FIRE RETARDANT EFFECTIVENESS OF INTUMESCENT SYSTEM WITH NANOSILICA

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Introduction

One of the most efficient ways of flame and fire retardancy of combustible materials is the application of intumescent systems. It provides coatings, which swell as the result of heat or flame and create a thick carbonized and porous layer. Such a layer perfectly isolates the covered material from the excessive rise of temperature and oxygen penetration and thus protects flammable materials against thermal decomposition and, in consequence, against loss of mechanical properties. The effectiveness of intumescent coatings can be improved by application of nano particle additives. A small amount of highly-dispersed particles can significantly change material properties. The previous INF&MP research showed that both the type of silica and the degree of its dispersion influence the level of flammability [1]. The application in intumescent system silica in the form of nano-particles increases the efficiency of fireproofing properties of such systems. A high degree of particle dispersion causes changes in combustion processes as well as decomposition of intumescent coating by modifying the carbon structure into a small-cell one, which improves thermo-insulating properties, conductivity and heat convection of the foam formed [1]. The best properties have been obtained using silica of the specific area at 320 - 400 m^2/g. The optimum content of nanosilica in the intumescent coating has been defined at 1 to 2 % [1]. The results were used to develop a technology of an effective intumescent, transparent fire retardant varnish for lignocellulosic composites. Another area of the INF & MP research is developing intumescent coatings with nanosilica for protecting vibrating or shape changing systems and barriers, especially made of textiles [2,3]. The use of appropriate fire barriers in upholstered systems enables to reduce the susceptibility of the filling material to fire development and spreading. Fire barriers are common materials placed under the fabric that covers a seat or a mattress and makes the first layer of the filling material. Fire blocking is more and more widely used and includes direct lamination of a fire barrier on the bottom or rear part of the covering fabric.

Experimental

Materials

- cotton fabric of plain weave and with surface mass of 180 g/m^2, the fabric was bleached, free of finishing agents
- standard decorative plush fabric made of blended fibres (45% polyester, 26% polyacrylonitrile, 25% cotton) with surface mass of 450 g/m^2
- halogen-free intumescent system obtained in condensation process, based on amino resin with polyphosphates and with 1 % of nanosilica particle size of about 7 nm (UDPD)

Method of investigation

The effectiveness of flame retardancy was evaluated according to the Limiting Oxygen Index method (LOI) and PN-ISO 3795. The flammability was also tested using the cone calorimeter method acc. to ISO 5660 (heat flux 35kW/$m^{2)}$. The heat release rate (HRR) including maximum (HRR_{max}) and average HRR_{av}), mass loss rate MLR_{av} and time to ignition (TTI) were determined.

Preparation of samples

The intumescent formulation was introduced to the surface of cotton fabric in the amount of 36wt% and then subjected to soaking in water repeated three times.

The decorative plush fabric was covered by UDPD system at the bottom sides in the amount of 28,9wt%. Then the upholstery systems with polyurethane foam as a filling material were constructed. To determine the resistance of UDPD to washing out, upholstery containing the flame retarded (FR) fabrics was subjected to multiple cleaning with water and detergents by spray-suction system. The effectiveness of flame-retardancy was evaluated after 10, 15 and 20 cleaning cycles. Then the upholstery system was disassembled and UDPD protected fabrics was subjected to flammability test.

Results and Discussion

Fig. 1. Flammability of flame retarded cotton fabric tested by the LOI method.

UDPD system efficiently protects cotton fabric against fire. LOI index for FR treated fabric is over 50%. However, soaking it for three times resulted in FR washing out which is also reflected by the reduction in the value of oxygen index, yet the index remains at very high level (above 40%).

Fig. 2. Heat release rate (HRR) from flame retarded cotton fabric.

Table 1. Flammability parameters of flame retarded cotton tested by cone calorimeter.

Fabric	TTI s	HRR_{max} kW/m^2	HRR_{av} kW/m^2	MLR_{av} $g/s*m^2$
Untreated	17,8	169,96	37,98	9,92
UDPD treated	∞	21,89	10,67	3,54
UDPD treated after soaking	∞	21,43	10,86	3,04

Table 2. Flammability of flame-retarded cotton fabric acc. to PN-IS0 3795

Fabric	Soaking	Burnt length mm	Combustion time s	Flammability degree mm/min
UDPD	before	0	0	0
	after	0	0	0

Fabrics flame retarded with UDPD also show a high resistance to ignition in conditions of the cone calorimeter test. They do not ignite (Fig. 1, Table 1), what is represented by promising other flammability parameters such as HRR_{max}, HRR_{av} and MLR_{av}. The UDPD after soaking, which did not ignite, deserves special attention. Its combustibility parameters after soaking are comparable to those of non-soaked fabric. High flame-retarding effectiveness of UDPD was also confirmed by results acc. to PN-IS0 3795 (Table 2).

Table 3. Flammability of flame retarded decorative fabric, tested by the LOI method and acc. to PN-ISO 3795

Fabric	Cleaning	Burnt length mm	Combustion time s	Flammability degree, mm/min	LOI, %
Untreated		254	197	77	21,4
UDPD	no	254	597	26	24,6
	10x	254	659	23	24,6
	15x	21	274	5	26,1
	20x	5	101	3	26,1

The results of tests acc. to the PN-ISO 3795 (Table 3), show that the UDPD reduced the intensity of burning of the decorative fabric. However, the flame combustion of the fabric from the unprotected side (web) was observed. It was found that cleaning increases the effect of flame-retardant treatment. It may be concluded that washing causes penetration of flame retardant to upper layers of the fabric and that increased number of washing operations decreases the flammability degree. The UDPD caused the increase in LOI, which increased to 26,1% after 15 and 20 cleaning cycles. The flammability parameters presented in the Table 4 confirm the reduction in combustion intensity of the decorative fabric after repeated washing.

Table 4. Flammability parameters of flame retarded decorative fabric. Cone calorimeter test.

Fabric	Cleaning	TTI, s	HRR_{max} kW/m^2	HRR_{av} kW/m^2	THR, MJ/m^2
Untreated		19,2	340,9	79,3	8,56
	10x	24,1	292,4	75,7	8,35
UDPD	15x	25,8	273,1	73,9	7,83
	20x	28,3	270,8	73,2	7,76

However, it was concluded that the high ability to swelling intumescent formulations do not form the intumescent carbonized foamed coating on the protected fabrics, when exposed to flame or heat. The processes undergoing during the combustion of fabrics flame retarded with intumescent system lead to changes of reactions happening between the substances, which components are responsible for foam formation, carbonization and dehydratation. This might be the cause of the change in velocity of carbon layer formation and its structure, what is followed by its thermal resistance.

Conclusion

The intumescent flame retardant with nanosilica reduces the flammability of the fabric by acting as a flame and heat barrier. The high effectiveness of the intumescent systems at protecting fabrics against fire and the promising results of the tests of washing resistance allow for finding new applications of intumescent systems in fire retardancy of upholstery furniture.

References

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