Andrius LUKOŠIUS

RELIABILITY OF MEASUREMENT RESULTS OBTAINED DURING TESTING OF BUILDING PRODUCTS FOR REACTION TO FIRE PERFORMANCE

Summary of Doctoral Dissertation
Technological Sciences, Measurement Engineering (10T)

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Vilnius **2005**

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Andrius LUKOŠIUS

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General characteristic of work

Topicality of work

Nowadays the harmonization within the fire field raise and we can feel increasing demands for accredited fire-testing laboratories to guarantee that the tests give repeatable results. In the new European classification system it is important to have high quality on fire testing within the whole of Europe.

The quality assurance standard ISO/IEC 17025 demands that accredited laboratories have control over measurement uncertainty for the methods used within the laboratory.

Nowadays there is quite complicated situation because of evaluation of measurement uncertainty in fire testing. For the fire testing method which have a formulas for calculating final results there are possibilities to calculate measurement uncertainty using members of formula as main sources of measurement uncertainty. But sometimes in this way calculated measurement uncertainties don't show real situation about the precision of the measurement results because there are made a lot of "if" and assumptions.

For fire test methods like EN/ISO 11925-2 "Ignitability of building products subjected to direct impingement of flame" where the result of the test is "the material ignites/does not ignite", it is very difficult, if not impossible, to determine the total uncertainty for the test result. Reference materials would be one way of achieving this.

Anyone who has experience in fire testing knows that most fire test methods don't have a good precision and repeatability.

Purpose and tasks. The purpose of the doctoral dissertation is to analyse two main fire test methods and to improve precision and reliability of test results. To realize the purpose the following scientific and technical tasks have been dealt:

- to determine the most optimal method of measurement uncertainty evaluation for fire test methods;
- to examine the reliability of two main fire test methods on the ground of Round Robin test results;
- to create candidate reference materials for two main fire test methods;
- to create main aspects and principles for development methodology of reference materials creation and measurement uncertainty evaluation for reaction to fire tests methods;

Scientific originality. For the first time the reliability of SBI test method has been evaluated, i.e. measurement uncertainty, sources of measurement uncertainty, repeatability and reproducibility standard devations has been analysed in detail and sources of measurement uncertainty which contribute most to the uncertainty has been determined. Candidate reference materials for

SBI and EN ISO 11925-2 test methods have been proposed and criteria for further development of reference materials for these tests methods have been determined. The most optimal method of measurement uncertainty evaluation has been determined and principles for development methodology of reference materials creation and measurement uncertainty evaluation for reaction to fire tests methods has been presented. Additional calibration requirements for SBI and EN ISO 11925-2 test equipments has been created and possible improvements of test method and test equipment have been proposed.

Practice value. Evaluated measurement uncertainty of SBI test method will be useful information for European fire laboratories. Value of measurement uncertainty will give valuable additional information about SBI test method precision. Calculated standard uncertainties of separate sources will be useful for laboratory staffs which perform SBI equipment calibration, maintenance.

Proposed candidate reference materials and criteria will be valuable information for further development of reference materials in the future. These proposed materials should be used in interlaboratory comparison tests and in fire laboratories on purpose maintain internal quality.

In dissertation given principals and aspects of evaluation of measurement uncertainty and development of reference materials will be valuable background for preparation guidelines and standards of uncertainty evaluation and development of reference materials in reaction to fire testing field.

Approval of work. 2 articles under review and 5 articles in different conference proceedings were published on research field of the thesis. The main results of the work were presented at the international and national conferences:

- 3th Conference of Lithuanian junior scientists „Lithuania without Science – Lithuania without future“ – „Mechanical and material engineering, industry engineering and management“. Vilnius, Lithuania. October 12 – 13, 2000.
- International Conference „Mechanika-2003“. Kaunas, Lithuania. April 3 – 4, 2003.
- 4th International Conference „Measurement 2003“. Smolenice, Slovak Republic. June 15 – 19 d. 2003.
- 14th Scientific Symposium with International Participation "Metrology and metrology assurance 2004". Sozopol, Bulgaria. September 14-18, 2004.
- 8th International Symposium on Measurement and Quality Control in Production held on October 12-15, Erlangen, Germany, 2004.

Size and structure of dissertation. The doctoral dissertation consists of introduction, 4 chapters and conclusion, list of 61 literature sources and 7 presentations according to the dissertation theme list. The size of work is 87 pages including 50 figures and 34 tables.

Work contents

The first chapter gives a review of the state of the art of measurement uncertainty evaluation in fire testing field. The new European fire classification system of construction products and building elements, two main test methods of this system are described. Detail analysis of existing methods of measurement uncertainty evaluation is presented. It was found out that in fire testing field quite complicated situation since real precision of most test methods is unknown. The analysis of literature shows that heat release rate obtained in SBI test is one of the most important parameter of new reaction to fire classification system and that there wasn't real measurement uncertainty evaluation for this parameter. Survey of existing reference materials in fire test field shows that only several materials were certified as reference materials for use in certain fire test. It was found out that main part of them have been developed in USA. Also it was cleared up that only one European test method has certified reference material.

The purpose and the tasks of work have been formulated after the critical and exhaustive literature analysis.

The second chapter describes detail measurement uncertainty evaluation and detail analysis of HRR measurement uncertainty sources. Also detail analysis of SPR measurement uncertainty calculation is given. The evaluation results for HRR, SPR are given in 1 and 2 tables.

The results in these tables clearly indicate which parameters in the SPR and HRR measurements that contribute most to the uncertainty. For the HRR, the oxygen concentration contributes most followed by the E-factor and the mass flow. The uncertainty in the oxygen measurement depends on the instrument used and the size of the fire. The E-factor is independent of the experimental apparatus but depends on the fuel used. If the fuel is known then the uncertainty decreases. The uncertainty in the velocity profile in the duct and the bi-directional probe constant are the most important for the mass flow.The uncertainty in the velocity profile can be decreased by designing the duct correctly and determining the velocity profile more precisely.

For the SPR the most important factors are the calibration of the filters used for calibrating the equipment together with the temperature sensitivity of the photocell. The most interesting result is the very high uncertainty on the low SPR levels (Fig 1), a fact that should be considered when classifying products

Table 1. HRR uncertainty (35 kW and 50 kW)

Quantity, x_i	Relative error, (%)		Probability distribution	Relative standard uncertainty, $u(x_i)/x_i$, (%)		Sesivity coefficient, $c_{r,i}$		Contribution to combined relative uncertainty of HRR measurement $c_{r,i} \cdot u(x_i)/x_i = u_i(y)$ (%)	
	35 kW	50 kW		35 kW	50 kW	35 kW	50 kW	35 kW	50 kW
q_m				1.7	1.7	1	1	1.7	1.7
X_{O_2}				0.078	0.082	-81	-53	6.3	4.2
X_{CO_2}	2	2	triangular	0.82	0.82	-0.18	-0.18	0.15	0.15
E	5	5	triangular	2.0	2.0	1	1	2.0	2.0
α	10	10	rectangular	5.8	5.8	-0.017	-0.025	0.1	0.1
$X^0_{H_2O}$	150	150	triangular	61.2	61.2	-0.0038	-0.0038	0.2	0.2
M	1	1	rectangular	0.58	0.58	1	1	0.6	0.6
Combined expanded relative standard uncertainty								13.5%	10.0%

Table 2. SPR uncertainty (SPR = 0.5 m^2/s)

Quantity, x_i	Relative error, (%)	Probability distribution	Relative standard uncertainty, $u(x_i)/x_i$, (%)	Sesivity coefficient, $c_{r,i}$	Contribution to combined relative uncertainty of HRR measurement $c_{r,i} \cdot u(x_i)/x_i = u_i(y)$, (%)
Soot (I)	0.011	rectangular	0.063	$1/\ln(I_0/I)$	0.08
Calibration (I)	0.027	rectangular	0.016	$1/\ln(I_0/I)$	0.20
Temp. Influence (I)	1.08	rectangular	0.63	$1/\ln(I_0/I)$	7.8
Filter (I)	1.0	rectangular	0.58	$1/\ln(I_0/I)$	7.2
Noise (I)	0.005	t-distribution	0.0031	$1/\ln(I_0/I)$	0.04
Drift (I)	0.005	t-distribution	0.0031	$1/\ln(I_0/I)$	0.04
Volume flow	-	-	1.6	1	1.6
Temperature influence (L)	0.13	rectangular	0.07	1	0.07
Combined expanded relative standard uncertainty					21.5 %

that produce little smoke.

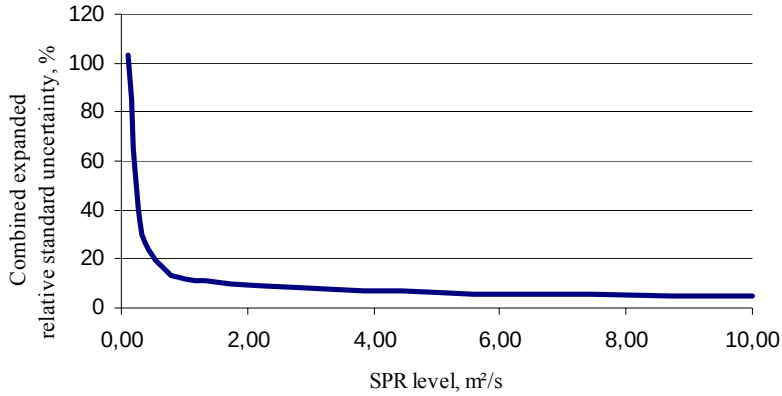


Fig 1. Combined expanded relative uncertainty dependence on SPR level

In the fourth part of the second chapter CFD models developed with two commercial codes Fluent and FDS are described. The models simulate the SBI test and they are able to describe the characteristics of the test and the influence of changed testing conditions (Fig 2 and 3).

Calculations with Fluent and FDS models show significant changes in predicted temperature and velocity fields in the burning room and in the measurement section for changes in ventilation and different ambient air temperatures. All calculations were performed with non combustible specimens. Data from several laboratories for 210 to 270 s of the test (base line) has been selected from round robin tests. They show the connection of ventilation and temperatures in the measurement section as predicted.

Changed temperatures in the burning room and on specimens may lead to changed ignition conditions and may influence the rate of heat release which is used for classification. Total heat release of specimen in first 600 s of exposure to the main burner flames, THR_{600s}, has been chosen as characteristic benchmark to estimate impact of changed testing conditions on test results. Some selected round robin data seem to show the impact of ventilation on heat release of the specimen; other selected data doesn't show the connexion that clear. The many parameters, ventilation, ambient air temperature and humidity make it difficult to see the impact of one parameter on the test results without further testing.

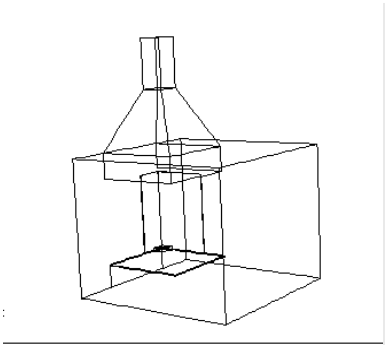


Fig 2. Fluent model geometry

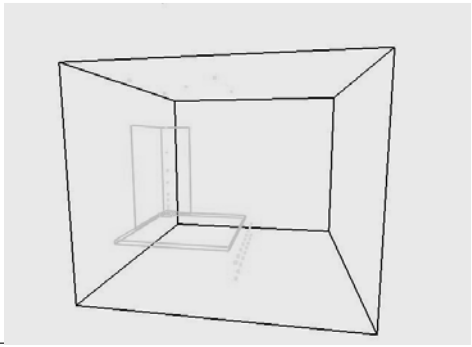


Fig 3. FDS model geometry

Calculations with Fluent and FDS models show particularly impact on temperature and velocity fields in case of special combinations of the parameters ventilation and ambient air temperature. Two extreme cases, combination of high ventilation with low ambient air temperatures in contrast to low ventilation with high ambient air temperatures have been investigated. Results give reason to think about narrowing the ranges for ventilation and ambient air temperatures in the standard.

In the fifth part of the second chapter performed experimental tests to investigate the influence of varying this extraction rate between 200 l/s and 1000l/s are presented. Both wooden fiberboard and PIR are considered. Additionally, surface temperature measurements were performed for the different extraction rates, with an inert specimen, in order to compare the results to what is obtained from numerical simulations. Additionally, numerical simulations were carried out.

For wooden fiberboard, higher values are observed for THR and for FIGRA at the reduced extraction rate. This may be explained by the fact that a sufficient amount of O_2 is present for any extraction rate and that the chemistry in the flames is sufficiently fast to obtain complete combustion. By increasing the extraction rate, the flame geometry changes (Fig 4), reducing the view factor for radiative heat transfer. Moreover, more heat is removed by convection from the flame region, decreasing the energy available for gasification of the material and slowing down the pyrolysis of the material. Both effects lead to lower FIGRA values, but the estimated class does not change.

For PIR, the combustion process is completely different, as mentioned above. Clearly, the flame shape again changes when varying the extraction rate

(Fig 5), but there is no clear trend in the Figra as function of the extraction rate. Note that the flame region is much smaller than for fiberboard and the values of THR and Figra are much lower. Also note that there is a difference in the estimated class for PIR for the lowest extraction rate, indicating a reduced reproducibility.

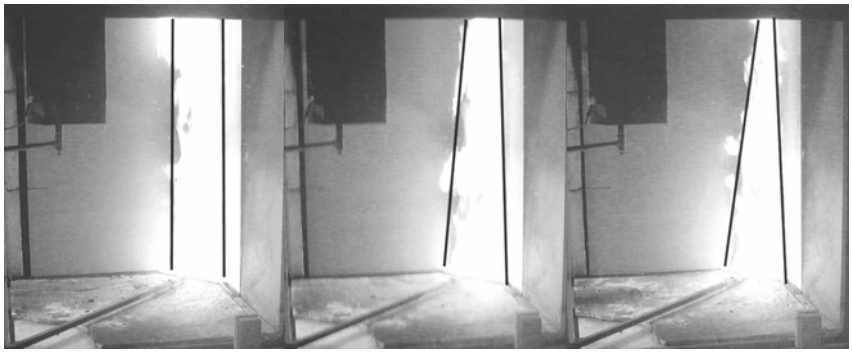


Fig 4. Photographs during the fiberboard test, five minutes after ignition of the main burner

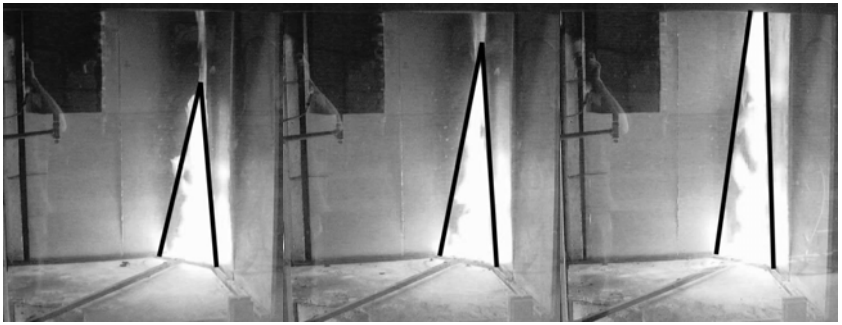


Fig 5. Photographs during the PIR test, five minutes after ignition of the main burner

The Smogra classification does not seem entirely reproducible for wooden fiberboard, when the extraction rate is reduced. One reason can be that, at low suction rates, not all the smoke is removed from the test room. Indeed, some materials, like wooden fiberboard, generate a lot of smoke during the burning process. Towards the end of the test, the room is filled with smoke that did not pass through the measuring sections, situated in the exhaust duct. As a

consequence, Smogra results can become questionable, especially at very low suction rates. This implies that reducing the extraction rate does not seem to be appropriate. This is not confirmed for PIR, though, where even more smoke is produced and there is no difference in estimated classification with respect to smoke production. One reason may be that the smoke remains more in the neighborhood of the corner and is as such more easily evacuated.

As a final remark, it is noted that the deviations between the measured values, reported in all the tables, are the smallest for the highest extraction rate. This seems logical, since the process is better controlled, thus improving the reproducibility of the experiments. This is an argument in favor of increasing the extraction rate, rather than decreasing it. Surely, two sets of experiments is much too little to make this a hard statement, but the indication is in that direction. A counter-argument is that increasing the extraction rate enlarges the difference from a natural fire and leads to reduced accuracy for the oxygen depletion technique. Finally, somewhat ironically, it is noted that the largest deviations are observed for the extraction rate in EN13823:2002.

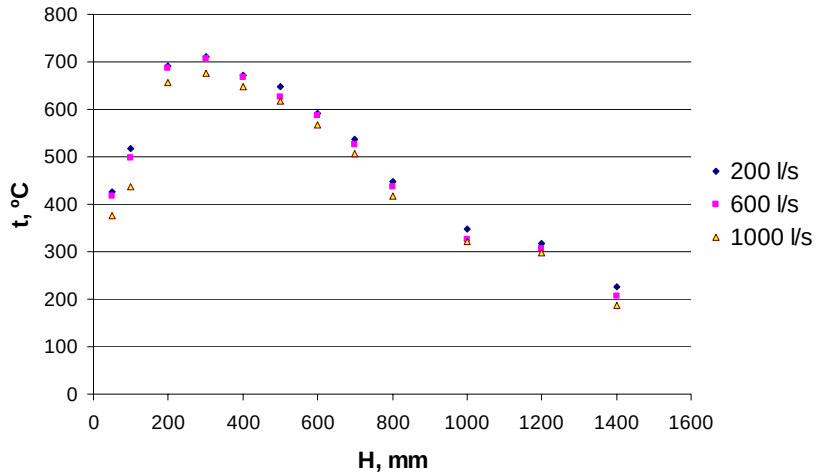


Fig 6. Measured temperature values in the corner for the three extraction rates

The influence of the extraction rate on the burner flame shape and subsequently the incident heat flux onto the specimen was examined with inert samples (steel plates). Figure 6 shows the profiles in the corner for the three extraction rates. There is hardly any influence from the extraction rate on the

shape of the profiles. The position of maximum temperature remains unaltered, around 300mm above the burner. The temperatures decrease on all positions as the extraction rate increases. Probably, more heat is convected away. This tendency is confirmed in the numerical simulations (see further).

In the sixth part of the second chapter the results of numerical simulatios are presented. Figure 7 shows the computational mesh, containing 60000 tetrahedral cells. The numerical solutions were obtained with the commercial CFD package FLUENT.

Table 3. Measured and calculated temperatures (K) at different positions

Height, mm	200 l/s		600 l/s		1000 l/s	
	Eks.	Mod.	Eks.	Mod.	Eks.	Mod.
100	517	80	497	129	437	134
600	597	889	587	637	577	591
1200	327	892	317	757	297	713

Table 3 gives measured and computed temperatures in the corner at different heights. Since the inlet fuel temperature is set to environment temperature, the simulated temperatures are far too low close to the burner. Further, it is noted in figure 8, showing isotherms, that combustion takes place, further away from the burner than what is experimentally observed (figure 6): indeed the temperatures decrease in the experiments from a height of 300 mm, while numerically, the values at 1200 mm are higher than the ones at 600 mm.

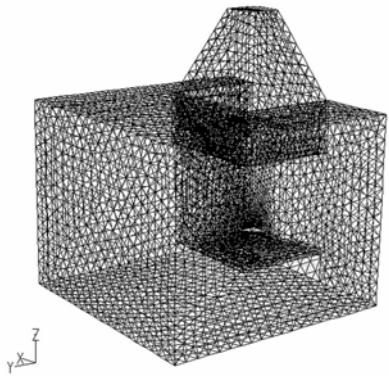


Fig 7. Computational mesh

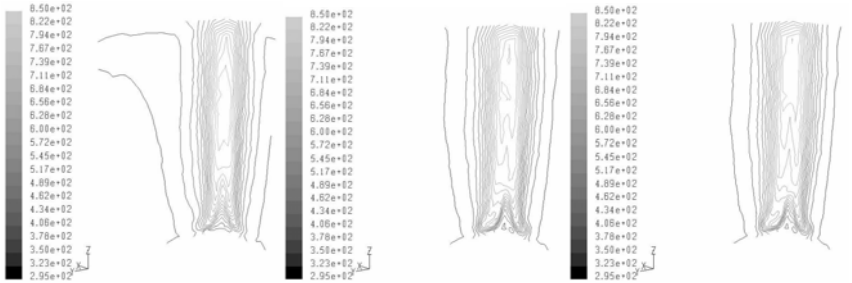


Fig 8. Contours of numerically obtained isotherms for different extraction rates

Note that the simulation results confirm the visual influence of the different extraction rates, shown in figures 4 and 5, where combustion (of the specimen) takes place in the region, predicted in the numerical simulations (which may be a coincidence). Indeed, higher extraction rates pull the flames up to the top, shifting the location of maximum temperature upwards. They also concentrate the burning process to the center of the specimen whereas lower extraction rates intensify lateral flame spread. As the location of the maximum temperature moves up for increased extraction rates, certain materials might behave differently. Lower speeds support low lateral heating, high speeds support ignition above the burner along larger and higher areas of the axis.

In the third chapter the analysis of two SBI Round Robin (table 4) and EN ISO 11925-2 Round Robin test results are given. The accuracy of SBI method as assessed in both round robins do not differ substantially. Only the reproducibility of the smoke measurements shows some improvements.

After analysis of EN ISO 11925-2 Round Robin test results were made following conclusions:

The variability of yes/no response for each product is generally a function of the product itself rather than the method. However, some of the lack of reproducibility could be attributed to the positioning of the ignition source, different areas of impingement may have led to different ignition results.

The values of s_r/m and s_R/m for t_{150} are within acceptable limits for the 15 s and 30 s flame applications, the mean of the standard deviations for all products being comparable with the same parameter achieved in other round robins on fire test methods.

The relative repeatability is also acceptable for this method.

In the same chapter also the simple example of statistical method application for EN ISO 11925-2 test method is given. This example shows how

is easy applying statistical method to determine how many results from test series may be failures that tested product may pass the test.

Table 4. Accuracy data for the 1st (1997) and the 2st (2004) SBI round robin

	$FIGRA_{0,2MJ}$, %	$FIGRA_{0,4MJ}$, %	THR_{600s}, %	SMOGRA, %	TSP_{600s}, %
SBI RR2, 2004					
Average s_r /m	32	38	23	70	17
Average s_R/m	50	63	34	111	34
SBI RR1, 1997					
Average s_r/m	40	48	26	53	20
Average s_R/m	54	62	37	109	48
SBI RR2, 2004					
Average s_r/m	16	20	16	11	17
Average s_R/m	26	31	21	26	34
SBI RR1, 1997					
Average s_r /m	14	15	11	15	18
Average s_R/m	23	25	21	40	44

In the fourth chapter theoretical analysis and initial experimental results of reference materials development for SBI and EN ISO 11925-2 test methods are discussed. PMMA material (Fig 9) was determined as one of the most realistic candidate reference material for small flame test since this material should be very practical in use because of the factors given below:

- homogeneous;
- simple storage;
- simple use, i.e. simple clamping in the specimen holder.

But there were two main disadvantage determined:

- long flame application time to receive ignition (surface expose);
- unstable second part of the flame spread on PMMA surface (the last 75 mm).

It was concluded that these two disadvantages can be eliminated in further comprehensive investigation together with the manufacture, i.e. second part of the flame spread on PMMA surface can be improved making "rough-correct" surface of the spread zone during production process. Also it was concluded that the flame application area should be flat.

During initial development of reference material for ISO EN 11925-2 the criteria for the determination of the candidate reference material and sources of measurement uncertainty have been set, verified and analysed in detail.

Verification results of first main criterion are given in Table 5. Also the possible additional requirement for flame calibration is proposed and developed the flame test arrangement is presented.

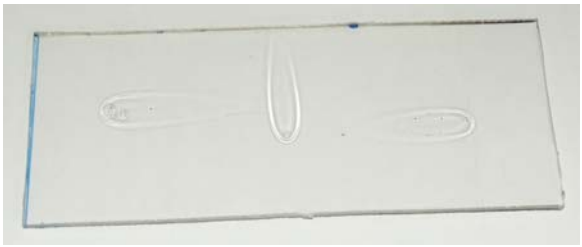


Fig 9. PMMA material after tests



Fig 10. Particle board mounted in SBI trolley

Particle board (Fig 10) was determined as one of the most realistic candidate reference material for SBI method. Based on particle board test results which were obtain during second SBI Round Robin the possible reference values as reference material and statistical parameters have been calculated.

Table 5. PMMA test results

Material PMMA	Mean, s	Standard deviation	Count
Surface exposure (ignition criteria)	40,41	0,139	10
Surface exposure (non-ignition criteria)	31,38	0,0683	10

Table 6. Statistical parameters of particle board test results obtained during second SBI Round Robin

	$FIGRA_{0,4MJ}$, W/s		THR_{600s}, MJ		SMOGRA, m^2/s^2		TSP_{600s}, m^2	
Number of laboratories	30		30		29		29	
Mean value (m)	**454.6**		**26**		**3.8**		**42.9**	
Number of tests	30		30		29		29	
Standard deviation	46.4		2		2.7		13.5	
Coefficient of variation , %	10.21		7.69		71.1		31.47	
95 % confidence interval for mean	± 17,3	**471.9** **437.3**	± 0,75	**26.8** **25.3**	± 1	**4.8** **2.7**	± 5.1	**48.1** **37.8**
95 % confidence interval for individual data point	± 92,7	**547.3** **361.9**	± 4	**30** **21.98**	± 5,4	**9.2** **-1.66**	± 27	**69.9** **15.9**
Separate test results of particle board performed in Lithuania Fire Research Centre								
FRC	456.1		28.5		5.5		26.3	

Conclusions

1. The oxygen concentration contributes most to heat release rate uncertainty followed by E-factor and the mass flow. Smoke production rate measurement results are the most unreliable results in SBI test. Precision of SPR measurement results could be improved by increasing volume flow rate and narrowing the ranges for ventilation and ambient air temperatures in the standard.
2. The calculated reliability indexes of HRR measurement results (13,5 % expanded uncertainty of heat release rate, 38 % repeatability of heat release rate, 54 % reproducibility of heat release rate, 47 % repeatability of total heat release, 71 % reproducibility of total heat release) are medium as compared to the reliability indexes of the other HRR determination methods.
3. It was determined that one of the best evaluation methods of measurement uncertainty for reaction to fire testing field is evaluation using data from Round Robin which were performed with reference material.
4. PMMA and particle board were determined as the most realistic candidate reference materials for SBI and EN ISO 11925-2 methods, respectively. The application of these reference materials will improve the repeatability and reproducibility of test results of two main fire test methods.
5. It was determined that generally problems of repeatability and reproducibility can be traced back to the model fire itself and variation of products.
6. It was determined, that application of statistical methods for the evaluation of the fire test results and for development of fire testing standards improve the precision of test results obtained in fire laboratories.

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5. Lukošius, A. Candidate Reference Materials for the EN ISO 11925-2 Test Method. In: 8th International Symposium on Measurement and Quality Control in Production (Erlangen, Germany, October 12-15, 2004). Dusseldorf: VDI Verlag GmbH, 2004, p. 757-762.
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Matavimo rezultatų patikimumas tiriant statybinių medžiagų degumą (reziumė)

Problemos aktualumas

Didėjant Europoje harmonizacijai gaisrinių bandymų srityje jaučiamas poreikis akredituotoms gaisrinių bandymų laboratorijoms laiduoti, kad bandymų rezultatai patikimi, t.y. pasižymi pakartojamumu bei preciziškumu. Ypač yra labai svarbu naujai Europos statybinių gaminių degumo klasifikacijai turėti gaisrinių bandymų aukštą kokybės lygį visoje Europoje.

Kokybės standartas LST EN ISO/IEC 17025:2003 reikalauja, kad akredituotos bandymų laboratorijos privalo turėti ir taikyti matavimo neapibrėžties įvertinimo procedūras akredituotiems bandymų metodams. Šiuo metu yra ganėtinai komplikuota padėtis dėl matavimo neapiprėžties įvertinimo degumo gaisriniuose bandymuose. Kartais gaisriniams bandymų metodams, kuriems naudojamos matematinės formulės galutinio rezultato skaičiavimui, matavimo neapibrėžtis įvertinama naudojant formulės narius kaip pagrindinius matavimo neapibrėžties sandus. Bet dažniausiai tokiu būdu apskaičiuotos matavimo neapibrėžtys neparodo realios situacijos apie matavimo rezultato preciziškumą, kadangi vertinimo metu daroma daug prielaidų bei “jei”. Gaisrinių bandymų metodams tokiems kaip EN ISO 11925-2, kur bandymų rezultatai išreiškiami žodine forma, t.y. “medžiaga užsidegė/medžiaga

neužsidegė", yra labai sunku, galbūt neįmanoma, nustatyti matavimo rezultatų neapibrėžtį. Kiekvienas, kuris turi patirties gaisrinių bandymų srityje, žino, kad daugelis degumo gaisrinių bandymų metodų nepasižymi geru pakartojamumu bei preciziškumu. Atliekant gaisrinius bandymus dažnai galima gauti gana skirtingus bandymų rezultatus tam pačiam bandymo objektui prie tų pačių aplinkos sąlygų (toje pačioje laboratorijoje). Kai kuriais atvejais bandymų rezultatai gali skirtis net 25%. Gaisriniams bandymams atlikti naudojamos gana tikslios matavimo priemonės, tačiau tai dažniausiai nepadidina rezultatų tikslumo. Šiai dienai dažniausiai gaisrinių bandymų laboratorijų specialistai bei jų klientai neturi informacijos apie naudojamų bandymo metodų preciziškumą.

Šių problemų sprendimui ir skirtas šis darbas, pateikiantis vieno iš sudėtingiausių naujos Europos statybinių gaminių degumo klasifikacijos bandymo metodo matavimo neapibrėžties įvertinimo bei pamatinių medžiagų degumo tipo gaisriniams bandymams kūrimo metodikų pagrindinius principus bei šių metodikų pritaikymo praktikoje pirminius rezultatus.

Darbo tikslas ir uždaviniai

Darbo tikslas – ištirti pagrindinius statybinių medžiagų degumo bandymo metodus ir pagerinti šių metodų tikslumą bei rezultatų patikimumą. Šiam tikslui pasiekti suformuluoti šie uždaviniai:

1. Nustatyti optimaliausią degumo bandymo metodų matavimo neapibrėžties įvertinimo metodiką.
2. Ištirti pagrindinių degumo gaisrinių bandymo metodų patikimumą remiantis tarplaboratorinių lyginamųjų bandymų bei matavimo neapibrėžties rezultatais.
3. Sukurti kandidates pamatines medžiagas pagrindiniams statybinių medžiagų degumo gaisriniams bandymų metodams.
4. Sukurti pagrindinius aspektus bei principus pamatinių medžiagų vystymo-kūrimo bei matavimo neapibrėžties įvertinimo degumo bandymuose metodikoms rengti.

Mokslinis naujumas

1. Pirmą kartą išsamiai išnagrinėtas pagrindinio gaisrinio degumo bandymo metodo rezultatų patikimumas, t.y. įvertinta matavimo neapibrėžtis, išsamiai išanalizuoti matavimo neapibrėžčių sandai, nustatyti sandai, kurie įneša didžiausią įnašą į išplėstinę neapibrėžtį bei išsamiai ištirti pakartojamumo bei atkuriamumo standartiniai nuokrypiai.

2. Nustatyta optimaliausia matavimo neapibrėžties įvertinimo metodika bei pagrindiniai principai pamatinių medžiagų kūrimo bei matavimo neapibrėžties įvertinimo metodikoms rengti.
3. Sukurtos kandidatės pamatinės medžiagos pagrindiniams gaisriniams bandymo metodams bei nustatyti kriterijai tolimesniam pamatinių medžiagų kūrimui šiems bandymų metodams.
4. Sukurti papildomi pagrindinių gaisrinių bandymo metodų įrangos kalibravimo reikalavimai bei galimi patobulinimai.

<u>Gynimui pateikiami darbo rezultatai</u>

1. Gaisrinio bandymo metodo matavimo neapibrėžties įvertinimo rezultatai.
2. Gaisrinio bandymo modeliavimo rezultatai.
3. Kandidatės pamatinės medžiagos gaisriniams bandymo metodams.
4. Pamatinių medžiagų kūrimo gaisriniams bandymo metodams pagrindiniai kriterijai.
5. Gaisrinių bandymo metodų tarplaboratorinių lyginamųjų bandymų rezultatų papildomos statistinės analizės rezultatai.
6. Pagrindiniai principai pamatinių medžiagų kūrimo bei matavimo neapibrėžties įvertinimo metodams rengti.
7. Gaisrinės bandymo įrangos papildomi kalibravimo reikalavimai bei galimi patobulinimai.

Apibendrinant darbe pateiktus eksperimentų, skaičiavimų bei jų analizės rezultatus, padarytos šios išvados:
1. Nustatyta, kad didžiausius įnašus į šilumos išsiskyrimo greičio jungtinę santykinę neapibrėžtį turi deguonies koncentracijos, E faktoriaus bei masės srauto išmetimo vamzdyje neapibrėžtys, todėl siekiant pagerinti šilumos išsiskyrimo greičio matavimo rezultatų tikslumą šiems parametrams turi būti skiriamas didžiausias dėmesys. Taip pat nustatyta, kad dūmų susidarymo greičio matavimų rezultatai prie žemo dūmų susidarymo greičio lygio yra vieni iš nepatikimiausių SBI bandyme. Dūmų susidarymo greičio matavimų rezultatų tikslumas galėtų būti pagerintas padidinant išmetimo tūrinį srautą bei sugriežtinant standarto reikalavimus, t.y. susiaurinant ventiliacijos bei aplinkos temperatūros kitimo ribas.
2. Teorinių bei eksperimentinių tyrimų metu apskaičiuoti SBI bandymu nustatomų degumo parametrų patikimumo rodikliai (13,5 % šilumos išsiskyrimo greičio išplėstinė neapibrėžtis, 38 % šilumos išsiskyrimo greičio pakartojamumas, 54 % šilumos išsiskyrimo greičio atkuriamumas, 47 % suminio šilumos išsiskyrimo pakartojamumas bei 71 % suminio šilumos

išsiskyrimo atkuriamumas) yra vidutiniai lyginant su kitų bandymų metodų turinčių panašų veikimo principą rodikliais.

3. Nustatyta, kad vienas iš idealiausių matavimo neapibrėžties vertinimo metodų gaisrinių bandymų srityje būtų matavimo neapibrėžties įvertinimas naudojant sertifikuotas pamatines medžiagas tarplaboratorinių palyginamųjų bandymų metu.

4. Nustatyta, kad realiausios kandidatės pamatinės medžiagos SBI bandymo metodui yra medžio drožlių plokštė bei PMMA EN ISO 11925-5 bandymo metodui. Šių pamatinių medžiagų naudojimas pagerintų gaisrinių bandymų metodų pakartojamumą bei atkuriamumą.

5. Nustatyta, kad pagrindiniai du faktoriai dėl ko nustatomo gan didelės degumo bandymų pakartojamumo bei atkuriamumo vertės yra pats degumo bandymų metodų pobūdis bei gaminių nevienalytiškumas (kitimas).

6. Nustatyta, kad statistinių metodų taikymas vertinant bandymų rezultatus bei kuriant gaisrinių bandymų metodus padidina gaisrinių bandymų laboratorijų bandymų rezultatų tikslumą.

Disertacijos struktūra ir apimtis

Daktaro disertaciją sudaro įvadas, 4 skyriai, išvados, literatūros sąrašas ir 2 priedai. Bendra apimtis 87 psl., kuriuose yra 50 paveikslai, 34 lentelės ir 61 pavadinimų literatūros sąrašas.

Rezultatų aprobavimas

Disertacijos tema paskelbti 7 moksliniai straipsniai, 2 iš jų recenzuojame Lietuvos moksliniame leidinyje, įtrauktame į Mokslo ir studijų departamento patvirtintą sąrašą. Pagrindiniai rezultatai paskelbti 5 pranešimuose konferencijose, 4 iš jų tarptautinės.

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RELIABILITY OF MEASUREMENT RESULTS OBTAINED DURING TESTING OF BUILDING PRODUCTS FOR REACTION TO FIRE PERFORMANCE

Summary of doctoral dissertation
Technological Sciences, Measurement Engineering (10T)

Andrius Lukošius

MATAVIMŲ REZULTATŲ PATIKIMUMAS TIRIANT STATYBINIŲ MEDŽIAGŲ DEGUMĄ

Daktaro disertacijos santrauka
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