Impulse excitation characterization of resin bond composite abrasives with different concentration of porous in the structure.

Katia Cristiane Gandolpho Candioto[1,a*] , Alexandre Dutra Golanda[1,b], Bruna Sávio Zarbini[1,c], Larissa Kaori Kurotaki[1,d], Cauê Petterman Carvalho[1,e], Carlos Yujiro Shigue[1,f]

[1]School of Engineering of Lorena, University of Sao Paulo, EEL USP, Lorena – SP, Brazil

[a*]kcandioto@usp.br, [b]alexandredg@usp.br, [c]bruna.sz@alunos.eel.usp.br, [d]larissa.kk@alunos.eel.usp.br, [e]caue.pc@alunos.eel.usp.br, [f]cyshigue@usp.br

Keywords: Alumina grains, abrasive composites, mechanical properties, impulse excitation technique

Abstract. In this work we report the preparation and evaluation of the mechanical characteristics of resin bond composite abrasives with different structures based on the porous concentration. The composite abrasives were made with phenolic resin and alumina grains. Three different structures were studied: i) 53%g-42%b-5%p; ii) 53%g-32%b-15%p; and iii) 53%g-21%b-26%p. The concentration of porous and bond in the structure composition were employed in order to compare the mechanical performance of the prepared composite abrasive. The apparent density and the apparent porosity were determined by the method of Archimedes. In order to evaluate the mechanical properties of composites, Impact strength, Young´s Modulus by impulse excitation and Flexural strength were realized. It was observed a distinct behavior in the modulus of elasticity for the material before and after curing, and that before curing its behavior was decreasing with increasing porosity, while after, the behavior was increasing. This is due to the polymerization, occurring the formation of a polymer with good elastic capacities. Although the porosity is higher, the impact resistance is lower, which confirms the lower resistance produced by the surface area contact (grain/binder) and a greater accumulation of tension in the binder material, the higher porosity value, higher the flexural strength value.

Introduction

Abrasives tools are very important economically because are largely employed for grinding, cutting, and surface finishing in many industrial manufacturing processes. However, consistency, efficiency and durability are commonly superior which proves to be more sustainable. On the other hand, few researches [1] are dedicated to characterization of the abrasive tools.

Abrasive machining processes are those in which granular abrasive particles are used to remove material. The abrasives are either held in a bonding as high hardness cutting tool, in a coating as abrasive belts, or in a slurry. Abrasive processes are used to change the surface of parts, with efficient and agile removal of large amount of material or fine finishing in parts that require high precision in their dimensions [2-4].

One of the industrial applications of abrasive grains is grinding, one of the most common machining processes used in the manufacture of precision parts. Its emphasis is on the quality of the product. Only the surface of the abrasive tool is affected by the use of the abrasive tool and as such their disposal is a loss of material and resource. Understanding grinding as a controlled process of abrasive wear on a surface in which there is a close relationship between the many input and output variables involved is not yet complete. The knowledge of the properties of abrasives composities enables a better understanding of the stages of grinding [5]. The choice of types of abrasive grain and binder influences the ground workpiece surface quality [2]. Tool geometry, machine specifications, coolant, and grinding process parameters will promote a particular cut. Only the surface of the abrasive tool is affected by the use of the abrasive tool and as such their disposal is a loss of material and resource.

Despite the importance of the subject, there is a limited number of published articles and research directed to abrasive composites mechanical properties characterization, leading to a slow and empirical development. With the growing market of grinding tools, a need of research on this topic featuring innovative approaches is apparent.

This study report the preparation and evaluation of the mechanical characteristics of resin bond composite abrasives with different structures based on the porous concentration to perform an analysis of mechanical properties of abrasive composites using destructive and non-destructive characterizations.

Abrasive composite

Abrasive composites were prepared by mixing liquid and powder phenolic resin supplied by SI Group Crios (Rio Claro, SP, Brazil) and alumina grains supplied by Elfusa (S. João Boa Vista, SP, Brazil). Table 1 shows the structure composition from different kinds of composite abrasives. The resol/novolac ratio were 1:7 and the alumina volume fraction is 50% whereas phenolic resin accounts from 40 til 20%.

Table 1. Composition of the composite abrasives

Sample	Grain(wt%)	Bond(wt%)	Grain(v%)	Bond(v%)	Porous(v%)
A	79.4	20.6	53	42	5
B	83.7	16.3	53	32	15
C	88.5	11.5	53	21	26

The abrasive composite samples were made according to the method described in Klocke [3] whose flowsheet is displayed in Fig. 1 and in Fig. 2 is shown the materials after manufacturing.

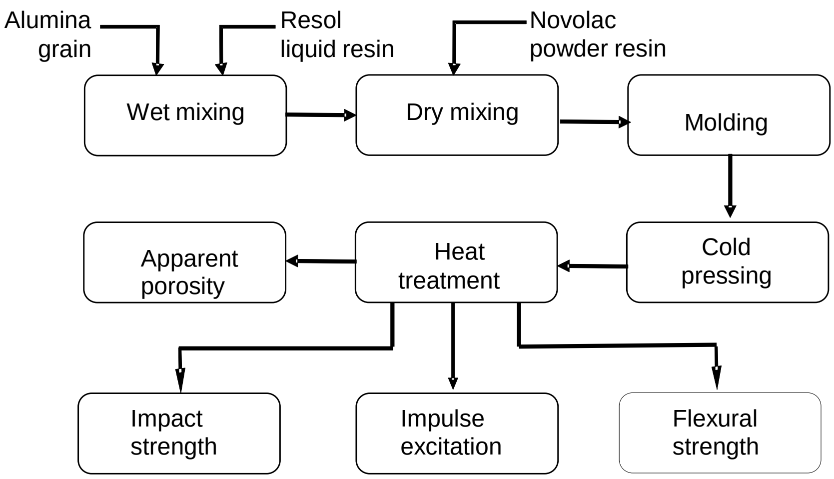

Fig. 1 - Flowsheet describing the main processes applied for the composite abrasive

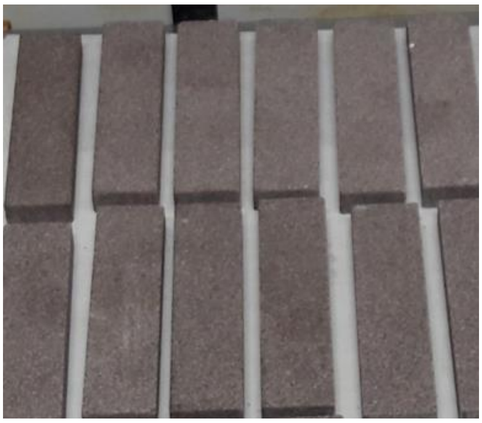

Fig. 2 – Abrasive composites after manufacturing

In the Fig. 3 is shown the heat treatment scheme followed by the oven controller.

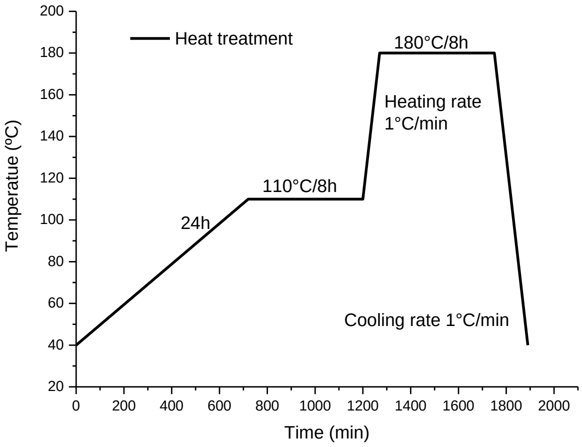

Fig. 3 - Heat treatment scheme for curing the composites.

Characterization of the composite abrasives

The apparent density and the apparent porosity were determined by the Archimedes method. The measurement procedure was done in accord to the ASTM C20-00 (2015).

In order to evaluate the mechanical properties of composites, Impact strength, Flexural strength and Young´s Modulus by impulse excitation were realized.

The composite abrasive samples were characterized by Impact strength using a 2.75 J pendulum at room temperature using un-notched Izod specimens (ASTM-D256-10). On the other hand, the Flexural strength obtained following the D7264/D7264M - 15. In order to evaluate the mechanical properties of composites by means of a non-destructive test, the impulse excitation technique was realized. The experimental procedure is described in the ASTM-C1548-02 standard test method for dynamic Young's modulus, shear modulus, and Poisson's ratio of refractory materials by impulse excitation of vibration.

Results

The apparent porosity determined by the method of Archimedes are shown in Fig. 4.

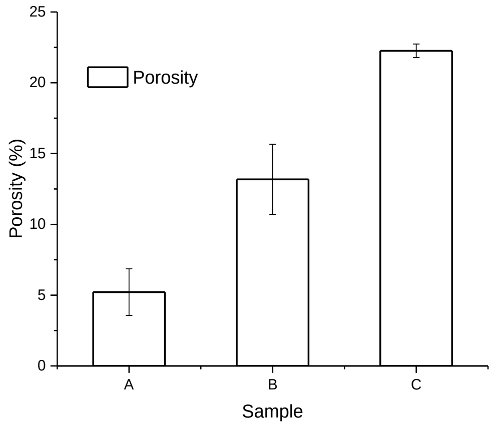

Fig. 4 - Apparent porosity determined by the method of Archimedes for the abrasive composites.

The Fig 5 shows the Young´s Modulus by impulse excitation technique of the abrasive composites before and after heat treatment. As can be shown, the behavior of the samples changes after curing. Before curing, samples with higher volumes of theoretical porosity have a lower Young´s Modulus. The explanation of this fact is due to the concept that the Young´s modulus is directly connected with the bonds driving force. Therefore, the greater the number of discontinuities present in a material, the lower the bond strength between the atoms, reflecting in a smaller Young's modulus. Thus, as porosities are discontinuities, the larger the volume of these, the lower the Young´s Modulus of the material, as described in the behavior before the cure.

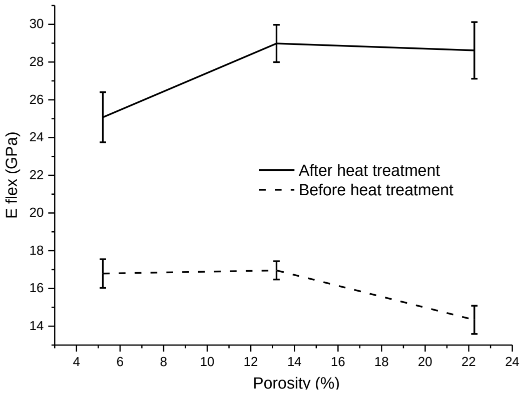

Fig. 5 – Young´s Modulus by impulse excitation technique of the abrasive composites before and after heat treatment.

However, it is noticed that after the curing, the behavior is reversed, the samples with higher volumes of porosity presented higher Young´s Modulus as can be seen in Fig. 4. Since all the samples had the same volume percentage of abrasive grains, the amount of phenolic resin is increased by decreasing the amount of porosity. The presence of pores produced by volatiles by-products (mainly water) should act as stress concentrators, thus favoring lower mechanical properties at the resin-grain interface. The surface smoothness of the microstructure follows the same trend observed in the composites Flexural strenght (Fig. 7) indicating the relationship between the the resin-grain interface of the composites.

The Flexural strength and the Young´s Modulus by impulse excitation is shown in Fig. 6. As can be seen the samples demonstrated the same tendency of higher modulus as the increase of porosity in the abrasive structure composition.

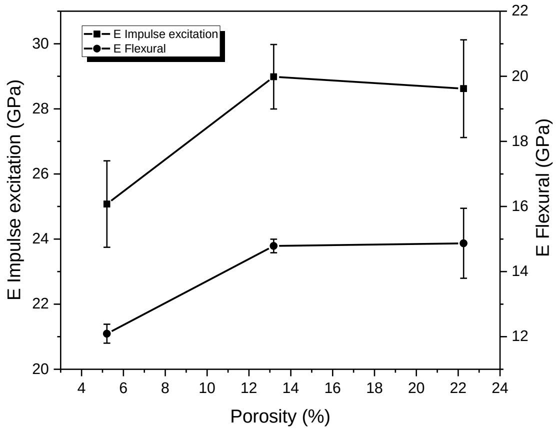

Fig. 6 - Flexural strength and the Young´s Modulus by impulse excitation.

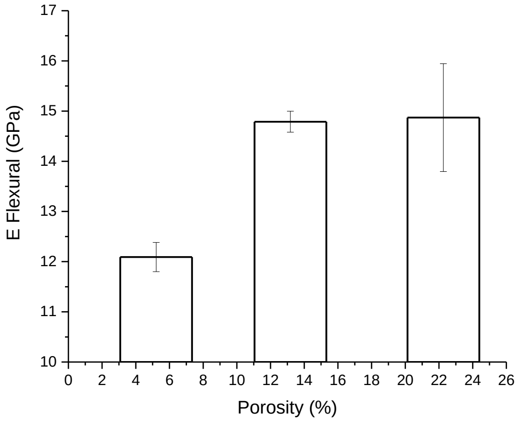

Fig. 7 - Flexural strength and porosity composition.

It can be seen that, unlike the high Flexural strength presented by the composites (Fig. 7), their impact strength (Fig 8) is low, thus indicating low toughness for all composites. The reason is related to the composite structure, which is determined by the low binder/porosity ratio because this composition favors the higher Young´s Modulus in opposite to the impact strength. which may be due to the low phenolic resin content and the interface between the resin and the alumina grit.

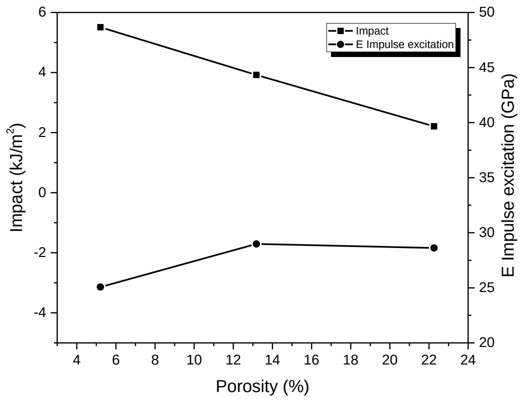

Fig. 8 - Impact strength and the Young´s Modulus by impulse excitation.

For the conditions in which the porosity degree is lower, the Young´s Modulus of the material is shown to be lower, as well as the impact resistance higher. These clues invalidate the proposal addressed by the hypothesis that the resin bond is the responsible of the mechanical properties of the abrasive composite materials since the data shows that there was no inversion in the porosity concentration.

For a material with a high degree of porosity, the surface area interaction, grain/binder, of the composite material becomes smaller, thus, there is a greater accumulation of tension in the binder material, which results in a fracture with lower values. This fact is represented in Fig 8, the higher porosity value, higher the flexural strength value.

Conclusion

With the tests performed in abrasives with phenolic resin binders, for different concentrations of porosity, it was possible to obtain the mechanical properties of the abrasive composite materials following conclusions:

i. It was observed a distinct behavior in the modulus of elasticity for the material before and after curing, and that before curing its behavior was decreasing with increasing porosity, while after, the behavior was increasing. This is due to the polymerization, occurring the formation of a polymer with good elastic capacities.

ii. The Young´s Modulus obtained by the Flexural test had the same behavior as that obtained by Impulse excitation. The Young´s Modulus obtained had an increasing behavior with the increase of the porosity, due to the decrease of the superficial area between grain/binder of the abrasive composite materials.

iii. Regarding the impact resistance behavior, although the porosity is higher, the impact resistance is lower, which confirms the lower resistance produced by the surface area contact (grain/binder).

Acknowledgments

This work was supported by Fapesp through Proc. 2013/26633-0. The authors would like to thank Brazilian companies SI Group Crios, Ascontec and Elfusa for the kind donation of materials used in this work.

References

[1] B. Linke, Lyfe Cycle and Sustainability of Abrasive Tools, Aachen, Germany: Springer, 2016.
[2] S. Malkin,Grinding Technology: Theory and Applications of Machining With Abrasives. 1st ed. West Sussex: Ellios Horwood Ltd., 1989
[3] I. D. Marinescu, Tribology of abrasive machining processes, 2nd Ed. New York: Willian AnDrew, 751 p., 2004
[4] F. Klocke, Manufacturing processes 2: Grinding, Honing, Lapping, Springer-Verlag, Aachen; 2009.
[5] M. Jackson, J. Davim, Machining with Abrasives, Springer, 2011