Production & Industrial Engineering

Manufacturing Process - II

Comprehensive Theory

with **Solved Examples** and **Practice Questions**

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Manufacturing Process - II

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CHAPTER 04

Abrasive Machines and Hole Making Processes

Section : I Abrasive Machines

INTRODUCTION

Grinding is the most common form of abrasive machining. It is a material cutting process which engages an abrasive tool whose cutting elements are grains of abrasive material known as grit. These grits are characterized by sharp cutting points, high hot hardness, chemical stability and wear resistance. The grits are held together by a suitable bonding material to give shape of an abrasive tool.

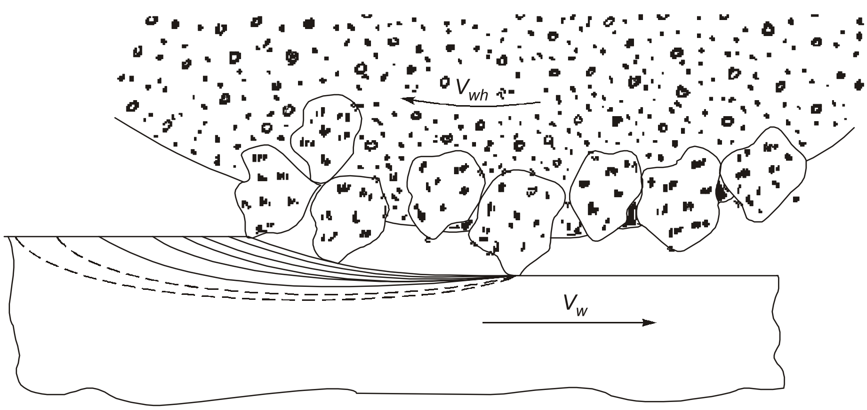


Fig. Cutting action by abrasive grains

A properly selected grinding wheel exhibits self sharpening action. As the cutting proceeds, the abrasive particles at the cutting edge become dulled and eventually these become plane. This process continues toll the abrasive grain get worn down till the level or bond.

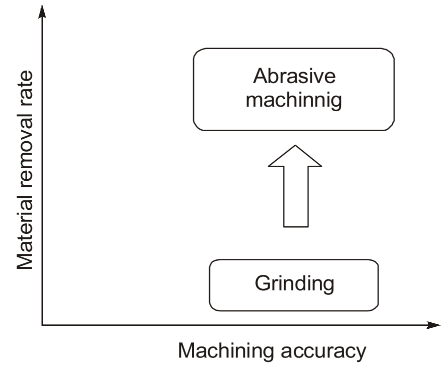
The distance between two cutting edges of grinding wheel is called **structure**.

4.1 Major Advantages and Applications of Grinding

Advantages

- A grinding wheel requires two types of specification
- Dimensional accuracy
- Good surface finish
- Good form and locational accuracy
- Applicable to both hardened and unhardened material

Applications
- Surface finishing
- Slitting and parting
- Descaling, deburring
- Stock removal (abrasive milling)
- Finishing of flat as well as cylindrical surface
- Grinding of tools and cutters and resharpening of the same.



Conventionally grinding is characterized as low material removal process capable of providing both high accuracy and high finish. However, advent of advanced grinding machines and grinding wheels has elevated the status of grinding to abrasive machining where high accuracy and surface finish as well as high material removal rate can be achieved even on an unhardened material as shown in figure.

4.2 Interaction of the Grit With the Workpiece

The importance of the grit shape can be easily realized because it determines the grit geometry e.g. rake and clearance angle as illustrated in following figure. It appears that grit does not has any definite geometry unlike a cutting tool and grit rake angle may vary from –45° to 60° or more.

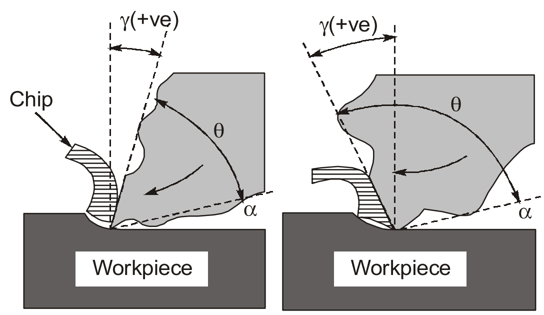


Fig. Variation in rake angle with grits of different shapes

Grit with favourable geometry can produce chip in shear mode. However, grits having large negative rake angle or rounded cutting edge do not form chips but may rub or make a groove by ploughing leading to lateral flow of workpiece material as shown in figure below.

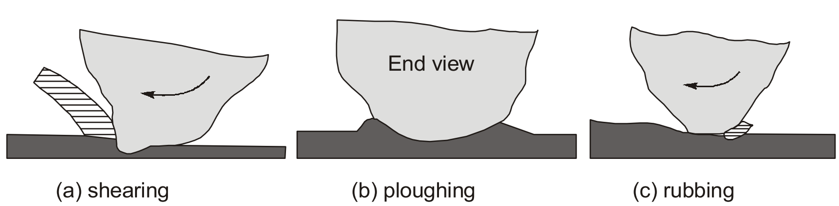


Fig. Variation of grinding force and grinding velocity with grit rake angle

4.3 Effect of Grinding Velocity and Grit Rake Angle on Grinding Force

Figure below shows the role of rake angle on cutting force. A negative rake angle always leads to higher cutting force than what is produced with a cutting point having positive rake angle. The figure further illustrates that at low grinding velocity this difference in grinding force is more pronounced. It is interesting to note that the difference is narrowed at a high grinding velocity and the grinding force became virtually independent of rake angle. This is one of the reasons that grinding is performed at very high speed in order to minimize the influence of negative rake angle.

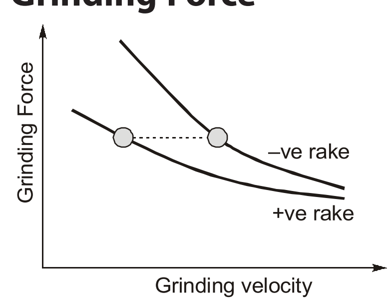


Fig. Variation of grinding force and grinding velocity with grit rake angle

4.4 Residual Stress

Temperature gradients within the workpiece during grinding are primarily responsible for residual stresses. Grinding fluids and the method of application as well as process parameters such as depth of cut and speed significantly influences the magnitude and the type of residual stresses developed.

Because of the adverse effect of tensile residual stresses on fatigue strength process variable should be carefully selected. Residual stress can usually be reduced by lowering wheel speed and increasing work piece speed. Softer grade wheels, known as full cutting wheels may also be used.

4.5 Designation and Selection of Grinding Wheel

51 — C — 30 — M — 5 — V — 20

C → ①, 30 → ②, M → ③, 5 → ④, V → ⑤

First and Last Number

Manufacture has to give special information about the grinding wheel.

4.5.1 Abrasive type

These are the hard materials with adequate toughness so that they will be able to act as cutting edge for sufficiently long time. Some of the most common types of abrasives are as follows:

- Aluminium oxide (Al_2O_3): This is one of the natural abrasives found and is commonly called corundum and emery.
- Silicon Carbide (SiC): Silicon carbide is made from silica sand and coke with small amounts of common salt.
- Cubic Boron Nitride (CBN): Cubic Boron Nitride (CBN) is next in hardness only to diamond. It is a natural material but produced in the laboratory using a high-temperature high-pressure process similar w making of artificial diamond.
- Diamond: It is hardest known material used as cutting tool. It is generally not used with ferrous metals due to high chemical affinity.

4.5.2 Grain size

Sieve number is specified in the terms of the number of openings per square inch. Thus, larger the grain number, finer is the grain size.

10-24 → Roughening
30–60 → Medium
70-180 → Finishing
220-600 → Super-finishing operations

Large grit- big grinding capacity, rough workpiece surface.

Fine grit- small grinding capacity, smooth workpiece surface

4.5.3 Bond

The function of the bond is to keep the abrasive grains together under the action of the grinding forces. The commonly used bond materials are

- Vitrified
- Synthetic resin
- Shellac
- Silicate
- Rubber
- Metal

Vitrified bond :

Vitrified bond is suitable for high stock removal even at dry condition. It can also be safely used in wet grinding. It can not be used where mechanical impact or thermal variations are like to occur. This bond is also not recommended for very high speed grinding because of possible breakage of the bond under centrifugal force.

Resin bond :

Conventional abrasive resin bonded wheels are widely used for heavy duty grinding because of their ability to withstand shock load. This bond is also known for its vibration absorbing characteristics and finds its use with diamond and cBN in grinding of cemented carbide and steel respectively. Resin bond is not recommended with alkaline grinding fluid for a possible chemical attack leading to bond weakening. Fiberglass reinforced resin bond is used with cut off wheels which requires added strength under high speed operation.

Shellac bond :

At one time this bond was used for flexible cut off wheels. At present use of shellac bond is limited to grinding wheels engaged in fine finish of rolls.

Oxychloride bond :

It is less common type bond, but still can be used in disc grinding operation. It is used under dry condition.

Rubber bond :

Its principal use is in thin wheels for wet cut-off operation. Rubber bond was once popular for finish grinding on bearings and cutting tools.

Metal bond :

Metal bond is extensively used with superabrasive wheels. Extremely high toughness of metal bonded wheels makes these very effective in those applications where form accuracy as well as large stock removal is desired.

Electroplated bond :

This bond allows large (30-40%) crystal exposure above the bond without need of any truing or dressing. This bond is specially used for making small diameter wheel, form wheel and thin superabrasive wheels. Presently it is the only bond for making wheels for abrasive milling and ultra high speed grinding.

Brazed bond :

This is relatively a recent development, allows crystal exposure as high 60-80%. In addition grit spacing can be precisely controlled. This bond is particularly suitable for very high material removal either with diamond or CBN wheel. The bond strength is much greater than provided by electroplated bond. This bond is expected to replace electroplated bond in many applications.

4.6 Selection of Grinding Wheel

Selection of grinding wheel means selection of composition of the grinding wheel and this depends upon the following factors:

1. Physical and chemical characteristics of the work material
2. Grinding conditions
3. Type of grinding (stock removal grinding or form finish grinding)

4.7 Grinding Wheel Wear

Grinding wheel wear is an important consideration because it adverse affects the shape and dimensional accuracy of grounding surface, as does wear on cutting tools. Grinding wheel wear is caused by three different mechanism: attributious gram wear, Grain fracture, and bond fracture.

(a) **Attributious Grain Wears:** In attributious wear, the cutting edges of an originally sharp grain become dull by attributious developing a wear flat that is similar to the flank wear in cutting tool. Wear is caused by the interaction of the grain with the workpiece material involving both physical and chemical reactions. These reactions are complex and involve diffusion, chemical degradation or decomposition of the grain, fracture at a microscopic scale, plastic deformation and melting. The selection of the type of abrasive for low attributious wear is, therefore based on the reactivity of the gain with the workpiece and on their relative mechanical property such as hardness and toughness. The environment and type of grinding fluid used also have an influence on grain workpiece interaction.

(b) **Grain fracture:** Because abrasive grain are brittle, their fracture characteristics in grinding are important. If the wear that caused by attritious wear is excessive, the grain become dull and grinding become inefficient and produces undesirably high temperature.

Optically, the grain should fracture or fragment at a moderate rate, so that the new sharp cutting edges are produced continuously during grinding. This is equivalent to braking a dull piece of chalk or a stone into two or more pieces in order to expose new sharp edges.

(c) **Bond fracture:** The strength of the bond is a significant parameter in grinding. If the bond is too strong dull grains cannot be dis-logged. This prevents other sharp grains along the circumference of the grinding wheel from contacting the workpiece to remove chips and the grinding process becomes inefficient. On the other hand if the bond is too weak, the grain are easily dis-logged and the wear rate of the wheel increases. In this case maintaining direction accuracy becomes difficult.

4.7.1 Dressing, Turning and Shaping of Grinding Wheels

Dressing is the process of producing sharp new edges on grains, condition worn grains on the surface of a grinding wheel and turning (Producing a true circle) an out rounding wheel. Dressing is necessary when excessive attritious wear dulls the wheels called grazing because of the shiny appearance of the wheel surface or when wheel become loaded. Loading is when the porosities on the grinding surfaces of the wheel becomes filled or clogged with chips.

Three techniques are used to dress grinding wheels. In the first method a specially shaped diamond point tool or diamond cluster (figure below) is moved across the width of the grinding face of a rotating wheel and removes a small layer from the wheel surface with each pass.

In the second method, a set of star shaped steel disks is manually pressed against the wheel. Material is removed from the wheel surface by crushing the grain. As a result, this method produces a coarse surface on the wheel and is used only for rough grinding operation on bench.

In third method, abrasive sticks may be used to dress grinding wheels. Particularly softer wheels. However this technique is not appropriate for precision grinding operations dressing techniques and how frequently the wheel surface is dressed are important because they affect grinding forces and surface finish. Modern computer-controlled grinder are equipped with automatic dressing features which dress the wheel continually as grinding. Progresses the first contact between the dressing tool and the grinding and the grinding wheel is very important. It is usually monitored precisely by piozelectric and acoustic emission sensors.

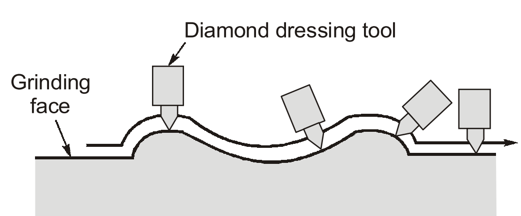


Fig. Shaping the grinding face of a wheel by dressing it with computer control.

ANSWERS

1. (b)	2. (a)	3. (b)	4. (c)
5. (b)	6. (b)	7. (b)	8. (a)
9. (b)	10. (a)	11. (b)	12. (c)
13. (0.78)	14. (7.87)	15. (22.21)	

HINTS

12. (c)

Different types of bond used in grinding :

R - Rubber
V - Vitrified bond
B - Resinoid
E - Shellac
S - Silicate
O - Oxychloride

13. (0.78)(0.75 to 0.80)

$$\text{MRR} = \frac{\pi}{4}D^2 fN$$

$$D = 25 \text{ mm}; \; f = 0.25 \text{ mm/rev}$$

$$V = \frac{\pi DN}{1000}$$

$$\Rightarrow \quad 30 = \frac{\pi \times 25 \times N}{1000}$$

$$N = 381.971 \text{ rpm}$$

$$MRR = \frac{\pi}{4} \times 25^2 \times 0.25 \times 381.971 \text{ mm}^3\text{/min}$$

$$= 46874.9 \text{ mm}^3\text{/min}$$

$$= 0.78 \text{ cm}^3\text{/sec}$$

14. (7.87) (7.6 to 9.14)

Mean grinding power

$$= \frac{\text{Velocity of work piece} \times \text{depth of cut} \times \text{transverse feed} \times \text{factor} \times \text{specific cutting energy}}{60 \times 1000}$$

$$= \frac{25 \times 0.025 \times 4.4 \times 5 \times 2200}{60 \times 1000} = 0.504166 \text{ kW}$$

$$\text{Feed power} = \text{grinding power} \times \frac{\text{workpiece speed}}{\text{wheel speed}}$$

$$= 0.504166 \times \frac{25}{1600} = 7.877 \text{ W}$$

15. (22.21) (22.0 to 22.4)

$$\text{Drilling time} = \frac{L}{fN}$$

$$L = L_1 + \text{Break through distance}$$

Break through distance,

$$A = \frac{D}{2\tan\left(\frac{\alpha}{2}\right)} = \frac{30}{2\tan 59^\circ}$$

$$= 9.012 \text{ mm}$$

$$L = 45 + 9.012 = 54.012 \text{ mm}$$

$$\text{Spindle speed, } N = \frac{1000 \times 55}{\pi \times 30}$$

$$= 583.568 \text{ rev/min}$$

$$\text{Drilling time} = \frac{54.012}{0.25 \times 583.568}$$

$$= 0.3702 \text{ min} = 22.21 \text{ sec}$$

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