BAB IV
HASIL DAN PEMBAHASAN

4.1. PENGOLAHAN DATA HASIL PENGUKURAN

4.1.1. Penentuan anak timbangan yang digunakan

Resolusi timbangan (d) = 0,0001 g = 0,1 mg

e = 10.d
 = 10 x 0,1 mg
 = 1 mg

Kapasitas timbangan = 200 g

Anak timbangan yang digunakan = 1/3 . e
 = 1/3 . 0,1 mg
 = 0,33 mg

Sesuai tabel (3.1) tentang maximum permissible errors (mpe) pada nominal 200 g nilai yang lebih kecil dari 0,33 mg adalah kelas E2 dengan nilai mpe sebesar 0,3 mg.

4.1.2. Hasil Perhitungan Standar Deviasi Pada pengukuran daya ulang pembacaan

Repeatibility pada ½ kapasitas max

Nominal = 100g

Tabel 4.1 Lembar kerja daya ulang pembacaan kapasitas 50%

Nominal 100 g

Pembacaan no	zi (g)	mi (g)	ri = mi - zi (g)
1	0,0000	100,0000	100,0000
2	0,0000	99,9999	99,9999
3	0,0000	99,9998	99,9998
4	0,0000	100,0000	100,0000
5	0,0000	99,9999	99,9999
6	0,0000	100,0000	100,0000
7	0,0000	99,9998	99,9998
8	0,0000	99,9997	99,9997
9	0,0000	100,0000	100,0000
10	0,0000	100,0001	100,0001
Standard Deviasi, S			0,000123

Repeatibility pada kapasitas max
Nominal = 200g

Tabel 4.2 Lembar kerja daya ulang pembacaan kapasitas 100 %

Nominal	200	g	
Pembacaan no	zi (g)	mi (g)	ri = mi - zi (g)
1	0,0000	199,9996	199,9996
2	0,0000	199,9997	199,9997
3	0,0000	199,9996	199,9996
4	0,0000	199,9996	199,9996
5	0,0000	199,9997	199,9997
6	0,0000	199,9997	199,9997
7	0,0000	199,9997	199,9997
8	0,0000	199,9996	199,9996
9	0,0000	199,9996	199,9996
10	0,0000	199,9996	199,9996
Standard Deviasi, S			0,000052

Dari tabel 4.1 dan 4.2 didapat bahwa Standar deviasi maksimum adalah sebesar 0,000123 g

4.1.3. Hasil perhitungan koreksi pada penyimpangan penunjukan

Tabel 4.3 Lembar kerja penyimpangan penunjukan

NO	Massa Konv g	Ketidakpastian g	Beban pan g	Pembacaan g	Rata2 g	Perbedaan g	Koreksi g	sum U g
10%	20,0000280	0,0000250	0 20,0000280	0,0000 19,9998 19,9997	0,0000 19,9998	19,9998	0,0002780	0,0000250
20%	20,0000280 20,0000320	0,0000250 0,0000250	0 40,0000600	0,0000 40,0000 40,0000	0,0000 40,0000	40,0000	0,0000600	0,0000500
30%	50,000030 10,0000060	0,000035 0,0000076	0 60,0000360	0,0000 60,0001 59,9998	0,0000 60,0000	60,0000	0,0000860	0,0000426
40%	50,000030 20,0000280 10,0000060	0,000035 0,0000250 0,0000076	0 80,0000640	0,0000 80,0001 79,9999	0,0000 80,0000	80,0000	0,0000640	0,0000676
50%	99,999960	0,000045	0 99,99996	0,0000 99,9999 99,9998	0,0000 99,9999	99,9999	0,0001100	0,0000450
60%	99,999960 20,0000280	0,000045 0,0000250	0 119,9999880	0,0000 120,0000 119,9998	0,0000 119,9999	119,9999	0,0000880	0,0000700
70%	99,999960 20,0000280 20,0000320	0,000045 0,0000250 0,0000250	0 140,0000200	0,0000 139,9999 139,9999	0,0000 139,9999	139,9999	0,0001200	0,0000950
80%	99,999960 50,000030 10,0000060	0,000045 0,000035 0,0000076	0 159,9999960	0,0000 159,9998 159,9997	0,0000 159,9998	159,9998	0,0002460	0,0000876
90%	99,999960 50,000030 20,0000280 10,0000060	0,000045 0,000035 0,0000250 0,0000076	0 180,0000240	0,0000 179,9997 179,9998	0,0000 179,9998	179,9998	0,0002740	0,0001126
100%	200,000090	0,000072	0 200,000090	0,0000 199,9999 199,9997	0,0000 199,9998	199,9998	0,0002900	0,0000720
	Koreksi min	0,0000600	Abs koreksi min		0,000060			
	Koreksi max	0,0002900						
	Abs koreksi max	0,0002900				Ketidakpastian max		0,0001126

Dari tabel 4.3 diatas didapat bahwa nilai absolut koreksi maksimum sebesar 0,000290 g.

4.1.4. Hasil perhitungan perbedaan maksimum pada pembebanan tidak di pusat pan

Nominal massa yang digunakan:

M = ½ x kapasitas maksimum timbangan

= ½ x 200 g

= 100 g

Tabel 4.4 Lembar kerja efek pembebanan tidak di pusat pan

Posisi	Pembacaan 1 g	Pembacaan 2 g	Rata-rata g	Koreksi g	Absolut koreksi g	Max. Perbedaan g
0	99.9999	100.0001	100.0000	0.0000	0.0000	0.0002
1	99.9998	99.9999	99.9999	0.0002	0.0002	
2	99.9997	99.9998	99.9998	0.0002	0.0002	
3	99.9999	99.9999	99.9999	0.0001	0.0001	
4	99.9999	100.0000	100.0000	0.0001	0.0001	

Dari tabel 4.4 diatas didapat bahwa maksimum perbedaan yang didapat sebesar 0,0002 g.

4.2. ANALISA KETIDAKPASTIAN

4.2.1. Analisa Ketidakpastian Titik ukur 10 % (nominal 20 g)

4.2.1.1. Ketidakpastian anak timbangan standar, $u(m_{cr})$ (type B)

$$U_m = \frac{U_e}{k}$$

U(m) = 0,025 mg / 2

= 0,0125 mg

Derajat kebebasan :

k = 2, maka v = 60 (tabel 2.2)

4.2.1.2. Ketidakpastian daya ulang pembacaan, u(repeat) (type A)

Data pada tabel 4.1

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}123\ mg}{\sqrt{2}}$$

u(repeat) = 0,087 mg

Derajat kebebasan :

v = n -1

v = 10 – 1

v = 9

4.2.1.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}}.\sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}}.\sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.1.4. Ketidakpastian instability standard, u_s (type B)

$u(d) = k.\frac{U}{\sqrt{3}}$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.1.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{19{,}9998\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,000014 g

$u(I_{ecc})$ = 0,0144 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.1.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.20\ g}{\sqrt{3}}$$

U(b) = 0,000012 g
U(b) = 0,012 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.1.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

U_{reg} = s
U_{reg} = 0,00011 g
U_{reg} = 0,11 mg

Derajat kebebasan :
v = n – 2 = 10 – 2
= 8

4.2.1.8. Budget ketidakpastian

Tabel 4.5 Budget ketidakpastian titik ukur 10 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	derajat kebebasan, vi	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,02500	2	60	0,0125	1	0,0125	0,00015625	4,07E-10
Readability (mg)	Rectangular	7,071068E-02	1,73205081	5000	0,040824829	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,122927259	1,41421356	9	0,086922699	1	0,086922699	0,007555556	6,34E-06
Instability (mg)	Rectangular	0,01250	1,73205081	5000	0,007216878	1	0,007216878	5,20833E-05	5,43E-13
Eccentricity (mg)	Rectangular	0,024999687	1,73205081	5000	0,014433576	1	0,014433576	0,000208328	8,68E-12
Bouyancy (mg)	Rectangular	0,02	1,73205081	5000	0,011547005	1	0,011547005	0,000133333	3,56E-12
regresi (mg)	Normal	0,107628661	1	8	0,107628661	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,021356146	2,31E-05
Combined standard uncertenly (mg)								0,146137421	
Effective degree of freedom, veff								19,72913115	
Coverage factor, k-factor for veff and CL = 95%								2,093024054	
Expended Uncertanly U=k.Uc (mg)								0,305869137	

Dari tabel 4.5 didapat nilai :
Ketidakpastian gabungan (U_c) = 0,146 mg
Derajat kebebasan efektif (v_{eff}) = 19,7
Faktor koreksi (k) = 2,09
Ketidakpastian terentang (U) = 0,31 mg

4.2.2. Analisa Ketidakpastian Titik ukur 20 % (nominal 40 g)

4.2.2.1. Ketidakpastian anak timbangan standar, $u(m_{cr})$ (type B)

$$U_m = \frac{U_s}{k}$$

U(m) = 0,05 mg / 2
= 0,025 mg

Derajat kebebasan :
k = 2, maka v = 60 (tabel 2.2)

4.2.2.2. Ketidakpastian daya ulang pembacaan, u(repeat) (type A)
Data pada tabel 4.1

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}123\ mg}{\sqrt{2}}$$

u(repeat) = 0,087 mg

Derajat kebebasan :
v = n -1
v = 10 – 1
v = 9

4.2.2.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}}.\sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}}.\sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.2.4. Ketidakpastian instability standard, u_s (type B)

$u(d) = k.\frac{U}{\sqrt{3}}$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.2.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.\,L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{40{,}0000\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,000029 g
$u(I_{ecc})$ = 0,029 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.2.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.40\ g}{\sqrt{3}}$$

U(b) = 0,000023 g
U(b) = 0,023 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.2.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

U_{reg} = s
U_{reg} = 0,00011 g

U_{reg} = 0,11 mg

Derajat kebebasan :
v = n – 2 = 10 – 2
= 8

4.2.2.8. Budget ketidakpastian

Tabel 4.6 Budget ketidakpastian titik ukur 20 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	Sensitivity coefficient (vi)	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,05000	2	60	0,025	1	0,025	0,000625	6,51E-09
Readability (mg)	Rectangular	7,071068E-02	1,73205081	5000	0,040824829	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,122927259	1,41421356	9	0,086922699	1	0,086922699	0,007555556	6,34E-06
Instability (mg)	Rectangular	0,02500	1,73205081	5000	0,014433757	1	0,014433757	0,000208333	8,68E-12
Eccentricity (mg)	Rectangular	0,05	1,73205081	5000	0,028867513	1	0,028867513	0,000833333	1,39E-10
Bouyancy (mg)	Rectangular	0,04	1,73205081	5000	0,023094011	1	0,023094011	0,000533333	5,69E-11
regresi (mg)	Normal	0,107628661	1	8	0,107628661	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,023006151	2,31E-05
Combined standard uncertenly (mg)								0,151677787	
Effective degree of freedom, veff								22,88926720	
Coverage factor, k-factor for veff and CL = 95%								2,073873068	
Expended Uncertanly U=k.Uc (mg)								0,314560477	

Dari tabel 4.6 didapat nilai :
Ketidakpastian gabungan (U_c) = 0,152 mg
Derajat kebebasan efektif (v_{eff}) = 22,9
Faktor koreksi (k) = 2,07
Ketidakpastian terentang (U) = 0,31 mg

4.2.3. Analisa Ketidakpastian Titik ukur 30 % (nominal 60 g)

4.2.3.1. Ketidakpastian anak timbangan standar, u(m_{cr}) (type B)

$$U_m = \frac{U_e}{k}$$

U(m) = 0,0396 mg / 2
= 0,0198 mg

Derajat kebebasan :
k = 2, maka v = 60 (tabel 2.2)

4.2.3.2. Ketidakpastian daya ulang pembacaan, u(repeat) (type A)

Data pada tabel 4.1

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}123\ mg}{\sqrt{2}}$$

u(repeat) = 0,087 mg

Derajat kebebasan :

v = n -1

v = 10 – 1

v = 9

4.2.3.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}}.\sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}}.\sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.3.4. Ketidakpastian instability standard, u_s (type B)

$u(d) = k.\frac{U}{\sqrt{3}}$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.3.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{60{,}0000\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,0000433 g

$u(I_{ecc})$ = 0,043 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.3.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.60\ g}{\sqrt{3}}$$

U(b) = 0,000035 g

U(b) = 0,035 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.3.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

$U_{reg} = s$

$U_{reg} = 0{,}00011$ g

$U_{reg} = 0{,}11$ mg

Derajat kebebasan :

v = n – 2 = 10 – 2

= 8

4.2.3.8. Budget ketidakpastian

Tabel 4.7 Budget ketidakpastian titik ukur 30 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	Sensitivity coefficient (vi)	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,03960	2	60	0,0198	1	0,0198	0,00039204	2,56E-09
Readability (mg)	Rectangular	7,071068E-02	1,73205081	5000	0,040824829	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,122927259	1,41421356	9	0,086922699	1	0,086922699	0,007555556	6,34E-06
Instability (mg)	Rectangular	0,01980	1,73205081	5000	0,011431535	1	0,011431535	0,00013068	3,42E-12
Eccentricity (mg)	Rectangular	0,074999937	1,73205081	5000	0,043301234	1	0,043301234	0,001874997	7,03E-10
Bouyancy (mg)	Rectangular	0,06	1,73205081	5000	0,034641016	1	0,034641016	0,0012	2,88E-10
regresi (mg)	Normal	0,107628661	1	8	0,107628661	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,024403868	2,31E-05
Combined standard uncertenly (mg)								0,156217374	
Effective degree of freedom, veff								25,75850285	
Coverage factor, k-factor for veff and CL = 95%								2,059538553	
Expended Uncertanly U=k.Uc (mg)								0,321735704	

Dari tabel 4.7 didapat nilai :

Ketidakpastian gabungan (U_c) = 0,156 mg

Derajat kebebasan efektif (v_{eff}) = 25,8

Faktor koreksi (k) = 2,06

Ketidakpastian terentang (U) = 0,32 mg

4.2.4. Analisa Ketidakpastian Titik ukur 40 % (nominal 80 g)

4.2.4.1. Ketidakpastian anak timbangan standar, $u(m_{cr})$ (type B)

$$U_m = \frac{U_e}{k}$$

U(m) = 0,0646 mg / 2

= 0,0323 mg

Derajat kebebasan :
k = 2, maka v = 60 (tabel 2.2)

4.2.4.2. Ketidakpastian daya ulang pembacaan, u(repeat) (type A)
Data pada tabel 4.1

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}123\ mg}{\sqrt{2}}$$

u(repeat) = 0,087 mg

Derajat kebebasan :
v = n -1
v = 10 – 1
v = 9

4.2.4.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}}.\sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}}.\sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.4.4. Ketidakpastian instability standard, u_s (type B)

$u(d) = k.\frac{U}{\sqrt{3}}$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.4.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.\,L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{80{,}0000\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,0000577 g

$u(I_{ecc})$ = 0,058 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.4.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.80\ g}{\sqrt{3}}$$

U(b) = 0,000046 g

U(b) = 0,046 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.4.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

U_{reg} = s

U_{reg} = 0,00011 g

U_{reg} = 0,11 mg

Derajat kebebasan :

v = n – 2 = 10 – 2

= 8

4.2.4.8. Budget ketidakpastian

Tabel 4.8 Budget ketidakpastian titik ukur 40 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	Sensitivity coefficient (vi)	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,06460	2	60	0,0323	1	0,0323	0,00104329	1,81E-08
Readability (mg)	Rectangular	7,071068E-02	1,73205081	5000	0,040824829	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,122927259	1,41421356	9	0,086922699	1	0,086922699	0,007555556	6,34E-06
Instability (mg)	Rectangular	0,03230	1,73205081	5000	0,018648414	1	0,018648414	0,000347763	2,42E-11
Eccentricity (mg)	Rectangular	0,1	1,73205081	5000	0,057735027	1	0,057735027	0,003333333	2,22E-09
Bouyancy (mg)	Rectangular	0,08	1,73205081	5000	0,046188022	1	0,046188022	0,002133333	9,10E-10
regresi (mg)	Normal	0,107628661	1	8	0,107628661	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,027663871	2,31E-05
Combined standard uncertenly (mg)								0,166324595	
Effective degree of freedom, veff								33,07471132	
Coverage factor, k-factor for veff and CL = 95%								2,034515297	
Expended Uncertanly U=k.Uc (mg)								0,338389933	

Dari tabel 4.8 didapat nilai :

Ketidakpastian gabungan (U_c) = 0,166 mg

Derajat kebebasan efektif (v_{eff}) = 33,1

Faktor koreksi (k) = 2,03

Ketidakpastian terentang (U) = 0,34 mg

4.2.5. Analisa Ketidakpastian Titik ukur 50 % (nominal 100 g)

4.2.5.1. Ketidakpastian anak timbangan standar, $u(m_{cr})$ (type B)

$$U_m = \frac{U_s}{k}$$

U(m) = 0,045 mg / 2

= 0,0225 mg

Derajat kebebasan :
k = 2, maka v = 60 (tabel 2.2)

4.2.5.2. Ketidakpastian daya ulang pembacaan, u(repeat) (type A)
Data pada tabel 4.1

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}123\ mg}{\sqrt{2}}$$

u(repeat) = 0,087 mg

Derajat kebebasan :
v = n -1
v = 10 – 1
v = 9

4.2.5.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}}.\sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}}.\sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.5.4. Ketidakpastian instability standard, u_s (type B)

$u(d) = k.\frac{U}{\sqrt{3}}$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.5.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.\,L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{99{,}9999\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,0000722 g

$u(I_{ecc})$ = 0,072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.5.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.100\ g}{\sqrt{3}}$$

U(b) = 0,000058 g

U(b) = 0,058 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.5.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

$U_{reg} = s$

$U_{reg} = 0{,}00011$ g

$U_{reg} = 0{,}11$ mg

Derajat kebebasan :

$v = n – 2 = 10 – 2$

$= 8$

4.2.5.8. Budget ketidakpastian

Tabel 4.9 Budget ketidakpastian titik ukur 50 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	Sensitivity coefficient (vi)	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,04500	2	60	0,0225	1	0,0225	0,00050625	4,27E-09
Readability (mg)	Rectangular	7,071068E-02	1,73205081	5000	0,040824829	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,122927259	1,41421356	9	0,086922699	1	0,086922699	0,007555556	6,34E-06
Instability (mg)	Rectangular	0,02250	1,73205081	5000	0,012990381	1	0,012990381	0,00016875	5,70E-12
Eccentricity (mg)	Rectangular	0,124999812	1,73205081	5000	0,072168675	1	0,072168675	0,005208318	5,43E-09
Bouyancy (mg)	Rectangular	0,1	1,73205081	5000	0,057735027	1	0,057735027	0,003333333	2,22E-09
regresi (mg)	Normal	0,107628661	1	8	0,107628661	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,030022802	2,31E-05
Combined standard uncertenly (mg)								0,173270892	
Effective degree of freedom, veff								38,97162956	
Coverage factor, k-factor for veff and CL = 95%								2,024394164	
Expended Uncertanly U=k.Uc (mg)								0,350768582	

Dari tabel 4.9 didapat nilai :

Ketidakpastian gabungan (U_c) = 0,173 mg

Derajat kebebasan efektif (v_{eff}) = 39

Faktor koreksi (k) = 2,02

Ketidakpastian terentang (U) = 0,35 mg

4.2.6. Analisa Ketidakpastian Titik ukur 60 % (nominal 120 g)

4.2.6.1. Ketidakpastian anak timbangan standar, $u(m_{cr})$ (type B)

$$U_m = \frac{U_e}{k}$$

U(m) = 0,07 mg / 2

= 0,035 mg

Derajat kebebasan :
k = 2, maka v = 60 (tabel 2.2)

4.2.6.2. Ketidakpastian daya ulang pembacaan, u(repeat) (type A)

Data pada tabel 4.2

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}052\ mg}{\sqrt{2}}$$

u(repeat) = 0,037 mg

Derajat kebebasan :
v = n -1
v = 10 – 1
v = 9

4.2.6.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}}.\sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}}.\sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.6.4. Ketidakpastian instability standard, u_s (type B)

$$u(d) = k.\frac{U}{\sqrt{3}}$$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.6.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.\,L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{119{,}9999\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,0000866 g

$u(I_{ecc})$ = 0,087 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.6.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.120\ g}{\sqrt{3}}$$

U(b) = 0,000069 g

U(b) = 0,069 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.6.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

$U_{reg} = s$

$U_{reg} = 0{,}00011$ g

$U_{reg} = 0{,}11$ mg

Derajat kebebasan :

$v = n – 2 = 10 – 2$

$= 8$

4.2.6.8. Budget ketidakpastian

Tabel 4.10 Budget ketidakpastian titik ukur 60 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	Sensitivity coefficient (vi)	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,07000000	2	60	0,035	1	0,035	0,001225	2,50E-08
Readability (mg)	Rectangular	0,07071068	1,73205081	5000	0,040824829	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,05163978	1,41421356	9	0,03651484	1	0,036514837	0,001333333	1,98E-07
Instability (mg)	Rectangular	0,03500000	1,73205081	5000	0,020207259	1	0,020207259	0,000408333	3,33E-11
Eccentricity (mg)	Rectangular	0,14999987	1,73205081	5000	0,086602468	1	0,086602468	0,007499987	1,12E-08
Bouyancy (mg)	Rectangular	0,12000000	1,73205081	5000	0,069282032	1	0,069282032	0,0048	4,61E-09
regresi (mg)	Normal	0,10762866	1	8	0,107628661	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,02851725	1,70E-05
Combined standard uncertenly (mg)								0,168870511	
Effective degree of freedom, veff								47,80235974	
Coverage factor, k-factor for veff and CL = 95%								2,011740514	
Expended Uncertanly U=k.Uc (mg)								0,339723649	

Dari tabel 4.10 didapat nilai :

Ketidakpastian gabungan (U_c) = 0,169 mg

Derajat kebebasan efektif (v_{eff}) = 47.9

Faktor koreksi (k) = 2,01

Ketidakpastian terentang (U) = 0,34 mg

4.2.7. Analisa Ketidakpastian Titik ukur 70 % (nominal 140 g)

4.2.7.1. Ketidakpastian anak timbangan standar, $u(m_{cr})$ (type B)

$$U_m = \frac{U_e}{k}$$

U(m) = 0,095 mg / 2

= 0,0475 mg

Derajat kebebasan :
k = 2, maka v = 60 (tabel 2.2)

4.2.7.2. Ketidakpastian daya ulang pembacaan, u(repeat) (type A)
Data pada tabel 4.2

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}052\ mg}{\sqrt{2}}$$

u(repeat) = 0,037 mg

Derajat kebebasan :
v = n -1
v = 10 – 1
v = 9

4.2.7.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}}.\sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}}.\sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.7.4. Ketidakpastian instability standard, u_s (type B)

$u(d) = k.\frac{U}{\sqrt{3}}$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.7.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{139{,}9999\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,000101 g

$u(I_{ecc})$ = 0,101 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.7.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.140\ g}{\sqrt{3}}$$

U(b) = 0,000081 g

U(b) = 0,081 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.7.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

U_{reg} = s

U_{reg} = 0,00011 g

U_{reg} = 0,11 mg

Derajat kebebasan :

v = n – 2 = 10 – 2

= 8

4.2.7.8. Budget ketidakpastian

Tabel 4.11 Budget ketidakpastian titik ukur 70 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	Sensitivity coefficient (vi)	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,09500000	2	60	0,0475	1	0,0475	0,00225625	8,48E-08
Readability (mg)	Rectangular	0,07071068	1,73205081	5000	0,040824829	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,05163978	1,41421356	9	0,03651484	1	0,036514837	0,001333333	1,98E-07
Instability (mg)	Rectangular	0,04750000	1,73205081	5000	0,027424138	1	0,027424138	0,000752083	1,13E-10
Eccentricity (mg)	Rectangular	0,17499987	1,73205081	5000	0,101036225	1	0,101036225	0,010208319	2,08E-08
Bouyancy (mg)	Rectangular	0,14000000	1,73205081	5000	0,080829038	1	0,080829038	0,006533333	8,54E-09
regresi (mg)	Normal	0,10762866	1	8	0,107628661	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,034333914	1,71E-05
Combined standard uncertenly (mg)								0,185294129	
Effective degree of freedom, veff								68,99380310	
Coverage factor, k-factor for veff and CL = 95%								1,995468931	
Expended Uncertanly U=k.Uc (mg)								0,369748677	

Dari tabel 4.11 didapat nilai :

Ketidakpastian gabungan (U_c) = 0,185 mg

Derajat kebebasan efektif (v_{eff}) = 69

Faktor koreksi (k) = 2,00

Ketidakpastian terentang (U) = 0,37 mg

4.2.8. Analisa Ketidakpastian Titik ukur 80 % (nominal 160 g)

4.2.8.1. Ketidakpastian anak timbangan standar, $u(m_{cr})$ (type B)

$$U_m = \frac{U_s}{k}$$

U(m) = 0,0846 mg / 2
= 0,0423 mg

Derajat kebebasan :
k = 2, maka v = 60 (tabel 2.2)

4.2.8.2. Ketidakpastian daya ulang pembacaan, u(repeat) (type A)
Data pada tabel 4.2

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}052\ mg}{\sqrt{2}}$$

u(repeat) = 0,037 mg

Derajat kebebasan :
v = n -1
v = 10 – 1
v = 9

4.2.8.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}}.\sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}}.\sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.8.4. Ketidakpastian instability standard, u_s (type B)

$$u(d) = k.\frac{U}{\sqrt{3}}$$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.8.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.\,L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{159{,}9998\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,000115 g

$u(I_{ecc})$ = 0,12 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.8.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.160\ g}{\sqrt{3}}$$

U(b) = 0,000092 g

U(b) = 0,09 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.8.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

U_{reg} = s

U_{reg} = 0,00011 g

U_{reg} = 0,11 mg

Derajat kebebasan :

v = n – 2 = 10 – 2

= 8

4.2.8.8. Budget ketidakpastian

Tabel 4.12 Budget ketidakpastian titik ukur 80 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	Sensitivity coefficient (vi)	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,08460000	2	60	0,04230000	1	0,0423	0,00178929	5,34E-08
Readability (mg)	Rectangular	0,07071068	1,73205081	5000	0,04082483	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,05163978	1,41421356	9	0,03651484	1	0,036514837	0,001333333	1,98E-07
Instability (mg)	Rectangular	0,04230000	1,73205081	5000	0,02442192	1	0,024421916	0,00059643	7,11E-11
Eccentricity (mg)	Rectangular	0,19999969	1,73205081	5000	0,11546987	1	0,115469873	0,013333292	3,56E-08
Bouyancy (mg)	Rectangular	0,16000000	1,73205081	5000	0,09237604	1	0,092376043	0,008533333	1,46E-08
regresi (mg)	Normal	0,10762866	1	8	0,10762866	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,038836274	1,71E-05
Combined standard uncertenly (mg)								0,197069211	
Effective degree of freedom, veff								88,33093618	
Coverage factor, k-factor for veff and CL = 95%								1,987289865	
Expended Uncertanly U=k.Uc (mg)								0,391633645	

Dari tabel 4.12 didapat nilai :

Ketidakpastian gabungan (U_c) = 0,197 mg

Derajat kebebasan efektif (v_{eff}) = 88,3

Faktor koreksi (k) = 1,99

Ketidakpastian terentang (U) = 0,39 mg

4.2.9. Analisa Ketidakpastian Titik ukur 90 % (nominal 180 g)

4.2.9.1. Ketidakpastian anak timbangan standar, $u(m_{cr})$ (type B)

$$U_m = \frac{U_s}{k}$$

U(m) = 0,1096 mg / 2

= 0,0548 mg

Derajat kebebasan :

k = 2, maka v = 60 (tabel 2.2)

4.2.9.2. Ketidakpastian daya ulang pembacaan, u(repeat) (type A)

Data pada tabel 4.2

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}052\ mg}{\sqrt{2}}$$

u(repeat) = 0,037 mg

Derajat kebebasan :

v = n -1

v = 10 – 1

v = 9

4.2.9.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}} . \sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}} . \sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.9.4. Ketidakpastian instability standard, u_s (type B)

$u(d) = k.\frac{U}{\sqrt{3}}$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.9.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{179{,}9998\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,00013 g

$u(I_{ecc})$ = 0,13 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.9.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.180\ g}{\sqrt{3}}$$

U(b) = 0,000104 g
U(b) = 0,0104 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.9.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

U_{reg} = s
U_{reg} = 0,00011 g
U_{reg} = 0,11 mg

Derajat kebebasan :
v = n – 2 = 10 – 2
= 8

4.2.9.8. Budget ketidakpastian

Tabel 4.13 Budget ketidakpastian titik ukur 90 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	Sensitivity coefficient (vi)	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,10960000	2	60	0,05480000	1	0,0548	0,00300304	1,50E-07
Readability (mg)	Rectangular	0,07071068	1,73205081	5000	0,04082483	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,05163978	1,41421356	9	0,03651484	1	0,036514837	0,001333333	1,98E-07
Instability (mg)	Rectangular	0,05480000	1,73205081	5000	0,03163879	1	0,031638795	0,001001013	2,00E-10
Eccentricity (mg)	Rectangular	0,22499969	1,73205081	5000	0,12990363	1	0,12990363	0,016874953	5,70E-08
Bouyancy (mg)	Rectangular	0,18000000	1,73205081	5000	0,10392305	1	0,103923048	0,0108	2,33E-08
regresi (mg)	Normal	0,10762866	1	8	0,10762866	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,046262935	1,72E-05
Combined standard uncertenly (mg)								0,215088203	
Effective degree of freedom, veff								124,41705441	
Coverage factor, k-factor for veff and CL = 95%								1,979280117	
Expended Uncertanly U=k.Uc (mg)								0,425719804	

Dari tabel 4.13 didapat nilai :

Ketidakpastian gabungan (U_c) = 0,215 mg
Derajat kebebasan efektif (v_{eff}) = 124,4
Faktor koreksi (k) = 1,98
Ketidakpastian terentang (U) = 0,43 mg

4.2.10. Analisa Ketidakpastian Titik ukur 100 % (nominal 200 g)

4.2.10.1. Ketidakpastian anak timbangan standar, u(m_{cr}) (type B)

$$U_m = \frac{U_e}{k}$$

U(m) = 0,072 mg / 2
= 0,036 mg

Derajat kebebasan :
k = 2, maka v = 60 (tabel 2.2)

4.2.10.2. Ketidakpastian daya ulang pembacaan, u (repeat) (type A)

Data pada tabel 4.2

$$u(repeat) = \frac{stdev\ timbangan}{\sqrt{n}}$$

$$u(repeat) = \frac{0{,}052\ mg}{\sqrt{2}}$$

u(repeat) = 0,037 mg

Derajat kebebasan :
v = n -1
v = 10 – 1
v = 9

4.2.10.3. Ketidakpastian daya baca timbangan, u_d (type B)

$$u(res) = \frac{0{,}5xresolusi\ timbangan}{\sqrt{3}}.\sqrt{2}$$

$$u(res) = \frac{0{,}5x0{,}1\ mg}{\sqrt{3}}.\sqrt{2}$$

u(res) = 0,041 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.10.4. Ketidakpastian instability standard, u_s (type B)

$u(d) = k.\frac{U}{\sqrt{3}}$, nilai k = 1

$$u(d) = \frac{0{,}025\ mg}{\sqrt{3}}$$

u(d) = 0,0072 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.10.5. Ketidakpastian pembebanan tidak di pusat pan, $u(I_{ecc})$ (type B)

$$u(I_{ecc}) = \frac{I\,[\Delta I_{ecc-i}]_{max}}{2.\,L_{ecc}.\sqrt{3}}$$

$$u(I_{ecc}) = \frac{199{,}9998\ g\ .0{,}0002\ g}{2.100\ g.\sqrt{3}}$$

$u(I_{ecc})$ = 0,00014 g

$u(I_{ecc})$ = 0,14 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.10.6. Ketidakpastian buoyancy, u_b (type B)

$$u(b) = \frac{1ppm\ x\ nominal\ titik\ ukur}{\sqrt{3}}$$

$$u(b) = \frac{10^{-6}.200\ g}{\sqrt{3}}$$

U(b) = 0,0002 g

U(b) = 0,012 mg

Derajat kebebasan :

$$v = \frac{1}{2}\left\{\frac{100}{R}\right\}^2$$

$$v = \frac{1}{2}\left\{\frac{100}{1}\right\}^2$$

v = 5000

4.2.10.7. Ketidakpastian dari persamaan regresi, u_{reg} (type B)

Nilai standard error regresi (s) didapat pada perhitungan data analisis regresi excel sebesar 0,00011 g

U_{reg} = s

U_{reg} = 0,00011 g

U_{reg} = 0,11 mg

Derajat kebebasan :

v = n – 2 = 10 – 2

= 8

4.2.10.8. Budget ketidakpastian

Tabel 4.14 Budget ketidakpastian titik ukur 100 %

Ketidakpastian	Distribusi	Ketidakpastian terentang (Ui)	Pembagi	Sensitivity coefficient (vi)	Ketidakpastian baku (ui)	ci	uici	(uici)^2	(uici)^4/vi
Standard (mg)	Normal	0,07200000	2	60	0,03600000	1	0,036	0,001296	2,80E-08
Readability (mg)	Rectangular	0,07071068	1,73205081	5000	0,04082483	1	0,040824829	0,001666667	5,56E-10
Reapeatibility (mg)	t-student	0,05163978	1,41421356	9	0,03651484	1	0,036514837	0,001333333	1,98E-07
Instability (mg)	Rectangular	0,03600000	1,73205081	5000	0,02078461	1	0,02078461	0,000432	3,73E-11
Eccentricity (mg)	Rectangular	0,24999975	1,73205081	5000	0,14433742	1	0,144337423	0,020833292	8,68E-08
Bouyancy (mg)	Rectangular	0,20000000	1,73205081	5000	0,11547005	1	0,115470054	0,013333333	3,56E-08
regresi (mg)	Normal	0,10762866	1	8	0,10762866	1	0,107628661	0,011583929	1,68E-05
Sums (mg)								0,050478554	1,71E-05
Combined standard uncertenly (mg)								0,224674328	
Effective degree of freedom, veff								148,82015619	
Coverage factor, k-factor for veff and CL = 95%								1,976122494	
Expended Uncertanly U=k.Uc (mg)								0,443983994	

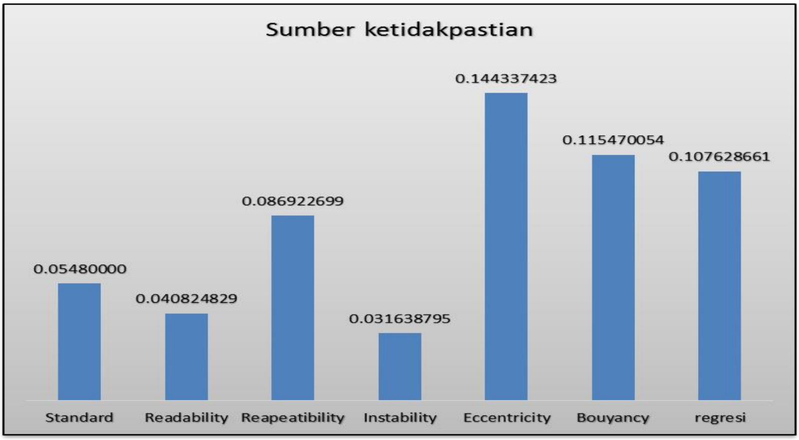
Dari tabel 4.14 didapat nilai :
Ketidakpastian gabungan (U_c) = 0,225 mg
Derajat kebebasan efektif (v_{eff}) = 148,8
Faktor koreksi (k) = 1,98
Ketidakpastian terentang (U) = 0,44 mg

4.2.11. Summary hasil ketidakpastian

Ketidakpastian terentang maksimum U_{95} = 0,44 mg
Faktor cakupan, k-factor = 2,09
Derajat kebebasan = 148

Tabel 4.15 Perbandingan sumber ketidakpastian

Sumber ketidakpastian	Ketidakpastian max (mg)
Standard	0,05480000
Readability	0,040824829
Reapeatibility	0,086922699
Instability	0,031638795
Eccentricity	0,144337423
Bouyancy	0,115470054
Regresi	0,107628661



Gambar 4.1 Grafik perbandingan sumber ketidakpastian

Dari analisa ketidakpastian didapat faktor penyumbang nilai terbesar dari ketidakpastian adalah pembebanan tidak di pusat pan.

4.3. Perhitungan limit of performance (F)

F = koreksi pembacaan maksimum + ketidakpastian maksimum

= 0,055 mg + 0,44 mg

= 0,495 mg

Berdasarkan tabel 2.3 diketahui bahwa kinerja timbangan adalah “CUKUP”.