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Research Article

Calculation of measurement uncertainty for elasticity module of automobile deadening panels [#]

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Abstract: All manufacturers need to develop their products applying test to get better performance and higher quality them before distributing the competitive market. In order to get long working life without losing performance of the materials, different tests are applied on the material to determine modulus of elasticity and rupture/deformation stresses using material testing machines. In order to develop repeatable and high quality products, test results should be known very well. The measurement uncertainty of test results should be calculated adding the all influencing parameters during tests.
In this study, parameters which have effects on the quality of compression testing are causes the increase measurement uncertainty of test results, Standard measurement uncertainty of modulus of elasticity should be calculated to give reliable results to customer.
This study details the work, findings and calculations of the measurement uncertainty of automobile deadening panels after compression testing on the material are presented. Influencing uncertainty parameters on the test results are taken into account and explained in detail.

1. Introduction

The material supply and related industries are worth trillions US $ each year over the world. In all cases, the measurement of the material properties by mechanical testing is very important for use and developing new materials.

The quality of the mechanical parts such as bolts, machines elements, aircraft parts etc. is controlled by testing the material properties (such as the tensile strength, compression strength, elasticity module, lower yield stress, proof stress, impact strength, Brinell, Rockwell and surface hardness, elongation after fracture). Each of these properties is measured according to an appropriate test method for tensile properties. [1]. Several tests are necessary during development process of the products. The compression and tensile testing are applied on the materials used in research studies, in civil engineering, military applications, materials development, automotive, ship and aircraft industry. In order to make precise and accurate compression testing, all influencing parameters on the test results must be analyzed very well. In this way, such parameters can be controlled and lower measurement uncertainty can be achieved in order to make true conformity assessment for defected parts resulting in less scrap.
For the acoustic insulation inside vehicle bodywork, specify characteristics the panel materials used. Fiat procedure specification 9.55655 is defined the modes and the equipment to be used for testing such characteristics [2]. However, the available procedure for panel materials does not provide an uncertainty budget and do not present the calculation of measurement uncertainty.

This study explains the calculations of measurement uncertainty for compression testing of panel materials. The calculation model can also be used for compression testing of all other materials.

2. Material and Test Conditions

Porous material properties and photo are given bellow [2]. The porous material specimens are prepared circular shape at diameter of 99 mm for compression test.

Table 1. Properties of porous specimens

Properties	Material	
	Porous 700	Porous 1000
Mass (g/m^2)	> 700	> 1000
Thickness (mm)	12 to 15	17 to 21

Figure 1. Test specimens

The porous material specimens were prepared mechanically in accordance with the Fiat procedure specification 9.55655 [2]. The experiments conducted with a Zwick Z250 tensile machine at the National Metrology Institute in TUBITAK. The force accuracy class of the machine was “class 0.5”

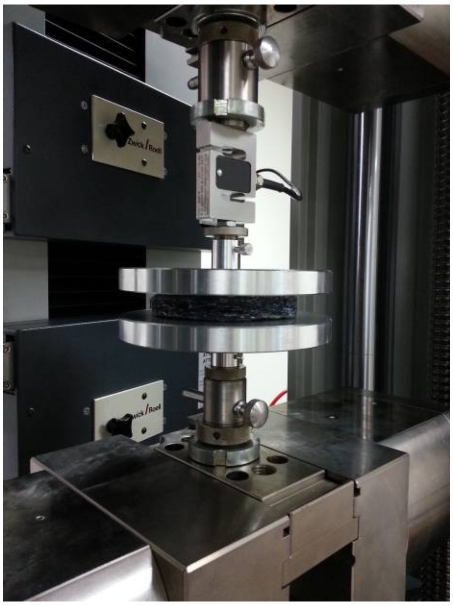

Figure 2. Test specimens, test conditions and test machine

according to EN ISO 7500-1 standard [3]. Its extensometer was used together with machine for strain measurement. The extensometer accuracy class of the machine was "class 0.5" according to EN ISO 9513 standard [4]. All tests performed at 23 ± 1°C and 50 ± 10 % humidity. The compression test was carried out with test speed of 5 mm/min.

3. Uncertainty Analysis

Material testing machine is calibrated according to EN ISO 7500-1 for requirements of its force measuring system [3]. The calibration certificates of the testing machine mentions only that they meet EN ISO 7500-1 standard requirements for force measuring system of the testing machine. This standard requires that the indication of the testing machine has to be correct to within specified limits given in those standards [5]. Adding, extensometer of material testing machine is calibrated according to EN ISO 9513 [4].

In order to determine combined uncertainty of test results of porous material or any materials first take in to account the calibration uncertainties of the testing machine used to measurement of compression force and extensometer used for measurement of thickness of tested specimens. Then, the standard deviation of the uncertainty of elasticity module measurement is calculated in the 3 test results for porous 700 materials.

Figure 3. Measurement of test specimens dimensions by caliper

Sensitivity coefficients are essentially conversion factors that allow one to convert the units of an input quantity into the units of the measured [5-9]. Sensitivity coefficients measure of how much change is produced in the measured 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 c_i of the input quantity x_i is given by which expresses mathematically how much f changes given an infinitesimal change in x_i [5-9].

$$c_i = \frac{\partial f}{\partial c_i} \qquad (1)$$

In this case, it can be determined the model function of the elasticity module for find to the measurement uncertainty of elasticity module as below [2];

$$E = \frac{h \bullet \Delta F}{A \bullet \Delta h} = \frac{h \bullet \Delta p}{\Delta h} \qquad (2)$$

$$\Delta P = \frac{\Delta F}{A} \qquad (3)$$

Where E is the elasticity module in N/m^2, h is sample thickness in m, ΔF is load variation on sample in N, A is sample surface in m^2, h_i is variation of h thickness due to F variation of load in m, ΔP is pressure variation of F load on sample in N/m^2.

The sensitivity coefficients, c_h , $c_{\Delta p}$ and $c_{\Delta h}$ can be obtained easily as follows:

$$c_h = \frac{\partial E}{\partial h} = \frac{\Delta p}{\Delta h} \quad (4)$$

$$c_{\Delta p} = \frac{\partial E}{\partial \Delta p} = \frac{h}{\Delta h} \quad (5)$$

$$c_{\Delta h} = \frac{\partial E}{\partial \Delta h} = -\frac{h \bullet \Delta p}{\Delta h^2} \quad (6)$$

Once, all of the values of the uncertainty contributor u_i have been estimated and reduced to one standard deviation, and the sensitivity coefficients c_i have been determined. It is usually necessary only to "root-sum-square" their products, i.e., take the square root of the sum of the squares of the uncertainty estimates multiplied by the squares of their corresponding sensitivity coefficients, in order to determine combined standard uncertainty u_c

$$u_c = \sqrt{\left[((c_1.u(x_1))^2 + ((c_2.u(x_2))^2 + ...\right]} = \sqrt{\sum_{i=1}^{N} [c_i \bullet u(x_i)]^2} \quad (7)$$

Measurement uncertainty for elasticity module (u_E) can be written as follows,

$$u_E = \sqrt{c_h^2 \times u_h^2 + c_{\Delta p}^2 \times u_{\Delta p}^2 + c_{\Delta h}^2 \times u_{\Delta h}^2} \quad (8)$$

c_h : Sensitivity coefficient for initial sample thickness measurement

$c_{\Delta p}$: Sensitivity coefficient for difference pressure measurement

$c_{\Delta h}$: Sensitivity coefficient for difference thickness measurement

u_h : Measurement uncertainty of initial sample thickness measurement taken directly from calibration certificate of extensometer of material testing machine

$u_{\Delta p}$: Measurement uncertainty of pressure measurement taken directly from calibration certificate of force of material testing machine

$u_{\Delta h}$: Measurement uncertainty of thickness measurement taken directly from calibration certificate of extensometer of material testing machine

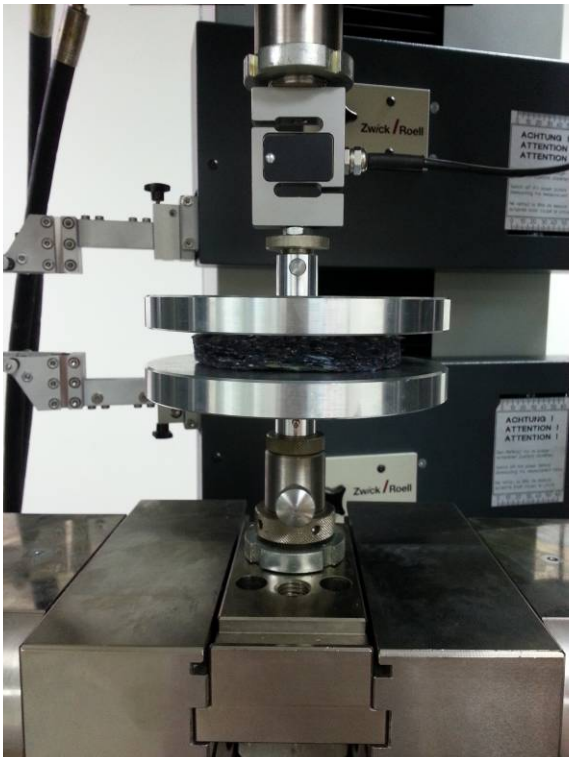

Figure 4. Measurement of test specimen during compression testing

The two error sources that are measurement of specimens' thickness and measurement of compression force have already been added into the measurement uncertainty calculations. The calculations of other effects are very difficult due to determination of all influencing parameters. Instead of uncertainty calculations for listed all error sources, the standard deviation of the test results can be used to calculation of measurement uncertainty of all other parameters mentioned in the listed error sources. The test data covers the influencing parameters. The standard deviation of test data gives the standard uncertainty of testing (u_{test}) as a combined uncertainty of the above error sources;

$$u_{test} = \frac{s_{test}}{\sqrt{n_{test}}} \quad (9)$$

S_{test} : standard deviation of the test results of five test bars for tensile strength,

n_{test} : number of test results for tested bars

$$s_{test} = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \overline{X}_{test})^2}{n_{test} - 1}} \quad (10)$$

X_i : value of the tensile strength measurement

$\overline{X}_{test}$: Average of the tensile strength measurement

Then, combined uncertainty (U_c) can be calculated the measurement uncertainty for elasticity module (u_E) and test uncertainty (u_{test}) as shown in below;

$$u_c = \sqrt{u_E^2 + u_{test}^2} \quad (11)$$

Estimated expanded uncertainty (U_{exp}) can be calculated as;

$$U_{\exp} = k \times u_c \quad (12)$$

4. Sample Calculations

The test result of the three test specimens tested in material testing machine are given in Table 2. The calculation of measurement uncertainties of the test results using equations from (2) to (12) are given in Table 3.

u_h and $u_{\Delta h}$ are taken from calibration certificate of extensometer of material testing machine. $u_{\Delta p}$ is also taken from the calibration certificate of material testing machine.

The average elasticity modules are 1949,03 – 3004,84 - … N/mm^2. The elasticity module and uncertainty in the result of test no 1 are shown 1949,03 N/mm^2 ± 74,09 N/mm^2.

5. Conclusion

Analysis of the uncertainty sources incorporated during measurements of the compression test of the porous material has been performed. All sources of uncertainty have been investigated in detail. Examples illustrate the importance of uncertainty sources relevant to the variability of the parameters measured from a series of tests specimens in same porous material. The test results were reported with the calculated uncertainty values, and their impact is studied. It is expected that this will provide the automotive industry with selecting better material for safety and longer life of their end product as well as conducting further improvements. Besides, the given uncertainty calculation model in the measured properties following specific test procedures can be a guide for better testing procedures.

References

[1] Evolving Needs for Metrology in Material Property Measurements, Report of the CIPM Working Group on Materials Metrology (WGMM), October 2007

[2] Fiat Group Automobiles normazione, FLAT AND PREFORMED SOUND DEADENING PANELS PROCUREMENT SPECIFICATION, 9.55655, Date:01/17/2008

[3] EN ISO 7500-1, Metallic materials – Verification of static uniaxial testing machines, Part 1: Tension/compression testing machines-Verification and calibration of the force-measuring system, 2004

[4] EN ISO 9513, “Metallic materials − Calibration of extensometers used in uniaxial testing”. 2012

[5] Room Temperature Tensile Testing: A method for Estimating Uncertainty of measurements, http://midas.npl.co.uk

[6] Aydemir, B., Fank, S., Malzeme Deneylerinde (Çekme-Eğme) Ölçüm Belirsizliğinin Hesaplanması Eğitim Dokümanı - G2KV-100, 2011, G2KV-100, Haziran 2011, TÜBİTAK UME

[7] Fank, S., Aydemir, B., Calculation of measurement uncertainty for cellulose based transformed board material in tensile testing, 2012, International Journal of Metrology and Quality Engineering, Volume 3, Issue 01, January 2012, pp 15-18

[8] Aydemir, B., Fank, S., Proficiency test report for tensile and flexural strength, 2011

[9] Aydemir, B., Fank, S., Vatan, C., Proficiency technical protocol for tensile and flexural strength, 2011

Table 2. Compression test results for porous specimens

Sample No	Test No	Load pressure	Force to be applied	Relevant thickness	Present load increments	Relevant settling increments	Elasticity Module
		p, [N/m^2]	F, [N]	h_i [mm]	Δp, [N/m^2]	Δh [mm]	E, [N/m2]
1	1	100	0,770	20,19	100	1,01	1999
	2	200	1,539	19,18	400	2,69	3002
	3	500	3,849	17,50	900	4,22	4306
	4	1000	7,697	15,97	1400	5,21	5425
	5	1500	11,546	14,98	1900	5,93	6469
	-	2000	15,395	14,26			
2	1	100	0,770	20,19	100	1,07	1887
	2	200	1,539	19,12	400	2,84	2844
	3	500	3,849	17,35	900	4,45	4083
	4	1000	7,697	15,74	1400	5,49	5149
	5	1500	11,546	14,70	1900	6,25	6138
	-	2000	15,395	13,94			
3	1	100	0,770	20,20	100	1,03	1961
	2	200	1,539	19,17	400	2,55	3169
	3	500	3,849	17,65	900	4,36	4170
	4	1000	7,697	15,84	1400	5,28	5356
	5	1500	11,546	14,92	1900	6,06	6333
	-	2000	15,395	14,14			

Table 3. Calculations of sensitivity coefficients and uncertainties of the testing

Test No	$E_{average}$	E_{STD}	u_{test}	c_h	$c_{\Delta p}$	$c_{\Delta h}$	u_h	$u_{\Delta p}$	$u_{\Delta h}$	u_E	u_C	U_{exp}
1	1949,03	57,02	32,92	97,09	19,61	-1904,04	0,10	0,50	0,01	16,98	37,05	74,09
2	3004,84	162,50	93,82	156,86	7,92	-1242,60		2,00	0,01	27,44	97,75	195,50
3	4186,34	112,20	64,78	206,42	4,63	-956,36		4,50	0,02	36,11	74,17	148,33
4	5310,01	143,98	83,13	265,15	3,83	-1014,41		7,00	0,03	46,38	95,19	190,39
5	6313,35	166,51	96,13	313,53	3,33	-1045,10		9,50	0,03	54,85	110,68	221,36