THE EFFECT OF ABRASIVE GRAIN SHAPES ON QUALITY OF FERRITE MAGNETS GRINDING PROCESS

PENGARUH BENTUK BUTIRAN ABRASIV TERHADAP KUALITAS PROSES GERINDA FERIT MAGNIT

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Abstract

A research was conducted on the grinding process of ferrite magnet with Strontium ferrite type (SrO_6 (Fe_2O_3)) using electroplated single layer grinding wheels. Many cracks have been found on workpieces during this work, which was identified coming from grinding processes. Research is conducted starting from chemical composition test and the effect of the shape and size of the abrasive grain of grinding wheels to the quality of grinding process results by measuring crack ratio of the workpiece. In this experiment, 3 (three) model design of grinding wheels with three different sizes and shapes of abrasive grains are made. All of the processing parameters are set at the same value as ordinary process. The experimental results show that the 3rd model has the best results from the output's number and also the lowest reject crack ratio compared to 1st and 2nd models. This is because the 3rd model has a blocky shape which its distribution structure is denser and more uniform compared to the irregular shape so that continuous grinding on hard and brittle workpieces is more stable and suitable.

Key Words: Abrasive; Grinding wheels; Strontium ferrite; Irregular; Blocky.

Abstrak

Penelitian dilakukan pada proses gerinda terhadap bahan magnit Strontium ferit (SrO_6 (Fe_2O_3)) dengan menggunakan roda gerinda yang telah dilapisi secara electro plating dengan lapisan tunggal. Latar belakang masalahnya adalah selalu ditemukannya retak yang disebabkan oleh batu gerinda. Penelitian dilakukan dimulai dengan, pengujian komposisi kimia benda uji dan meneliti pengaruh bentuk dan ukuran butir abrasiv pada roda gerinda terhadap kualitas hasil gerinda dengan mengukur rasio keretakan benda uji. Pada penelitian ini dilakukan 3 model desain bahan roda gerinda dengan perbedaan ukuran dan bentuk bahan abrasive. Semua parameter proses diatur sama dengan parameter yang biasa dilakukan. Hasil penelitian menunjukkan bahwa model ke 3 menghasilkan produk yang terbaik dengan tingkat keretakan terendah. Hal ini karena model ke 3 disusun dari bentuk butiran blocky yang mempunyai distribusi lebih merata dan lebih padat, sehinga sesuai untuk penggerindaan bahan yang rapuh dan dilakukan secara terus menerus.

Kata kunci: Abrasif; Roda Gerinda; Ferit Strontium; Irregular; Blocky.

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INTRODUCTION

The use of electroplated super abrasive grinding wheels for grinding ferrite ceramic material was chosen because it has several advantages such as high material removal ability and ability to grind on complex profile shapes**1)**. In ordinary production process, an electroplated grinding wheel type is used to grind ferrite magnet workpieces but the results are not in accordance with the target, many cracks occur on workpieces so that many ferrite magnet products are rejected[2,3].

Generally, the grinding process of ferrite magnet is carried out to form precise dimensions and shapes after sintering. Ferrite magnet workpieces should have a semi-circular shape with dimensions of 50 mm length, 23 mm width and 2.3 mm thickness[1].

Grinding Process Flow

Grinding process uses a special grinding machine which was designed by the factory to grind ferrite magnet directly as it comes from the mold, the machine works sequentially with a conveyor feeding system. The workpiece enters in the initial dimension called raw material and passes the stage of the grinding position[3,4]. Until it gets the desired dimension, the grinding process starts at position 1 and position 2, i.e. the short side position grinding for the workpiece chamfer formation is rotated 90° for the near side grinding, after heading 1 and heading 2 are finished, the workpiece is rotated back 90° to its original position to enter position 3. Namely, the outer diameter surface grinding (OD Grinding), finished position 3, proceed to position 4, it is called the inner diameter grinding (ID grinding). In the new process[5], the grinding is in the lower position and the design adjusts to the grinding profile. Next step goes to position 5, namely the outer surface grinding for finishing, at position 5 uses a grinding wheel of the same type as position 3 but with different cutting depths, all stages of the process have followed the standard process and SOP (standard operating procedure) of process manufacturing plant. The results of the grinding can be seen after heading 5, where there appears to be a reject crack with the ferrite magnet workpiece. After heading 5, the workpiece can be called finish, from the production, there is a crack that appears on the workpiece on the outer surface position (Outer diameter) [6].

This research was conducted to analyse the failure of the grinding process that resulted in the occurrence of defect cracks in ceramic ferrite workpieces and to obtain an improvement in the grinding process through experiments on modelling the grinding wheel design[7,8]. It is expected that the experiments carried out can get the optimal solution to reduce the defect ratio of the grinding process.

MATERIAL AND METHOD

Research Method

Method of this research is conducted into several stages. It begins with the analysis of the causes of workpieces crack using fishbone diagram to find the root cause of failure using the 4M (Man, Material, Method, Machine) analysis as presented in Figure 1.

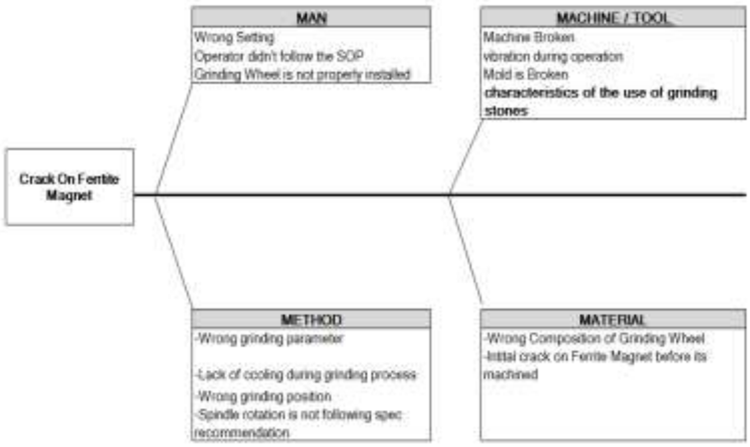

Figure 1.
Root Cause Analysis using 4 M System.

In this stage the work is focused on analysing the causes of cracks in the workpiece, to get an initial clue whether the workpiece cracks due to the ceramic material itself or caused by an external process such as the grinding process with an electroplating type grinding wheel. This examination includes several tests on material composition, the size of the crack, whether it is constant from one workpiece to another. Further analysis of this research is on the machine/tool because these factors can be

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analysed in terms of manufacturing effectiveness and time availability of research. Deeper analysis from the machine/tool is broken down into specific characteristics of the grinding wheels used as schematically presented in Figure 2.

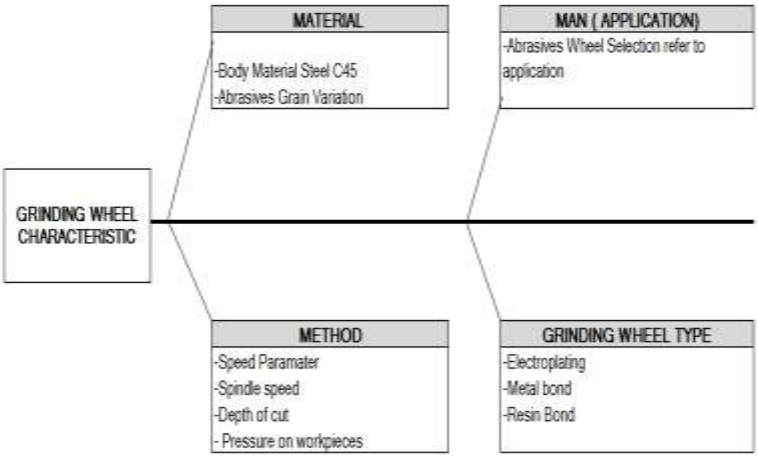


Figure 2.
Analysis Method on Grinding Wheel.

The second stage is planning to make a grinding wheel model with variations in the shape and size of abrasive grains. In this research, two types of abrasive grain size and two types of abrasive grain shapes were selected. The type abrasive items which are used are PDA 657 and PDA 878[9)]. From the two variations of shape and size, it has three electroplating type grinding wheel design models for the field-testing process. In one field experiment, it needs four grinding wheels, or two sets in each experiment, so in this research, the total grinding wheels needed for four total grinding wheel design models are twelve. The third stage is conducting field experiments of some of the grinding wheel models, then the output of the grinded work pieces and number of cracked workpieces is also recorded. The fourth stage is to analyse the results of the test by comparing the output data of the number of workpieces produced, the service life of the grinding wheel, and the reject ratio of cracks from the workpiece. Simulations of the grinding force are also carried out to prove that different abrasive grain designs affect the force of the grinding process. Detail of stages in this research is schematically shown in Figure 3.

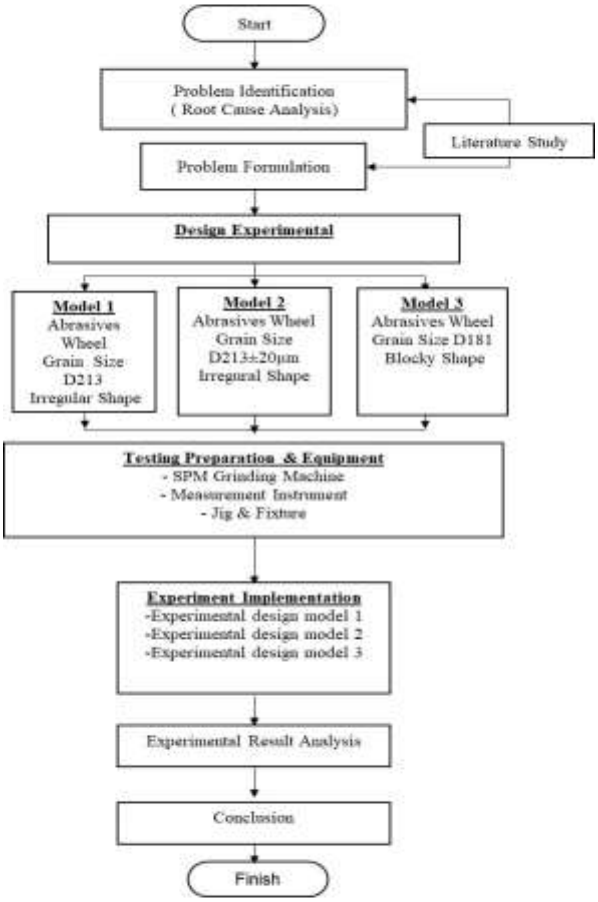


Figure 3.
Research Flow Diagram.

Variable in Research

The data of this research uses an experimental method or direct application experiment of the grinding process of the workpiece by comparing three different grinding wheel specification models.

The variable consists of independent and dependent variable[9,10)]. The independent variable is a large process variable. The independent variables used in this study are:

1. The abrasive grain shape of the grinding wheel.
2. The dimensions of abrasive grains.

While the dependent variable is the response variable whose magnitude cannot be determined, and the value depends on the experimental results, these variables are[11]:

1. The total amount of output from the workpiece produced in one test.
2. The total number of reject/damaged workpieces.

Material

Material of the workpiece is ceramic magnet ferrite with a dimension of 50 mm length, 23 mm width and 2.3 mm thickness. The types of ferrite magnets are Strontium ferrite SrO_6 (Fe_2O_3) with density 4.85 ± 0.01 g/cm^3 and Hardness (HV): 826 ± 10[12,13].

RESULT AND DISCUSSION

Analysis of the Experimental Model

Experiments were carried out by creating three electroplated grinding wheel models with variations of grit size. In model 1, a grinding wheel with irregular variations in the shape of the abrasive grains with grit size D213 or 213 µm [14] as shown in Figure 4. The results of grinding show that workpiece still has crack. Total of workpieces produced is 972,856, with 2,332 pieces or 0.24% cracks as is shown in Figure 5 and Table 1.

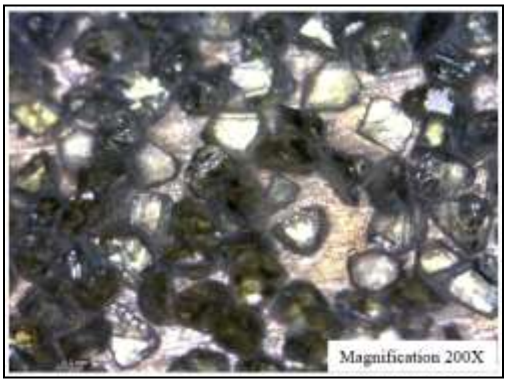


Figure 4.
Surface Profile of Grinding Wheel in Model-1.

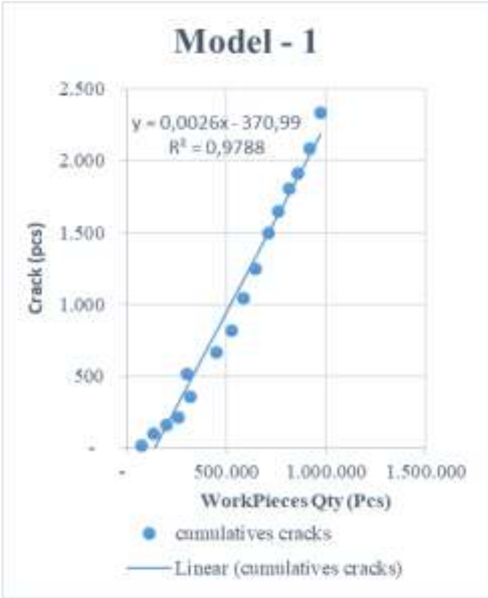
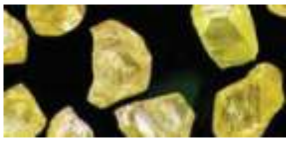


Figure 5.
Curve of Experiment Result on Model-1

Table 1.
Experiment Result on Model-1

Irregular Grain Dimension: 213µm	
Total Production	972,856 pieces
Total Rejected	2,332 pieces
Rejection Ratio	0.24 %

Improvements were made to the abrasive grains on Model-2 experiment, sorting the abrasive grains in an irregular shape but with more precise grit size D213, or 213µm ± 20µm as is shown in Figure 6.

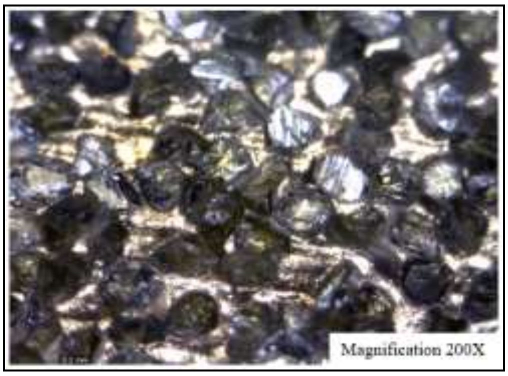


Figure 6.
Surface Profile of Grinding Wheel Model-2.

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The result indicates that the crack ratio of the workpiece is reduced, and the service life is increased. The number of workpieces produced is 1,373,514 pcs, with the number of rejects is 206 pcs or 0.015% as shown in Table 2 and Figure 7.

Table 2.
Experiment Result on Model-2

Irregular Grain Dimension: 213 ± 20µm	
Total Production	1,373,514 pieces
Total Rejected	206 pieces
Rejection Ratio	0.02 %

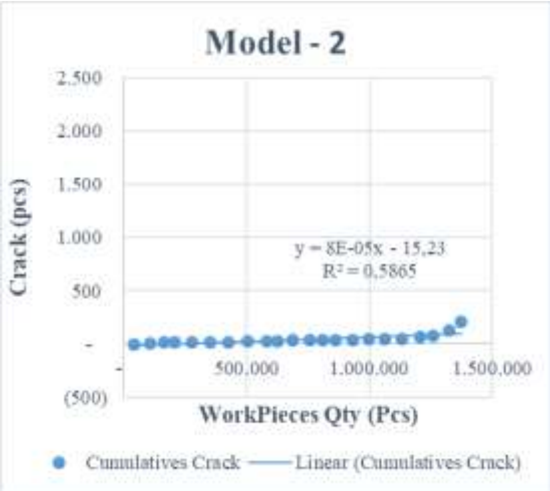


Figure 7.
Curve of Experiment Result on Model-2

Changes were made in Model-3 experiment in term of the shape of the abrasive items from irregular shapes into regular shapes and blocky shapes as presented in Figure 8.

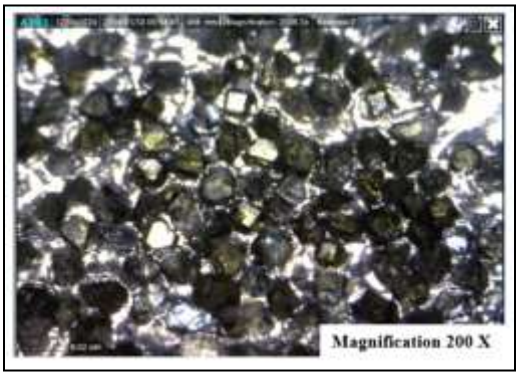
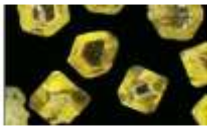


Figure 8.
Surface Profile of Grinding Wheel Model-3

There was a significant change compared to the two previous models, the result of work for Model-3 is 1,354,816 pieces, with the number of cracks is 51 pieces or 0.004% from total production as is presented in Table 3 and Figure 9.

Table 3
Experiment Result Model-3

Blocky Grain Dimension: 181µm	
Total Production	1,354,816 pieces
Total Rejected	51 pieces
Rejection Ratio	0.004 %

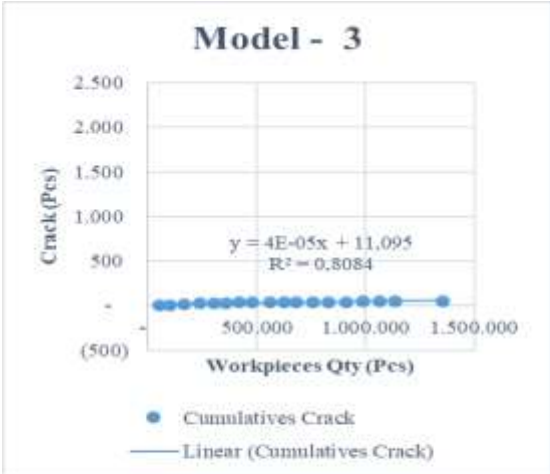


Figure 9.
Curve of Experiment Result on Model-3

From three experiments that have been done, the results show that using a grinding wheel with blocky shape grains in Model-3 give the best results compared to Model-1 and Model-2. The grinding process produces a relatively stable output and significantly fewer cracks. It can be explained that blocky shape has smoother surface roughness than the other two shapes so that dynamic load which is applied to the workpiece is lower, as a result, the stress that is formed in the ceramic workpiece is also lower, consequently, fewer cracks are generated[14,15]. Similar results can also be seen in the relationship of dimensional changes in the shape of abrasive grains to the reject ratio of the workpiece as presented in Figure 10. From this figure, it can be seen that the smaller diameter of grains used the better result is obtained. This phenomenon is related to the surface area contact between grinding grain and workpieces, where smaller grains have a larger surface contact area with workpiece compared to bigger grain. Therefore, during the grinding process, the possibility of vibration that may occur is smaller, as a result, the workpiece withstands the applied load relatively constant so that less crack is formed[12,15].

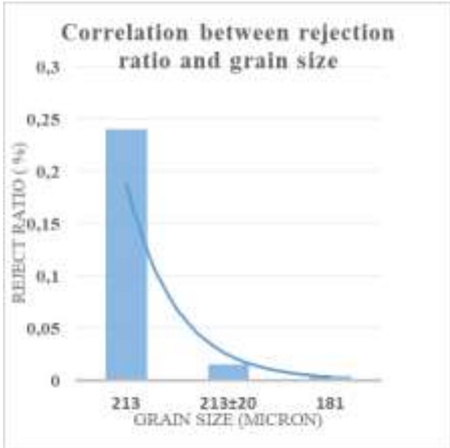


Figure 10.
Trend of Declining Reject Ratio of Work Piece against Abrasive Grain Size

Workpiece Structure Analysis

Analysis on the workpiece is done to observe its characteristics and analyse the defect of the workpiece to confirm the effect of grinding structure on the formation of crack on ceramic ferrite. In this research, the inspection of ceramic workpieces is carried out on the cross-section on the workpiece by cutting out such as presented in Figure 11.

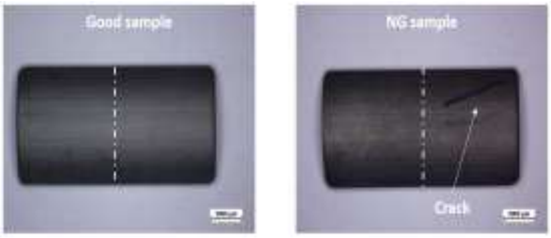


Figure 11.
Cross Sectional Cutting on Good Workpiece (Left) and Cracked Workpiece (Right)

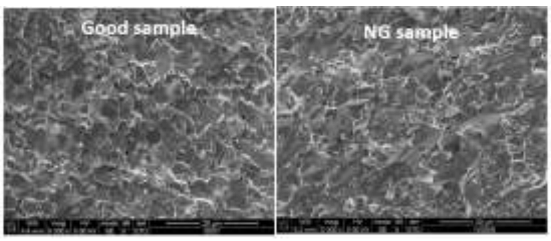


Figure 12.
Microstructure of Cross Section of Good Workpieces (Left) and Not Good (Cracked) Workpiece (Right).

From the results of microstructure examination of the good workpiece and rejected workpiece, it can be seen that microstructures of both workpieces are not different (Figure 12), it can be concluded that all of the cracks that formed after grinding is not caused by workpiece material matter.

To confirm whether the crack formed due to the scratch generated from rough abrasive grain or due to other factors during grinding, three pieces of cracked workpieces are taken from the results of Model-1 design grinding wheel output for analysis. The result of examinations can be seen in Table 4, and Figure 13.

Table 4.
Results of Cracked Workpiece Examinations.

Sample No	*Crack Max Depth (µm)*	*Crack Max Width (µm)*
1	54.434	~ 70
2	120.933	~ 100
3	102.948	~ 150

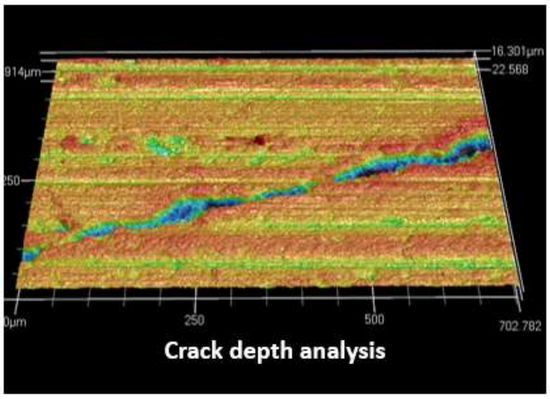


Figure 13.
Topographic Photograph of Cracks Depth

It can be seen from Table 4 that the crack depth varies from about 54 to 102 µm and crack width between 70 to 150 µm. This value is smaller than grinding grain diameter (± 213 µm) so that it can be concluded that the crack is not caused by scratched from grinding wheel. Moreover, the examination result that taken from Scanning Electron Microscopy (SEM) shows that the crack is not parallel to the grinding track directions (Figure 13). This evidence indicates that the

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crack is not originated from grinding scratch on the workpiece surface.

The best model of abrasive grain on grinding wheel to produce the best quality has been obtained, however, the productivity of this grinding wheel should be tested to get economic feasibility for production.

From the early experiment, it is found that the best result was obtained by Model-3 which has specifications of the blocky grain shape with 181μm average diameter. Economic feasibility research is done by comparing each model output/day, lifetime wheel and reject rate percentage to the determined factory target, and the result is presented in Table 5.

Table 5.
Results of Experiments Compared to Targets

Parameter	*Target*	*Result*		
		Model-1	*Model-2*	*Model-3*
Production output (pieces/day)	> 40,000	60,804	62,432	75,268
Lifetime wheel (pieces)	> 1,000,000	972,856	1,373,514	1,354,816
Rejection rate (%)	Max 0.12	0.24	0.015	0.004
Rank		3	2	1

It can be seen in Table 5 that the result of Model-1 still does not meet the targets of the process, while Model-2 has been able to meet the target but is not optimal yet, and the best result and most optimal experiment can be obtained by Model-3.

CONCLUSION

From results of experiments and also the results of analysis that have been carried out in this research, it can be concluded that the quality of ferrite magnets on grinding process is significantly affected by the shape and size of abrasive grain on the grinding wheel. From the experiment result, it indicates that the best shape of grain is blocky grain shape with 181μm average diameter. While the effect of grain size on the grinding quality result shows that the smaller diameter of grains used the better result is obtained.

AUTHOR CONTRIBUTIONS

Bayu Rahmat Saputro and Amin Suhadi contribute equally in this work, but Amin Suhadi is corresponding auditor.

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