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Comparison Of A And B Type Measurement Uncertainties in Tensile Testing of Metallic Materials at Ambient Temperature

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Abstract
Uncertainty of Measurement in Tensile Testing has been gaining much more importance in the last few decades due to the widespread usage of tensile in metallic materials. Main objective of this paper is to compare the uncertainties of Type A and Type B in tensile tests of metallic materials whose tensile tests were conducted in ambient temperature. In this scope, 60 samples from 6 different groups were subjected to 3 different tensile tests in accordance with EN ISO 6892-1:2016 quality standards. Width, thickness and force of the samples have been measured, then their average force, dimension and standard deviation values were calculated. Samples have been characterized through the use of a universal tensile testing device. Tensile tests were conducted in accordance with EN ISO 6892-1:2016 quality standards. Based on the results obtained measurement uncertainty of Type A was calculated at an average of 1%, whereas measurement uncertainty of Type B was calculated at an average of 2% while the tensile strength was at a confidence level of 95% . As a result of experimental studies, it was found that in numerical precision measurements, use of Uncertainty Type A results in relatively more precise values than Uncertainty Type B.

Keywords: *Measurement uncertainty, Tensile test,* A-*type uncertainty,* B-*type uncertainty*

INTRODUCTION

Measurements have to conduct for the efficient use of the devices used in production, for the maintenance of device quality, for the control and process control. A measurement result is only complete if it is accompanied by a statement of the uncertainty in the measurement. Measurement uncertainty is an array that is constituted by executable outcomes where to every outcome, possibilities are indicated. If a statement of the accompanied uncertainties that are related to measured values and their uncertainties, follow measurements, only then all measurements are concluded. Measurement uncertainties can come from the measuring instrument, from the item being measured, from the environment, from the operator, and from other sources.

Tensile stress is defined as the highest force a material can resist without breaking. In other words, it is the limit of the material to withstand exerted force without causing faulty, Furthermore, the tensile strength can be calculated as force per unit area.

Such uncertainties can be estimated using statistical analysis of a set of measurements, and using other kinds of information about the measurement process.

Up to the present, There are any study in scope of comparison between A type Measurement Uncertainty and B type Measurement Uncertainty. As a consequence, the aim of this study was assesting quantitative differences between this two uncertainty types and help to guiding which one has more sensitive results.

To achieve this goal, study began with production of a group of specimens with shape and dimensional standardized according to the reference followed by standard tensile test.A statistical analysis of the test results was then carried out to assess the irreliability. Finally, a methodology was applied to assess the uncertainty of measurement in conjunction with the test results, with the aim of obtaining final mechanical properties.

MATERIALS AND METHODS

In this section, tensile tests of specimens of different structures were carried out to calculate the measurement uncertainty between the obtained values and to compare the results. Tensile tests were carried out at the Besmak, Zwick & Roll and Mohr & Federhaff AG tensile testing devices at Yıldız Technical University Materials Science Department Laborataries. A total of 60 samples were tested in 6 groups. All samples were tested and results were recorded. Samples were grouped from 1 to 6. While sample group 1,2,5,6 are rod samples, 3rd and 4th groups were samples with round cross-sections. Mohr & Federhaff AG, Zwick & Roll tensile test devices was used for rod samples, Besmak was used for round samples.

In scope of relevant standards, the following steps are tracked. In accordance with the stated steps, experimental studies were carried out and calculations were made. All the factors that could affect the measurement results have to be clarified and included. It should not limited to experimental conditions, sample preparation, as well as the test or calibration method to be used the contributions of these quantities have to be taken into account for the determination of measurement uncertainty.

Table 1 : Effect of uncertainty sources on tensile strength specified in BS EN ISO 6892-1:2016

Uncertainty Source	Tensile Strength
Force	Major Contribution
Cross Sectional Area	Major Contribution
Specimen Size and Shape	Major Contribution
Temperature and Humidity	Minor Contribution
Extension	No Contribution
Gauge Length	No Contribution

Identify and Characterization of the Uncertainty Sources
Minor components are negligible. Barely, Major sources have to be considered while deriving model function. Table 1 shows that Force and Cross Sectional Area have taken into consideration as part of model.

Derivation of Mathematical Model

After all sources of uncertainities have been listed, mathematically relationship between the measurand function and all of the input quantities upon which measurand depends have to be expressed. All sources have to be included that, can significantly affect to the Uncertainty of the measurement. If input quantities are specified as (x1, x2, …, xn.).
Mathematical relationship between the measurement result y and the input quantities xi can be specified as follow.

$$y = f(x_1, x_2, \ldots, x_n)$$

Tensile stress is defined as the highest force a material can resist without breaking. Tensile strength is found by the following formula. In this formula, S represents Tensile Strength, F represent maximum force, T (Thickness)*W(Width) multiply represents cross sectional area. Accordingly, This equation is chosen as mathematical model of tensile strength measurement. Therefore, as a first approximation, we will take as the mathematical model of our tensile strength measurement:

$$S = f(F, T, W) = \frac{F}{TW} \quad (1)$$

A measurement is considered to be a function of the all the input quantities that affect the measurement. Sometimes, as in the tensile strength example, the function is a know equation. For many tests,however, the "function" is not well defined. The GUM assumes the measurement result, y, is caused by one or more input quantities, which are designated x1, x2,.., xn acting through some functional relationship, f:

Quantifying sources of uncertainty

All measurement factors affecting the measured value are determined, Type A Uncertainty is described as uncertainty is by a statistical method based on a series of repeated observations. The statistically calculated standard deviation of observations is called a Type A standard uncertainty.

$$S = \sqrt{\textstyle\sum_{n-1}^{n}(p - \overline{p})^2} \quad (2)$$

$$u(p) = \frac{s}{\sqrt{n}} \quad (3)$$

Where,
s= Standard Deviation of
Specimen p= Chosen parameter for
equation $\overline{p}$ = Average of
parameter n= Sample number
u= A type Standard Uncertainty value of parameter

If the predicted x value for in input values is not obtained as a result of repeated measurements. All the different values that x have to be taken into account using all available information in a scientific approach. Type B uncertainty can be estimated with the help of these following informations:

-Datas from calibration and other
certificates; -Properties that manufacturer's
specified -Reference data from handbooks;
-Datas from previous measurements
-Experience or general knowledge about relevant materials and instruments

Evaluation of sensitivity coefficients

Sensitivity coefficients measures of how much change is produced in the measurand by changes in an input quantity. Mathematically, sensitivity coefficients are obtained from partial derivatives of the model function f with respect to the input quantities. In particular, the sensitivity coefficient ci of the input quantity xi is given by

$$Ci = \frac{\partial f}{\partial Xi}$$

Model function that is used for the tensile strength determination is where S is the tensile strength, F is the force needed to break a test bar, T and W are the thickness and width respectively of the test bar. Sensitivity coefficients is obtained as follows:

$$C_F = \frac{\partial S}{\partial F} = \frac{1}{TW} = \frac{S}{F} \quad (5)$$

C_f= Sensitivity Coefficient of Specimen Force

$$C_T = \frac{\partial S}{\partial T} = \frac{1}{T^2W} = \frac{-S}{T} \quad (6)$$

C_t= Sensitivity Coefficient of Specimen Thickness

$$C_W = \frac{\partial S}{\partial W} = \frac{-F}{TW^2} = \frac{-S}{W} \quad (7)$$

C_W= Sensitivity Coefficient of Specimen Width

Where S is the tensile strength, F is the force needed to break a test bar, and A_0 is square and D_0 is diameter of the test bar.

Sensitivity coefficients are obtained as follows:

$$S = \frac{F}{A_0} = \frac{F}{\frac{\pi d_0^2}{4}} \quad (8)$$

$$C_F = \frac{\partial S}{\partial F} = \frac{1}{\frac{\pi d_0^2}{4}} = \frac{S}{F} \quad (9)$$

C_f= Sensitivity Coefficient of Specimen Force

$$Cd_0 = \frac{\partial s}{\partial f} = \frac{(0x\frac{\pi d_0^2}{4} - (2\frac{\pi d_0}{4}xF)}{\frac{\pi^2 d_0^4}{16}} = \frac{8F}{\pi d_0^3} \quad (10)$$

C_{d0}= Sensitivity Coefficient of Specimen Diameter

Combining of Inputs

Values of all uncertainty inputs have to be evaluated and degraded to a single standard uncertainty. This combination is obtained by the positive square root of the sum of the calculated variance expressions. Accordingly, combined uncertainty for the independent input quantities is given by:

$$\mu_C^2 = \sum_i c_i^2 \mu_i^2 \quad (11)$$

Due to measuring of thickness and width with same micrometer, correlation occurs. Correlation coefficient r(xi,xj) is an explanation of degree of correlation between the input quantities xi and xj.. First step in evaluation of correlation coefficient is estimation of “covariance”. Covariance is calculated by:

$$s(\bar{T},\bar{W}) = \frac{1}{n(n-1)} \sum_{i=1}^{n} (Ti - \bar{T})(Wi - \overline{W}) \quad (12)$$

Correlation coefficient is estimated by:

$$r(\bar{T},\bar{W}) = \frac{s(\bar{T},\bar{W})}{s(\bar{T})s\bar{W})} \quad (13)$$

Where s(xi) and s(x j) are the experimental standard deviations of the input quantities xi and xj.

$$\mu_c^2 = \sum_{i=1}^{N} c_i^2 u_i^2 + 2\sum_{i=1}^{N-1} \sum_{J=l+1}^{N} C_i C_j \mu_i \mu_j \, r(x_i, x_j) \quad (14)$$

In case of correlated input values, combined certainty can be estimated by:

$$\mu_c^2 = \sum_{i=1}^{N} c_i^2 u_i^2 + 2\sum_{i=1}^{N-1} \sum_{J=l+1}^{N} C_i C_j \mu_i \mu_j \, r(x_i, x_j) \quad (15)$$

Determination of Expanded Uncertainty

Expanded uncertainty is defined as a range which containts large part of measurement results of a measured quantity. Student’s t-table is taken as a reference. Combined standard uncertainty multiply by coverage factor associated with the estimated degrees of freedom and desired level of confidence. (see Appendix 1)

U=k.Uc (16)

Table 2. Coverage factors for confidence level

v=N-1 (Degree of Freedom)	*t80%*	*t90%*	*t95%*	*t99%*
9	1.383	1.833	2.262	3.250

*N= Sample Number

Reporting of Measurement

After all these stages completed; measurement uncertainty have to be reported that includes definition of measurand, expanded uncertainty within level of confidence. Uncertainty that expanded and preferred confidence level is added to measured value as in the formula. Reporting is made as followed equation:

That expanded and preferred confidence level is added to measured value as in the formula. Reporting is made as followed equation:

$$Y = y \pm U \quad (17)$$

Where U is expanded uncertainty, y is measured value.

Example: Tensile strength of 1st specimen group is defined by BS EN ISO 6892-1:2016 was estimated to be (344,19 ± 7,86) MPa. Expanded uncertainty value is found after the ± symbol. Expanded Uncertainty
estimated from a combined standard uncertainty uc = 3,48 MPa using a coverage factor of k =2.26 and defines an interval estimated to have a level of confidence of 95 percent with 9th. degrees of freedom.

Experimental

Specimens were divided into 6 groups used in the experiments 10 samples were used in each group. 1st, 2nd, 5th , 6th groups of specimens were strips; 4th and 5th groups were cylindrically shaped. The width and thickness of all specimens were measured by using a calibrated digimatic micrometer, and at least three different places within the gauge length area were recorded. Firstly, these samples were subjected to sample preparation. The dirt and rust on the test specimens were removed by sanding and cleaning. The samples were conditioned at ambient temperature of 24 ± 3°C and relative humidity of 50 ± 10%. EN ISO 6892-1:2016 was applied to determine tensile strength at the same temperature and relative humidity as sample conditioning procedure. The test was conducted by Mohr & Federhaff AG, Zwick &Roll tensile test devices was used for rod samples, and Besmak was used for cylindrical samples. Test procedure contains fixing of specimens in grips and stretching them uniaxially, until breaking occurs , by increasing stress at a prespecified rate, with the shape of specimens being defined by standard that specifies the method for tensile testing of metallic materials and defines the mechanical properties that can be determined at room temperature. Equal pull speed were applied to the samples during the test. Standard deviation and average values are calculated as a result of the information coming from devices softwares.

Table 3. Chemical composition of sample groups

Alloying Elements	**DIN EN 10130 99**		**AISI 4140**		**S235 JR**	
	1st Sample Group (%)	2nd Sample Group (%)	3rd Sample Group (%)	4th Sample Group (%)	5th Sample Group (%)	6th Sample Group (%)
Fe	99,33	99,35	97,07	97,01	98,96	98,19
C	0,05	0,04	0,41	0,40	0,14	0,19
Si	0,02	0,02	0,23	0,28	0,13	0,19
Mn	0,13	0,13	0,83	0,79	0,55	0,72
P	0, 01	0,01	0,01	0,02	0,01	0,01
S	0,16	0,16	0,02	0,02	0,02	0,03

RESULTS

Data sets which used for the calculation of tensile strength (Rm) and the measurement uncertainty of 1st specimen group is showed in Table 4.

Table 4: Tensile test results of specimen group 1

No. Of Sample	**A_0 (mm)**	**B_0 (mm)**	**Fm (N)**	**Elongation (%)**	**Rm (MPa)**
1	0,49	20,35	3480,76	38%	346
2	0,50	20,37	3511,90	40%	346
3	0,49	20,37	3473,49	41%	348
4	0,49	20,38	3443,72	39%	343
5	0,49	20,36	3434,48	41%	341,4
6	0,49	20,38	3486,96	49%	348
7	0,50	20,36	3445,45	38%	340,46
8	0,50	20,38	3491,14	35%	346
9	0,50	20,37	3461,19	48%	339
10	0,49	20,36	3474,40	44%	344
Mean Value	0,49	20,368	3470,35	41%	344,19
Standart Deviation	0,00363	0,010328	24,19	4,4%	3,14

Sensitivity coefficients were determined with the help of formula 5, 6, 7 based on the measured values in the test

Correlation coefficient was estimated according to formula 12, 13, 14. Obtained values are presented in Table 5.

Table 5: Sensitivity and correlation coefficients of specimen group 1

Group	$\overline{Rm}\ (Mpa)$	$\overline{T}$	$\overline{W}$	c_f	c_t	c_w	μ_f	μ_t	μ_w	$r(\overline{T},\overline{W})$
1	344,19	0,49	20,37	0,10	-696,11	-16,90	24,19	0,003	0,010	-0,03

Uncertainty of Type A was calculated according to Formula 2, 3 indicated in Table 6.

Type B Measurement Uncertainty for 1st specimen group was calculated according to formula 11 and indicated in Table 6.

Coverage Function (k) was used as k=2,26 for a 95 % level of confidence. Coverage Function was multiplied by combined standard Uncertainty and total expanded Uncertainty was obtained.

Table 6: Measurement uncertainty values of specimen group 1

	Value	Percentage
Uncertainty of Type A	0,99	0,29%
Uncertainty of Type B	3,49	1,01%
Expanded Uncertainty of Type A	2,24	0,65%
Expanded Uncertainty of Type B	7,86	2,29%

Data sets which used for the calculation of tensile strength (Rm) and the measurement uncertainty of 2nd specimen group is showed in Table 7.

Table 7. Tensile test results of specimen group 2

No. Of Sample	A_0(mm)	B_0(mm)	S_0(mm_2)	**Rm (MPa)**
1	0,49	20,36	9,98	353
2	0,50	20,37	10,17	340
3	0,50	20,37	10,24	344
4	0,50	20,36	10,12	345
5	0,50	20,37	9,98	342
6	0,49	20,37	10,18	354
7	0,51	20,37	9,99	344
8	0,50	20,35	10,13	343
9	0,49	20,39	10,08	353
10	0,50	20,35	10,07	352
Mean Value	0,50	20,366	10,093	349,125
Standard Deviation	0,00458	0,01264	0,0903	4,93

Sensitivity coefficients were determined with the help of formula 5, 6, 7 based on the measured values in the test.

Correlation coefficient was estimated according to formula 12, 13, 14. Obtained values are presented in Table 8.

Table 8: Sensitivity and correlation coefficients of specimen group 2

Group	$\overline{Rm}\ (Mpa)$	$\overline{T}$	$\overline{W}$	c_f	c_t	c_w	μ_f	μ_t	μ_w	$r(\overline{T},\overline{W})$
2	349,125	0,50	20,366	0,01	-704,45	-17,14	32,22	0,005	0,013	-0,13

Uncertainty of Type A was calculated according to formula 2, 3 indicated in Table 9. Type B Measurement Uncertainty for 2nd specimen group was calculated according to formula 11 and indicated in Table 9.

Coverage Function (k) was used as k=2,26 for a 95 % level of confidence. Coverage Function was multiplied by combined standard Uncertainty and total expanded Uncertainty was obtained.

Table 9: Measurement uncertainty values of specimen group 2

	Value	Percentage
Uncertainty of Type A	1,56	0,45%
Uncertainty of Type B	4,55	1,30%
Expanded Uncertainty of Type A	3,52	1,01%
Expanded Uncertainty of Type B	10,28	2,95%

Data sets which used for the calculation of tensile strength (Rm) and the measurement uncertainty of 3rd specimen group is showed in Table 10.

Table 10. Tensile test results of specimen group 3.

No. Of Sample	**Do (mm)**	**S_0 (mm^2)**	**Force (N)**	**Rm (MPa)**
1	10,02	78,81	83306,73	1057
2	10,03	78,97	83394,12	1056
3	10,02	78,81	84368,69	1073,9
4	10,04	79,13	83402,24	1054
5	10,01	78,66	84556,36	1075
6	10,02	78,81	84646,57	1074
7	10,03	78,97	84205,90	1064
8	10,02	78,81	83621,99	1061
9	10,02	78,81	82912,66	1052
10	10,04	79,13	84589,17	1069
Mean Value	10,02	78,89	83909,44	1063,59
Standard Deviation	0,00971	0,15298	660,94	8,87

Sensitivity coefficients were determined with the help of Formula 8, 9, 10 based on the measured values in the test.

Table 11. Sensitivity and correlation coefficients of specimen group 3

Group	$\overline{Rm}$ (Mpa)	$\overline{d_0}$	$\overline{S_0}$	$\overline{F_m}$	c_f	μ_f	c_{d_0}	μ_{d_0}
3	1063,59	10,025	78,89	83909,44	0,013	660,9379	212,19	0,009718

Uncertainty of Type A was calculated according to Formula 2, 3 and indicated in Table 12.

Type B Measurement Uncertainty for 3rd specimen group was calculated according to Formula 11 and indicated in Table 12.

Coverage Function (k) was used as k=2,26 for a 95 % level of confidence. Coverage Function was multiplied by combined standard Uncertainty and total expanded Uncertainty was obtained.

Table 12: Measurement uncertainty values of specimen group 3

	Value	Percentage
Uncertainty of Type A	2,81	0,26%
Uncertainty of Type B	8,63	0,81%
Expanded Uncertainty of Type A	6,35	0,60%
Expanded Uncertainty of Type B	19,50	1,83%

Data sets which used for the calculation of tensile strength (Rm) and the measurement uncertainty of 4th specimen group is showed in Table 13.

Table 13. Tensile test results of specimen group 4.

No. Of Sample	**Do (mm)**	**S_0 (mm^2)**	**Force (N)**	**Rm (MPa)**
1	10,01	78,66	82668,59	1051,00
2	10,03	78,97	82288,52	1042,00
3	10,02	78,81	83251,56	1056,30
4	10,04	79,13	83259,80	1052,20
5	10,02	78,81	83700,80	1062,00
6	10,02	78,81	83543,17	1060,00
7	10,03	78,97	82920,29	1050,00
8	10,02	78,81	82833,84	1051,00
9	10,03	78,97	83394,12	1056,00
10	10,03	78,97	84341,78	1068,00
Mean Value	10,03	78,89	83220,27	1054,85
Standard Deviation	0,0085	0,13	580,95	7,30

Sensitivity coefficients were determined with the help of Formula 8, 9, 10 based on the measured values in the test.

Table 14. Sensitivity and correlation coefficients of specimen group 4

Group	$\overline{Rm}\ (Mpa)$	$\overline{d_0}$	$\overline{S_0}$	$\overline{F_m}$	c_f	c_{d_0}	μ_f	μ_{d_0}
4	1054,85	10,03	78,89	83220,27	0,012	210,44	580,95	0,0085

Uncertainty of Type A was calculated according to Formula 2, 3 indicated in Table 15. Type B Measurement Uncertainty for 4th specimen group was calculated according to Formula 11 and indicated in Table 15.

Coverage Function (k) was used as k=2,26 for a 95 % level of confidence. Coverage Function was multiplied by combined standard Uncertainty and total expanded Uncertainty was obtained.

Table 15. Measurement uncertainty values of specimen group 4

	Value	Percentage
Uncertainty of Type A	2,31	0,22%
Uncertainty of Type B	7,58	0,72%
Expanded Uncertainty of Type A	5,22	0,49%
Expanded Uncertainty of Type B	17,13	1,62%

Data sets which used for the calculation of tensile strength (Rm) and the measurement uncertainty of 5th specimen group is showed in Table 16.

Table 16. Tensile test results of specimen group 5.

Sample Number	T_0 (mm)	W_0 (mm)	S_0 (mm^2)	Force (N)	Rm (MPa)
1	1,98	20,33	40,25	16604	412,49
2	1,96	20,38	39,94	16624	416,17
3	1,95	20,34	39,66	16572	417,82
4	1,94	20,33	39,44	16553	419,70
5	1,99	20,36	40,52	16608	409,91
6	1,98	20,35	40,29	16584	411,59
7	1,95	20,36	39,70	16658	419,58
8	1,95	20,36	39,70	16650	419,37
9	1,95	20,36	39,70	16703	420,71
10	1,97	20,33	40,05	16651	415,75
Mean Value	1,96	20,35	39,89	16620	416,31
Standard Deviation	0,017	0,017	0,34	45,58	3,82

Sensitivity coefficients were determined with the help of Formula 5, 6, 7 based on the measured values in the test.

Correlation coefficient was estimated according to Formula 12, 13, 14. Obtained values are presented in Table 17.

Table 17. Sensitivity and correlation coefficients of specimen group 5

Group	$\overline{Rm}\ (Mpa)$	$\overline{T}$	$\overline{W}$	c_f	c_t	c_w	μ_f	μ_t	μ_w	$r(\overline{T},\overline{W})$
5	416,31	1,96	20,35	0,03	-212,40	-20,46	45,58	0,017	0,017	-0,01

Uncertainty of Type A was calculated according to Formula 2, 3 and indicated in Table 18. Type B Measurement Uncertainty for 5th specimen group was calculated according to Formula 11 and indicated in Table 18.

Coverage Function (k) was used as k=2,26 for a 95 % level of confidence. Coverage Function was multiplied by combined standard Uncertainty and total expanded Uncertainty was obtained.

Table 18. Measurement uncertainty values of specimen group 5

	Value	Percentage
Uncertainty of Type A	1,21	0,29%
Uncertainty of Type B	3,78	0,91%
Expanded Uncertainty of Type A	2,73	0,66%
Expanded Uncertainty of Type B	8,52	2,05%

Data sets which used for the calculation of tensile strength (Rm) and the measurement uncertainty of 6th specimen group is showed in Table 19.

Table 19. Tensile test results of specimen group 6.

Sample Number	T_0 (mm)	W_0 (mm)	S_0 (mm^2)	Force (N)	Rm (MPa)
1	1,98	20,32	40,23	16657	414,01
2	1,99	20,35	40,50	16650	411,15
3	1,97	20,32	40,03	16636	415,58
4	1,98	20,34	40,27	16643	413,25
5	1,98	20,39	40,37	16631	411,94
6	1,99	20,35	40,50	16650	411,15
7	1,99	20,34	40,48	16693	412,41
8	1,97	20,35	40,09	16664	415,67
9	1,96	20,34	39,87	16634	417,24
10	1,95	20,35	39,68	16662	419,88
Mean Value	1,96	20,35	40,20	16652	414,23
Standard Deviation	0,013	0,020	0,28	18,44	2,86

Sensitivity coefficients were determined with the help of Formulas 5, 6, 7 based on the measured values in the test.

Correlation coefficient was estimated according to Formula 12, 13, 14. Obtained values are presented in Table 20.

Table 20. Sensitivity and correlation coefficients of specimen group 6

Group	$\overline{Rm}\ (Mpa)$	$\overline{T}$	$\overline{W}$	c_f	c_t	c_w	μ_f	μ_t	μ_w	$r(\overline{T},\overline{W})$
6	414,23	1,98	20,35	0,025	-209,63	-20,36	18,44	0,014	0,020	-0,03

Uncertainty of Type A was calculated according to Formula 2, 3 and indicated in Table 21.

Type B Measurement Uncertainty for 6th specimen group was calculated according to Formula 11 indicated in Table 21.

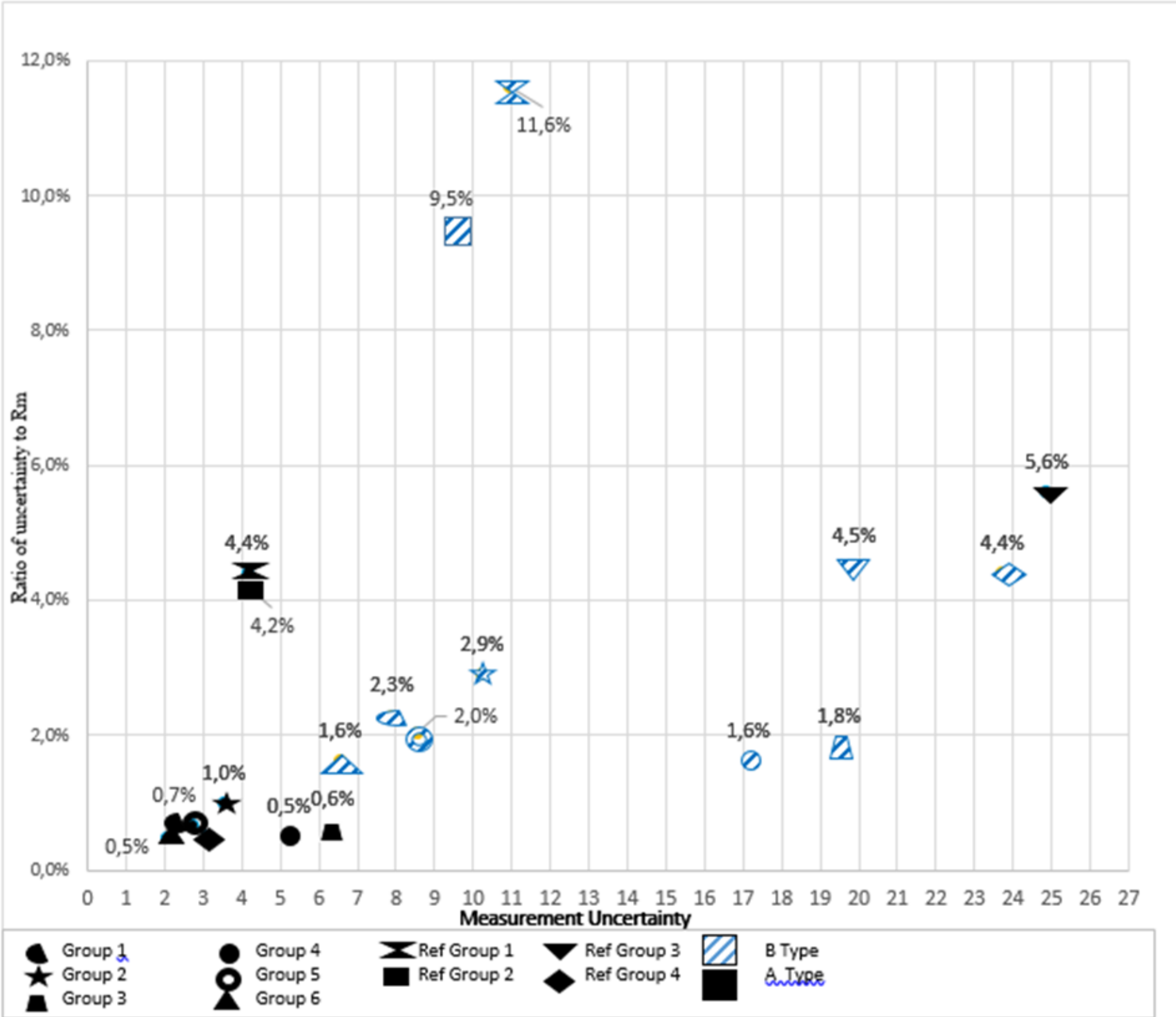
Coverage Function (k) was used as k=2,26 for a 95 %level of confidence. Coverage Function was multiplied by combined standard Uncertainty and total expanded Uncertainty was obtained.

Table 21. Measurement uncertainty values of specimen group 6

	Value	**Percentage**
Uncertainty of Type A	0,90	0,22%
Uncertainty of Type B	2,89	0,69%
Expanded Uncertainty of Type A	2,04	0,49%
Expanded Uncertainty of Type B	6,54	1,56%

Obtained uncertainty values of all samples and reference uncertainty values are shown in Table 22.

Table 22. Measurement uncertainty values of all specimen groups



CONCLUSIONS

1- It was observed that the uncertainty values obtained are in the range of standards when compared to the reference articles.

2- The highest uncertainty was calculated for the both two types of samples in the 3rd group.

3) The lowest uncertainty was again found in the number 2nd sample group for both two types.

4) Uncertainty values of Type A and Type B are closest to each other is defined as 1st sample group

5- Type A gave more accurate results than the type of uncertainty. The results of Type B uncertainty were higher for all sample groups.

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