QUALITY OF MATERIAL TENSILE TEST

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Abstract: *Today, tensile test is widely use for product assurance, product performance testing and research activities which is very important for manufacturers and R&D institutes. Quality and reliability of results of tensile tests also has importance. In this study parameters which have effect on quality of tensile test are defined as uncertainty. Addition to measured values of yield stress, tensile stress, elongation and cross-section reduction also uncertainty values were calculated. Also effects of uncertainty values on test results are shown. To get high quality material tensile test results we should have calibrated testing machine periodically and should get low uncertainty results.*
Keywords: *Tensile test, uncertainty, calibration*

1. INTRODUCTION

Nowadays, global comparability of the measured values of material properties is based on some fundamental metrological concepts. These concepts are widely used in current procedures and standards for materials testing and also many measuring systems. For instance, current standards for tensile testing are EN ISO 6892-1 for metals, ISO 527-1 for plastics. Similarly, there are a lot of standards for different materials and applications.

All tensile test standards are expressed necessary conditions for test, test setup and expected results. Comparison of different devices with the differences in test results has been made by using these standards.

An important aspect of metrological comparability of measurement results is traceability. This study, aims to illustrate with practical examples how to apply the concept of metrological traceability as defined in ISO/IEC Guide 99:2007 and the VIM (International Vocabulary of Metrology), in the field of material tensile properties. In section 2, an example is given from the field of material tensile properties according to VIM, including appropriate traceability statements and means to achieve the traceability.

Mainly, traceability provided thought the device. All measurements are affected more or less by errors coming from measuring device and its readout system. Considering that the errors can not be known perfectly, it can be accepted that the result of the measurement is affected by an uncertainty. The measurement result is jointed with its respective uncertainty, that can be define as an interval of values inside of which will be a true value of a quantity.

This study is presented to create calculation methodology for determining the result of measurement concerning tensile mechanical properties and their respective uncertainties. The methodology has a systematic application associated with advanced metrology concepts, aiming to a guarantee of metrological reliability to the results of the tensile properties, as well as the possibility of implementation in industrial laboratories, researches centers and related tensile test firm. Uncertainty in calculating the correct values and the reduction of the value, we have achieved our indicator of the quality test results.

2. EXPERIMENTAL STUDY

Tensile test results of a material are defined as the relation between stress(σ) imposed on material and strain(ε) response of the material. The results are to clarify inherent material properties. If the calibration of the test machine is performed in a SI-traceable manner, reported results can and should be accompanied by the statement: the measurement result is traceable to the SI (Fig. 1). The figure shows that tensile test machines should calibrated by reference devices.

In this study, a Zwick model Z250, nominal range of 250 kN tensile test machine was used. The force accuracy class of the machine is 1 with respect to EN ISO 7500-1 standard. Its extensometer was used together with machine. The extensometer accuracy class of the machine is 0.5 with respect to EN ISO 9513 standard.

The test specimens were rods prepared from same material. Their dimensions were prepared according to the tensile testing standard EN ISO 6892-1 for metals.

To get reliable results 5 test specimens were tested. All samples were tested under identical testing protocols. The test speeds were selected 1 mm / min. All tests were performed at 23 C ± 1 ºC temperature and 50 ± 10 % humidity. Results are shown in Table1.

At the end of tensile tests following mechanical properties were measured and calculated automatically by tensile testing machine; Yield Strength, Tensile Strength, Reduction of Area and Percent Elongation. To measure initial and final diameters and lengths of the proof bodies testing, a caliper was used

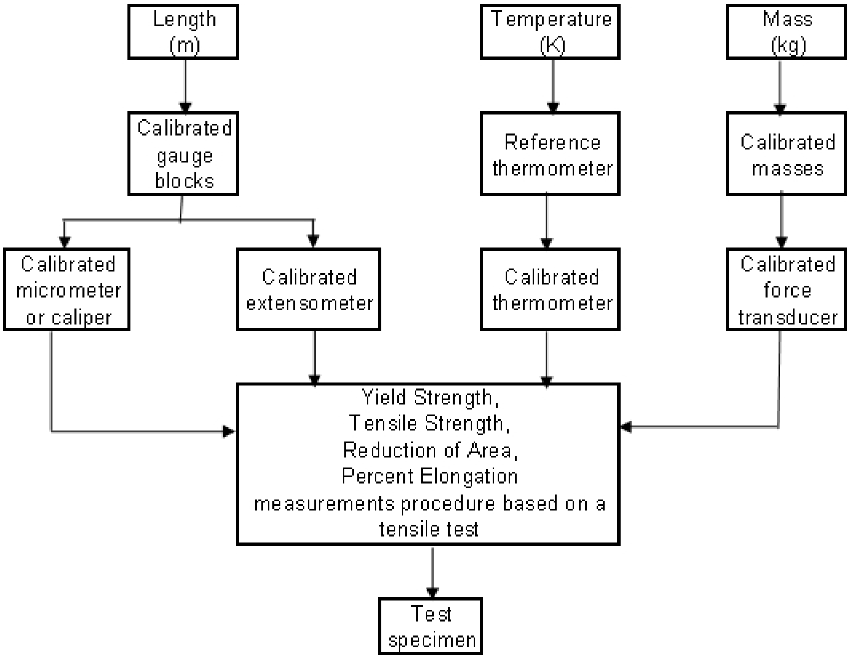

Figure 1. Traceability chain linking the measurement of the mechanical properties of a test specimen using a uniaxial tensile test to the relevant units of the SI

Table 1. The results of tensile test specimens

No	Yield Strength YS	Tensile Strength TS	Percent Elongation PE	Reduction of Area RA
	MPa	Mpa	%	%
1	1189,4	1289,2	16,3	20,7
2	1197,4	1295,1	15,6	20,1
3	1183,8	1283,2	16,3	19,4
4	1197,7	1299,5	16,3	20,8
5	1177,3	1277,2	16,3	19,8
Average Value	1189,12	1288,84	16,12	20,16
Standard Deviation	8,81	8,95	0,28	0,59
Test Uncertainty, %	0,66	0,62	1,54	2,64

Also statistical analysis of the test results was done with the purpose of assessing their reliability. The uncertainty calculations were made by using different references. The uncertainty in measurements of the test parameter (U_{test}) is calculated by standard distribution formula.

$$U_{test} = \frac{S}{\sqrt{n}} \quad (k=2)$$

U_{test} : Test Uncertainty
S: Standard Deviation
n: number of test

Standard uncertainty of Yield Strength (U_{YS}) measurements are consist of uncertainities of; specimen values(U_{test}), force device (U_f), extensometer (U_{ext}), mean area(U_{ma}) and gage length(U_{gl}). Uncertainty formula is:

$$U_{YS} = 2x\sqrt{u_{test}^2 + u_f^2 + u_{ext}^2 + u_{ma}^2 + u_{gl}^2}$$
(k=2)

Standard uncertainty of Tensile Strength (U_{TS}) measurements are consist of uncertainities of; specimen values(U_{test}), force device(U_f) and mean area(U_{ma}). Uncertainty formula is:

$$U_{TS} = 2x\sqrt{u_{test}^2 + u_f^2 + u_{ma}^2} \quad (k=2)$$

Standard uncertainty of Reduction of Area (U_{RA}) measurements are consist of uncertainities of; specimen values(U_{test}), caliper(U_c), initial(U_{ima}) and final(U_{fma}) mean area. Uncertainty formula is:

$$U_{RA} = 2x\sqrt{u_{test}^2 + u_c^2 + u_{ima}^2 + u_{fma}^2}$$
(k=2)

Standard uncertainty of Percent Elongation (U_{PE}) measurements are consist of unncertainities of; specimen values(U_{test}), machine resolution(U_r), caliper(U_c), initial(U_{ifl}) and final mean length(U_{fml}). Uncertainty formula is:

$$U_{PE} = 2x\sqrt{u_{test}^2 + u_r^2 + u_c^2 + u_{iml}^2 + u_{fml}^2}$$
(k=2)

Table 2. Summary of standard uncertainty components for Yield Strength

Source of Uncertainty	**Estimated Value**		**Distribution**	**Divider**	**Sensitivity coefficients**	**Standard Uncertainty,%**
Specimen value	0,66	%	Normal	2	1	0,33
Force	1,00	%	Normal	2	1	0,50
Extensometer	0,50	%	Normal	2	1	0,25
Mean Area	0,28	%	Normal	2	1	0,14
Gage Length	0,04	%	Normal	2	1	0,02
Combined uncertainty of measurement						0,66
Expanded uncertainty of (U_{ys})			k = 2 (P = 95 %)			1,33

Table 3. Summary of standard uncertainty components for Tensile Strength

Source of Uncertainty	**Estimated Value**		**Distribution**	**Divider**	**Sensitivity coefficients**	**Standard Uncertainty,%**
Specimen value	0,62	%	Normal	2	1	0,31
Force	1,00	%	Normal	2	1	0,50
Mean Area	0,28	%	Normal	2	1	0,14
Combined uncertainty of measurement						0,60
Expanded uncertainty of (U_{TS})			k = 2 (P = 95 %)			1,21

Table 4. Summary of standard uncertainty components for Reduction of Area

Source of Uncertainty	**Estimated Value**		**Distribution**	**Divider**	**Sensitivity coefficients**	**Standard Uncertainty,%**
Specimen value	2,64	%	Normal	2	1	1,32
Caliper	0,14	%	Normal	2	1	0,07
Initial Mean Area	0,28	%	Normal	2	1	0,14
Final Mean Area	0,28	%	Normal	2	1	0,14
Combined uncertainty of measurement						1,33
Expanded uncertainty of (U_{RA})			k = 2 (P = 95 %)			2,67

Table 5. Summary of standard uncertainty components for the Percent Elongation

Source of Uncertainty	**Estimated Value**		**Distribution**	**Divider**	**Sensitivity coefficients**	**Standard Uncertainty,%**
Specimen value	1,54	%	Normal	2	1	0,77
Machine Resolution	0,10	%	Rectangular	0,577	0,5	0,09
Caliper	0,14	%	Normal	2	1	0,07
Initial Mean Length-extensometer	0,50	%	Normal	2	1	0,25
Final Mean Length-extensometer	0,50	%	Normal	2	1	0,25
Combined uncertainty of measurement						0,85
Expanded uncertainty of (U_{PE})			k = 2 (P = 95 %)			1,71

Table 6. Summary of mechanical properties and uncertainty values

Mechanical Properties	Symbol	Results		Uncertainty, % (k = 2)
Yield Strength	YS	1189,12	MPa	± 1,33
Tensile Strength	TS	1288,84	MPa	± 1,21
Reduction of Area	RA	16,13	%	± 2,67
Percent Elongation	PE	20,16	%	± 1,71

3. RESULT AND CONCLUSIONS

As seen in the results given in tables of previous section;

1. Uncertainty of specimen is the main factor of total measurement uncertainty in most of mechanical properties. As seen in Table1 to Table5 uncertainty values coming from specimen varies from 50 to 90% of the total uncertainty for the different mechanical properties.
2. Uncertainty coming from force instrument is the main factor of total uncertainty in yield and tensile strength. This shows the importance of the force value on the strength values. To reduce uncertainty value coming from force instrument; the devices must be maintained and calibrated periodically and the devices that have low uncertainty, should be preferred.
3. The uncertainty associated with the extensometer represented the variation up to 38% of the total uncertainty of dimensional change in test samples. The extensometer is the fundamental instrument for determination of the limit of yield strength of the materials. So it should be attached to surface of the specimen previously to get true nominal capacity.

This study shows effect of quality and uniformity of specimen and also error caused by operator has a definite effect on total measurement uncertainty in most material tensile testing.

In addition to specimen, approved testing method, steady force measuring system and periodically calibrated machine lowers the total measurement uncertainty.

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