

Module 5 Abrasive Processes (Grinding)

Lesson

28

Selection of wheels and their conditioning

Instructional Objectives

At the end of this lesson the students would be able to

- (i) identify need and purpose of grinding wheel specification
- (ii) state the role of various compositional parameters of the grinding wheel
- (iii) state the logical steps in selecting a grinding wheel
- (iv) recognize need and purpose of grinding wheel conditioning
- (v) illustrate various methods of wheel conditioning

28. Grinding wheels

Grinding wheel consists of hard abrasive grains called grits, which perform the cutting or material removal, held in the weak bonding matrix. A grinding wheel commonly identified by the type of the abrasive material used. The conventional wheels include aluminium oxide and silicon carbide wheels while diamond and cBN (cubic boron nitride) wheels fall in the category of superabrasive wheel.

28.1 Specification of grinding wheel

A grinding wheel requires two types of specification

- (a) Geometrical specification
- (b) Compositional specification

28.1.1 Geometrical specification

This is decided by the type of grinding machine and the grinding operation to be performed in the workpiece. This specification mainly includes wheel diameter, width and depth of rim and the bore diameter. The wheel diameter, for example can be as high as 400mm in high efficiency grinding or as small as less than 1mm in internal grinding. Similarly, width of the wheel may be less than an mm in dicing and slicing applications. Standard wheel configurations for conventional and superabrasive grinding wheels are shown in Fig.28.1 and 28.2.

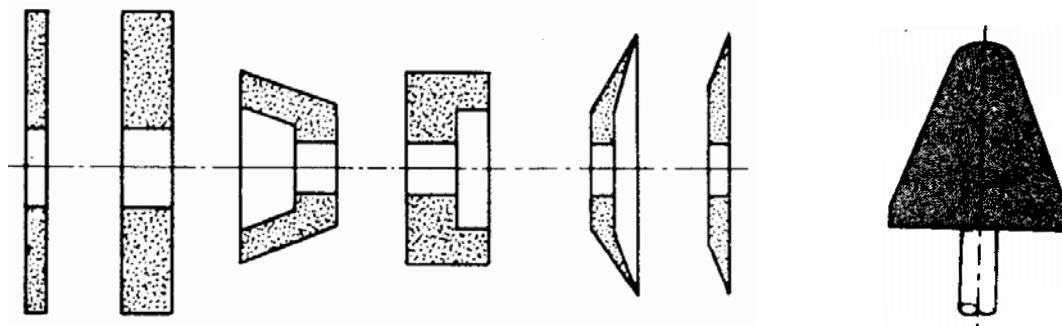


Fig.28.1: Standard wheel configuration for conventional grinding wheels

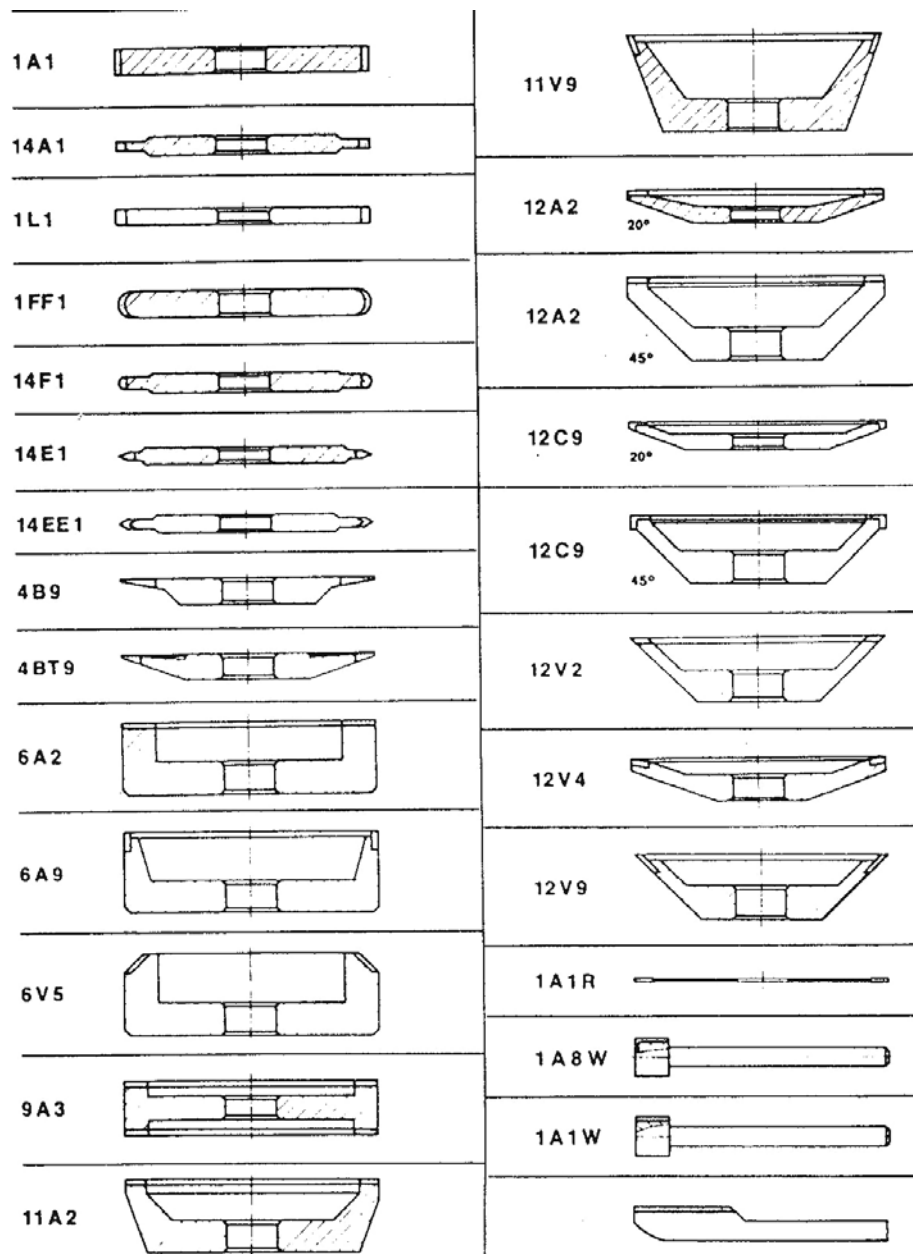


Fig.28.2: Standard wheel configuration for superabrasive wheel

28.1.2 Compositional specifications

Specification of a grinding wheel ordinarily means compositional specification. Conventional abrasive grinding wheels are specified encompassing the following parameters.

- 1) the type of grit material
- 2) the grit size
- 3) the bond strength of the wheel, commonly known as wheel hardness
- 4) the structure of the wheel denoting the porosity i.e. the amount of inter grit spacing
- 5) the type of bond material
- 6) other than these parameters, the wheel manufacturer may add their own identification code prefixing or suffixing (or both) the standard code.

Marking system for conventional grinding wheel

The standard marking system for conventional abrasive wheel can be as follows:

51 A 60 K 5 V 05, where

- The number '51' is manufacturer's identification number indicating exact kind of abrasive used.
- The letter 'A' denotes that the type of abrasive is aluminium oxide. In case of silicon carbide the letter 'C' is used.
- The number '60' specifies the average grit size in inch mesh. For a very large size grit this number may be as small as 6 where as for a very fine grit the designated number may be as high as 600.
- The letter 'K' denotes the hardness of the wheel, which means the amount of force required to pull out a single bonded abrasive grit by bond fracture. The letter symbol can range between 'A' and 'Z', 'A' denoting the softest grade and 'Z' denoting the hardest one.
- The number '5' denotes the structure or porosity of the wheel. This number can assume any value between 1 to 20, '1' indicating high porosity and '20' indicating low porosity.
- The letter code 'V' means that the bond material used is vitrified. The codes for other bond materials used in conventional abrasive wheels are B (resinoid), BF (resinoid reinforced), E(shellac), O(oxychloride), R(rubber), RF (rubber reinforced), S(silicate)
- The number '05' is a wheel manufacturer's identifier.

Marking system for superabrasive grinding wheel

Marking system for superabrasive grinding wheel is somewhat different as illustrated below

R D 120 N 100 M 4, where

- The letter 'R' is manufacture's code indicating the exact type of superabrasive used.
- The letter 'D' denotes that the type of abrasive is diamond. In case of cBN the letter 'B' is used.
- The number '120' specifies the average grain size in inch mesh. However, a two number designation (e.g. 120/140) is utilized for controlling the size of superabrasive grit. The two number designation of grit size along with corresponding designation in micron is given in table 28.1.
- Like conventional abrasive wheel, the letter 'N' denotes the hardness of the wheel. However, resin and metal bonded wheels are produced with almost no porosity and effective grade of the wheel is obtained by modifying the bond formulation.
- The number '100' is known as concentration number indicating the amount of abrasive contained in the wheel. The number '100' corresponds to an

abrasive content of 4.4 carats/cm^3 . For diamond grit, '100' concentration is 25% by volume. For cBN the corresponding volumetric concentration is 24%.

- The letter 'M' denotes that the type of bond is metallic. The other types of bonds used in superabrasive wheels are resin, vitrified or metal bond, which make a composite structure with the grit material. However, another type of superabrasive wheel with both diamond and cBN is also manufactured where a single layer of superabrasive grits are bonded on a metal perform by a galvanic metal layer or a brazed metal layer as illustrated in Fig.28.3.

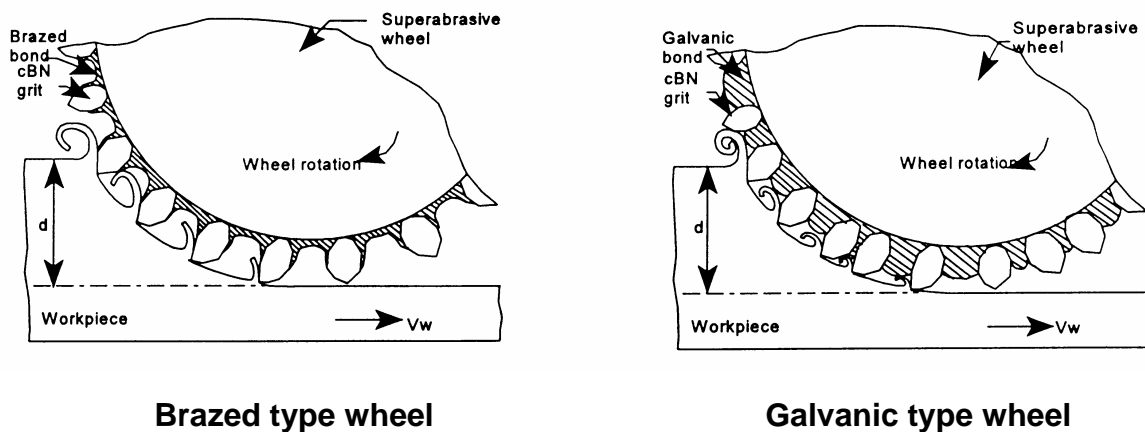


Fig.28.3 Schematic diagrams for the relative comparison of brazed type and galvanically bonded single layer cBN grinding wheel

28.2 Selection of grinding wheels

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)

28.2.1 Type of abrasives

Aluminium oxide

Aluminium oxide may have variation in properties arising out of differences in chemical composition and structure associated with the manufacturing process.

Pure Al_2O_3 grit with defect structure like voids leads to unusually sharp free cutting action with low strength and is advantageous in fine tool grinding operation, and heat sensitive operations on hard, ferrous materials.

Regular or brown aluminium oxide (doped with TiO_2) possesses lower hardness and higher toughness than the white Al_2O_3 and is recommended heavy duty grinding to semi finishing.

Al_2O_3 alloyed with chromium oxide (<3%) is pink in colour.

Monocrystalline Al_2O_3 grits make a balance between hardness and toughness and are efficient in medium pressure heat sensitive operation on ferrous materials.

Microcrystalline Al_2O_3 grits of enhanced toughness are practically suitable for stock removal grinding. Al_2O_3 alloyed with zirconia also makes extremely tough grit mostly suitable for high pressure, high material removal grinding on ferrous material and are not recommended for precision grinding. Microcrystalline sintered Al_2O_3 grit is the latest development particularly known for its toughness and self sharpening characteristics.

Silicon carbide

Silicon carbide is harder than alumina but less tough. Silicon carbide is also inferior to Al_2O_3 because of its chemical reactivity with iron and steel.

Black carbide containing at least 95% SiC is less hard but tougher than green SiC and is efficient for grinding soft nonferrous materials.

Green silicon carbide contains at least 97% SiC. It is harder than black variety and is used for grinding cemented carbide.

Diamond

Diamond grit is best suited for grinding cemented carbides, glass, sapphire, stone, granite, marble, concrete, oxide, non-oxide ceramic, fiber reinforced plastics, ferrite, graphite.

Natural diamond grit is characterized by its random shape, very sharp cutting edge and free cutting action and is exclusively used in metallic, electroplated and brazed bond.

Monocrystalline diamond grits are known for their strength and designed for particularly demanding application. These are also used in metallic, galvanic and brazed bond.

Polycrystalline diamond grits are more friable than monocrystalline one and found to be most suitable for grinding of cemented carbide with low pressure. These grits are used in resin bond.

cBN (cubic boron nitride)

Diamond though hardest is not suitable for grinding ferrous materials because of its reactivity. In contrast, cBN the second hardest material, because of its chemical stability is the abrasive material of choice for efficient grinding of HSS, alloy steels, HSTR alloys.

Presently cBN grits are available as monocrystalline type with medium strength and blocky monocrystals with much higher strength. Medium strength crystals are more friable and used in resin bond for those applications where grinding force is not so high. High strength crystals are used with vitrified, electroplated or brazed bond where large grinding force is expected.

Microcrystalline cBN is known for its highest toughness and auto sharpening character and found to be best candidate for HEDG and abrasive milling. It can be used in all types of bond.

28.2.2 Grit size

The grain size affects material removal rate and the surface quality of workpiece in grinding.

Large grit- big grinding capacity, rough workpiece surface

Fine grit- small grinding capacity, smooth workpiece surface

28.2.3 Grade

The worn out grit must pull out from the bond and make room for fresh sharp grit in order to avoid excessive rise of grinding force and temperature. Therefore, a soft grade should be chosen for grinding hard material. On the other hand, during grinding of low strength soft material grit does not wear out so quickly. Therefore, the grit can be held with strong bond so that premature grit dislodgement can be avoided.

28.2.4 Structure / concentration

The structure should be open for grinding wheels engaged in high material removal to provide chip accommodation space. The space between the grits also serves as pocket for holding grinding fluid. On the other hand dense structured wheels are used for longer wheel life, for holding precision forms and profiles.

28.2.5 Bond

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.

28.3 Truing and dressing of grinding wheel

28.3.1 Truing

Truing is the act of regenerating the required geometry on the grinding wheel, whether the geometry is a special form or flat profile. Therefore, truing produces the macro-geometry of the grinding wheel.

Truing is also required on a new conventional wheel to ensure concentricity with specific mounting system. In practice the effective macro-geometry of a grinding wheel is of vital importance and accuracy of the finished workpiece is directly related to effective wheel geometry.

28.3.2 Truing tools

There are four major types of truing tools:

Steel cutter:

These are used to roughly true coarse grit conventional abrasive wheel to ensure freeness of cut.

Vitrified abrasive stick and wheel:

It is used for off hand truing of conventional abrasive wheel. These are used for truing resin bonded superabrasive wheel.

Steel or carbide crash roll

It is used to crush-true the profile on vitrified bond grinding wheel.

Diamond truing tool:

Single point diamond truing tools

The single point diamond truing tools for straight face truing are made by setting a high quality single crystal into a usually cylindrical shank of a specific diameter and length by brazing or casting around the diamond. During solidification contraction of the bonding metal is more than diamond and latter is held mechanically as result of contraction of metal around it. Some application of single point diamond truing tool is illustrated in Fig.28.4

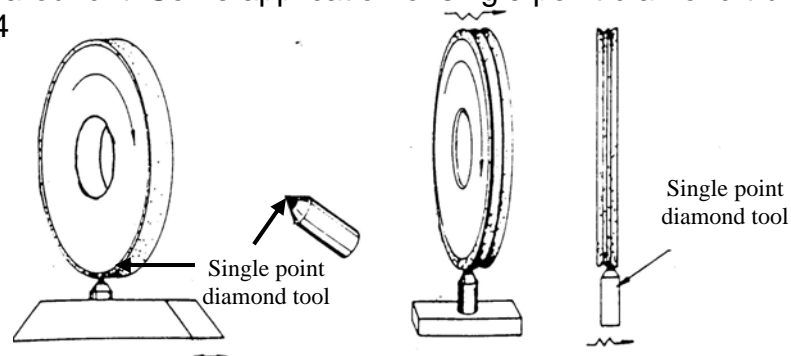
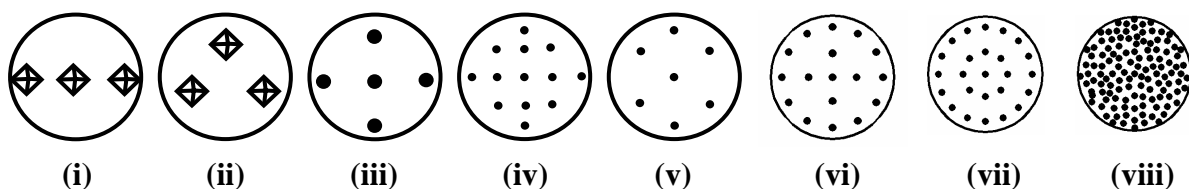


Fig 28.4 Application of single point diamond truing tool

Multi stone diamond truing tool

In this case the truing tool consists of a number of small but whole diamonds, some or all of which contact the abrasive wheel at the same time. The diamond particles are surface set with a metal binder and it is possible to make such tool with one layer or multilayer configuration. Normal range of diamond used in this tool is from as small as about 0.02 carat to as large as of 0.5 carat. These tools are suitable for heavy and rough truing operation. Distribution pattern of diamond in this tool shown in Fig.28.5



Distribution of diamond	Diamond weight	Distribution of diamond`	Diamond weight
(i) 1 layer-3stone	10	(v) 5 layer-17 stone	50
(ii) 2 layer-3 stone	10	(vi) 5 layer-7 stone	10
(iii) 3 layer-5 stone	10	(vii) 5 layer-25 stone	250
(iv) 5 layer-13 stone	25	(viii) throughout	50

Fig 28.5 Diamond distribution pattern of diamond particles in multi-stone diamond

Impregnated diamond truing tools

This wheel truing tool consists of crushed and graded diamond powder mixed with metal powder and sintered. The diamond particles are not individually set in a pattern but are distributed evenly throughout the matrix in the same way that an abrasive wheel consists of abrasive grains and bonding agent. The size of diamond particles may vary from 80-600 microns. By using considerably smaller diamond grit and smaller diamond section it is possible to true sharp edge and fine grit grinding

wheel. The use of crushed diamond product ensures that there are always many sharp points in use at the same time and these tools are mainly used in fine grinding, profile grinding, thread grinding, cylindrical grinding and tool grinding. Truing action of an impregnated diamond tool is shown schematically in Fig28.6.

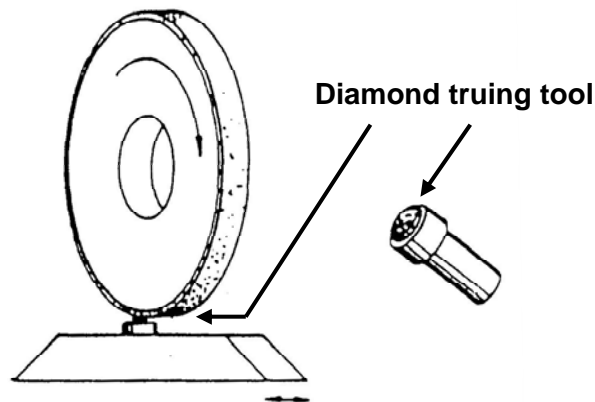


Fig. 28.6 Impregnated diamond truing tools

Rotary powered diamond truing wheels

Rotary powered truing devices (Fig.28.7) are the most widely recommended truing tool in long run mass production and are not ideally suited for those wheels with large diameters (greater than 200 mm). They can be pneumatic, hydraulic or electrically powered. Rotary powered truing device can be used in cross axis and parallel axis mode. Basically there are three types of truing wheels.

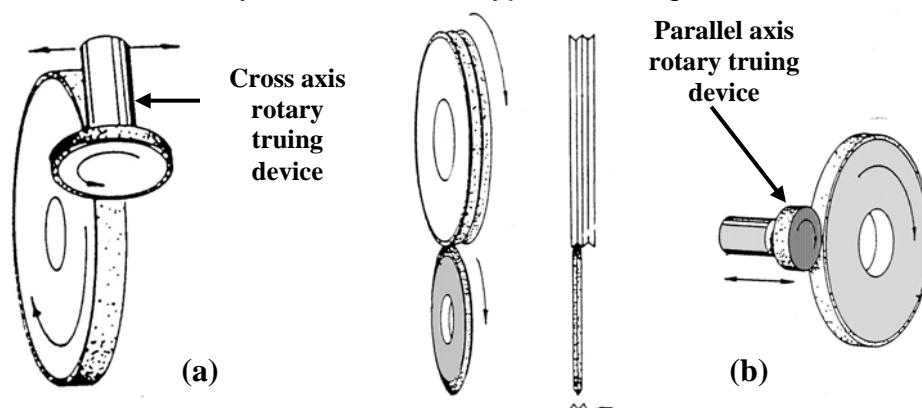


Fig. 28.7 Rotary power truing wheel being used in (a) cross-axis (b) parallel-axis

Surface set truing wheels

Here the diamond particles are set by hand in predetermined pattern. A sintered metal bond is used in this case. These truing wheels are designed for high production automated operations.

Impregnated truing wheels

In this case impregnated diamond particles are distributed in a random pattern to various depths in a metal matrix. This type of roll finds its best applications (i.e. groove grinding) where excess wheel surfaces must be dressed of.

Electroplated truing tool

In this truing wheel diamond particles are bonded to the wheel surface with galvanically deposited metal layer. Main advantage of this technique is that no mould is necessary to fabricate the diamond truing wheel unlike that of surface set or impregnated truing wheels.

Diamond form truing blocks

Diamond form truing block can be either diamond impregnated metal bond or electroplated, as shown in Fig.28.8. Brazed type diamond truing block has also come as an alternative to electroplated one. They can be as simple as flat piece of metal plated with diamond to true a straight faced wheel or contain an intricate form to shape the grinding wheel to design profile. Truing block can eliminate the use of self propelled truing wheels and are used almost exclusively for horizontal spindle surface grinder to generate specific form.

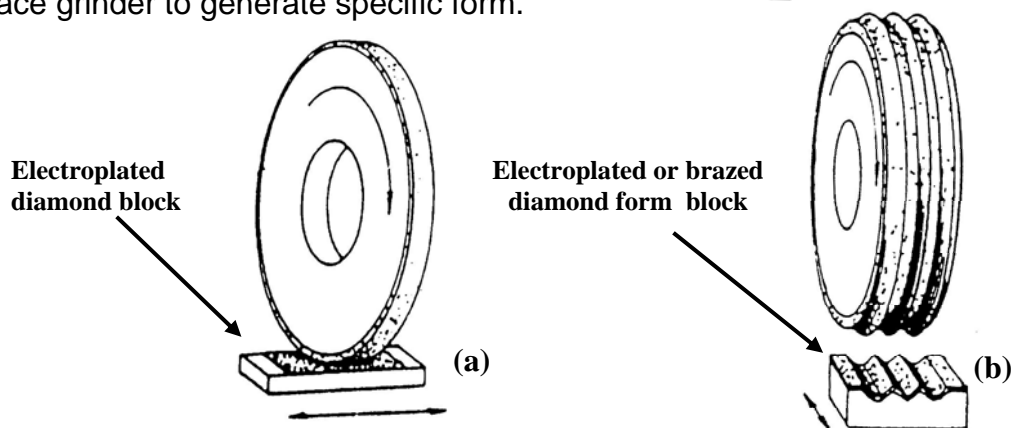


Fig. 28.8 Diamond form truing block to true
(a) a straight faced wheel (b) a form wheel

28.3.3 Dressing

Dressing is the conditioning of the wheel surface which ensures that grit cutting edges are exposed from the bond and thus able to penetrate into the workpiece material. Also, in dressing attempts are made to splinter the abrasive grains to make them sharp and free cutting and also to remove any residue left by material being ground. Dressing therefore produces micro-geometry. The structure of micro-geometry of grinding wheel determine its cutting ability with a wheel of given composition. Dressing can substantially influence the condition of the grinding tool.

Truing and dressing are commonly combined into one operation for conventional abrasive grinding wheels, but are usually two distinctly separate operation for superabrasive wheel.

Dressing of superabrasive wheel

Dressing of the superabrasive wheel is commonly done with soft conventional abrasive vitrified stick, which relieves the bond without affecting the superabrasive grits.

However, modern technique like electrochemical dressing has been successfully used in metal bonded superabrasive wheel. The wheel acts like an anode while a cathode plate is placed in front of the wheel working surface to allow electrochemical dissolution.

Electro discharge dressing is another alternative route for dressing metal bonded superabrasive wheel. In this case a dielectric medium is used in place of an electrolyte.

Touch-dressing, a new concept differs from conventional dressing in that bond material is not relieved. In contrast the dressing depth is precisely controlled in micron level to obtain better uniformity of grit height resulting in improvement of workpiece surface finish.

Exercise 28

- Q1. Why is aluminium oxide preferred to silicon carbide in grinding steel?
- Q2. Why is coarse grain and open structured wheel is preferred for stock removal grinding?
- Q3. What is the main short coming of vitrified bond?
- Q4. Is dressing necessary for single layer wheel?
- Q5. Can a resin bonded cBN wheel be electrochemically dressed?

Answer to Exercise 28

Answer to Q1:

Al_2O_3 is tougher than SiC. Therefore it is preferred to grind material having high tensile strength like steel. Moreover, Al_2O_3 shows higher chemical inertness than SiC towards steel leading to much improved wear resistance during grinding.

Answer to Q2:

Coarse grit allows large grit protrusion and open structure provides large inter grit chip space. Thus in combination those two provide large space for chip accommodation during stock removal grinding and risk of wheel loading is minimized.

Answer to Q3:

Vitrified bond is brittle and can not with stand high impact loads. This bond can not be used for high wheel speed due to risk of wheel breakage under centrifugal force.

Answer to Q4:

Conventional macro level dressing is not required because the wheel inherently has an open structure. However, touch dressing is carried out to obtain better uniformity in grit height in order to improve surface finish of the workpiece.

Answer to Q5:

Electrochemical dressing is not possible with resin bonded wheel because it is not electrically conducting.