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INFLUENCE OF HUMECTANT QUANTITY AND MIXING TIME ON THE QUALITY OF ABRASIVE STONES USED IN HONING PROCESSES

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ABSTRACT
In the manufacturing process of abrasive stones with cubic boron nitride (CBN) as abrasive and metallic binder, some differences were observed regarding abrasive density at different heights of the stones. If abrasive density is too low, honing stones do not cut the material properly. Honing stones are obtained by means of sintering processes. Previously, a humectant material is added to abrasive grains, and then they are mixed with metallic binder. Humectant is used to assure covering of each abrasive grain with binder. In the present work, along the manufacturing process of honing stones, quality of the mixing process of components was assessed by means of two different parameters: covering degree of grains by binder (CD) and homogeneity degree (HD) of the mix before sintering process. Both parameters are calculated by means of weight measurement in the mixing step. Different quantities of humectant and different mixing times were taken into account. A higher quantity of humectant implies a higher covering degree, leading to more homogeneous honing stones. For this reason, highest quantity of humectant is recommended within the range studied. However, a certain mixing time is required to assure homogeneity of the mix prior to sintering.
Keywords: abrasive stones, cubic boron nitride, homogeneity degree, covering degree

1. INTRODUCTION
Stones used for interior honing are usually made of an abrasive material and a binder. In addition, during their manufacturing process a humectant material is added in order to assure that each abrasive grain is surrounded by the binder. Abrasive materials can be divided into two categories: conventional ones made of ceramics such as Al_2O_3, SiC or ZrO_2, and superabrasives, like cubic boron nitride and diamond [1]. Common binders are resins or polymers, ceramics or metals. In order to obtain stones with superabrasives, the most employed metals are bronze, iron or nickel [2]. Owing to the differences in the electronic and chemical structure between metals and superabrasives, good adhesion between them is difficult [3]. In abrasive stones, it is usual to find defects such as sedimentation of abrasive grains on the lower part of the stone (next to the base) or the formation of groups of abrasive grains or lumps. Different abrasive concentrations will lead to different material removal rates as the stone wears out. In order to assure that the stone cuts the material properly, cutting conditions of the honing machine need to be varied as the operation proceeds.

Different authors proposed methods for improving homogeneity of the honing stones. For example, for stones with ceramic binder based on silica and alumina, the ceramic is mixed with water and a flux so as to obtain a paste that later hardens and is compacted in order to remove voids [4]. For stones with resin binder, use of microbubbles was proposed in order to create a sponge structure that favours mixing of the different components before the resin hardens [5]. For either organic or vitrified binders

pre-formed clusters of grains are employed, that are joined so as to obtain a more homogeneous wheel or stone [6]. For metallic binder and superabrasives homogeneity can be improved by adding high hardness nanoparticles or increasing the content of humectant used, for example cellulose nitrate [7].
A humectant is an organic material that is used as a temporal adhesive. It is previously mixed with the binder or with the abrasive, and allows each abrasive grain to be evenly covered with the binder. Thus, the abrasive grains will be uniformly distributed within the stone volume after sintering. For vitrified binder compounds such as polyethylene glycol (or other glycols), dextrin or polyvinilic acid are used as humectants [8].

In the manufacturing process of honing stones with CBN and metallic binder, after the mixing step, the mix is poured into a mould prior to sintering. Since density of the abrasive is higher than that of the binder, after the mould is filled abrasive grains could tend to descend towards the base, leading to non-homogeneous stones. Such problem can be minimized in the mixing step. In order to study it, in the present work two new parameters were used: covering degree of grains by binder (CD) and homogeneity degree of the mix (HD). Tests were performed at different mixing times ranging between 15 and 510 s.

2. MATERIALS AND METHODS

2.1. Materials

CBN abrasive was used with metallic binder. Components were mixed in a Turbula machine. Density of CBN is 3.5 g cm^{-3}, while apparent densities of metallic powder range between 0.7 g cm^{-3} and 3 g cm^{-3}. Three different quantities of humectant were used: Q_H, which corresponds to one drop of humectant per g of abrasive, $1.25Q_H$ and $1.5Q_H$.

2.2. Methods

For preparing the mix, first the humectant was added to the abrasive; afterwards, binder was added and the mix was placed in the Turbula machine for mechanical mixing. Important variables in the mixing operation are quantity of abrasive, quantity of humectant, quantity of binder, and time of mechanical mixing in the Turbula machine. In all tests a fixed quantity of abrasive and a fixed quantity of binder was used. Quantity of humectant and mechanical mixing time were varied.

In order to assess quality of the mechanical mixing operation, two new parameters were defined, homogeneity degree (HD) and covering degree (CD).

Homogeneity degree (HD) quantifies the homogeneity of a mechanical mix from the Turbula machine, by means of the calculation of variability in the quantity of abrasive in different samples of the mix. Different samples of an abrasive + humectant + binder mechanical mix were obtained. They were washed with water in order to remove the humectant and the binder. The quantity of abrasive in each sample was weighed. HD is obtained as follows (Eq. 1).

$$HD = \frac{Ata - \sum_{i=1}^{n} \left| Ata - Ai \right| / n}{Ata} \qquad \text{(Eq. 1)}$$

Where HD is the homogeneity degree, Ata is theoretical average abrasive quantity per sample (g), Ai is the quantity of abrasive in the *i* sample (g) ($1 \leq i \leq n$), and n is the number of samples considered. In the present work, for each quantity of humectant at each mechanical mixing time, 3 samples were extracted from different places in the Turbula machine (n = 3).

Highest possible value for HD is 1.The higher homogeneity degree, the lower variability in the abrasive quantity among samples is.

Covering degree (CD) is related to the quantity of binder surrounding abrasive grains. First, a sample of the mechanical mix (abrasive + humectant + binder) is weighed. Then it is sieved. Binder not surrounding abrasive grains goes through the sieve, while abrasive grains surrounded by binder remain on the sieve, A(g). After washing it with water, abrasive material is weighed, B(g). Calculation of CD is presented in Eq. 2.

$$CD = \frac{Lr}{Ltm} = \frac{A - B}{Ltm} \qquad \text{(Eq. 2)}$$

Where CD is the covering degree; Lr is the residual binder + humectant per sample after sieving (g), or binder + humectant surrounding abrasive grains after sieving; Ltm is the theoretical maximum binder + humectant quantity per sample (g), in case all binder surrounded abrasive grains; A is the quantity of abrasive + humectant + binder remaining on the sieve (g), and B is the quantity of abrasive remaining on the sieve (g).

If an abrasive grain is covered by binder, grains are less likely to form lumps. In addition, weight of the grain per unit volume is reduced, thus minimizing the effect of grains descending towards the base of the sintering mould. This will lead to a more homogeneous distribution of abrasive grains in the honing stone after sintering. However, not all binder will surround abrasive grains. For this reason, actual CD value will be far from the theoretical maximum value of 1. Figure 1 (left) shows a stone with little binder surrounding abrasive grains. Grains tend to form lumps.

Figure 1 (right) shows a stone with a binder layer surrounding each abrasive grain. Grains tend to separate. The higher covering degree, the more homogeneous a stone is.

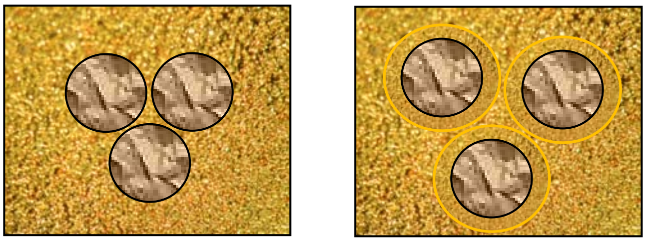

Figure 1. Schematic representation of a stone with low CD (left) and with high CD (right)

3. RESULTS

Results regarding HD at different mechanical mixing times are shown in Table 1.

Table 1. Homogeneity degree (HD) at different mechanical mixing times, for different humectant quantities

Mechanical mixing time (s)	QH drops·g^{-1} abrasive	1.25QH drops·g^{-1} abrasive	1.50QH drops·g^{-1} abrasive
15	0.97	0.99	0.86
30	0.97	0.97	0.95
60	0.96	0.97	0.91
90	0.97	0.99	0.93
150	0.97	0.99	0.99
300	0.99	0.99	0.97
420	0.99	0.99	0.99
510	0.99	0.99	0.99

Maximum HD obtained was 0.99. When QH was used, homogeneity degree of 0.99 was reached after 300 s of mechanical mixing, while if 1.25 QH was used, homogeneity degree was reached after 90 s. For 1.50 QH, homogeneity degree of 0.99 was reached after 150 s.
Table 2 shows results about CD at different mechanical mixing times.

Table 2. Covering degree (CD) at different mechanical mixing times, for different humectant quantities

Mechanical mixing time (s)	**QH** drops·g^{-1} abrasive	**1.25QH** drops·g^{-1} abrasive	**1.50QH** drops·g^{-1} abrasive
15	0.04	0.06	0.17
30	0.05	0.06	0.10
60	0.02	0.04	0.09
90	0.01	0.03	0.06
150	0.01	0.02	0.03
300	0.01	0.02	0.03
420	0.01	0.01	0.03
510	0.01	0.01	0.03

After the shortest mixing time of 15 s, highest CD was 0.17 for 1.50 Q_H. After the longest mixing time of 510 s, highest CD obtained was 0.03, also for 1.50 $Q_{H,}$ showing that most binder does not surround abrasive grain when the material is poured inside the mould.
As a general trend, at a certain mechanical mixing time the higher the quantity of humectant, the higher covering degree is. Thus, within the range studied, the highest quantity of humectant is recommended, since covering degree will be higher even at high mechanical mixing times. Mechanical mixing time should be high enough to assure a homogeneity degree of 0.99.

4. CONCLUSIONS

Within the range studied, the higher the quantity of humectant, the higher covering degree is at a certain mechanical mixing time. A higher covering degree will lead to less lumps of abrasive in the mechanical mix. It will also minimize the fact that the abrasive grains tend to descend towards the base of the mould before sintering. Thus, homogeneity of the stone will improve. However, a certain mechanical mixing time is necessary to assure high homogeneity degree of the mix prior to sintering.

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