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Preparation and Optimization of High-Purity Silicon Carbide Magnetic Abrasives for the Magnetic Induction-Wire Sawing Process

Wei Zhang[1,*], Tengwei Qiu[1] and Chunyan Yao[2]

[1]Precision Mold Processing and Intelligent Manufacturing Research Center, Ningbo Polytechnic, Ningbo, 315800, China
[2]Key Laboratory of Special Purpose Equipment and Advanced Processing Technology, Ministry of Education, Zhejiang University of Technology, Hangzhou, 310014, China
[*]Corresponding Author: Wei Zhang. Email: 464126116@qq.com
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Abstract: In this study, magnetic abrasives were obtained by crushing and sieving sintered iron-silicon carbide (Fe-SiC) composites. Fe and SiC powders with different mesh numbers were pre-compacted using different pressures and then sintered at various temperatures and with different holding times. The dispersion uniformity of the SiC powder was improved through surface modification using polyethylene glycol (PEG) 300. The resulting magnetic abrasives were characterized in terms of phase composition, density, relative permeability, and microstructure; this was followed by a comprehensive analysis to reveal the optimal processing parameters. The ideal combination of process parameters for preparing SiC magnetic-abrasive grains for the magnetic induction-wire sawing process was obtained, which are preparation load of 60 kN, a SiC mesh number of 1,500, a sintering temperature of 1100°C, and a holding time of 4 h.

Keywords: Wire sawing; magnetic abrasives; sintering; phase compositions

1 Introduction

Magnetic abrasives are the key materials used in the magnetic induction-wire sawing (MIWS) process. Magnetic abrasives need to have not only the ability to be used in grinding but also magnetic properties and to be water resistant and oil resistant [1,2]. At present, there are many manufacturing methods for magnetic abrasives, such as the sintering method, the in situ reaction method, and the sol–gel method. The manufacturing process for magnetic abrasives is very complex, and it requires specific working conditions (e.g., high-temperature, high-pressure devices) and inert-gas protection [3]. Hence, the manufacturing cost is very high. To develop a better manufacturing technology for magnetic abrasives, scholars have conducted many studies. Shinmura et al. [4,5] propose the preparation of hybrid magnetic abrasives using iron (Fe) powders of a larger abrasive size. This could increase the magnetic properties of the magnetic brush. Hence, the finishing efficiency of the magnetic abrasives will be improved. Zhang et al. [6] manufactured a new spherical, composite, Fe-based silicon carbide (SiC) magnetic abrasive by controlling the machining parameters and the composition proportions of the raw materials. The results of this experiment indicate that the new magnetic abrasive exhibited good sphericity, and the SiC grains were embedded tightly into the ferromagnetic matrix phase. Hao [7] produced Fe-based SiC magnetic abrasives using the hot-pressing sintering method, where magnetic abrasives with a hardness of HV300-HV310 were manufactured under the following conditions: a sintering temperature of 1100°C, a sintering pressure of 50 MPa, and a holding time of 30 min. Shukla et al. [8] studied the process parameters for the preparation of sintered magnetic abrasives using an experimental design. The results reveal that the magnetization decreased with a higher sintering temperature and more holding time, and the scanning electron microscope (SEM) images indicate that there was sufficient bonding of the SiC grains around the Fe powders sintered at 950°C. These traditional production processes are highly complex, and most of them require high-temperature and high-pressure devices, as well as inert-gas protection.

Magnetic abrasive is the cutting tool utilized in the MIWS process, and its performance plays a significant role in the cutting efficiency and wafer quality. To lower the cost of the magnetic abrasives used in the MIWS process, this study has adopted a sintering method to manufacture magnetic abrasives. The compositions of the magnetic abrasives were designed based on the requirements for the magnetic abrasives. During the process, a series of optimizations were performed to prepare the magnetic-abrasive particles using the traditional sintering method. Firstly, a PEG 300 dispersant was used to improve the fluidity of the SiC micropowder effectively. Secondly, the full-coverage-ratio method was used to determine the composition ratio instead of the traditional method of determination by experience. Finally, the "agitation-ultrasonic, dispersion-agitation" method was used to mix the powders, which improves the uniformity of the mixed powder. The processing parameters for the proportions used for the magnetic abrasives were studied using orthogonal experiments, and the preparation process was optimized by modifying the surface of the SiC powder. The effects of the process parameters (including preparation load, sintering temperature, and holding time) on the performance of the magnetic abrasives were then studied. Finally, the composition ratio and optimal process parameters for the magnetic abrasives were obtained to improve the overall properties of the magnetic abrasives.

2 Materials and Methods

2.1 Manufacturing Process Technology for Magnetic Abrasives

To prepare the magnetic abrasives using normal-pressure sintering, the substances, including the ferromagnetic material phase and the abrasive phase, were first processed using high-temperature sintering in an atmospheric furnace with no atmospheric protection. Next, the substances were processed by crushing and sieving them to obtain the required particle size for the magnetic abrasives. The main process for manufacturing the magnetic abrasives is presented in Fig. 1.

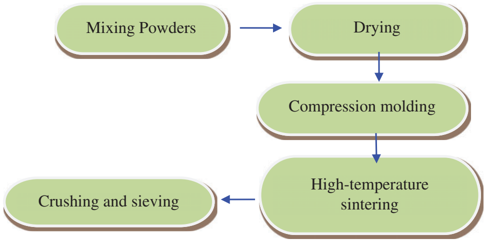


Figure 1: Manufacturing process for magnetic abrasives using the sintering method

In this study, the ferromagnetic material phase was Fe powder, and the abrasive phase was SiC powder. First, the ferromagnetic powder and SiC powder were mixed uniformly and loaded into the mold, where the powders were formed into the desired shape and size using a press machine at a certain preparation load. The powders were then dried at 70°C in a drying box (DGG-9140BD, Senxin Laboratory Instrument Co., Ltd., Shanghai, China). The mixture was weighed every 2 h until it was determined that its mass was not changing further. Next, the mixture was processed using compression molding at a normal atmospheric temperature, and preparation loads of 20, 40, and 60 kN were selected. In the fourth step, the mixture was processed using high-temperature sintering in a sintering furnace (QSH-1700M, Alarge Furnace Co., Ltd., Shanghai, China) without atmospheric protection, and sintering temperatures of 1000°C, 1100°C, and 1200°C were selected. Finally, the required magnetic abrasives were obtained successfully through crushing and sieving processes.

2.2 Raw-Materials Ratio for the Magnetic Abrasive

Fe powder with a mesh number of 10,000 (average size 1.5 μm) (Nangong Xindun Alloy Welding Material Spraying Co., Ltd., Hebei Province, China) was used as the ferromagnetic phase of the magnetic abrasives, and SiC grains with three different sizes (i.e., a mesh number of 1,000 [average size of 11.5 μm], a mesh number of 1,200 [average size of 9.5 μm], and a mesh number of 1,500 [average size of 8 μm]) (Dongtai Zhiming Silicon Carbide Factory, Jiangsu Province, China) were used as the hard abrasive phase of the magnetic abrasives. Dextrin (Jiaozhou Cultural Goods Factory, Shanghai City, China) was used as the binder. In addition, an amount of nickel (Ni) 4% (Qinghe Bozuan Metal Material Co., Ltd., Hebei Province, China) was added to improve the wettability of Fe and SiC [9]. Also, an amount of Si 4% (Qinghe Bozuan Metal Material Co., Ltd., Hebei Province, China) was added to increase the deformation resistance, impact resistance, wear resistance, and corrosion resistance of the steel [10].

At present, there is no uniform regulation for the ratio of magnetic abrasives; most ratios have been devised based on experience and are typically 3:1 or 4:1 [11,12]. To obtain magnetic abrasives that have excellent performance and are low cost, this paper proposes a novel method, named full-coverage ratio, which is to be used instead of the traditional method based on experience. Utilizing this method, Fe powder with a smaller particle size can be fully attached to and occupy the surface of SiC grains with a bigger particle size. According to the full-coverage-ratio method, the mass ratios to be used for the raw materials are presented in Tab. 1.

Table 1: The ratios of raw materials at different SiC mesh numbers

SiC mesh number	Mass fraction wt. [%]				
	SiC	Fe	Ni	Si	Dextrin
1000	47	44	4	4	1
1200	42	49	4	4	1
1500	36	55	4	4	1

The selected SiC powder belongs to the micropowder category, for which the phenomena of agglomeration and stacking are caused easily [13]. Therefore, surface-modification treatment is required. The dispersant was made of PEG 300 (Haian Guoli Chemical Co., Ltd., Jiangsu Province, China) and ethanol (Nanjing Seeking Chemical Co., Ltd., Jiangsu Province, China), which were mixed uniformly based on a mass ratio of 1:19. Next, each of the different SiC powders (i.e., with mesh numbers of 1000, 1200, and 1500) was added to an individual portion of the prepared dispersant. The mixtures were blended fully using continuous stirring by an electrical mixer (JJ-1A, Changzhou Yuexin Instrument Manufacturing Co., Ltd., Jiangsu Province, China) for 30 min. The supernatant was then poured out after having been left standing for some minutes, and the remaining slurry was dried at 70°C. The slurry was weighed every 2 h until its mass no longer changed.

2.3 Experimental Process

There are many factors affecting the sintered body of magnetic abrasives, with the main factors being the preparation load, sintering temperature, and holding time. Hence, we have primarily considered the parameters of SiC mesh number, preparation load, sintering temperature, and holding time as those factors impacting the final performance of magnetic abrasives. All the experiments were conducted with the same sintering furnace at a heating rate of 20°C per minute, and the same type and amount of additive were used. The orthogonal experiment consisted of varying the four typical factors identified, and three levels of each factor were applied; the experimental scheme is presented in Tab. 2. Nine groups of magnetic abrasives were prepared under different process parameters using the atmospheric-pressure sintering method.

Table 2: Experimental scheme

Experiment number	Factor			
	Preparation load (A) [kN]	SiC mesh number (B)	Sintering temperature (C) [°C]	Holding time (D) [h]
1	20	1000	1000	3
2	20	1200	1100	4
3	20	1500	1200	5
4	40	1000	1100	5
5	40	1200	1200	3
6	40	1500	1000	4
7	60	1000	1200	4
8	60	1200	1000	5
9	60	1500	1100	3

3 Results and Discussion

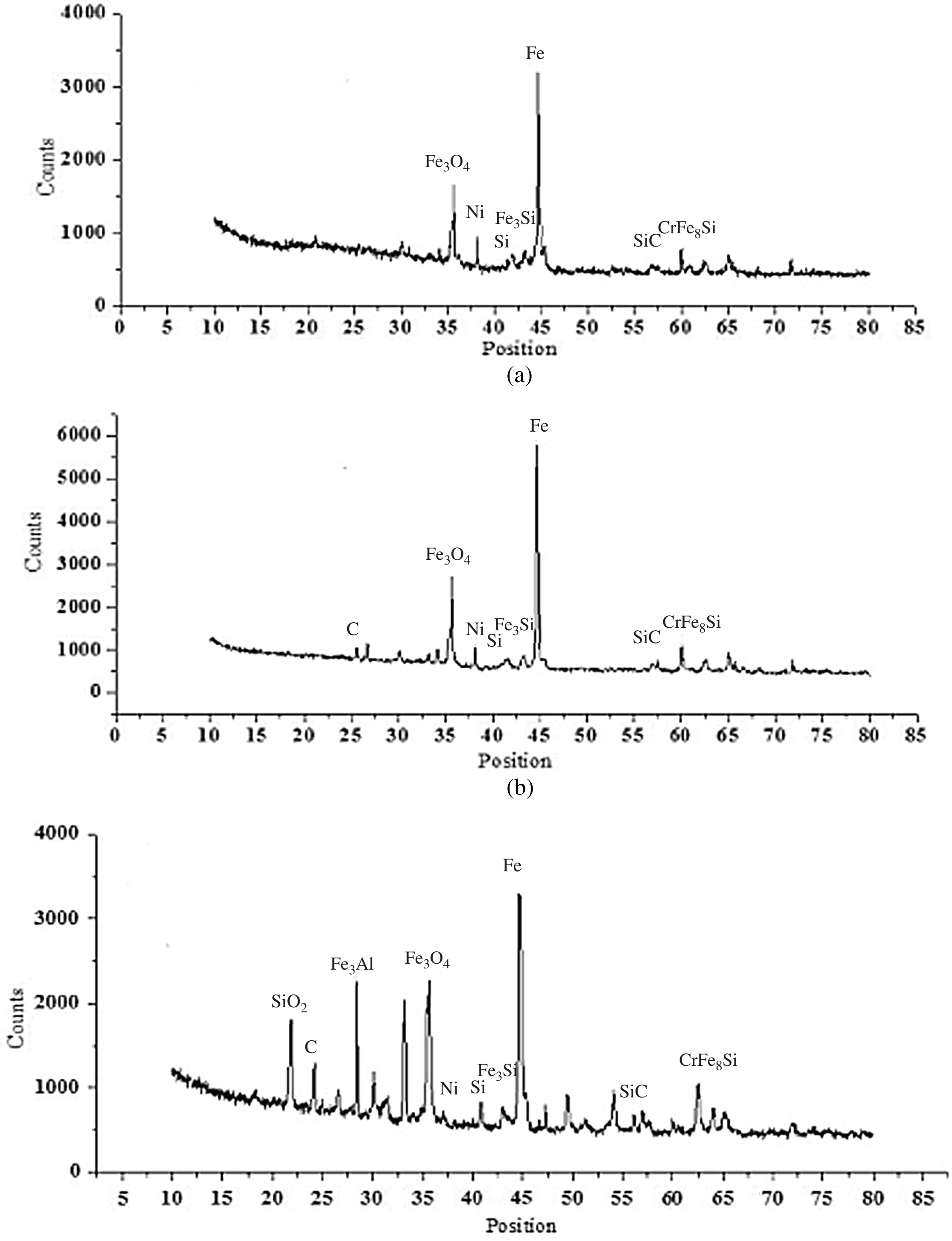
In this study, the phase compositions of the magnetic abrasives manufactured using the sintering method were tested and analyzed using X-ray diffraction (XRD). The influences of the preparation load, SiC mesh number, sintering temperature, and holding time on the density, magnetic properties, and surface morphology of the magnetic abrasive were then studied.

3.1 X-Ray-Diffraction Analysis

To study the effect of temperature on the phase compositions of the magnetic abrasives, a phase analysis of the sintered powders at different temperatures was conducted using XRD [14]. In this experiment, the temperature only affects the final phase composition, so the first three groups of samples were selected as the research objects. The spectra of these three groups of samples are presented in Fig. 2.

It is illustrated in Fig. 2a that the phase composition of the magnetic abrasive was mainly SiC, Fe, Ni, Si, $CrFe_8Si$, Fe_3Si, and Fe_3O_4 when the sintering temperature was 1000°C. Compared with the mixed powder before sintering, the phase composition contains three additional compounds: $CrFe_8Si$, Fe_3Si, and Fe_3O_4. Because the sintering process was conducted in the absence of atmospheric protection, the Fe powder reacted with O_2 at a high temperature, leading to the formation of Fe_3O_4. This process is similar to the Fe combustion process in the air. The elements Fe, Si, and Cr were combined with each other at the same time, sintering and generating the intermetallic compounds Fe_3Si and $CrFe_8Si$.

It can be seen from Fig. 2b that the phase composition of the magnetic abrasive included mainly SiC, Fe, Ni, Si, $CrFe_8Si$, Fe_3Si, Fe_3O_4, and carbon (C) at a temperature of 1100°C. The diffraction peaks are similar to those in Fig. 2a, whereas C is a new phase. This is because the further increase in the temperature led to an



(a)

(b)

(c)

Figure 2: XRD results for magnetic abrasives at different temperatures. (a) Temperature of 1000°C, (b) Temperature of 1100°C, (c) Temperature of 1200°C

increase in the Si dissolving in the Fe, which reduced the solubility of the C in the Fe. Then, finally, the C component was precipitated into graphite.

It is demonstrated in Fig. 2c that SiC, FeNi, Si, $CrFe_8Si$, Fe_3Si, Fe_3O_4, C, SiO_2, and Fe_3Al were included in the phase composition at a temperature of 1200°C. Compared with the original mixture, six additional compounds were found in the phase composition: $CrFe_8Si$, Fe_3Si, Fe_3O_4, C, SiO_2, and Fe_3Al. When the temperature reached 1200°C, the liquid phase appeared during the sintering process, or, in other words, the liquid-phase sintering stage occurred. The migration and diffusion of the components were more important, which led to the generation of SiO_2, because some of the Si element came into contact with O_2. Meanwhile, three kinds of intermetallic compounds were generated: $CrFe_8Si$, Fe_3Si, and Fe_3Al.

3.2 Sintering Density

The sintering density was used to characterize the densification of the magnetic abrasives in this study. It was measured by immersing the sintered products into molten paraffin, which stems the pore. The sintering density was then obtained by weighing. Based on the experimental results, the average densifications under different experimental conditions were calculated as presented in Fig. 3.

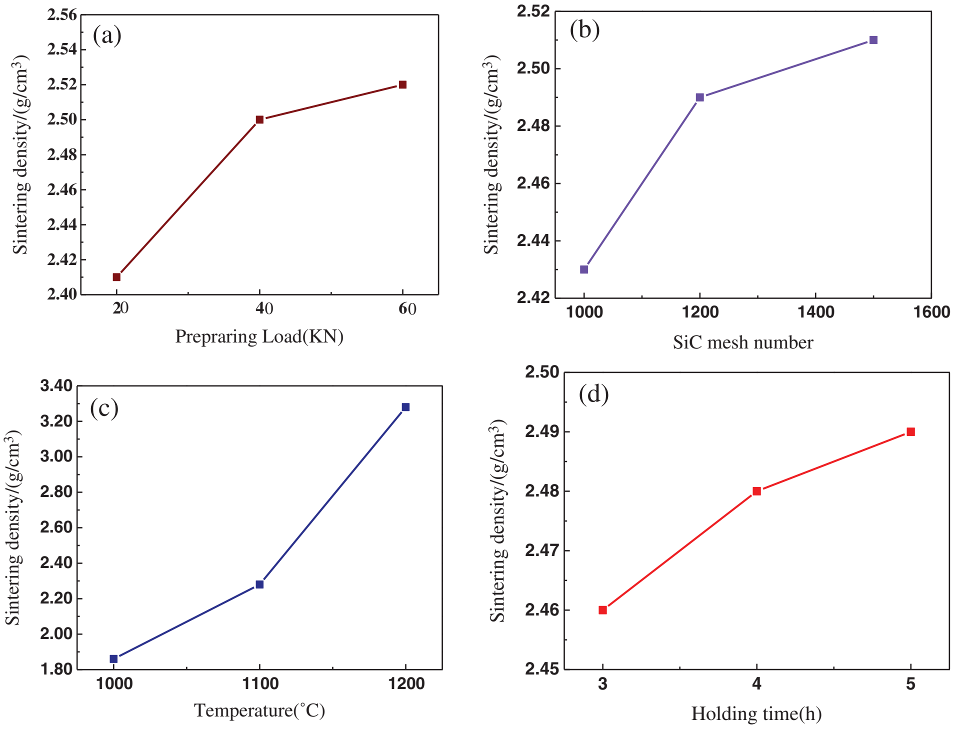


Figure 3: Experimental results for sintering density: (a) sintering density *vs.* preparation load; (b) sintering density *vs.* SiC mesh number; (c) sintering density *vs.* temperature; and (d) sintering density *vs.* holding time

It is presented in Fig. 3a that the sintering density increased with the increase in the preparation load. The arch bridge that formed between the Fe powder and the SiC powder was destroyed gradually with the increase in the pressure. Therefore, the particles began to move, which caused the volume to decrease and the density to increase. It can be seen from Fig. 3b that the sintering density increased with the increase in the SiC mesh number, and the growth rate gradually decreased. Fe powder has a high surface energy, and the combinations of Fe, SiC, and Ni powders further reduced the number and size of the pores. Hence, the sintering density increased. Compared with the other two groups, the SiC grains with the mesh number of 1,500 had a larger specific surface area and surface energy; therefore, the sintering density of the sintered body was the highest of the three, and the densification degree was also the highest. As illustrated in Fig. 3c, the sintering density increased with the increase in the sintering temperature. The sintering densification of the products improved with the increase in temperature, and the sintering density increased. Fig. 3d indicates that the sintering density increased with the increase in holding time. This is because prolonging the holding time can be done to avoid under-sintering when the other parameters are constant. The longer the holding time, the longer the process of material migration, and hence, the degree of densification increases. However, the holding time cannot be too long, else over-burning will occur.

Based on the analysis described, the sintering density increased with the increase in each of the sintering temperature, holding time, preparation load, and SiC mesh number. To show which of these are primary and secondary factors, a range value was introduced, which is the maximum average value minus the minimum average value for the same factor. The bigger the range value of the factor, the more important it is; therefore, the factor with the largest range is the most important or is the primary factor. Based on the results of the experiment, the range value of each factor was calculated. By sorting the range values of the various factors affecting the sintering density, it can be identified that the primary and secondary factors are as follows: sintering temperature (primary) > preparation load > SiC mesh number > holding time.

3.3 Magnetic Property

The magnetic property is a key feature of a magnetic abrasive, and it plays a major role in the determination of the magnetic force acting on a magnetic abrasive. The relative magnetic permeability was used to characterize the magnetic property of the magnetic abrasives. The hysteresis curves of the nine groups of magnetic abrasives were measured using a vibrating sample magnetometer (VSM) (Lake-Shore-VSM-7307). The average values of the relative magnetic permeability of the magnetic abrasives were then calculated, as illustrated in Fig. 4.

It can be seen from Fig. 4a that the relative magnetic permeability increased with the increase in the preparation load. The bonding strengths of the Fe powder and SiC powder increased with the increase in the preparation pressure, which caused more Fe powder to bind to the surface of the SiC; thus, the relative magnetic permeability increased. Fig. 4b shows that the relative magnetic permeability of magnetic abrasives increased with the increase in the SiC mesh number. According to the matching principle, the Fe powder's mass ratio increased with the increase in the SiC mesh number. Hence, increasing the SiC mesh number can improve effectively the relative magnetic permeability of magnetic abrasives. It is demonstrated by Fig. 4c that the relative magnetic permeability of the magnetic abrasives decreased with the increase in the sintering temperature. This was due to the formation of a new phase. In addition, the amount of trace elements, which are paramagnetic or inverse magnetic, dissolved in the Fe powder increased with the increase in the sintering temperature. The lattice distortion and the internal stress of the solid solution continued to rise, causing the specific saturation magnetization of the magnetic abrasives to decrease and the coercivity to increase. Hence, the relative magnetic permeability of the magnetic abrasives decreased. As illustrated in Fig. 4d, the relative magnetic permeability decreased with the increase in the holding time. This was because the specific saturation magnetization decreased, and the coercivity increased with the increase in the holding time, which led to the decrease in the relative magnetic permeability.

Through the analysis described, we determined that a lower sintering temperature and holding time and a higher SiC mesh number and preparation load are beneficial for improving the magnetic properties of magnetic abrasives. We again calculated the range value for each factor, and sorting these range values in descending order indicates that the primary and secondary factors affecting the magnetic properties of magnetic abrasives are as follows: sintering temperature (primary) > SiC mesh number > preparation load > holding time.

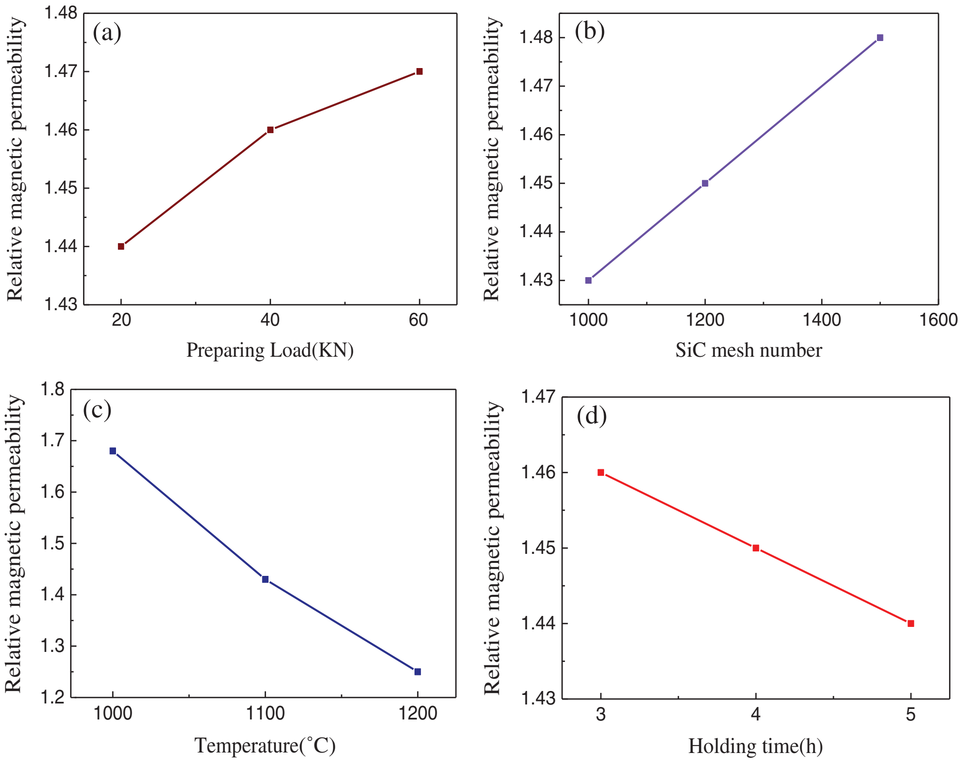
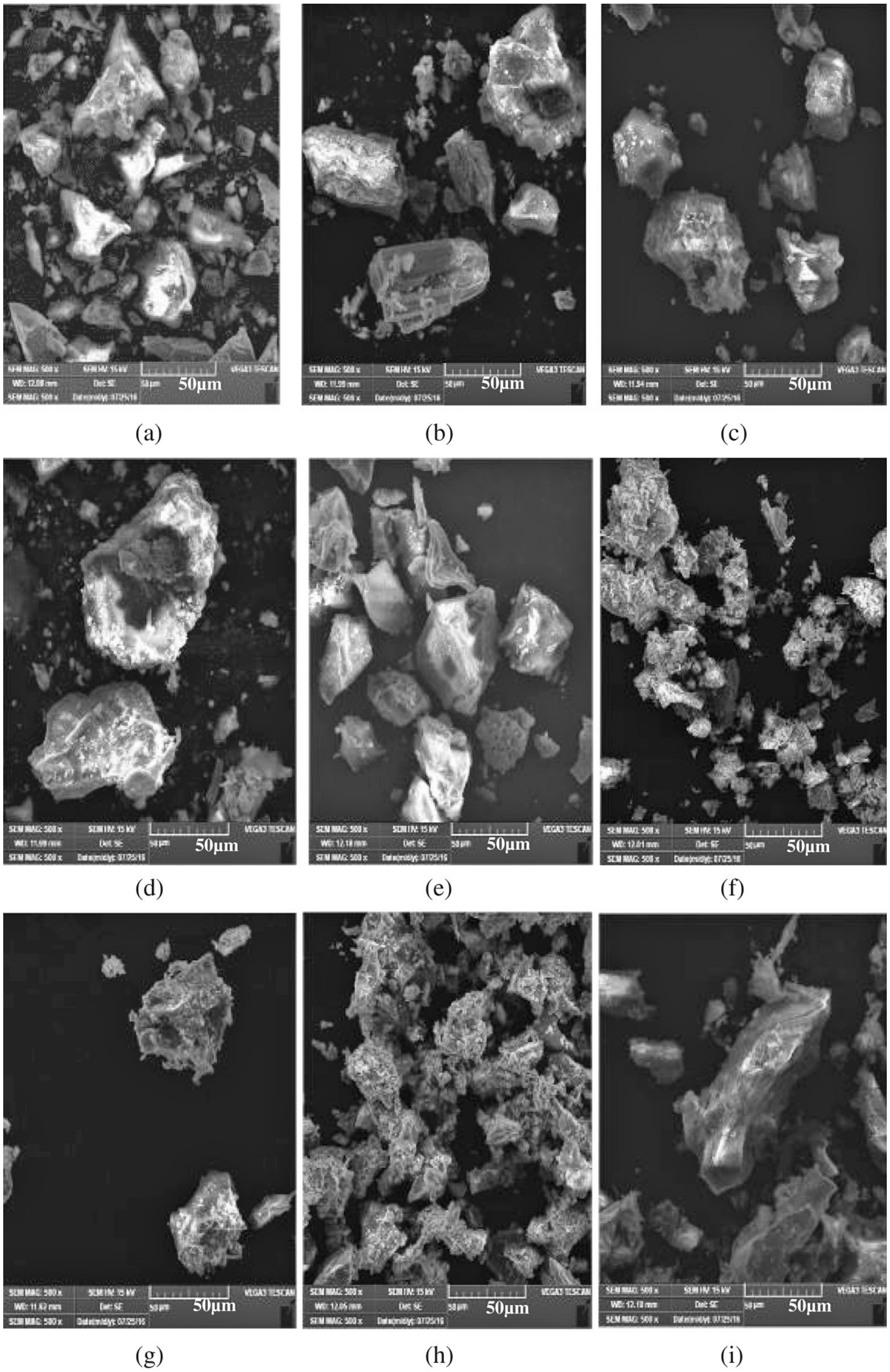


Figure 4: Experimental results for relative magnetic permeability: (a) relative magnetic permeability *vs.* preparation load; (b) relative magnetic permeability *vs.* SiC mesh number; (c) relative magnetic permeability *vs.* temperature; and (d) relative magnetic permeability *vs.* holding time

3.4 Scanning Electron Microscope Analysis

The compacts of the sintered magnetic abrasives were processed by crushing and grinding them, and then they were screened using a standard sieve with a mesh number of 325. Next, we used the VEGA-3 desktop SEM to examine the microstructures of the nine groups of magnetic abrasives prepared using orthogonal tests. Typical SEM photographs of the nine groups of magnetic-abrasive grains are presented in Fig. 5.

It can be seen from Fig. 5 that the bonding strength of the magnetic abrasives increased, and the sphericity became higher with the increase in the sintering temperature. However, the sharp edges and corners disappeared gradually, and the cutting edge was passivated slowly. This is because the temperature is the main factor affecting the densification of sintering. The densification of magnetic abrasives was not high when the sintering temperature was 1000°C, which resulted in a lower bonding strength for the superfine Fe powder and SiC powder. The migration between powders was very slow, and the number of pores between the powders was constant. Therefore, the final shapes of the magnetic abrasives were mostly irregular and were of strip and plate types. The material migration continued to be strengthened when the sintering temperature increased to 1100°C. Then, the diffusion and flow types of mass transfer began to take effect, which led to the improvement of the densification of the magnetic abrasives. Hence, the bonding strength increased. The ultrafine particles began to fill the pores between particles under the effect of material migration, which decreased the number of pores. Therefore, the shape of the magnetic abrasives became more regular and subspherical. When the sintering temperature increased to 1200°C, liquid-phase sintering appeared during the sintering process. The mass transfer was very intense at this stage, and various kinds of mass transfer were enhanced, which led to the



(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

Figure 5: SEM images of the magnetic abrasives. (a) Preparation load: 20 kN, SiC mesh number: 1000, Sintering temperature: 1000°C, Holding time: 3 h; (b) Preparation load: 20 kN, SiC mesh number: 1200, Sintering temperature: 1100°C, Holding time: 4 h; (c) Preparation load: 20 kN, SiC mesh number: 1500, Sintering temperature: 1200°C, Holding time: 5 h, (d) Preparation load: 40 kN, SiC mesh number: 1000,

(continued)

Figure 5: (continued).
Sintering temperature: 1100°C, Holding time: 5 h; (e) Preparation load: 40 kN, SiC mesh number: 1200, Sintering temperature: 1200°C, Holding time: 3 h, (f) Preparation load: 40 kN, SiC mesh number: 1500, Sintering temperature: 1000°C, Holding time: 4 h (g) Preparation load: 60 kN, SiC mesh number: 1000, Sintering temperature: 1200°C, Holding time: 4 h; (h) Preparation load: 60 kN, SiC mesh number: 1200, Sintering temperature: 1000°C, Holding time: 5 h; (i) Preparation load: 60 kN, SiC mesh number: 1500, Sintering temperature: 1100°C, Holding time: 3 h

considerable reduction of the number of particles between the pores. Therefore, the degree of densification and the bonding strength were further enhanced, and the shapes of the magnetic abrasives were mostly regular and subspherical. However, a higher temperature may enable Fe and other components to produce eutectics, which leads to the edges of SiC powder grains becoming wrapped. Hence, the cutting edge is passivated. Moreover, the particle size of the magnetic abrasives manufactured using SiC with a mesh number of 1,000 was relatively large. The particle size of the magnetic abrasives produced using SiC with a mesh number of 1,200 was medium, and the particle size of the magnetic abrasives created using SiC with a mesh number of 1,500 was small. The particle size of the manufactured magnetic abrasive decreased as the SiC mesh number increased. Therefore, the SiC mesh number selected has a huge influence on the particle size of the magnetic abrasives manufactured.

3.5 Comprehensive Analysis

The physical properties of the magnetic abrasives that were prepared are the sintering density and magnetic properties. These two indicators have equal weight in the MIWS process, so each of them accounts for 50%. We can calculate the weighting scores for various factors using the following formula:

$$\begin{aligned}\text{Weighting score} = {} & (\text{range of single influencing factor} \times \text{score of the index})/\\ & (\text{sum of range of each factor corresponding to the index})\end{aligned}$$

The results of this calculation are presented in Tab. 3. The scores for each influencing factor indicate the importance of that influencing factor in the analysis of the physical properties. The larger the total score, the more important the factor.

Table 3: Weighting scores of different factors

Factor	Indicator Weighting Score		Total Score
	Sintering density	Magnetic property	
Preparation load (kN)	3.35	2.83	6.18
SiC mesh number	2.44	4.72	7.16
Temperature (°C)	43.29	40.57	83.86
Holding time (h)	0.91	1.89	2.80

As demonstrated in Tab. 3, sorting the factors that affect the physical properties of magnetic abrasives in descending order gives the following: sintering temperature (primary) > SiC mesh number > preparation load > holding time. The total weight score (83.86) of the sintering temperature was far higher than that of the other factors. Hence, the sintering temperature plays a decisive role in the physical properties of magnetic abrasives. Based on this analysis, the sintering density increased with the increase in the sintering temperature, but the magnetic properties decreased. The higher the sintering temperature, the more serious the passivation of the magnetic abrasives' cutting edge. The sintering temperature needs to be neither too high nor too low. Therefore, the optimal sintering temperature is C_2, which is 1100°C.

The SiC mesh number is the factor with the second-highest influence on the physical properties of magnetic abrasives. The larger the mesh number of the SiC particles, the higher the magnetic properties and the sintering density of the prepared magnetic abrasives. Hence, the optimal SiC mesh number is B_3, which is 1,500.

The preparation load is the factor with the third-highest effect on the physical properties of magnetic abrasives. The magnetic properties and sintering density increased with the increase in the preparation load. Therefore, the optimal preparation load is A_3, which is 60 kN.

The holding time is the factor with the lowest impact of the four on the physical properties of magnetic abrasives. The sintering density increased with the increase in the holding time, whereas the magnetic property decreased. Thus, the optimal holding time is D_2, which is 4 h.

Utilizing the integrated-balance method gives the optimal combination of $A_3B_3C_2D_2$, namely, a preparation load of 60 kN, a SiC mesh number of 1,500, a sintering temperature of 1100°C, and a holding time of 4 h, for the preparation of SiC magnetic abrasives using the sintering method. Under this process, the relative permeability of the magnetic abrasive that was manufactured was 1.80, and the sintering density was 3.32 g/cm^3 (the SEM image is presented in Fig. 6), which confirms the validity of the optimal processing parameters. Furthermore, an MIWS experiment was conducted using the sintered magnetic abrasive produced using the optimal conditions. The average cutting width and edge-breaking

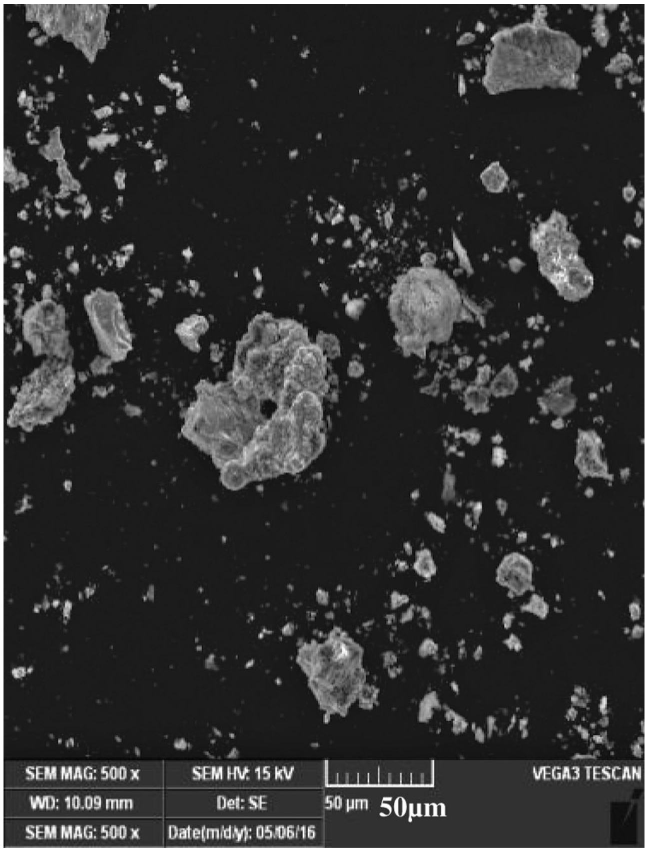


Figure 6: SEM image of the magnetic abrasive produced using the optimal processing parameters

width of the sintered magnetic abrasive can reach 522.10 and 79.97 μm, and the average material removal rate is 2.737×10^{-4} g/s. The results reveal that the magnetic-abrasive particles prepared using this sintering method can meet the requirements of the MIWS process.

4 Conclusions

Through this experimental study of the manufacturing process for magnetic abrasives using the sintering method, the following conclusions have been drawn:

1. During the process of SiC magnetic-abrasive grain preparation, the final phase compositions of the sintered magnetic-abrasive grains underwent a series of changes as a result of the increase in the sintering temperature. In detail, the phase composition included mainly SiC, Fe, Ni, Si, $CrFe_8Si$, Fe_3Si, and Fe_3O_4 at 1000°C; SiC, Fe, Ni, Si, $CrFe_8Si$, Fe_3Si, Fe_3O_4, and C at 1100°C; and SiC, Fe, Ni, Si, $CrFe_8Si$, Fe_3Si, Fe_3O_4, C, SiO_2, and Fe_3Al when the temperature rose to 1200°C, during which liquid-phase sintering began.
2. The sintering density of the magnetic abrasives increased with the increase in the sintering temperature, holding time, preparation load, and SiC mesh number. The primary and secondary factors were as follows: sintering temperature (primary) > preparation load > holding time > SiC mesh number.
3. The relative magnetic permeability of the magnetic abrasives increased with the increases in the preparation load and SiC mesh number and decreased with the increase in the sintering temperature and holding time. The primary and secondary factors were as follows: sintering temperature (primary) > SiC mesh number > preparation load > holding time.
4. Using comprehensive analysis, the optimal combination of process parameters for the preparation of SiC magnetic-abrasive grains utilizing the sintering method was identified to be $A_3B_3C_2D_2$; namely, a preparation load of 60 kN, a SiC mesh number of 1,500, a sintering temperature of 1100°C, and a holding time of 4 h. The magnetic-abrasive particles that were manufactured met the requirements of the MIWS process, and therefore, the use of this combination of parameters in this process shows considerable promise for the production of magnetic abrasives that would be a cost-effective tool for the MIWS process.

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Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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