

LAMPIRAN A
CONTOH PERHITUNGAN

Lampiran A. Contoh Perhitungan

B.1 Perhitungan kebutuhan sampel

Rumus persentase kebutuhan cor untuk 2 unsur paduan :

$$BU = \frac{K_3 - K_2}{K_1 - K_2} \times 100\%$$

$$BT = 100\% - BU$$

Keterangan:

BU = persentase bahan utama

BT = persentase bahan tambahan

K_1 = kandungan unsur bahan utama

K_2 = kandungan unsur bahan tambahan

K_3 = kandungan unsur yang ingin dicapai

Sampel 0,5% wt tembaga

$$\text{Berat aluminium 5052} = \left(\frac{3,15 - 0,5}{3,15 - 0,01} \times 100\% \right) \times 200 \text{ gram} = 170 \text{ gram}$$

$$\text{Berat aluminium 2024} = 200 \text{ gram} - 170 \text{ gram} = 30 \text{ gram}$$

Sampel 1% wt tembaga

$$\text{Berat aluminium 5052} = \left(\frac{3,15 - 1}{3,15 - 0,01} \times 100\% \right) \times 200 \text{ gram} = 135 \text{ gram}$$

$$\text{Berat aluminium 2024} = 200 \text{ gram} - 135 \text{ gram} = 65 \text{ gram}$$

Sampel 2% wt tembaga

$$\text{Berat aluminium 5052} = \left(\frac{3,15 - 2}{3,15 - 0,01} \times 100\% \right) \times 200 \text{ gram} = 75 \text{ gram}$$

$$\text{Berat aluminium 2024} = 200 \text{ gram} - 75 \text{ gram} = 125 \text{ gram}$$

B.2 Perhitungan elongasi uji tarik

Rumus persen elongasi

$$E = \frac{p - P_0}{P_0} \times 100\%$$

Keterangan :

p = panjang akhir

P₀ = panjang awal

Data Sampel 0,5Cu 10% reduksi

$$E = \frac{28,24 - 26}{26} \times 100\% = 8,6\%$$

Data Sampel 0,5Cu 20% reduksi

$$E = \frac{25,26 - 25}{25} \times 100\% = 1,04\%$$

Data Sampel 0,5Cu 30% reduksi

$$E = \frac{24,097 - 25}{24} \times 100\% = 0,4\%$$

Data Sampel 1Cu 10% reduksi

$$E = \frac{29,108 - 25}{25} \times 100\% = 16,44\%$$

Data Sampel 1Cu 20% reduksi

$$E = \frac{25,17 - 25}{25} \times 100\% = 0,83\%$$

Data Sampel 1Cu 30% reduksi

$$E = \frac{25,26 - 25}{25} \times 100\% = 1,08 \%$$

Data Sampel 2Cu 10% reduksi

$$E = \frac{28,79 - 25}{25} \times 100\% = 15,2 \%$$

Data Sampel 2Cu 20% reduksi

$$E = \frac{25,17 - 25}{25} \times 100\% = 0,68 \%$$

Data Sampel 2Cu 30% reduksi

$$E = \frac{25,15 - 25}{25} \times 100\% = 0,6 \%$$

B.3 Perhitungan rata-rata ukuran butir

Rumus rata-rata ukuran butir metode *jeffries planimetric*

$$f = \frac{M^2}{a}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right]$$

$$A = \frac{1}{N_A}$$

$$d = (A)^{1/2}$$

Keterangan:

f = jeffries faktor

M = Perbesaran Mikroskop

a = Luas area lingkaran pada 1x (mm²)

N_A = Jumlah butir per luas area lingkaran (mm⁻²)

n₁ = rata-rata butir yang terhitung di dalam lingkaran

n_2 = rata-rata butir terhitung yang bersinggungan dengan lingkaran

A = Rata-rata luas butir (μm^2)

d = Rata-rata ukuran butir (μm)

Data Sampel 0,5Cu 0% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[30,67 + \left(\frac{18}{2} \right) \right] = 496,31 \text{ mm}^{-2}$$

$$A = \frac{10^6}{496,31} = 2014,863 \mu\text{m}^2$$

$$d = (2014,863)^{1/2} = 44,89 \mu\text{m}$$

Data Sampel 0,5Cu 10% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[102,33 + \left(\frac{19,33}{2} \right) \right] = 1401,351 \text{ mm}^{-2}$$

$$A = \frac{10^6}{1401,351} = 713,6 \mu\text{m}^2$$

$$d = (713,6)^{1/2} = 26,71 \mu\text{m}$$

Data Sampel 0,5Cu 20% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[113 + \left(\frac{27,33}{2} \right) \right] = 1584,86 \text{ mm}^{-2}$$

$$A = \frac{10^6}{1584,86} = 630,97 \mu\text{m}^2$$

$$d = (630,97)^{1/2} = 25,12 \mu\text{m}$$

Data Sampel 0,5Cu 30% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[125,67 + \left(\frac{32}{2} \right) \right] = 1772,542 \text{ mm}^{-2}$$

$$A = \frac{10^6}{1772,542} = 564,16 \mu\text{m}^2$$

$$d = (564,16)^{1/2} = 23,75 \mu\text{m}$$

Data Sampel 1Cu 0% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[52,67 + \left(\frac{20}{2} \right) \right] = 784,9 \text{ mm}^{-2}$$

$$A = \frac{10^6}{784,9} = 1275,37 \mu\text{m}^2$$

$$d = (1275,37)^{1/2} = 35,71 \mu\text{m}$$

Data Sampel 1Cu 10% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[188 + \left(\frac{30}{2} \right) \right] = 2539,95 \text{ mm}^{-2}$$

$$A = \frac{10^6}{2539,95} = 393,71 \mu\text{m}^2$$

$$d = (393,71)^{1/2} = 19,84 \mu\text{m}$$

Data Sampel 1Cu 20% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[15,67 + \left(\frac{7,33}{2} \right) \right] = 241,9 \text{ mm}^{-2}$$

$$A = \frac{10^6}{241,9} = 4133,94 \text{ } \mu\text{m}^2$$

$$d = (4133,94)^{1/2} = 64,3 \text{ } \mu\text{m}$$

Data Sampel 1Cu 30% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[210,33 + \left(\frac{31}{2} \right) \right] = 2825,64 \text{ mm}^{-2}$$

$$A = \frac{10^6}{2825,64} = 353,9 \text{ } \mu\text{m}^2$$

$$d = (353,9)^{1/2} = 18,81 \text{ } \mu\text{m}$$

Data Sampel 2Cu 0% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[45,33 + \left(\frac{14,33}{2} \right) \right] = 656,88 \text{ mm}^{-2}$$

$$A = \frac{10^6}{656,88} = 1522,34 \text{ } \mu\text{m}^2$$

$$d = (1522,34)^{1/2} = 39,02 \text{ } \mu\text{m}$$

Data Sampel 2Cu 10% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[103,67 + \left(\frac{14,33}{2} \right) \right] = 1457,66 \text{ mm}^{-2}$$

$$A = \frac{10^6}{1457,66} = 686,03 \text{ } \mu\text{m}^2$$

$$d = (686,03)^{1/2} = 26,19 \text{ } \mu\text{m}$$

Data Sampel 2Cu 20% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[117,67 + \left(\frac{31,33}{2} \right) \right] = 1668,274 \text{ mm}^{-2}$$

$$A = \frac{10^6}{1668,274} = 599,42 \text{ } \mu\text{m}^2$$

$$d = (599,42)^{1/2} = 24,48 \text{ } \mu\text{m}$$

Data Sampel 2Cu 30% reduksi

$$f = \frac{M^2}{a} = \frac{50^2}{199,8} = 12,5 \text{ mm}^{-2}$$

$$N_A = f \left[n_1 + \left(\frac{n_2}{2} \right) \right] = 12,5 \left[159,67 + \left(\frac{34,67}{2} \right) \right] = 2214,63 \text{ mm}^{-2}$$

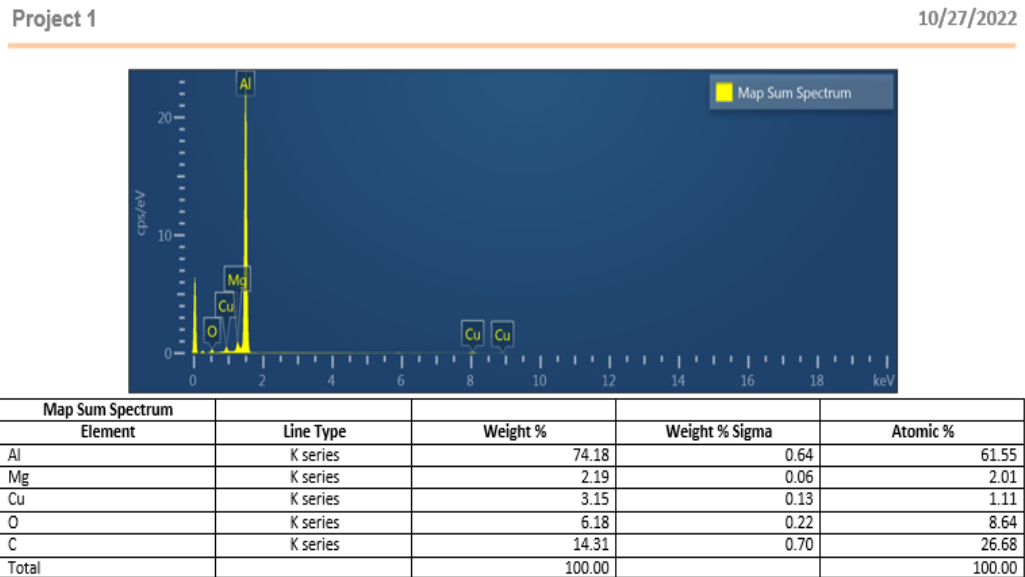
$$A = \frac{10^6}{2214,63} = 451,54 \text{ } \mu\text{m}^2$$

$$d = (451,54)^{1/2} = 21,25 \text{ } \mu\text{m}$$

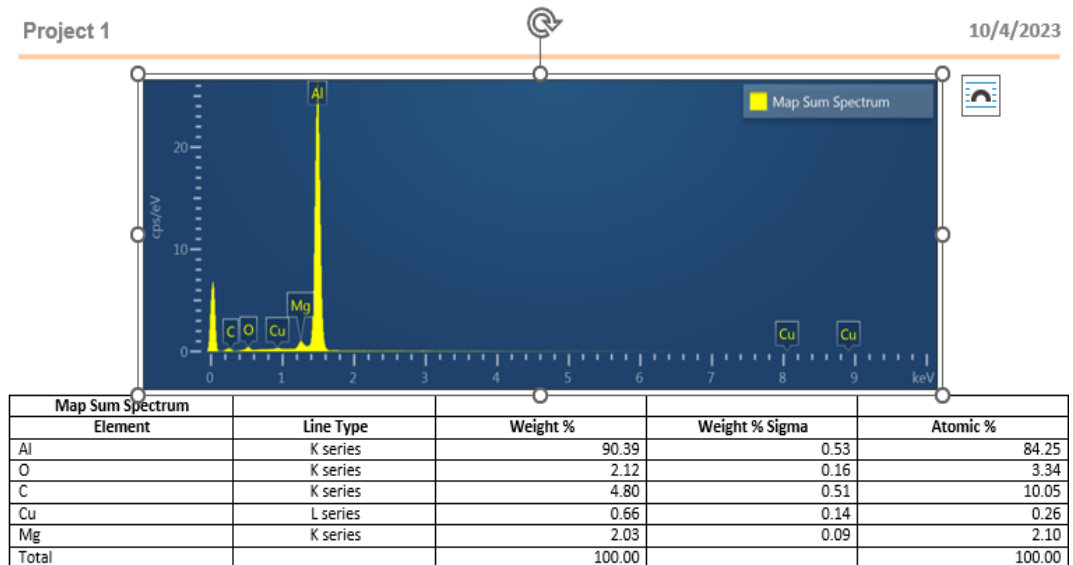
LAMPIRAN B
DATA HASIL PENELITIAN

Lampiran B. Data Hasil Penelitian

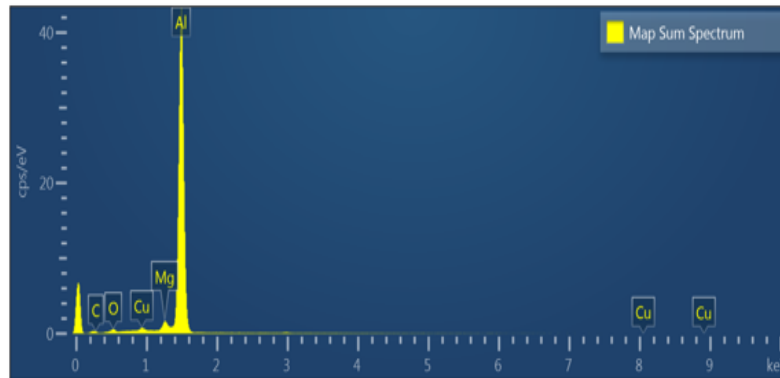
B.1 Data Hasil Pengujian SEM-EDS



Gambar B.1 Hasil uji komposisi EDS *Masteralloy* aluminium 2024

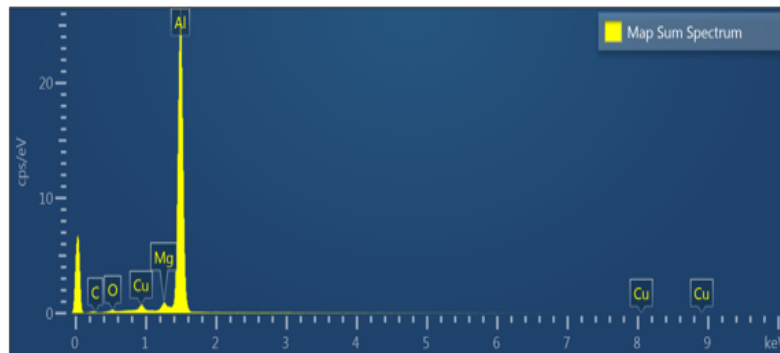


Gambar B.2 Hasil uji komposisi EDS penambahan Cu 0,5 %



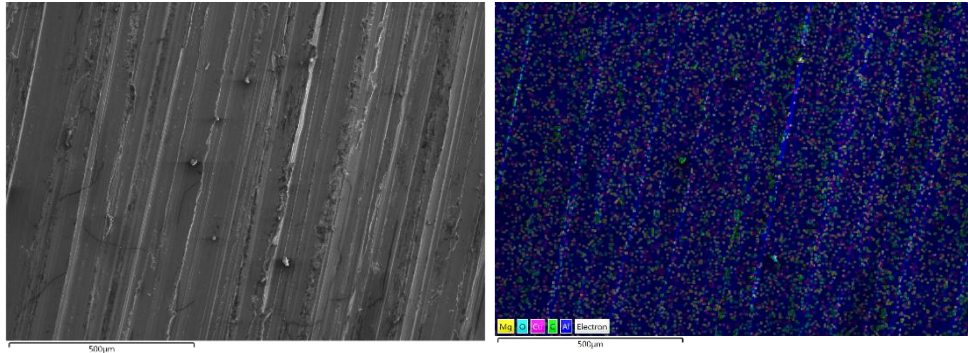
Map Sum Spectrum				
Element	Line Type	Weight %	Weight % Sigma	Atomic %
Al	K series	91.68	0.40	87.73
Mg	K series	1.98	0.07	2.10
O	K series	1.62	0.12	2.62
Cu	L series	1.49	0.12	0.61
C	K series	3.23	0.38	6.94
Total		100.00		100.00

Gambar B.3 Hasil uji komposisi EDS penambahan Cu 1 %

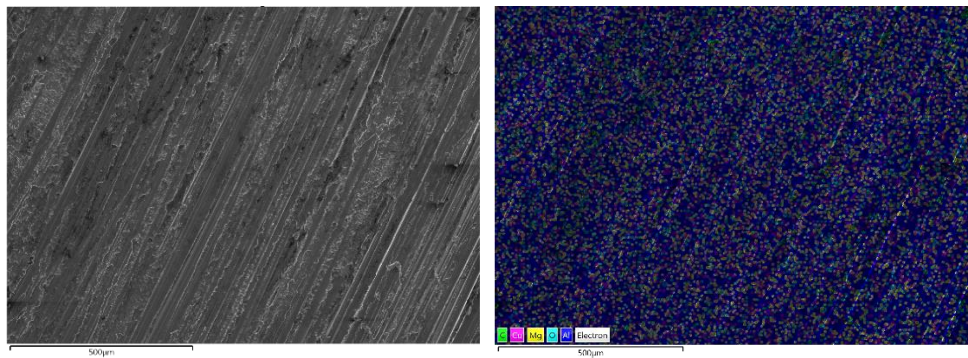


Map Sum Spectrum				
Element	Line Type	Weight %	Weight % Sigma	Atomic %
Al	K series	92.46	0.47	91.34
O	K series	1.10	0.15	1.83
C	K series	1.64	0.43	3.64
Cu	L series	3.07	0.17	1.29
Mg	K series	1.72	0.09	1.89
Total		100.00		100.00

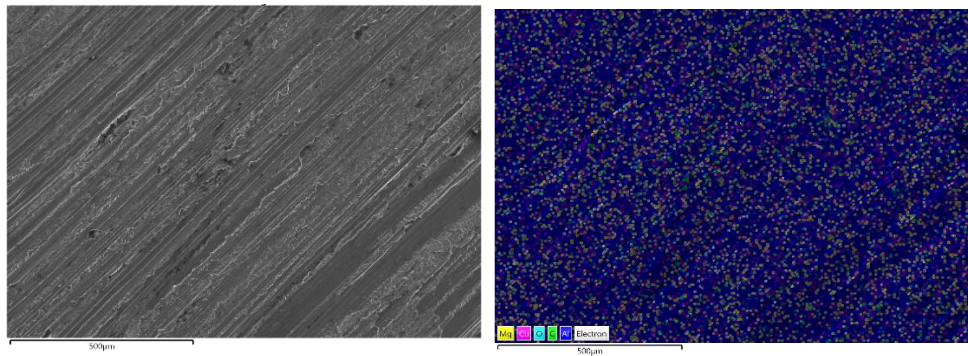
Gambar B.4 Hasil uji komposisi EDS penambahan Cu 2 %



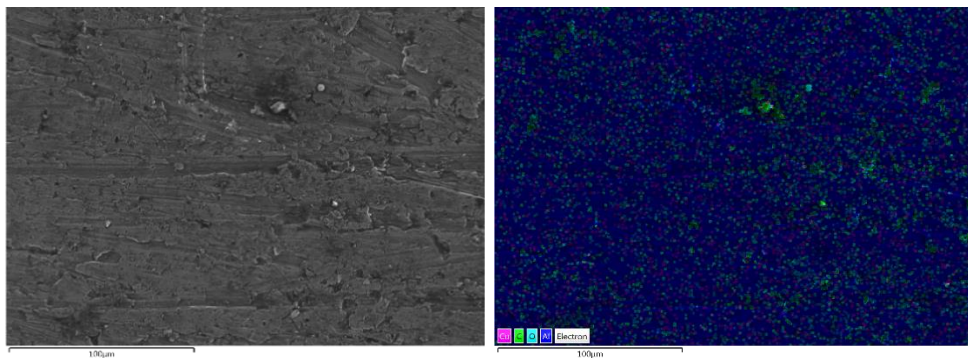
Gambar B.5 Gambar SEM Sampel 0,5Cu 0% Reduksi



Gambar B.6 Gambar EDS Sampel 1Cu 0% Reduksi



Gambar B.7 Gambar EDS Sampel 2Cu 0% Reduksi



Gambar B.8 Gambar EDS Sampel 0,5Cu 10% Reduksi

B.2 Data Hasil Pengujian Tarik

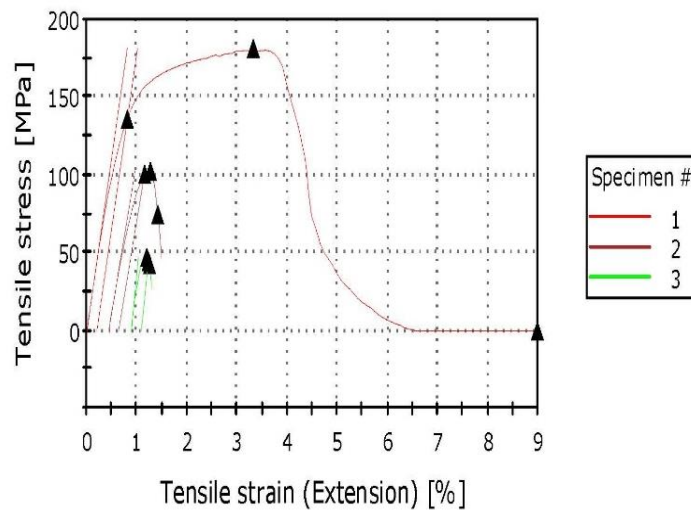


TEST RESULT

Report No	061/EXT/UNT/09/23
Material	Aluminium
Test Method	ASTM E8
Test Machine	INSTRON 5982
Extensometer	Clip On GL 50 mm
Operator Name	AF
Room Temp.	27
%Humidity	70
Rate 1	0.005 mm/mm/min
Rate 2	0.05 mm/mm/min

Graph 1

Specimen 1 to 3



	Width [mm]	Thickness [mm]	Maximum Load [kN]	Tensile stress at Maximum Load [MPa]	Tensile stress at Yield (Offset 0.2 %) [MPa]	Tensile strain (Extension) at Maximum Load [%]	Break Location	Modulus-1 [Gpa]	Code
1	5.49	4.74	4.71	181.32	135.76	3.324	A (Inside GL)	5.454	0.5 Cu 10%
2	6.04	4.32	2.68	102.64	100.36	0.827	A (Inside GL)	12.416	0.5 Cu 20%
3	6.00	3.98	1.13	47.21	44.73	0.304	A (Inside GL)	15.539	0.5 Cu 20%

Note: The result just for this test

Gambar B.9 Data pengujian tarik sampel 10% reduksi

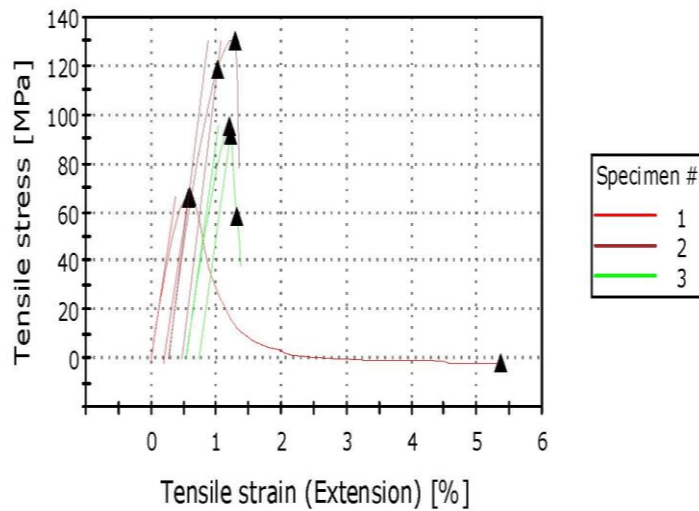


TEST RESULT

Report No	062/EXT/UNT/09/23
Material	Aluminium
Test Method	ASTM E8
Test Machine	INSTRON 5982
Extensometer	Clip On GL 50 mm
Operator Name	AF
Room Temp.	27
%Humidity	70
Rate 1	0.005 mm/mm/min
Rate 2	0.05 mm/mm/min

Graph 1

Specimen 1 to 3



	Width [mm]	Thickness [mm]	Maximum Load [kN]	Tensile stress at Maximum Load [MPa]	Tensile stress at Yield (Offset 0.2 %) [MPa]	Tensile strain (Extension) at Maximum Load [%]	Break Location	Modulus-1 [Gpa]	Code
1	5.74	4.92	1.88	66.50	66.24	0.591	A (Inside GL)	11.250	1 Cu 10%
2	5.88	4.12	3.16	130.36	118.71	1.017	A (Inside GL)	12.813	1 Cu 10%
3	6.47	4.30	2.65	95.38	91.88	0.664	A (Inside GL)	14.374	1 Cu 10%

Note: The result just for this test

Gambar B.10 Data pengujian tarik sampel 20% reduksi

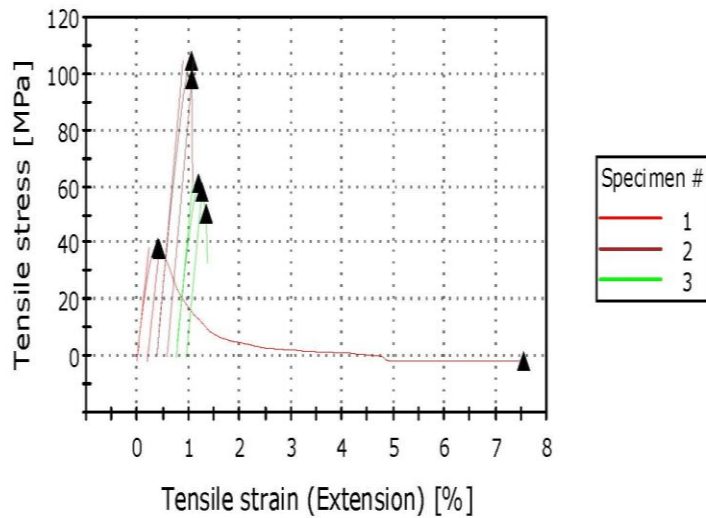


TEST RESULT

Report No	063/EXT/UNT/09/23
Material	Aluminium
Test Method	ASTM E8
Test Machine	INSTRON 5982
Extensometer	Clip On GL 50 mm
Operator Name	AF
Room Temp.	27
%Humidity	70
Rate 1	0.005 mm/mm/min
Rate 2	0.05 mm/mm/min

Graph 1

Specimen 1 to 3



	Width [mm]	Thickness [mm]	Maximum Load [kN]	Tensile stress at Maximum Load [MPa]	Tensile stress at Yield (Offset 0.2 %) [MPa]	Tensile strain (Extension) at Maximum Load [%]	Break Location	Modulus-1 [Gpa]	Code
1	5.88	4.69	1.07	38.70	38.28	0.403	A (Inside GL)	9.604	2 Cu 10%
2	6.04	4.39	2.77	104.54	98.12	0.679	A (Inside GL)	15.398	2 Cu 20%
3	6.02	4.17	1.54	61.45	58.15	0.439	A (Inside GL)	13.995	2 Cu 30%

Note: The result just for this test

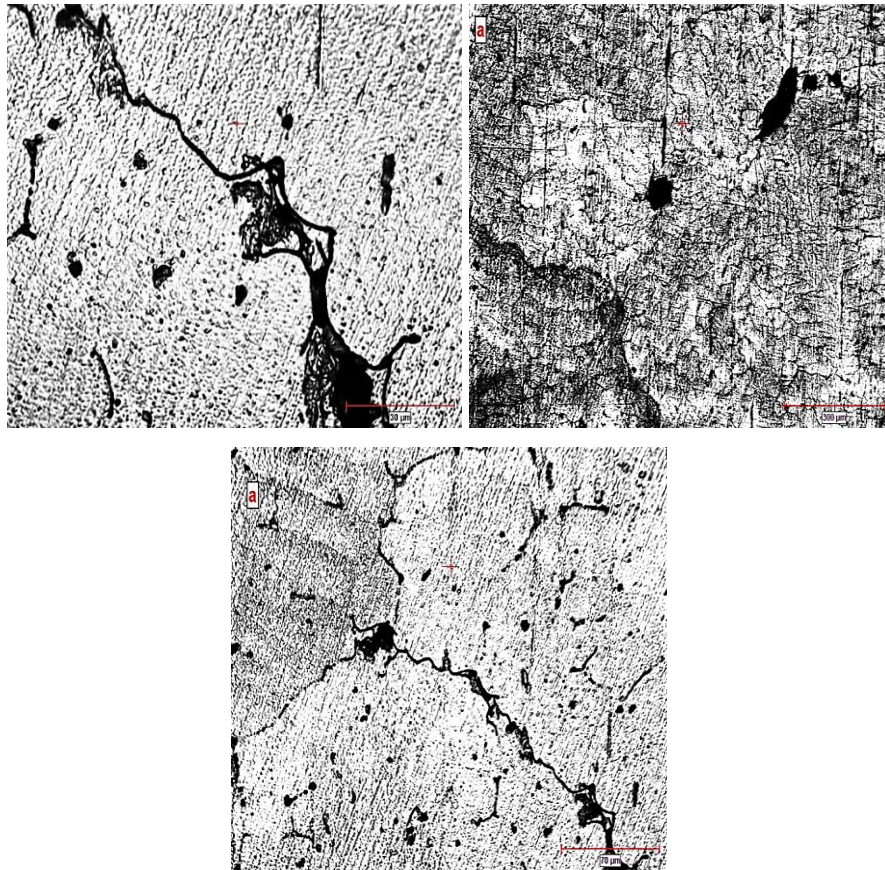
Gambar B.11 Data pengujian tarik sampel 30% reduksi

B.3 Data Hasil Pengujian Metalografi & Kekerasan

Sample Name : 0.5 Cu 10%
Free Text :
Calibration : 0.465909 $\mu\text{m}/\text{pixel}$
Magnification : 20x
Force : 100 gf
Dwell Time : 10 sec .

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	40.7	41.4	110.10
2	44.2	40.2	104.15
3	43.2	40.2	106.47
4	43.2	41.2	104.15
5	41.8	42.1	105.30

50x, 200x, 500x

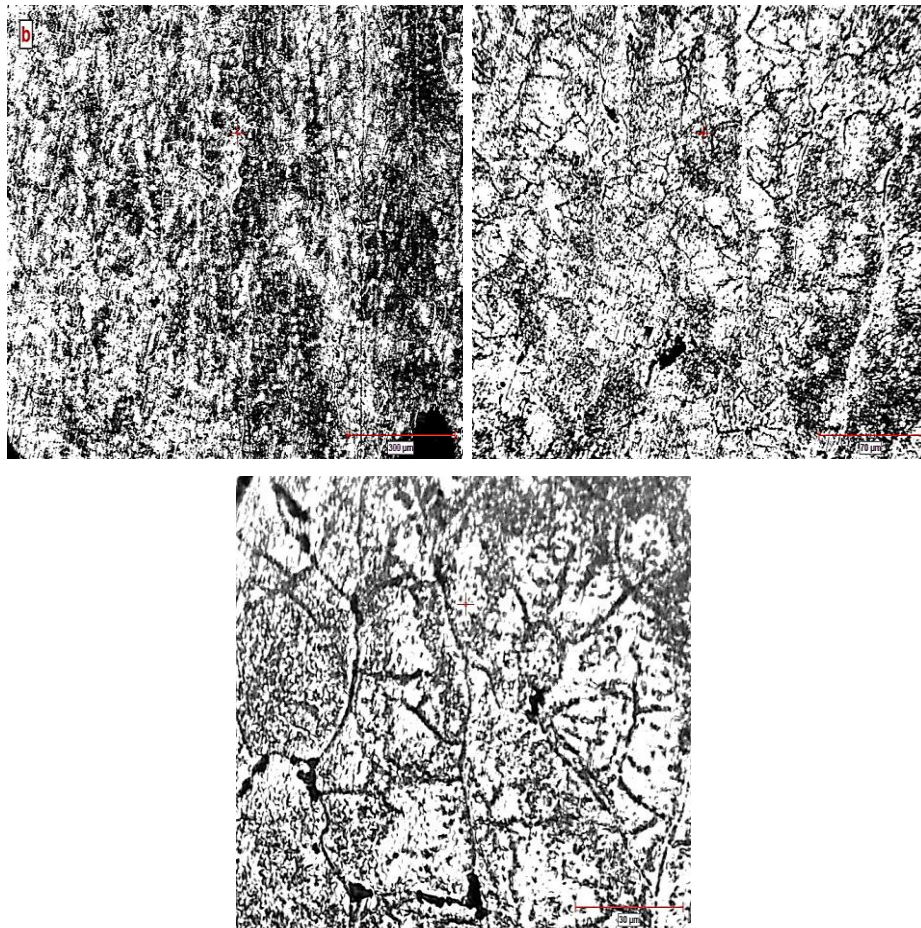


Gambar B.12 Data pengujian metalografi dan kekerasan 0,5Cu 10% reduksi

Sample Name : 0.5 Cu 20%
 Free Text :
 Calibration : 0.465909 $\mu\text{m}/\text{pixel}$
 Magnification : 20x
 Force : 100 gf
 Dwell Time : 10 sec.

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	47.2	46.7	84.18
2	44.2	46.0	91.22
3	46.5	46.9	85.01
4	48.1	47.2	81.74
5	45.5	46.0	88.48

50x, 200x, 500x

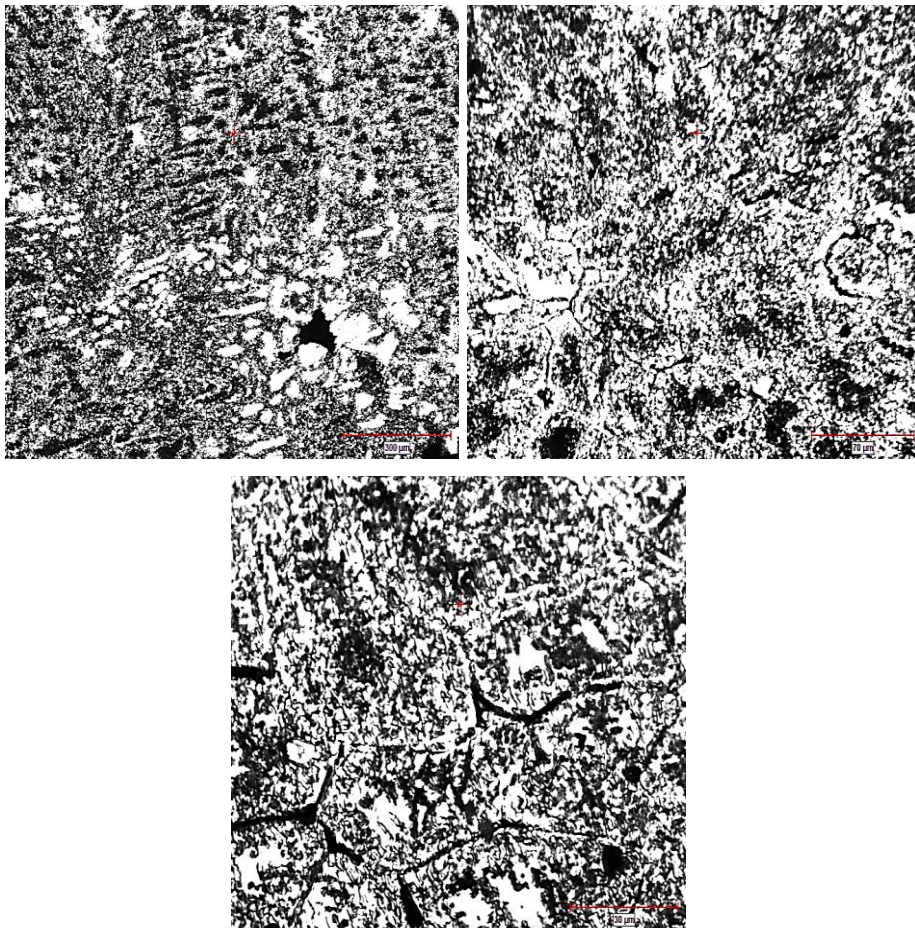


Gambar B.13 Data pengujian metalografi dan kekerasan 0,5Cu 20% reduksi

Sample Name : 0.5 Cu 30%
 Free Text :
 Calibration : 0.4659 $\mu\text{m}/\text{pixel}$
 Magnification : 20x
 Force : 100 gf
 Dwell Time : 10 sec

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	46.7	47.2	84.2
2	48.3	49.9	76.8
3	47.4	46.2	84.6
4	56.4	58.3	56.4
5	46.9	46.0	85.9

50x, 200x, 500x

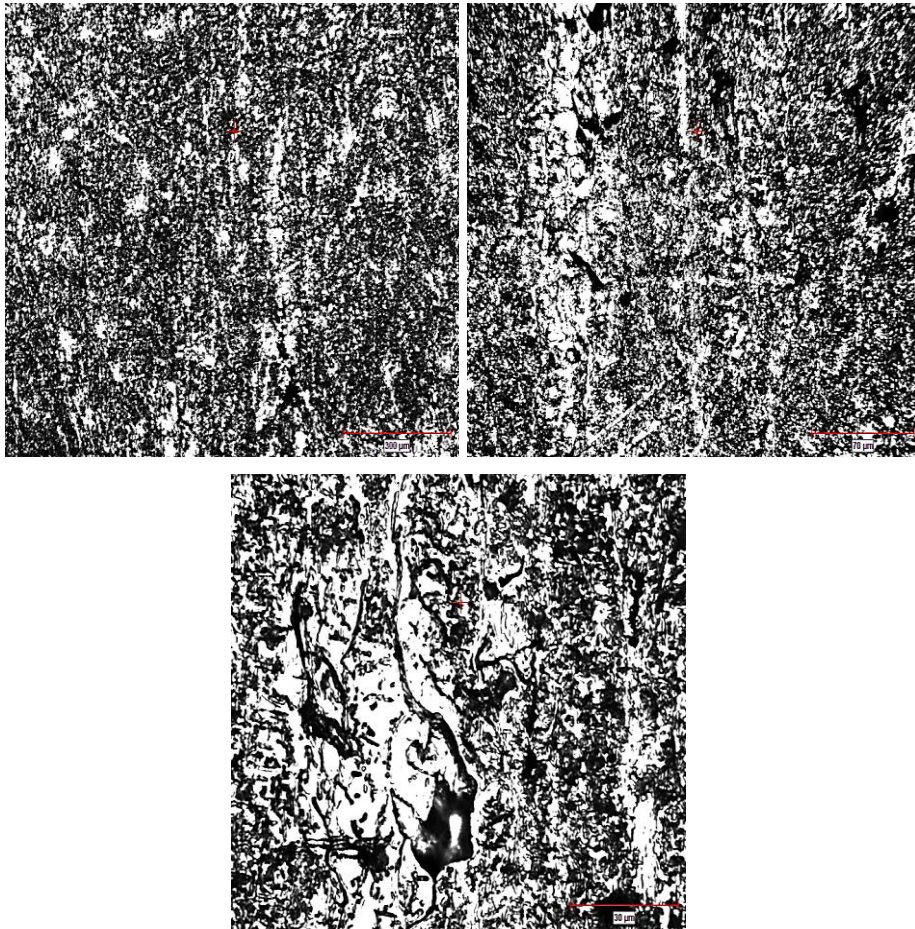


Gambar B.14 Data pengujian metalografi dan kekerasan 0,5Cu 30% reduksi

Sample Name : 1 Cu 10%
 Free Text :
 Calibration : 0.4659 $\mu\text{m}/\text{pixel}$
 Magnification : 20x
 Force : 100 gf
 Dwell Time : 10 sec.

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	50.4	47.9	76.82
2	48.8	48.6	78.28
3	49.5	50.6	74.00
4	49.7	49.5	75.39
5	47.9	48.1	80.56

50x, 200x, 500x

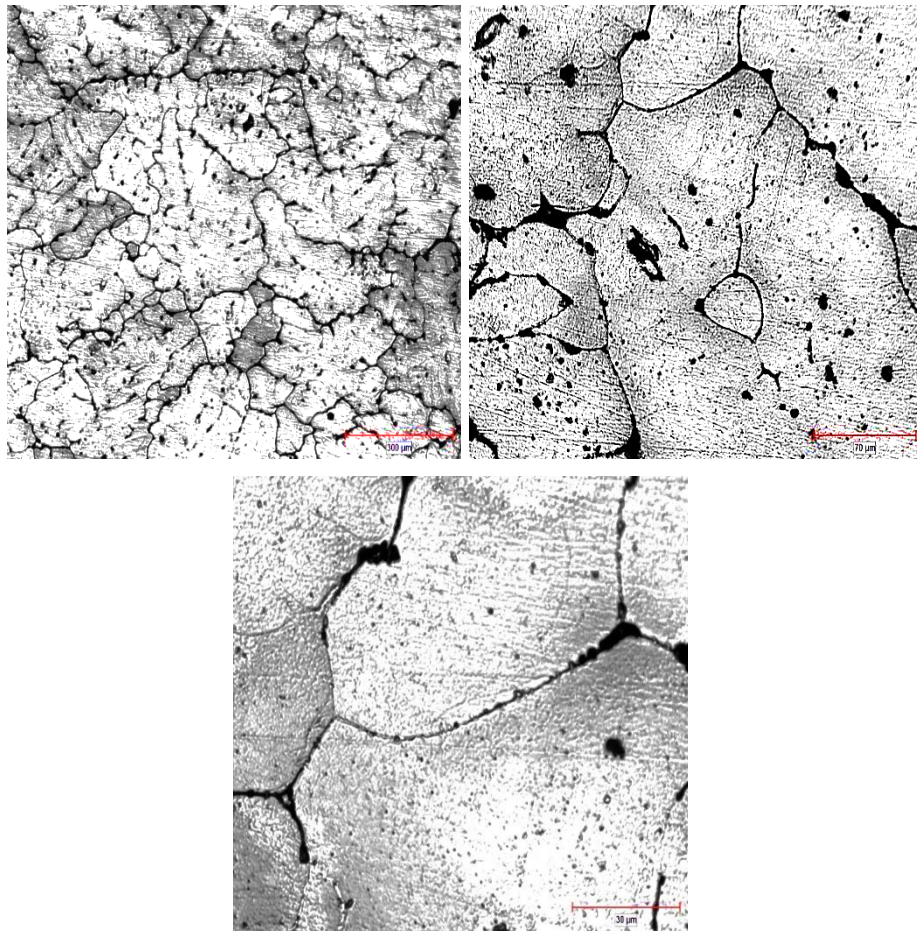


Gambar B.15 Data pengujian metalografi dan kekerasan 1Cu 10% reduksi

Sample Name : 1 Cu 20%
 Free Text :
 Calibration : 0.465909 $\mu\text{m}/\text{pixel}$
 Magnification : 20x
 Force : 100 gf
 Dwell Time : 10 sec

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	43.9	41.4	101.90
2	45.3	42.8	95.58
3	43.2	44.2	97.11
4	43.7	42.5	99.73
5	43.7	42.8	99.20

50x, 200x, 500x

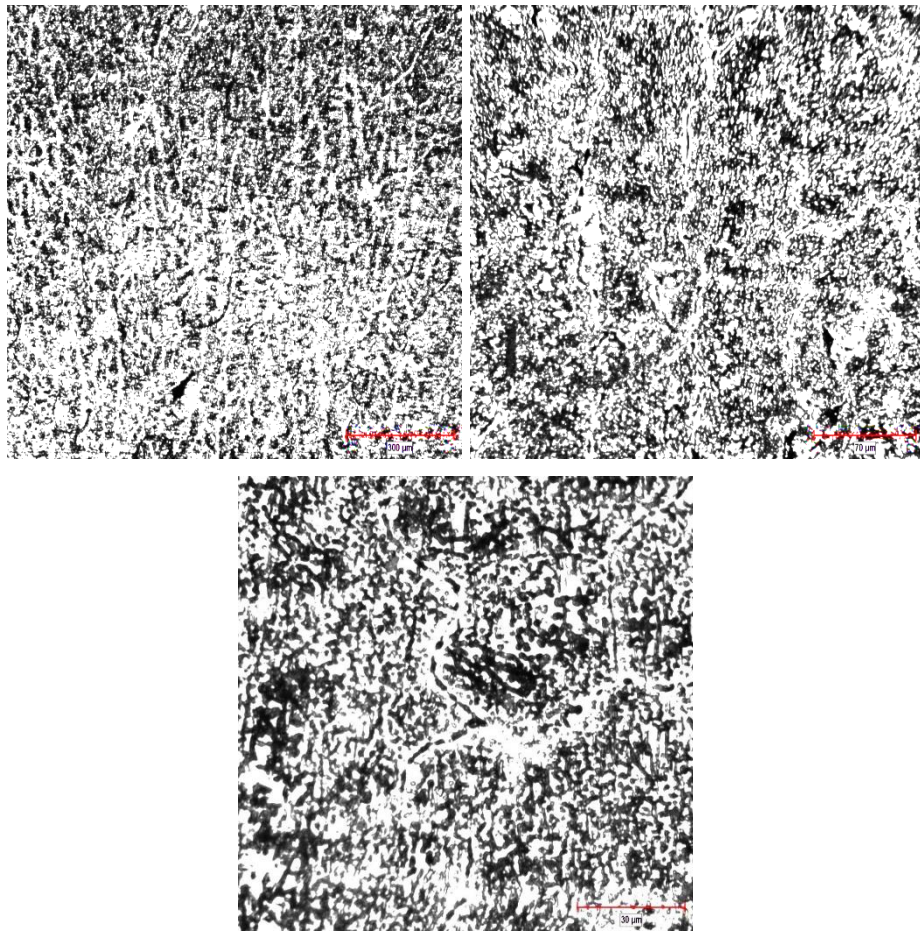


Gambar B.16 Data pengujian metalografi dan kekerasan 1Cu 20% reduksi

Sample Name : 1 Cu 30%
 Free Text :
 Calibration : 0.465909 $\mu\text{m}/\text{pixel}$
 Magnification : 20x
 Force : 100 gf
 Dwell Time : 10 sec

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	43.0	45.3	95.1
2	46.9	43.5	90.8
3	46.7	44.4	89.4
4	45.3	46.7	87.6
5	45.1	44.2	93.1

50x, 200x, 500x

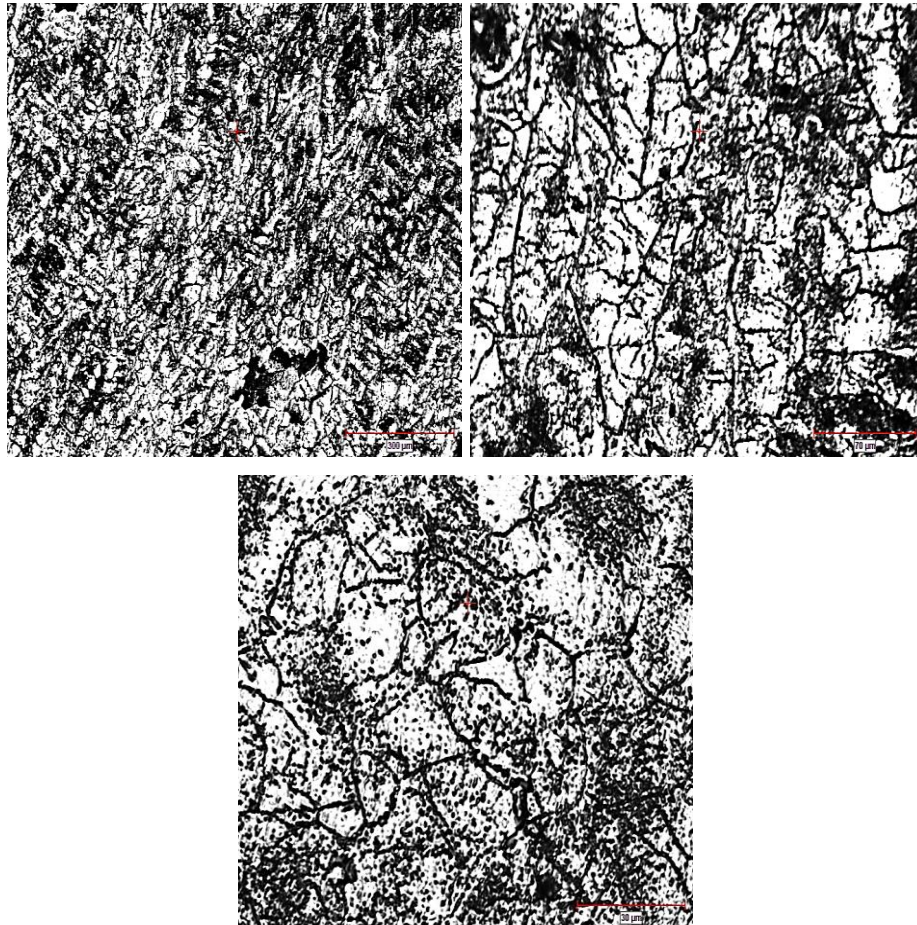


Gambar B.17 Data pengujian metalografi dan kekerasan 1Cu 30% reduksi

Sample Name : 2 Cu 10%
 Free Text :
 Calibration : 0.465909 $\mu\text{m}/\text{pixel}$
 Magnification : 20x
 Force : 100 gf
 Dwell Time : 10 sec

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	50.2	48.6	76.10
2	52.7	48.6	72.32
3	49.9	48.6	76.46
4	46.7	47.6	83.35
5	51.6	48.3	74.35

50x, 200x, 500x

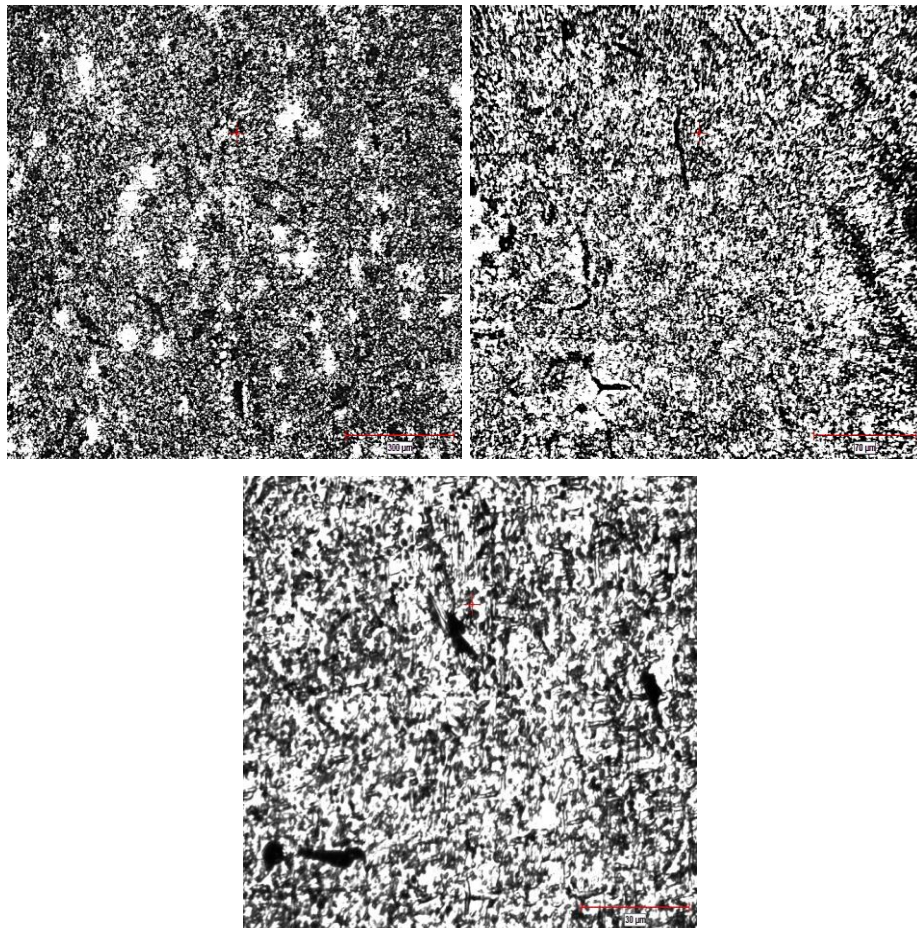


Gambar B.18 Data pengujian metalografi dan kekerasan 2Cu 10% reduksi

Sample Name : 2 Cu 20%
 Free Text :
 Calibration : 0.465909 $\mu\text{m}/\text{pixel}$
 Magnification : 20x
 Force : 100 gf
 Dwell Time : 10 sec

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	45.30	44.60	91.69
2	45.30	45.50	89.84
3	45.50	45.10	90.29
4	48.30	43.50	88.03
5	41.40	42.50	105.30

50x, 200x, 500x

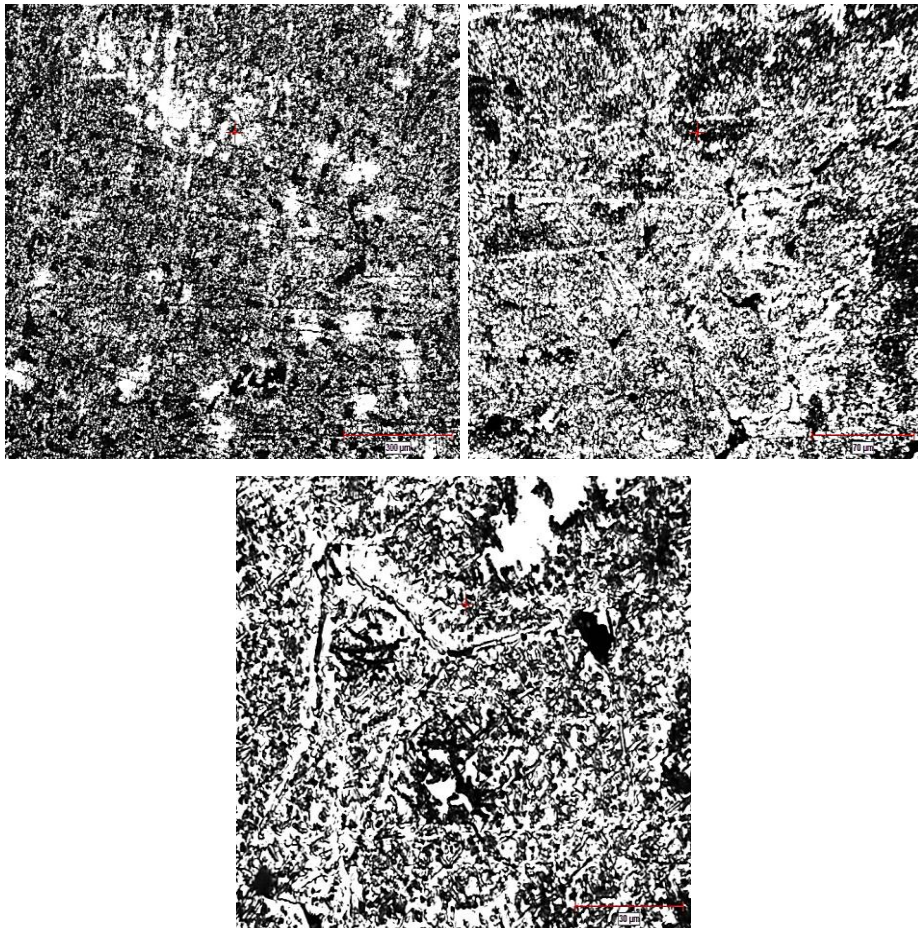


Gambar B.19 Data pengujian metalografi dan kekerasan 2Cu 20% reduksi

Sample Name : 2 Cu 30%
Free Text :
Calibration : 0.465909 $\mu\text{m}/\text{pixel}$
Magnification : 20x
Force : 100 gf
Dwell Time : 10 sec

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	47.4	45.3	86.29
2	45.1	48.3	85.01
3	45.5	46.5	87.59
4	45.5	45.5	89.38
5	47.9	46.7	82.94

50x, 200x, 500x

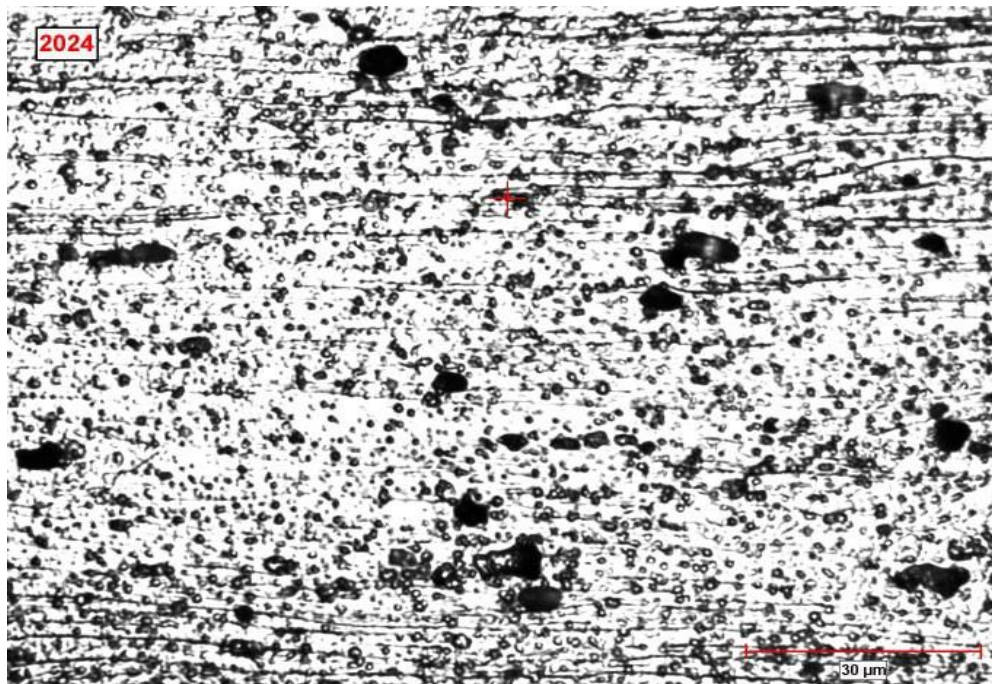


Gambar B.20 Data pengujian metalografi dan kekerasan 2Cu 30% reduksi

Sample Name : base material
Free Text :
Calibration : 0.465909 $\mu\text{m}/\text{pixel}$
Magnification : 20x
Force : 100 gf
Dwell Time : 10 sec

Field #	H Diag. μm	V Diag. μm	Hard. HV0.1
1	50.90	55.30	65.86
2	50.90	54.10	67.32
3	51.80	53.40	67.02
4	52.00	536.00	66.44
5	52.30	52.70	67.32

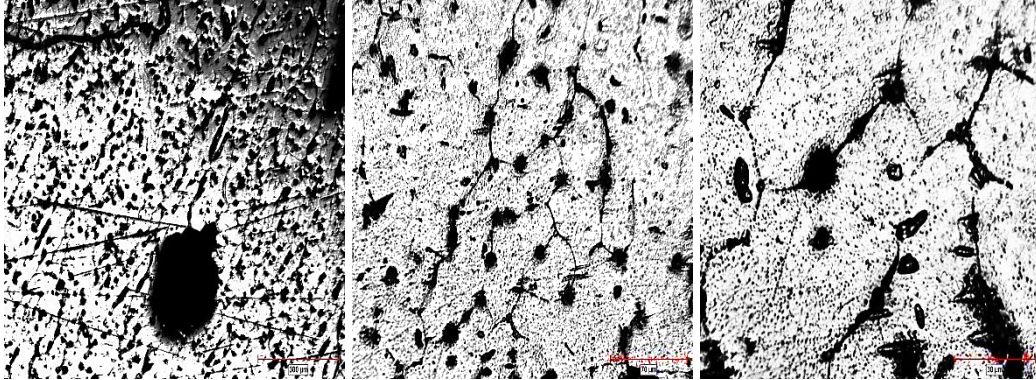
500x



Gambar B.21 Data pengujian metalografi dan kekerasan *base material*

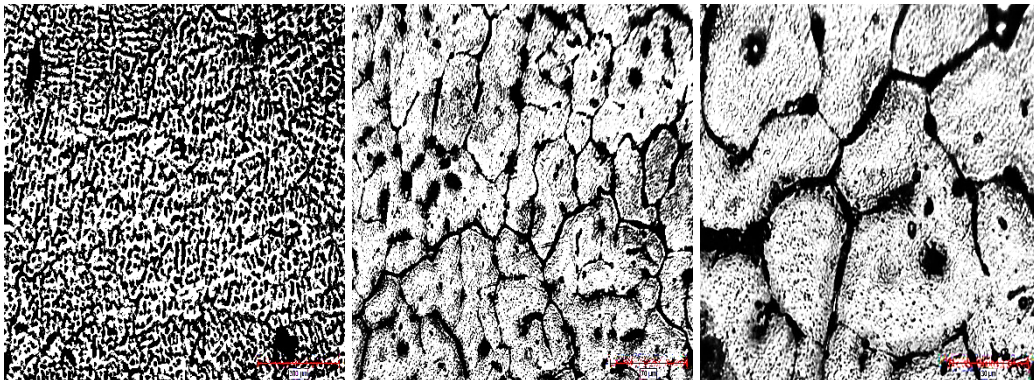
Cu 0,5%

(50x,200x,500x)



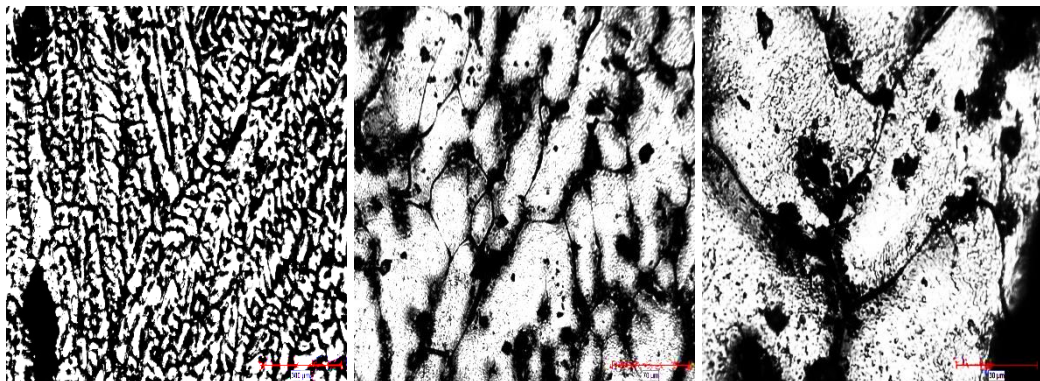
Cu 1%

(50x,200x,500x)



Cu 2%

(50x,200x,500x)



Gambar B.22 Data pengujian metalografi sampel sebelum di rol

B.4 Data Sertifikat Material

CERTIFICATE OF CONFORMITY

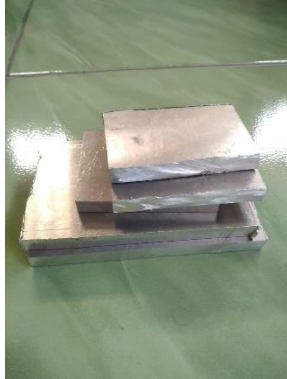
ACTUAL MILL CHEMICAL UNIT %														
Heat No	SIZE(mm)	Alloy No	Temper	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others (single)	Others (total)	Al
STANDARD				0.25	0.4	0.1	0.1	2.2-2.8	0.15-0.35	0.1	-	0.05	0.15	REMAIN
TXG2109X50639	10*1500*3000	5052	H112	0.112	0.331	0.032	0.083	2.411	0.177	0.047	0.017	0.05	0.15	REMAIN
MECHANICAL PROPERTY TEST REPORTS														
Heat No	SIZE(mm)	Alloy No	Temper	Tensile Strength	Yield Strength	Elongation								
STANDARD				Min.178	Min.85	Min.10								
TXG2109X50639	10*1500*3000	5052	H112	197	128	28								

THE GOODS ARE IN ACCORDANCE WITH EN STANDARDS - EN-AW ASTM B209M

Gambar B.23 Sertifikat Base Material

LAMPIRAN C
GAMBAR ALAT DAN BAHAN

Lampiran C. Alat dan Bahan



Gambar C.1 Aluminium 5052



Gambar C.2 Aluminium 2024



Gambar C.3 Krusibel



Gambar C.4 *Thermogun*



Gambar C.5 Tabung Gas



Gambar C.6 Tungku Peleburan



Gambar C.7 Cetakan



Gambar C.8 *Burner*



Gambar C.9 *Alat Safety*



Gambar C.10 *Mesin Grinding*



Gambar C.11 *Alat Uji Tarik*



Gambar C.12 *Mesin Mounting*



Gambar C.13 Mikroskop Optik



Gambar C.14 *Muffle Furnace 1*



Gambar C.15 Alat Uji Keras



Gambar C.16 *Muffle Furnace 2*



Gambar C.17 Mesin Roll