DAFTAR PUSTAKA

[1] D. Guan, X. He, R. Zhang, and X. Qu, “Microstructure and tensile properties of in situ polymer-derived particles reinforced steel matrix composites produced by powder metallurgy method,” *Mater. Sci. Eng. A*, vol. 705, pp. 231–238, 2017, doi: 10.1016/j.msea.2017.07.084.

[2] J. R. Pickens, “Aluminium powder metallurgy technology for high-strength applications,” *J. Mater. Sci.*, vol. 16, no. 6, pp. 1437–1457, 1981, doi: 10.1007/BF02396863.

[3] V. V. Vani and S. K. Chak, “The effect of process parameters in Aluminum Metal Matrix Composites with Powder Metallurgy,” vol. 7, 2018.

[4] J. R. Davis, *ASM Hndbook Aluminum and Aluminum Alloys*. 1993.

[5] W. D. Callister and D. G. Rethwisch, *Fundamentals of materials science and engineering : an integrated approach*. 2016. [Online]. Available: https://www.wiley.com/en-us/Fundamentals+of+Materials+Science+and+Engineering%3A+An+Integrated+Approach%2C+5th+Edition-p-9781119175506R120

[6] P. R. Matli, U. Fareeha, R. A. Shakoor, and A. M. A. Mohamed, “A comparative study of structural and mechanical properties of Al-Cu composites prepared by vacuum and microwave sintering techniques,” *J. Mater. Res. Technol.*, vol. 7, no. 2, pp. 165–172, 2018, doi: 10.1016/j.jmrt.2017.10.003.

[7] A. Gökçe, F. Findik, and A. O. Kurt, “Microstructural examination and properties of premixed Al-Cu-Mg powder metallurgy alloy,” *Mater. Charact.*, vol. 62, no. 7, pp. 730–735, 2011, doi: 10.1016/j.matchar.2011.04.021.

[8] A. I. Y. Tok, F. Y. C. Boey, and X. L. Zhao, “Novel synthesis of Al2O3 nano-particles by flame spray pyrolysis,” *J. Mater. Process. Technol.*, vol. 178, no. 1–3, pp. 270–273, 2006, doi: 10.1016/j.jmatprotec.2006.04.007.

K. Abbass and B. F. Sultan, “Effect of Al2O3 Nano Particles on rrosion Behaviour of Aluminum Alloy (Al-4.5wt% Cu-1.5wt% Mg) bricated by Powder Metallurgy,” vol. 11, no. 1, pp. 25–31, 2019.

[10] G. Rodríguez-Cabriales *et al.*, "Synthesis and characterization of Al-Cu-Mg system reinforced with tungsten carbide through powder metallurgy," *Mater. Today Commun.*, vol. 22, no. July, p. 100758, 2020, doi: 10.1016/j.mtcomm.2019.100758.

[11] B. Zlaticanin, B. Radonjic, and M. Filipovic, "Characterization of Structure and Properties of As-cast AlCuMg Alloys," *Mater. Trans.*, vol. 45, no. 2, pp. 440–446, 2004, doi: 10.2320/matertrans.45.440.

[12] B. V. Ramnath *et al.*, "Aluminium metal matrix composites - A review," *Rev. Adv. Mater. Sci.*, vol. 38, no. 1, pp. 55–60, 2014.

[13] M. Rahimian, N. Ehsani, N. Parvin, and H. reza Baharvandi, "The effect of particle size, sintering temperature and sintering time on the properties of Al-Al2O3 composites, made by powder metallurgy," *J. Mater. Process. Technol.*, vol. 209, no. 14, pp. 5387–5393, 2009, doi: 10.1016/j.jmatprotec.2009.04.007.

[14] M. Rahimian, N. Parvin, and N. Ehsani, "Investigation of particle size and amount of alumina on microstructure and mechanical properties of Al matrix composite made by powder metallurgy," *Mater. Sci. Eng. A*, vol. 527, no. 4–5, pp. 1031–1038, 2010, doi: 10.1016/j.msea.2009.09.034.

[15] D. M. Nuruzzaman, S. N. S. Jamaludin, F. F. B. Kamaruzaman, S. Basri, and N. A. M. B. Zulkifli, "Fabrication and mechanical properties of aluminium-aluminium oxide metal matrix composites," *Int. J. Mech. Mechatronics Eng.*, vol. 15, no. 6, pp. 68–75, 2015.

[16] C. D. Boland, R. L. Hexemer, I. W. Donaldson, and D. P. Bishop, "Industrial processing of a novel Al-Cu-Mg powder metallurgy alloy," *Mater. Sci. Eng. A*, vol. 559, pp. 902–908, 2013, doi: 10.1016/j.msea.2012.09.049.

[17] G. Pitchayyapillai, P. Seenikannan, K. Raja, and K. Chandrasekaran, "Al6061 Hybrid Metal Matrix Composite Reinforced with Alumina and Molybdenum Disulphide," vol. 2016, 2016.

Zabihi, M. Reza, and A. Shafyei, "Materials Science & Engineering A plication of powder metallurgy and hot rolling processes for nufacturing aluminum / alumina composite strips," *Mater. Sci. Eng. A*, vol. 560, pp. 567–574, 2013, doi: 10.1016/j.msea.2012.09.103.

[19] T. Suwanda, “Dan Waktu Sintering Terhadap Kekerasan Dan Berat Jenis Aluminium Pada Proses,” *J. Ilm. Semesta Tek.*, vol. 9, pp. 187–198, 2006.

[20] W. D. Callister, *Materials Science and Engineering: An Introduction*, Wiley Asia. 2007.

[21] S. Hadi, “Teknologi Bahan Lanjut,” no. Komposit, p. 103, 2017.

[22] Budiarto, “Sintesis Paduan Alumunium (6061) dengan Metalurgi Serbuk Bahan Fin Rocket,” 2019.

[23] R. M. German, *Powder Metalurgy Science*, Second Edi. 1994.

[24] S. Kalpakjian, *Manufacturing Engineering and Technology*. 1989.

[25] J. T. S. Iman, P. Agus, H. Ricki, “Studi Karakteristik Sifat Mekanik Alumunium Matrix Composite (AMC) Paduan AL,5% Cu, 12%Mg, 15%SiC Hasil Proses Stir Casting dengan Variasi Temperatur Pendinginan,” vol. 12, no. 2, pp. 151–164, 2018.

[26] M. K. Surappa, “Aluminium matrix composites : Challenges and opportunities,” vol. 28, no. April, pp. 319–334, 2003.

[27] X. Du, R. Liu, X. Xiong, and H. Liu, “Effects of sintering time on the microstructure and properties of an Al-Cu-Mg alloy,” *J. Mater. Res. Technol.*, vol. 9, no. 5, pp. 9657–9666, 2020, doi: 10.1016/j.jmrt.2020.06.083.

[28] R. . Smallman and R. . Bishop, *Metalurgi Fisik Modern dan Rekayasa Material*. Erlangga, 2000.

[29] E. Medvedovski, “Alumina-mullite ceramics for structural applications,” *Ceram. Int.*, vol. 32, no. 4, pp. 369–375, 2006, doi: 10.1016/j.ceramint.2005.04.001.

[30] J. Campbell, *Castings*, Second Edi. Elsevier, 2003.

[31] M. Kuts, *Handbook of Materials Selection*. Jhon Wiley & Sons, 2002.

[32] A. International, “ASTM G99-– 95a: Standard test method for wear testing with a pin-on-disk apparatus,” *ASTM Int.*, vol. 1, no. Reapproved, pp. 1–5, 17.

Leng, *Materials Characterization: Introduction to Microscopic and ectroscopic Methods*. Hongkong: John Wiley & Sons (Asia) Pte Ltd, 2008.

[34] A. Setiabudi, R. Hardian, and A. Muzakir, *Karakterisasi Material: Prinsip dan Aplikasinya dalam Penelitian Kimia*, vol. 1. 2012.

[35] Widyastuti, H. Ardhyananta, H. Purwaningsih, and R. M. Quluq, *Karakterisasi Material Bagian 1 : Komposisi, Topografi dan Sifat Mekanik*. ITS Press, 2019.

[36] P. Bindu and S. Thomas, "Estimation of lattice strain in ZnO nanoparticles: X-ray peak profile analysis," *J. Theor. Appl. Phys.*, vol. 8, no. 4, pp. 123–134, 2014, doi: 10.1007/s40094-014-0141-9.

[37] L. F. Francis, *Materials Processing: A Unified Approach to Processing of Metals, Ceramics and Polymers*. Elsevier, 2016.

[38] C. Suryanarayana, "Mechanical alloying and milling," *Prog. Mater. Sci.*, vol. 46, no. 1–2, pp. 1–184, 2001, doi: 10.1016/S0079-6425(99)00010-9.

[39] Z. Razavi Hesabi, H. R. Hafizpour, and A. Simchi, "An investigation on the compressibility of aluminum/nano-alumina composite powder prepared by blending and mechanical milling," *Mater. Sci. Eng. A*, vol. 454–455, pp. 89–98, 2007, doi: 10.1016/j.msea.2006.11.129.

[40] J. Raharjo and S. Rahayu, "Pengaruh Penambahan MgO dan SiO 2 Serta Suhu Sintering Terhadap Sifat Fisis dan Mekanis Komposit Keramik α – Alumina," *Pros. Semin. Nas. Tek. Kim. "Kejuangan" Pengemb. Teknol. Kim. untuk Pengolah. Sumber Daya Alam Indones.*, pp. 1–6, 2015.

[41] R. N. Lumley, T. B. Sercombe, and G. B. Schaffer, "Surface oxide and the role of magnesium during the sintering of aluminum," *Metall. Mater. Trans. A Phys. Metall. Mater. Sci.*, vol. 30, no. 2, pp. 457–463, 1999, doi: 10.1007/s11661-999-0335-y.

[42] G. Tosun and M. Kurt, "The porosity, microstructure, and hardness of Al-Mg composites reinforced with micro particle SiC/Al2O3 produced using powder metallurgy," *Compos. Part B Eng.*, vol. 174, no. February 2019, p. 106965, 2019, doi: 10.1016/j.compositesb.2019.106965.

M. Sankhla *et al.*, "Effect of mixing method and particle size on rdness and compressive strength of aluminium based metal matrix mposite prepared through powder metallurgy route," *J. Mater. Res.*

Technol., vol. 18, pp. 282–292, 2022, doi: 10.1016/j.jmrt.2022.02.094.

[44] R. Simanjuntak, "Pembuatan dan Karakterisasi Keramik Konstruksi dengan Memanfaatkan Limbah Padat Pulp dengan Bahan Baku Bentonit," Universitas Sumatra Utara, 2010.

[45] J. Anggono, "Penyusutan dan Densifikasi Keramik Alumina: Perbandingan antara Hasil Proses Slip Casting dengan Reaction Bonding," Universitas Kristen Petra, 2008. [Online]. Available: https://www.researchgate.net/profile/Juliana-Anggono/publication/43649397_Penyusutan_dan_Densifikasi_Keramik_Alumina_Perbandingan_Antara_Hasil_Proses_Slip_Casting_dengan_Reaction_Bonding/links/565b2b3208aeafc2aac60d15/Penyusutan-dan-Densifikasi-Keramik-Al

[46] G. Manohar, A. Dey, K. M. Pandey, and S. R. Maity, "Fabrication of metal matrix composites by powder metallurgy: A review," *AIP Conf. Proc.*, vol. 1952, 2018, doi: 10.1063/1.5032003.

[47] A. Slipenyuk, V. Kuprin, Y. Milman, V. Goncharuk, and J. Eckert, "Properties of P/M processed particle reinforced metal matrix composites specified by reinforcement concentration and matrix-to-reinforcement particle size ratio," *Acta Mater.*, vol. 54, no. 1, pp. 157–166, 2006, doi: 10.1016/j.actamat.2005.08.036.

[48] R. N. Lumley and G. B. Schaffer, "The effect of additive particle size on the mechanical properties of sintered aluminium-copper alloys," *Scr. Mater.*, vol. 39, no. 8, pp. 1089–1094, 1998, doi: 10.1016/S1359-6462(98)00278-4.

[49] A. M. Al-Qutub, A. Khalil, N. Saheb, and A. S. Hakeem, "Wear and friction behavior of Al6061 alloy reinforced with carbon nanotubes," *Wear*, vol. 297, no. 1–2, pp. 752–761, 2013, doi: 10.1016/j.wear.2012.10.006.

[50] F. H. Latief and E. S. M. Sherif, "Effects of sintering temperature and graphite addition on the mechanical properties of aluminum," *J. Ind. Eng. Chem.*, vol. 18, no. 6, pp. 2129–2134, 2012, doi: 10.1016/j.jiec.2012.06.007.

M. Y. K. & A. K. Khanra, "Hot Deformation Studies of Al-Cu-Mg

Powder Metallurgy Alloy Composite," *Lect. Notes Mech. Eng.*, pp. 75–81, 2019, doi: 10.1007/978-981-13-1780-4_9.

LAMPIRAN 1
Perhitungan Beban Kompaksi

Diketahui :

- Diameter lubang cetakan (d) = $20\ mm = 20 \times 10^{-3}\ m$
- Tekanan Kompaksi (P) = 200 MPa = 200 x 10^6 N/m

Ditanyakan :

- Besar beban kompaksi (dalam Ton)

Penyelesaian ;

F = PA

= $200\ x\ 10^6\ [N/m^2]\ x\ 0.25\ x\ \pi\ x\ (20 \times 10^{-3})^2\ [m^2]$

= $200\ x\ 10^6\ [N/m^2]\ x\ 0.25\ x\ \pi\ x\ 400\ x\ 10^{-6}\ [N]$

= 62.800 N

= 6.280 Kg

= **6,28 Ton**

LAMPIRAN 2
Perhitungan Densitas Teoritis

Diketahui

- Massa Jenis / Densitas Alumunium ($\rho_{Alumunium}$) = 2,700 g/cm^3
- Massa Jenis / Densitas Tembaga ($\rho_{Tembaga}$) = 8,960 g/cm^3
- Massa Jenis / Densitas Magnesium ($\rho_{Magnesium}$) = 1,738 g/cm^3
- Massa Jenis / Densitas Alumina ($\rho_{Alumina}$) = 3,950 g/cm^3

Ditanyakan

- Massa Jenis / Densitas Teoritis Logam Paduan 1 ($\rho_{Al-4.5Cu-1.5Mg-1Al^2O^3}$)
- Massa Jenis / Densitas Teoritis Logam Paduan 2 ($\rho_{Al-4.5Cu-1Mg-1Al^2O^3}$)

Penyelesaian

$$\rho_c = \rho_m \times v_{fm} + \rho_{p1} \times v_{p1} + \rho_{p2} \times v_{p2} + \rho_{p3} \times v_{p3}$$

$$\rho_{Al-4.5Cu-1.5Mg-1Al^2O^3} = 2{,}700 \times 93\% + 8{,}960 \times 4{,}5\% + 1{,}738 \times 1.5\% + 3{,}950 \times 1\%$$

$$= 2{,}511 + 0{,}403 + 0{,}026 + 0{,}039$$

$$= 2{,}980\ g/cm^3$$

$$\rho_{Al-4.5Cu-1Mg-1Al^2O^3} = 2{,}700 \times 93.5\% + 8{,}960 \times 4{,}5\% + 1{,}738 \times 1\% + 3{,}950 \times 1\%$$

$$= 2{,}524 + 0{,}403 + 0{,}017 + 0{,}039$$

$$= 2{,}983\ g/cm^3$$

Keterangan:

ρ_c = Densitas Paduan

ρ_m = Densitas Bahan Utama

ρ_{p1} = Densitas Bahan Paduan 1

ρ_{p2} = Densitas Bahan Paduan 2

ρ_{p3} = Densitas Bahan Paduan 3

v_{fm} = Volume Fraksi Bahan Utama

v_{p1} = Volume Fraksi Bahan Paduan 1

v_{p2} = Volume Fraksi Bahan Paduan 2

v_{p3} = Volume Fraksi Bahan Paduan 3

LAMPIRAN 3
Perhitungan Volume dan Berat Komposit Matriks Alumunium

Diketahui :

- Jari-jari Spesimen = 10 mm
- Tinggi Spesimen = 6 mm
- Fraksi Volume Alumunium 1 = 93 %
- Fraksi Volume Alumunium 2 = 93.5 %
- Fraksi Volume Magnesium 1 = 1.5 %
- Fraksi Volume Magnesium 2 = 1 %
- Fraksi Volume Tembaga = 4.5 %
- Fraksi Volume Alumina = 1 %

Ditanya :

- Volume Komposit Matriks Alumunium
- Volume Matrik Alumunium
- Volume Filler (Cu, Mg, Al_2O_3)
- Berat Matrik Alumunium
- Berat Filler (Cu, Mg, Al_2O_3)

Penyelesaian

a. Volume Komposit Matrik Alumunium

Cetakan berbentuk tabung dengan ukuran :

Diameter : 20 mm

Tinggi : 6 mm

Volume Komposit Matrik Alumunium $= \pi r^2 t$

$= 3{,}14 \times 10^2 \times 6$

$= 1.884\ mm^3$

$= 1{,}884\ cm^3$

b. Volume Alumunium (Al) 93% dan 93.5%

I. V_{Al} = 93 % x volume komposit matrik alumunium

= 93 % x 1,884 cm^3

= 1,752 cm^3

II. V_{Al} = 93.5 % x volume komposit matrik alumunium

= 93.5 % x 1,884 cm^3

= 1,762 cm^3

III. V_{Al} = 100 % x volume komposit matrik alumunium

= 100 % x 1,884 cm^3

= 1,884 cm^3

c. Volume Tembaga (Cu) 4.5 %

V_{Cu} = 4.5 % x volume komposit

= 4.5 % x 1,884 cm^3

= 0,085 cm^3

d. Volume Magnesium (Mg) 1 % dan 1.5 %

I. V_{Mg} = 1.5 % x volume komposit
= 1.5 % x 1,884 cm^3
= 0,028 cm^3

II. V_{Mg} = 1 % x volume komposit
= 1 % x 1,884 cm^3
= 0,019 cm^3

e. Volume Alumina (Al_2O_3) 1 %

V_{Al2O3} = 1 % x volume komposit
= 1 % x 1,884 cm^3
= 0,019 cm^3

Berat Material yang dibutuhkan

Berat material dapat ditentukan menggunakan persamaan berat jenis :

$$\rho = \frac{m}{v}$$

Maka berat material : m = ρ x v

Dimana : ρ = massa jenis
v = Volume jenis
m = massa

a. Berat Alumunium (Al) 93 %

m_{Al} = 2,7 g/cm^3 x volume **Alumunium I**
= 2,7 g/cm^3 x 1,752 cm^3
= 4,731 gram

b. Berat Alumunium (Al) 93.5 %

m_{Al} = 2,7 g/cm^3 x volume **Alumunium II**
= 2,7 g/cm^3 x 1,762 cm^3
= 4,757 gram

c. Berat Alumunium (Al) 100 %

m_{Al} = 2,7 g/cm^3 x volume **Alumunium III**
= 2,7 g/cm^3 x 1,884 cm^3
= 5,087 gram

d. Berat Tembaga (Cu) 4.5 %

m_{Cu} = 8,96 g/cm^3 x volume **Tembaga**
= 8,96 g/cm^3 x 0,085 cm^3
= 0,762 gram

e. Berat Magnesium (Cu) 1.5 %

m_{Mg} = 1,738 g/cm^3 x volume **Magnesium I**
= 1,738 g/cm^3 x 0,028 cm^3
= 0,049 gram

f. Berat Magnesium (Cu) 1 %

m_{Mg} = 1,738 g/cm^3 x volume **Magnesium II**
= 1,738 g/cm^3 x 0,019 cm^3
= 0,033 gram

g. Berat Alumina (Al_2O_3) 1 %

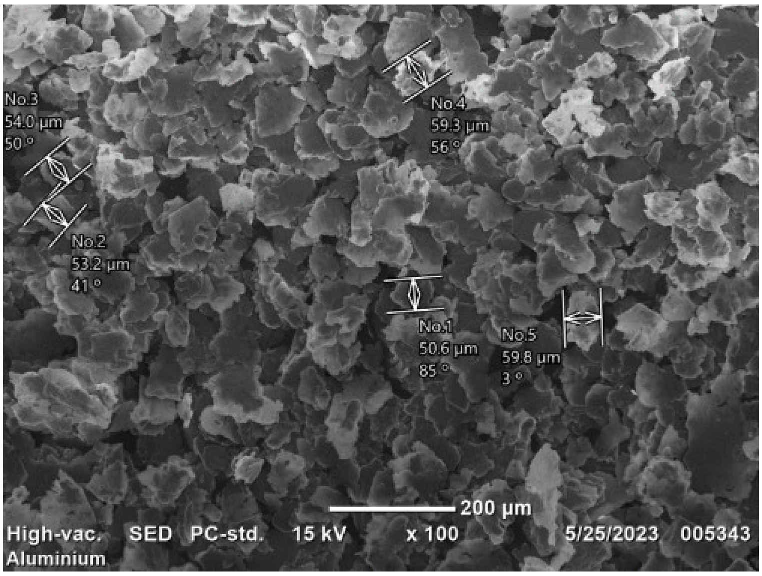
3,95 g/cm^3 x volume **Alumina**
3,95 g/cm^3 x 0,019 cm^3
0,075 gram

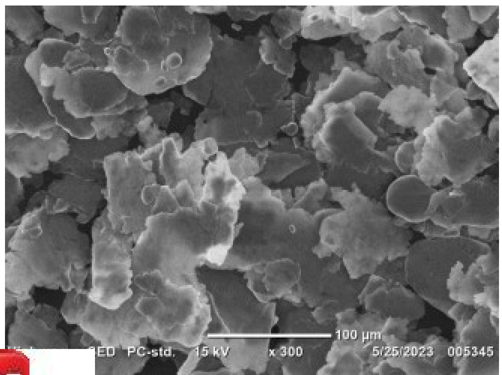
LAMPIRAN 4

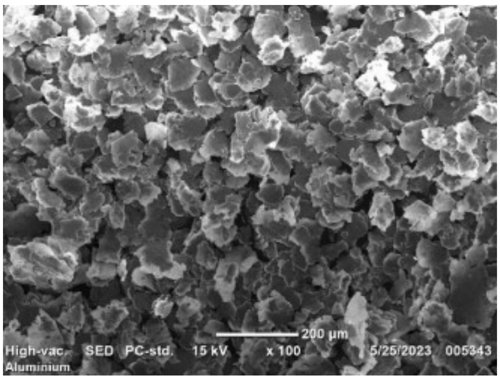
ESTIMASI UKURAN SERBUK BAHAN UTAMA PENELITIAN

Alumunium

No.	Length	[unit]	Angle[deg]
1	50.6	um	85
2	53.2	um	41
3	54	um	50
4	59.3	um	56
5	59.8	um	3
Rata-rata	**55.38**	**um**	
Standar Deviasi	**4.01273**		

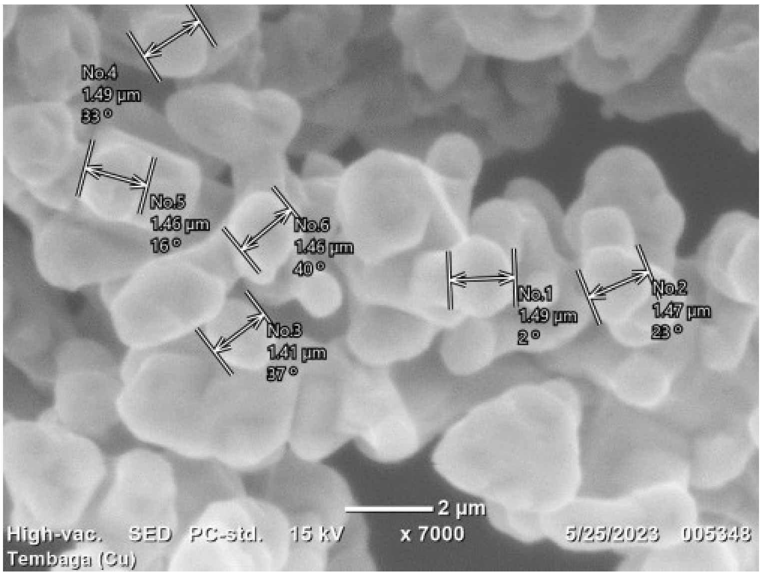


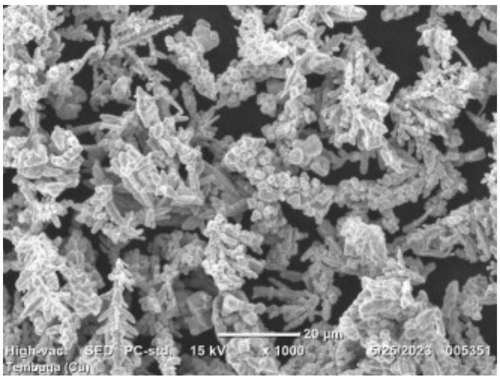


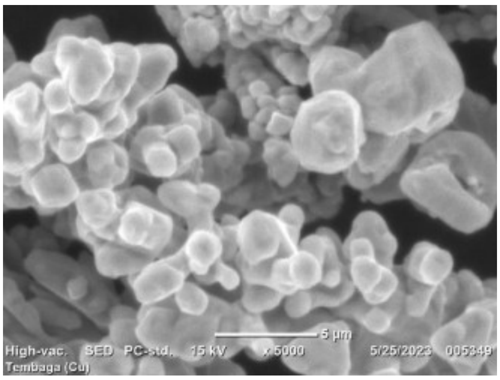


Tembaga

No.	Length	[unit]	Angle[deg]
1	1.49	um	2
2	1.47	um	23
3	1.41	um	37
4	1.49	um	33
5	1.46	um	16
6	1.46	um	40
Rata-rata	**1.463333**	**um**	
Standar deviasi	**0.029439**		

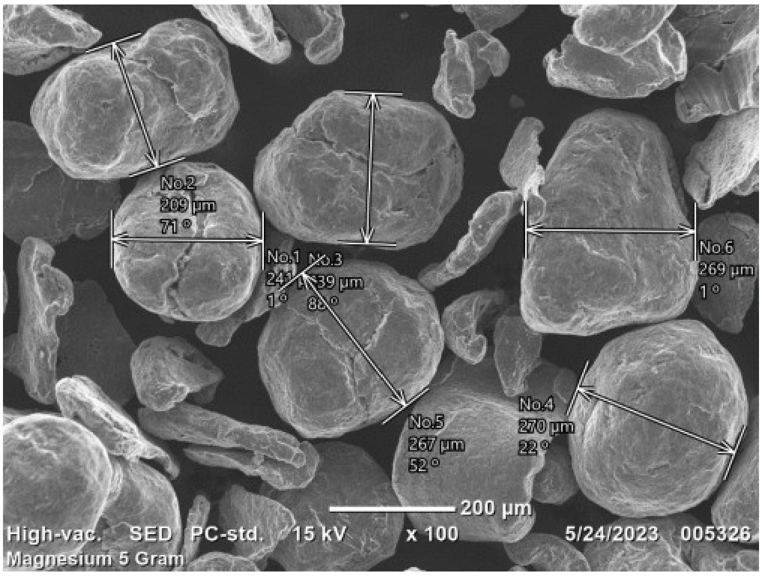


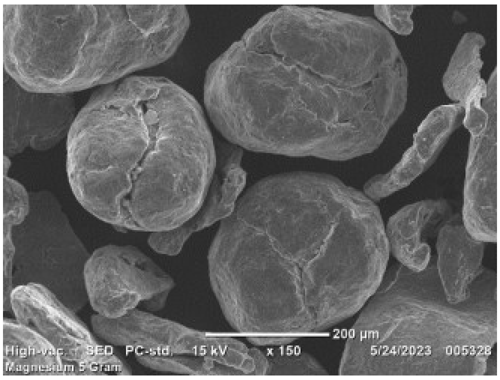


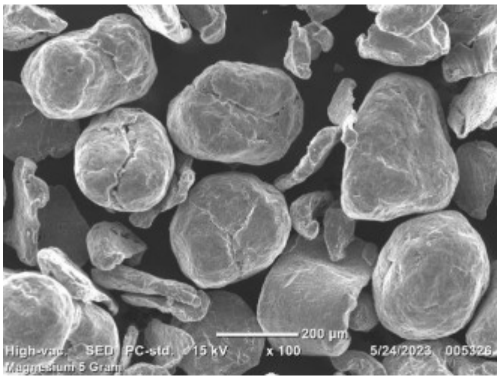


Magnesium

No.	Length	[unit]	Angle[deg]
1	241	um	1
2	209	um	71
3	239	um	88
4	270	um	22
5	267	um	52
6	269	um	1
Rata-rata	**249.1667**	**um**	
Standar deviasi	**24.20262**		

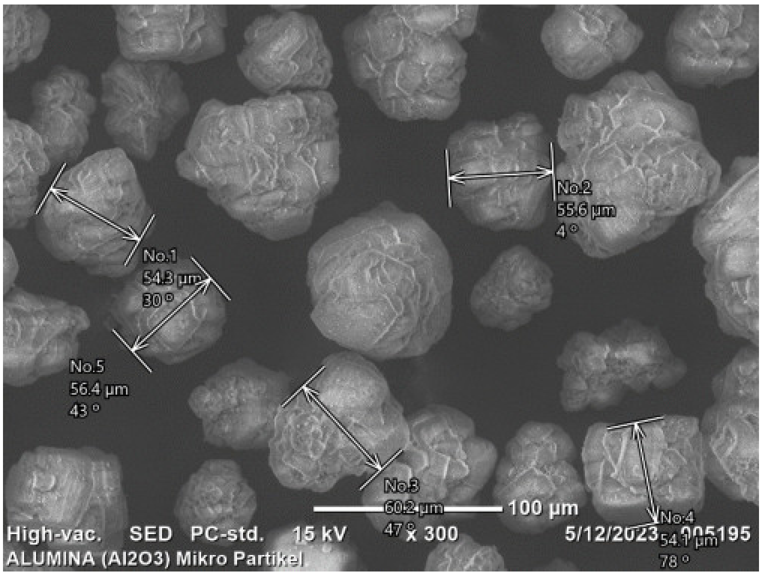


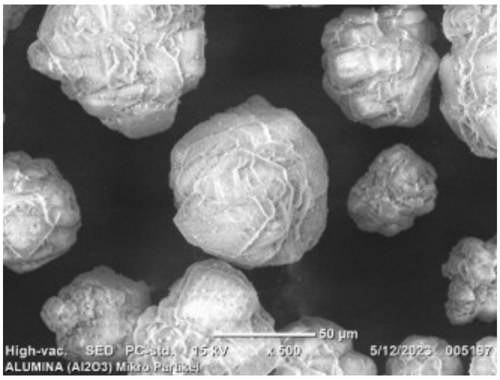


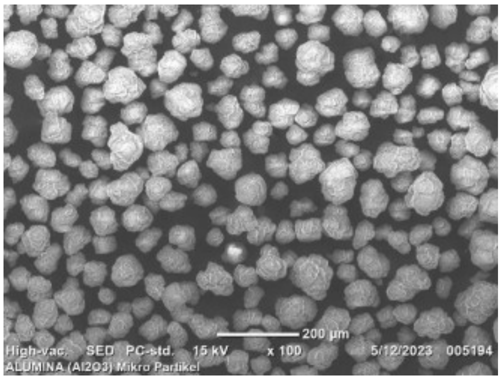


mikro-Alumina

No.	Length	[unit]	Angle[deg]
1	54.3	um	30
2	55.6	um	4
3	60.2	um	47
4	54.1	um	78
5	56.4	um	43
Rata-rata	**56.12**	**um**	
Standar deviasi	**2.46921**		

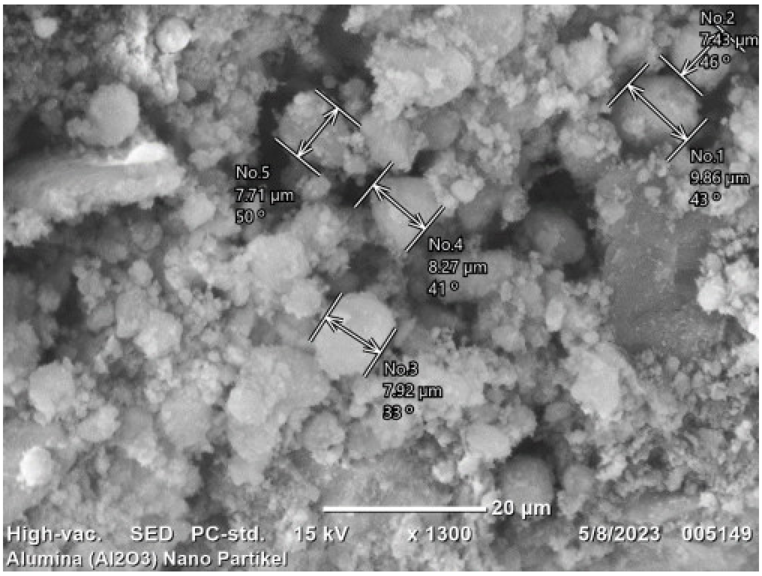


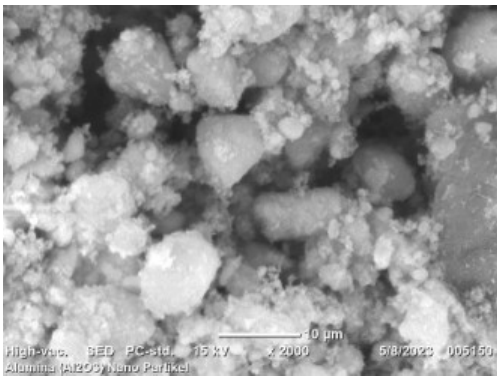


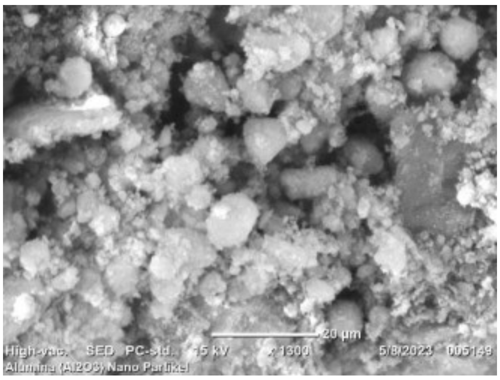


nano-Alumina

No.	Length	[unit]	Angle[deg]
1	9.86	um	43
2	7.43	um	46
3	7.92	um	33
4	8.27	um	41
5	7.71	um	50
Rata-rata	**8.238**	**um**	
Standar deviasi	**0.957168**		







LAMPIRAN 5

Fotografi Sampel *Green Compact* dan *Sintered Compact*

Fotografi Spesimen **Green Compact**				
				
SP 1	**SP 2**	**SP 3**	**SP 4**	**SP 5**

Fotografi Spesimen **Sintered Compact**				
				
SP 1	**SP 2**	**SP 3**	**SP 4**	**SP 5**
				
SP 6	**SP 7**	**SP 8**	**SP 9**	**SP 10**
				
SP 11	**SP 12**	**SP 13**	**SP 14**	**SP 15**

LAMPIRAN 6
Tabulasi Nilai Densitas dan Densitas Relatif *Green Compact*

Kode	% Fraksi Komposisi				Ukuran Butir Al_2O_3	$\rho_{teoritis}$ (g/cm^3)	ρ (g/cm^3)	$\rho_{relatif}$ (%)	ρ (g/cm^3)	$\rho_{relatif}$ (%)	ρ (g/cm^3)	$\rho_{relatif}$ (%)	$\bar{x}\ \rho$ (g/cm^3)	$\bar{x}\ \rho_{relatif}$ (%)
	Al	Cu	Mg	Al_2O_3			Sampel 1		Sampel 2		Sampel 3			
SP 1	100	0	0	0	-	2.700	1.723	63.81	1.724	63.86	1.724	63.84	1.724	63.83
SP 2	93.5	4.5	1	1	56 μm	2.983	1.661	55.69	1.661	55.67	1.660	55.64	1.661	55.67
SP 3	93.5	4.5	1	1	20 nm	2.983	1.609	53.94	1.612	54.03	1.610	53.97	1.610	53.98
SP 4	93	4.5	1.5	1	56 μm	2.980	1.705	57.23	1.700	57.04	1.706	57.25	1.704	57.17
SP 5	93	4.5	1.5	1	20 nm	2.980	1.624	54.49	1.617	54.25	1.615	54.19	1.618	54.31
SP 6	100	0	0	0	-	2.700	1.723	63.80	1.724	63.86	1.724	63.85	1.724	63.84
SP 7	93.5	4.5	1	1	56 μm	2.983	1.661	55.68	1.660	55.65	1.661	55.67	1.661	55.67
SP 8	93.5	4.5	1	1	20 nm	2.983	1.610	53.96	1.611	54.02	1.610	53.97	1.610	53.98
SP 9	93	4.5	1.5	1	56 μm	2.980	1.705	57.20	1.700	57.03	1.707	57.29	1.704	57.17
SP 10	93	4.5	1.5	1	20 nm	2.980	1.624	54.48	1.618	54.28	1.615	54.20	1.619	54.32
SP 11	100	0	0	0	-	2.700	1.722	63.79	1.725	63.87	1.724	63.85	1.724	63.84
SP 12	93.5	4.5	1	1	56 μm	2.983	1.661	55.69	1.660	55.66	1.660	55.65	1.660	55.66
SP 13	93.5	4.5	1	1	20 nm	2.983	1.609	53.94	1.611	54.01	1.611	54.00	1.610	53.98
SP 14	93	4.5	1.5	1	56 μm	2.980	1.707	57.29	1.701	57.09	1.708	57.31	1.705	57.23
[illegible]	[illegible]	4.5	1.5	1	20 nm	2.980	1.624	54.51	1.623	54.46	1.616	54.22	1.621	54.40

LAMPIRAN 7
Tabulasi Nilai Densitas & Densitas Relatif *Sintered Compact*

Kode	% Fraksi Komposisi				Ukuran Butir Al_2O_3	Temp. Sinter (℃)	$\rho_{teoritis}$ (g/cm^3)	ρ (g/cm^3) Sampel 1	$\rho_{relatif}$ (%) Sampel 1	ρ (g/cm^3) Sampel 2	$\rho_{relatif}$ (%) Sampel 2	ρ (g/cm^3) Sampel 3	$\rho_{relatif}$ (%) Sampel 3	$\bar{x}\ \rho$ (g/cm^3)	$\bar{x}\ \rho_{relatif}$ (%)	STDV
	Al	Cu	Mg	Al_2O_3												
SP 1	100	0	0	0	-	500	2.700	1.718	63.6	1.729	64.0	1.740	64.4	1.729	64.04	0.41
SP 2	93.5	4.5	1	1	56 μm		2.983	1.690	56.7	1.679	56.3	1.678	56.3	1.682	56.39	0.23
SP 3	93.5	4.5	1	1	20 nm		2.983	1.621	54.3	1.625	54.5	1.635	54.8	1.627	54.55	0.25
SP 4	93	4.5	1.5	1	56 μm		2.980	1.704	57.2	1.705	57.2	1.706	57.2	1.705	57.21	0.03
SP 5	93	4.5	1.5	1	20 nm		2.980	1.640	55.0	1.635	54.9	1.645	55.2	1.640	55.03	0.16
SP 6	100	0	0	0	-	550	2.700	1.749	64.8	1.742	64.5	1.747	64.7	1.746	64.66	0.14
SP 7	93.5	4.5	1	1	56 μm		2.983	1.694	56.8	1.699	56.9	1.696	56.8	1.696	56.85	0.09
SP 8	93.5	4.5	1	1	20 nm		2.983	1.640	55.0	1.639	54.9	1.639	54.9	1.639	54.96	0.03
SP 9	93	4.5	1.5	1	56 μm		2.980	1.706	57.2	1.704	57.2	1.708	57.3	1.706	57.25	0.08
SP 10	93	4.5	1.5	1	20 nm		2.980	1.648	55.3	1.637	54.9	1.646	55.2	1.644	55.15	0.21
SP 11	100	0	0	0	-	600	2.700	1.757	65.1	1.758	65.1	1.756	65.0	1.757	65.06	0.03
SP 12	93.5	4.5	1	1	56 μm		2.983	1.699	57.0	1.702	57.1	1.705	57.2	1.702	57.07	0.10
SP 13	93.5	4.5	1	1	20 nm		2.983	1.646	55.2	1.644	55.1	1.645	55.1	1.645	55.15	0.03
SP 14	93	4.5	1.5	1	56 μm		2.980	1.714	57.5	1.709	57.3	1.712	57.5	1.712	57.45	0.10
SP 15	93	4.5	1.5	1	20 nm		2.980	1.674	56.2	1.639	55.0	1.659	55.7	1.657	55.61	0.59

LAMPIRAN 8
Tabulasi Nilai Porositas *Sintered Compact*

Kode	% Fraksi Komposisi				Ukuran Butir Al_2O_3	Temp. Sinter (°C)	m_1 (g/cm³)	m_2 (g/cm³)	ε (%)	m_1 (g/cm³)	m_2 (g/cm³)	ε (%)	m_1 (g/cm³)	m_2 (g/cm³)	ε (%)	$\bar{x}\ \varepsilon$ (%)	STDV
	Al	Cu	Mg	Al_2O_3			Sampel 1			Sampel 2			Sampel 3				
SP 1	100	0	0	0	-	500	4.864	5.097	4.79	5.029	5.268	4.75	5.053	5.289	4.67	4.74	0.06
SP 2	93.5	4.5	1	1	56 μm		5.195	5.686	9.45	5.187	5.681	9.52	5.269	5.777	9.64	9.54	0.10
SP 3	93.5	4.5	1	1	20 nm		5.170	5.514	6.65	5.169	5.519	6.77	5.245	5.590	6.58	6.67	0.10
SP 4	93	4.5	1.5	1	56 μm		5.045	5.455	8.13	5.005	5.431	8.51	5.046	5.509	9.18	8.60	0.53
SP 5	93	4.5	1.5	1	20 nm		5.036	5.358	6.39	5.023	5.354	6.59	5.057	5.372	6.23	6.40	0.18
SP 6	100	0	0	0	-	550	5.070	5.307	4.67	5.070	5.306	4.65	5.067	5.293	4.46	4.60	0.12
SP 7	93.5	4.5	1	1	56 μm		5.357	5.834	8.90	5.290	5.765	8.98	5.251	5.728	9.08	8.99	0.09
SP 8	93.5	4.5	1	1	20 nm		5.236	5.566	6.30	5.264	5.610	6.57	5.333	5.673	6.38	6.42	0.14
SP 9	93	4.5	1.5	1	56 μm		4.103	4.409	7.46	4.104	4.423	7.77	4.102	4.444	8.34	7.86	0.45
SP 10	93	4.5	1.5	1	20 nm		5.186	5.495	5.96	5.111	5.435	6.34	5.171	5.467	5.72	6.01	0.31
SP 11	100	0	0	0	-	600	5.100	5.335	4.61	5.118	5.338	4.30	5.095	5.316	4.34	4.41	0.17
SP 12	93.5	4.5	1	1	56 μm		5.125	5.571	8.70	5.078	5.524	8.78	5.126	5.577	8.80	8.76	0.05
SP 13	93.5	4.5	1	1	20 nm		5.272	5.596	6.15	5.227	5.551	6.20	5.181	5.503	6.22	6.19	0.04
SP 14	93	4.5	1.5	1	56 μm		5.037	5.404	7.29	5.053	5.424	7.34	5.050	5.444	7.80	7.48	0.28
[illegible]	[illegible]	[illegible]	1.5	1	20 nm		5.170	5.462	5.65	5.177	5.453	5.33	5.133	5.411	5.42	5.47	0.16

LAMPIRAN 9
Tabulasi Nilai Penyusutan *Sintered Compact*

Kode	% Fraksi Komposisi				Ukuran Butir Al_2O_3	Temp. Sinter (℃)	V_{GC}	V_{SC}	ΔV (%)	V_{GC}	V_{SC}	ΔV (%)	V_{GC}	V_{SC}	ΔV (%)	$\bar{x}$ ΔV (%)	STDV
	Al	Cu	Mg	Al_2O_3			Sampel 1			Sampel 2			Sampel 3				
SP 1	100	0	0	0	-		2.065	2.033	1.55	2.155	2.120	1.62	2.187	2.149	1.74	1.64	0.09
SP 2	93.5	4.5	1	1	56 μm		2.205	2.121	3.81	2.181	2.097	3.85	2.215	2.129	3.88	3.85	0.04
SP 3	93.5	4.5	1	1	20 nm	500	2.030	1.981	2.41	2.038	1.988	2.45	2.090	2.038	2.49	2.45	0.04
SP 4	93	4.5	1.5	1	56 μm		2.152	2.085	3.11	2.134	2.069	3.05	2.153	2.088	3.02	3.06	0.05
SP 5	93	4.5	1.5	1	20 nm		2.001	1.966	1.75	1.987	1.951	1.81	2.019	1.982	1.83	1.80	0.04
SP 6	100	0	0	0	-		2.215	2.171	1.99	2.202	2.159	1.95	2.210	2.166	1.99	1.98	0.02
SP 7	93.5	4.5	1	1	56 μm		2.284	2.194	3.94	2.267	2.176	4.01	2.242	2.154	3.93	3.96	0.05
SP 8	93.5	4.5	1	1	20 nm	550	2.097	2.044	2.53	2.106	2.052	2.56	2.133	2.079	2.53	2.54	0.02
SP 9	93	4.5	1.5	1	56 μm		1.760	1.698	3.52	1.751	1.695	3.20	1.756	1.701	3.13	3.28	0.21
SP 10	93	4.5	1.5	1	20 nm		2.087	2.039	2.30	2.029	1.988	2.02	2.073	2.030	2.07	2.13	0.15
SP 11	100	0	0	0	-		2.249	2.197	2.31	2.257	2.206	2.26	2.245	2.193	2.32	2.30	0.03
SP 12	93.5	4.5	1	1	56 μm		2.199	2.109	4.09	2.184	2.095	4.08	2.210	2.120	4.07	4.08	0.01
SP 13	93.5	4.5	1	1	20 nm	600	2.124	2.069	2.59	2.103	2.048	2.62	2.085	2.031	2.59	2.60	0.01
SP 14	93	4.5	1.5	1	56 μm		2.180	2.099	3.72	2.172	2.096	3.50	2.175	2.101	3.40	3.54	0.16
[illegible]	[illegible]	[illegible]	1.5	1	20 nm		2.133	2.081	2.44	2.069	2.018	2.46	2.091	2.039	2.49	2.46	0.02

LAMPIRAN 10
TABULASI DATA SIFAT FISIS KOMPOSIT

Tabulasi Data Hasil Penelitian **Sifat Fisis** Komposit Paduan Al – Cu – Mg - Al_2O_3

Kode	Komposisi (%)				Ukuran Butir Al_2O_3	Densitas Teoritis (g/cm³)	Densitas GC (g/cm³)	Densitas SC (g/cm³)	Densitas Relatif GC (%)	Densitas Relatif SC (%)	Porositas (%)	Shrinkage (%)
	Al	Cu	Mg	Al_2O_3								
500℃												
SP1	100	0	0	0	-	2.700	1.724	1.729	63.83	64.04	4.74	1.64
SP2	93.5	4.5	1	1	μ	2.983	1.661	1.682	55.67	56.39	9.54	3.85
SP3	93.5	4.5	1	1	n	2.983	1.610	1.627	53.98	54.55	6.67	2.45
SP4	93	4.5	1.5	1	μ	2.980	1.704	1.696	57.17	57.21	8.60	3.06
SP5	93	4.5	1.5	1	n	2.980	1.618	1.640	54.31	55.03	6.40	1.80
550℃												
SP6	100	0	0	0	-	2.700	1.724	1.746	63.84	64.66	4.60	1.98
SP7	93.5	4.5	1	1	μ	2.983	1.661	1.696	55.67	56.85	8.99	3.96
SP8	93.5	4.5	1	1	n	2.983	1.610	1.639	53.98	54.96	6.42	2.54
SP9	93	4.5	1.5	1	μ	2.980	1.704	1.706	57.17	57.25	7.86	3.28
SP10	93	4.5	1.5	1	n	2.980	1.619	1.644	54.32	55.15	6.01	2.13
600℃												
SP11	100	0	0	0	-	2.700	1.724	1.757	63.84	65.06	4.41	2.30
SP12	93.5	4.5	1	1	μ	2.983	1.660	1.702	55.66	57.07	8.76	4.08
[illegible]	[illegible]	[illegible]	1	1	n	2.983	1.610	1.645	53.98	55.15	6.19	2.60
[illegible]	[illegible]	[illegible]	1.5	1	μ	2.980	1.705	1.712	57.23	57.45	7.48	3.54
[illegible]	[illegible]	[illegible]	1.5	1	n	2.980	1.621	1.657	54.40	55.61	5.47	2.46

LAMPIRAN 11

Tabulasi Nilai Kekerasan Mikro *Sintered Compact*

Kode	% Fraksi Komposisi				Ukuran Butir Al_2O_3	Temp. Sinter (℃)		Kiri (HV)	Tengah (HV)	Kanan (HV)	$\bar{x}$ HV (%)
	Al	Cu	Mg	Al_2O_3							
							Atas	23.5	28.5	23.6	
SP 1	100	0	0	0	-		**Tengah**	31.2	30.1	29.5	27.5
							Bawah	32.2	23.0	25.6	
							Atas	47.3	50.5	50.8	
SP 2	93.5	4.5	1	1	56 μm		**Tengah**	50.6	46.7	44.6	48.1
							Bawah	48.1	47.8	46.3	
							Atas	52.5	55.6	59.8	
SP 3	93.5	4.5	1	1	20 nm	500	**Tengah**	50.6	46.7	44.8	52.1
							Bawah	58.1	47.8	52.8	
							Atas	55.0	51.4	37.7	
SP 4	93	4.5	1.5	1	56 μm		**Tengah**	49.9	51.8	50.2	49.6
							Bawah	45.4	50.6	54.8	
							Atas	55.3	51.3	56.0	
SP 5	93	4.5	1.5	1	20 nm		**Tengah**	52.2	52.9	52.1	53.5
							Bawah	48.1	57.7	55.7	

Kode	% Fraksi Komposisi				Ukuran Butir Al_2O_3	Temp. Sinter (℃)		Kiri (HV)	Tengah (HV)	Kanan (HV)	$\bar{x}$ HV (%)
	Al	Cu	Mg	Al_2O_3							
SP 6	100	0	0	0	-	550	**Atas**	27.9	37.4	23.6	29.4
							Tengah	33.7	30.1	29.5	
							Bawah	32.2	29.0	21.1	
SP 7	93.5	4.5	1	1	56 μm		**Atas**	46.1	46.9	45.8	49.0
							Tengah	53.9	58.8	56.9	
							Bawah	44.3	43.9	44.7	
SP 8	93.5	4.5	1	1	20 nm		**Atas**	55.6	54.9	66.4	53.6
							Tengah	50.3	61.4	43.3	
							Bawah	57.6	46.2	47.0	
SP 9	93	4.5	1.5	1	56 μm		**Atas**	56.1	57.0	56.9	51.3
							Tengah	47.3	57.9	42.2	
							Bawah	34.5	57.9	51.8	
SP 10	93	4.5	1.5	1	20 nm		**Atas**	55.1	49.6	58.0	54.6
							Tengah	54.7	58.8	51.9	
							Bawah	57.6	53.8	52.3	

Kode	% Fraksi Komposisi				Ukuran Butir Al_2O_3	Temp. Sinter (℃)		Kiri (HV)	Tengah (HV)	Kanan (HV)	$\bar{x}$ HV (%)
	Al	Cu	Mg	Al_2O_3							
							Atas	27.9	37.4	33.1	
SP 11	100	0	0	0	-		**Tengah**	33.7	31.1	29.5	31.1
							Bawah	32.2	29.0	25.6	
							Atas	47.3	58.5	49.8	
SP 12	93.5	4.5	1	1	56 μm		**Tengah**	50.6	51.1	54.6	51.3
							Bawah	48.1	55.5	46.3	
							Atas	64.2	66.3	58.2	
SP 13	93.5	4.5	1	1	20 nm	600	**Tengah**	48.0	56.7	44.8	54.8
							Bawah	54.2	47.8	52.8	
							Atas	58.2	49.3	57.7	
SP 14	93	4.5	1.5	1	56 μm		**Tengah**	49.9	51.8	51.2	52.1
							Bawah	45.4	50.6	54.8	
							Atas	65.3	51.3	46.0	
SP 15	93	4.5	1.5	1	20 nm		**Tengah**	62.2	52.9	52.1	55.7
							Bawah	48.1	57.7	65.7	

LAMPIRAN 12
Tabulasi Nilai Laju Keausan *Sintered Compact*

Kode	Al	Cu	Mg	Al_2O_3	Ukuran Butir Al_2O_3	ρ (g/cm^3)	Beban Uji (N)	Panjang Lintasan (meter)	Waktu Uji (detik)	Temp. Sinter (℃)	M loss (gram)	vol. Keausan (mm^3)	Laju Keausan (mm^3/m)	Laju Keausan (mm^3/m-N)
SP 1	100	0	0	0	-	1.730					0.025	14.449	0.895	0.358
SP 2	93.5	4.5	1	1	56 μm	1.682					0.021	12.484	0.773	0.309
SP 3	93.5	4.5	1	1	20 nm	1.626				500	0.020	12.300	0.762	0.305
SP 4	93	4.5	1.5	1	56 μm	1.705					0.021	12.318	0.763	0.305
SP 5	93	4.5	1.5	1	20 nm	1.636					0.019	11.614	0.720	0.288
SP 6	100	0	0	0	-	1.745					0.023	13.183	0.817	0.327
SP 7	93.5	4.5	1	1	56 μm	1.694					0.019	11.217	0.695	0.278
SP 8	93.5	4.5	1	1	20 nm	1.639	2.5	16.14	60	550	0.018	10.979	0.680	0.272
SP 9	93	4.5	1.5	1	56 μm	1.705					0.019	11.144	0.690	0.276
SP 10	93	4.5	1.5	1	20 nm	1.649					0.016	9.702	0.601	0.240
SP 11	100	0	0	0	-	1.757					0.020	11.381	0.705	0.282
SP 12	93.5	4.5	1	1	56 μm	1.703					0.017	9.980	0.618	0.247
SP 13	93.5	4.5	1	1	20 nm	1.646				600	0.015	9.113	0.565	0.226
SP 14	93	4.5	1.5	1	56 μm	1.709					0.016	9.360	0.580	0.232
[illegible]	[illegible]	4.5	1.5	1	20 nm	1.659					0.012	7.235	0.448	0.179

LAMPIRAN 13

TABULASI DATA PENELITIAN SIFAT MEKANIS KOMPOSIT

Tabulasi Data Hasil Penelitian **Sifat Mekanis** Komposit Paduan Al – Cu – Mg - Al_2O_3

Kode	Komposisi (%)				Ukuran Butir Al_2O_3	Densitas SC (g/cm^3)	Hardness (HV)	Laju Aus (mm^3/m)
	Al	Cu	Mg	Al_2O_3				
					500°C			
SP1	100	0	0	0	-	1.729	27.5	0.895
SP2	93.5	4.5	1	1	μ	1.682	48.1	0.773
SP3	93.5	4.5	1	1	n	1.627	52.1	0.762
SP4	93	4.5	1.5	1	μ	1.696	49.6	0.763
SP5	93	4.5	1.5	1	n	1.640	53.5	0.720
					550°C			
SP6	100	0	0	0	-	1.746	29.4	0.817
SP7	93.5	4.5	1	1	μ	1.696	49.0	0.695
SP8	93.5	4.5	1	1	n	1.639	53.6	0.680
SP9	93	4.5	1.5	1	μ	1.706	51.3	0.690
SP10	93	4.5	1.5	1	n	1.644	54.6	0.601
					600°C			
SP11	100	0	0	0	-	1.757	31.1	0.705
SP12	93.5	4.5	1	1	μ	1.702	51.3	0.618
[illegible]	[illegible]	4.5	1	1	n	1.645	54.8	0.565
[illegible]	[illegible]	4.5	1.5	1	μ	1.712	52.1	0.580
[illegible]	[illegible]	4.5	1.5	1	n	1.657	55.7	0.448

EFEK DARI SUHU SINTERING, UKURAN BUTIR ALUMINA DAN KOMPOSISI MAGNESIUM PADA KOMPOSIT $Al\text{-}Cu\text{-}Mg\text{-}Al_2O_3$ TERHADAP SIFAT FISIS, MEKANIS, DAN STRUKTUR MIKRO DIPRODUKSI DENGAN METALURGI SERBUK

Effects of Sintering Temperature, Grain Size of Alumina and Magnesium Composition of $Al\text{-}Cu\text{-}Mg\text{-}Al_2O_3$ on Physical, Mechanical and Microstructural Properties Produced by Powder Metallurgy

TOMMY TARMINSYAH
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ILYAS R.

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