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Analysis of Micro Structure, Porosity Disability and Wear Resistance with Volume Variation from Riser On the Engine Cover of Electric Motors

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ABSTRACT

This research to analyze the microstructure, porosity defects, and wear resistance of aluminum casting in the presence of variations in the volume of risers. The method used is the pre-experimental method of the One-Shot Case Study type, because in this study a treatment will be carried out and the results will be observed. The treatment that will be carried out is the addition of variations not using risers, variations of riser cylinders with a volume of $2826mm^3$, variations of riser cylinders with a volume of 4710mm3, variations of riser cylinders with a volume of $6594mm^3$. Microstructure testing used the Meji Techno IM 7200 test tool. Wear testing used the Ogoshi High Speed Universal Wear Testing Machine (Type OAT-U). The data analysis used is descriptive analysis to provide an overview of the research subject based on data from the variables obtained from the group of subjects studied. The best microstructure is shown by the cast specimens with the riser volume variation of $6594mm^3$ as evidenced by the formation of a more dense and even structural phase. The best porosity results were shown by the specimens that were cast with a volume variation of the riser $6594mm^3$ of 37.97%. The best wear resistance results in variations of the volume riser $6594mm^3$ with wear values of $0.51x10\text{-}7mm^2/kg$.

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1. INTRODUCTION

The electric motor is a device commonly used in the automotive and industrial sectors. With age, wear and tear inevitably occur. One common type of damage to electric motors is abrasion, such as wear on the electric motor cover components that serve as the bearing location for the bearings.

This casting defect is influenced by various factors, one of which is the inadequate design of the channel system [1]. The channel system in sand molds includes the pouring cup, sprue, dam or reservoir, runner, riser, and ingate [2], [3]. This research will delve into the volume of the riser. The riser plays a crucial role as it is the channel through which molten metal exits the mold cavity. By considering the volume of the riser, it is expected to reduce the risk of defects that commonly occur in sand casting [4].

The sand casting process consists of a gating system that delivers molten metal into the mold cavity, where the molten metal is transformed into a solid product [5]. Molten metal is poured into the mold through the gating system and flows through the cavity, eventually reaching the riser. Once the molten metal reaches the riser, the pouring of molten metal is stopped. Due to the riser being positioned higher than the cavity, its potential energy is higher than the molten metal in the cavity [6], [7]. With this arrangement, the molten metal in the riser compensates for the volume reduction due to shrinkage during the solidification of the molten metal when compacted in the mold. Therefore, the molten metal in the riser must be compacted in the subsequent stage after the molten metal in the cavity. If the riser size is properly designed, the shrinkage cavity generated in the mold is reduced, and a solid structure can be obtained in the casting product, resulting in high-quality casting. However, if the riser size is not properly designed (if it is too large), productivity is affected due to high material costs, low recovery rates, longer compaction times, and a lengthy post-process to remove the riser. On the other hand, if the riser size is too small, defective casting is produced [8]. Since casting defects are the biggest issue in the process, casting companies use larger risers than the product size for casting processes to obtain a solid structure in the casting product, resulting in high-quality casting [9].

The riser is a channel that compensates for the shrinkage process during the solidification of the casting, so the riser's solidification must be slower than the casting. The riser must have a suitable size because if it is too large, the utilization percentage will be reduced, and if it is too small, it will cause shrinkage in the casting [10]. The riser serves as a fluid supplier during casting shrinkage and also as an outlet for trapped air in the mold cavity [11].

The determination of the diameter of the riser can use the formula ø = 3.5 x t (product thickness) [12]. In this study, the product thickness is 10 mm, and if this formula is applied, a diameter of 35 mm is obtained. Then the researcher tried to examine the results with diameters of 15 mm, 25 mm, and 35 mm, and the height of all risers is 60 mm. Therefore, the researcher created variations in specimens in this study, namely without a riser, a riser with a volume of 2826 mm3, a riser with a volume of 4710 mm3, and a riser with a volume of 6594 mm3.

This study focuses on variations in the volume of open risers concerning microstructure, porosity defects, and wear resistance from aluminum sandcasting results. Different riser volumes in the gating system will produce different microstructures and compositions of products, resulting in different wear resistance. The study uses wear resistance testing to determine the wear rate of casting results, which is one of the essential mechanical properties. And microstructure testing is used to obtain images of the metal structure of casting results. For these purposes, the researcher is interested in understanding how the volume of the riser in the sand mold affects the quality of the resulting remelted aluminum casting components of used electric motors.

2. METHOD

In this study, the research design used is the One-Shot Case Study type, as the research involves a treatment that will be subsequently observed for its outcomes. The riser used for the cylinder has a volume of 4710 mm3, and one pattern is used for the variation of the riser with a volume of 6594 mm3. In the sand mold, observations of the microstructure and wear resistance testing will be conducted on the results of casting components from used electric motors. The treatment involves variations, including not using a riser, one pattern for a riser with a cylinder volume of 2826 mm3, and another pattern for a riser with a volume of 6594 mm.

2.1. Research Specimens

The research specimens were taken from the castings of DC electric motor covers, as shown in Figure 1, which were cut open. Three specimens were taken for each variation. The total number of specimens is 12 pieces.

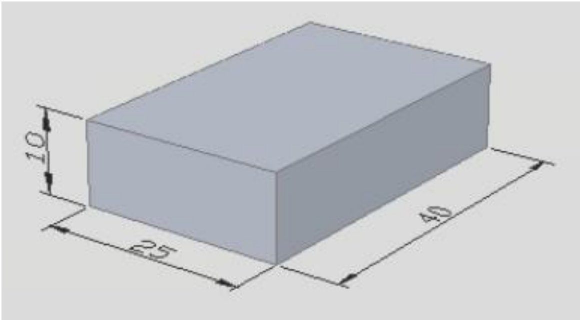

Figure 1. Dimensions of Test Specimens

Figure 2. Photo of Test Specimens

Data collection techniques to be gathered and later processed are presented in tabular form after conducting observations. The data analysis technique used in this research is descriptive statistical analysis. Descriptive statistics refer to statistics used to depict or analyze collected data without altering or engineering it, ensuring that the data remains authentic and conclusions are drawn without specific or generalized modifications. This technique is presented through tables and graphs. The research analysis employs quantitative analysis to describe the analysis of variations in the volume of the riser in aluminum sand casting concerning microstructure, porosity, and wear resistance.

3. RESULTS AND DISCUSSIONS

3.1 Microstructure testing

The testing of the pulse sensor was conducted to determine whether the heartbeat sensor is functioning correctly. Figure 5 shows the readings from the pulse sensor connected to analog pin 0 of the Arduino. The test results indicate that the sensor is working well, as evident from the matching shape of the generated signal.

From the signal waveform of the pulse sensor, we can obtain the BPM value by establishing a threshold point on the signal. When the ADC signal exceeds the specified threshold value, it counts as one beat or one pulse. The determination of the threshold value is based on the sensor's output signal as displayed on the signal plotter when the sensor detects a pulse, as well as the results of comparison testing with BPM values obtained using a digital OMRON blood pressure monitor.

During testing, if the number of BPM on the device is lower than the number of BPM on the OMRON, the adjustment made is to reduce the threshold value. This adjustment is necessary because a threshold that is set too high can lead to some beats not being counted since they have ADC values lower than the threshold. In this research, the threshold value was set at 550. To obtain BPM, the calculation process is conducted over one minute. During this one-minute interval, the number of beats that successfully surpass the specified threshold value is counted and becomes the BPM value.

Figure 6 shows the readings of the BPM values displayed on the device, while Table 2 provides a comparison between the BPM values on the device and the results measured by the digital OMRON blood pressure monitor. The average percentage error in BPM values from the testing is 2.18%, indicating that the BPM results from the device have an accuracy of 97.28%.

Table 1. Elements of the cover of the Kijang electric motor engine

Unsure	Kadar %
Al	84,56
Si	12,6
Fe	1,1
Cu	0,126
Mn	0,264
Mg	<0,05
Cr	<0,015
Ni	<0,02
Zn	1,13
Sn	0,0556
Ti	0,0099
Pb	<0,03
Be	0,0001
Ca	0,0061
Sr	<0,0005
V	<0,01
Zr	<0,003

Table 2. Elements of the research specimens

Unsure	Kadar %
Al	68,51
Si	21,3
Fe	6,62
Cu	0,680
Mn	0,0202
Mg	0,296
Cr	<0,015
Ni	0,175
Zn	0,0603
Sn	<0,05
Ti	0,0244
Pb	0,256
Be	0,0003
Ca	0,0036
Sr	<0,0005
V	1,57
Zr	0,0467

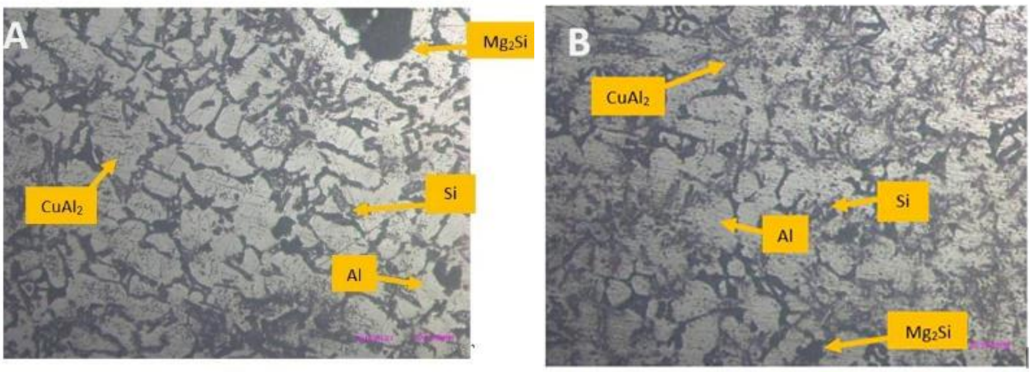

Figure 4. Microstructure of specimens with a variation of the riser channel volume of 2826 mm^3

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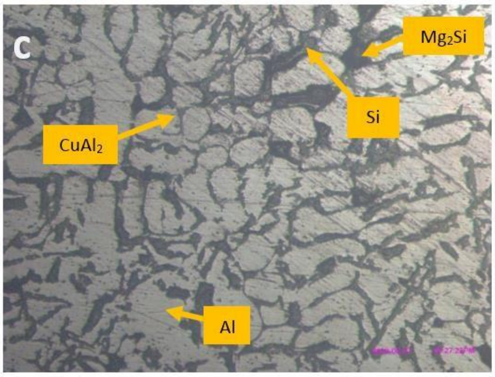

Figure 5. Microstructure of specimens with a variation of the riser channel volume of 4710mm^3

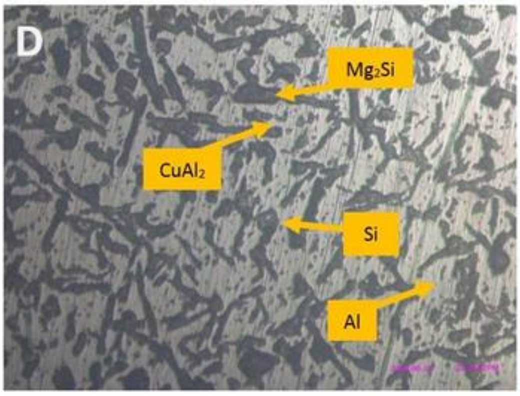

Figure 6. Microstructure of specimens with a variation of the riser channel volume of 6594mm^3

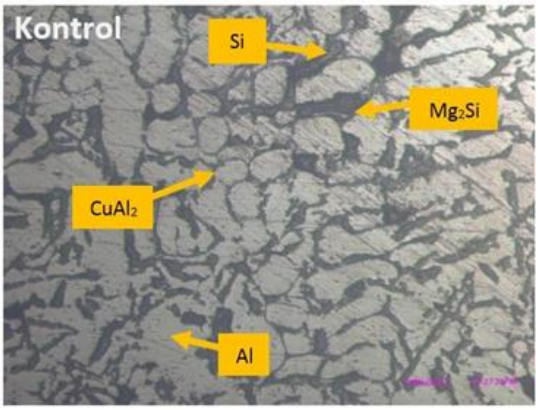

Figure 7. Microstructure of the control specimen

The best microstructure in the casting results is indicated by specimens with a variation of the riser channel volume of 6594 mm3 compared to variations with a riser channel volume of 4710 mm3, a riser channel diameter volume of 2826 mm3, and variations without using a riser channel. This is evidenced by the formation of a denser and more uniform phase structure. However, the microstructure of the electric motor cover is superior to the casting specimens, as indicated by a more homogenous arrangement of phases. The aluminum alloy used for wear resistance is an aluminum-silicon alloy. The hypoeutectic alloy contains a soft and ductile primary aluminum phase and a hard and brittle silicon phase in accordance with the eutectic reaction. It is this silicon phase that contributes to the good wear resistance of this alloy. Silicon is insoluble in aluminum [13].

The improvement in the quality of the microstructure can be determined through the chemical content of the product material. If the chemical content of the product material contains more than 12% silicon, it can be concluded that the wear resistance of the product will increase because silicon has brittle and hard properties that contribute to the properties of the main material, which is aluminum.

3.2 Porosity Testing

Actual density or sample: $\rho_m = \frac{m_s}{(m_s - m_g)} \; x \; \rho_{H_2O}$

Porosity: $P = \frac{D_{teoritis} - D_{actual}}{D_{teoritis}} \; x \; 100\%$

Table 3. Results Calculation Data

Porosity Data Testing								
Specimens					Densitas calculation (cm^3)	Densitas Teoritis (g/cm3)	Porosity (%)	The average porosity of each variation (%)
Volume Riser (mm^3)		Wbefore (gram)	Wafter (gram)	Volume Specimen (g/cm^3)				
Tanpa Saluran penambah	A1	25,75	11,19	10	1,77	2,65	33,01	33,07
	A2	25,73	11,04	10	1,75	2,65	33,65	
	A3	26	11,4	10	1,78	2,65	32,54	
2826	B1	24,57	10,41	10	1,73	2,65	34,27	35,06
	B2	26,02	10,71	10	1,07	2,65	35,63	
	B3	26,69	11,07	10	1,71	2,65	35,28	
4710	C1	25,25	10,26	10	1,68	2,65	36,19	36,91
	C2	23,97	9,55	10	1,66	2,65	37,03	
	C3	24,65	9,71	10	1,65	2,65	37,50	
6594	D1	26,07	10,07	10	1,63	2,65	38,28	37,97
	D2	25,17	9,83	10	1,64	2,65	37,85	
	D3	26,1	10,19	10	1,64	2,65	37,86	
Kontrol 1		3,87	1,45	1,5	1,6	2,65	39,62	39,36
Kontrol 2		3	1,10	1,25	1,59	2,65	39,24	
Kontrol 3		3,14	1,17	1,26	1,59	2,65	39.24	

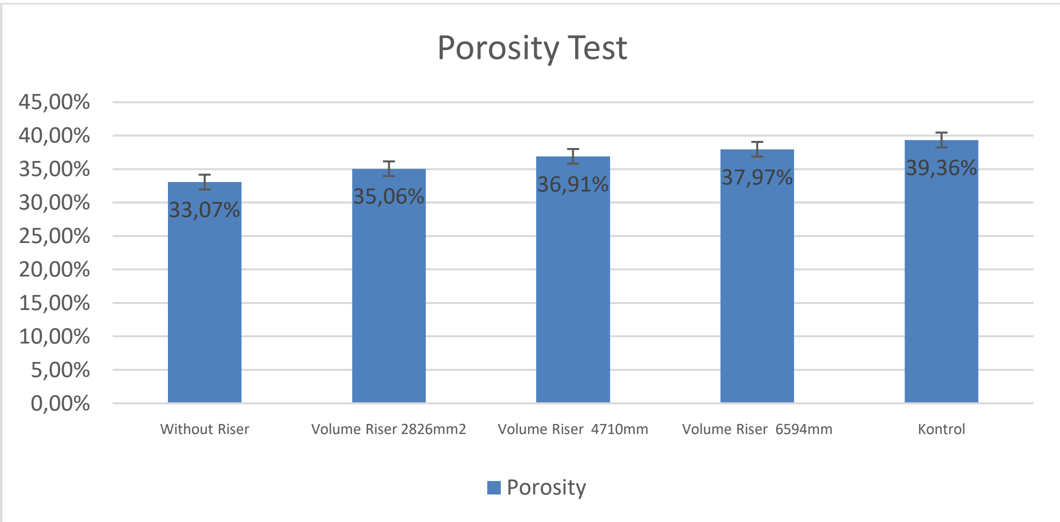

Figure 8. Representation of Porosity Testing Results with a Bar Graph

Porosity defect values indicate changes in porosity values after treatment. The influence of the addition of the riser channel on porosity values can be observed, with the best porosity value observed for the addition of a riser channel with a volume of 6594 mm3 at 37.97%, and the worst porosity value for the variation without a riser channel at 33.07%. This is in line with the findings of a study by Fasya and Iskandar [14] titled "Melt Loss and Porosity in Recycled Aluminum," which states that the varied and relatively high

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porosity values can be attributed to the enlargement of formed pores, different pouring times leading to trapped air, and variations in different levels of impurities (slag) in the molding sand due to the use of different molds for each casting.

The increase in porosity values can be determined through the permeability of the molding sand, which can be influenced by the volume of the riser channel. If the volume of the riser channel increases, it is concluded that it will increase the permeability of the molding sand because gases trapped in the mold cavity can easily escape to the surface through the riser channel, thereby reducing porosity, and vice versa. To strengthen the measurement data, a microphotography test was conducted with a magnification of 100x, and the results are as follows:

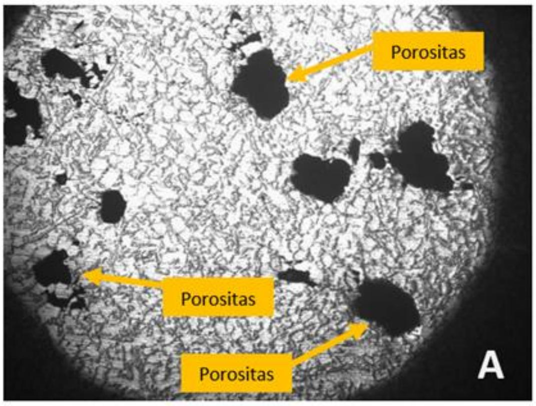

Figure 9. Micro Photo Of The Porosity Of The Variation Specimen Without Riser

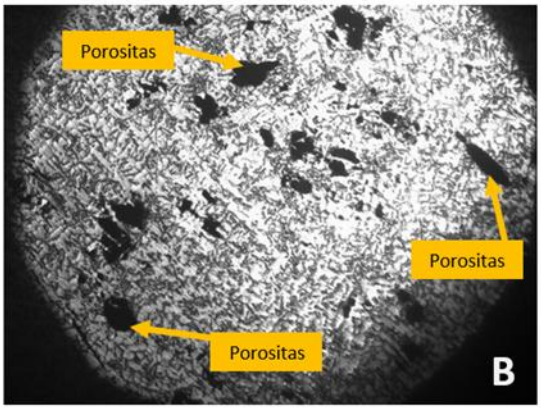

Figure 10. Micro Photo Of The Porosity Of The Volume Riser, Variation Specimen 2826mm^3

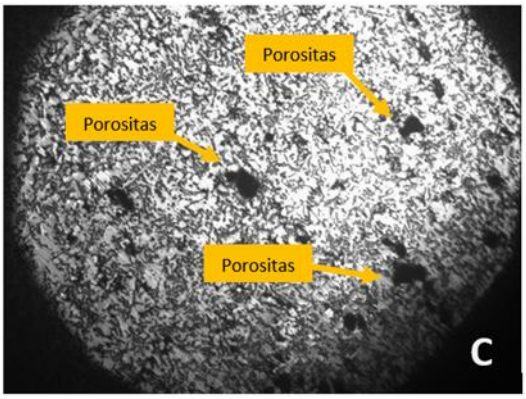

Figure 11. Micro Photo Of The Porosity Of The Volume Riser, Variation Specimen 4710mm^3

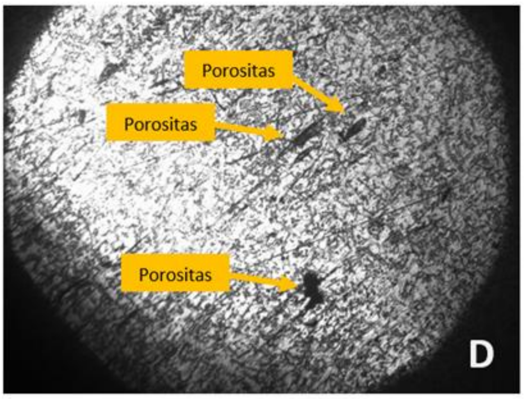

Figure 12. Micro Photo Of The Porosity Of The Volume Riser, Variation Specimen 6594mm^3

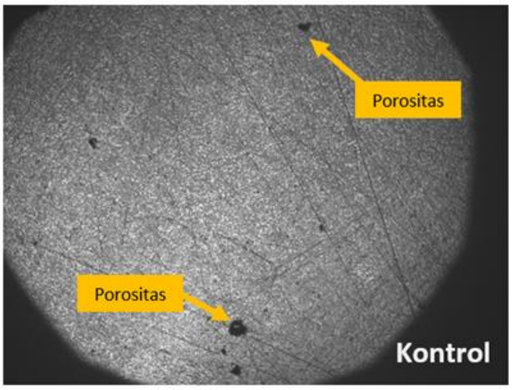

Figure 13. Micro Photo Of The Porosity Of The Volume Riser, Control Variation Specimen

Table 4. Measurement Data Of Abrasion Groove Width Using A Microscope

Abrasion Groove Witdh (b_0)

Specimen		Experiment			average b_0
Riser volume (mm^3)		I	II	III	(mm)
Without Riser	A1	34	32	27	1,63
	A2	35	31	30	1,68
	A3	29	30	35	1,65
2826	B1	30	28	28	1,51
	B2	21	27	30	1,37
	B3	24	28	29	1,42
4710	C1	19	15	18	0,91
	C2	19	16	19	0,94
	C3	21	19	20	1,05
6594	D1	16	15	11	0,74
	D2	16	12	18	0,81
	D3	18	16	17	0,89
control 1		33	29	21	1,46
control 2		30	28	24	27,33
control 3		29	28	25	26,67

Next, the parameter values are entered in the table below. With a time of 1 minute, abrasion distance of 66.6m, and load of 2.12kg. To calculate the wear value, use the formula:

$$Ws = \frac{B.\, Bo^3}{8.\, r.\, p.\, lo}$$

(source: *Ogoshi Testing Machine Instruction Manual*,1987)

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Table 5. Calculate Data *Specific Abrasion*

Ogoshi Wear Test									
Spesimen		Abration Time	Abration Distance	Abration Speed	Final Load (Po)	Abration Groove Width		Specific Abration (ws)	Average Specific Abration (ws) of each variation
Riser Volume (mm^3)		second	m	m/s	kg	bo	bo3	$x10^{-7}$ mm^2/kg	
Without riser	A1	60	66,6	0,250	2,12	1,63	4,33	4,06	4,24
	A2	60	66,6	0,250	2,12	1,68	4,24	4,44	
	A3	60	66,6	0,250	2,12	1,65	4,49	4,21	
2826	B1	60	66,6	0,250	2,12	1,51	3,44	3,22	2,77
	B2	60	66,6	0,250	2,12	1,37	2,57	2,41	
	B3	60	66,6	0,250	2,12	1,42	2,86	2,68	
4710	C1	60	66,6	0,250	2,12	0,91	0,75	0,71	0,87
	C2	60	66,6	0,250	2,12	0,94	0,83	0,78	
	C3	60	66,6	0,250	2,12	1,05	1,16	1,08	
6594	D1	60	66,6	0,250	2,12	0,74	0,4	0,38	0,51
	D2	60	66,6	0,250	2,12	0,81	0,53	0,5	
	D3	60	66,6	0,250	2,12	0,89	0,70	0,66	
control 1		60	66,6	0,250	2,12	1,46	3,11	2,91	2,76
control 2		60	66,6	0,250	2,12	1,44	2,99	2,80	
control 3		60	66,6	0,250	2,12	1,40	2,7	2,57	

The smaller the value of a specific abrasion, the better the wear resistance of the object. The best results were obtained in the casting with the variation of the riser channel volume of 6594 mm^3. To facilitate the interpretation of the results from the Ogoshi wear testing method, a graph is created.

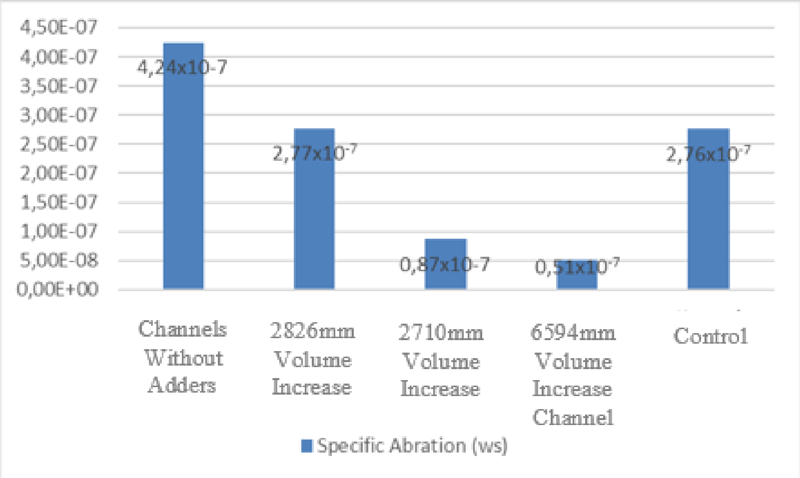

Figure 13. Depiction Of Wear Test Results Using The Method Ogoshi Using Bar Graphs

The data obtained in this study regarding wear values indicate a change in wear values after treatment. The best wear resistance of the test material is in the variation with a riser channel volume of 6594 mm^3, which is 0.51×10^{-7} mm²/kg. Above it is the variation with a riser channel volume of 4710 mm^3, which is 0.87×10^{-7} mm²/kg. Next is the variation with a riser channel volume of 2826 mm^3, which is 2.77×10^{-7} mm²/kg. The highest wear value is in the variation without a riser channel, which is 4.24×10^{-7} mm²/kg. From these observations, it can be seen that in the variation without a riser channel, the wear value is relatively high compared to the others, followed by the variation with a riser channel volume of 2826 mm^3, the variation with a riser channel volume of 4710 mm^3, and the variation with a riser channel volume of 6594 mm^3.

The increase in wear resistance or abrasion can be determined through the duration of solidification, which is influenced by the casting surface area. If the casting surface area increases, it is concluded that it will accelerate the duration of solidification, resulting in increased wear resistance, and vice versa. The increase in the casting surface area in the specimens is due to the addition of the riser channel volume. The longer the solidification rate, the lower the hardness, and wear resistance will be directly proportional to hardness. It can be concluded that the larger the volume of the riser channel of an object, the better its resistance to wear or abrasion will be [15].

4. CONCLUSION

The microstructure of the casting results is influenced by variations in the volume of the riser channel. The best microstructure is exhibited by specimens cast with a riser channel volume of 6594 mm^3 compared to variations with a riser channel volume of 4710 mm^3, a riser channel diameter volume of 2826 mm^3, and a variation without using a riser channel, as evidenced by the formation of a denser and more uniform phase structure. However, the microstructure of the electric motor cover is better than the casting specimens, as indicated by a more homogenous arrangement of formed phases.

Porosity defects in the casting results are influenced by variations in the volume of the riser channel. The smallest porosity is exhibited by specimens cast with a riser channel volume of 6594 mm^3 at 37.97%. The wear value of the casting results is influenced by variations in the volume of the riser channel. Consistent with previous research, the addition of variations in the volume of the riser channel can reduce the wear resistance value of the casting results. The most effective in reducing the wear resistance value is the addition of a riser channel with a volume of 6594 mm^3, with a wear value of 0.51×10^{-7} mm²/kg.

REFERENCES

[1] E. Sriwahyudi, B. Kusharjanta, and W. P. Raharjo, "Pengaruh Bentuk Saluran Turun (Sprue) Terhadap Cacat porositas dan Nilai Kekerasan pada Pengecoran Aluminium Menggunakan Metode Lost foam casting," *Mekanika*, vol. 13, no. 1, 2014.

[2] R. Y. Salam, "Studi Eksperimental Pengaruh Model Sistem Saluran dan Variasi Temperatur Tuang terhadap Prosentase Porositas, Kekerasan dan Harga Impact pada Pengecoran Adc 12 dengan Metode Lost Foam Casting," Institut Teknologi Sepuluh Nopember, 2015.

[3] S. Raharjo, F. Abdillah, and Y. Yanto, "Analisa Pengaruh Pengecoran Ulang Terhadap Sifat Mekanik Paduan Alumunium ADC 12," in *Prosiding SNST Fakultas Teknik*, 2011. doi: http://dx.doi.org/10.36499/psnst.v1i1.370.

[4] Widayat, Widi, Budiyono, and Aris, "Pengaruh Kadar Air Pasir Cetak Terhadap Kalitas Coran Paduan Aluminium," *J. Kompetensi Tek.*, vol. 6, no. 1, 2014.

[5] A. . Raharja, *Teknik Pengecoran*. Yogyakarta: Insan Madani, 2011.

[6] C. K. Jin, H. Y. Seo, and C. G. Kang, "Heating System for Riser Size Minimizing in Sand Casting Process and Its Experimental Verification," *Metals (Basel).*, vol. 7, no. 4, p. 130, Apr. 2017, doi: 10.3390/met7040130.

[7] S. L. Nimbulkar and R. S. Dalu, "Design optimization of gating and feeding system through simulation technique for sand casting of wear plate," *Perspect. Sci.*, vol. 8, pp. 39–42, Sep. 2016, doi: 10.1016/j.pisc.2016.03.001.

[8] H.-Y. Seo, C.-K. Jin, and C.-G. Kang, "Design of a gate system and riser optimization for turbine housing and the experimentation and simulation of a sand casting process," *Adv. Mech. Eng.*, vol. 10, no. 8, p. 168781401879504, Aug. 2018, doi: 10.1177/1687814018795045.

[9] V. Gopinath, "Effect of Solidification Parameters on the Feeding Efficiency of Lm6 Aluminium Alloy Casting," *IOSR J. Mech. Civ. Eng.*, vol. 4, no. 2, pp. 32–38, 2012, doi: 10.9790/1684-0423238.

[10] R. A. Hardin, T. J. Williams, and C. Beckermann, "Riser Sleeve Properties for Steel Castings and the Effect of Sleeve Type on Casting Yield," 2013. [Online]. Available: https://api.semanticscholar.org/CorpusID:201824601

[11] P. Lagdive and M. Departmaent, "Optimization of Riser in Casting Using Genetic Algorithm," 2013. [Online]. Available: https://api.semanticscholar.org/CorpusID:59033617

[12] A. Sudibyo, B. Kusharjanta, and W. P. Raharjo, "Pengaruh Penampang Ingate Terhadap Cacat Porositas dan Nilai Kekerasan pada Proses Pengecoran Aluminium menggunakan Cetakan Pasir," *Mekanika*, vol. 12, no. 1, 2013.

[13] T. G. Tirta Nindhia, "Studi Struktur mikro Silikon dalam Paduan Aluminium-Silikon pada Piston dari Berbagai Merek Sepeda Motor," *J. Energi Dan Manufaktur; Vol 4, No.1 April 2010*, [Online]. Available: https://ojs.unud.ac.id/index.php/jem/article/view/2315

[14] F. Fasya and N. Iskandar, "Melt Loss dan Porositas pada Aluminium Hasil Daur Ulang. Jurnal Teknik Mesin," *J. Tek. MESIN; Vol 3, No 1 Vol. 3, NOMOR 1, JANUARI 2015*, Jan. 2015, [Online]. Available: https://ejournal3.undip.ac.id/index.php/jtm/article/view/8694

[15] K. Roziqin, H. Purwanto, and I. Syafa'at, "Pengaruh Model Sistem Saluran Pada Proses Pengecoran Aluminium Daur Ulang Terhadap Struktur Mikro Dan Kekerasan Coran Pulli Diameter 76 Mm Dengan Cetakan Pasir," *J. Momentum UNWAHAS*, vol. 8, no. 1, 2012, doi: 10.36499/jim.v8i1.285.