ICEM/199 Investigation of functional properties of new shape memory polymer

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1. Introduction
Shape Memory Polymer (SMP) belongs to a new type of material with fascinating properties and high potential for application as functional materials. The polymer can change its shape in a predefined manner when exposed to an appropriate stimulus, such as temperature, light, water, chemical factor. Among the polymers, shape memory polyurethanes represent the largest group, since their strength is high and the shape memory properties are triggered by temperature that can be chosen arbitrary. The temperature at which the polymer returns to the original shape is its glass transition (Tg) or transition temperature (Ttrans). If the polymer is heated to the temperature above Tg, it can be easily deformed. After cooling down below its Tg followed by unloading to remove the stress, the modified shape is largely maintained. This property is called a shape fixity. Heating again to temperature above the Tg enables the polymer to return to the original shape. This property is called a shape recovery. H. Tobushi and S. Hayashi have investigated shape memory polymer properties for many years in Japan. They proposed a method for determining the shape fixity and shape recovery parameters which enable estimation of the SMP application capacity [1]. The complex structure and high sensitivity to external factors cause that the research on SMP has to be still developed.

The paper presents results of investigation of functional properties of new shape memory polyurethane, designed and fabricated by the author within her fellowship program, conducted in IK4-CIDETEC, San Sebastian, Spain. The new functional polymer, characterized by transition temperature Ttrans≈100°C, was based on trifuctional polyurethane 6000 (PU6000) and difunctional polyurethane 4000 (PU4000). The complete research was conducted in the frames of the KMM-VIN program supported by the European Commission.

2. Experimental procedure
Four fabricated kinds of the SMP samples, characterized by Ttrans≈100°C (determined by dynamic mechanical analysis as the peak of the tan δ curve) and various content of the PU6000 and PU4000, were subjected to a thermomechanical loading program in order to estimate their shape memory properties. The investigation was performed on MTS 858 testing machine equipped with a thermal chamber.
The thermomechanical loading program was as follows. At first, maximum strain (≈100 %) was applied at high temperature Th =120°C (Ttrans+20°C). While maintaining the strain, the sample was cooled down to Tl (20°C). After holding at Tl for 30 min, the sample was unloaded at Tl. During subsequent heating from Tl to Th under no-load conditions the SMP sample almost recovered its original shape, however a residual strain was recorded. The SMP loading and unloading was conducted with strain rate 5·10-3s-1. Such experiments are difficult in realization but they are crucial for the shape memory polymer applications according to the reliability estimation.

3. Results and discussions
The SMP functional parameters - shape fixity Rf and shape recovery Rr, were designated taking into account the obtained experimental data and using following equations [1]:

$$Rf=(\varepsilon un/\varepsilon m)*100\%,\ Rr=((\varepsilon m-\varepsilon ir)/\varepsilon m)*100\%;\ (1)$$

where εm - the maximum strain; εun - the strain obtained after unloading at Tl, εir - the irrecoverable strain, i.e. the strain gained after the SMP heating to Th under no-load conditions.
Samples with ratio of 80% P6000-20% PU4000 and 100% PU6000 have been destroyed during loading at 120ºC, so the estimation of shape memory properties has been impossible. However, SMP samples with ratio of 60% P6000-40% PU4000 and 40% PU6000-60% PU4000 exhibit good shape fixity of temporary shape and good shape recovery to its original shape. The average value of shape fixity parameter for both samples is about 82%. The average value of shape recovery parameter for SMP with 60% PU6000-40% PU4000 is about 86%, while this value for SMP with 40% PU6000-60% PU4000 is a little bit higher ≈ 88%. It is worth noticing that for the material with the excellent shape memory properties the shape memory and shape fixity values are close to 100% [1-3].

4. Conclusions
The important functional parameters of new shape memory polymers, crucial for its applications, have been estimated quantitatively in the thermomechanical loading program. It has been observed that if the SMP sample deformed above the transition temperature is cooled down to room temperature, the deformed shape is fixed. The original shape is recovered markedly when the SMP sample is heated again to temperature above Ttrans under no load. Obtained results confirmed good shape memory properties of samples with 60% trifuctional P6000-40% difunctional PU4000 and 40% trifuctional PU6000-60%

difunctional PU4000.

References
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