

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Remigijus GUOBYS

INVESTIGATION OF MULTILAYER STRUCTURES IN FIRE

SUMMARY OF DOCTORAL DISSERTATION

TECHNOLOGICAL SCIENCES,
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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Remigijus GUOBYS

SLUOKSNIUOTŲJŲ KONSTRUKCIJŲ TYRIMAS GAISRO SĄLYGOMIS

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TECHNOLOGIJOS MOKSLAI,
MECHANIKOS INŽINERIJA (09T)



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Introduction

Topicality of the problem. Contemporary buildings and products of large overall dimensions for production convenience are more often produced of assembled segmental layered structures. Such deformable structures are widely common in habitable and industry buildings, heat and atomic electrical stations, space stations, airplanes and ships. It may be stationary partitions, mobile structures or doors, intended to save premises and people from fire.

Door resistant to fire temperature is one of the main elements of the building design for fire safety. It must perform two functions at the same time: to have durability to use at normal conditions, safety and security at fire conditions. It leads to a complex structure, formed of different materials, which are used in the door and fixed frame. Every of these parts must demonstrate particular thermal and mechanical stability, summed as integral criterion E and isolation criterion I in purpose to secure mentioned functionality (EN 1363-1 and EN 1634-1, 2008). Big variety of steel frames is in the European market, which can be combined with adequately large variety of passible door and simply in most cases producers of frames and doors are not the same. It creates requirement to differentiate between the characteristics of door and frames. Together with different test conditions, it is massive walls or light weight walls, different configurations, it is opening towards or out of fire, this variability of products leads to big number of costly obligatory fire tests. Though this number can be partly decreased by means of numerical analysis, although numerical research, justified by means of liquid dynamic numerical simulation with influence of door gap on smoke and fire penetration, at use of common assembly of door and frame, may be not satisfactory. Most of authors dealt with the door as an integral structure not analyzing details of temperature and deformation change in steel frame in time neither experimentally, nor numerically seeking to find the main factors which have influence on frame isolation criterion I. Such research enables to help classify similar frame structures to categories and for it to decrease the number of necessary fire tests. Although new aesthetic, strength and fire safety requirements are not reflected at contemporary research, because the main disadvantage of contemporary fire door structure, defined by tests, is that it deforms being acted by fire. It is connected with the phenomenon that from the side of heated structure a metal leaf expands while the contrary side of the structure which is not acted by temperature, does not change its dimensions. For this the structure warps, forming the gap through the jamb middle (if in the room, in which the fire arose, the door opens inside) or at the top or bottom of jam (if the door opens outside). In such a way structure looses its hermetic and opens the way for air flow to fire possessed room and for spread of heat, smoke

and fire to neighbouring rooms. At suitable isolation the accommodation will let to reach the highest fire safety. So, only the fire door of a new structure can provide suitable isolation of accommodation, because traditional structures have limited strength and fire safety action time.

The main attention in the work is intended to define the possibility of layered structures to isolate the rooms and people in them from fire, also to meet aesthetic and strength requirements.

Relevance of the work. Because of increased market competition requirements of products and buildings aesthetical appearance, strength and fire safety properties are more and more increased. Aesthetically fine component parts of products in most cases are produced of material, characterized by bad physical properties, for that reason selection of materials of the product in whole and their overall dimensions must be harmonized with the common structure of the product, that would not worsen strength and fire safety properties of an existing building or product, which are defined in requirements of a usable product. To combine properly all these properties it is possible only after fulfilment of theoretical and experimental investigation, on the ground of which it would be possible to produce the product competitive for a world market.

It would secure timely isolation quality of fire temperatures, would enable to use, where it is necessary, good aesthetic appearance, necessary strength and high fire safety in living apartments, bureaus, atomic electric stations, submarines, space stations, bomb shelters, power and military objects.

The object of research – layered structures at fire situation.

Aim of the work – to investigate deformation regularities of layered structures at fire situation and form research methodic of such structures.

Tasks of the work. To achieve the aim of the work, the following tasks must be completed:

1. To analyze the science literature about types of layered structures, insulation material and investigation of their thermal deformation.
2. To research by numerical simulation and experimentally the deformation process of layered structures at fire conditions and to define the marginal states of thermal displacements at different constitutions of structures.
3. To define regularities of layered structures isolation materials disintegration in layers and indices of heat conduction.

4. By comparable experimental investigation at fire conditions to define deformation processes and regularities of layered structures.
5. To propose algorithm and methodic of experimental research of the layered structures, justified by temperature change of the real fire.

Methodology of research. The work was prepared fulfilling theoretical and experimental research, applying principles of numerical analysis, fulfilling comparative tests of new type layered structures at fire conditions and evaluation of temperature deformations, applying mathematical statistical analysis for evaluation of reliability of received results.

Scientific novelty. At preparing the dissertation such new results were received for the science of mechanical engineering:

1. Numerically modelled and experimentally examined relation between location of isolation materials in layers and temperature change and temperature dislocations of layered structures and deformation regularities at fire conditions. Influence of this relation on effectiveness of isolation at high temperatures is evaluated.
2. Original technology is proposed and programmable and experimentally realized, which enables to unite forming processes of a structure and isolation layers, while the proposed algorithms and fire test methods let to design and develop such structures, location of isolation layers in them and to define the disintegration regularities.
3. Methodic was proposed for evaluation of change of real temperatures at fire tests of layered structures.

Practical value. At apply of made – up layered structures of a new type for isolation of fire temperatures with new aesthetic and strength requirements, the production, competitive in European Union, is designed and produced, while the fire safety becomes more reliable if to compare with other methods used at this time for apartment isolation from high temperatures.

Defended propositions

1. New forming method of layered structures, justified by tests at fire conditions and by specifics of isolation materials location and disintegration increase effectiveness of high temperature isolation.
2. The proposed methodic of fire tests enables to evaluate the influence of real temperatures on the structure at fire uprise.
3. The layered structures are created which acted by fire temperatures, keep thermo mechanical resistance for one hour time.

The scope of the scientific work. The scientific work consist of the introduction, three chapters, conclusions, list of literature, list of publications. The total scope of dissertation is 140 pages, 84 figures, 5 tables, 28 numbered formulas. 139 sources of scientific literature were used.

1. Development evolution and research analysis of multilayered structures

In published science papers large attention was appointed to fire temperature isolation for structures and isolation methods, their simulation, analysis, experimental tests and for search of methods and means for isolation by layered structures. Analysis of references shows that apartments of new generation, energetic and military objects require the temperature isolation structures of higher aesthetical and strength level, especially at a zone of fire spread. Traditional layered structures are frequently used to separate the rooms one from the other and partly to secure wealth when isolation of high temperatures is not needed. Some authors affirm that at use of special materials in a multilayer structure in some cases such structures can present the better isolation of high temperatures. At these cases when the better aesthetic, strength and temperature isolation results are required, which traditional structures can not provide, the new type multilayer structures for high temperature isolation are created. In some cases at use gypsum in multilayer structures and other refrigeration materials, such structures have showed better characteristics of high temperature isolation then the structures with classical materials. Although also it is known that such structures are more expansive, complex, but more reliable then classical. The main limitation of use the classical structures is that isolation of fire temperatures is not sufficient. For that reason the use of multilayer structures of new type can be limited in some cases when for their use expenses, complexity and mass increase markedly. For that reason in pursuance to decrease expenses and improve characteristics of high temperature isolation the layered structures of new type with specifics of layers location and use the new method of fixing the contact surfaces with environment were created. In announced publications methods of high temperature isolation were analyzed, but final result of heat isolation is the same, only differ used materials, calculation algorithms, program software, structures, computer technic, and fire tests in accordance with requirements of ISO standards, but small number of tests are announced solution search of these problems, especially for location of materials in layers, methods of their fixing and for real temperature change at fire tests. The real temperature change and recommended by ISO standard for fire tests is shown in Fig. 1. The notable difference is seen. For that reason the structure, tested by ISO Standard, can not answer to results required in real fire conditions. Defining by such a method high temperature isolation parameters of a multilayer

structure when it is necessary to agree aesthetical, strength and fire safety requirements and to summarize effectiveness of a structure, the final result may be unsatisfactory.

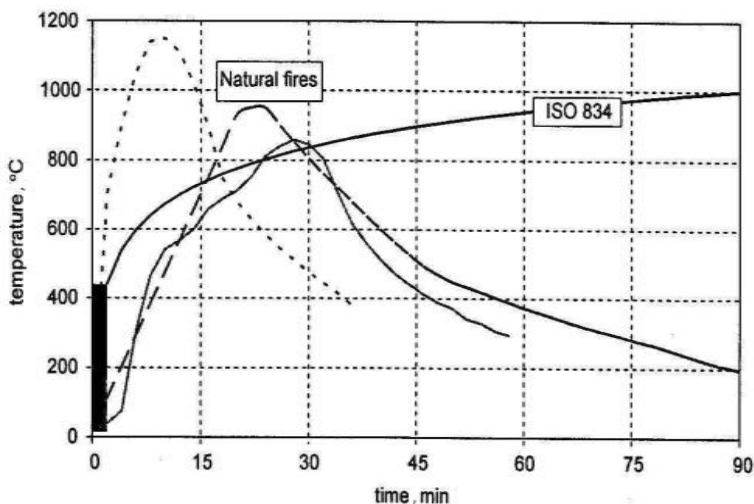


Fig. 1. Comparison of temperature-time curves at natural fires with ISO 834 standard fire

From different arrangements of high temperature isolation structures being described in science literature, the mostly popular type are structures with fillers of cooling materials, in which temperature is distributed evenly in all structure, while keeping high effectiveness of temperature isolation.

Not depending on speedy development of high temperature isolation structures and good results received in fire safety, increase of science publications is recently seen and an interest in new type of layered system structures, which are aesthetic, has high resistance to inbreak and are able to work at high temperatures and at action of military operations, while traditional structures are straightly enable for it. So the layered structures for wealth protection and isolation of high temperatures have a niche in living premises, industry, energetics and military objects.

2. Thermomechanical simulation of multilayer structures

Numerical simulation of fire temperature isolation of layered structures with different methods of material location in layers and fixing methods are presented in this chapter. Linear and not linear methods are used in simulation at comparison the received results with experimental results.

At linear analysis the conductivity matrix does not change during the solution process, at nonlinear analysis it must be modified because material properties and / or boundary conditions are temperature dependent. At steady state analysis material conditions and boundary conditions do not change with time; at time dependent (transient) they do change. Algorithm of such research is proposed.

On the grounds of research a number of different arrangement of multilayer structures and their temperature fixing mechanisms are created and patented. Mathematical model of heat transfer is created and multilayer structures of different arrangements are analyzed. By numerical methods it is defined, that when the examined structure is formed of 1.5 mm thickness steel plate, 50 mm thickness and 33 kg/mm³ density stone wool, which from the other side is covered by 0.7 mm thickness steel leaf, while inside of the structure through its middle is a vertically fixed stiffener, its temperature at fire conditions arise up to 420 °C, and at experiment's time up to 395 °C (Fig. 2, a, b, c). In result of simulation (Fig. 2, a) temperature meanings were given at points coinciding with the points at which the temperature was measured at experiment time.

All these temperature values largely exceed fire safety requirements.

At research of multilayer structure fire temperature isolation possibilities, when such structure has a temperature field activating connection mechanisms and in centre part, at the central steel plate, 10 mm gypsum layer from both its sides, while other cavities of steel structure are filled with stone wool of 140 kg/m³ density, the defined effectiveness of its fire temperature isolation shows, that in a structure, in which the gypsum layer was inserted at fire side straight after the steel plate, the temperature of all middle points (14, 15, 16, 17, 18) after 15 min have reached 95 °C (Fig. 3. a) and begun to fall abruptly up to temperature of 55 °C (Fig. 3, a). At time of the experiment temperature changes were analogous (Fig. 3, b). This structure because of composition layers has cooled itself about 20 min. Later the temperature gradually picked up with speed approximately 1.5 °C per minute.

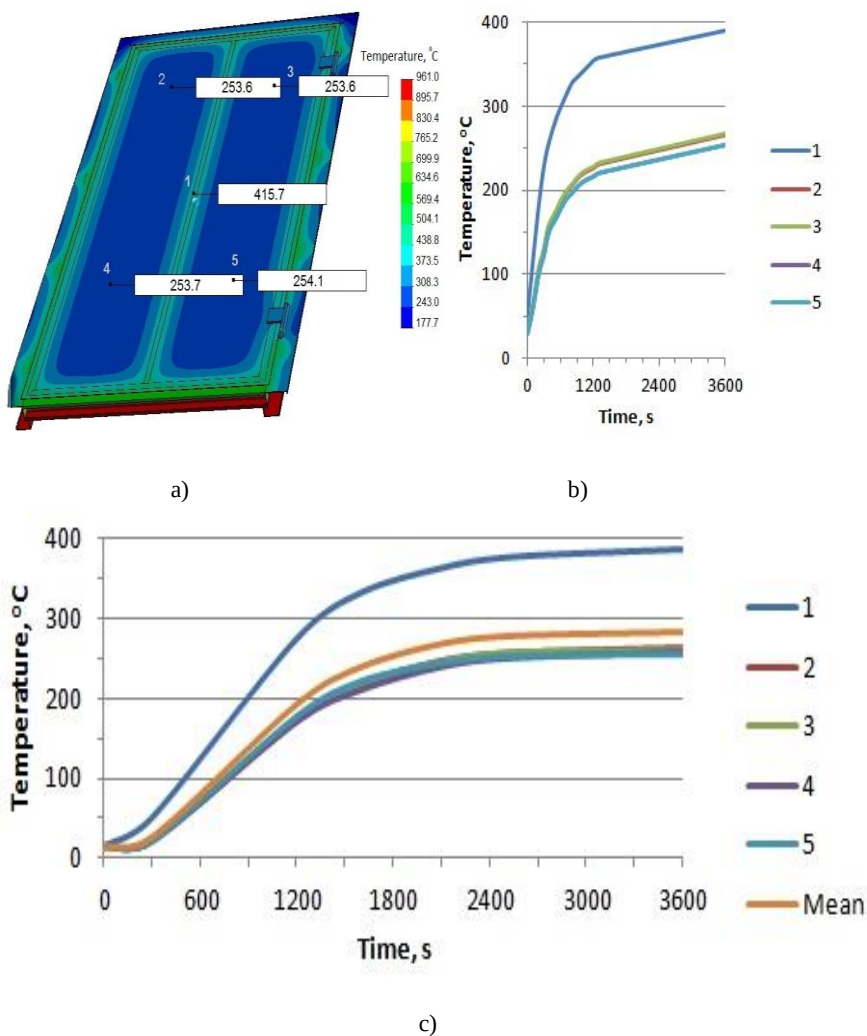


Fig. 2. Graphics of temperature change received by simulation (a, b) and by experimental methods (c)

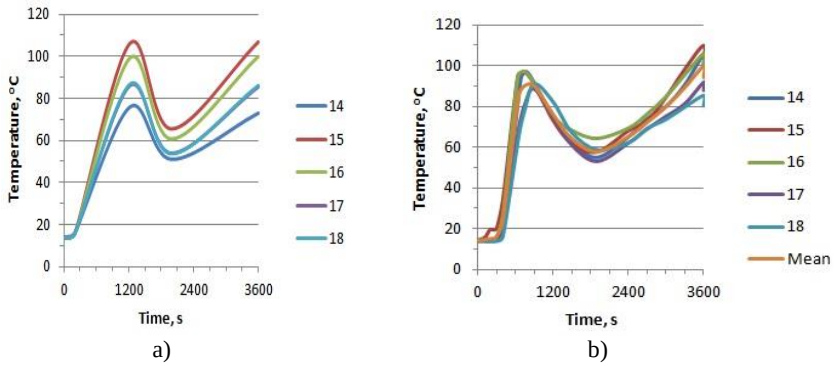


Fig. 3. Simulation (a) and experimental results (b) at insulation by gypsum layer material

Such cooling was observed through all structure at places where the contact was with gypsum. Temperature means and temperature displacements were researched by numerical methods and compared with experimentally received results. It was defined that when the gypsum layer is in centre of a structure, the temperature changes from 60 to 135 °C, while temperature displacements at the centre of structure varies from 1.1 mm up to 5.4 mm (Fig. 4, a, b).

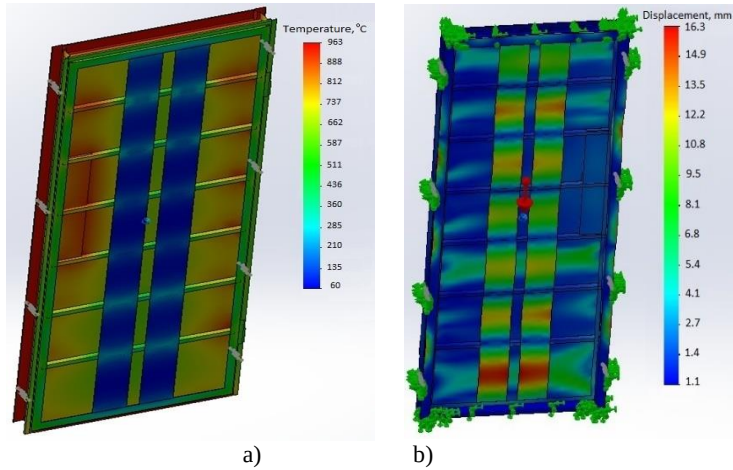


Fig. 4. Change of door temperature (a) and temperature displacements (b)

Such location of isolation layers in a structure enables to reach minimal temperatures and temperature displacements in a centre zone.

3. Experimental research of thermomechanical of multilayer structures

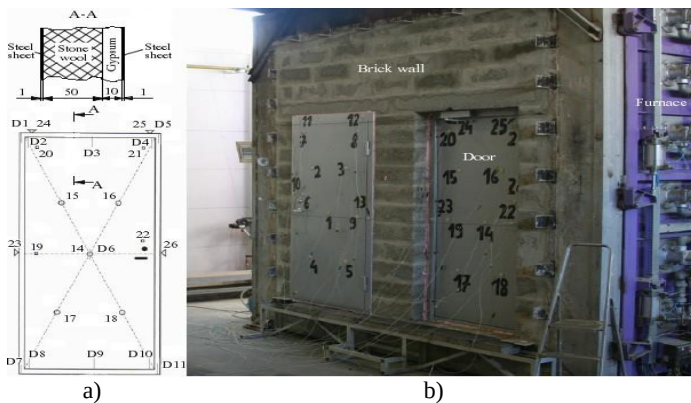
Temperature change and temperature displacements of new type multilayer structures were experimentally researched. Research methodic was created. Fig. 5 shows research scheme of temperature spread, temperature deformation and temperature displacements of layered structures at fire conditions.

Characters of temperature spread (Fig. 6, a, b) and deformation change (Fig. 7, a, b) of the multi-layered structures were received and compared with results received at simulation. It was defined that at use the gypsum and special fixing elements structures meet the highest requirements of fire safety.

Thermomechanical resistance to high temperature and isolation effectiveness of multilayer structures were researched.

At research time temperature of door middle points 1–5 and 14–18 in an hour picked up to 95 °C. It shows that door structure is formed of well temperature isolating materials. Resting on temperature curves (Fig. 6, a, b) it is possible to do assumption that such three layers structure would heat up to 180 °C not earlier that after two hours.

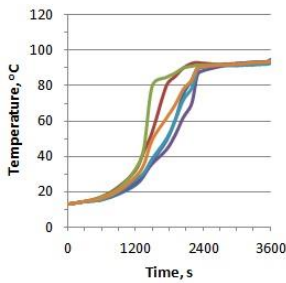
In a structure in which gypsum layer was installed at fire side, the temperature of all middle points 14–18 after 15 min have reached 95 °C and begun to fall sharply up to 55 °C (Fig. 6, b). This structure for layer composition cooled itself for 20 min. Speed of cooling reached approximately 2 °C per min. Later the temperature gradually picked up with approximate speed of 1.5 °C per min.



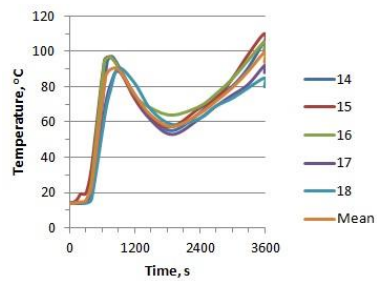


c)

Fig. 5. Scheme of investigated multilayer structure (a) and photography of the wall with specimens fastened to the furnace (b) and fire tests (c): 1–26 – temperature measuring points; D1–D11–thermal displacement measuring points



a)



b)

Fig. 6. Temperatures measured (Fig. 3.1, b) at the points 1–5 (a) and at the points 14–18 (b) as function of time

Thermal displacement at the centre point of the structure shown on the right side of Fig. 5, b, were insufficient for the practical applications. Maximum value of 4 mm was reached at the end of the test (Fig. 7, blue curve). In case

shown on the left side of Fig. 5, b, displacement reached 12–13 mm at the end of the test (Fig. 7, red curve).

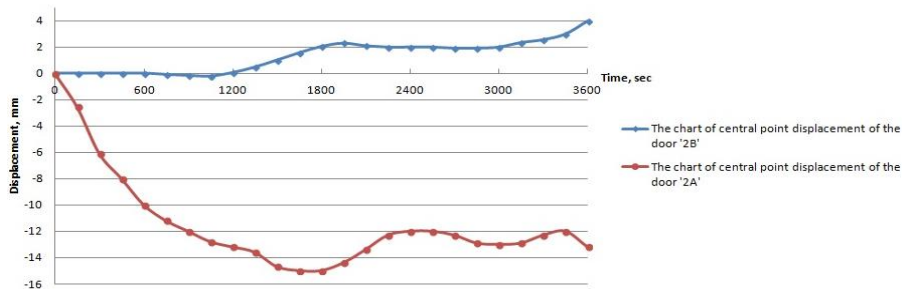


Fig. 7. Displacements measured at the centre point of the structure (D6) as function of time: 1 – case shown on the right side of Fig. 5b; 2 – case shown on the left side of Fig. 5b

Displacements of isolation cooling points in structure itself have large influence on temperature spread as function of time. Tests showed that at cooling layer being nearer to a heating source cooling goes more quickly, but smaller time interval then of specimen, which layers are placed at the centre of structure (Fig. 8).

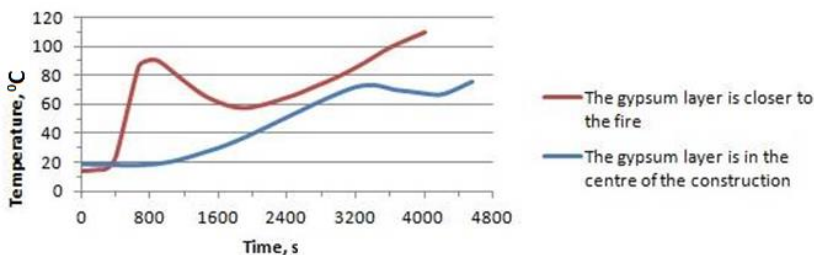


Fig. 8. Experimentally received temperature spread graphics of two multilayer structures with gypsum layer placed at the centre of structure

Temperature values of specimens after 1 h and 15 min have reached 89 °C (Fig. 8), displacement values were from 1.1 to 5.4 mm. On the ground of re-research results methodic of fire specimens, using temperature values of natural fire, was proposed. Received comparative graphics according new and old methodic are shown on Fig. 9.

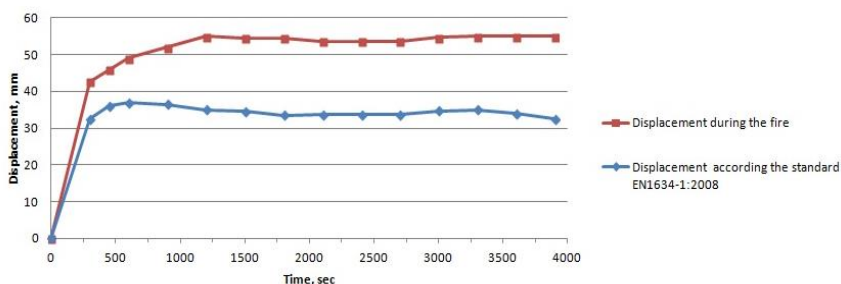


Fig. 9. Temperature displacement of the structure at standard EN 1634-1:2008 fire tests and at natural fire test

Presented graphics of temperature displacement (Fig. 9) else more prove that the same product at the case of a real fire will not correspond to fire properties received at its test by requirements of the standard EU 1634-1:2008, while the proposed methodic evaluates action of real temperature.

General conclusions

1. Analysis of science sources shows that layered structures isolate the high (fire) temperature in dependence on type of structure, placement of isolation materials in it, burning temperature. Results presented in literature are not satisfactory from the point of view of aesthetics, strength and new requirements of fire safety.
2. At evaluation of complex conditions of fire tests and variety of structures the method of layered structures simulation and test, and algorithm of parameters control was proposed. It unites control of fire temperature, correction of structure parameters and modulus of a measuring system. By use of inter-adjustment corrections of these modulus, the research methodic must enable to analyze the character temperatures and temperature deformations.
3. It was stated that rigid or hinge connections limit deformations between separate segments of layered structure, while influence of temperature on a structure decrease suitable material, e.g. gypsum layer, having good cooling properties. It was noticed that when the oven was heated up to 800 °C, gypsum has decreased heat temperature of door central part even to 40 °C.
4. Methodic of new layered structures experimental investigation and definition of temperature characteristics was proposed and approved, evaluating temperature change at fire case. Limitary (up to 5 mm) dis-

placements and values (60–135 °C) of external layer temperatures, meeting fire safety requirements, were defined, what coincides with requirements of fire safety.

5. Layered structures of new generation, promoted by design specifics of isolation layers and metallic parts, were created. The metallic structure, resistant to high temperatures, must be designed so, that component external structural layers, expanding by high temperature action, would buckle, in such a way decreasing common expanding force, which would be able to deform all structure. At such constitution the other layers of a metallic structure keep necessary form for the all multilayer structure. Regularities of isolation layer disruption in dependence of their location in a structure are defined. Layers located at central part of a structure does not disrupt up to 70% of area, if to compare with location along the all perimeter. Gypsum layer convection heat transfer coefficient is corrected in dependence on its location in a structure.
6. It was investigated that large temperature displacements (76.4–80.5 mm), being formed in the area of internal elements of a metallic structure, are less dangerous for fire penetration if to compare with displacements (17–23.34 mm) formed in all object.
7. It was defined that measurement uncertainty of experimental temperature displacements vary from 2.7 to 9.1 percent.

List of published works on the topic of the dissertation

In the reviewed scientific periodical publications

Guobys, R.; Vekteris, V.; Mokšin, V. 2012. Investigation and simulation of temperature changes and thermal deformations of multilayered structure with gypsum plate, *Mechanika* 18(3): 306–310.

Guobys, R.; Vekteris, V.; Mokšin, V. 2012. Effect of dehydration of gypsum board used in multilayered fire resistant structure, *Machine design* 4(2): 79–82.

In the other editions

Guobys, R.; Vekteris, V. 2009. Temperature deformation tests of multilayer mechanical structures, in *Mechanika-2009: Proceedings of the 14th international conference*, April 2–3, 2009, Kaunas University of Technology, Lithuania / Kaunas University of Technology, Lithuanian Academy of Sciences, IFTOMM National Committee of Lithuania, Baltic Association of Mechanical Engineering (BAME). Kaunas: Technologija, p. 116–121.

Guobys, R.; Vekteris, V.; Mokšin, V. 2012. Dehydration process of gypsum board at elevated temperatures, in *The seventh international symposium about machine and industrial design in mechanical engineering*, KOD 2012, 24–26 May 2012, Hotel Marina, Balatonfüred, Hungary : proceedings / Novi Sad (Serbia): Faculty of Technical Sciences (University of Novi Sad). Novi Sad : Faculty of Technical Sciences, p. 277–280.

Patent

Guobys, R. 2011. *A fireproof door*. European patent EP 2 146 043 A3.

Guobys, R. 2007. *Multi-point lock supplement for use with safe, garage, apartment or other door locks*. European patent EP 1865132 A.

Guobys, R. 2002. *B Protection device for door*. Lithuanian patent LT 4961.

Guobys, R. 2009. *Heat activated device of fire door for unwrapped blocking in a casing*. Lithuanian patent LT 5569.

Guobys, R. 2009. *A method for fixing plat bands to a door casing and a holder*. Lithuanian patent LT 5558.

Guobys, R. 2012. *Door lock thermal pin*. Lithuanian patent LT 5871.

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Remigijus Guobys was born at 25th of February, 1973 in Vilnius town. At 2003 he have obtained diploma of Mechanical engineer in Vilnius Gediminas Technical University. From 2003 to 2005 he has studied in Vilnius Gediminas Technical University in Department of Machine Engineering, at Master degree studies. From 2002 he was the production director, chief engineer and technical ideologist of the Closed Stock Company „Plieninis skydas“. About 120 people work in the Closed Stock Company.

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SLUOKSNIUOTŲJŲ KONSTRUKCIJŲ TYRIMAS GAISRO SĄLYGOMIS

Problemos formulavimas. Šiuolaikiniai statiniai ir stambiagabaričiai gaminiai dėl gamybos patogumo vis dažniau gaminami iš surenkamųjų segmentinių sluoksniuotųjų konstrukcijų. Tokios konstrukcijos plačiai naudojamos gyvenamiesiems ir pramoniniams pastatams, šiluminėms ir atominėms elektrinėms, kosminėms stotims, lėktuvams ir laivams statyti. Tai gali būti stacionarios pertvaros, mobilios konstrukcijos arba durys, apsaugančios patalpas ir žmones kilus gaisrui.

Gaisro temperatūrai atsparios durys – vienas pagrindinių elementų, naudojamų projektuojant pastatų gaisrinę saugą. Jos turi atlikti dvi funkcijas tuo pat metu: užtikrinti tinkamumą naudoti normaliomis sąlygomis, saugumą ir apsaugą gaisro sąlygomis. Todėl durų struktūra yra sudėtinga – jos sudarytos iš įvairių medžiagų ir rėmo. Kiekviena naudojama dalis turi atlikti tam tikrą terminį ir mechaninį stabilumą, atitinkantį integralumo kriterijų E ir izoliavimo kriterijų I , kad būtų užtikrintas minėtas funkcionalumas (EN 1363-1 ir EN 1634-1, 2000). Europos rinkoje plieninių rėmų įvairovė yra didelė, jie gali būti derinami su gausybe durų. Paprastai rėmų ir durų gamintojai nėra tie patys, tad kyla reikalavimas diferencijuoti durų ir rėmų charakteristikas. Dėl skirtingų bandymo sąlygų, t. y. kokios sienos yra – masyvios ar lengvos, dėl jų konfigūracijos, t. y. durys atidaromos į patalpos, kurioje kilo gaisras, vidų arba į išorę, su šiais gaminiais būtina atlikti labai daug brangių privalomų gaisrinių bandymų. Nors šis bandymų skaičius gali būti iš dalies sumažintas skaitinės analizės priemonėmis, tačiau durų plyšių įtakos dūmų ir ugnies prasiskverbimui skaitinio tyrimo, pagrįsto skaitinėmis skysčių dinamikos modeliavimo priemonėmis bendrai surinkus duris ir rėmą, gali nepakakti. Daugelis autorių analizavo duris kaip ištisą konstrukciją, eksperimentiškai ir skaitiškai nenagrinėdami laikino temperatūrų ir deformacijų kitimo plieno rėme detalių. Jie siekė atskleisti pagrindinius veiksnius, darančius poveikį rėmo izoliacijos I kriterijui. Tokie tyrimai gali padėti klasifikuoti vienodas rėmų struktūras į kategorijas ir sumažinti gaisrinių bandymų skaičių. Tačiau naujų estetikos, stiprumo ir priešgaisrinės saugos reikalavimų šiuolaikiniai tyrimai neatspindi. Tyrimais nustatytas esminis dabartinių priešgaisrinių durų konstrukcijų trūkumas tas, kad durys, veikiamos aukštos temperatūros, deformuojasi. Taip yra todėl, kad kaitinamos konstrukcijos pusės metalo lakštas išsiplečia, tačiau priešinga konstrukcijos pusė, kurios neveikia temperatūra, savo matmenų nekeičia. Dėl to konstrukcija išsiriečia ir suformuoja tarpą per varčios vidurį (jei patalpos, kurioje kilo gaisras, durys atsidaro į vidų) arba varčios viršuje ir

apačioje (jei durys atsidaro į išorę). Konstrukcija praranda savo hermetiškumą ir sudaro sąlygas orui pritekėti į gaisro apimtą patalpą bei karščiui, dūmams ir gaisrui plisti į gretimas patalpas.

Darbe siekiama nustatyti sluoksniuotųjų konstrukcijų gebėjimą izoliuoti patalpas ir jose esančius žmones nuo gaisro metu pakilusios temperatūros, taip pat jos turi tenkinti estetinius ir stiprumo reikalavimus.

Darbo aktualumas. Dėl padidėjusios konkurencijos prekybos srityje vis labiau didinami reikalavimai gaminių ir statinių išvaizdai, stiprumo ir priešgaisrinėms savybėms. Estetiškai gražios sudedamosios gaminio detalės dažniausiai būna pagamintos iš medžiagos, kurios fizikinės savybės yra prastos, todėl viso gaminio medžiagų parinkimas ir jų dydis turi būti taip suderintas su bendra gaminio konstrukcija, kad nepablogėtų esamo statinio ar gaminio stiprumas bei priešgaisrinės savybės, nurodomos produkto specifikacijose. Tinkamai suderinti visas šias savybes galima tik atlikus teorinius ir eksperimentinius mokslinius tyrimus, kuriais remiantis būtų galima gaminti konkurencingą pasaulinėje rinkoje gaminį.

Tai užtikrintų gaisrinių temperatūrų izoliavimo kokybę, leistų konstrukcijas naudoti ten, kur reikia užtikrinti gerą estetinę išvaizdą, reikiamą stiprumą ir aukštą gaisrinę saugą gyvenamosiose patalpose, biuruose, atominėse elektrinėse, povandeniniuose laivuose, kosminėse stotyse, slėptuvėse, energetiniuose ir kariniuose objektuose.

Darbo tyrimų objektas – sluoksniuotosios konstrukcijos gaisro sąlygomis.

Darbo tikslas – ištirti sluoksniuotųjų konstrukcijų deformavimosi dėsninumus gaisro sąlygomis ir suformuluoti tokių konstrukcijų tyrimo metodiką.

Darbo uždaviniai. Darbo tikslui pasiekti reikia spręsti šiuos uždavinius:

1. Išanalizuoti mokslinę literatūrą apie sluoksniuotųjų konstrukcijų tipus, jų temperatūrinių deformacijų tyrimus.
2. Skaitinio modeliavimo metodais ir eksperimentais ištirti sluoksniuotųjų konstrukcijų deformavimosi procesą gaisro sąlygomis ir nustatyti temperatūrinių poslinkių ribinius būvius, kai konstrukcijos sandara skirtinga.
3. Nustatyti sluoksniuotųjų konstrukcijų izoliacinių medžiagų irimo sluoksniuose dėsninumus ir šiluminio laidumo rodiklius.
4. Lyginamaisiais eksperimentiniais bandymais gaisro sąlygomis, nustatyti sluoksniuotųjų konstrukcijų deformavimosi procesus ir dėsninumus.

5. Pasiūlyti sluoksniuotųjų konstrukcijų eksperimentinių tyrimų algoritmą ir metodiką, pagrįstą realaus gaisro temperatūrų pokyčiais.

Tyrimų metodika. Darbas parengtas atliekant teorinius ir eksperimentinius tyrimus, taikant skaitinės analizės principus, atliekant lyginamuosius naujo tipo sluoksniuotųjų konstrukcijų bandymus gaisro sąlygomis ir temperatūrinių poslinkių įvertinimus, taikant matematinę statistinę analizę gautų rezultatų patikimumui įvertinti.

Mokslinis naujumas

Rengiant disertaciją buvo gauti šie mechanikos inžinerijos mokslui nauji rezultatai:

1. Skaitiškai sumodeliuotas ir eksperimentais ištirtas ryšys tarp medžiagų išdėstymo sluoksniuose, sluoksniuotųjų konstrukcijų temperatūrų kitimo ir temperatūrinių poslinkių bei deformacijų dėsningumo gaisro sąlygomis. Įvertinta šio ryšio įtaka aukštų temperatūrų izoliavimo efektyvumui.

2. Pasiūlyta ir programiškai bei eksperimentais realizuota originali technologija, leidžianti sujungti konstrukcijos ir izoliacinių sluoksnių formavimo procesus. Pasiūlyti algoritmai ir gaisrinių bandymų metodai leidžia projektuoti ir tobulinti šias konstrukcijas, izoliacinių sluoksnių išdėstymą jose ir nustatyti jų irimo dėsningumus.

3. Pasiūlyta metodika realių temperatūrų pokyčiams įvertinti atliekant sluoksniuotųjų konstrukcijų priešgaisrinius bandymus.

Praktinė vertė. Sukurtos naujo tipo sluoksniuotosios konstrukcijos gaisrinėms temperatūroms izoliuoti, atsižvelgiant į naujus estetikos ir stiprumo reikalavimus, Europos Sąjungoje yra konkurencingas produktas, o gaisrinė sauga tampa patikimesnė, palyginti su kitais šiuo metu taikomais patalpų izoliavimo nuo gaisrinių temperatūrų būdais.

Ginamieji teiginiai

1. Pasiūlytas sluoksniuotųjų konstrukcijų formavimo metodas, pagrįstas bandymais gaisro sąlygomis ir izoliacinių medžiagų išdėstymo bei irimo specifika, padidina aukštų temperatūrų izoliavimo efektyvumą.
2. Pasiūlytoji gaisrinių bandymų metodika leidžia įvertinti realių temperatūrų poveikį konstrukcijai kilus gaisrui.
3. Sukurtos sluoksniuotosios konstrukcijos, veikiamos gaisro temperatūros, išlaiko termomechaninį atsparumą vienos valandos laikotarpyje.

Darbo apimtis. Disertaciją sudaro įvadas, trys skyriai, rezultatų apibendrinimas, naudotos literatūros ir autoriaus publikacijų disertacijos tema sąrašai, du priedai.

Įvadiniamе skyriuje aptariama tiriamoji problema, darbo aktualumas, aprašomas tyrimų objektas, formuluojamas darbo tikslas ir uždaviniai, aprašoma tyrimų metodika, darbo mokslinis naujumas, praktinė darbo rezultatų reikšmė, ginamieji teiginiai. Įvado pabaigoje pristatomos autoriaus paskelbtos publikacijos ir pranešimai konferencijose disertacijos tema ir disertacijos struktūra. Pirmajame skyriuje analizuojami sluoksniuotųjų konstrukcijų tipai, jų pranašumai ir trūkumai izoliuojant gaisrines temperatūras. Antrajame skyriuje pateikta naujo tipo sluoksniuotųjų konstrukcijų analizė ir skaitiniai tyrimai. Trečiajame skyriuje pateikti sluoksniuotųjų konstrukcijų temperatūrinių poslinkių ir deformacijų eksperimentiniai tyrimai.

Bendrosios išvados

1. Mokslinės literatūros šaltinių analizė rodo, kad sluoksniuotosios konstrukcijos aukštą (gaisro) temperatūrą izoliuoja priklausomai nuo konstrukcijos tipo, izoliacinių medžiagų išdėstymo sluoksniuose, degimo temperatūros. Literatūroje pateikti rezultatai nepakankami estetikos, stiprumo ir naujų priešgaisrinės saugos reikalavimų požiūriu.
2. Įvertinus sudėtingas gaisrinių bandymų sąlygas ir konstrukcijų įvairovę buvo pasiūlytas sluoksniuotųjų konstrukcijų modeliavimo ir bandymo metodas bei parametų valdymo algoritmas. Jis apima gaisro temperatūros valdymą, konstrukcijos šiluminių parametų patikslinimą ir matavimo sistemos modulį. Taikant šių modulių tarpusavio derinimo ryšius, tyrimo metodika padeda analizuoti charakteringas temperatūras ir temperatūrines deformacijas.
3. Nustatyta, kad deformacijas tarp atskirų sluoksniuotosios konstrukcijos segmentų riboja standžios arba lankstinės jungtys, o temperatūros įtaką konstrukcijai sumažina tinkamos medžiagos, pavyzdžiui, gipso sluoksnis, turintis gerų aušinimo savybių. Kai krosnis įkaista iki 800 °C, gipsas sumažina durų centrinės dalies įkaitimo temperatūrą net 40 °C.
4. Pasiūlyta ir aprobuota naujų sluoksniuotųjų konstrukcijų eksperimentinio tyrimo ir temperatūrinių charakteristikų nustatymo metodika, įvertinanti realius temperatūros, kilus gaisrui, pokyčius. Nustatyti konstrukcijos ribiniai poslinkiai (iki 5 mm) ir konstrukcijos išorinio sluoksnio temperatūrų 60–135 °C reikšmės, tenkina gaisrinės saugos reikalavimus.

5. Naujos kartos sluoksniuotosios konstrukcijos sukurtos atsižvelgiant į izoliacinių ir metalinių sluoksnių projektavimo specifiką. Metalinė konstrukcija, atspari aukštomis temperatūroms, turi būti projektuojama taip, kad sudedamieji išoriniai konstrukciniai sluoksniai, besiplečiantys dėl aukštos temperatūros poveikio, sukauptų, tuo sumažindami bendrą plėtimosi jėgą, kuri galėtų deformuoti visą konstrukciją. Esant tokiai konstrukcijai, likusieji metalinės konstrukcijos sluoksniai išlaiko reikiamą visos daugiasluoksnės konstrukcijos formą. Nustatyti izoliacinio sluoksnio irimo dėl jų išdėstymo sluoksniuose dėsningumai. Išdėstyti centrinėje konstrukcijos dalyje jie nesuyra iki 70 proc. ploto, lyginant su išdėstymu visu perimetru. Patikslintas gipso sluoksnio konvekcinis šilumos atidavimo koeficientas, atsižvelgiant į jo išdėstymą konstrukcijoje.
6. Ištirta, kad dideli 76,4–80,5 mm temperatūriniai poslinkiai, susidarę metalinės konstrukcijos vidinių elementų srityje, yra mažiau pavojingi prasiskverbti gaisro ugniai, lyginant su 17,00–21,34 mm poslinkiais, susidariusiais visame objekte.
7. Nustatyta, kad eksperimentinių temperatūrinių poslinkių matavimo neapibrėžtys svyruoja nuo 2,7 iki 9,1 procento.

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Summary of Doctoral Dissertation

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