Advances and Recent Trends in Grinding Technology

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1. Introduction

Grinding is a well known and widely used engineering process to finish different materials with high dimensional accuracy and good surface finish. Contrary to the conventional machining operations, cutting velocity used in grinding is quite high, whereas feed and depth of cut employed in grinding are very low. Another important fact is that the grinding wheel is made of mainly with large numbers of abrasive particles like alumina, silicon carbide, etc. bonded firmly with appropriate bonding materials like vitrified bond resins, rubber, shellac, etc. Due to this fact, unlike conventional machining process, there is no well defined rake and clearance angles provided on the individual abrasive grits each of which open to the surface of machining acts as a cutting edge. In aggregate, there is high degree of negative rake angle present in the cutting edges. This causes large specific grinding force and energy and high generation of grinding temperature due to intense rubbing between the cutting tool and the workpiece. High Rate of Wheel material Removal (WRR) and clogging of chips in the inter-grit spaces, known as wheel loading, are also inherent characteristics of grinding. Hence, to improve the grinding process, control of the related factors is essential.

The performance of the grinding process is usually judged by.

i) Metal removal rate (MRR)
ii) Accuracy of the finished product
iii) Surface finish and integrity
iv) Wheel life
v) Grinding ratio (MRR/WRR)
vi) Overall economy

The main problem areas to achieve high grindability and economy are

i) Grinding forces and specific grinding forces
ii) High specific grinding energy
iii) High grinding temperature
iv) Surface damage
v) Vibration
vi) High rate of wheel wear
vii) Controlling the process

Amongst the above problem areas, generation of high grinding zone temperature during grinding may cause severe adverse effects [1-3] on the grinding wheel and the workpiece, like

i) High wheel loading
ii) High grinding force
iii) Lowering of wheel life
iv) Low grinding ratio
v) Lesser dimensional accuracy
vii) Induction of tensile residual stresses on the job surface
viii) Open surface cracks and microcracks on the ground surface
ix) High rate of oxidation and corrosion, etc.

The ways of improving performance of grinding are listed below :

i) Reduction in grinding forces by the appropriate selection of the grinding wheel and dressing parameters and methods, by the use of CBN wheel, electrochemical grinding, cryogrinding, etc. [4,5].

ii) To reduce the temperature during grinding, selection of suitable wheel composition, cleaning the wheel ultrasonically, applying grinding fluid to cool and lubricate the cutting region in such a way that the fluid enters deep inside the grinding zone [6], cryocooling [7],

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electrolytic-assisted grinding [8], *proper selection* of process parameters and appropriate dressing of the wheel may be adopted.

iii) Surface quality can be improved by using the methods of reducing force and temperature and also by adopting cryogrinding, dual-axis grinding, etc.

iv) Grinding ratio can be increased by proper selection of the wheel, optimization of the process parmeters, by electrochemical grinding, efficient temperature control, creep-feed grinding and making the wheel surface free of clogged chips through suitable means.

2. Advancement in Grinding Technology

Some advances and recent research areas in grinding are outlined in the following sections.

2.1 Grinding by Poly-Crystalline Diamond (PCD)

Polycrystalline diamond is used [4,5] as a wheel abrasive material to grind ceramic materials, which have many superior properties. Diamond being extremely hard, strong, tough and wear resistant material can be used effectively to give high degree of finish and accuracy of the ground workpiece due to retainability of edge sharpness. High speed abrasive machining is facilitated by PCD coated wheel. This pasted diamond wheel over a metal matrix through Chemical Vapour Deposition (CVD) is also used in high production applications.

Helical scan grinding can also be done using these wheels to obtain high degree of finish. In helical scan grinding, the grinding wheel axis is made inclined to the feed diretion of the grinding machine table, so that the prominent lays are reduced to a great extent.

2.2 Grinding by CBN wheels

Cubic born nitride (CBN) grit with its very high hardness, wear resistance, thermal and chemical stability and low grinding temperatures has *facilitated a great advance in grinding technology.* CBN wheels can allow [3-5] a grinding speed of the order of 120m/sec. in comparison with 40-80 m/sec. grinding speeds available with the resin, metal and vitreous bonded wheels. CBN grits with single layer configuration has the distinct advantage of having high crystal protrusion, about one third of the crystal height. This causes large chip clearance space, minimal wheel loading, lesser force, better surface qualities, etc.

CBN grits can be electroplated or brazed onto an electroformed metal. In case of the conventional galvanic bonded wheel, the chip clearance space is relatively less due to lesser protrusions. However, precision brazing method is used to bond the CBN grits in a single layer requiring only 20-30% of the grit height coverage by the braze material. This further improves the effectiveness of the CBN wheels.

2.3 Creep-Feed Grinding

Bulk material removal is possible [4,5] with the creep-feed grinding. Particularly when there is a need of material removal from a high hardness and difficult-to-machine material, creep-feed grinding offers the possibility of material removal from these exotic materials. In this case an infeed in the order of 10-30 mm is possible in a single pass. This process needs slow table feed, high speed ratio (wheel speed/ workpiece speed) and profuse cooling action. Continuous dressing of the wheel is needed during grinding, which should be in the up-grinding mode. This precess is mainly used to precess extremely hard and difficult-to-machine materials.

Longer chip contact length, possibility of stike-slip motion and lesser self-sharpening capability pose problems to the success of this method. Effective cooling by cryogenic fluid application may bring in some success in the creep-feed grinding process.

2.4 Ductile Regime Grinding

Ductile regime grinding is an alternative method

[5] of finishing to give polished job surface of extremely high hardness. In this process, grinding with very small infeed of about 0.1 to 1.0 micron is done so that fracture cannot initiate.

This process can work only if the smooth servo controlled drives of the machining system provide linear or nonlinear error of less than 100 nanometer and the machine is of high dynamic stiffness. Ultra-processing of optical grade germanium single crystal with diamond wheel is an example of this process with a typical infeed of 2 microns or less to obtain average surface roughness of 1.6 nanometer.

2.5 Grinding with Electrolytic In-Process Dressing

Electrolytic in process dressing (ELID) provides [5,8] an opportunity to get rid of loaded chip problem during grinding. The wheel is made an anode and the cathode is fixed near the wheel surface to allow electrochemical action in the small clearance between the wheel and work during grinding.

The electrochemical dissolution results in removal of chip and hence the self dressing. This method has been applied for the cast iron fibre bonded (CIFB) diamond wheel while grinding silicon wafers, precision grinding of ferrites, etc.

3. Conclusion

In this paper, first, the characteristics of the grinding process have been highlighted. Typical and inherent problem areas of grinding and the possible means to overcome these limitations have also been dicussed in brief.

Few recent advances in the grinding process using diamond and CBN wheels for high precision application have also been reviewed. Some other potential areas of research in grinding, such as creep feed grinding, ductile regime grinding and electrolytic in-process dressing of grinding wheel have also been briefly discussed.

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"Who dares to teach must never cease to learn."

- John Cotton Dana