CHAPTER 1

INTRODUCTION

Grinding is a precision machining process which is widely used in the manufacturing of components which require close tolerances and smooth finish. It has become an important process for the material removal and finishing of different materials for several applications. Rapid developments in work materials and enforcement of stringent work specifications increase the demand for accuracy and surface quality of work pieces, with improved productivity and cost effectiveness. The wide spread use of new hard to machine materials also increases the demand for different grinding tools. Innovative changes in manufacturing processes and methods are other important factors, opening up new applications for abrasive machining.

The important feature that differentiates grinding from other machining processes is that the cutting points which are spatially distributed over the cutting surface. The number, geometry and dimensions, of the cutting edges can only be defined statistically. Higher cutting speeds, smaller depth of cut, specific wear behavior and high temperatures are the specific characteristics features of grinding process.

For many years, coated abrasives were regarded as finishing tools. Coated abrasives are extensively used for manual operations such us cleaning, deburring, polishing etc. Continual improvements in grinding process have made belt grinding as one of the versatile methods. Moreover, the rate of material removal is high in the case of grinding compared to that in deburring
and polishing, which necessitates the evaluation of characteristics of coated abrasives to withstand high forces. A progressive improvement during the past ten years in the strength of backings and the toughness of minerals has resulted in the expanded use of abrasive belts for rapid material removal on wide surfaces, an area previously reserved for milling operations or vertical spindle grinding.

Coated abrasives shall be classified into two ways. They are classified in terms of the quantum of material removal. In addition to cutting, machining with coated belts often offers advantages like less heat generation, discontinuous scratch finish patterns (lay/texture) that provide excellent seatings for mating parts and easy control of flatness. Belt grinding technology now constitutes an economic alternative for the finishing of metallic materials. Abrasive belt grinding is used over grinding wheel; due to economical and faster grinding reasons. Coated abrasive belt grinding has gained increasing importance as chip removal process in recent years. As modern manufacturing is driven by flexible concepts with increased demands, newer application opportunities are presented for coated abrasives.

1.1 COATED ABRASIVES

Coated abrasive product comprises three basic elements (Figure 1.1) forming adjacent layers namely backing, adhesive film and abrasive grains. Though the basic elements have remained the same, a stronger, tougher and sharper grain combined with better bond and rigid backing makes the product work for different applications. Coated abrasives used in the form of discs, belts, blast machines and sandblasters, as well as sheets, rolls, and hand pads. Some abrasives are designed for use on bench or back stand grinders, while others are designed for use on portable or handled grinders or sanders. Acceptance of these abrasives has immensely increased with the
developments of machines and machining methods to use abrasives in different shapes to suit specific applications.

![Figure 1.1 structure of coated abrasive]

Figure 1.1 structure of coated abrasive

Abrasive belt grinding is the most important part of the grinding system as it performs the cutting operations. The quality of the coated abrasive belt is characterized by weight proportion, physical properties such as grit hardness, bond strength, chemical stability of the abrasives and bond in the working environment which considerably influence the belt wear and surface roughness, accuracy of the size and shape of the work piece and life of the belt as well. The other parameters which influence the grinding operations are the mesh number, grain shape, grit size and roughness of the cutting edges and factors such as belt speed, grinding pressure, contact area and rotation of the work piece.

1.2 ABRASIVE BELT SPECIFICATION

An abrasive belt can be specified by the following parameters

1. Type of the abrasive in the belt
2. Abrasive grain size
3. Type of bond
4. Type of backing
5. Type of joint

1.2.1 Type of Abrasive

The abrasives used in coated abrasives are alumina, silicon carbide, mixed alumina-zirconia, cubic boron nitride and diamond. The first three are known as conventional abrasives while the last two are known as super abrasives. Alumina is used for grinding of ferrous and wood materials. It is the softest of the conventional abrasives but relatively tougher. Alumina is also used in different forms such as brown aluminum oxide and white aluminum oxide. Brown aluminium oxide is less pure but more durable, while white aluminium oxide is the purest form of aluminium oxide. Silicon carbide is commonly used for grinding nonferrous and wood materials. It is the hardest of the all conventional abrasives with less impact resistance than alumina. There are two varieties of silicon carbide namely black and green. Black silicon carbide is less pure but more durable. Green silicon carbide is high in purity, the hardest conventional abrasive and relatively expensive. In coated abrasive application, silicon carbide grains are used for polishing and for wood and metal. It finds very less application in machine grinding. Alumina zirconia is used for rough grinding applications. It has the highest impact resistance. There are two types of zirconia abrasives: one with 25% zirconia is more durable and has got higher impact resistance. The second type has higher percentage of zirconia and is more friable and generating sharp surfaces. Abrasives are used to remove surface materials such as metal, ceramics, glass, plastics, and paint. Aluminum oxide and silicon carbide are widely used minerals in coated abrasives. Table 1.1, shows the properties of conventional abrasives.
Some common examples of abrasive materials are:

- Aluminium oxide
- Zircon Alumina
- Silicon carbide
- solgel alumina
- Cubic Boron Nitride
- Diamond dust
- Emery (mineral) (impure corundum) and Garnet

Table 1.1 Properties of Aluminium oxide and Silicon carbide

<table>
<thead>
<tr>
<th>Properties</th>
<th>Aluminium oxide</th>
<th>Silicon carbide</th>
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</thead>
<tbody>
<tr>
<td>Molecular formula</td>
<td>Al₂O₃</td>
<td>SiC</td>
</tr>
<tr>
<td>Molar mass</td>
<td>101.96 g/mol</td>
<td>40.097 g/mol</td>
</tr>
<tr>
<td>Density and phase</td>
<td>3.97 g/cm³, solid</td>
<td>3.22 g/cm³, solid</td>
</tr>
<tr>
<td>Melting point</td>
<td>2054°C</td>
<td>2700°C</td>
</tr>
</tbody>
</table>

1.2.2 Grit Size

Grit size plays dominant role in the performance of the abrasive belt. Grit size refers to the approximate size of the abrasive grit particles employed in building up the abrasive belt and is an indication of their fineness or coarseness. The abrasives are classified or screened by passing through them in a standard screen containing fixed number of holes per inch. The grain size is defined by a number which correlates to the number of holes per inch. Higher the grit number lesser the grit size.
1.2.3 Bonds

The adhesive used to bond the abrasive grain onto the backing plays a crucial role in the performance of the coated abrasive. It is usually applied in two layers for anchoring and locking the minerals to the backing normally designated as maker and sizer. The first coat or make coat adheres the grains to the backing ensuring proper orientation and the second coat or the size coat gives the strength.

Resin is a hydrocarbon secretion of many plants, particularly coniferous trees, valued for its chemical constituents and uses such as varnishes and adhesives. The term is also used for synthetic substances of similar properties. Resin as produced by most plants is a viscous liquid, typically composed of volatile fluid terpenes, with lesser components of dissolved non-volatile solids which makes it viscous and sticky. Example: Phenol-Formaldehyde (PF) resin. Glue refers to protein colloids prepared from animal tissues. Table 1.2 shows typical bonding systems used in the coated abrasives.

**Table 1.2 Make coat and Size coat of bonding type**

<table>
<thead>
<tr>
<th>Bonding Type</th>
<th>Make Coat</th>
<th>Size Coat</th>
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<tbody>
<tr>
<td>Glue over Glue (G/G)</td>
<td>Glue</td>
<td>Glue</td>
</tr>
<tr>
<td>Resin over Glue (R/G)</td>
<td>Glue</td>
<td>Resin</td>
</tr>
<tr>
<td>Resin over Resin (R/R)</td>
<td>Resin</td>
<td>Resin</td>
</tr>
</tbody>
</table>

1.2.4 Backings

Backings are the base for abrasive minerals and are classified into three groups such as paper, cloth and fiber.
(a) **Paper** – This is made to particular specification ensuring the desired strength and other properties used with rubber or resin for wet strength and pliability. ‘A’ (68-80 gsm) weight paper is used as base for fine grits for light stock removal. Finishing paper, C and D (100-120 gsm) weight paper are used as cabinet papers and are of intermediate strength and are coated with medium grit size. ‘E’ (220-240 gsm) weight paper is primarily used for mechanical sanding and is of high strength grade and used for complete range of grain size. For certain extra heavy duty mechanical operation even ‘F’ (270-300 gsm) weight paper is used.

(b) **Cloth** – This is made of cotton or other cellulosic fiber yarns woven into drills, jeans, satins and plain weaves and are suitably processed to obtain necessary strength and flexibility of coating surface. In most cases, a finished layer is necessary before an actual coating is done. Plain weave is used for conventional items like emery and garnet for hand applications. The others are used for mechanical operations such as ‘J’ light weight and flexible to suit intricate work surface contours. ‘X’ durable and strong. X weight backings are heavier than the ‘J’ weight backings but also have a different weave. X weight backings are the predominant used in metal working applications. ‘Y’ is for heavy duty grinding. Y weights are heavier than X weight fabric and the weave is different. ‘M” weight fabrics are used in extra heavy duty class.

(c) **Fiber** – Fiber backings are laminates made of vulcanized fiber, a very hard, strong, yet flexible, materials made of cotton, rag, base paper suitably treated chemically to gelatinize the cotton cellulose. Several layers of these are combined together, vulcanized and smoothened under pressure rollers. This backing is used for high speed sanding.
1.2.5 Belt Joint

Another influencing factor for belt performance is the belt joint. Belt joint called splice, is used to join the free ends of the grinding belt. The requirements imposed on the splice, especially with belt grinding of metals, are necessary smooth joint, tear resistance, ability to withstand the grinding pressure, retaining the shape under grinding heat and jerk free operation. Depending on the job and the grain size involved grinding belts with a great diversity of joint types are produced. The types of joints are butt joint, overlapping and scalp-up or zig zag joints. Mostly overlapped splices are used. The type of application decides the joint requirements. For fine finishing applications, the grits near the joints are removed in order to even out differences in belt thickness. For heavy duty grinding, where the grinding pressure and rate of material removal are high, a straight butt joint or zig zag joint is used.

1.3 ABRASIVE BELT GRINDING

Belt grinding has generally achieved a very high level of industrial significance with applications from manual to fully automated operations. In abrasive belt grinding, a continuous moving belt with abrasives is used for grinding the surfaces. The abrasive belt is normally passed between two wheels, one is a driver and another is an idler.

1.3.1 Types of Belt Grinding

Three basic contact methods are employed in coated abrasive belt grinding. They are classified as slack of belt, platen and contact wheel types. In slack of belt operation (Figure 1.2a) abrasive belt runs over a drive wheel and idler, and the work is applied to the open unsupported area. This type of method is used to deburr or polish at light to medium pressure. Platen
(Figure 1.2b) application has a fixed steel plate supporting the abrasive belt where the work piece makes contact. This type of contact element is used for dimensioning and truing of flat workpieces. Most commonly used contact element is contact wheel. The contact wheel (Figure 1.2c) supports the abrasive belt where workpiece makes contact. The workpiece may be presented to the belt on the face of the wheel or occasionally is worked over the edges of the wheel.

![Types of abrasive belt grinding](image)

**Figure 1.2 Types of abrasive belt grinding**

Typically, the use of abrasive belt grinding appears in two methods: offhand and power assisted. Each method has unique process parameter that significantly affects its performance. Off hand grinding is the oldest form of abrasive belt grinding and is found in many applications. This is used when the construction of a fixture is impractical as in cases where the workpieces are with irregular shapes. The method includes all methods of abrading metal in which the operator holds the work piece in his hand and press it on the abrasive belt.

Power assist abrasive plunge is very common method in metal working industries. This grinding operation is usually controlled and repeatable, offering many advantages to large volume production methods. Power assist makes higher pressures grinding possible and takes advantage of the properties of abrasive grains without the problems associated with operator fatigue. Equipment used in power, assist grinding falls into two
distinctly different operations designs, called ‘Fixed force” and “Fixed feed” power assist units.

Normally fixed force power assist unit has a fixture to position the metal part on a sliding table top that is moved by an air cylinder. Air pressure within the cylinder is adjusted to control the grinding force. Travel speed of the table is restrained by an air flow control valve. The energy requirements of “Fixed force” design varies considerably during the life of the belt. In a ‘Fixed Feed” design, the rate of infeed is controlled while grinding force will vary. Workpieces are placed in the fixture on a slide table that is powered by electric or hydraulic system. For a particular application, proper belt infeed rate is to be established. Since the infeed rate is constant, the force generated between the belt and metal part varies due to abrasive wear. Within each cycle, the constant feed rate creates changes in forces and material removal rates.

The performance of abrasive belt grinding depends on grinding conditions, type of abrasives and machining parameters. Hence in order to have a better understanding and reliable prediction of abrasive belt performance, both analytical and experimental studies are to be carried out. The experimental studies centered around abrasive belt properties and machining parameters will help to understand the significance on output. In the present day industry , abrasive belts are selected based on thumb rules and no exact analysis is available. Hence, optimal selection of abrasive belt and optimization of its performance for a given application require detailed analytical and experimental studies.

High speed grinding aims at acheiving higher material removal , with less belt wear i.e higher grinding ratio. In higher stock removal, the process needs more attention on selection of abrasive belt and machining parameters (Duwell 1978). The performance of the abrasive belt is mostly
controlled by the abrasive used, bond strength and grit bond relationship. Hence the belt has to be properly selected, based on the application and desired results. It is seen that failure of abrasive belt is largely influenced by the wrong selection of belt and machining parameters. By a proper analysis it is possible to identify the optimum machining parameters and belt properties for maximum output.

The effect of bonding system, backing material, abrasive grit size, flexing pattern, belt speed, contact area, grinding pressure on material removal and belt wear have been studied. In the present study, two approaches are considered one is the selection of coated abrasive belt based on the product characteristics and second is the effect of machining parameters on the grinding process. Based on the analysis, the optimum conditions are identified. The results are discussed in appropriate sections.