CHAPTER 3- MECHANICS OF GRINDING

LEARNING OBJECTIVES

- To derive an expression for uncut chip thickness in Surface grinding
- To derive an expression for uncut chip thickness in cylindrical grinding
- To understand mechanics of wheel wear
- Power required for Grinding
- Specific energy for Grinding

Uncut chip thickness in Surface grinding

We will derive the expression for uncut chip thickness in class
Uncut chip thickness in cylindrical grinding

We will derive the expression for uncut chip thickness in class
Mechanics of Wheel Wear

The wear of a grinding wheel measured as a change in its diameter follows a curve similar to that of an edged cutting tool. It has three zones,

- Initial rapid wear zone
- Zone of constant wear with time or with metal removal rate
- Rapid wheel wear zone

This is illustrated in the Figure 3. It is all the beginning of the third zone we say that the life of wheel is over and needs redressing. By life of the grinding wheel we mean the grinding time between two consecutive redressing. Generally wear performance of wheel is specified by grinding ratio $G$ which is defined as

$$G = \frac{\text{Amount of metal removed}}{\text{amount of wheel wear}}$$

In the above equation, the metal removed and the wheel wear is up to the beginning of the third zone of wear. The grinding ratio can also be approximated by the increase of slope of the second portion of wear curve. This definition is particularly helpful where the grinding forms a substantial portion of manufacturing process. The investigations about the grinding ratio for various material and types of wheels have been too meager if we consider the variables in grinding process such as abrasive, size, bond, structure,
etc. Besides there are large varieties of material that are ground. This shows the enormous magnitude of the wear testing problem in grinding.

Therefore, to avoid the trouble of testing each and every wheel, we must investigate the basic nature of wear or the mechanics of wear. Until now it has been recognized that grinding wheel wear is generally of three types.

- Attritious wear of abrasive grains
- Grain fracture
- Bond fracture

The attritious wear is similar to flank wear on the edged tool. (Figure 4) Its effect on other cutting parameters is also similar, i.e. more by wear, larger are the grinding forces. Attritious wear is measured by projecting the wheel surface on a screen and note the flat areas on the grains. The unit of the measure of attritious wheel wear is the ratio of total flat areas on the grains to the total wheel area taking part in grinding. The greater the wear flat area, the higher are the grinding force. But after a particular value of wear flat area, the rate of increase in grinding forces suddenly increases as shown in Figure 5. Both the horizontal and vertical components of grinding force increase linearly with increase in wear flat area. This suggests that the contact flat of abrasive grains with the ground surface is elastic.

![Figure 4: Attritious wear in Grinding](image)
The grinding forces are in fact a combination of the cutting forces and the frictional forces due to rubbing of the grain wear flats. At zero wear the flat area, the grinding force is almost entirely due to the cutting action of the abrasive grains.

**Attritious wear accounts for only 4% of the total wheel wear.** The bulk of wheel wear is due to the bond fracture and grain fracture. The results of work of Malkin et al, show that **grain fracture is about 15% of the total wheel wear.** Distinction or separate measurement of two types of wear i.e. grain fracture at the bond fracture, is still an unsolved problem, though some attempts have been made.

One of methods consisting of collecting the wear particles during grinding and separating out the chips by dissolving them in acid and determining the size distribution of remaining particles. It has been noticed that distribution of grain size in the wheel is not very different from that of wear particle size. This is particularly true for soft wheels wherein the maximum wear is due to bond fracture. Even in precision grinding, the size distribution of wear particles has been found similar to that in wheel, thus confirming that grain fracture constitutes only a small fraction of the wheel wear.

The main reason for abnormality high wear rate of grinding wheel as compared to edged tools (the ratio is about million times) is due to weaker bond of the wheel.

Test on single grain cutting (i.e. by fixing a single grain on the surface of the disc wheel) have shown some startling results. A single grain of aluminum oxide has the capability to cut about 15000 times its own volume and with a diamond grain it is much higher, However the grinding ratios are less by about 100 to 200 times or even more. There are two reasons for this

- The bond of the wheel is quite weak
- Forces coming on individual grains during usual grinding are rather excessive.

This leads to rapid fracture of the abrasive grains and development of wear flat areas. If some how the fracture of the abrasive grain can be minimized, the life of grinding wheel between dressings can be greatly increased. The controlled force grinding tests and the high speed grinding of metals have shown beyond doubt that much higher grinding ratios are achievable. At higher speeds, the normal force between the wheel and surface decreases, thus diminishing the probability of fracture of grains. Research in high speed grinding has shown that grinding ration as high as 4000 are achievable. However, at such high speeds, there arise problems of high rotational stresses in grinding wheels. Only specially designed wheels should be used for high speed grinding for reasons of safety.
Power required for Grinding

During the grinding size of the chip removed depends on the grit size used in grinding wheel. A fine grit should be used for finishing operations as it will remove finer chips and leave a smoother surface finish.

Power required for grinding
= Tangential force upon wheels x wheel speed (watts)

Power required per mm$^3$ of metal removed per second
= P/MRR

Where MRR = metal removal rate = depth of cut x width of cut x work table speed.

Mathematically,
Specific Energy for Grinding

The energy per unit volume of metal removed or specific energy for surface or internal or external grinding is given by the following relation

\[
\text{Specific energy} = \frac{\text{Power required per mm}^3 \text{ of MRR} \times \text{Surface speed of G wheel}}{\text{Table speed} \times \text{width of cut} \times \text{wheel depth of cut}}.
\]

Examples:

1. Calculate the power required per mm\(^3\) of metal removed per second for a surface grinding operation using the following data.

   Wheel speed = 50 m/s, work speed = 0.2 m/s, tangential force = 90N. Depth of cut = 0.02mm and width of cut = 15mm.

2. During external cylindrical grinding following observations are made

   Diameter of work piece = 50mm. Diameter of grinding wheel = 250mm. Wheel velocity = 20m/sec, work velocity = 15 m/min, wheel depth of cut = 0.03mm, grains are 0.5mm apart. Calculate the grain depth of cut.