. This simplifies the analysis and helps to visualize the forces and chip formation more easily.

Here are the key parameters and concepts associated with the Merchant circle:

Chip Thickness Ratio (r): The chip thickness ratio is the ratio of the chip thickness (t) to the uncut chip thickness (t0). It is represented as r = t / t0. This parameter gives an indication of the deformation that the material undergoes during cutting.

Cutting Forces: In orthogonal cutting, there are three main cutting forces:

Cutting Force (Fc): This force is applied along the direction of the cutting edge and is responsible for the actual material removal. It is the force required to shear the material.

Thrust Force (Ft): This force is applied perpendicular to the cutting edge and is responsible for advancing the tool along the workpiece.

The cutting force (Fc) vector is plotted along the horizontal axis.

The thrust force (Ft) vector is plotted along the vertical axis.

Resultant force (Fres): It is the vector sum of the cutting force (Fc) and the feed force (Ff). The magnitude and direction of the resultant force can be found by constructing a closed triangle with these vectors.

Chip Thickness Variation: The Merchant circle diagram also helps to visualize how the chip thickness ratio (r) varies along the cutting edge. As the tool progresses along the workpiece, the chip thickness changes, affecting the deformation and cutting forces.

In the Merchant circle diagram, various scenarios can be analysed based on the relationships between the cutting forces, feed forces, and chip thickness ratios. These relationships are essential for optimizing cutting parameters, tool geometry, and material selection to achieve efficient and effective machining operations.

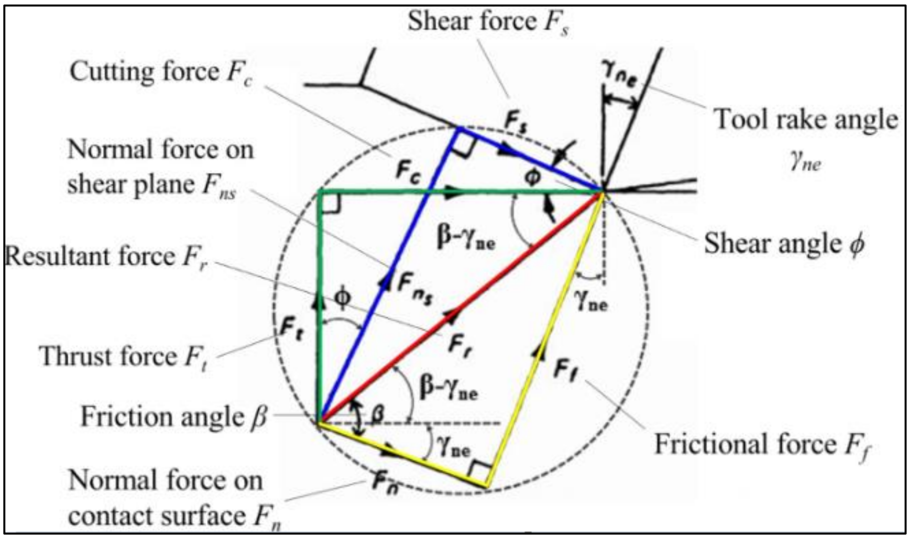

Figure 2: Merchant Circle diagram

Orthogonal Cutting	**Oblique Cutting**
The inclination of the cutting edge of the tool is perpendicular to the cutting tool velocity or cutting speed.	In oblique cutting, it is inclined at an acute angle with the normal to the cutting velocity vector (direction of the tool travel).
The chip flows over the surface of the cutting tool in orthogonal cutting and the chip movement is normal to the cutting edge.	The chip flows on the surface of the cutting tool at an angle (chip flow angle) with normal to the cutting edge.
In orthogonal cutting, the chip coils in a tight flat spiral.	In oblique cutting, the chip flows sideways in a long curl.
The thickness of the chip may be slightly increased in the middle.	Whereas in oblique cutting, it may not occur.
In orthogonal cutting, only two force components (Cutting force and thrust force) acts on the cutting tool.	There are three force components (such as Cutting force, thrust force, and Radial force) acting on the cutting tool, and they are mutually perpendicular to each other in oblique cutting
Tool contacts the chip only on the rake face in orthogonal cutting.	At sometimes, multiple cutting edges may be in contact to chip in oblique cutting.
In orthogonal cutting, tool life will be less.	Tool life will be more while comparing orthogonal cutting.
It is easy to analyse.	It is complex to analyse.
The surface finish is not as good as oblique cutting.	Better surface finishes while comparing orthogonal cutting.

AIM:

To evaluate shear angle and friction angle and analyse the cutting forces in orthogonal cutting.

PROCEDURE:

1) Perform orthogonal cutting on a lathe using a single point tool of known rake angle (10°) at 3 levels of speed and 3 levels of feed rate.
2) Measure thickness (minimum 10 data points) of chip and estimate shear angle and friction angle for all the process parameters.
3) Evaluating cutting and feed components of machining forces from material properties.

RESULTS:

1) Tabulate the dimensional measurements of the chip.
2) Use the shear angle relation, $\tan\Phi = (r\cos\alpha/1 - r\sin\alpha)$ and Merchant's 1st solution, $\Phi = 45° + \alpha/2 - \beta/2$ to evaluate shear angle and friction angle.
3) Evaluate the force components using Merchant's circle (See Fig. 1) and material properties (given shear strength of the work piece which is Al alloy = 200 MPa).
4) Plot the variation of shear angle, cutting ratio (from chip thickness measurement) and friction angle (from cutting force measurement) as a function of processing parameters (feed rate and speed).
5) Draw the Merchant's circle of forces.
6) Write down your conclusions on the results.