Journal of
MECHANICAL and ENERGY
ENGINEERING

ISSN: 2544-0780
Vol. 1 | No. 1(41) | June 2017
pp. 45-50

ORIGINAL METHODS OF CERAMIC GRINDING WHEELS IMPREGNATION

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(Received 28 April 2017, Accepted 22 May 2017)

Abstract: The manuscript focuses on an author's original methods of ceramic grinding wheels impregnation. The authors developed 3 original methods of impregnation ceramic grinding wheels with sulphur, amorphous carbon and solid lubricants like molybdenum disulfide, graphite or hexagonal boron nitride. At the end the issue of evaluation of the application potential of developed grinding wheel impregnation methods were raised.

Keywords: grinding wheel impregnation, corundum grinding wheel, molybdenum disulfide, graphite, adhesion

1. INTRODUCTION

One of the simplest methods of impregnation of grinding wheels industrially used is direct grinding wheel treatment by melted impregnate. After cool-down of the impregnate, the grinding wheel can be used as a grinding tool. Impregnation process can be conducted not only by the producers but also by the users.

The main goal of grinding wheel impregnation is reducing of the intensity of grinding wheel active surface (GWAS) gumming up with grinding products, thereby prolongation of grinding wheel's life span and influencing positively it's surface roughness. Impregnated grinding wheels (GWs) are widely used in bearing and vehicle industry. It is estimated that even 70% - 80% honing stones are impregnated by sulphur [1]. Impregnation methods in gravity and vacuum conditions known from the scientific literature [2,3,4,5,6,7,8] have three main disadvantages:

- impregnate fulfills all the intergranular spaces of the grinding wheel and hence the tool lose its ability to transport cooling liquid (CL) into grinding zone (GZ) and removing products of the process;
- unequal spacing of impregnate in grinding wheel volume;
- complicated and comfortless exploitation of the equipment used for impregnation of the grinding wheels [7,8].

2. MATERIALS AND METHODS

In the case of hard-to-cut materials like nickel alloys, it is important to use grinding wheels with high porosity to ensure the transport of long and ductile chips into the GZ. Impregnation of grinding wheels in the traditional way would cause its structure reduction. Hence in this chapter original methods of the impregnation of grinding wheels with antiadhesive substances like sulphur, amorphous carbon, graphite and molybdenum disulfide have been proposed.

3. RESULTS AND DISCUSSION

3.1. Sulphur implementation method

The proposed method of the impregnation of grinding wheels consists of sulphur into the grinding wheel likewise in the method proposed by Wozniak [7], the impregnation takes place in a vesel under lowered pressure, then grinding wheel is propelled into rotary motion in order to centrifuge Sulphur's surplus.

The change of final centrifuge parameters (speed of the centrifugation, nr and the centrifugation time) can influence the final impregnate content and control grinding wheel's porosity at the same time.

For entering specific amount of sulphur into the grinding tool, the grinding wheel should be dried for about 30 minutes in the laboratory drier in 80 degrees (353 K) in order to get rid of possible damp. After this time grinding wheel should be placed in exsiccator, and left for cooling down. After cooling down grinding wheel should be weighted on the analytical balance and then the sulfurizing process should be started. Sulphur is a solid body in a room temperature. Its melting point is about 115 degrees (388 K). Sulfurizing process should be conducted in temperature between 120°C (393 K) and 160 °C (433 K). Solid sulphur should be placed in heat resistance vessel and heated on electrical bath. Whereas weighted grinding wheel should be screwed down to the mechanicals stirrer metal arbor which has the possibility of vertical feed and rotation control. When the temperature in the vessel reaches 150 degrees (423 K) grinding wheel is immerged in liquid sulphur. After about 10 minutes grinding wheel should be lifted about 3 to 4 cm over liquid sulphur's surface and next the stirrer should be turned on in order to conduct slulphur's surplus offtake (rotation number can be controlled). If under the influence of_centrifugal force sulphur does not flow out from the tool, the electrical bath should be turned off and sulphur should be stirred until its solidification point. Thanks to this treatment thin layer of sulphur will lay down radially in the grinding wheel. Tool which is prepared in such way should be weighted again in order to mark total content of sulphur in grinding wheel.

In the figure no 1 the scheme of the stand used for sulfurizing ceramic grinding wheel was shown. The main element of this stand was CMUT1000/CE heat jacket produced by Thermo Fisher Scientific Inc. (USA). It was used in order to produce and maintain demanded temperature in boiling flask, in which sulfurizing was conducted.

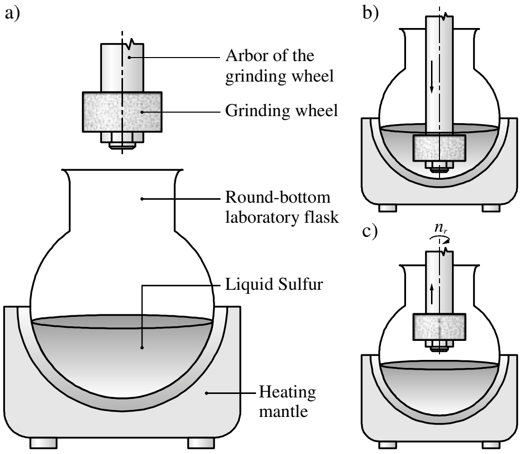

Fig. 1. Schematic diagram of the experimental setup for sulfurization of grinding wheels: (a) main elements of the setup, (b) position during sulfurization stage, and (c) position during centrifugation stage

In the figure 2 comparison of CPS microscope views before (fig. 2a) and after sulfurizing process (before centrifugation – fig. 2b and sulfurizing process after the centrifugation fig 2c). Grinding wheels with technical characteristics: 1-25×20×10-SG/F46G10VTO were sulfurized as it was described above. In the table no 1 data concerning mass change of grinding wheels as a result of impregnation were posted. The mass of grinding wheel which is not sulfurized was m_1=24.28 g, the mass of the grinding wheel after impregnation but before centrifugation of sulphur's surplus was m_2=31.91g. In order to centrifugate sulphur's surplus, grinding wheel was put in rotary motion with the speed n_r=1200 1/min, sulphur's mass after centrifugation was m_3=23.90 g. It means, that sulphur's concentration in grinding wheel after centrifugation process was C_s=9.74%, sulphur's mass loss due to centrifugation was 34.34%. The most important difference that is visible when comparing microscopic images of not sulfurized GWAS (fig. 2a) and GWAS after sulfurizing before centrifugation (fig. 2b) is large sulphur's share on grinding wheel's active surface and almost entire filling of the free intergranular spaces. It should be noticed that filling of the grinding wheel's pores cause limitation of the positive results of using high porosity grinding wheels. When analyzing CPS microscope view after sulfurizing and after sulphur's surplus centrifugation process (fig. 2c) sulphur's share on GWAS decreased, however it is still significant, comparing to sulfurized CPS before centrifugation process. After centrifugation of the sulphur's surplus, noticeable develope of GWAS occurred and free intergranular spaces appeared. Thanks to centrifugation process sulphur is evenly distributed on the whole grinding wheel's volume. However, not all of the free intergranular spaces are filled in. Those intergranular spaces ease coolant provision into the GZ and disposing of the products of the process from it. The fact that sulphur majorly fills grinding wheel's pores comparing to not impregnated grinding wheel guarantees that GW conditioning treatments and grinding wheel's sharpening do not significantly influence the grinding process.

Tab. 1. Mass change caused by the sulphur impregnation process

Mass m_1 before impregnation process	Mass m_2 before centrifugation	Mass m_3 after centrifugation	Concentration C_s of sulfur $((m_3-m_1)/ /m_3 \cdot 100\%)$
24.28 g	31.91 g	26.90 g	9.74%

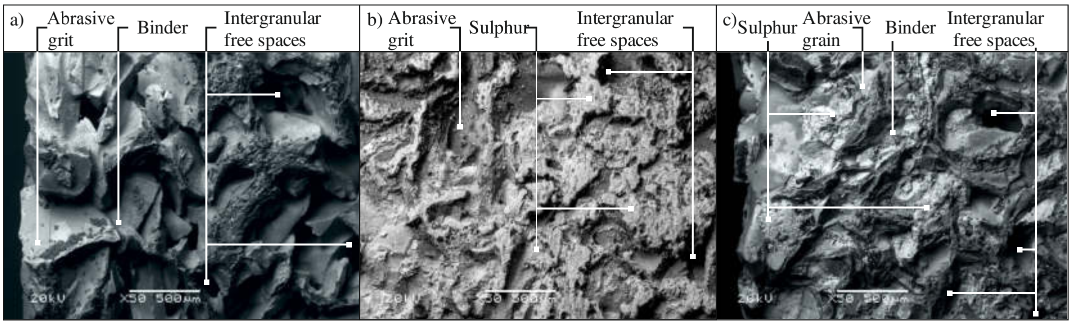

Fig. 2. Microscopic SEM views of GWAS made of microcristalline sintered corundum grains size 46: a) before sulfurization; after sulfurization, before centrifugation (b) and after centrifugation (c) with marked areas of visible sulphur

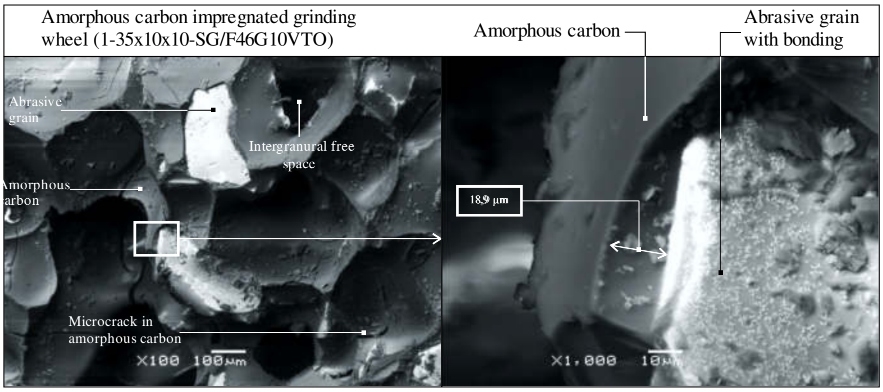

Fig. 3. Microscopic SEM views of the grinding wheel active surface before grinding, after amorphous carbon impregnation

3.2. Amorphous carbon impregnation method

Shapeless carbon likewise carbon in the form of graphite is inert therefore, it might be used as impregnate with its antiadhesive effect. Amorphous carbon was inserted into grinding wheel's pores in the way of thermal decomposition of organic compounds, in this case carbohydrates, according to original method contained in patent application no P. 395441 [9].

During ceramic grinding wheel modification through amorphous carbon impregnation, abrasive tool is being soaked with melted or soluted organic compound and then roasted without air access leading to decomposition of this compound with emission and carbon mounting in the modified grinding tool pores.

Abrasive tool is soaked with melted sucrose favorably in 200 °C what is main advantage of this invention.

The positive effect of the method is inserting into GWAS and grinding wheel's intergranular free spaces of a thin layer of 19 µm thin amorphous carbon (fig. 3), what should lead to obtaining better surface roughness of workpiece, grinding resistance decrease, prolongation of the tool wear and significant decrease of adhesion of chips into GWAS.

In the figure 3 microscope views of GWAS after the amorphous carbon impregnation process were shown. In the process of impregnation the amorphous carbon was inserted into grinding wheel volume technically marked 1-35×10×10-SG/F46G10VTO according to described method.

In the table no 2 data concerning the change of the grinding wheel's mass due to impregnation process were posted. Grinding wheel's mass before impregnation process was m_1=17.23 g, and after impregnation process m_2=18.28 g. It means that amorphous carbon mass concentration in grinding wheel after impregnation process was C_{ac}=5.74%.

Tab. 2. Mass change caused by the amorphous carbon impregnation process

Mass m_1 before impregnation process	Mass m_2 after impregnation process	Concentration C_{ac} of amorphous carbon
17.23 g	18.28 g	5.74%

Visual analysis of the microscope views of grinding wheel active surface after impregnation process indicates that impregnate was uniformly distributed on whole GWAS and its whole volume. This quality is significant especially considering grinding wheel's operation in the polishing process during which it is necessary to renew periodically grinding wheel cutting ability in the process of conditioning the tool. Impregnate implementation into whole grinding wheel's volume guarantees its constant participation in the process of material removal regardless of the number of conditionings. From microscopic SEM images (fig. 3) it can be seen, that chosen degree of impregnation caused that not pores were filled. The pores are playing very important role in the process of hard-to-cut materials grinding, which affect on ductile chips removal rate outside the grinding zone and better coolant provision to the grinding zone as well. In case of filling whole pores, this grinding wheel's feature would be lost.

3.3. Graphite and molybdenum disulfide MoS_2 impregnation method

The proposed method of ceramic grinding wheel impregnation by introducing a supplementary substance as solid lubricant in the grinding wheel structure rely on dipping the grinding tool in a prepared suspension of graphite, MoS_2, hBN and others powders (the internal phase). As the external phase an organic dissolvent with small quantity of varnish (a batter binder) can be used. Formation of thin layer of impregnate which adheres to grinding wheel grits is an effect of the method. The proposed method of impregnation allows to control the amount of impregnate which is added in whole volume of grinding wheel. Thanks to this method user is able to adjust amount of impregnate to specified grinding process.

Four types of grinding wheels with the same structure but different hardness and grit size were impregnated with graphite and molybdenum disulphide. The characteristics of the grinding wheels is described below:

- 1-35x10x10-9A5X60L10VE01PI-50;
- 1-35x20x10-9A5X60G10VE01PI-50;
- 1-35x20x10-9A5X80G10VE01PI-50;
- 1-35x20x10-9A5X46G10VE01PI-50.

In order to impregnate the grinding wheels, at first, surplus weights of the solid lubricants were prepared (10-30 g of graphite and 10-45 g of MoS_2 with step of 5 g each). Next, from each surplus weight a suspensions, consisted of 50 cm^3 of nitrocellulose dissolvent and 25 cm^3 of SOLAK NC 352520 PÓŁMAT varnish (the external phase), were prepared. Additionally, in order to indicate grinding wheel weight loss ratio induced by the external phase incomplete evaporation, a solution of nitrocellulose dissolvent and varnish with the same volume proportion (2:1) were prepared.

Then 3 grinding wheels each type were treated by the prepared solutions. During the treatment process masses before treatment, right after the treatment and after full external phase evaporation of the grinding wheels were noted. For weighing the Radwag PS 2100.R2 were used. 70% of particles size of graphite powder which was used to impregnation of the grinding wheels were in the range between 0 to 30 µm (fig. 4), during MoS_2 impregnation Molykote® Microsize powder with particles size between 0,65 and 0,75 µm (Fischer) were used.

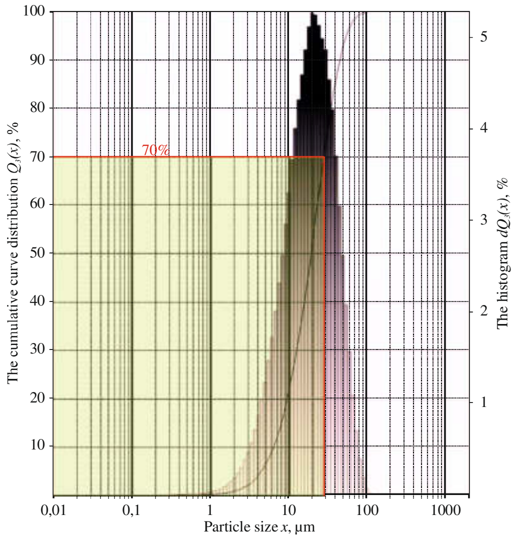

Fig. 4. Particle size distributions of graphite used for the impregnation process

Based on given data, the relationship between the average content percentage of impregnate in the weight of grinding wheel C_{pi} (equation 2) and the mass concentration of impregnate C_i in the suspension were determined. The relationship let to establish the maximum mass concentration of MoS_2 (fig. 5a) and graphite (fig. 5b) for the suspension where adding more internal phase does not increase the content percentage of impregnate in the weight of grinding wheel.

$$Cp_i = \frac{m_i}{m_{po}} \cdot 100\% \quad (1)$$

where Cp_i is the average content percentage of impregnate in the grinding wheel weight; m_i is the weight of impregnate in the structure of grinding wheel; m_{po} is the grinding wheels weight after full evaporation of external phase.

The macrophotographs of GWAS after the impregnation process were taken (fig. 6). This figure shows that there is a limited weight of impregnate (typical for each substance) which can be soluted in the solvent. Adding more internal phase the suspension is not able to penetrate the whole volume of grinding wheel. Most of impregnate is accumulated on the top of the grinding wheel surface and makes bruises – fig. 6f and j.

In both cases (impregnation of MoS_2 and graphite) by maximum mass concentration of similar volumes of MoS_2 and graphite were observed. In the case of graphite impregnation, a particle size of graphite powder plays decisive role and determine suspension heterogeneous. The most of graphite powder is able to penetrate the grinding wheel with 46 grit size. Bigger grit size lowers the capability of impregnation with

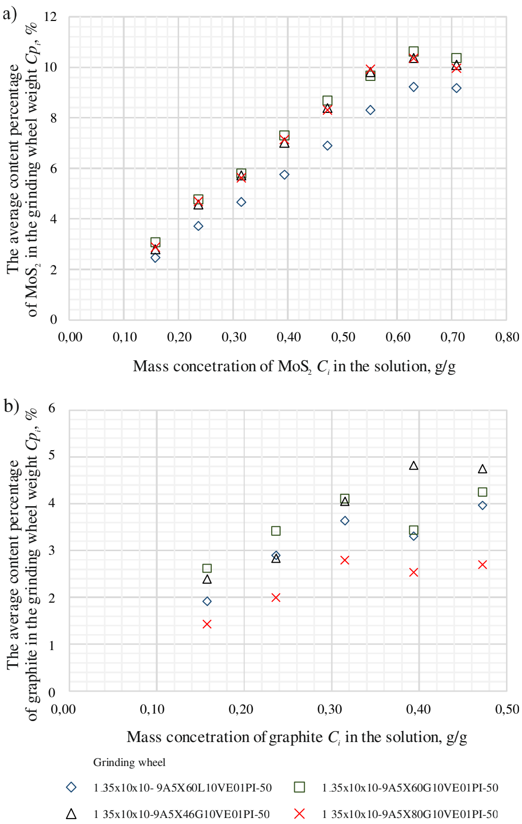

Fig. 5. Relationship between the average content percentage of impregnate in the grinding wheel weight Cp_i and the weight of impregnate in the structure of grinding wheel m_i: a) MoS_2 impregnation process; b) graphite impregnation process

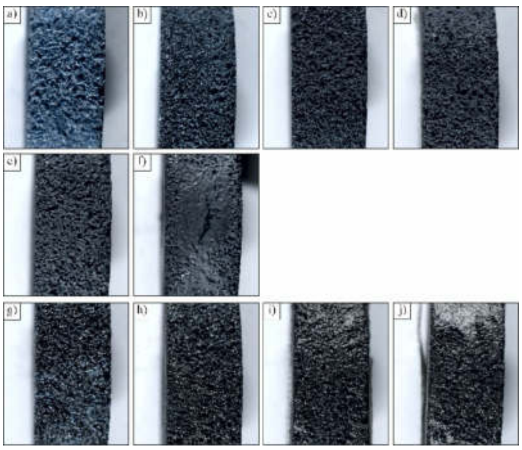

Fig. 6. Macroscopic GWAS views of the grinding wheel marked 1-35x10x10 9A5X60L10VE01PI-50 before and after impregnation process at a different concentrations of impregnate in impregnating: a) reference grinding wheel; b) MoS_2 – C_i = 15.7%; c) MoS_2 – C_i = 31.5%; d) MoS_2 – C_i = 47.2%; e) MoS_2 – C_i = 63.0%; f) MoS_2 – C_i = 70.9%; g) graphite – C_i = 15.7%; h) graphite – C_i = 31.5%; i) graphite – C_i = 39.4%; j) graphite – C_i = 47.2%

graphite. For each types of grinding wheels impregnated by MoS_2 the maximum grinding wheel weight gain were achieved by the same mass concentration of impregnate in the suspension. In case of grinding wheel's hardness increase, grinding wheel's binder share increases as well what causes decrease of impregnate mass per unit of tool mass.

4. CONCLUSIONS

Due to sulphur aggressiveness and numerous controversies that occurred during scientific conferences dealing with grinding whilst presenting diagnostic research concerning sulphur impregnation methods, the application potential of developed grinding wheel impregnation method is insignificant. The second argument against sulphur impregnated grinding wheels concerns partial centrifugation of fluid impregnate. Partial centrifugation of fluid impregnate prevents fulfilling of all tool's intergranular free spaces what in terms of grinding is favorable, however, the method causes some problems with centrifugation process as it is necessary to constantly control the temperature during centrifugation due to the possibility of ignition of impregnate (sulphur, paraffin). Due to this reason the application potential of this method is infinitesimal.

Those disadvantages led to developing another ceramic grinding tools impregnation method which is more universal and can be conducted not only by the producers but also by the users, adjusting impregnation composition according to current technological needs (like it was described in paragraph 3.3). Application character of this method seems to be promising.

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Biographical note

Michal Wojtewicz received his M.Sc. degree in Environmental Protection from West Pomeranian University of Technology Szczecin, in 2009. Since 2010 he has been a researcher in the Subject Group of Applied Chemistry at the Koszalin University of Technology, where currently he works as an lecturer. His scientific interests focus on problems concerning impregnation of grinding wheels processes, machining processes, efficiency. Actually he writes an PhD Thesis about The research on the influence of grinding wheels impregnation with antiadhesive substances on the nickel alloys grinding process efficiency. He published more than 20 scientific papers in international and national journals, book chapters, as well as conference proceedings. He is also the author of 1 national patent.