Bulk Surface Coatings for Performance Enhancement In Abrasives

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ABSTRACT

Abrasive grains are subjected to severe cutting conditions as in a grinding wheel. The life of the grinding wheel depends on the ability of an abrasive grain to perform without fracturing under the cutting stresses. In order to improve the behaviour of abrasives, the internal chemistry of the abrasive is normally altered to get different types of abrasive grains-characterised by their toughness. In this work, a bulk surface modification technique is employed to provide a chemical conversion coating onto the abrasive grains, without altering the internal chemistry of the abrasives. The effect of such a coating is studied in two different grinding conditions. It is seen that surface coating on abrasives can improve the grinding performance by delaying the fracture of grains. The results are supported with Optical and Scanning Electron Microscopic analysis of the treated grains and fractured surfaces.

KEY WORDS*:* Surface modified abrasives, grinding, cut-off wheels, Depressed Centre wheels, Grinding performance enhancement.

1. INTRODUCTION

Surface modification for enhancement of tool life is quite popular in single point cutting tools (Bradbury, 1997). Surface modification of abrasive grains is not reported in the literature. Abrasives being smaller in size and of undefined / unpredictable geometries, coating an abrasive grain are quite tough. Any line of sight process like CVD or PVD which are used for single point cutting tools, become either impossible to use or are very costly. Hence the use of surface modifications on abrasives has not been explored much. There are a few patents that talk about silane coating on abrasives, particularly to improve the bonding between abrasive grains and the resin used for making the grinding wheel (Anuj Seth and Ying Cai, 2009). The possibility of a protective coating onto the abrasive grain is studied in the present work.

2. MATERIALS AND METHODS

Raw abrasive grains of brown Alumina, were chosen and subjected to surface treatment. The coating comprises of using a liquid component to wet the grains and then coating it in bulk mixers with chemical additives like iron oxide and other grinding aids, and subjecting it to a heat treatment process. The process is described in a patent (Annamalai and Mukherjee, 1997).

Experimental work: Figure.1, shows untreated grain and figure.2, shows treated grains.

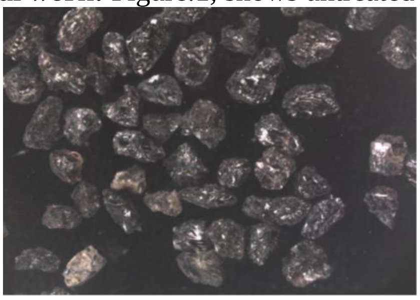

Figure.1. Untreated grains (shiny and reflective) 20X

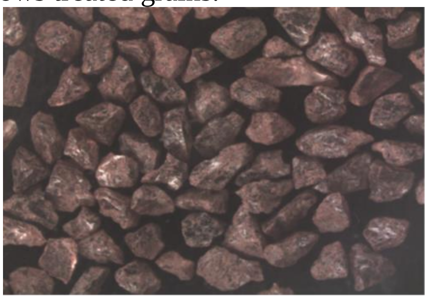

Figure.2. Treated grains (dull surface) 20X

Figure.2, shows the presence of a uniform coating on the surface of the abrasives. Figure.3, shows the uniformity of coating around the edges of the grain. Figure.4, shows a cut and polished section wherein the surface coating can be seen clearly around the edges like a protective outer shell.

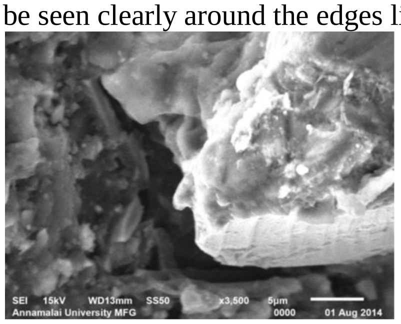

Figure.3. Effectiveness of coating around the edges

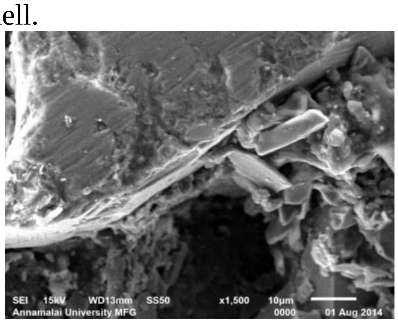

Figure.4. Edge tenacity of coating after polishing

The raw and treated abrasives were characterised for their properties and then manufactured into grinding wheels. The wheels were subjected to wear studies by grinding performance tests. Grinding forces and energy are important in any grinding operation (Brach et al, 1988). Grinding forces act on the grain and on the bond thereby leading to fracture of grains or fracture of bonds leading to premature falling of grains. The wear of grinding wheels has been studied extensively and is found to be mainly due to the dulling of abrasive grains (Malkin and Cook, 1971). The wear rate depends on the grinding forces which in turn affect the grain fracture (Malkin and Cook, 1971).

To simulate differing stress conditions, two different grinding applications were chosen-a cutting off operation and a Depressed Centre (DC) wheel surface grinding operation. In a cut off wheel, the wheel is very thin and at any point in time, the cutting happens by the wheel advancing into the work piece which remains stationary. Such a condition imposes a heavy load on the grain. Mostly it can be taken as a single grain taking the entire cutting load at any instant. Cut-off operation is very popular in many industries. However, because the cutting off wheels are of a very low price, this operation has not been studied much and there are no reports on the life of the abrasive grits in such an application (Neugebauer, 2005).

Hou and Komanduri (2004) have developed a model for cut-off grinding operation. The cumulative area of actual contacting grains present at the interface is only a small fraction of the total contact area. This is because only a small percentage of the abrasive grains present on the surface of the cut-off wheel are in actual contact with the workpiece at any given point in time. Also, a smaller fraction of them are actual cutting grains taking part in the cut-off operation.

Gunawardane and Yokouchi (2004), describe the snagging operation in detail. They explain that snagging operation involves uniformly distributed wear behaviour around the wheel. However, in snagging type of operations, wheel vibration and rattling on the work lead to unpredictability of the wear pattern of the wheel (Gunawardane and Yokouchi, 2004).

Because of the extremely different load exerted on the grain in cut off and snagging applications, a cut -off wheel and a snagging kind of Depressed Centre (DC) wheel application were chosen for the study.

Experimental work in Cutting -off operation: The cutting off operation was done for a standard number of 25 cuts on an Stainless Steel tube.

Table.1, indicates the conditions used for evaluation in a cutting off operation.

Table.1. Cutting Off performance evaluation

Wheel type	Wheel dia loss [mm]	Average current [Amps]
Treated wheel 1	3.38	3.17
Treated wheel 2	3.43	2.95
Treated average	3.41	3.26
Untreated wheel 1	3.65	3
Untreated wheel 2	4.44	2.93
Untreated average	4.05	2.97

Wheel size was 125 mm x 1 mm x 22.23 mm (Outer diameter, inner diameter and thickness)

Work piece SS 303 tube of 12 mm diameter

Experimental Work in Depressed Centre Wheel Usage: Depressed Centre (DC) wheels of grade A24 TBF of size 175 mm diameter, 7 m thick and 22.23 mm arbour were made out of both type of abrasives and were evaluated in snagging application on mild steel flats of about 6 mm thick and 50 mm wide, held in a vice in such a way that the thickness portion is subjected to grinding.

Table.2. Depressed Centre Wheel Performance Evaluation

Wheel type	MRR (gm / min)	GR
Treated	42	21
	51.8	15.7
Treated average	46.9	18.35
Untreated	31	13.5
	31.6	12.6
Untreated average	31.3	13.05

MRR-Metal Removal Rate=metal loss / grinding time

GR-Grinding Ratio=metal loss / wheel loss

3. RESULTS & DISCUSSION

The cutting off operation was done for a standard number of 25 cuts on an SS tube. The treated grain wheel showed a diameter reduction of around 3.4 mm as compared to the untreated grain wheel which showed a diameter reduction of 4.05 mm. This was an approximately 20% improvement in life.

The Treated grain wheels have drawn a 10% higher power -explaining that the cut has been aggressive. Also, it is noteworthy that the wheel loss is quite consistent in the treated grain wheels and varies abnormally in the untreated grain wheels. This could be possibly due to the better anchoring of the grains with the bond due to the surface modification.

The Depressed Centre wheel grinding operation was done for a standard grinding time of 10 minutes on mild steel plates. The wheels with treated grains showed a grinding ratio of 18.35 compared to that of the untreated wheel which showed a Grinding ratio of 13.05. This is roughly a 40% higher performance over untreated abrasives.

The material removal rate was around 47 grams per minute for treated wheel and around 31 grams per minute for the untreated wheel. This is approximately 52 % higher performance than the untreated wheel. These results show a minimum of at least 25% plus improvement in both grinding ratio and metal cutting ability.

Correlation of performance to property change due to treatment of grain: The fracturing of abrasive grains in a grinding environment is normally characterised by a property called Friability in abrasive terms. There is a standard test for friability (American National Standards, B7418, 1965).

It involves subjecting a known quantity of abrasives to the impinging action of grinding media balls in a ball mill. The grains that get caught between the grinding media get a hammering effect during rotation of the ball mill and thereby break down. This is considered to simulate the grinding forces to some extent.

A friable grain indicates a relatively large break down of grains as compared to a tough grain. The coating was seen to provide a lower friability value (25%) than the raw grain (40%) indicating that the fracture has been delayed, probably by the surface coating. The same effect would have offered more time for the grain in the grinding wheel to perform before fracturing. This explains the performance enhancement of the grinding wheels with surface treated abrasives.

4. CONCLUSIONS

Surface modification of abrasive grains through a bulk coating process is seen to delay the fracture of abrasive grains, thereby extending the life of abrasives upto 25% in a grinding performance testing. Results differ based on the application and on the work piece; but in all cases, a minimum of 25% enhancement in performance was observed.

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