GRINDABILITY OF INCONEL-600 UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

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ABSTRACT

Grindability is considered as a measure of the ease by which a material can be ground with minimum effort and without incurring surface damage. The grindability of Inconel-600 alloy is generally considered to be poor because of its low specific heat, low thermal conductivity, high chemical reactivity and greater affinity with the materials used for common grinding wheels. In this work, Inconel-600 alloy is ground by alumina wheel at an infeed of 20 micron under dry, wet and wet with pneumatic barrier conditions. Pneumatic barrier is used to break the stiff layer formed around grinding wheel. The effect of different environment conditions has been investigated in respect with grinding force, chip formation and wheel condition. The experimental result shows that the grinding forces as well as wheel wear are reduced and favourable chip formation occur in pneumatic barrier setup conditions.

Keywords: *Alumina wheel, Grindability, Inconel-600, Pneumatic barrier, Stiff layer*

I. INTRODUCTION

Grinding is a well known process in manufacturing, and it is widely employed mainly for finishing jobs with high dimensional accuracy and surface finish. In grinding, work material is removed in the form of micro chips by sharp and hard abrasive grits. These grits are being strongly held in a circular wheel by suitable bond materials. The process of grinding depends on the inherent properties of the grinding wheel, such as types of abrasive, the size and distribution of grits, amount and types of bond material and volume of pores related to that of grits and bonds [1].

A superalloy, or high performance alloy, is an alloy that exhibits excellent mechanical strength and creep resistance at high temperature, good surface stability, corrosion and oxidation resistance. Nickel-based super alloys (Inconel-600) are widely used in aeroplane and nuclear industries owing to its high-temperature mechanical properties, and high resistance to corrosion and oxidation [2]. The problems that arise during grinding of Inconel-600 alloy are attributed to high specific energy and high grinding zone temperature due to poor thermal properties of Inconel-600 alloys. The high temperature produced in the grinding zone can caused various types of thermal damage to the workpiece such as, surface burn, micro-cracks, plastic deformation, phase transformation high tensile residual stress on the work surface, and high wheel loading.

Extensive researches were conducted on grinding of super alloys over past 30 years to control thermal related problems. Various techniques were tried to reduce temperature during grinding process. These include application of conventional flood cooling, Z-Z method of cooling, mist cooling, and cryogenic cooling, etc. Flood cooling system is commonly used in industry, to control grinding zone temperature. But flood cooling system is not capable enough to deliver grinding fluid satisfactory into grinding zone due to presence of stiff air layer around rotating grinding wheel [3]. Due to high speed of porous wheel stiff layer around the wheel is generated. This air layer prevents the applied grinding fluid to enter the grinding zone. Engineer et al. [4] developed a test rig. Using the rig, they observed that only 4-30% of applied fluid was passing through the grinding zone. Flow through grinding zone increased with the increased in porosity of the wheel, and by close positioning of fluid delivery nozzle. To suppress bad effect of the stiff air layer many method have been tried. Das [5] used painted wheels and a scraper board fitted just ahead of fluid nozzle to penetrate the stiff air layer around the wheel. The gap between scraper plate and wheel periphery needs to be kept very small and needs frequent adjustment. They observed a reduced wheel wear rate and an increased grinding ratio with a painted wheel. Mandal et al. [6] reported that effective fluid flow through grinding zone can be increased by using a pneumatic barrier, and thereby enhancing the grinding performance. They used a pneumatic barrier for breaking stiff air layer which resulted in maximum fluid penetration and provided better cooling action in grinding zone.

In this experimental work, Ni-based super alloy, Inconel-600 is grounded by alumina wheel at an infeed of 20 micron (µm) under dry, wet and wet with pneumatic barrier environmental conditions. The experimental result shows that grinding forces as well as wheel wear is reduced, and favourable chip formation occurs in wet with pneumatic barrier condition due to better cooling and lubrication effect.

II EXPERIMENTAL DETAIL

The experimental investigation has been performed on a surface grinding machine. The specification of the main equipment, tools and workpiece used in this experiment are given below:

Table 2.1: Experimental Details

Machine Tools	*Surface grinding Machine.* *Make: Manekal & Sons, Kolkata, India* *Model: 600 x 200 PARROT* *Specification: Infeed Resolution: 10µm, Speed Range: 2900 RPM*
Grinding Wheel	*Type of Wheel: Dish Type Alumina Wheel* *Make: Carborandum Universal Limited* *Specification: AA/46/54 K5 V8* *Size: 200 mm diameter x 13 mm thick x 31.75 mm bore* *Wheel Speed: 2800 rpm* *Grinding Condition: Up Grinding*
Workpiece	*Inconel-600* *Composition: Ni -74.35%, Cr -15.83%, Fe -9.44%, Mn -0.38%*

	Job size: 120 mm x 65 mm x 6mm
Load or force Dynamometer	*Make: Sushma Grinding Dynamometer* *Model No. SA116* *Range: 100 gm – 100kg* *Resolution: 100 gm*
Air Compressor	*Make: Elgee* *Power: 220 V, 50 Hz, A.C.*
Grinding Conditions	*Wheel velocity: 30 m/s (constant)* *Pneumatic barrier pressure: 400 mm of water (constant)* *Grinding fluid flow rate: 1 lit/min (constant)* *Infeed: 20 micron (μm)* *No. of passes: 10*
Environments	*Dry, Wet, Wet with Pneumatic barrier*

III. EXPERIMENTAL PROCEDURE

The grinding wheel has been fitted on surface grinding machine to perform the grinding operation. A flow meter has been used for measuring fluid flow through nozzle. An air compressor has been used to provide pneumatic pressure for application of pneumatic barrier. The set up of wet with pneumatic barrier is shown in Fig. 3.2 The experiments has been performed on three different conditions (Dry, Wet and Wet with pneumatic barrier), for 10 passes each in the up-grinding mode. For each passes the infeed is 20 (μ) microns. Tangential force (Ft) and Normal force (Fn) reading are taken from the display unit of the grinding dynamometer. Force ratio (Ft / Fn) is also calculated.

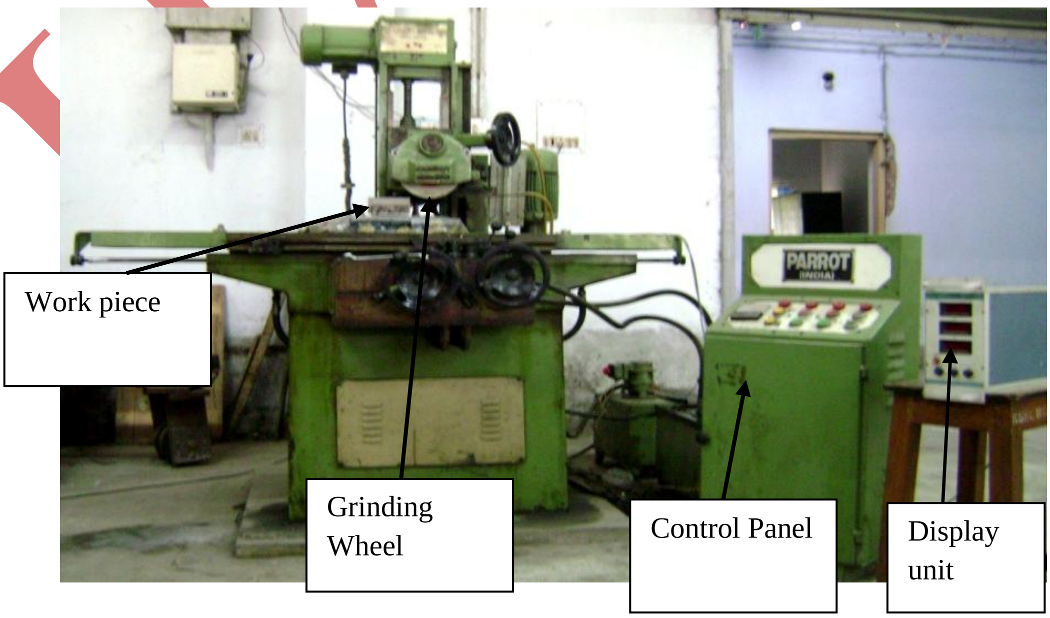

Figure.3.1: Surface Grinding Machine Set up

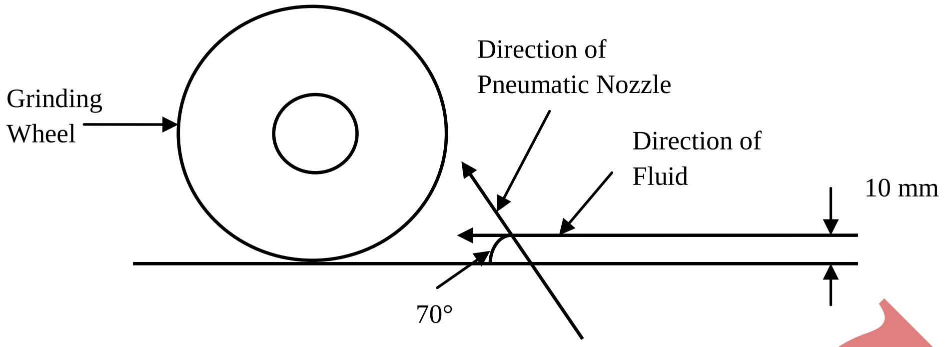

Figure.3.2: Experimental setup showing pneumatic and fluid nozzle position with grinding wheel

IV. RESULT AND DISCUSSION

In the grinding of Inconel-600 in dry environmental conditions the tangential (Ft) and normal force (Fn) is high as compared to wet and wet with pneumatic barrier conditions. This is due to large negative rake angle of grit and predominant wheel rubbing. The gradual increasing tendency of Fn may also be because of wheel loading and rubbing which increase friction and grinding temperature. In this experimental investigation, no spark and spatter has been observed. The surface is free from burning spot.

In wet condition both the forces tends to decreased slightly, compared with dry grinding. This may be due to cooling and lubrication action in the grinding zone. In case of wet with pneumatic barrier condition the force component is very much decreased as shown in Fig.4.1. This is due to the better penetration of the coolant in grinding zone which reduces friction as well as wheel loading. The reason due to better penetration of the grinding fluid in the grinding zone is the application of high jet air pressure which reduces the thin stiff air barrier around grinding wheel.

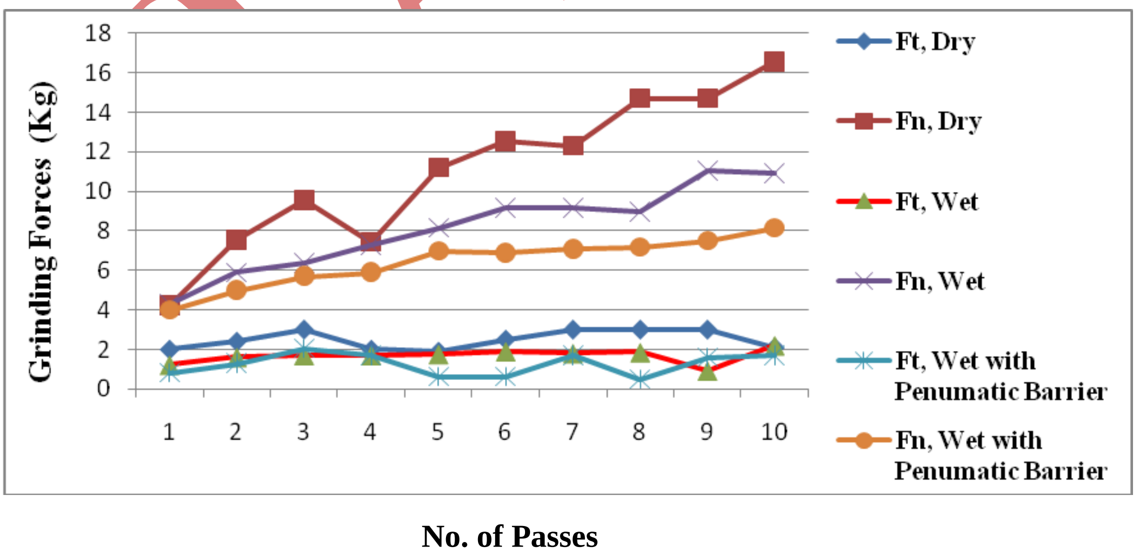

Figure.4.1: Comparison of tangential force (Ft) and normal force (Fn) with No. of passes under varying infeeds of 20 µm in different environmental conditions

In Fig.4.2 Variations of grinding force ratio with different conditions at 20 µm infeed are shown. Here in dry conditions, force ratio gradually decreased with increased in passes due to rapid increased in normal force ratio. In case of wet conditions, force ratio is marginally around 0.2 after the 4th pass. In wet with pneumatic barrier condition, initially the force ratio is less but this goes on increasing as the No. of passes increases this shows better grindability.

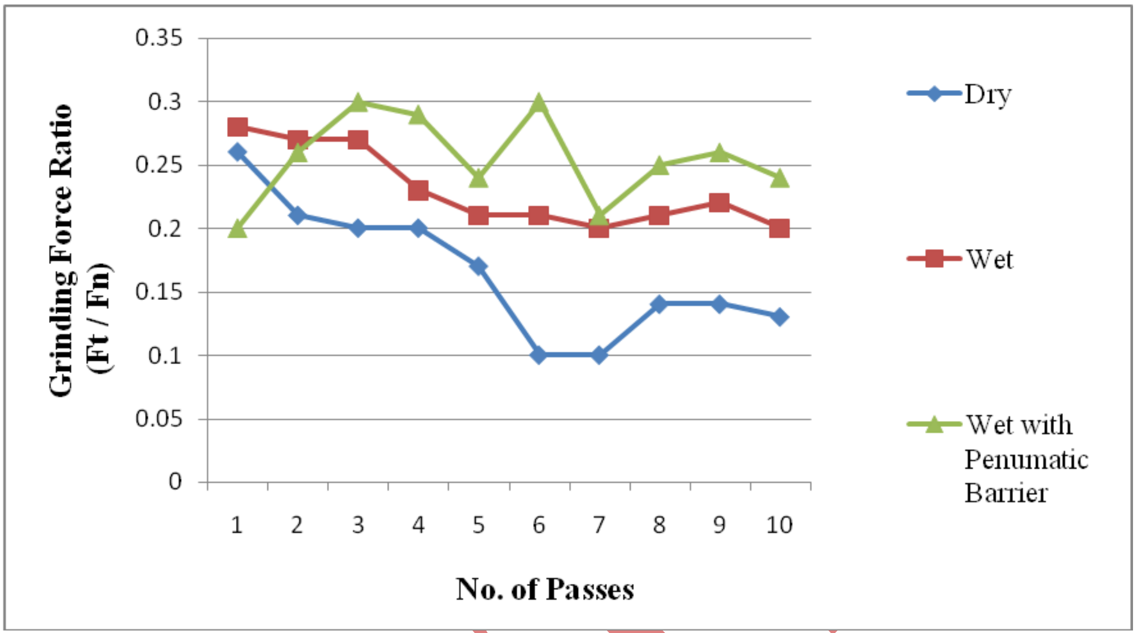

Figure.4.2 Comparison of force ratio under different environmental conditions with 20µm infeed

V.CONCLUSION

On the basis of the present experimental investigation on grinding of Inconel-600 following conclusion may be drawn:

1. Both Tangential force (Fn) and Normal force (Ft) in dry grinding are higher than wet and wet with pneumatic barrier conditions.
2. Compared with dry and wet grinding, both the grinding forces are found lower with the use of wet with pneumatic barrier set up. This indicates better fluid penetration achieved by using pneumatic barrier set up.
3. Wheel wear is also observed to be much lower when pneumatic barrier set up with wet system is used.
4. It may be recommended that under wet with pneumatic barrier condition and with 20 µm infeed, grindability of Inconel-600 with alumina grinding wheel is good, and can be used in practice.

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