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POLYURETHANE – ALTERNATIVE TO MINERAL WOOL AND POLYSTYRENE

POLIURETAN – ALTERNATYWA DLA WEŁNY MINERALNEJ I STYROPIANU

A b s t r a c t

Polyurethane was discovered in 1937. It is a common name for material which can be hidden under many forms, such as, rigid foam, flexible foam, coatings, sealants, adhesives and elastomers. The main constituents are isocyanate and polyol. Depending on the components and proportions it can have different properties. Polyurethane is widely used in industry and has a variety of uses in everyday life. Rigid foam is used in building construction as a thermal insulation. It is produced by the so-called polyurethane system. This material is light and durable. Besides, it has closed-cell structure and a low thermal conductivity.

Keywords: polyurethane, isocyanate, polyol, thermal insulation, thermal conductivity, foam

S t r e s z c z e n i e

Poliuretan został wynaleziony w 1937 roku. Jest to popularna nazwa dla materiału, który może być ukryty pod wieloma formami, między innymi sztywnej pianki, elastycznej pianki, powłok, substancji łączących, past uszczelniających i elastomerów. Jego głównymi składnikami są izocyjanian i poliol. Zależnie od ich proporcji i użytych dodatków może on mieć różne właściwości. Poliuretan ma wiele zastosowań w przemyśle i życiu codziennym. W budownictwie do izolacji cieplnej używana jest sztywna pianka. Jest ona produkowana w procesie zwanym systemem poliuretanowym. Jest to materiał przede wszystkim lekki i wytrzymały na wiele czynników zewnętrznych. Ponadto cechuje się zamkniętą strukturą i niską przewodnością cieplną.

Słowa kluczowe: poliuretan, izocyjanian, poliol, izolacja cieplna, przewodność cieplna, piana

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1. History of polyurethane

Production of polyurethane (PU) from other substances was discovered and patented by the German chemist Otto Bayer in 1937. At the beginning of World War II there was a deficit of rubber and it reached high prices. This led to a situation that the rubber began to be replaced with PU. One example of such an application is the use of rigid polyurethane foam to seal the aircraft and protective coating of metal, wood and stone. During the war, PU has become more and more popular because of its properties and began to be produced on a global scale. In the fifties it was available on the commercial market in the form of elastomers, adhesives and rigid foam. At the end of the decade, the widespread use also introduces flexible polyurethane foam similar to the one that is currently very popular in many areas. Over the next years, the research was ongoing on the development of PU applications mainly in the automotive industry, construction, clothing and medical equipment. In the 70s PU began to be used as a thermal insulation of buildings in the form of spray. In the 80s it was used in the production of cars as a material which absorbs impact energy and thereby improves the safety of the passengers. In the 90s the first medical tubing was made with polyurethane elastomer. In 2001 the car tires started to contain PU in order to increase their efficiency. Nowadays, most people are not familiar with the use of PU because it is often hidden in various forms in everyday products [1–3].

2. Types of polyurethanes

PU is hidden under many forms. Its composition is characterized by two main components. Namely: an isocyanate and a polyol derived from petroleum. By mixing them along with presence of various catalysts, stabilizers and other additives, PU of different properties may be created. Different proportions and components can influence the composition, flexibility, rigidity, insulation and other properties needed for a particular use. PU can be found in several forms. One of them is the flexible foam that can be easily shaped. This material is characterized by lightness, durability and resistance to deformation. Rigid foam has a very good insulation. There are two kinds of rigid foam: polyurethane rigid foam (PUR) and polyisocyanurate rigid foam (PIR). Their compositions are similar, but in the second one there is more isocyanate at the extense of polyol. This difference causes the PIR to have better fire resistant properties, but because of the higher cost and difficulty of production it is less often produced. PU can also be present in coatings, adhesives, sealants, and elastomers. The coatings enhance the appearance and durability of the products. Adhesives are durable and strong. Sealants layer does not have to be thick in order to fulfil its function and elastomers are resistant to environmental influences and adapt well to the variable stress. One of the types of PU is thermoplastic polyurethane which can be processed in many ways, for example, by extrusion, injection, blow and compression molding equipment. It is also highly flexible, resistant to abrasion, impact and influence of weather. PU is also used as a binder, for example in the manufacture of oriented strand board. Not only to join fibres and particles to each other, but also to impart flexibility and improve endurance [1, 3–5].

3. The use of polyurethane

The use of PU depends on the form in which it is produced and specific properties related to this. Flexible foams are used mainly in the furniture and upholstery as supplementary filling material. PUR and PIR are primarily used in construction as insulation. It is also available in a number of devices as an insulator. PU is exploited in the automotive industry because of its light weight, durability and insulation. It is used in the production of many parts, such as, car body, bumpers and seats. In medicine PU can be found in hospital bed sheets, curtains and also in short-term implants. PU is exploited in the manufacture of paints, lacquers, glues, composite wood, clothing, footwear and many accessories used in everyday life [3, 4].

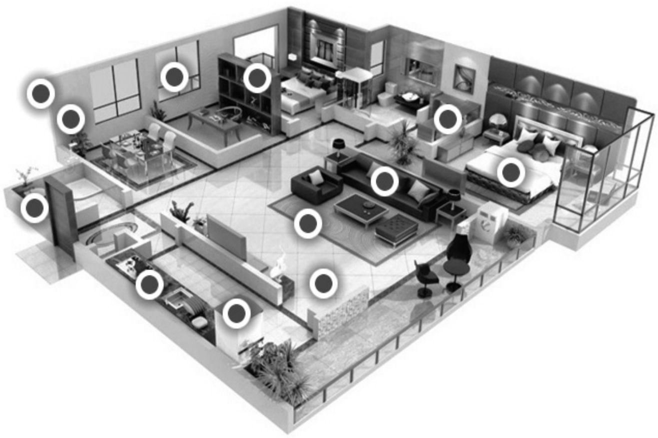

Fig. 1. The variety of polyurethane applications [2]

4. Characteristics of rigid polyurethane foams

As thermal insulation in construction, PUR is mainly used. It is produced by the so-called polyurethane system. It consists of polyol chemically reacting with toluene diisocyanate (TDI) or diphenylmethane diisocyanate (MDI) with the presence of suitable catalysts and additives. As a foaming agent, pentanes or low-boiling, inert solvents may be used, usually derived from halogens. During the reaction there is an increase of temperature, evaporation of the blowing agent starts and the volume of the foam expands. The obtained PU foams must be in a closed cell structure in order to be used as thermal insulation material. This process, simplified to the laboratory conditions, is shown in Fig. 2. For the industrial production of PUR equipment is needed, which includes storage, metering, heating, dosing and mixing ingredients. Depending on the application of the final product, mixing unit can be low or high pressure or in the form of spray using special spray guns. Some manufacturers also practise hand-mixing that, along with the right experience, ensures good quality of the material.

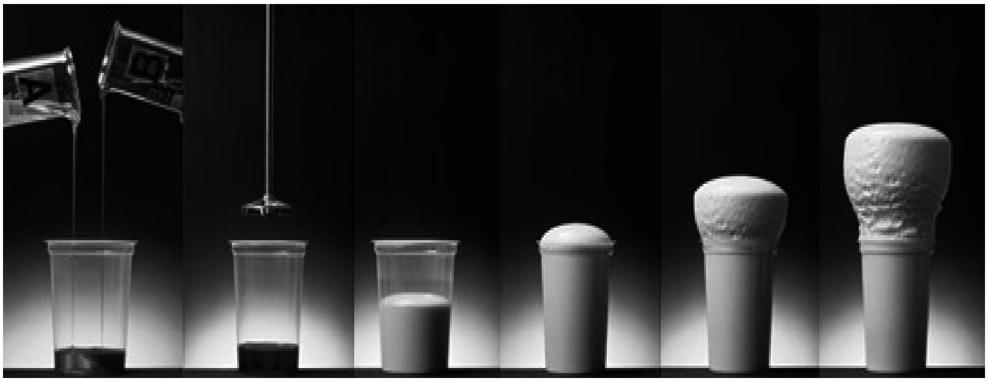

Fig. 2. The formation of polyurethane foam [2]

PUR has a closed cell structure, which is 90% filled with gas. The density is in the range of 24–60 kg/m^3. Noticeable is the fact that with increasing density, the water absorption decreases and the compressive strength increases. The level of water absorption is in the range of 0.3–0.4% by volume of the material. The thermal conductivity is about 0.024 W/(m·K) and is not dependent on humidity. The water vapour permeability of PUR is very low due to the closed structure and is 70 g/m^2/24 h. PUR is resistant to the biological effects of the environment and does not react with grease, organic solvents and diluted acids and alkali. However, it is susceptible to the negative effects of UV radiation. Because of this, it is covered with a special paint or plaster to protect the foam from the radiation. PUR is a slow burning and self-extinguishing material which can withstand temperatures up to 150°C [1, 3, 5–7].

5. Comparison of insulation: polyurethane rigid foam, mineral wool and expanded polystyrene

The most common insulating materials are mineral wool (MW) and expanded polystyrene (EPS). Comparing the thermal insulation obtained using these materials and PUR, clear differences can be seen. One of them is the thickness of insulation needed to achieve the same heat transfer coefficient when other layers are the same. In order to achieve the heat transfer coefficient of U = 0.25 W/(m^2·K) 14 cm of EPS should be used, 13cm of MW and 9 cm of PUR. The combination of these data and the thermal conductivity of materials can be found in Table 1.

While choosing the insulation, attention is mainly paid to thermal conductivity, but other properties are also important. The EPS is the lightest. However the weight of material with the thickness needed to achieve the same heat transfer coefficient is comparable to the weight of the required PUR. The MW is incomparably heavier than EPS and PUR and is characterized by non-flammability and fire resistance. The PUR has worse fire properties but PIR allows to overcome the problem [8–11].

Table 1

Comparing thickness of the thermal insulation obtained using expanded polystyrene, mineral wool and polyurethane rigid foam

U = 0.25 [W/(m²·K)]		
Heat insulating material	Thermal conductivity	Thickness of insulation
Expanded polystyrene	0.038 [W/(m·K)]	14 [cm]
Mineral wool	0.037 [W/(m·K)]	13 [cm]
Polyurethane rigid foam	0.024 [W/(m·K)]	9 [cm]

6. Conclusions

The most common thermal insulating materials on the market in Poland are MW and EPS. However, the PUR and PIR insulation is gaining attention due to its superior thermal performance and decreasing costs of production. These are important advantages in the increasingly stringent thermal requirements of buildings because the traditional insulation materials must increase its already considerable thickness to about 20 cm. In addition, research to improve the properties of the PU is ongoing and it makes this material more attractive on the construction market.

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