

Mechanical Properties Study of High Impact Polystyrene Under Impact and Static Tests

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Abstract. This article deals with the study of high impact polystyrene (HIPS) mechanical properties. Injection moulded samples were subjected to the tensile impact test, tensile test, impact test – Charpy and three-point bending test at the ambient temperature. Tensile test was measured at two crosshead speeds 50 and 500 mm/min and bending test at 2 and 50 mm/min. The results show the great adaptability of HIPS which classify this material to the group of very well adaptable polymers to different loadings.

1. Introduction

High impact polystyrene (HIPS) is generally produced by the radical polymerization of styrene monomer with polybutadiene rubber. It is a thermoplastic polymer, which micro-structure is composed of an amorphous polystyrene matrix containing spheroid domains which are responsible for HIPS's opacity, elongation, craze plasticity and energy absorption. The rubbery phase of HIPS is dispersed in the rigid polystyrene matrix which causes the excellent elongation at break and the impact resistance. The thermal and oxidative degradation of this polymer is caused by double carbon-carbon bonds (C=C). HIPS has very good properties in comparison to common thermoplastics such as the impact resistance, flexibility, low cost, shatterproof and easy process-ability. This material is commonly used to the production of the toys, housewares, packaging, bottles light-duty industrial components and electronic appliances. [1-2]

From HIPS it is possible to create a super-hydrophobic and wear abrasion resistance HIPS/silica nanocomposite coatings for metal surfaces. The best concentration of silica is 50 wt. %. [1]

The scientists from Brazil dealt with the HIPS derived from electronic devices and its subsequent recycling. They created virgin and recycled HIPS samples and exposed these to an accelerated aging process. Subsequently they studied the consequences of the photo-oxidation on the properties. They found out that the recycled samples did not show big changes in the properties of process-ability compared to virgin samples. [2]

Luca Andena et al. studied the influence of processing conditions on the impact resistance of two types of HIPS. First one was „standard“ and second was specifically resistant to environmental stress cracking. They found out that higher degree of orientation increased the impact resistance in the air but had no effect in the active sunflower oil. [3]



Recycled HIPS is able to be used to the production of low-pressure membranes. It was found that in the comparison to the membranes produced from pure HIPS, recycled membranes with additives made the membranes more hydrophilic. In comparison to the membranes from pure HIPS, the thermal properties were similar and also they had similar asymmetric membrane structures. [4]

Our scientists in cooperation with Slovakia's scientist investigated the influence of fall height on HIPS deformation. It was found out that the optimal energy for penetration of tested samples is 50 J. Higher doses are not needed because of the higher power consumption of the testing device. [5]

This study deals with the study of mechanical properties of HIPS and shows the adaptability of this material on different loadings with minimal differences in the results.

2. Experimental

2.1. Sample preparation

HIPS (EDISTIR SR 550 07) was used as the material for the production of tested samples. An ARBURG Allrounder 470 H injection moulding machine was used for the test samples preparation, with the processing conditional to comply with HIPS producer's recommendations, as can be seen in Table 1. The samples for the impact test – Charpy and three-point bending test were in the shape of blocks with the thickness of 4 mm, width 10 mm and length 80 mm. For the tensile impact test and the tensile test, the samples were in the shape of “dog-bone” with the thickness of 4mm, width 10 mm and length 100 mm. Conditioning was taken for 5 days in the ambient temperature and relative humidity of 50 %. All subsequent measurements were measured 10 times to the creation of the arithmetic mean (values displayed in Figures) and standard deviation.



Figure 1. Arburg Allrounder 470 H injection moulding machine.



Figure 2. Test samples.

Table 1. Injection moulding parameters.

Injection Parameters	HIPS
Injection Pressure [MPa]	70
Injection velocity [mm.s⁻¹]	50
Holding Pressure [MPa]	60
Cooling Time [s]	20
Mould Temperature [°C]	30
Melt Temperature [°C]	225

2.2. Tensile Impact test

The tensile impact test was carried out on Zwick HIT50P according to ISO 8256 standard. In this test impact pendulum with potential energy 15 J was used. Samples were tested and values were evaluated in program TestXpert II.

**Figure 3.** Zwick HIT50P machine.

2.3. Tensile test

A ZWICK 1456 tensile machine was used for the estimation of the tensile behaviour. Measurements were carried out according to the ISO 527 standard at ambient temperature, the crosshead speeds were 50 and 500 mm/min.

**Figure 4.** Zwick 1456 machine.

2.4. Impact test - Charpy

The Charpy impact test was carried out on Zwick HIT50P device at ambient temperature according to the ISO 179 standard. There are two types of samples, with the notch of width 2 mm and without notch. In this impact hammer test, 50 J of potential energy was used for research purposes. Samples were tested and their impact toughness values were evaluated in the program TestXpert II.

2.5. Three-point bending test

Three-point bending test was carried out on ZWICK 1456 device according to the CSN EN ISO 178 standard. The crosshead speed was 2 and 50 mm/min.

3. Results and Discussion

3.1. Tensile Impact test

In Table 2 the arithmetic mean and standard deviation of the maximal force and impact toughness calculated from 10 measurements are displayed. The maximal force of HIPS samples is around 628 N and impact toughness is around 548 kJ/m².

Table 2. Tensile impact test results.

	Maximal Force (N)	Impact Toughness (kJ/m²)
Arithmetic Mean	627,91	548,13
Standard deviation	8,92	7,65

3.2. Tensile test

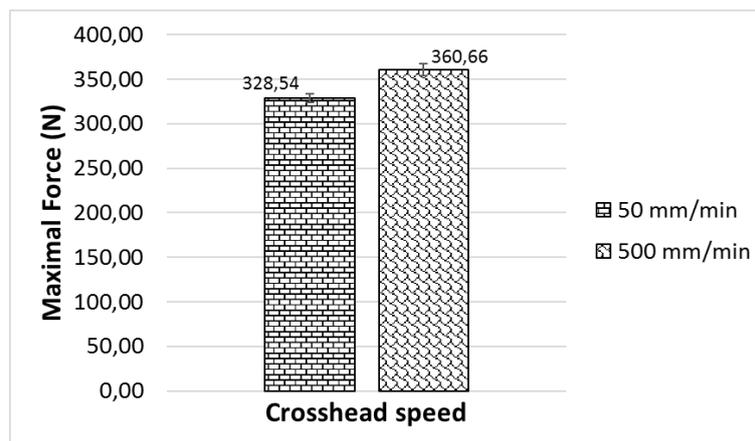


Figure 5. The comparison of maximal force with crosshead speed 50 and 500 mm/min.

As can be seen in Figure 5, maximal force of tensile test was measured at two crosshead speeds. There is a small difference between crosshead speed of 50 and 500 mm/min. The maximal force at the speed of 50 mm/min is 328.54 N and at speed of 500 mm/min is 360.66 N. The small difference can be caused by the polybutadiene particles dispersed in the polystyrene matrix, which are able to absorb the energy inside the material during the test.

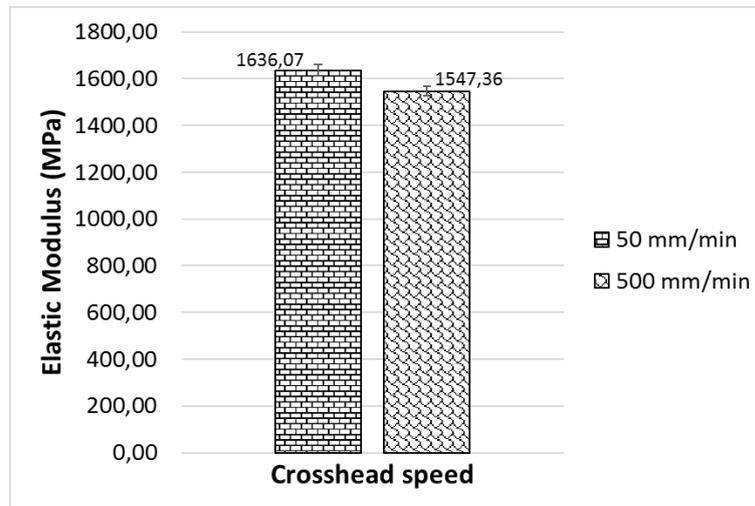


Figure 6. The comparison of elastic modulus with crosshead speed 50 and 500 mm/min.

The elastic modulus of HIPS samples is displayed in Figure 6. There is also only small difference between crosshead speed of 50 and 500 mm/min. The elastic modulus at the speed of 50 mm/min is 1636.07 MPa and at speed 500 mm/min 1547.36 MPa. The inner structure of HIPS is able to adapt during the tensile strength test because of the rubbery phase.

3.3. Impact test - Charpy

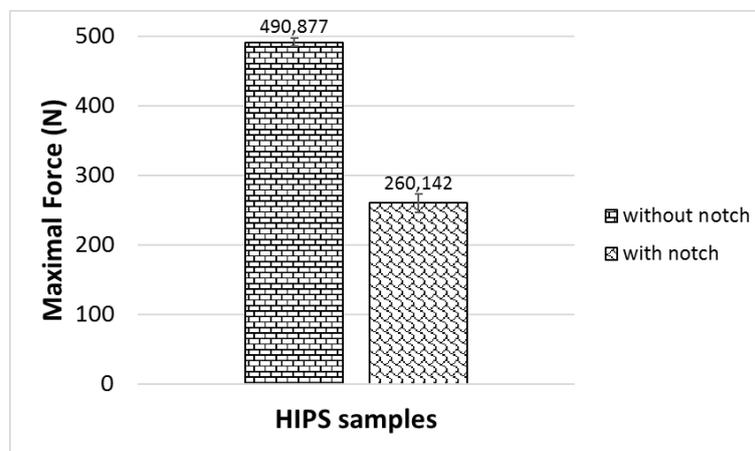


Figure 7. The comparison of maximal force of the samples without notch and with 2 mm width notch.

The Charpy test was carried out at samples with (width 2 mm) and without the notch. From the results in Figure 7 it is clearly visible that HIPS samples without notch has significantly higher maximal force – 490.877 N, while the sample with the notch only 260.142 N. This phenomenon can be explained by the width of the samples. In the case of the sample with the notch, there is about one-fifth narrower width and thus the easier way of the crack growth. And as was already mentioned above, the measurement conditions were the same for all samples.

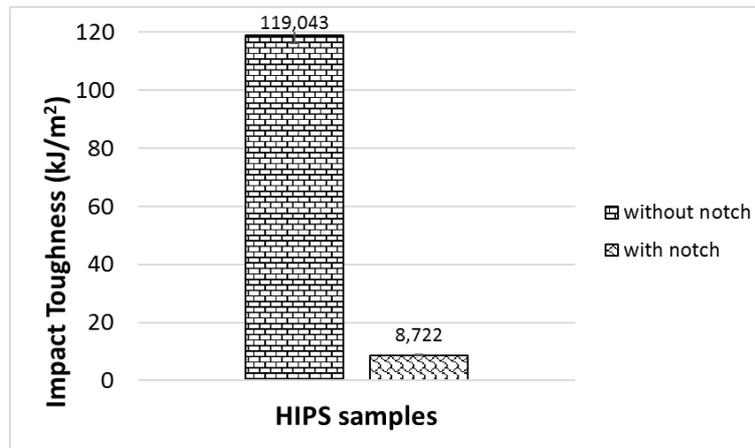


Figure 8. The comparison of impact toughness of the samples without notch and with 2 mm width notch.

The impact toughness is displayed in Figure 8. The comparison of HIPS samples without notch and with notch shows a big difference. The impact toughness of the sample without notch is 119.043 kJ/m², while at the sample with the notch, it is only 8.722 kJ/m². These results can be also connected with the width of the sample. In the case of the samples with 2 mm notch there is easier way of the crack growth caused by the notch cut into the sample.

3.4. Three-point bending test

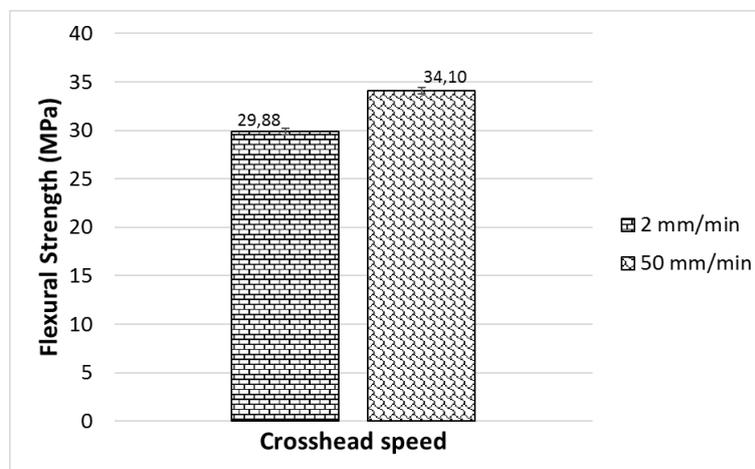


Figure 9. The comparison of flexural strength with crosshead speed 2 and 50 mm/min.

In Figure 9 it is possible to find the results of three-point bending test in the form of the flexural strength. HIPS samples were subjected to two crosshead speeds of 2 and 50 mm/min. In this case the difference is very slight. It can be as in above displayed cases caused by the rubbery phase of the HIPS, which causes a very good adaptability of this material.

4. Conclusion

In this article, HIPS samples were injection moulded in the shape of block with the thickness of 4 mm, width 10 mm and length 80 mm. These samples were conditioned for 5 days at the ambient temperature and 50 % of humidity and subsequent subjected to the tensile impact test, tensile test, impact test – Charpy and three-point bending test. In case of the tensile test, there were two crosshead speeds – 50 and 500 mm/min and in the case of three-point bending test 2 and 50 mm/min.

The biggest difference was found out in the case of the impact test – Charpy compared to HIPS samples with and without the notch. The notch causes the increase in the crack growth, which shows that the sample without notch has a greater impact toughness.

During measurement of the tensile test and the three-point bending test, it was found out, that there is a minimal difference in different crosshead speeds, which can be caused by the rubbery phase in HIPS.

As a conclusion it can be said that HIPS is a very adaptable polymeric material which is able to react quickly during big changes in the conditions of the loading and because of this it is a suitable material for the application in the practice where the great adaptability on the different loading is needed.

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