Shore D hardness of cast PA6 based composites

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Abstract

Shore-D hardness gives additional help for tribological analysis of engineering polymers and their composites. On the basis of the tested samples it was determined that additives below 10% does not have significant effect on hardness of the samples. However with softening additives between 10 and 25%, hardness decreases in great extent. A particular rate of rigidity decrease can be advantageous as the particle embedding ability of friction surface arises in abrasive wear systems.

Keywords

cast polyamide 6 composites, additives, hardness

1. Introduction

One of the advantageous field of the material developments is the friction and wear materials. Its importance is given by the fact that the wear and different friction phenomena in the long run can cause huge losses during the operation. Energy and wear losses can be reduced directly with materials of lower friction coefficient, but in long-term use in contaminated area the abrasion resistance is also very important. Tribological processes are complex due to many acting operational factors (mating material parts, surface macro and micro geometry, third-body behaviour, sliding speed, contact pressure, ambient temperature etc). For better understanding the tribological test results of different polymer composites, there is a need for other examinations. For plastics one of those examinations is the Shore-D hardness measurement. With Shore D hardness measurement it is possible to approach the embedding ability – how the polymer surface react against moving hard particle on it -, which has basic importance in abrasive friction systems. The hardness of plastic surface also plays important role in evaluating of wear volume and wear mechanism in case of hard mating surface, too.

This article gives a brief review about the results of Shore-D measurements by magnesium catalyzed polyamide 6 composites having different additives.

2. Base materials

PA6 is a strategic engineering plastic, which has quite good mechanical and tribological characteristics, and is used on several fields of engineering life. The material developing process, composite research, is supported by industrial company, thus, the selected base matrix is the magnesium catalyzed cast polyamide 6. This material is produced by Quattroplast Kft. under the name of DOCAMID 6G-H.

The basic raw material of the natural product is caprolactame ($C_6H_{11}NO$), which is available among chemical products.

In Germany PA6 was first produced in 1938. This is a polycondensational procedure, during water exit (Kalácska 2007). Natrium-catalyzed PA6 was developed only later, but it did not fulfil the requirements. It was not appropriate for fibre production but it was excellent for block casting. The use of the magnesium catalyzer did not solve the problem of the fiber production, it only modified the characteristics of PA6. The Quattroplast Kft. produces cast PA6 with an unique production technology in the world, in industrial volumes. It takes the advantage of ring opening polymerisation without water exit (Macskási 1996).The natural cast material perform in average a tensile strength of 85 MPa, Charpy impact strength of 8 kJ/m^2, and Shore-D hardness of 83. In the present stage of the composite development, different quantity of montmorillonite, graphite and TA52 softening materials are added to the base matrix.

One of the new additive materials to achieve better fire-safe composite is the montmorillonite (Pál 2006). Montmorillonite is a clay mineral, which is modified in a way that the layers in the clay are extended so that the polymers are able to diffuse between them. If the distance is increased further, the contact between the layers ceases to exist and they are dissolved in a homogeneous way in the base matrix. It was shown several times that during the burning process it decreases HRR (Heat Release Rate kW/m^2).

Graphite was several times used as additive to increase the conductive ability of plastics. Novák (2004) found out on the basis of his measurements that by adding graphite independently from the base matrix (polyurethane and epoxy resin), antistatics can be reached with the addiction of more than 20%.

TA52 is used originally for polyurethane production, in our case its role to increase the toughness and abrasive wear resistance. With TA52 application the molecule chain consists of 3 elements (A-B-A). The original aim of the additives was to increase the toughness and impact strength.

3. Shore-D hardness measurement

Shore-D hardness measurement is standardized in MSZ EN ISO 868:2003 [Plastics and ebonite. Determination of indentation hardness by means of a durometer (Shore hardness)]. The principle of the method is simply: pushing a needle into the material with given force for a given time, and the deepness of the indentation is measured. The value of the indentation hardness is in inverse proportion to the intrusion and highly depended on the form of the pushing needle. For the measurements, in accordance with the recommendation, the D type needle was selected. The measurements were carried out on samples in accordance with the standard, applying 9 measurement points. The results - 1 second after the intrusion of the needle – were recorded (according to the standard, 2nd indication technique). The hardness durometer were made with Zwick/Roell HO4 3150 type equipment (Fig. 1).

Figure 1. Shore-D hardness durometer

4. Measurement results

The results of the Shore-D hardness measurements are affected by the humidity content of the sample. Therefore the measurements were made with dry samples, which were worked out from the same location of the cast blocks. The outrageous faults were excluded from the results. The results were between 40 and 90 Shore-D hardness, therefore on the diagram this range is shown.

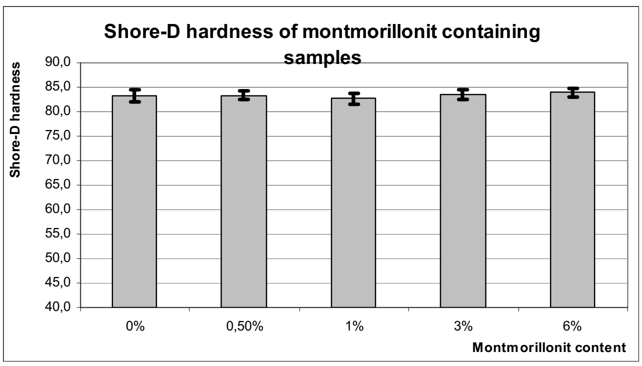

Figure 2. Shore-D hardness of montmorillonite containing samples

In case of montmorillonite and graphite containing samples the additive was below 10 %, and in this range it is not possible to show any tendencies between the additive content and hardness (results are shown in the Fig. 2 and 3). The value of the hardness is nearly the same as the base material has. On the basis of this, it can be expected that in the tribological systems their embedding ability will be similar to the base material's ability. (This expectation is going to be tested during the research project later.) The additives can modify the tribological systems in case of not abrasive-type wear processes, too. (Graphite is often used as lubricant).

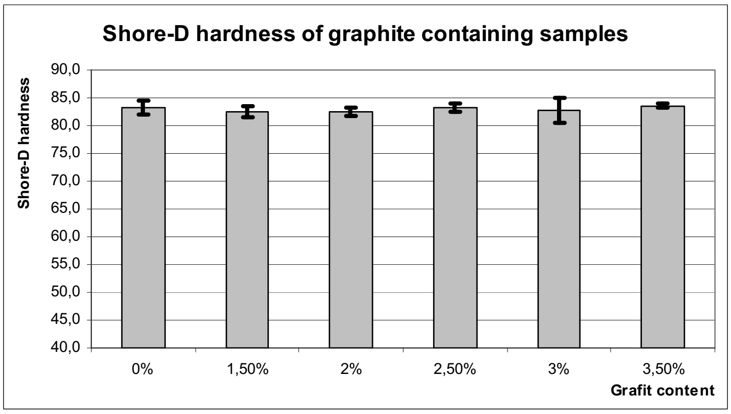

Figure 3. Shore-D hardness of graphite containing samples

In case of adding the TA52 softening material rigidity has changed significantly. On figure 4 it can be seen how TA52 influences the hardness of the cast PA 6 composites.

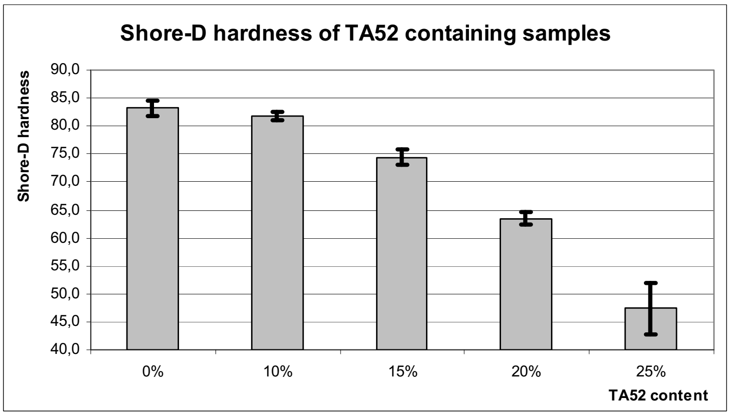

Figure 4. Shore-D hardness of TA52 containing samples

It can be seen that higher content of the TA52 softening material can decrease the hardness continuously. Between 0 -10% of TA52 additive the change of hardness is about 4 %, but over 10 % additive the decrease of the hardness is more progressive. In case of 25 % additive the hardness is only 50% of the natural version. Based on former experiments it can be considered advantageous in some abrasive circumstances due to the probably increased embedding property (this statements is going to be controlled with further measurements in the project). Extreme decrease of surface hardness of polymers can be disadvantageous in normal sliding systems due to the decreased load-carrying capacity and higher strain. The transition rate, the limit of additive percentage should be clarified by not abrasive wear tests. Also important to clarify the resulting effects of the toughness and hardness on friction and wear.

5. Summary

For safety and economical use of machines it is important to decrease different types of losses. One possible solution is the specialized materials for different applications. In plastic industry the composite developments can offer many advantageous new materials fit to challenges. Cast polyamide 6 as strategic, general engineering polymer has unique casting technology with magnesium catalyser. We launched a broad project to develop some special composites on that material to achieve better tribological, electrical (antistatics, ESd) and fire retardant versions. To evaluate the tribological behaviour in abrasive and adhesive sliding systems some other properties have to known. Among them the Shore-D hardness of composites has highlighted importance due to embedding ability. That feature is essential in abrasive systems. After getting to know the different hardness values the control tribological tests are going to be launched.

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