REVIEW OF DRESSING AND TRUING OPERATIONS FOR GRINDING WHEELS

UJJAWAL MAYANK SRIVASTAVA
Department of Manufacturing Processes and Automation Engineering,
Netaji Subhas Institute of Technology, Sector-3, Dwarka, Delhi, India
ujjawal1991@nsitonline.in, ujjawal1991@gmail.com
http://www.nsit.ac.in

Abstract:

Grinding is an operation applied in almost every type of manufacturing process. It aims to produce high surface finish and to maintain close tolerances in the manufactured product. To make the grinding operation more productive and efficient, dressing and truing operations are performed on the grinding wheels. Various techniques are available and are used for the same. Since many permutations and combinations exists among the factors like economics, efficiency, accuracy, complexity, etc. of the dressing process, so continuous efforts are made to develop or adopt a technique that gives the best result while fulfilling the maximum number of factors. This can be accomplished by comparing the present techniques on the same ground. With this aim, the unconventional techniques with in-process configuration were developed that have several advantages over their conventional counterparts.

Keywords*:* Grinding; dressing; truing; in-process.

1. Introduction

Grinding is a machining process that utilizes abrasives for the removal of material. The sharp edges of abrasive grains act as cutting tool that remove material in the form of mostly powder or extremely fine chips. The abrasive grains or grit (like silicon carbide (SiC), aluminium oxide (Al_2O_3) or fine diamond grains) are used in the form of a wheel. The grit is present along with binder (metal, resin or vitrified), a material that bonds the abrasive particles together and imparts the mixture, the shape of a wheel. When grinding operation is performed the edges of grains become blunt which reduces the cutting performance of the wheel. The wheel also tends to be loaded with material that is being machined. In order to use the grinding wheel again for machining satisfactorily, the wheel must be able to cut as before. This is accomplished by the application of additional procedures like dressing and truing.

Dressing is an operation performed on the grinding wheel with an aim to restore the cutting ability. The basic principle for dressing is the generation and exposure of the new cutting egdes on the surface of the wheel. The principle of dressing is demonstrated in Fig. 1. It is achieved by fracturing the existing abrasive grains and allowing desired protusion of abrasive particles on the surface. The operation also unloads the grinding wheel i.e. removes work piece material that is embedded on wheel surface after the grinding operation. On performing this operation, the wheel can machine again with higher feed and in-feed (depth of cut) rate, which permits to conclude the machining in less time but with higher accuracy. Dressing is required at regular intervals to maintain the desired grain edge sharpness and the grain protrusion.

Truing is another operation performed with the purpose to restore the shape of the grinding wheel that is out of shape due to wear and deformation. The purpose of truing operation can be understood by referring to Fig. 2. Truing makes the periphery of the wheel concentric to the central bore and also imparts a perfect form to the surface of the wheel. It is carried out with the same tool but with lighter depth of cut.

Conventional or Traditional dressing methods involve the use of tools that remain in contact with wheel during the entire dressing operation. These dressing procedures are time consuming and cause extensive wear to the grinding wheel as well as to the dresser (tool). To overcome these shortcomings, in-process dressing procedures were researched and developed. These procedures can be effectively applied on the wheel during the on-going grinding operation (in-process). Also the methods are of non-contact type that prevents wear and deformation of wheel and the dresser because the dressing forces are eliminated. These processes can be regarded as Unconventional or Non-Traditional dressing methods.

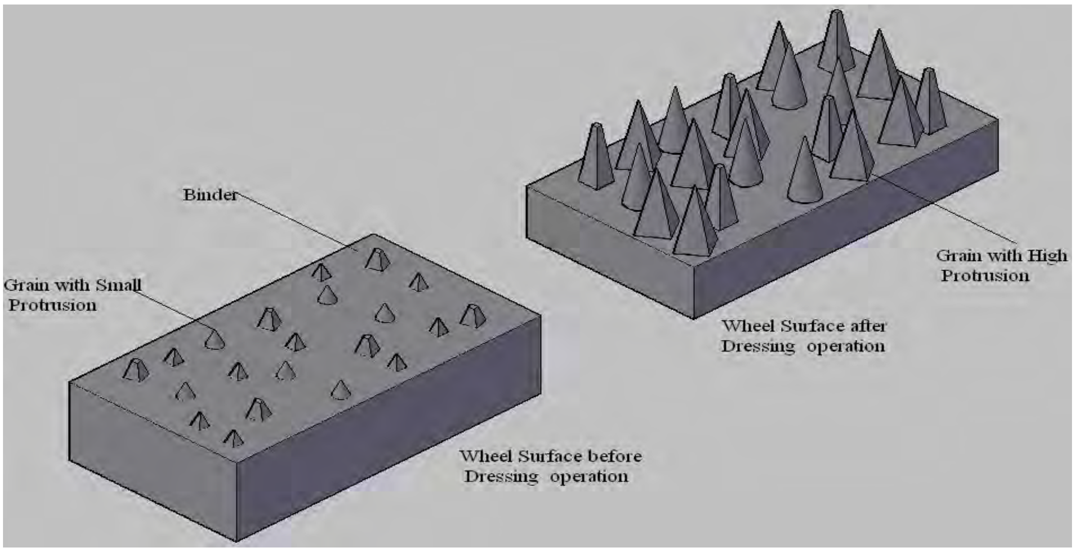

Fig. 1. Principle of dressing operation.

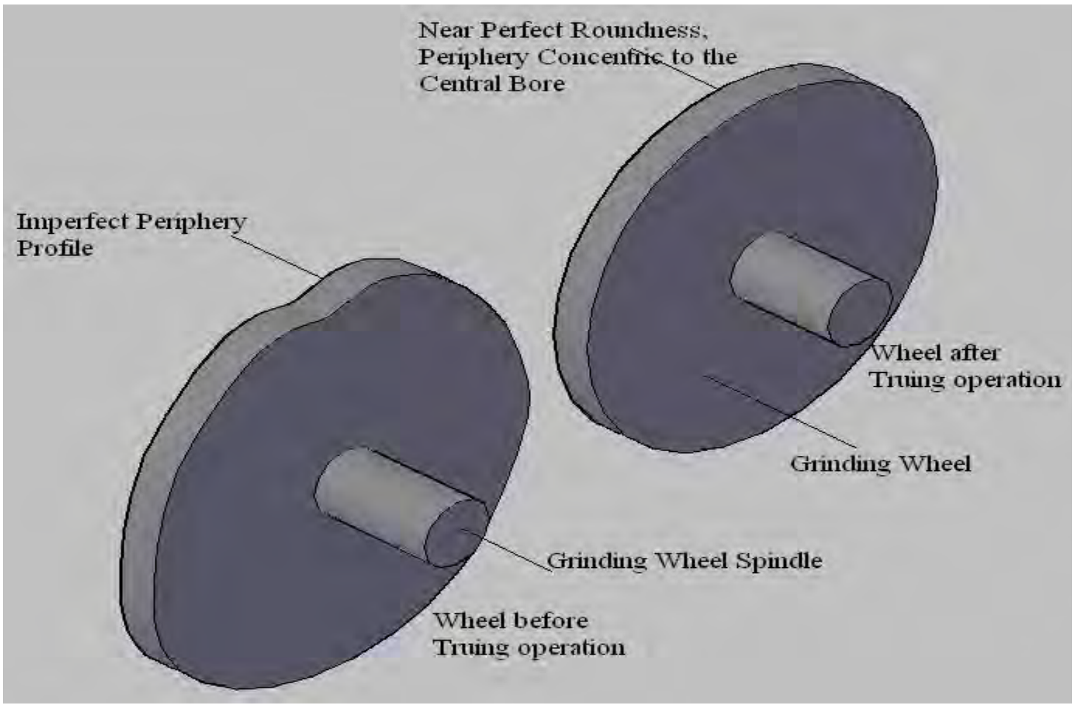

Fig. 2. Purpose of truing operation.

2. Conventional Dressing Operations

These dressing methods utilize tools that remain in contact with the grinding wheel until the operation is concluded. Therefore, these methods can be applied where dressing and truing is carried out at slow rates and involves small dressing forces. These operations are used where highly accurate dressing of grinding wheel and grinding operation is not desired. Also, the operations are carried at the operating speed of the wheel and cannot be used to generate complex profiles on the surface. They are widely used and are inexpensive when compared to the less used unconventional methods. Conventional methods cannot be applied in-process but have to be carried out using different set of tools before commencing the grinding operation. These methods come under the category of Mechanical Contact methods and are as follows:

2.1. Abrasive Sticks and Abrasive Wheels

Abrasive sticks and wheels are generally made up of same grit material, but of different binder material. They are held against the grinding wheel surface. To perform dressing, the abrasive sticks are run across the surface of the grinding wheel while it rotates. Abrasive wheels rotate in the direction opposite to the direction of rotation of grinding wheel. Abrasive wheels work at higher rate so they can dress at higher traverse rate (feed). These types of dressers come in various grit sizes and are chosen corresponding to grain size of the grinding wheel.

2.2. Disc Dressers

These dressers are in the form of metal discs that have number of projections (in the form of spikes) on the periphery (circumference). The dresser comes in contact with the grinding wheel and rotates. In this process, the projections dress the grinding wheel. Generally, a number of such discs are used together at a time mounted on a shaft. This type is used for grinding wheels with coarse grain size. Sometimes they are also referred as Star-Disc dressers and are generally made from hardened steel. The two types of discs commonly used in dressing are shown in Fig. 3.

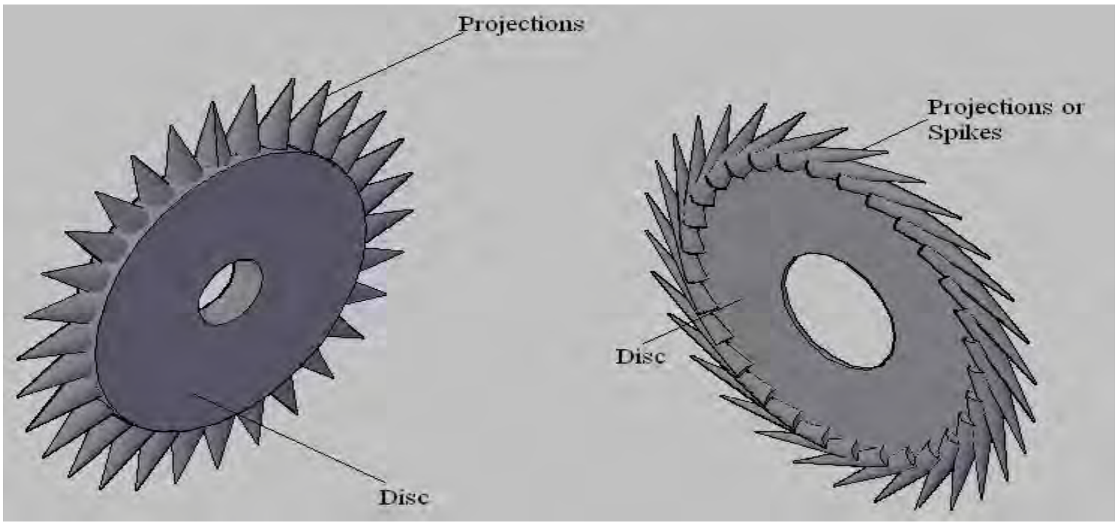

Fig. 3. Two types of discs used for disc dressers.

2.3. Diamond Dressers

As the name suggests, these dressers utilize a diamond which is mounted and installed on a holder. The two types of diamond dressers are shown in Fig. 4. The diamond is pointed (at one place only) in shape and the only point performs the dressing operation. The holder is inclined to the line passing through the centre of grinding wheel at an angle (known as drag angle) of 10 to 15 degrees. The use of diamond dresser is depicted in Fig. 5. Owing to high hardness and high brittleness, the diamond can be easily damaged by sudden loading, shocks and jerks. This type of dresser is used only for light cuts accompanied with light feeds. Coolant has to be supplied in most cases to eliminate overheating which prevents the dislocation of the diamond from its position in the holder. Diamond dressers are used for precise dressing where high accuracy of dressing of grinding wheel is required.

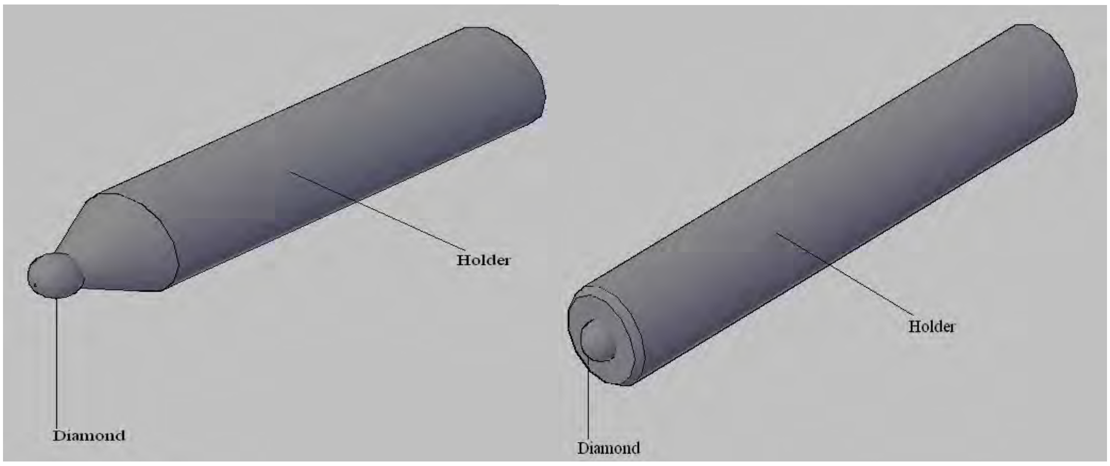

Fig. 4. Two types of diamond dressers most commonly used.

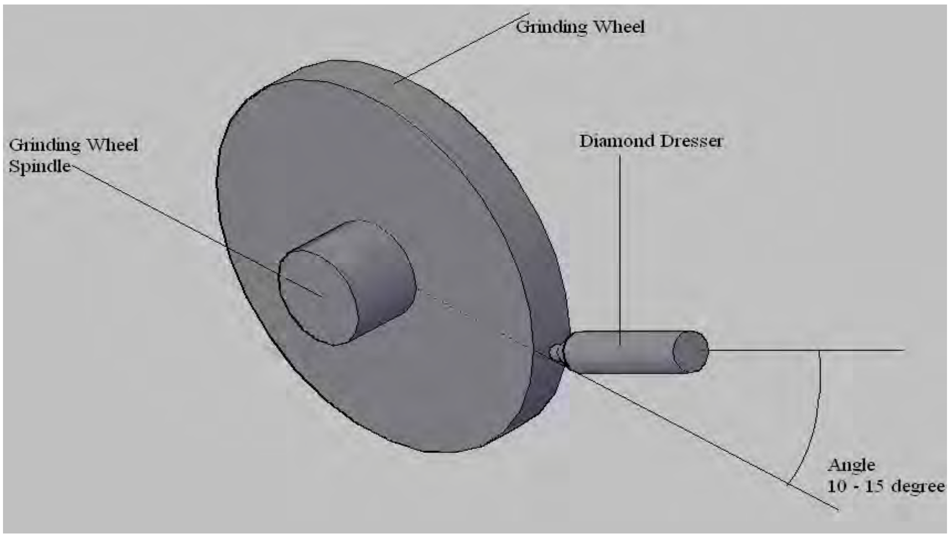

Fig. 5. Dressing of a grinding wheel by a diamond dresser.

2.4. Reactive Dressing

During the machining operation, the wheel becomes loaded and dull causing decrease in the cutting performance. Due to this, the process (machine tool) requires higher power to complete the operation. In this case, we increase the rotational speed of work as well as of the grinding wheel which causes the abrasives to fracture under large forces produced which generates new cutting edges. It also unloads the wheel thereby increasing its cutting ability.

3. Unconventional In-process Dressing Operations

Unconventional techniques differ from conventional techniques in respect of no physical contact between the grinding wheel and the tool. Unconventional processes are non-contact type. These processes perform dressing along (simultaneously) with the grinding operation without halting the machining operation i.e. in-process. This saves dressing time and improves the productivity of the machining operation.

Additional tools are required to be installed along with the grinding machine to perform simultaneous (in-process) dressing. The processes utilize heat or current to have desired protrusion of the abrasives and generation of new cutting edges. These methods are used for highly precise dressing and in cases where close tolerances of the form of a grinding wheel are to be maintained. These techniques are noted for their high efficiency which is subjected to the selection of appropriate parameter values. The major unconventional methods used for dressing are based on different non-traditional machining operations and are as follows:

(1) Electro-Discharge Machining based Dressing (EDM)

(2) Electrolytic In-process Dressing (ELID)

(3) Electrochemical-Discharge based Dressing (ECDM)

(4) Laser based Dressing

Method (1) mentioned above can be classified as electrothermal dressing method. Method (2) is a type of electrochemical machining (ECM) method. ECDM dressing uses the features of both ECM and EDM to dress and form a wheel. These methods are electrically dressing techniques that involve use of an electrode (non-contact type) and electric current. Process number (4) utilizes a laser to perform a similar operation.

3.1. EDM In-process Dressing

3.1.1. Principle of EDM dressing

EDM process is widely used for grinding wheels that are constructed with electrically conducting binding materials. EDM process uses an electrode as a tool that performs both truing and dressing. The action loosens the binder around the grain and allows desired grain (abrasive particle) protrusion on the surface by eroding the loose binding material. Abrasive grains are present on the surface of wheel; those being a non-conductor (insulator) of electricity are not affected by the process unlike the binder. This makes an abrasive grain open on all sides to expose all the cutting edges that impart better cutting performance to the wheel. This results in production of accurate geometry (truing) of the wheel with desired grain protrusion (dressing) which can be controlled by varying different parameters. The erosion of material takes only when discharging (striking of a spark) occurs. EDM technique is essentially used for truing of grinding wheel however grain protrusion can be controlled.

3.1.2. EDM process description

The process uses a Direct Current (D.C) supply with electrode having negative polarity. Due to the rotation of components, current has to be supplied using brushes that remain in contact with the spindle of the wheel. The electrode advances towards the wheel surface and a potential builds up between electrode and the surface. At an appropriate proximity, the potential becomes adequate for ionizing the gap. This breaks the dielectric medium present between the surfaces which allow the current to flow causing a spark (discharge) to be produced at the electrode surface. The spark strikes the surface of the wheel at very high speed, thus raising the temperature of the point which melts and vapourizes a small amount of metal binder. After the above action, the voltage drops to a stable value.

A fluid is used to flush out the molten metal particles produced in the electrode-surface interface thus leaving an indentation (crater) on the surface. Fluid used is a dielectric and is present continuously between the two surfaces. The fluid acts as a constant resistance in the current path and must be supplied constantly under pressure in the electrode-surface interface to erode molten material being produced. It also controls the temperature at the electrode-surface interface. Since the fluid bath cannot be used, fluid has to be supplied in form of mist from the nozzle.

Continuing the above operation we can have desired grain protrusion through continuous removal (erosion) of binding material. EDM performs truing as the binder is continuously eroded and abrasive grains are lost when sufficient binder to retain the grains is absent. EDM can also generate profiles on the wheel that are required for form grinding. The profile generated corresponds to the form of the electrode. EDM trues the surface with satisfactory grain protrusion over entire surface i.e. macro-geometry. It can be understood by referring to Fig. 6.

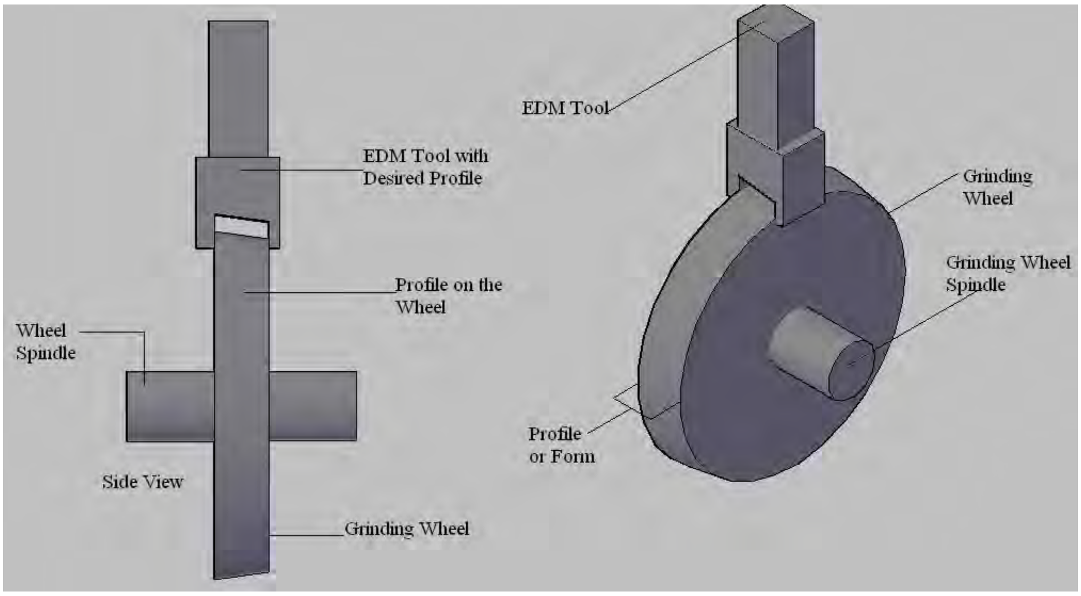

Fig. 6. Generating form using EDM operation.

3.1.3. Process specification and parameters

Copper, brass or graphite is preferred as electrode material because of their satisfactory performance, low cost, higher availability and ability to be formed easily in various profiles and shapes. Distilled Water, Kerosene Oil or Mineral Oil is used as dielectric fluid.

The space between surface and electrode (gap) must be maintained for the operation to continue and in case the electrode touches the surface, short-circuit occurs. Then electrode must be retracted quickly. Satisfactory range for gap in EDM technique is 0.015 to 0.500 mm. The frequency of sparks (number of sparks per second) can be controlled. Generally, spark frequency ranges from 20,000 to 3,00,000 sparks per second. Higher the spark frequency, higher is the material removal rate (MRR).

Other controlling parameter in EDM is gap voltage which varies from 35 to 70 volt. 70 volt of gap voltage is sufficient for ionization of the gap and breakdown of dielectric. Increased gap between surface and electrode requires higher voltages to achieve similar results. Increasing gap voltage also increases spark frequency.

3.1.4. Types of EDM techniques used

EDM is used in the form of Die-sinker EDM which is based on the same principle. Here an electrode is prepared which erodes the material on surface as it advances towards it. The profile (in the form of indentation) produced on the wheel surface corresponds to the shape and size of the cross-section of the electrode. (Refer Fig. 6.) Sparks are struck and erode the material as the tool (electrode) advances. Die-sinker EDM dressing is characterized by high wear of surface of the tool.

To eliminate above mentioned situation, Wire EDM (WEDM) technique has been developed. It has an electrode but in the form of a wire which is fed continuously through a spool. The wire is fed to a wire guide (in form of a disc with groove on the curved surface) that holds and positions the wire with respect to the grinding wheel. Fig. 7. Gives view of the guide. It provides damping that reduces deflection and vibrations. It also serves as a channel to the fluid. WEDM equipment setup is shown in Fig. 8.

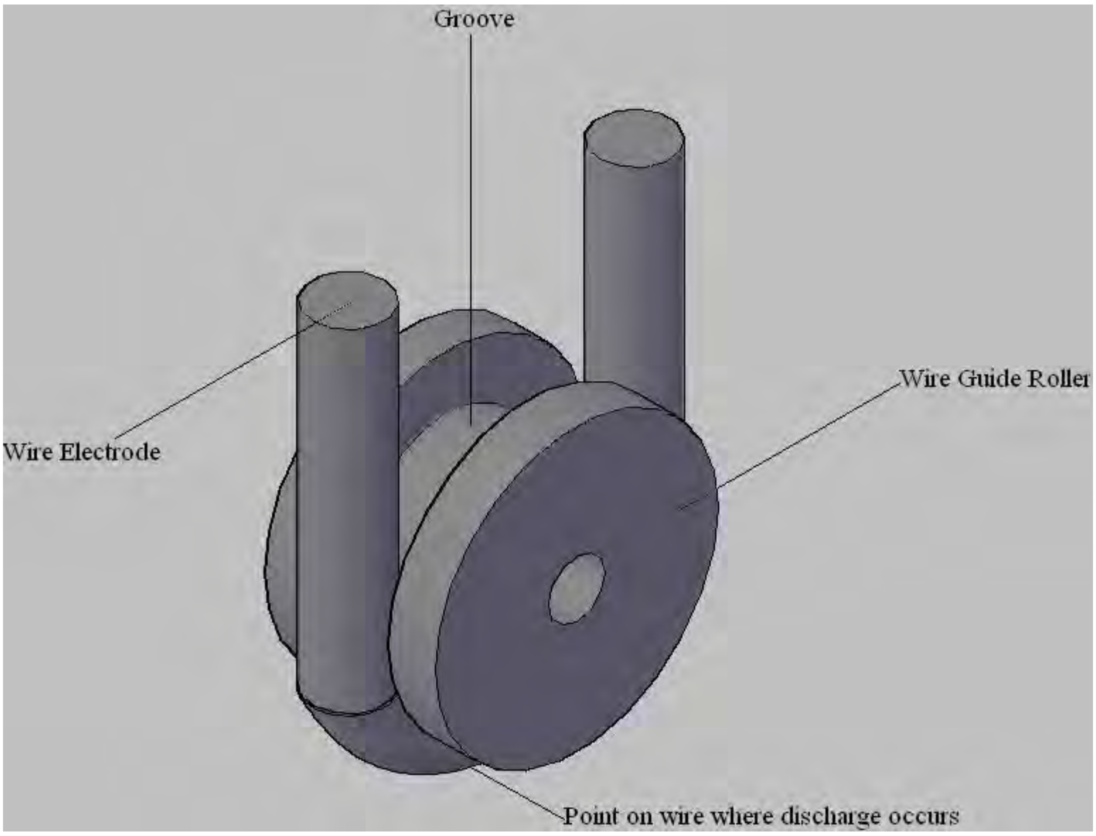

Fig. 7. Guide for wire electrode in EDM.

As the wire moves across the surface, it cuts (erodes) the material to generate a profile which gives form to the wheel. (Refer Fig. 9.) This process is characterized by higher MRR but the material removal takes place only at one point on the wire. WEDM requires control of feed rate of wire along with tension of wire [Rhoney, (2001)]. Spark Cycle (time interval between two consecutive discharges) is another parameter that has to be controlled to provide adequate time for the molten wire particles to escape the electrode-surface interface. Again copper or brass is preferred to manufacture Die-sinker electrodes and the wire element for WEDM.

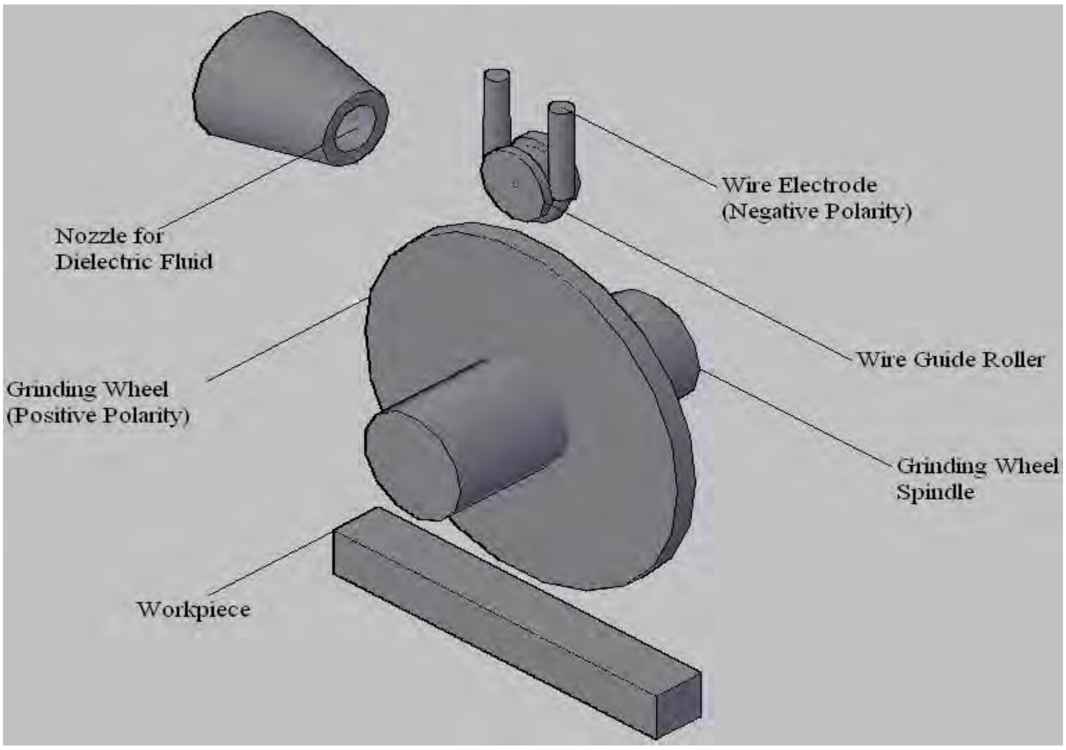

Fig. 8. Setup of WEDM equipment.

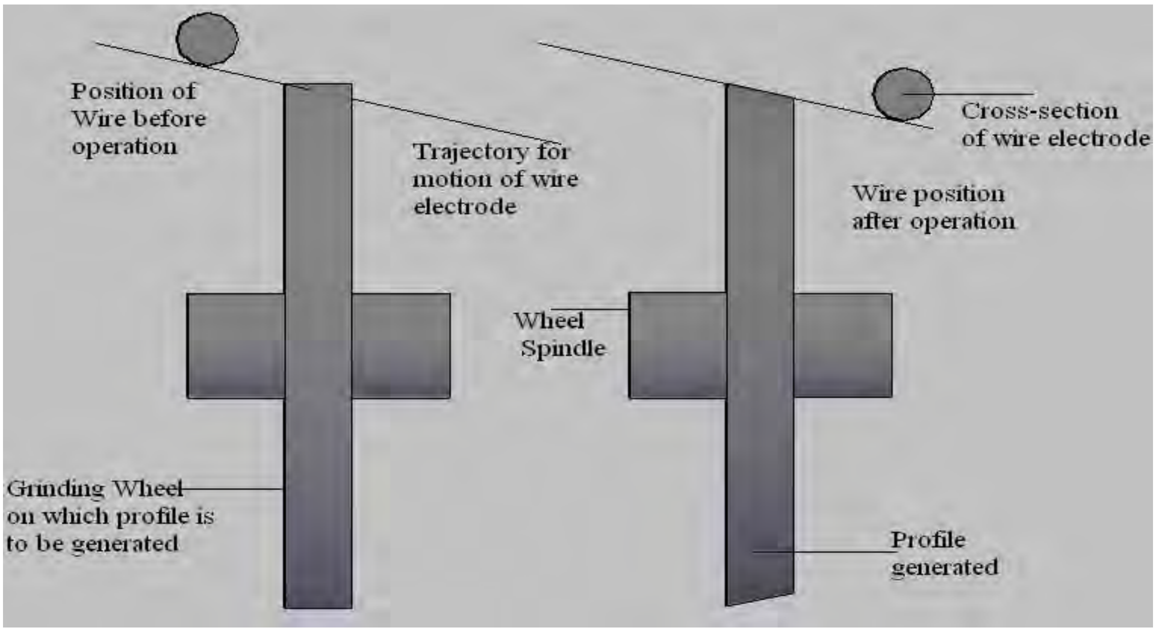

Fig. 9. Using of WEDM for profile generation.

3.2. ELID Grinding

3.2.1. ELID principle

ELID is based on laws of electrolysis and the dressing is performed by the electrochemical action. The grinding wheel dressed with ELID is a metal-bonded wheel that is electrically conducting metal binder. ELID tools and assembly can be installed on a conventional grinding machine as a subsystem. ELID uses an electrode which works as a tool that unloads the wheel and also controls the grit protrusion on the grinding wheel as the operation progresses. The surface roughness can be maintained throughout the operation. ELID removes the metal binder around the grains to expose them causing their protrusion on the surface. ELID is primarily used for dressing operation and not for truing.

3.2.2. ELID process description

ELID uses Direct Current (D.C) supply with electrode possessing positive polarity (as in case of electrolysis). Electrolyte is another imortant aspect of ELID which is used for providing a conductive path to the current. It also acts as a coolant and flushes the ions produced from the electrode-surface interface. Refer Fig. 10. For ELID process setup.

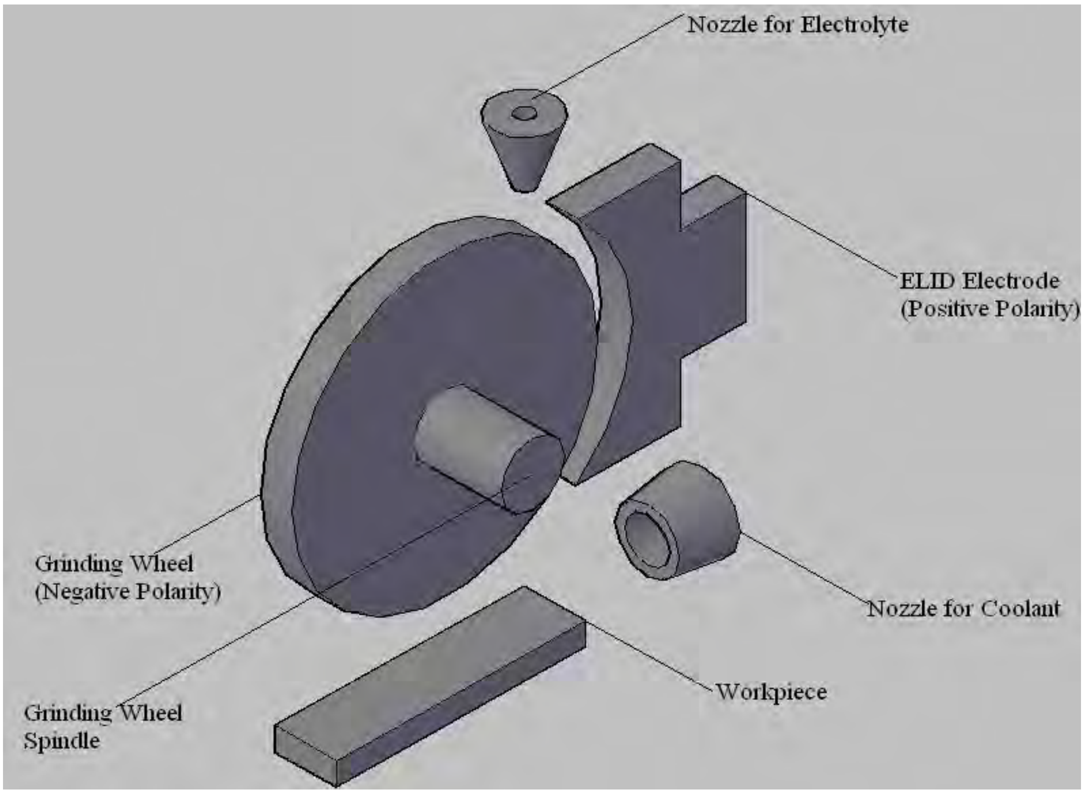

Fig. 10. Equipment setup for ELID operation.

ELID is accomplished in two stages. First stage commences with erosion and removal of binder material by the action of electrolysis that causes protrusion of the grains on the surface. With the progress in operation, an oxide layer gradually grows on the surface. It is the result of electrolysis and reduces the electrical conductivity of path of current. The oxide layer acts as an insulator which prevents further conduction of current and the voltage rises. Due to this action, the process of electrolysis (electrochemical action) ceases momentarily and the erosion of binding material stops. This step completes the first stage of the operation and is also referred to as Pre-Dressing.

The second stage follows which includes the grinding operation. As the grinding commences, the oxide layer developed on the surface wears out due to abrasive action of wheel thus exposing the binder underneath. Binder on coming in contact with the electrolyte resumes the electrolysis and the pre-dressing operation (first stage) starts. This entire cycle is repeated again with time to dress the wheel along with the grinding operation but with constant grain protrusion (macro-geometry) throughout. The entire dressing operation can be summarized in following chemical equations:

$$Fe \rightarrow Fe^{2+} + 2e^{-} \quad (1)$$

$$Fe^{2+} \rightarrow Fe^{3+} + e^{-} \quad (2)$$

$$H_2O \rightarrow H^{+} + OH^{-} \quad (3)$$

$$Fe^{2+} + 2OH^{-} \rightarrow Fe\,(OH)_2 \quad (4)$$

$$Fe^{3+} + 3OH^{-} \rightarrow Fe\,(OH)_3 \quad (5)$$

$$Fe\,(OH)_3 \rightarrow 3H_2O + Fe_2O_3 \quad (6)$$

The binder has Iron (Fe) present in its composition; it ionizes to form the ions Fe^{2+} and Fe^{3+}. (Eq. (1) and (2)) Water component present in electrolyte dissociates to form H^+ and OH^-. (Eq. (3)) In Eq. (4) and (5), Fe^{2+} and Fe^{3+} react with OH^- to form Iron Hydroxide (Fe $(OH)_2$ and Fe $(OH)_3$). These undergo further reaction (Eq. (6)) to produce oxide (Fe_2O_3) that covers the entire surface of the wheel.

3.2.3. Process specification and parameters

ELID electrodes are commonly manufactured using copper, brass, titanium or monel metal. ELID is affected by the surface finish of tool (electrode), so accuracy of the tool is a concern. Constant gap varying from 0.03 mm to 0.75 mm is satisfactory. Electrodes should be formed and placed such that the operation to replace the grinding wheel is not hindered.

Electrolyte plays a crucial role in the dressing operation. Commonly used electrolyte is water based saline solution. Salts like Potassium Chloride (KCl), Sodium Chlorate (NaOCl) or Sodium Fluoride (NaF) are used for special applications in the form of water based solutions. Electrolyte should possess high electrical conductivity as well as low viscosity. It is desired for easy removal of sludge of hydroxides formed during the operation. It is to be supplied under pressure from nozzles in the form of mist. Electrolytes also act as coolant and lubricant during the process and increase the process efficiency. ELID is affected by flow or supply rate of electrolyte. It is also influenced by the pH, conductivity and corrosive nature of the electrolyte.

3.3. ECDM Dressing

3.3.1. Principle and functioning

ECDM dressing technique combines the features of above discussed EDM and ECM (ELID is based on ECM). EDM is largely used for truing of grinding wheels whereas ECM is used for dressing operation. With ECDM, both dressing as well as truing is carried out in one step, thus a saving on time. This technique can be easily applied to metal-bonded grinding wheels.

The process uses two electrodes with Alternating Current (A.C) supply. One electrode is used for EDM operation and other electrode is for ECM. One electrode can also be used which performs ECM and EDM operations but alternatively. EDM process ensures proper formness of the wheel and ECM is responsible for satisfactory grit protrusion on the surface. The schematic depiction of ECDM process is shown in Fig. 11.

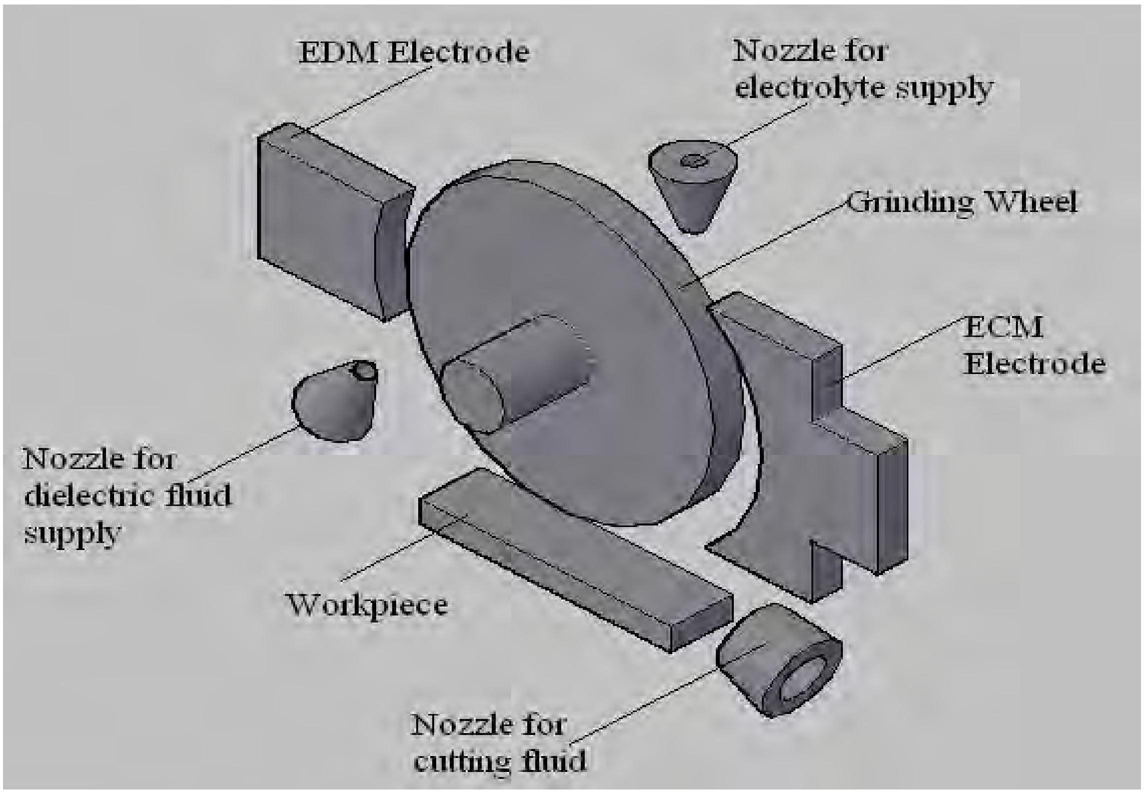

Fig. 11. Setup of equipment for ECDM operation.

The fluid is a crucial element of ECDM and requires special manufacturing because it serves as an electrolyte for ECM and also a dielectric for the EDM technique. Additionally, it serves the purpose of a coolant as well as a lubricant.

3.3.2. Process desciption and parameters

The ECDM process starts with the pre-dressing cycle during which large current is drawn and large number of sparks are struck. An oxide layer is deposited on the electrode surface owing to the use of A.C supply. Pre-dressing is followed by dressing cycle that draws small amount of current. High frequency of the supply results in shorter spark duration.

The electrodes are made of copper metal and the gap between electrode and surface is maintained in the range of 20 to 200 microns. Power supply is limited to 50V at normal mains frequency.

The ECDM process produces more accurate profiles and high average grain protrusion than the conventional methods. The grain protrusion in one case studied was approximately 75% of average grain size [Schöpf *et al.*, (2001)]. A deviation of 0.37% was observed in a similar case [Sudiarso and Atkinson, (2010)]. This ensures high roundness (form) of the grinding wheel.

3.4. Laser Dressing

3.4.1. Principle and description of Laser dressing

The process of Laser Dressing uses a solid state laser, Nd: YAG (Niobium doped Yttrium Aluminum Garnet) laser. This technique can be used in-process that saves dressing time which increases productivity of the process. Laser dressing has been studied for vitrified bonded and resonoid bonded grinding wheels [Babu *et al.*, (1989)] and for metal bonded wheels [Hoffmeister *et al*., (2000)]. Laser can be effectively used for dressing purpose as well as truing.

The principle of laser dressing is to heat and vapourize the metal binding material. Instant solidification of molten material (binder) occurs, so an air jet is requird through a nozzle to remove the molten metal from the interface. This allows the protrusion of the grits on the surface which can be controlled. Use of air jet also prevents thermal damage to binder and abrasive grains. Due to high viscosity of molten metal, it is not completely blown out of the crater and part of it solidifies at the crater edge after blowing. Conventional dressing or cutting tools can also be used to remove the molten binder material. Laser dressing principle is shown in Fig. 12.

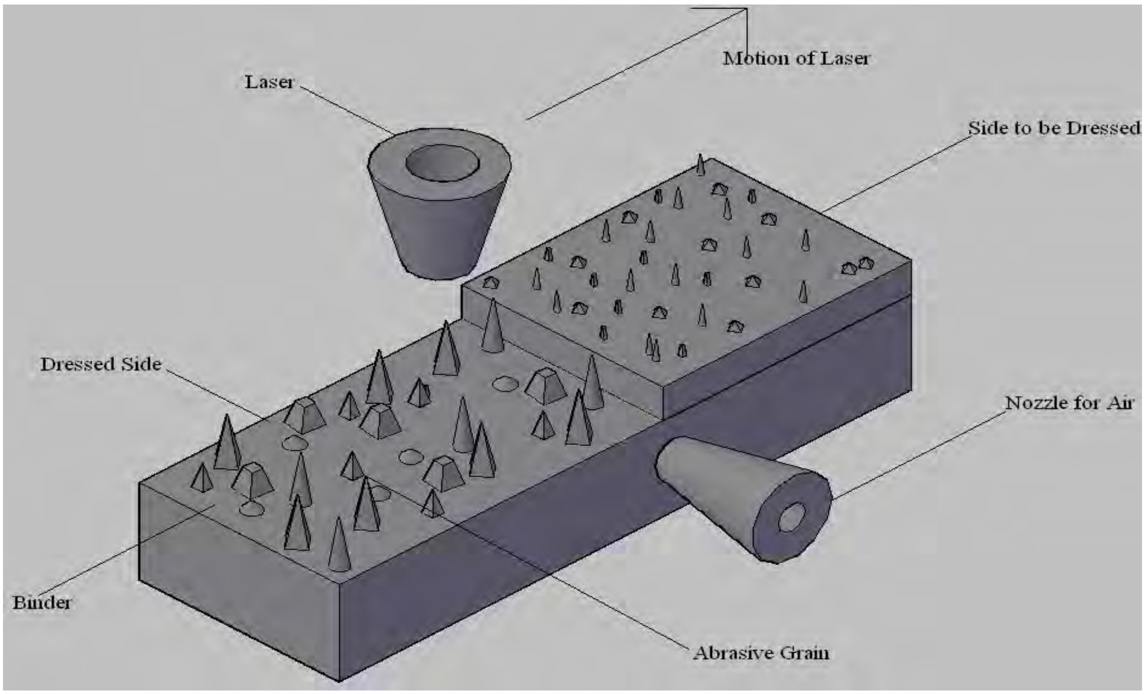

Fig. 12. Principle of laser dressing.

3.4.2. Laser dressing parameters

With the increase in laser power, amount of material (binder) removed increases i.e. increase in the dressing depth. Decreasing laser power does not create shallow indentation as re-solidification takes place instantaneously. Defocussing is useful in reducing dressing depth and increasing dressing region per pulse [Hosokawa *et al.*, (2006)].

Binding material thermal damage is present at a particular limit of laser power (intensity). Exceeding this limit results in loss of abrasive grains due to affect of heat on binding ability of binder. Abrasive grains do not suffer thermal damage at this laser power level. However, thermal damage of grains, residual stresses in grains increase with furthur increase in the laser power beyond a critical level.

It has been studied for bronze-bond diamond stone wheel using Nd: YAG laser, laser power 104 W is the limit for thermal damage to binder. Increasing power level beyond 152 W (critical level) results in graphitization and thermal damage to the diamond abrasives [Hosokawa *et al*., (2006)].

4. Results and Discussion

In this review paper, by studying and analysing all the dressing procedures, comparisons can be done between any two processes based on a number of factors. The factors can be economics, efficiency, accuracy, effectiveness, productivity or complexity of the process. Comparison can also be in the terms of cutting forces, wear of wheel or tool, wear of wheel during grinding, MRR or rapidity (pace of working) of the dressing process. The selection of dressing procedure also depends upon the properties of the grinding wheel such as type of abrasive type, abrasive grain size, density of grit and type of binder. So the comparisons are as follows:

4.1. Comparison of Conventional and ELID/EDM Dressing Techniques

(1) The conventional dressing tools cannot perform dressing or truing in-process. It has to be performed seperately on a machine dedicated for dressing or truing which is time consuming. On the other hand, ELID/EDM can be integrated as a subsystem on a conventional grinding machine tool that carries dressing or truing simultaneously. This cuts down the time required for separate dressing. This increases productivity and decreases cost of the operation.

(2) Conventional methods are contact type that results in large dressing force due to which grains become flat. Use of such dressed wheels dissipates heat and requires large power to function (due to low cutting ability of grains). The abrasives on grinding wheel come in direct contact with abrasive particles on dressers which cause mechanical damage to the grit. Unconventional methods have no physical contact so above mentioned shortcomings are overcome.

(3) There is non-uniform wear in the conventional dressing tools which is responsible for inaccuracy and low precision of the truing process. The grain protrusion in this case becomes uneven and irregular on the entire surface and deviates from the average value.

(4) ELID/EDM dressed wheel produces 20% to 40% less grinding force than a conventional dressed wheel due to higher grit protrusion in former dressed wheel [Rhoney, (2001)].

(5) Conventional dressing tools need to be conditioned frequently as wear is high due to mechanical contact. ELID/EDM electrodes also need conditioning to maintain their accuracy, but the frequency of such operation is very low.

(6) EDM techniques can be used to generate profile and forms on wheel surface very easily. Profile generation in case of conventional process requires many passes of the tool over the surface. Profile produced still lacks accuracy.

4.2. Comparison of Conventional and Laser Dressing Techniques

(1) Laser dressed grinding wheels produce lower grinding forces when compared with conventional dressed wheels. It is due to production of better chip pockets due to laser ablation on the surface [Rabiey *et al.*, (2012)]. It is also due to the fact that abrasive grains on the wheel become flat on coming in contact with tool in case of conventional dressing. Laser dressed wheels produce less heat and require small force during grinding operation.

(2) The wear of the laser dressed grinding wheel during grinding is higher when compared to conventional dressed wheel. The wear is high in the beginning and then stabilizes. This characteristic may be attributed to self-sharpening capability of wheel [Rabiey *et al.*, (2012)].

(3) Tangential forces observed during the grinding operation are lower for laser dressed wheel but there is not much difference in the normal forces for both conventional as well as the laser dressed wheels. Due to lower tangential forces, cutting is effective in laser dressed wheels which results in lower specific grinding energy of the process and long term stability of the grinding conditions is ensured [Rabiey *et al.*, (2012)].

(4) There is negligible difference between the material removal rate (MRR) of laser and conventional dressed wheels during grinding. However, machining in case of laser dressed wheel takes place with lower grinding forces.

(5) The dressing depth (crater depth) is a function of laser power and the speed of revolution of grinding wheel during the dressing operation [Rabiey *et al.*, (2012)]. With increase in the power of laser, the crater depth increases so the operation can be carried at high speed, making the process faster.

(6) Laser dressing operation is uneconomical in contrast with the conventional dressing method and requires indepth study of economics. The laser dressing operation can be made effective by selection of appropriate values for the parameters of the process.

4.3. Comparison of WEDM and Die-sinker EDM Dressing Techniques

(1) WEDM is an improvement over Die-sinker EDM method. Die-sinker EDM is characterized by very high electrode wear. Since the material removal takes place over entire cross-section of the electrode, wear is high. With high electrode wear, precision and accuracy is of concern in die-sinker EDM.

(2) Die-sinker process has higher efficiency in comparison with WEDM as material removal takes over entire cross-section. This also results in faster dressing operation in case of die-sinker EDM.

(3) WEDM suffers from use of specific tools and equipment and is generally performed on a separate system rather on an integrated WEDM system on a conventional grinding machine, unlike die-sinker EDM method.

(4) Since the electrode wear is high in die-sinker EDM, the electrode requires frequent grinding to maintain the form and accuracy. In case of WEDM, electrode does not require the grinding operation.

5. Conclusion

This paper primarily aims at dressing methods but also indicates the benefits of dressing. Dressing enhances the life and cutting ability of the tool which eliminates frequent replacement of wheels. This saves a lot of material and also reduces wheel replacing time which ultimately affects our costs. With in-process dressing, the wheel retains the cutting capacity for long which increases the productivity and cuts down on the labour costs. In the broader sense, a dressed wheel consumes less power to operate that also reduces our costs. So with a small investment in dressing, many benefits can be gained.

After the above discussion we can also deduce the following conclusions. Conventional methods are effective for wheels with coarser abrasive grains and has vitrified bond, since abrasives on a dresser can easily erode the vitrified bonding. When grinding with the wheel is tolerable with low accuracy and poor surface finish, conventional methods are preferred that are low cost and slow operations. However, their ability is lost against very hard metal-bond. In this case, EDM/ELID is used that takes advantage of conductivity of the bond material and erode binder with discharges (sparks). The wheel dressed has better roundness (form) and grinding with it takes place with enhanced accuracy and surface finish. The operation is less economical but the efficiency and the speed of operation remains high.

Laser is preferred in cases where accuracy, precision along with very high surface finish is the only concern. The process is very fast and is applied to wheels with resin-bond or metal-bond (these wheel types work at very high speed and produce very high finish). The dressed grinding wheel is used for special purposes only. Diamond is preferred as an abrasive because it resists thermal damage (graphitization, residual stresses and micro-cracks) effectively owing to its high hardness. The process needs to be carefully studied for its effective operation and economics (since this process is very expensive).

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