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IMPROVING GRINDING PERFORMANCE WITH THE USE OF GRINDING FLUID LEADING TO GREEN MANUFACTURING

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ABSTRACT

Grinding is characterized by high specific energy requirement along with high heat generation at the grinding zone. High grinding zone temperature causes high wheelloading and wear, and possible damage to the work surface. In the present work, effects of different grinding conditions, such as dry, compressed air, ice cooled compressed air and compressed CO_2 environment on surface grinding of low alloy steel specimens with disc type alumina wheel are investigated at 10 micron infeed. From experimental results, it is found that tangential force reduces more under compressed air, but normal force reduction is more for ice cooled compressed air than other conditions. It is found that with ice cooled compressed air, wheelloading is the least of all other conditions. Force ratio is also found maximum at ice cooled compressed air condition showing good grindability, and hence, can be recommended to use as an eco-friendly grinding fluid.

Keywords: Surface Grinding, Grinding Fluid Application, Grindability.

1. INTRODUCTION

Performance of grinding operation is dependent on several parameters [1-4], such as type of abrasive, grain sizes and their distribution, type of bonding material, grinding velocity, table speed, infeed, dressing condition, application of grinding fluid, etc. Grinding is characterized by low material removal rate, high specific energy, force, and heat generation. Most of the specific energy required in grinding is converted to heat, and it causes bad effects on both the wheel and workpiece.

A number of attempts have been made in the past to control high localized temperature inside the grinding zone. They include the application of conventional flood cooling, Z-Z method of cooling, mist cooling, jet cooling, etc. [2,3,5]. Although, profuse, flood cooling with synthetic oil is widely applied conventionally, majority of it is wasted. Main reason behind this is the formation of a stiff air layer around the rotating wheel, creating a major obstacle to achieve good grinding performance [1-3,6-8]. This air layer prevents the applied grinding fluid to enter the grinding zone. To suppress bad effects of the stiff air layer, many methods have been tried.

Kundu and Das [9] used painted wheels and a scraper board fitted just ahead of fluid nozzle to penetrate the stiff air layer around the wheel. They observed a reduced wheel wear rate and an increased grinding ratio with a painted wheel. Deeper penetration of grinding fluid was also reported possible by Sharmacharya et al. [10] and Das et al. [11] with rexine pasted wheel and appropriate selection of fluid jet velocity. Catai et al. [8] tried to optimize the application of cutting fluid through grinding zone to reduce thermal problems by an aerodynamic deflector to eliminate the stiff air layer generated around the grinding wheel.

Mandal and others [7,12] and Wu and others [6] carried out detailed experimental study on the air layer pressure distribution and Mandal et al. [12] observed that rexine pasted wheel causes substantial suppression of the air layer formed around the wheel periphery. Special type of fluid delivery system [13], pneumatic barrier assisted fluid delivery system [14,15], and use of high velocity coolant jet [16] were reported to give benefits in grinding in terms of controlling grinding temperature. Choi et al. [17] investigated the usefulness of using compressed air and a coolant in cylindrical grinding with a cBN wheel, whereas Nguyen and Zhang [18] employed cold air along with oil mist for effective reduction of grinding temperature and its bad effects.

However, of late, use of synthetic oil as the grinding fluid is not encouraged. Synthetic oil based grinding fluid is harmful to the operator, and causes environmental pollution. Paul and Chattopadhyay [19,20] utilized liquid nitrogen to supply to the grinding zone through a specially designed nozzle to observe great benefits in surface grinding of different steels maintaining eco-friendly environment. Compressed cold air was also tried as coolant by Choi et al. [21] in cylindrical grinding with alumina and CBN wheels.

In the present work, investigations are made to find out the effect of different environment employing dry condition, compressed air, compressed CO_2 and ice cooled compressed air conditions on surface grinding of low alloy steel specimens. Grinding tests are done with a disc type alumina wheel at an infeed of 10 μm without using synthetic oil, thereby maintaining an environment-friendly system.

2. EXPERIMENTAL DETAILS

In the present work, an alumina grinding wheel (specification: AA46/54K5V8, size: ϕ200 mm x 13 mm x ϕ31.75 mm) is used on Maneklal & Sons, India make surface grinding machine to perform grinding of low alloy steel specimens under different environmental conditions with 10 μm infeed and 6.7 mm width of cut. Details of the experimental conditions are shown in Table 1. Upgrinding mode is maintained throughout the experiment. The grinding machine and the setup for experimentation are shown in Fig. 1.

Table 1: Experimental conditions

Machine tool	Surface Grinding machine Make: Maneklal & Sons, India Model: Parrot (600x200) Main motor power: 1.5 kW
Grinding wheel	Specification: AA46/54K5V8 Make: Carborandum Universal Limited, India Size: ϕ200mm x 13mm x ϕ31.75 mm
Workpiece details	Material: Low alloy steel Composition: 0.17% C, 0.21% Si, 0.63% Mn, 0.001% Ni, 0.002% Cr Size: 118 mm x 60.7 mm x 6.7 mm
Dressing details	Dresser – Single point 0.5 carat diamond dresser Dressing depth - 30 μm Dressing speed – 0.36 m/min
Experimental Parameters	Grinding wheel velocity: 30 m/s Table feed: 4.5 m/min Width of cut: 6.7 mm Infeed: 10 micron
Environmental conditions	Room temperature: 33°C to 34°C 1) Dry 2) Compressed air Nozzle diameter: 4 mm Air pressure: 20 kPa Valve opening: 100% Nozzle exit temperature: 20°C 3) Compressed CO_2 Nozzle diameter: 2.38 mm Air pressure: 1.2 kPa Volume flow rate: 0.015 m^3/min Nozzle exit temperature: 30°C 4) Ice cooled compressed air Nozzle diameter: 4 mm Air pressure: 20 kPa Valve opening: 100% Nozzle exit temperature: 10°C

For obtaining the ice cooled compressed air, a properly insulated thermocol make box (Fig.2) is used. The copper tube of 4 mm ID, 5 mm OD and 3.8 m length is placed inside the box and then the box is filled with ice. Both ends of copper coil are connected to two pneumatic pipes by means of pneumatic pipe connectors. One of the pneumatic pipes gets connected to the Elgee make air compressor and the other pipe exit is used as a nozzle. The nozzle is attached and positioned 10 mm above the ground surface and directed towards the grinding zone. Radial gap between the pneumatic nozzle and the grinding wheel is maintained 10 mm. The same nozzle position is maintained for compressed CO_2 condition. A pressure gauge is used for measuring applied pressure.

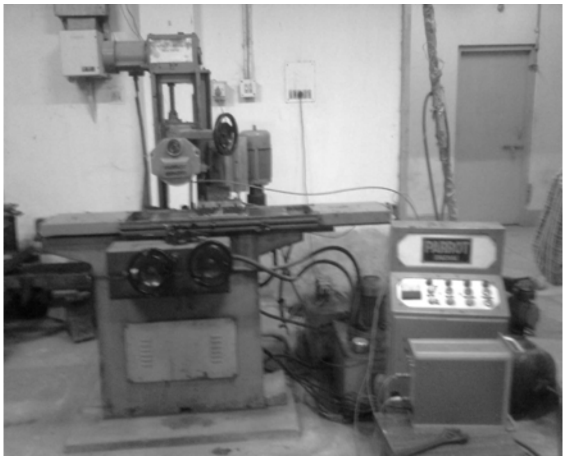

Fig 1. The Experimental Setup

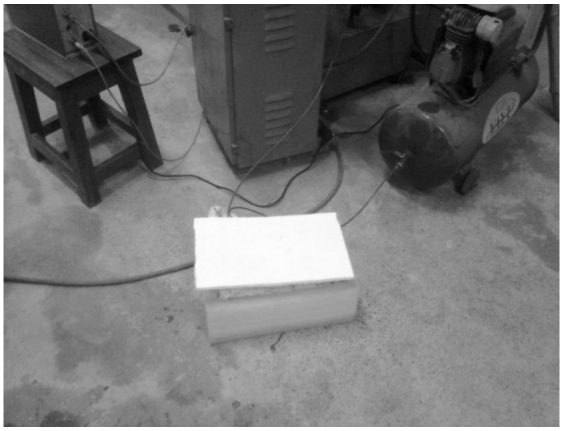

Fig 2. The cooling setup

Wheel speed of the grinding machine is 2900 rpm, for which surface cutting velocity becomes 30 m/sec. Sushma make force dynamometer (model no. SA116) with a range of 100 gm-100 kg and a resolution of 100 gm is used to measure the two grinding force components. A thermometer is used to measure the nozzle exit temperature, and a Mitutoyo, Japan make tool makers microscope (model: TM 510) is employed to observe types of grinding chips.

Variation of grinding forces and force ratio under dry grinding, compressed air, ice cooled compressed air (both at an air pressure of 20 kPa) and compressed CO_2 (at an air pressure of 1.2 kPa) on the surface grinding of low alloy steel specimens with a disc type alumina wheel are studied for 20 grinding passes. After each set of 20 passes, dressing is performed on the grinding wheel using a single point 0.5 carat diamond dresser with infeed of 30 µm.

3. RESULTS AND DISCUSSIONS

In the present experimental investigation, tangential and normal force components are measured for each of the twenty passes under four different environment during upgrinding with an infeed of 10 µm.

For dry grinding, variation of both components of grinding force with the number of passes is plotted in Fig 3. Initially, for four passes, there is a steady increase in forces. At the end of initial four passes, self sharpening occurs causing a decrease in forces. This is evident through the changing pattern of spark intensity noted during experimentation. After the process stabilizes after four passes, forces are almost uniformly maintained. In this case, presence of side burr and exit burr, presence of longitudinal lay marks, low wheelloading, and no surface burn are found. At 10 µm infeed, it is expected that force, heat generation, wheelloading and occurrence of surface burn would be less compared with that at high infeeds.

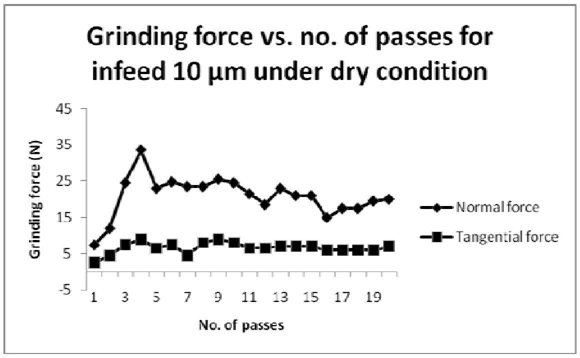

Fig 3. Variation of grinding forces with number of passes under dry condition

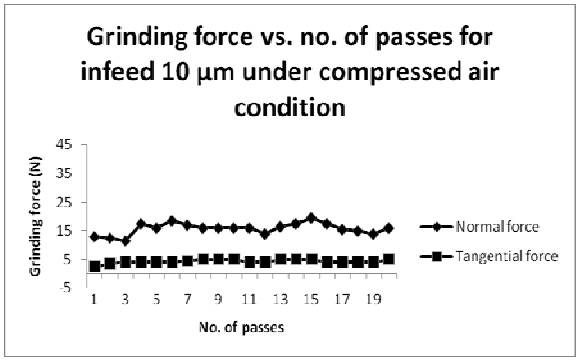

Fig 4. Variation of grinding forces with number of passes under compressed air condition

For grinding under compressed air condition, variation of tangential and normal force components with the progress of grinding passes are shown in Fig 4. Substantial reduction in force componets are noticed in this case compared to that under dry condition indicating some cooling action with the use of compressed air. In this condition, lesser side burr than dry grinding is found; presence of exit burr is also noticed. Almost no wheelloading, longitudinal lay marks and no surface burn are found during grinding with compressed air.

Under compressed CO_2 environment, changes in forces with the increase in grinding passes are depicted in Fig 5. In this case also, remarkable decrease in grinding forces is observed in comparison with that at dry condition. In this case, there is a steady increase in grinding force components up to five grinding passes till the process stabilizes. Presence of exit and side burrs are noticed at this condition, but these are less compared to both dry and compressed air conditions. Wheelloading observed was less than dry grinding and more than compressed air condition. No surface burn and presence of longitudinal lay marks are also seen on the ground surface.

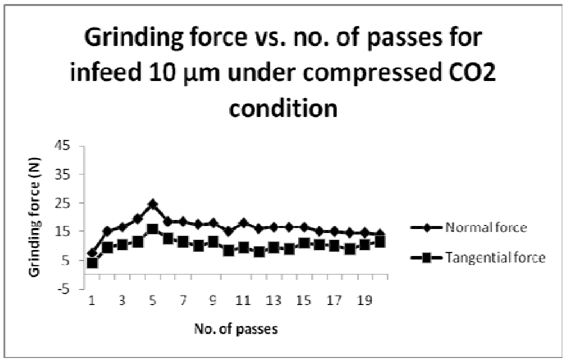

Fig 5. Variation of grinding forces with number of passes under compressed CO_2 condition

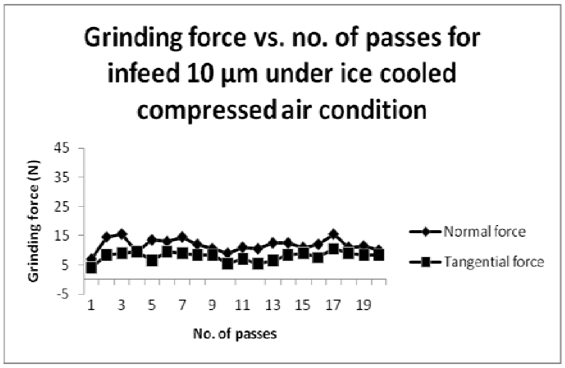

Fig 6. Variation of grinding forces with number of passes under ice cooled compressed air condition

Carbon dioxide being a relatively inert gas is used in this study to protect the grinding zone from possible oxidation of the chip, etc. such that temperature rise may be restricted. However, compressed CO_2 does not render cooling action to a considerable extent. Delivery gas pressure here is quite less compared to compressed air supply condition, and may have not penetrated the stiff air layer for effective cooling.

Fig 6 shows changes in forces under ice cooled compressed air condition with the change in grinding passes. Under this condition, substantial reduction in tangential and normal components of grinding forces is found out compared to other three conditions. Combined effects of air blast and cool atmosphere may have caused this benefit by lowering the grinding zone temperature. This effect also supports the fact that wheelloading in the case of ice cooled compressed air condition of grinding fluid is observed to be the least of all other conditions considered in the present experimental study. Exit and side burrs noted during grinding under this condition are found to be lesser than compressed air condition without ice cooled. Lesser grinding force, wheelloading and grinding zone temperature may be the possible reason behind this. Presence of longitudinal lay marks and no surface burn are also observed during grinding with ice cooled compressed air as seen in other three environmental conditions.

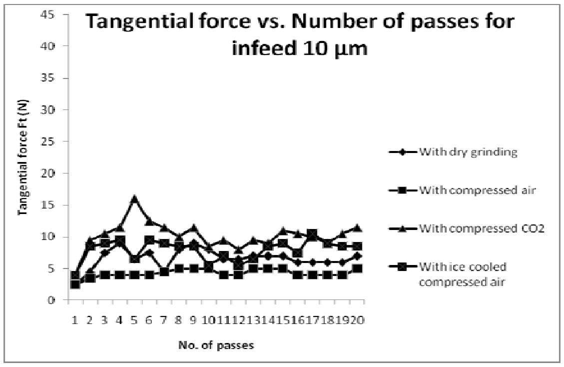

Fig 7. Comparison of tangential component of cutting force under different environmental conditions

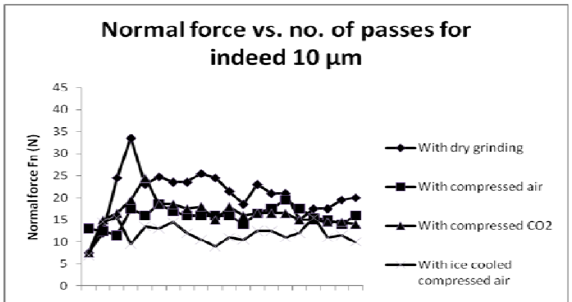

Fig 8. Comparison of normal component of cutting force under different environmental conditions

Fig 7 and Fig 8 clearly show that compressed ice cooled air requires the least tangential and normal components of grinding forces respectively. Normal component of grinding force, as seen from Fig 8, is high in dry grinding, while tangential component of force (Fig 7) is not that high. This indicates less force ratio, as also is seen in Fig 9, and involvement of large amount of hollow spherical type chip formation (Fig 10), and higher temperature rise at the grinding zone naturally. Force ratio is obtained by dividing tangential force component by normal force component, and a high force ratio indicates good grindability.

From Fig 9, it is noticed that under ice cooled compressed air condition, on the whole, high force ratios are there indicating good Grindability. Comparable force ratios are observed for compressed CO_2 condition. However, compressed CO_2 condition requiring high force values, may not be considered to have comparable grindability with that of ice cooled compressed air condition. Dry and compressed air conditions are showing to have considerably lesser force rations than the other two conditions, and hence, have less Grindability considering its force requirement, etc.

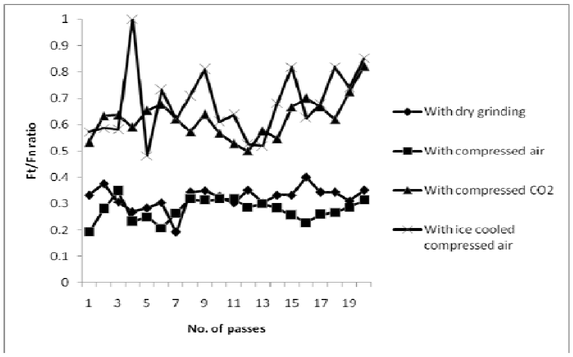

Fig 9. Variation of force ratio with the increase in grinding passes under different environmental conditions

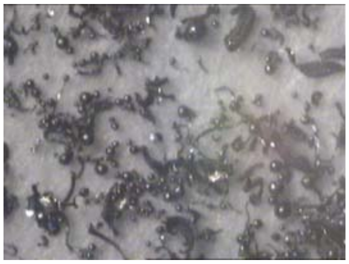

Fig 10. Chips obtained under dry grinding

Photographs of grinding chips collected as seen under a microscope are shown in Fig 10 through Fig 14. Large scale hollow spherical chips are obtained in dry condition expectedly due more force requirement and heat generation, and less cooling action. Few shear type leafy chips are also seen as shown in Fig 10.

Chips observed in Fig 11 under compressed air condition are again mostly of hollow spherical type indicating high generation of heat due to exothermic oxidation reaction that is responsible for formation of hollow spherical chips. Few shear type leafy chips are also obtained.

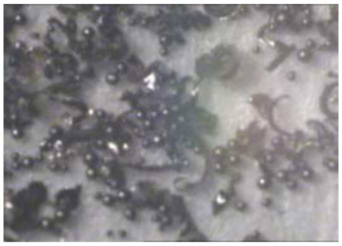

Fig 11. Chips obtained under compressed air condition

Fig 12. Chips obtained under compressed CO_2 condition

Fig 13. Chips obtained under ice cooled compressed air condition

Photograph of chips obtained in compressed CO_2 condition shows (Fig 12) presence of small to large sizes of spherical chips and shear type leafy chips. It indicates not-so-significant temperature control under this condition also.

When ice cooled compressed air is supplied during grinding, few hollow spherical chips, few leafy shear type chips and few blocky fragmented type chips are formed, as depicted in Fig 13.

Although, differences in kind of chip formation cannot be quite conclusively conferred, further grinding experiments with different infeeds, table speeds may be conducted to find out a clear trend. At the present case, the nozzle exit temperature of the ice cooled air is only 20°C, and this temperature may be further brought down by some means to achieve better temperature control.

4. CONCLUSION

From the results, the following conclusions may be drawn.

1. It is found experimentally that with ice cooled compressed air, wheelloading is quite less compared to other conditions, and maximum wheelloading is observed in dry grinding.
2. Compressed CO_2 gas has not much beneficial effect in improving the grinding performance at the present condition. Possible reason may be low nozzle exit pressure.
3. It can be said that tangential force reduction is more for compressed air than ice cooled compressed air. However, normal force reduction is more for ice cooled compressed air than compressed air indicating better Grindability. This is also supported by the fact that force ratio is maximum at ice cooled compressed air condition, thereby showing its applicability maintaining eco-friendliness.
4. Further experimental works may be undertaken to have lower temperature of compressed air to supply to the grinding zone to have comparatively good grinding performance leading to green manufacturing system.

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