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Grinding Titanium grade 1 alloy with an alumina wheelusing soap water

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Abstract

Grinding is a manufacturing process used mainly for semi finishing/ finishing operations. Many problems, such as high specific energy requirement, high grinding temperature and rapid wheel loading are associated with this process. These difficulties become more pronounced when grinding a difficult-to-grind material, such as titanium, a metal used mainly in aerospace, automotive, biomedical and nuclear industries. Inability of the conventional fluid in effective lubrication and cooling along with their adverse environmental impact has prompted a worldwide need for an alternative grinding fluid and its delivery systems. This paper focuses on the effect of soap water delivered in two ways- firstly, in a drop by drop method, and secondly, as a high velocity jet. Results show that using soap water drop by drop, high grinding ratio is achieved; however, forces increase and poor surface quality is observed. On the other hand, a jet of soap water applied during grinding results in lowest tangential force, acceptable surface quality and lower surface roughness; also, chips obtained are of shear type, indicating better grindability.

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Keywords: Grinding; wheel loading; titanium; lubrication; soap water; grinding ratio; surface quality; roughness; grindability

1. Introduction

Grinding is an abrasive machining process that employs a grinding wheel as the cutting tool and results in precision which can be up to ten times of that obtained in either turning or milling [1]. However, high specific energy requirement

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(almost 10- 30 times of that in turning) [2], wheel loading, rapid temperature rise and difficulty in lubrication (due to stiff air layer formation) tend to make grinding a challenging process.

Titanium is 30% stronger and nearly 50% lighter than steel, and also 60% heavier than aluminium but twice as strong [3]. It finds huge applications in aerospace parts, vehicles, engines and gas turbines, nuclear and biomedical industrial sectors [4]. Most of these industries require parts having high dimensional accuracy and high surface finish, so naturally grinding is the preferred choice for these demands. However, problems in grinding, as discussed, become much more evident due to low thermal conductivity, low elastic modulus, high temperature hardness, and high chemical reactivity of titanium [5]. This classifies titanium as a Difficult to Grind (DTG) material.

One of the main issues in grinding is generation of heat, which affects both wheel and workpiece properties. Regarding wheel selection in industries, conventional wheels are preferred due to relative ease of use and lower abrasive costs [6]. When grinding titanium alloys, alumina wheel exhibits low wheel loading and favourable chip formation, while SiC wheels exhibit less chip redeposition and better surface finish [7]. Another approach to control temperature rise in grinding zone and to improve grindability is by effective cooling and lubrication. Addressing this, several techniques are in use- jet cooling [8], flood cooling [9], Minimum Quantity Lubrication [10], mist cooling [11], use of solid lubricants [12], cryogenic cooling [13]. All of these techniques have their own merits which contribute to improvement in grindability. Despite this, use of lubricants/ coolants is being discouraged due to high procurement and disposal cost[14], harmful effect on workers' [15] and presence of a stiff air layer hinders penetration of lubricants in grinding zone, reducing its effectiveness [16], although this can be reduced using a compound nozzle and pneumatic barrier setup [17].

In this regard, effectiveness of soap water fulfils as a fluid has been evaluated by Teicher et al. [18] in grinding Ti-6Al-4V alloy with a cBN wheel. Lowest grinding force, favourable chip formation, suppression of chip redeposition on ground surface were reported using soap water. Soap water was also used by Babic et al. [19] when grinding AISI steel with alumina wheel. Two nozzles supplying compressed air-soap solution mixture were fitted on both sides of the wheel. Various concentrations of soap solutions were used. It was seen that heat dissipation increased with the soap concentration, but only up to a certain limit. In another study, grinding of titanium alloy with SiC wheel was done by Kundu et al. [20]. Results pointed out effectiveness of alkaline soap water in decreasing grinding forces, increasing G-ratio and producing favourable chips. This method was relatively simple and environment friendly.

2. Materials and methods

In this experimental study, Titanium grade I alloy is chosen as workpiece, obtained as rectangular flats. Grinding wheel used is of alumina (Al_2O_3) abrasive with a vitrified bond. Dry grinding was first conducted followed by drop by drop application of soap water, and finally microjet of soap water was used. Table 1 shows details of experiments and equipment.

Table 1: Complete list of experiments and equipment

Surface grinding machine	Make: HMT Praga Division, India, Model: 452 P, Main motor power: 1.5 kW, Infeed resolution:1 μm, Maximum spindle speed: 2800 rpm
Grinding wheel	Make: Carborundum Universal Limited, Specification: AA60K5V8, Type: Disc-type, Dimension: 200 mm x 20 mm thick x 31.75 mm bore
Workpiece	Material: Titanium grade 1, Hardness: 340 HV, Dimensions: 120 mm x 60 mm x 6 mm
Force dynamometer	Make: Sushma Grinding Dynamometer, Bengaluru, India, Model: SA 116, Range: 0.1-100 kg, Resolution: 0.1 kg
Dressing details	Make: Solar, India, Specification: 0.5 carat single point diamond tipDressing depth: 20 μm, Dressing speed: 1.8 m/min