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Analysis of oxygen index to support candle-like combustion of polyurethane

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Abstract

The main component of plastics are polymers, which despite numerous advantages also entail certain drawbacks. The least desired features of polymers comprise the low thermal stability and flammability, which in turn depend on chemical and physical changes taking place in the polymer at a high temperature. To minimise their adverse properties, various research works are being carried out to study the present and new polymer groups, including also polyurethanes, large amounts of which are manufactured in the form of foam materials and raw materials needed in the manufacturing of production plants all over Poland. Poland is currently in the group of major foam material manufacturers in Europe. Currently research works are oriented at enhancing durability, rigidity, insulating power and fire resistance of diverse plastics, including also polyurethanes, and limiting the costs of their production. The objective of the study is to define values of oxygen indices of selected polyurethane materials at ambient temperature and at elevated temperature, and also to compare the impact of modifiers on flammability of polyurethanes for non-modified samples.

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Keywords: Burning bahaviour; polyurethane; oxygen index.

1. Obtaining polyurethane foams and their properties

Polyurethanes (PUR) are a group of polymers obtained in a reaction of gradual polyaddition of isocyanates with compounds, a particle of which has a minimum of two hydroxyl or amine groups. Their general formula is $R(N=C=O)_n$, where n=2-5. There are two methods of polyurethane production, and namely the single-stage and the two-stage

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method. The single-stage method, the so-called one-shot process, is the most frequently used method in the manufacturing of PUR. No solvents are used in this method, and the PUR synthesis takes place in the presence of catalysers. The method is primarily used in the forming process of polyurethane foams. All components are mixed and placed in the mould very quickly. Mixed substrates include among others polyols, chain extenders, isocyanates, as well as such additives as emulsifiers, fillers, catalysers and foaming agents. The prepolymer method is also frequently used for the PUR synthesis. This is a two-stage method, which uses pre-polymers for PUR synthesis. It is generally used in the manufacturing process of elastomers, coats, putty and flexible foams [2,5,6,7].

Polyurethanes have a wide range of applications. These are relatively hard products, which nevertheless retain considerable flexibility. They are characterised by good mechanical properties and significant chemical strength, as an effect of which they gain popularity over such materials, as ceramics, rubber or metal. An important advantage of PUR materials is that they may be produced in diverse methods, and that various products of greatly divergent properties may be obtained from them. As an effect they have a range of diverse applications in various industrial sectors. Their properties may be affected in several ways. By modifying raw materials, their mutual volumetric relation, and by adapting appropriate production conditions and changing their apparent density (from 10 to 1100kg/m^3), it is possible to obtain composite and film-forming materials, artificial leather, structural materials, both solid and porous, as well as thermoplastics, elastomers, binders and glues. In the 1980s polyurethane occupied the seventh position worldwide with respect to manufacturing and application of polymers. At present they occupy the fifth position as regards volumes used. Market forecasts suggest that the demand for PUR foams will continue to grow thanks to their low price and easy obtaining of raw materials for PUR synthesis, economic development of the industry and environment friendly production technologies, diversification of physical and mechanical properties, a wide assortment of PUR applications and different options for its recycling [1,4,8,9,10].

1.1. Hazards during combustion of foamed plastics

The combustion of foamed plastics is accompanied by a release of a big amount of heat, smoke and volatile toxic decomposition products. At the very beginning of the fire there is a large amount of oxygen in the surroundings, and so combustion proceeds dynamically, but as combustion proceeds the amount of oxygen may quickly become reduced. This causes a lower fire spreading intensity, and at the same time there is a greater release of smoke and toxic decomposition products. No standard combustion conditions of polymer materials may be assumed, as each fire is a separate and unique physicochemical phenomenon. A tendency for oxidation or incandescence was only recorded for thermosetting polymer plastics or wood, while polymer thermoplastic materials tend to soften, melt and tend to burn the flammable volatile phase. Harmful substances produced during the combustion of plastics, including PU foams, are primarily absorbed by the human organism through the respiratory tracts, skin and the digestive system. The hazard posed by those compounds depends among others on the concentration of the substance, the rate at which it grows and the time spent on the hazardous atmosphere. Both the amount of smoke and the amount of toxic substances being released during the combustion of polymer materials are of great significance, as more frequent causes of death in a fire comprise toxic substances and smoke than the actual direct impact of the flame.

The release of volatile chemical substances from plastics takes place already at room temperature. Increase in ambient temperature causes a growth in the emission of vapour and gas. Given the common presence of polymer materials in our surroundings (and namely residential dwellings, office premises, manufacturing facilities, car interiors) the spreading of gaseous decomposition products is considered to be the basic harmful and toxic impact for humans and for the environment. The toxicity of decomposition and combustion products is tested based on the standard PN-88/B-02855 *Fire protection of buildings.* Toximetric indices (table 1) determined for gases (carbon oxide and dioxide, nitrogen dioxide, sulphur dioxide, hydrogen chloride and hydrogen cyanide), according to results of tests of emissions and threshold concentrations of the decomposition and combustion products of LC50, serve as a basis for the determination of the average toximetric index W_{LC50SM}, used generally for needs of classifying materials.

Table 1. Classification of toxicity criteria of decomposition and combustion products of materials.

W_{LC50SM} [g/m^3]	Toxic properties of decomposition and combustion products of materials