UNIT 4 ABRASIVE AND GRINDING WHEELS

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4.1 INTRODUCTION

Grinding is an important operation for finishing of machined component. Grinding operation is carried out on a grinding machine having a grinding wheel which is made of bonding material and abrasive particles. The properties of a grinding wheel are mainly governed by these two constituents, i.e., bond material and abrasive particles. Controllable machine parameters and properties of the grinding wheel determine the kind of surface characteristics that can be achieved. Hence, it is inevitable to study in detail, both the grinding wheel and the grinding machine.

Unit 4 discusses about the grinding wheel and its constituents. Depending upon the workpiece material properties and machined surface requirements, bonding material and abrasive particles type are selected. Commonly used bonding materials are resinoid, vitrified, silicate, shellac and rubber. Under certain circumstances, metal bonded grinding wheels are also used. Various types of abrasives used are Al₂O₃, CBN, SiC, and diamond. A grinding wheel marking tells about the various characteristics of grinding wheel, viz. type of abrasive, grain size, grade, structure and manufacturer’s mark.

Objectives

After studying this unit, you should be able to

- understand the working principle of grinding,
- know constituents of a grinding wheel and their functions,
- understand the marking/specification of a grinding wheel,
- find out defects in a grinding wheel, and
- understand role of truing, dressing and balancing of a grinding wheel.

4.2 PRINCIPLE OF GRINDING

Grinding is a surface finishing operation, which is capable of producing surface finish as good as less than 1 μm (say, 0.75 μm). In grinding operation (Figure 4.1), abrasive particles remove very thin layer of material producing discontinuous chips like that in milling operation. The abrasive particles held by the bonding material act as cutting tools.
Depending upon the protrusion height of the abrasive particles and depth of cut, some of the protruding abrasives are active (participating in cutting) while others are inactive (not participating in cutting). As grinding continues, the cutting edges of some of the grains become blunt hence the grinding forces on these grains increase until either the blunt abrasives fracture and expose new cutting edges, or whole of the blunt grain is consumed to expose new active grains, or partially used grain is dislodged from the grinding wheel. Thus, a grinding wheel can be said to have self-sharpening characteristic. The effective rake angle of the abrasive grains is negative, and the process is associated with high specific cutting energy as compared to that in traditional cutting operations like turning, milling, etc. For specifying a grinding wheel one needs to give details regarding abrasive type, abrasive size, wheel grade, wheel structure, bond material and manufacturer’s identification mark. The description of these characteristics of a grinding wheel is given in the following sections.

**4.3 GRINDING WHEELS**

**4.3.1 Abrasives**

Abrasives in grinding act as cutting tools. The cutting ability of abrasive grains depends on their properties like hardness, toughness, friability (ability to fracture) and resistance to attrition. Because of uniform cutting characteristics of the synthetic abrasive materials, they are more commonly used than natural abrasive materials. Conventionally used abrasives for grinding wheels are aluminum oxide (Al₂O₃), silicon carbide (SiC), boron carbide (B₄C), cubic boron nitride (CBN), and diamond. A grinding wheel consists of bonding material, abrasives and pores (or porosity). Depending upon individual constituent percentage, the grinding wheel attains its properties. Figure 4.2 shows grinding wheel structure showing all the three constituents. The large sized grains are crushed and graded into various sizes by passing them through standard sieves.

**Aluminum Oxide (Al₂O₃)**

Aluminum oxide (Al₂O₃) is a commonly used abrasive for grinding wheel. Aluminium-oxide grinding wheels have high hardness and toughness, and can
work at high temperature (say, up to 2000°C). Al₂O₃ is also known as Alumina. The abrasive content in a wheel decides its properties like hardness. The natural form of alumina is known as corundum and emery, which have impurities hence their performance is inconsistent. These wheels are good for grinding steel, soft bronze and high strength materials.

**Silicon Carbide (SiC)**

Silicon carbide (SiC) is made from silica sand and coke with a small amount of NaCl (common salt) and sawdust. It has high heat resistance (up to 2050°) and excellent cutting properties. The latter is due to the sharp cutting edges obtained when SiC is crushed. SiC grinding wheels are available in two categories – black and green. The black SiC wheel is of lower quality than the green one. The abrasives are brittle in nature, and are used to grind material with a low tensile strength (CI, cast bronze, cast aluminium, cemented carbides, etc.). SiC is also used for dressing grinding wheels as a substitute for diamond.

**Boron Carbide (B₄C)**

Boron carbide (B₄C) is expensive and is used for lapping, cutting and grinding. Its hardness is very close to that of diamond and heat resistance is even better than diamond.

**Cubic Boron Nitride (CBN)**

Cubic boron nitride (CBN) is a synthetic material, which also has properties very close to that of diamond. This can cut extremely hard materials at very high speed. It is very expensive.

**Diamond**

Diamonds used in cutting industries are artificial ones because of their capability to easily fracture, during machining. Due to fracture, it presents new cutting edges rather than getting glazed like natural diamond. Diamond is known hardest material, which cut at very high temperature and pressure. But it is quite expensive also.

Above discussed abrasives are identified by different letters as follows. These abbreviations are used in the specification of a grinding wheel.

(a) Aluminum oxide – A
(b) Cubic boron nitride – B
(c) Silicon carbide – C
(d) Diamond – D

**Grain Size (Grit Size)**

Abrasive materials are crushed in ball mills to obtain grains of different sizes. The grain size is represented by a number which indicates the number of holes per linear 25 mm (one inch) in the sieve used to size the grains (Figure 4.3). This means, larger the sieve number the finer the grains (Table 4.1).

<table>
<thead>
<tr>
<th>Classification</th>
<th>Grain Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse</td>
<td>10 12 14 16 20 24</td>
</tr>
<tr>
<td>Medium</td>
<td>30 36 40 46 54 60</td>
</tr>
<tr>
<td>Fine</td>
<td>70 80 90 100 120 150 180</td>
</tr>
<tr>
<td>Very fine</td>
<td>220 240 280 320 400 500 600</td>
</tr>
</tbody>
</table>
4.3.2 Bond Materials

A grinding wheel gets its shape by bond material, which also holds abrasive grains together. Various types of bond materials are used in making grinding wheels for different purposes. These bond materials are vitrified (V), silicate (S), shellac (E), resinoid (B), resinoid reinforced (BF), oxychloride (O), rubber (R), and rubber reinforced (RF). The letters within parentheses are used to indicate the bond material on marking of a grinding wheel. Some of these bond materials are discussed below.

Vitrified (V)

Vitrified (V) bond is also known as ceramic bond, and it is a commonly used bond material. It is made of clay, feldspar, quartz, talc, chalk and silicate of soda. These wheels have high strength and porosity but they are unaffected by the presence of water, acids, etc. These wheels are brittle, and they are weak in mechanical and thermal shock. These wheels are suitable for high production rates.

Silicate (S)

Silicate (S) bond has low hardness, and is water glass hardened by baking. It is used in making large sized grinding wheels and not used for precision grinding, but good enough for sharpening cutlery knives, and carpenters’ chisels like tools.

Shellac (E)

Shellac (E) bond is used for making grinding wheels for heavy duty, large diameter wheels especially for fine finish and cool cutting. These wheels are used for finishing mill rolls.

Resinoid (B)

Resinoid (B) bond wheels are strong and flexible, but are used for cutting at high speeds and comparatively low temperature. These wheels are used for dressing of castings and also as cut-off wheels. These wheels are made of bakelite (synthetic/organic resin). These wheels are affected by alkaline cutting fluid, and temperature higher than 180°C. Addition of graphite filler to the resinoid would improve upon surface finish of the ground surface.

Rubber (R)

Rubber (R) bonded wheels are flexible and hard, and are made of hard vulcanized rubber. These wheels are used like saw for cut-off operation, and as a control wheel in centerless grinding operation.

Metal (M)

Metal (M) bonded wheels are commonly used in the advanced machining processes like electrochemical grinding, and electric discharge grinding, and for diamond cutting. These wheels are made by using powder metallurgy techniques and use mostly CBN or diamond abrasives. The abrasives are bonded to the periphery of a metal wheel, up to the depth of 6 mm or less. Bonding is carried out under high pressure and temperature.

4.3.3 Grades

The grade of a grinding wheel indicates its strength which is usually represented in terms of scale of hardness in alphabet letters. Various grades of the grinding wheels are very soft (E, F, G), soft (H, I, J, K), medium (L, M, N, O), hard (P, Q, R, S) and very hard
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Grinding wheels are categorized as (T, U, W, Z). The grade of a grinding wheel is the property attributed by the type of bonding material used in the grinding wheel. The rate of wheel wear is less in hard wheels and more in soft wheels.

The grade of a wheel should be carefully selected according to the type of the work material. Too hard a wheel will generate excessive heat resulting in softening of the workpiece, and too soft wheel will be uneconomical (due to excessive wear of grinding wheel), and poor dimensional accuracy.

4.3.4 Structure

Structure of a grinding wheel indicates relationship in terms of volume of abrasive grains, bond material and voids, and their relative arrangement in a unit volume of the grinding wheel.

Grinding wheel structure is classified in three groups, and each group is sub-classified by numbers as: dense (0, 1, 2, 3), medium dense (4, 5, 6) and open (7, 8, 9, 10, 11, 12). Proper selection of the structure will reduce loading of the wheel by the chips, and will lead to higher output.

![Figure 4.4: Structure of a Grinding Wheel: (a) Dense; (b) Medium Dense; and (c) Open [Arshinov and Alekseev, 1976]](image)

4.4 SPECIFICATION/MARKING OF A GRINDING WHEEL

Specification or marking of any grinding wheel indicates its various characteristics. The specifications are to be given in a particular order; for example, abrasive type, grain size, grade, structure, bond type, and a manufacturer’s mark. In some cases, manufacturers mark is given as a prefix in place of suffix. Suppose, a wheel (Figure 4.4) is specified as A-36-L-5-V-26. Here, A indicates abrasive type that is aluminium oxide, 36 indicates medium grain size, L stands for medium grade, 5 represents medium dense structure, V is for vitrified bond, and 26 is manufacturer’s own identification mark.

![Figure 4.5: Grinding Wheel [Timings, 2002]](image)

Thus, a grinding wheel marking consists of the information in the following order:

(a) abrasive type,
(b) grain size,
(c) grade,
(d) structure,
(e) bond type, and
(f) identification mark.
Sometimes, manufacturer’s own identification mark is written first as follows:

38-B-60-J-5-V

Here, 38 is manufacturer’s mark.

4.5 SELECTION OF A GRINDING WHEEL

During the selection of a grinding wheel (or deciding its specification) for particular application, one should account for the workpiece material, workpiece requirements (in terms of tolerances, surface finish, etc.), type of operation to be conducted, grinding conditions and type of grinder to be used. As a rule of thumb, a soft grade wheel is recommended for the grinding of hard materials to facilitate self sharpening action of the wheel, while relatively harder wheel is advised for softer materials to be ground so that larger MRR can be achieved. Further, if workpiece-wheel contact area is small, wheel wear rate will be low, and if large contact area, wheel wear rate will be high. It is also recommended to use a close structure wheel on hard brittle material, but a more open structure wheel for soft ductile material.

A coarse grain wheel gives rapid stock removal and rough finish, while a fine grain wheel yields low MRR and fine finish. MRR is influenced by the method of dressing of the grinding wheel. Bonding material should provide sufficient strength to resist various forces acting on the grinding wheel.

4.6 TYPES OF GRINDING WHEEL

Grinding wheels are available in various shapes and sizes in the market. Some of these shapes of grinding wheels are shown in Figure 4.6. It should be noted that a robust grinding machine with soft grade wheel can produce accurate work.

Figure 4.6: Some Common Types of Grinding Wheels [Kalpakjian, 1989]

4.7 GRINDING WHEEL DEFECTS

The performance of a grinding wheel may deteriorate overtime on account of the following:

(a) loading,
(b) glazing,
Abrasive and Grinding Wheels

If a soft material is ground by an inappropriate grinding wheel, the space between the individual grains of the grinding wheel gets filled with chips (work material particles). Under such circumstances, the particles of work material can often be seen embedded in the wheel. This condition of grinding wheel is known as **loading** (or wheel loading).

Loading of a grinding wheel minimizes clearance between the grains. As a result of this, the grains rub against the workpiece rather than perform cutting. It may lead to fracture of the wheel due to high force or/and overheat it to weaken the bond and damage the wheel. More than this, high force overheat the workpiece as well. Hence, heating of the workpiece may lead to the undesirable change in workpiece surface properties like surface hardness and thermal cracks [Timings, 2002].

If a wheel consists of tough strongly bonded grains, then these grains even when they are worn out, do not fracture or dislodge from the wheel. Such grains quickly develop a glazed (or shining) appearance. This phenomenon is known as **glazing**. Such a glazed grinding wheel will not be able to cut the work material properly, and will overheat the wheel as well as workpiece.

A grinding wheel may be called **damaged** if the wheel is chipped off, cracked, worn unevenly, or dressed on even when it is too thin. Such a damaged wheel or unbalanced wheel which may lead to vibration should not be used.

Due to continuous fracture and breakage of abrasive grains and bond material, a grinding wheel during usage suffers uneven wear leading to form error in the wheel. This causes dimensional error in the ground workpiece. This is corrected by periodic turning of the wheel.

### 4.8 DRESSING, TRUING AND BALANCING

To make the glazed or loaded wheel serviceable, the wheel must be dressed and trued. **Dressing** of a wheel is done to achieve one or more of the following objectives: to remove blunt abrasive grains from the bond, to fracture the blunt grains to generate or expose sharp new cutting edges, and to remove embedded foreign matter from the grinding wheel. However, to make the periphery of the grinding wheel concentric to the spindle axis, it is **trued**.

There are various types of dressers that are used for dressing a grinding wheel, viz, Huntington wheel dresser, dressing stick, or diamond wheel dresser. A diamond wheel dresser cuts the wheel to shape, and is also simultaneously used for dressing and truing the wheel on a precision grinding machine, such as surface and cylindrical grinding machines. To retain sharpness of the diamond, it should trail the direction of rotation of the wheel at an angle between 5° to 15°, but lead the center of rotation slightly (Figure 4.7). Traversing the diamond rapidly across the face of the wheel will open the structure.

A grinding wheel should be accurately **balanced** to avoid any accident and to obtain accurate ground parts. Out-of-balance wheel would produce vibration and a pattern on the finished surface, and finally may lead to the damage of the spindle bearings. The balancing operation can be carried out in two ways (static balancing and dynamic balancing). Standard procedure given in the books should be followed for balancing of a grinding wheel.
SAQ 1

(a) Grinding is an operation performed to achieve surface finish of the order of
   (i) 10 nm
   (ii) 1 µm
   (iii) Any one of these two

(b) Grinding operation is classified as
   (i) Single point cutting
   (ii) Multipoint cutting
   (iii) None of these

(c) In grinding, the effective rake angle is
   (i) + ve
   (ii) − ve
   (iii) zero

(d) Which is not used as abrasive in a grinding wheel?
   (i) Alumina powder
   (ii) Silicon carbide powder
   (iii) Iron powder

(e) A grinding wheel properties depend on
   (i) Bond material
   (ii) Abrasive particles material
   (iii) % concentration of abrasive
   (iv) All of these

(f) 600 mesh size abrasive particles are larger in size (mm) as compared to
   (i) 800 mesh size
   (ii) 400 mesh size
   (iii) Both (i) and (ii)

(g) Which is not used as a bonding material for a grinding wheel?
   (i) Alumina
   (ii) Shellac
   (iii) Resinoid

(h) Which is the hardest grade of a grinding wheel?
   (i) F
   (ii) J
4.9 SUMMARY

Abrasives on the grinding wheel are used for finishing of pre-machined surfaces. Abrasives used for making grinding wheels are alumina, silicon carbide, cubic boron nitride and others. Abrasive grains are mixed in various percentages with bond material to make a grinding wheel. Depending upon the percentage of abrasive mixed in the bond material, the grinding wheel attains its properties, for example, structure of a grinding wheel. Type of the bonding material attributes strength to the grinding wheel. Some of the bond materials used for making a grinding wheel are vitrified, silicate, and resinoid. Sometimes metal is also used as a bond material. As per the shape of the workpiece to be finished, a particular type of grinding wheel is selected.

While giving specification of a grinding wheel, it should indicate abrasive type, grain size, grade, structure, bond material, and manufacturer’s identification mark. One should make sure before using a grinding wheel that it is free from any kind of defects.

4.10 ANSWERS TO SAQs

SAQ 1

(a) (ii)  
(b) (ii)  
(c) (ii)  
(d) (iii)  
(e) (iv)  
(f) (i)  
(g) (i)  
(h) (iii)  
(i) (iii)  
(j) (iv)

4.11 EXERCISES

Exercise 1

How is grinding different from other machining operations?
Exercise 2
How will you specify a grinding wheel? Explain the individual elements of information given in the specification.

Exercise 3
Explain various bonding materials used in a grinding wheel. Discuss the guidelines useful in its selection for different types of work materials.

Exercise 4
A grinding wheel carries the following marking:

39-C-120-K-4-V

What does this signify?

Exercise 5
What do you understand by dressing, truing and balancing of a grinding wheel?

BIBLIOGRAPHY


