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Resistance to Abrasive Wear of Materials Used as Metallic Matrices in Diamond Impregnated Tools

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Abstract

Metal-bonded diamond impregnated tools are being increasingly used in the processing of stone and ceramics, road repair, petroleum exploration, etc. Although the main tool wear mechanisms have been identified, the scientific background is inadequate and fundamental research has to be carried out to better understand the tool field behaviour. This work addresses the complex issues of modelling abrasive wear of the metallic matrix under laboratory conditions. The generated data indicates that the matrix wear resistance can be assessed in a simple manner; whereas tests carried out on diamond impregnated specimens may aid prediction of the tool life in abrasive applications.

Keywords : diamond impregnated tools, 2-body abrasion, 3-body abrasion

1. Introduction

In processing natural stone and ceramics diamond impregnated tools interact with the workpiece in a complex manner. On difficult to cut materials, such as granite, the diamond breakdown and pullout phenomena govern the matrix abrasion since they have a direct bearing on the distance by which the matrix clears the workpiece. On easy to cut materials, such as gritty sandstone, the matrix is capable of holding the diamonds firmly and allow them to project much better beyond its surface. In this case, the combination of grit size and concentration, and matrix resistance to abrasion takes responsibility for the tool life.

Tests performed on real tools provide useful information on virtually every aspect of tool performance. The obtained data has, however, a statistical nature which gives rise to high costs of the workpiece, labour, instrumentation, cutting consumables, etc. Therefore modeling wear by means of quick and inexpensive laboratory procedures has long been recognised as one of the most important tool-developing issues. It must be realised, however, that laboratory tests will inevitably limit the number of variables and incompletely imitate the actual tool application conditions.

2. Experimental Procedure and Results

The literature denotes two basic modes of abrasive wear, i.e. 2-body and 3-body abrasive wear. The 2-body abrasive wear is the most severe means of removing material. It arises when fixed abrasive grits pass over a surface and cut groves in it. A typical procedure used to evaluate wear rates by 2-body abrasion involves moving a pin-shaped specimen over abrasive paper in a manner ensuring that the pin travels on fresh abrasive throughout the test [1].

This condition has not been met in the experiments reported in Fig. 1. The test consisted in simultaneous wearing of four different specimens, having similar size and geometry, under controlled pressure on F220 (58μm) grit SiC paper and was conducted on a standard metallographic grinding machine. The specimen holder and turntable were set to a clockwise motion at 150 and 160rpm, respectively.

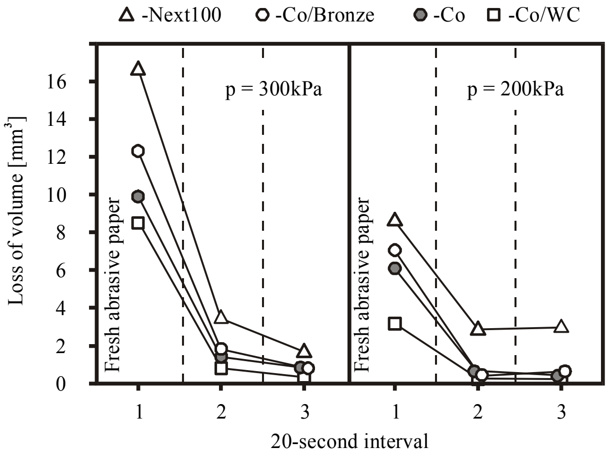

Fig. 1. 2-body abrasive wear as a function of pressure and grit sharpness.

Consequently, the sliding velocity was altering sinusoidally between 1.29 and 1.39m/s. The loss of volume was measured for each specimen at 20 second intervals.

The 3-body abrasive wear arises when hard abrasive grits are introduced between a pair of sliding surfaces and abrade the material of each. The abrasive particles spend about 90% of the time rolling and hence the wear rate is by an order of magnitude slower than in 2-body abrasion [2].

The materials examined for 2-body abrasion were also tested for 3-body abrasive wear by means of the Micro-Wear Test [3]. The measurements were conducted on a cast-iron backing wheel using either flint or quartz abrasive, both finer than 200 m. The specimens were forced against the backing wheel at a pressure of 800kPa and set in motion at a linear velocity of 1.08m/s. The results are presented in Table 1 as abrasive indices (*Ai*), which indicate an average loss of height of a specimen per 20m wear path distance.

Table 1. Material's hardness and abrasive wear indices measured with different abrasives.

Material	Hardness [HRB]	Ai [μm/20m]		
		Flint	Quartz	Sandstone
Co	105.3	81.2	56.1	60.6
Co/Bronze	102	83.9	57.6	70.1
Co/WC	103.2	53.8	33.6	33.1
Next100	108	65.1	46.3	68.1

To model wear by a mixed 2-body and 3-body abrasive wear, the measurements were continued with a hard sandstone backing wheel and sandstone abrasive slurry, to involve 2-body abrasion in wearing the material by its incidental contacts with stone asperities. The sliding speed and pressure were 1.3m/s and 800kPa, respectively. The results have been included in the last column of Table 2.

The second series of experiments involved wearing of diamond impregnated specimens. MBS920 synthetic diamond, in either 40/50 mesh or 50/60 mesh grit size, was used at 20 concentration. Each specimen was loaded at 20N and rubbed against a sandstone backing wheel, in the presence of water, so as to imitate a cutting action of a frame saw or core drill. In order to achieve a spiral wear path, the specimen holder and backing wheel were set to a clockwise motion at 150 and 160rpm, respectively, which resulted in a sliding velocity altering sinusoidally between 1.26 and 1.36m/s. The results are presented in Fig. 2.

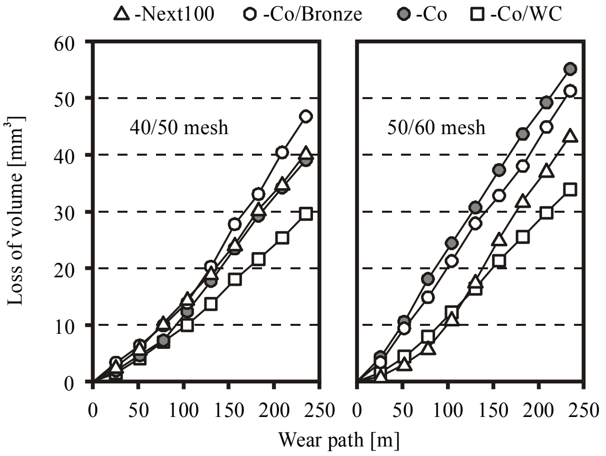

Fig. 2. Volume loss as a function of wear path length for specimens impregnated with different grit size.

3. Conclusion

The wear tests which involve 2-body abrasion, 3-body abrasion, and a combination of these two mechanisms rank the examined materials in a different order. The Next100 specimens, for example, exhibit the fastest wear by 2-body mode and a relatively slow wear under 3-body conditions. This accounts for moderate resistance of Next100 to wear by loose abrasive on the hard sandstone backing wheel that has much higher potential than the soft cast iron to abrade material by the 2-body mechanism due to a sliding contact with stone asperities and coarse abrasive particles trapped in irregularities of the backing wheel surface.

Frictional forces that occur between a sandstone backing wheel and loose abrasives continuously change to alter the particle movement pattern. Therefore tests performed on natural stone counter-bodies involve a variable contribution of 2-body abrasion to the volumetric loss of test specimens which results in poor resolution of wear data. Otherwise such procedures seem to better imitate the tool application environment than any 2-body and 3-body abrasive wear test.

The tests performed on diamond impregnated specimens are instrumental in studying the effect of diamond grits on the matrix wear rate under quasi-field conditions. As expected, the coarser grits better protect the matrix against abrasion by widening the clearance for chip removal. The specimens are prone to wide fluctuations in the instantaneous rate of wear which is apparently inversely related to the number of exposed diamonds.

The applied test conditions promote harsh abrasion of the wear surface since the forward motion of each specimen is accompanied by its rotation on the central axis. Thus the exposed diamonds are undercut from each side which prevents formation of matrix tails and chip removal groves. Moreover, the topography of the backing wheel surface facilitates 2-body abrasion due to instantaneous declines in clearance that continually happen when the load bearing grits intersect deep grooves, which have been cut in the sandstone by their spiral movement.

4. References

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