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Heat Transfer on inclined Floorings

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Abstract

The paper deals with the results of laboratory measurements of heat transfer of several flooring materials. The results of measurements show the impact of inclination towards on the heat transfer rate and mass loss. Heat transfer spread rate, mass loss in three different flooring materials were monitored and compared. The results show exponential dependence of heat transfer rate and mass loss on inclined samples. Inclining increases the flame speed significantly in all the flooring materials. It should be considered when the decline or inclined planes are designed into public buildings with the risk of fire.

Keywords: Inclined flooring, mass loss, flame spread rate, PVC, laminate, synthetic carpet.

Introduction

Inclined floorings are located in barrier-free public spaces, office buildings, hospitals, schools, banks etc. From the fire risk point of view the inclined planes bring higher risk to the health and property of the people. In case of fire, the flame spreads over an inclined plane faster than along the horizontal plane. Series of experiments had been carried out at laboratory belonging to Faculty of Special Engineering. The aim was to measure the quantities of flame spread rate and mass loss of inclined material. Similar measurements have not been recorded, yet. Therefore the results of these experiments need to be taken into account when for fire safety engineers and for developers when choosing the flooring materials. It is important to know the combustion properties of common flooring materials from environmental point of view, too. Accidental fires don't create the condition for environmentally friendly combustion due to lack of air entering the combustion process. The importance of air flow into combustion process for emission reduction was studied by Müllerová[1,2], Valíček[3], Benčíková[4] and other authors. Emission of CO_x, SO_x, NO_x and TOC (total organic compound) are normally measured during the laboratory tests. Also chlorine and dioxin compounds should be watched for their toxicity and often presence when synthetic materials are burned[5,6]. Three common flooring materials were chosen for testing. These were selected based on previous measurements in a horizontal orientation.

Laminate floating floors: Laminate flooring is a multi-layer laminate material, which combines wood respectively particle core in the form of densified or compressed wood fiber (chipboard, MDF or HDF board) located on the base layer, a decorative paper or foil, and several times the resin coating layer of varnish. Laminate floors are divided into three basic classes. DPL- pressure laminate, HPL-high pressure laminate, which is molded under high pressure and temperature and CML- a multi-layer laminate. Basic component adhesives that cement the floor layers are phenol and formaldehyde. In laboratory experiments were used samples of HPL laminate with a core of pine wood, which is a flexibility and structure for use in laminate floors ideal. Spruce characteristics as environmental friendly material also when thermally modified are described in detail by Osvald[7], Martinka[8], Kačíková[9] and Müllerová[10]

PVC: The basic ingredient is a polyvinyl chloride polymer which is normally very firm and inflexible. Softeners – plasticizers are added in large amounts to soften the PVC supplying PVC with flexibility and suppleness. About 90% of plasticizers in PVC are phthalates (phthalic acid esters. Most common plasticizers-phthalates used in PVC manufacturing are DEHP (or DOP), DINP and DIDP[11,12]. Their toxicity is monitored and tested intensively on rats and mice with various results[13,14]. E.g. total daily intoxication by DEHP in US was estimated 0.27 mg (0.25mg from food). Medical intravenous bags' weight can contain 35% of plasticizers and medical tubing can contain almost 80% of plasticizers[15,16]. Important fact is that vinyl products are pervasive[17].

PVC is also more flammable comparing to wood. It belongs to class E – moderately flammable (second most flammable class)[18]. Rarely tin or lead is added as a flame retarding compound into PVC. These substances including plasticizers are potentially harmful to human health. Various small amounts are released already at higher room temperatures, large amounts during the combustion[19]. There is a variety of PVC modifications thanks to variety of plasticizers and flame retardants added in various rates.

Synthetic polyamide carpet: Tested synthetic carpet is made from polyamide. According to EN 13501-1:2010 nylon carpets belong into class F–high flammable substances. The basic ingredient for the production of synthetic carpet fibers is nylon (polyamide, nylon), which are derived from petroleum.

Polyamides' disadvantage is a high sensitivity to temperature. Polyamide is a material with a regular crystal structure, thermal and dimensional stability unless not heated above 150 °C when it starts to degrade. At temperatures from -40 °C to +100 °C change the characteristics[19]. It was measured by Thermo mechanical analysis which principles are described in Mohd[20] and Müllerová[21]

Methodology

Experiment procedure: Experimental measurements were done under standard Department of Fire Engineering laboratory conditions. Gas burner pressure was 0.5 bar (50kPa) during the testing of all samples. Measurement time was 10 min. Each sample had a rectangle shape 50x15cm and was fitted on noncombustible material class A2-two joined drywall of the same size as the test samples. The board was fitted horizontally by standard clips. The burner was horizontally oriented at a distance of 3cm from the edge. The primary outcome variables were flame spread rate and mass loss. Time of flame spread is measured manually by digital stopwatch Casio at the moment of reaching three check points at the distance of 10, 20 and 30cm from the start point of burner's flame spike. The stopwatch was turned on at the moment of burner's start. The measured times correspond to the checkpoints-indicated distances represented by drawn lines on the samples. The times are named t_{10}, t_{20}, t_{30}.

Results and Discussion

The distance of 40cm from the burner was not reached in any of the measurements. The reason was not the lack of time but rather the flame intensity. Flame spread over sample very rapid at an early stage i.e. for the first 5 to 10s, then it slowed down, and after about one - three minutes, the spread in the observed direction stopped. However, the burning was not stopped at the point when the spread of flame along the longitudinal axis had stopped. The flame worked throughout the duration of the experiment, throughout the 10 minutes. Burning had continued and had showed the thinning of the sample so the mass loss continued. The recorded values of flame spread (t_{10}, t_{20}, t_{30}), as well as mass loss reported in each series had very similar values. The average value of the mass loss squared deviation (dispersion) Δm_0 was 0.48 % in the case of perpendicular action of the flame on the tested sample. Low values of dispersions in deviation from the perpendicular direction resulted from the similarity of the course of testing and measuring samples that were rated as identical hundred pieces of the same material. Another reason for the low values of deviation is the measuring procedure which was identical for each sample in each series of measurements.

Each value shown in table-1 represents average mass loss value out of ten measurements for each angle. Laminate flooring has a linear trend; synthetic polyamide carpet and PVC have a quadratic trend with similarly high coefficient of determination, which says about the accuracy of the regression curve expressed by the trend equation. The results confirmed the assumption that the plane inclination has a progressive impact on mass loss (y). Mass loss progressively increased with the angle inclination (x). Intervals of flame spread decreases with the increasing inclination. It also confirms the gradual slowdown and subsequent stopping the spread of the flame at the same inclination.

Table-1
Average values of mass loss for inclined floorings

Inclination/Material, Mass loss (%)	**Laminate Flooring**	**Synthetic Carpet**	**PVC**
Flammability class	D fl	F fl	E fl
0°	0,1175	0,2127	0,1733
5°	0,1274	0,2138	0,1923
10°	0,1367	0,2147	0,2142
15°	0,1464	0,2164	0,2337
20°	0,1478	0,2334	0,2456
25°	0,1512	0,2457	0,2508
30°	0,1488	0,2521	0,2590
35°	0,1635	0,2976	0,2925
40°	0,1754	0,3213	0,3324
45°	0,1891	0,3586	0,3752
Trend equation y =	$0.0068x + 0.1129$	$0.0025x^2-0.0119x+ 0.2253$	$0.0014x^2+0.0044x + 0.1787$
R^2	0.9314	0.989	0.9652

Figure-1 shows a graph of the average time values at an inclination of 45° and the corresponding trend curve for PVC flooring. The other materials also reached the first check point (distance of 10cm from the burner) very quickly. Consequently, reaching each other check points required still more time. From the graph it is clear that this trend has a quadratic relation. Regression curve is expressed by the equation of polynomial (quadratic) trend (1),

$$t = 9.7525x^2 - 27.664\,x + 23.598 \quad (1)$$

where *t* is the flame spread time, *x* represents distance from the burner. The coefficient of determination is unusually high (0.9921). This value indicates a high exactness of the equation (1).

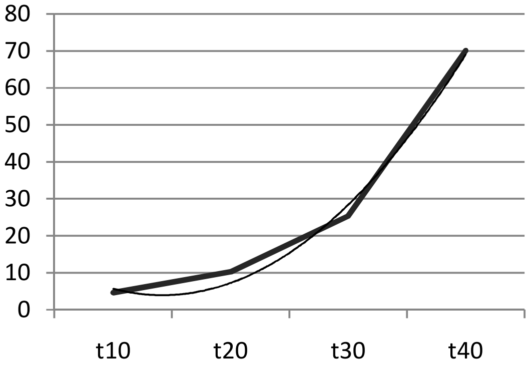

Figure-1
Flame spread rate of PVC flooring inclined in 45°, trend curve [s]

Another result of experiments observed is the dependence of the flame spread rate on increasing angle rate. The graph in figure-2 shows the curve depending on the inclination angle of the plane and the times of reaching the second check point at the distance of 20 cm. Flames on carpet and PVC achieved this distance at low angles of 0° respectively 10°, laminate flooring at an angle of 35°. This is given by the flammability of the materials, which is reflected in their flammability classification (Table-1). (Figuge 2) shows an exponential dependence for each material tested. Time to reach the distance of 20cm is reduced by quadratic function with increasing inclination of the plane.

Flame spread rate regression curve for PVC is:

$$t_{PVC} = 1.613x^2 - 28.37x + 134.93 \quad (2)$$

And its coefficient of determination R_{PVC}^2= 0.988. Regression curve for carpet is:

$$t_C = 0.6408x^2 - 11.859x + 61.285 \quad (3)$$

The coefficient of determination R_c^2 = 0.9559. Regression curve for laminate floating floor is:

$$t_{Lam} = 16.335x^2 - x + 321.7x + 1626 \quad (4)$$

The coefficient of determination R_{Lam}^2 = 1.

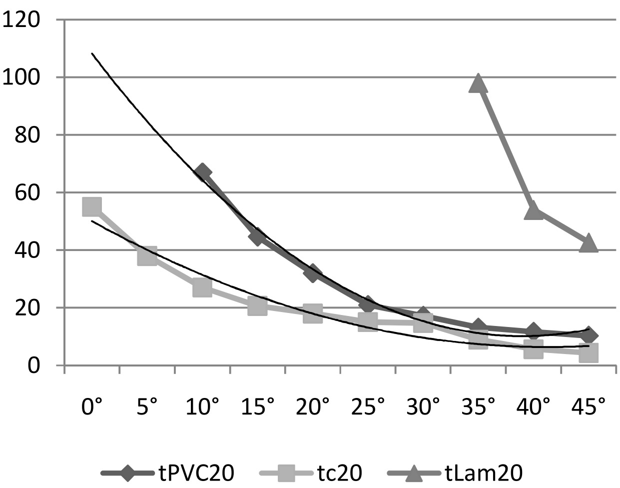

Figure-2
Flame spread rate [s] related to inclination measured on the second check point (distance of 20cm), trend curves for PVC and carpet

Last value of the coefficient of determination for t_{Lam} should be seen in the context of the low number of points (only three) on the regression curve. Nevertheless, we can consider the polynomic-quadratic shape of the regression curves as standard. High values of the coefficients of determination clearly confirm this trend of flame spread rate with increasing plane angle. It can be stated the observed results are non-linear what is more typical for special kind of fire phenomenom as fire backdraft[22,23].

Conclusion

The results of laboratory measurements of the flame spread on several flooring materials demonstrated the impact of an inclined plane on the flame spread rate along and mass loss. The increasing inclination increases the value of mass loss and flame spread rate. Both quantities grows by polynomial/quadratic trend, however the mass loss rate can be described also by linear curve, although slightly quadratic equation is more exact. Flame spread rate is expressed by the times measured at the check points (distance of 10 from each other). All the materials had a polynomial trend of flame spread rate measured as a time when the flame reached the check points. Laminate flooring mass loss is better described by linear rather than polynomial curve, most likely, due to lower flammability of this material. There are more measurements to be done, including wood based as well as synthetic materials. Flame spread rate and mass loss should be the main quantities to be watched. Ideally, also the smoke emission released during the combustion should be measured to complete the fire safety assessment of inclined floorings. Fire tests always should be considered in the broader context of health and environmental safety[23].

References

1. Müllerová J. and Mikulík M., Environmental and health risks of solid fuel boilers'emissions, Košice: *Multiprint,* (**2010**)
2. Müllerová J., Hloch S. and Valíček J., Decreasing of emissions released by biomass combustion in hot water boiler. *Chem. Listy*, **104 (9)**, 876-879, (**2010**)
3. Valíček J., Müllerová J., Kuběna V., Koštial P., Harničárová M. and Mikulík M., Emission distribution and regulation of local heat source, *Def. Dif. Forum,* **326-328**, 330-334, (**2012**)
4. Benčíková E., Hot water boiler risk elimination for environmental safety, *Hydraulika a pneumatika*, **13(3-4),** 52-55, (**2011**)
5. Müllerová J. and Mikulík M., Emission parametres for correct operation of gasifying boiler, *Technológ* **1,** 9-16, **(2011)**
6. Müllerová J. and Mikulík M., Technology and safety of biomass combustion, Saarbrücken : *LAP Lambert Academic Publishing*, (**2012**)
7. Osvald A. and Osvaldová L., *Retardácia horenia smrekového dreva*, TU ZV, Zvolen **2003**
8. Martinka J., Hroncová E., Chrebet T. and Balog K, Fire risk assessment of thermally modified spruce wood, *Acta Fac. Xylologiae,* **55(2)**, 117-128 (**2013**)
9. Kačíková D. and Kačík F., Influence of thermal loading at spruce wood lignin alteration, *Acta Fac. Xylologiae,* **51(2)***,*71-78, (*2009)*
10. Müllerová J., Fire Safety Properties of Heat Treated Wood., *Res. J. Recent Sci.,* **2(12),** 80-82 (**2013**)
11. European Chemical Agency, Data on manufacture, import, export, uses and releases of bis (2-ethylhexyl) phthalate (DEHP) as well as information on potential alternatives to its use, *Information on Chemicals*, (**2009)**
12. US consumer product safety commission, Toxicity review on Diisononyl Phthalate (DINP), [on line] (2013-11-12), www.cpsc.gov, **(2010)**
13. Boberg J., Christiansen S., Axelstad M., Kledal T.S., Vinggaard A.M., Dalgaard M., Nellemann C. and Hass U., Reproductive and behavioral effects of diisononyl phthalate (DINP) in perinatally exposed rats, *Reprod Toxicol*, **31(2)**, 200-9 (**2011**)
14. David R.M., Michael R., Moore M. R., Finney D. C. and Guest D., *Toxicol. Sci*., **58(2)**, 377-385 **(2000)**
15. Lowell Center for Sustainable Production, Executive summary – Chap.2. DEHP in PVC medical devices [on line], (2013-11-15) http: //www. Sustainable production. org/ downloads/ DEHP %20Full%20Text.pdf
16. Plastics and Health Risks, *Annual Review of Public Health,* **31(1)**,179-194, **(2010)**
17. Directive 2005/84/EC of the European Parliament and of the Council 14 December 2005, *Official Journal of the European Union*., 27, **(2005)**
18. EN 13501-1:2010 Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests, Křupalová Z.: *Nauka o materiálech*. SOBOTÁLES, (**2004**)
19. Müllerová J. and Kriššák P., Introductory Thermo mechanics II, *Multiprint* (**2007**)
20. Mohd S., Sayyed H., Sayyed A., Vidya P. and Mazahar F., Thermodynamic Characteristics of Solvents: A Review, *Res. J. Chem. Sci.* **3(11)**, 98-104 **(2013)**
21. Vráblová Ľ.. Müllerová J. and Flachbart J., Nonlinear forms of fire spread, fire simulator of backdraft *Advances in fire & safety engineering,***1,** 330-339 **(2012)**
22. Zachar M., Mitterová I., Xu Q., Majlingová A., Cong J. and Galla Š, Determination of fire and burning properties of spruce wood., *Drvna industrija*, **63(3),** 217-223, **(2012)**