

**LAMPIRAN A**  
**CONTOH PERHITUNGAN**

## Lampiran A. Contoh Perhitungan

### 1. Perhitungan Penimbangan Komposisi Sampel

Diketahui :

Komposisi masing-masing bahan (*raw material*) :

- Ti = 99,99 %
- Al = 99,99 %
- Nb = 99,99 %
- Sn = 99,99 %
- Zr = 99,99 %
- Si = 99,99 %

Setiap satu sampel memiliki berat sebesar  $\pm 20$  gram.

Perhitungan :

Sampel Ti-6Al-5Nb-3Sn-1Zr-0,5Si :

- $Al = \frac{6}{100} \times 20 \text{ gr} = 1,2 \text{ gram}$
- $Nb = \frac{5}{100} \times 20 \text{ gr} = 1 \text{ gram}$
- $Sn = \frac{3}{100} \times 20 \text{ gr} = 0,6 \text{ gram}$
- $Zr = \frac{1}{100} \times 20 \text{ gr} = 0,2 \text{ gram}$
- $Si = \frac{0,5}{100} \times 20 \text{ gr} = 0,1 \text{ gram}$
- $Ti = 20 - (1,2 + 1 + 0,6 + 0,2 + 0,1) = 16,9 \text{ gram}$

## 2. Perhitungan Luas Permukaan

Dalam mengolah data hasil uji oksidasi diperlukan data luas permukaan sampel.

Adapun bentuk sampel adalah bulat atau bentuk cakram dan berikut diketahui diameter masing-masing sampel :

**Tabel A.1** Data Diameter Preparasi Sampel Untuk Uji Oksidasi

| Jenis Paduan                            | Diameter (mm) |
|-----------------------------------------|---------------|
| <i>As-Cast</i> Ti-6Al-5Nb-3Sn-1Zr-0,5Si | 10            |
| <i>Solution Treatment</i>               | 10            |
| <i>Aging Treatment</i>                  | 10            |
| Ti-6Al-4V                               | 10            |

### Contoh Perhitungan Luas Permukaan Paduan Ti-6Al-4V :

$$\text{Luas Permukaan} = \pi \times r^2 = 3,14 \times (5)^2 = 78,5 \text{ mm}^2 = 0,785 \text{ cm}^2$$

## 3. Perhitungan Parameter Kisi XRD

Diketahui :

$$\lambda_{\text{Cu}} = 1,5406 \text{ \AA}$$

$$\lambda_{\text{Co}} = 1,78897 \text{ \AA}$$

### Contoh Perhitungan pada paduan Ti-6Al-5Nb-3Sn-1Zr-0,5Si *As-Cast* :

**Tabel A.2** Data Sudut  $2\theta$  (°) XRD Paduan

| Peak | $2\theta$ (°) | $\theta$ (°) | hkl |
|------|---------------|--------------|-----|
| 1    | 41,06587      | 20,532935    | 010 |
| 2    | 44,81969      | 22,409845    | 002 |

| <i>Peak</i> | <b>2θ (°)</b> | <b>θ (°)</b> | <b>hkl</b> |
|-------------|---------------|--------------|------------|
| 3           | 47,0042       | 23,5021      | 011        |
| 4           | 62,42347      | 31,211735    | 012        |
| 5           | 74,94638      | 37,47319     | 110        |
| 6           | 84,32116      | 42,16058     | 013        |
| 7           | 92,01876      | 46,00938     | 112        |

\* Gunakan nilai 2θ (°) pada salah satu *peak* untuk menghitung *interplaner spacing* (jarak antarplanar) (d) dan juga menghitung parameter kisi (a dan c). Perlu diingat bahwa dalam hal ini struktur kristal adalah HCP dan memiliki *unit cell* a = b ≠ c.

#### Contoh Percobaan Pada *Peak* 1 :

Perhitungan dilakukan dengan persamaan Hukum Bragg, berikut adalah persamaan Hukum Bragg :

$$d = \frac{n \lambda}{2 \sin \theta} \dots \dots \dots (A.1)$$

$$d = \frac{1 \times 1,78897}{2 \sin(20,532935)}$$

$$d = 2,550237636 \text{ Å}$$

Maka, jika dirangkum, didapatkan nilai masing-masing *interplaner spacing* (jarak antarplanar) (d) sebagai berikut.

**Tabel A.3** Data Jarak Antarplanar (d) Paduan

| <i>Peak</i> | <b>d (Å)</b> | <b>hkl</b> |
|-------------|--------------|------------|
| 1           | 2,550237636  | 010        |

| <i>Peak</i> | <i>d (Å)</i> | <i>hkl</i> |
|-------------|--------------|------------|
| 2           | 2,346317968  | 002        |
| 3           | 2,243038736  | 011        |
| 4           | 1,726131264  | 012        |
| 5           | 1,470249022  | 110        |
| 6           | 1,332644031  | 013        |
| 7           | 1,24328394   | 112        |

Persamaan parameter kisi diawali dengan mencari nilai a. Perhitungan nilai a dengan mencari yang nilai indeks miller L nya 0. Kita ambil indeks 110. Berikut adalah persamaan rumusnya :

$$\frac{1}{d^2} = \frac{h^2 + k^2}{a^2} + \frac{l^2}{c^2} \dots\dots\dots (A.2)$$

$$= \frac{1}{(1,470249022)^2} = \frac{(1)^2 + (1)^2}{a^2} + \frac{(0)^2}{c^2}$$

$$= \sqrt{\frac{1}{(1,470249022)^2}} = \sqrt{\frac{(1)^2 + (1)^2}{a^2}}$$

$$= \frac{1}{1,470249022} = \frac{2}{a}$$

$$a = 2,9404 \text{ Å}$$

Lalu, menghitung nilai c dengan mencari yang nilai indeks miller H,K nya 0. Kita ambil indeks 002 :

$$\begin{aligned}
\frac{1}{d^2} &= \frac{h^2 + k^2}{a^2} + \frac{l^2}{c^2} \\
&= \frac{1}{(2,346317968)^2} = \frac{(0)^2 + (0)^2}{a^2} + \frac{(2)^2}{c^2} \\
&= \sqrt{\frac{1}{(2,346317968)^2}} = \sqrt{\frac{(2)^2}{c^2}} \\
&= \frac{1}{2,346317968} = \frac{2}{c} \\
c &= 2 \times 2,346317968 \\
c &= 4,6926 \text{ \AA}
\end{aligned}$$

Maka, didapatkan data sebagai berikut.

**Tabel A.4** Data Nilai Parameter Kisi Paduan

| <i>Lattice Constant</i> | Nilai Parameter Kisi (Å) |
|-------------------------|--------------------------|
| a = b                   | 2,9404 Å                 |
| c                       | 4,6926 Å                 |

#### 4. Perhitungan Nilai Kekerasan

Diketahui :

**Tabel A.5** Data Nilai Kekerasan Paduan Ti-6Al-5Nb-3Sn-1Zr-0,5Si *As-Cast* :

| Titik Indentasi | Nilai Kekerasan (HVN) |
|-----------------|-----------------------|
| 1               | 353,7                 |
| 2               | 353,3                 |
| 3               | 351,5                 |

| Titik Indentasi | Nilai Kekerasan (HVN) |
|-----------------|-----------------------|
| 4               | 357,3                 |
| 5               | 359,8                 |
| 6               | 359,6                 |
| 7               | 345,3                 |
| 8               | 359                   |
| 9               | 358                   |

**Contoh Perhitungan pada paduan Ti-6Al-5Nb-3Sn-1Zr-0,5Si *As-Cast* :**

$$\overline{\text{HVN}} = \frac{\text{HVN}_1 + \text{HVN}_2 + \text{HVN}_3 + \dots + \text{HVN}_9}{9}$$

$$\overline{\text{HVN}} = \frac{353,7 + 353,3 + 351,5 + \dots + 358}{9}$$

$$\overline{\text{HVN}} = 355,28$$

## 5. Perhitungan Nilai Pertambahan Berat Oksida

Diketahui :

**Tabel A.6** Data Nilai Pertambahan Berat Oksida Sampel Ti-6Al-4V

| Sampel               | Jam | $\Delta W$  |
|----------------------|-----|-------------|
| Ti-6Al-4V<br>(700°C) | 5   | 1,78343949  |
|                      | 10  | 2,929936306 |
|                      | 15  | 3,821656051 |
|                      | 20  | 4,458598726 |

| Sampel | Jam | $\Delta W$  |
|--------|-----|-------------|
|        | 25  | 5,605095541 |
|        | 30  | 6,114649682 |
|        | 35  | 7,133757962 |
|        | 40  | 8,407643312 |
|        | 45  | 9,171974522 |
|        | 50  | 10,70063694 |

**Contoh Perhitungan pada paduan Ti-6Al-4V pada jam 15 :**

$$\text{Pertambahan Berat Oksida} = \frac{\Delta W}{A}$$

$$\text{Pertambahan Berat Oksida} = \frac{3,821656051 \text{ gram}}{0,785 \text{ cm}^2}$$

$$\text{Pertambahan Berat Oksida} = 0,003821656 \text{ g/cm}^2$$

$$\text{Pertambahan Berat Oksida} = 3,821656051 \text{ mg/cm}^2$$

## 6. Perhitungan Nilai Energi Aktivasi ( $E_A$ )

Diketahui :

**Tabel A.7** Data Nilai *Slope* (Kemiringan) Setiap Sampel

| Sampel                                         | <i>Slope</i> (Kemiringan) |
|------------------------------------------------|---------------------------|
| Ti-6Al-5Nb-3Sn-1Zr-0,5Si<br>( <i>As-Cast</i> ) | $y = -15.563x + 15,104$   |

| <b>Sampel</b>                                           | <b><i>Slope</i> (Kemiringan)</b> |
|---------------------------------------------------------|----------------------------------|
| Ti-6Al-5Nb-3Sn-1Zr-0,5Si<br><i>(Solution Treatment)</i> | $y = -14.507x + 14,15$           |
| Ti-6Al-5Nb-3Sn-1Zr-0,5Si<br><i>(Aging Treatment)</i>    | $y = -15.957x + 15,375$          |
| Ti-6Al-4V                                               | $y = -12.743x + 13,821$          |

**Contoh perhitungan energi aktivasi ( $E_A$ ) pada paduan Ti-6Al-4V :**

$$Slope = -\frac{E_A}{R}$$

$$E_A = -Slope \times R$$

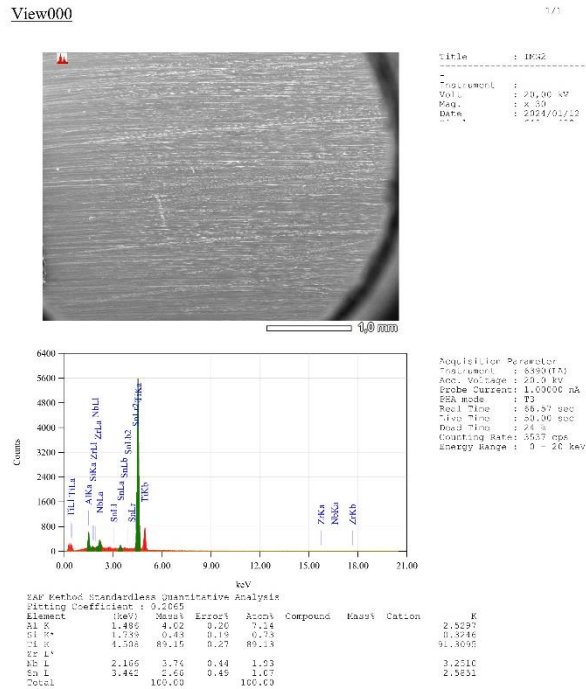
$$E_A = -(-12.743) \times 8,314$$

$$E_A = 105,95 \text{ kJ/mol}$$

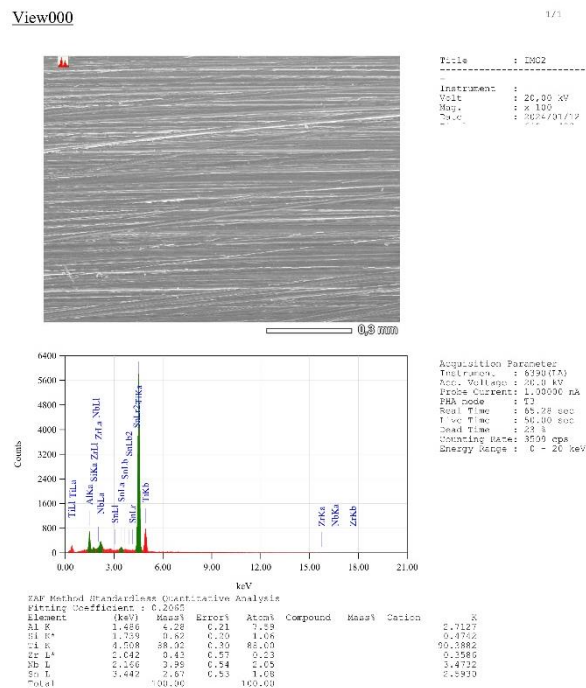
**LAMPIRAN B**  
**DATA PENELITIAN**

## Lampiran B. Data Penelitian

### 1. Data Hasil Komposisi (EDS)



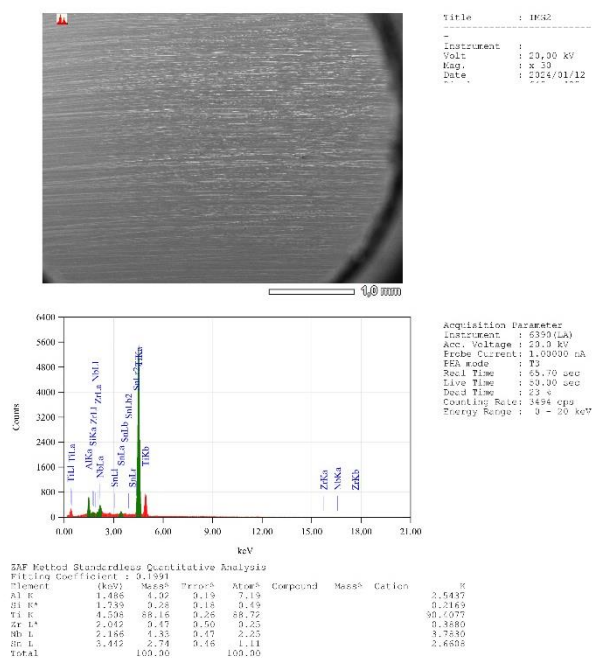
Gambar B.1 Data Uji Komposisi Kimia EDS Titik 1



Gambar B.2 Data Uji Komposisi Kimia EDS Titik 2

View000

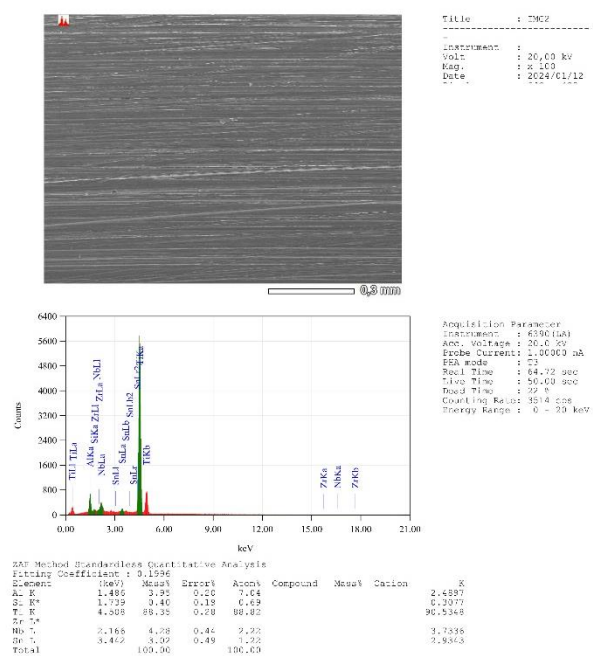
1/1



Gambar B.3 Data Uji Komposisi Kimia EDS Titik 3

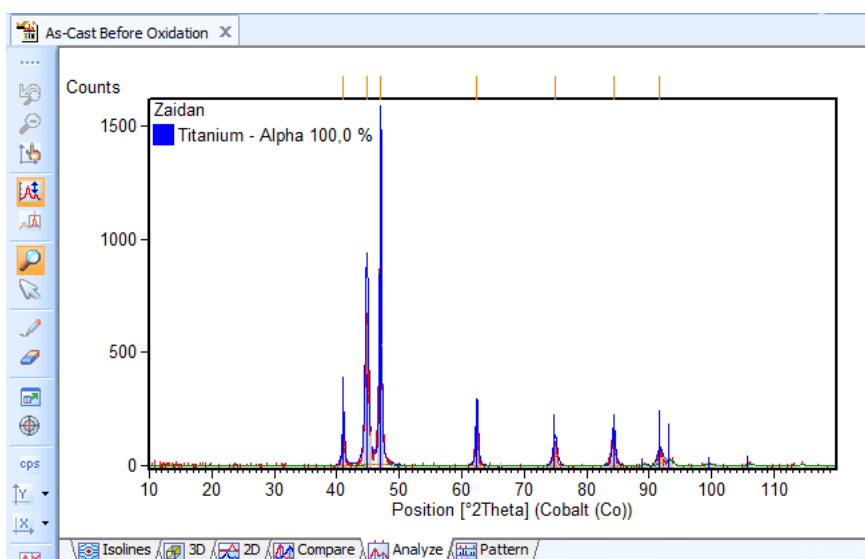
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Gambar B.4 Data Uji Komposisi Kimia EDS Titik 4

## 2. Data Hasil Karakterisasi XRD Sebelum Uji Oksidasi



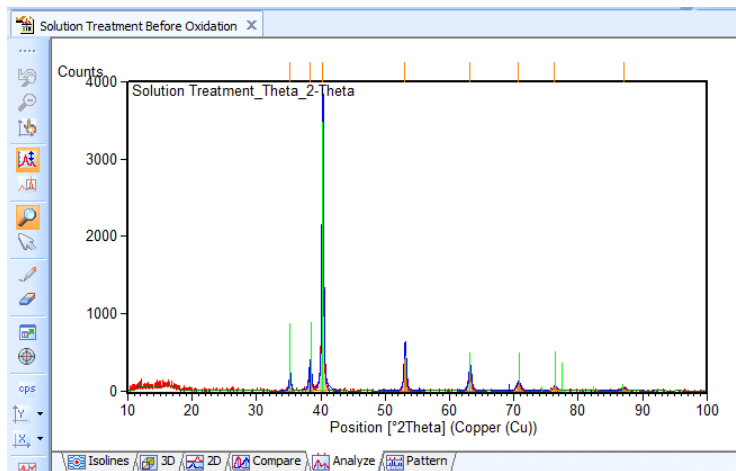
**Gambar B.5** Data XRD Paduan *As-Cast*

### *Peak List :*

| <i>Peak</i> | <i>2θ (°)</i> | <i>FWHM</i> | <i>d-Spacing Å</i> |
|-------------|---------------|-------------|--------------------|
| 1           | 41,06587      | 0,5431      | 2,550237636        |
| 2           | 44,81969      | 0,76024     | 2,346317968        |
| 3           | 47,0042       | 0,58301     | 2,243038736        |
| 4           | 62,42347      | 0,55286     | 1,726131264        |
| 5           | 74,94638      | 0,68296     | 1,470249022        |
| 6           | 84,32116      | 0,88112     | 1,332644031        |
| 7           | 92,01876      | 2,14814     | 1,24328394         |

### *Pattern List :*

| <i>Ref.Code</i> | <i>Score</i> | <i>Compound Name</i> | <i>Chemical Formula</i> |
|-----------------|--------------|----------------------|-------------------------|
| 98-005-2522     | 72           | Titanium - Alpha     | Ti <sub>1</sub>         |



**Gambar B.6** Data XRD Paduan Perlakuan *Solution Treatment*

**Peak List :**

**Fasa  $\alpha$**

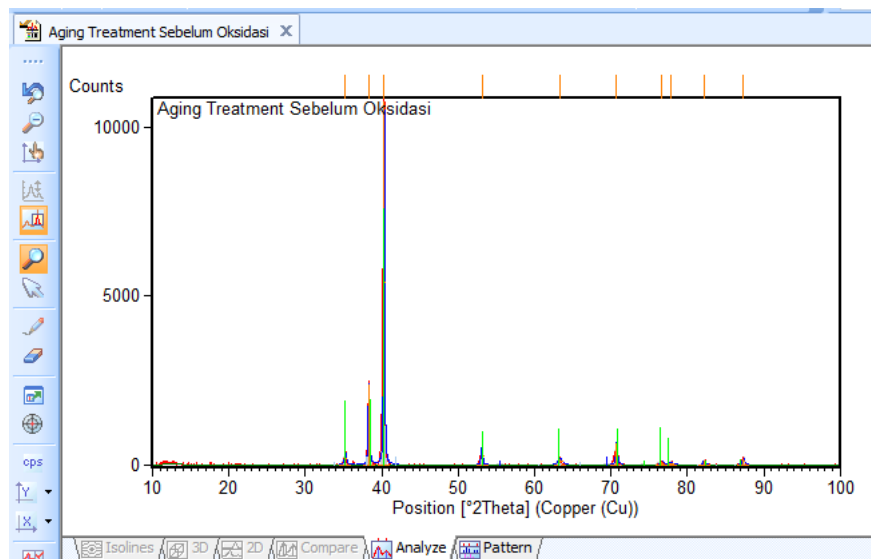
| Peak | $2\theta$ (°) | FWHM    | d-Spacing Å |
|------|---------------|---------|-------------|
| 1    | 35,28144      | 0,0385  | 2,541847888 |
| 2    | 37,69176      | 4,6081  | 2,38465528  |
| 3    | 40,27345      | 4,17501 | 2,237542891 |
| 4    | 53,25784      | 3,64114 | 1,718612683 |
| 5    | 63,25531      | 0,85023 | 1,468925405 |
| 6    | 70,69151      | 5,25082 | 1,331525958 |
| 7    | 76,6206       | 5,14304 | 1,242579487 |
| 8    | 87,21999      | 5,31806 | 1,116788143 |

**Fasa  $\beta$**

| Peak | $2\theta$ (°) | FWHM   | d-Spacing Å |
|------|---------------|--------|-------------|
| 2    | 37,69176      | 4,6081 | 2,541847888 |

**Pattern List :**

| Ref.Code    | Score | Compound Name    | Chemical Formula |
|-------------|-------|------------------|------------------|
| 98-007-6265 | 61    | Titanium - Alpha | Ti <sub>1</sub>  |
| 98-015-1409 | 33    | Titanium - Beta  | Ti <sub>1</sub>  |



**Gambar B.7** Data XRD Paduan Perlakuan *Aging Treatment*

**Peak List :**

**Fasa  $\alpha$**

| Peak | 2 $\theta$ (°) | FWHM     | d-Spacing Å |
|------|----------------|----------|-------------|
| 1    | 35,27132       | 0,14168  | 2,542554003 |
| 2    | 38,33333       | 0,3078   | 2,34620703  |
| 3    | 40,46512       | 0,60134  | 2,2273855   |
| 4    | 53,56589       | 0,04007  | 1,709453573 |
| 5    | 63,58527       | 52,9064  | 1,462095577 |
| 6    | 70,79457       | 1204,228 | 1,329840159 |
| 7    | 76,93798       | 72,31039 | 1,238243325 |
| 8    | 78,12016       | 5,88565  | 1,222436549 |
| 9    | 82,24806       | 4,14E-04 | 1,171218286 |
| 10   | 87,44186       | 28,36719 | 1,114524983 |

**Fasa  $\beta$**

| <i>Peak</i> | <i>2<math>\theta</math> (°)</i> | <i>FWHM</i> | <i>d-Spacing Å</i> |
|-------------|---------------------------------|-------------|--------------------|
| 2           | 38,33333                        | 0,3078      | 2,34620703         |
| 9           | 82,24806                        | 4,14E-04    | 1,171218286        |

***Pattern List :***

| <b>Ref.Code</b> | <b>Score</b> | <b>Compound Name</b> | <b>Chemical Formula</b> |
|-----------------|--------------|----------------------|-------------------------|
| 98-007-6265     | 49           | Titanium - Alpha     | Ti <sub>1</sub>         |
| 98-004-4391     | 31           | Titanium - Beta      | Ti <sub>1</sub>         |

**3. Data Nilai Kekerasan Paduan**

**Tabel B.1** Data Nilai Kekerasan Paduan *As-Cast*

| <b>Jenis Paduan</b>                            | <b>Titik Indentasi</b> | <b>Nilai Kekerasan (HVN)</b> | <b>Rata-Rata Nilai Kekerasan</b> |
|------------------------------------------------|------------------------|------------------------------|----------------------------------|
| Ti-6Al-5Nb-3Sn-1Zr-0,5Si<br>( <i>As-Cast</i> ) | 1                      | 353,7                        | 355,28                           |
|                                                | 2                      | 353,3                        |                                  |
|                                                | 3                      | 351,5                        |                                  |
|                                                | 4                      | 357,3                        |                                  |
|                                                | 5                      | 359,8                        |                                  |
|                                                | 6                      | 359,6                        |                                  |
|                                                | 7                      | 345,3                        |                                  |
|                                                | 8                      | 359                          |                                  |
|                                                | 9                      | 358                          |                                  |

**Tabel B.2** Data Nilai Kekerasan *Solution Treatment*

| Jenis Paduan                                              | Titik Indentasi | Nilai Kekerasan (HVN) | Rata-Rata Nilai Kekerasan |
|-----------------------------------------------------------|-----------------|-----------------------|---------------------------|
| Ti-6Al-5Nb-3Sn-1Zr-0,5Si<br>( <i>Solution Treatment</i> ) | 1               | 425,9                 | 422,35                    |
|                                                           | 2               | 406,2                 |                           |
|                                                           | 3               | 403,6                 |                           |
|                                                           | 4               | 400,7                 |                           |
|                                                           | 5               | 403,6                 |                           |
|                                                           | 6               | 440,1                 |                           |
|                                                           | 7               | 456                   |                           |
|                                                           | 8               | 457                   |                           |
|                                                           | 9               | 408,1                 |                           |

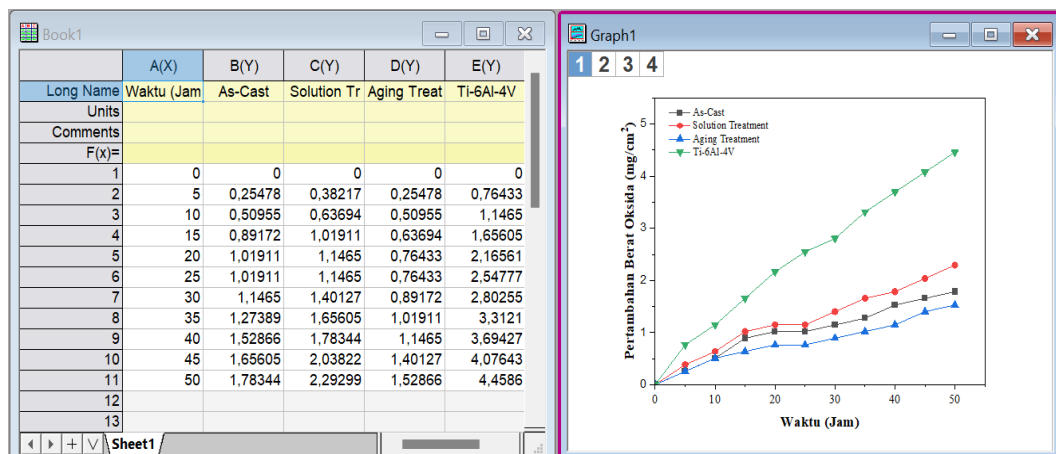
**Tabel B.3** Data Nilai Kekerasan *Aging Treatment*

| Jenis Paduan                                           | Titik Indentasi | Nilai Kekerasan (HVN) | Rata-Rata Nilai Kekerasan |
|--------------------------------------------------------|-----------------|-----------------------|---------------------------|
| Ti-6Al-5Nb-3Sn-1Zr-0,5Si<br>( <i>Aging Treatment</i> ) | 1               | 435                   | 447,63                    |
|                                                        | 2               | 432                   |                           |
|                                                        | 3               | 442,1                 |                           |
|                                                        | 4               | 434,7                 |                           |
|                                                        | 5               | 446,2                 |                           |
|                                                        | 6               | 464,6                 |                           |
|                                                        | 7               | 464,7                 |                           |
|                                                        | 8               | 464,3                 |                           |
|                                                        | 9               | 445,1                 |                           |

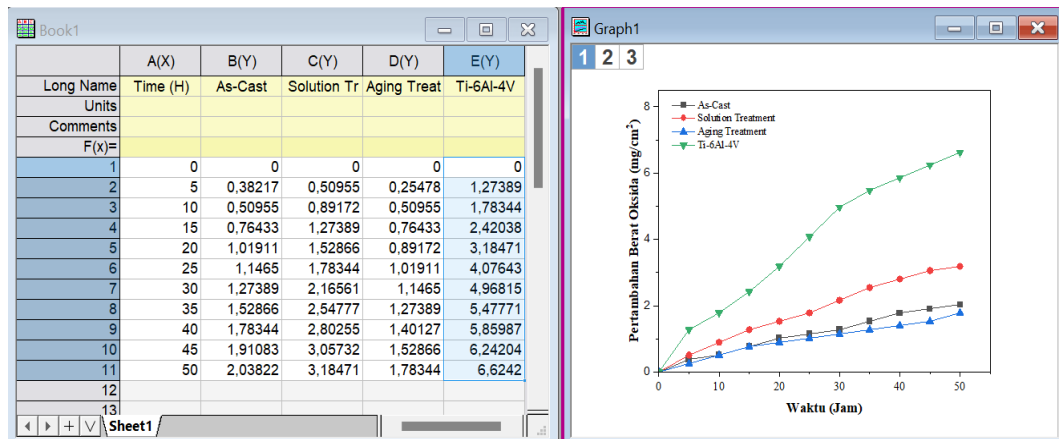
**Tabel B.4** Data Nilai Kekerasan Paduan Ti-6Al-4V

| Jenis Paduan | Titik Indentasi | Nilai Kekerasan (HVN) | Rata-Rata Nilai Kekerasan |
|--------------|-----------------|-----------------------|---------------------------|
| Ti-6Al-4V    | 1               | 356,2                 | 347,5                     |
|              | 2               | 340,6                 |                           |
|              | 3               | 348,1                 |                           |
|              | 4               | 346,3                 |                           |
|              | 5               | 351,7                 |                           |
|              | 6               | 343,7                 |                           |
|              | 7               | 346,9                 |                           |
|              | 8               | 340,8                 |                           |
|              | 9               | 353                   |                           |

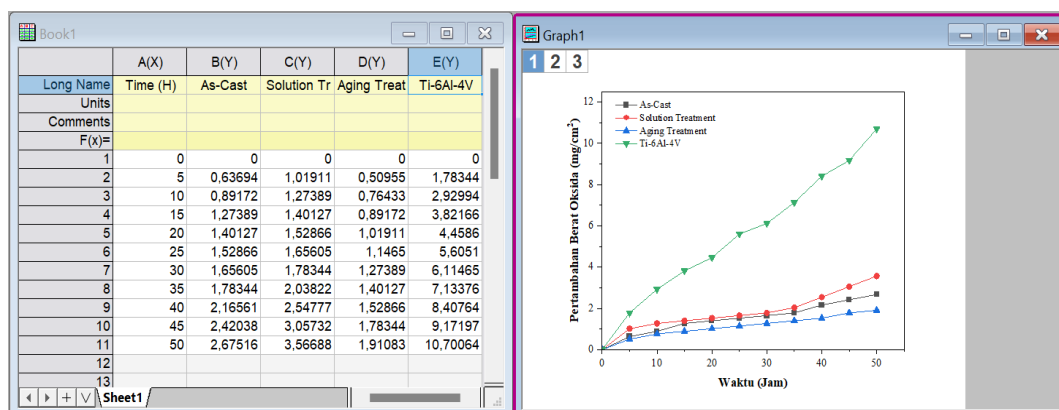
#### 4. Data Nilai Oksidasi



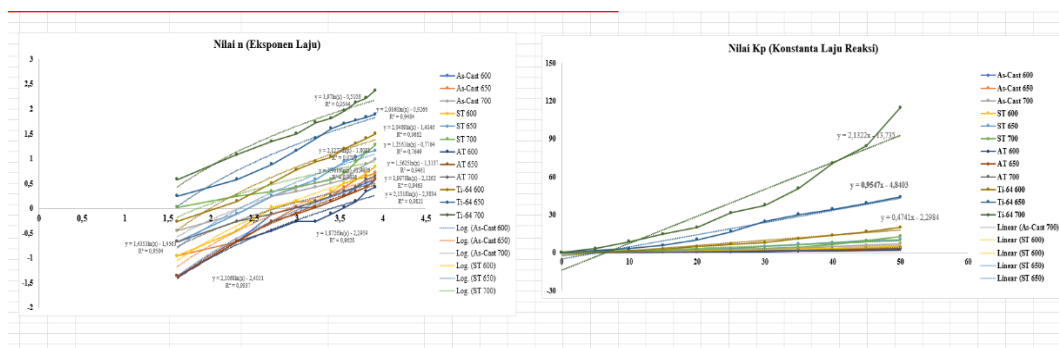
**Gambar B.8** Data Hasil Pengujian Oksidasi Temperatur 600°C



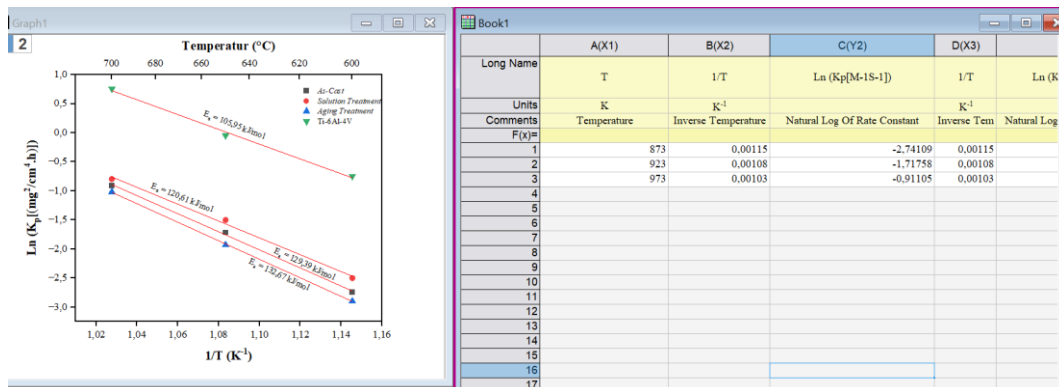
**Gambar B.9** Data Hasil Pengujian Oksidasi Temperatur 650°C



**Gambar B.10** Data Hasil Pengujian Oksidasi Temperatur 700°C

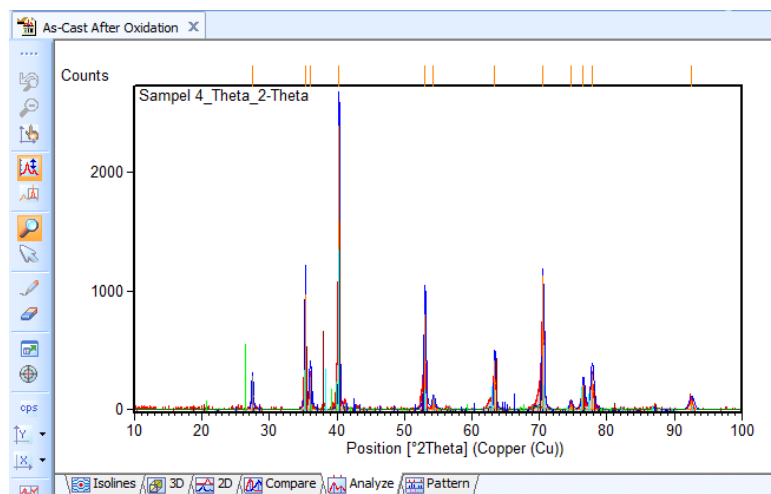


**Gambar B.11** Data Hasil Nilai n dan K<sub>p</sub> Semua Sampel

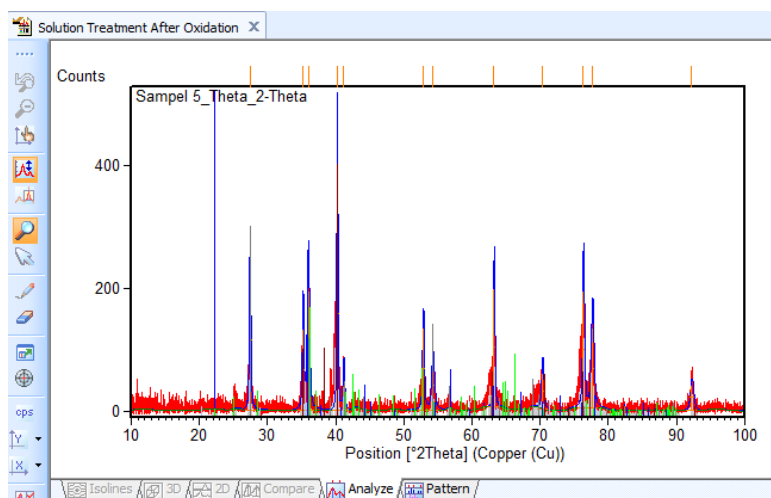


**Gambar B.12** Data Hasil Plot Arhenius Oksidasi

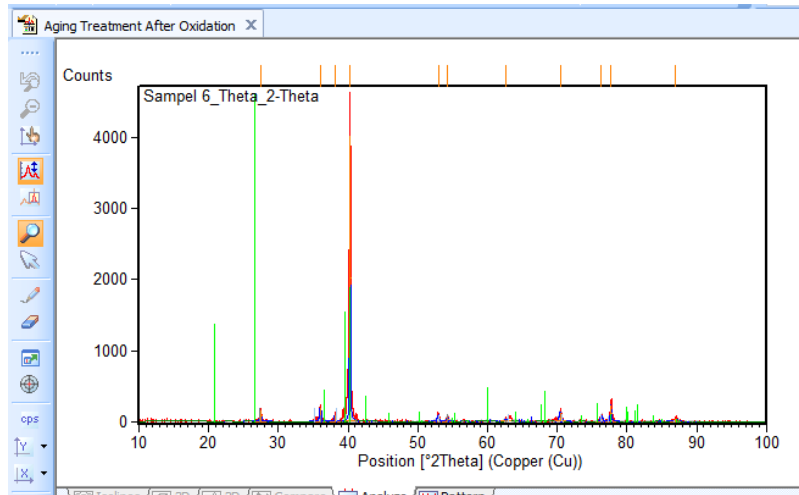
## 5. Data Hasil Karakterisasi XRD Setelah Uji Oksidasi



**Gambar B.13** XRD Sampel *As-Cast* Setelah Uji Oksidasi



**Gambar B.14** XRD Sampel *Solution Treatment* Setelah Uji Oksidasi



**Gambar B.15** XRD Sampel *Aging Treatment* Setelah Uji Oksidasi

**LAMPIRAN C**  
**GAMBAR ALAT DAN BAHAN**

## Lampiran C. Gambar Alat dan Bahan



**Gambar C.1** Air Dingin



**Gambar C.2** *As-Cast* Paduan Utama



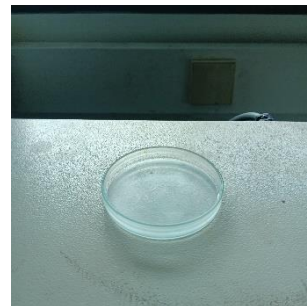
**Gambar C.3** *As-Cast* Ti-6Al-4V



**Gambar C.4** Aquades



**Gambar C.5** Cawan *Crucible*



**Gambar C.6** Cawan Petri



**Gambar C.7** Cetakan *Mounting*



**Gambar C.8** *Colloidal Silica*



**Gambar C.9** *Dryer*



**Gambar C.10** Etanol



**Gambar C.11** Gas Argon



**Gambar C.12** Gelas Kimia



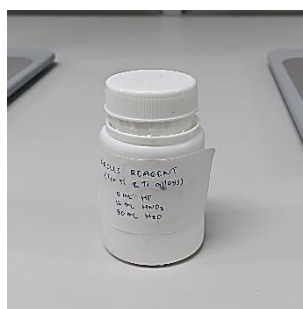
**Gambar C.13** *Hardener*



**Gambar C.14** Jangka Sorong



**Gambar C.15** Kertas Ampelas



**Gambar C.16** Larutan Kroll



**Gambar C.17** Mesin Bubut



**Gambar C.18** Mesin *Grinding-Polishing*



**Gambar C.19** Mikroskop Optik



**Gambar C.20** *Muffle Furnace*



**Gambar C.21** Neraca Digital



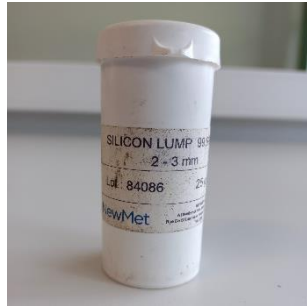
**Gambar C.22** Resin Bening



**Gambar C.23** Sampel Al Murni



**Gambar C.24** Sampel Nb Murni



**Gambar C.25 Sampel Si Murni**



**Gambar C.26 Sampel Sn Murni**



**Gambar C.27 Sampel Ti Murni**



**Gambar C.28 Sampel Zr Murni**



**Gambar C.29 SEM-EDS**



**Gambar C.30 Tang Penjepit**



**Gambar C.31 Tube Furnace**



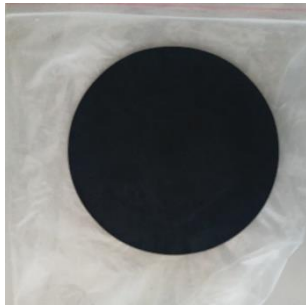
**Gambar C.32 VAR Furnace**



**Gambar C.33** *Vicker's Microhardness*



**Gambar C.34** *Wire-Cut*



**Gambar C.35** *Woll Polish*



**Gambar C.36** *XRD*