STUDY OF ABS AND SAN FAILURES UNDER DROP-WEIGHT IMPACT TEST

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Acrylonitrile butadiene styrene (ABS) is a tough material, which is used for engineering purposes (e.g. covers of electronic and engine parts). On the other hand, styrene acrylonitrile (SAN) is a brittle transparent material with good optical properties, it is used for household items, such as bowls and boxes in refrigerator. Both of these materials can be loaded by impact forces, for example fall of the item on the floor. In this study the influence of fall height on ABS and SAN samples under drop-weight impact test is tested. After the test, failures are evaluated as well as maximum impact force and all consumed work, which was used for the deformation and the failure of the material.

KEYWORDS

Mechanical properties, drop-weight impact test, failure, acrylonitrile butadiene styrene and styrene acrylonitrile.

1 INTRODUCTION

Styrene-acrylonitrile (SAN) is an amorphous thermoplastic copolymer of styrene containing 10–30 % of acrylonitrile. After addition of acrylonitrile, SAN has in comparison with styrene higher impact toughness, strength, fatigue resistance, modulus of elasticity, hardness resistance to thermal shock and also chemical resistance, resistance to the formation of surface scratches etc. [Senkerik 2016]. On the other hand, SAN tends to be brittle and is sensitive to UV radiation. The most common processing technologies of this polymeric material are injection moulding, compression moulding and extrusion. SAN is a highly abrasion-resistant material and this is the main reason why it is commonly used for the production of touch screens. Some of applications for this material are the automotive and the building industry, electronic devices, household products, medicine and packages [Zorc 2015].

Our second used material in this study is acrylonitrile-butadiene-styrene (ABS), which is a thermoplastic polymer toughened by a dispersed rubbery phase polybutadiene (PB), the rigid phase of this polymer is SAN. PB particles are grafted together with SAN to obtain the interaction with the SAN matrix [Xu 2005]. ABS has a great heat and solvent resistance, tensile and impact strength and surface hardness of ABS are also on a good level. ABS is commonly used for the production of automotive parts, house appliances and office machines. After addition of bigger amount of PB grafted in SAN, the impact strength increased rapidly, while flexural strength, melt flow index, flexural modulus, Rockwell hardness and tensile strength decreased slightly with the content of PB in SAN matrix [Jin 2010].

ABS and SAN are very often used for the creation of the polymeric blends. SAN as a matrix and ABS for more elastic material properties. The behaviour of the final blend depends on many factors. One of this factors is the size particles. The blends with smaller rubber particles had higher elasticity and slightly higher elastic modulus in comparison to the blend with bigger size of the particles. On the other hand, the impact strength is rapidly higher at the blend with bigger particles, more than four times in comparison to the blend with smaller particles [Xu 2011].

Blended SAN copolymer together with ABS resin with different amount of SAN content was prepared, subsequently injection moulded and FDM printed in the longitudinal and transverse direction. SAN content had little effects on glass transition temperature, but mass flow index and elongation at break can decrease while the tensile strength and modulus of ABS/SAN blends can be improved. For printed samples with the longitudinal and transverse direction of the print, the SAN content improved mechanical properties without the drop of the dimensional stability [Zhu 2017].

Many other studies have been investigated about blending of SAN together with ABS or other copolymers. SAN is also often used as a compatibilizator for blends such as ABS/polyamide, PC/SAN or sometimes only for modification of material properties of individual polymers such as poly(ethylene terephthalate) [Jung 2014], [Ohishi 2001], [Wellen 2012]. In the past our team investigated the impact strength of ABS before and after humidity loading and also the crack growth. It was proved that after humidity loading ABS proved significantly lower impact resistance than before loading [Hylova 2017]. This study compares SAN and ABS in the mechanical behaviour point of view of these materials using drop-weight impact tester.

2 EXPERIMENTAL

Acrylonitrile Butadiene Styrene (ABS) – STAREX HF 0660IW and Styrene Acrylonitrile (SAN) – STAREX HF 5661 were used as the basic polymer materials. An ARBURG Allrounder 470H Advance Injection moulding machine was used for sample preparation, with the processing conditional to comply with material producer's recommendations, as can be seen in Tab. 1. The samples were in the shape of plates with dimensions (100×100×3) mm according to ISO 6603-2.

Table 1: Process parameters of injection moulding

Injection Parameters	ABS Values	SAN Values
Injection Pressure [MPa]	70	100
Injection velocity [mm.s^{-1}]	40	30
Holding Pressure [MPa]	65	60
Cooling Time [s]	17	20
Mould Temperature [°C]	40	60
Melt Temperature [°C]	225	240

Before testing, injected specimens were conditioned for 7 days at temperature 23 °C and relative humidity 50 % according to ISO 10350-1 standard. Then injection moulded samples were tested on the drop weight test machine Zwick HIT230F according to ISO 6603-2 standard at ambient temperature 23 °C. Impactor with the hemispherical striker tip R = 10 mm was used and tested specimens were fitted into two clamping rings. As a main parameter the impact energy was used, which was set on the machine. 15 samples at each set energy (30, 50, 100, 150, 200 and 230 J) were tested and then maximum impact force and all consumed work were statistically evaluated in program TestXpert II, MiniTab 16 and MS Excel 2016. At the end crack surface after the test of each set energy was evaluated.

Table 2: Statistical evaluation of the maximum force at the potential energy – ABS

Set energy of fall [J] / Statistical characteristics [N]	30	50	100	150	200	230
Number of measurements	15	15	15	15	15	15
Arithmetic mean	4367	4123	5526	4721	4638	4695
Type error A	57	156	67	138	100	186
Standard deviation	180	493	213	437	317	589
Minimum value	4032	3195	5214	3940	4024	3798
Median	4450	4266	5563	4882	4606	4724
Maximum value	4573	4534	5795	5342	5033	5483
Variation range	541	1339	581	1402	1009	1685

Table 3: Statistical evaluation of the maximum force at the potential energy – SAN

Set energy of fall [J] / Statistical characteristics [N]	30	50	100	150	200	230
Number of measurements	15	15	15	15	15	15
Arithmetic mean	1237	1063	967	1207	1374	1198
Type error A	39	18	13	34	45	40
Standard deviation	125	58	41	108	142	126
Minimum value	1045	1004	890	1075	1223	1033
Median	1232	1036	978	1205	1327	1194
Maximum value	1468	1143	1033	1429	1685	1425
Variation range	423	140	143	354	461	392

3 RESULTS AND DISCUSSION

This study is concentrated on the comparison of two polymers (ABS and SAN) which belong into the same styrenic group. SAN is the transparent material with a bad impact resistance. On the other hand ABS is the material with very good impact behaviour. The drop-weight impact test was used for evaluation of the impact resistance against penetrator with the hemispherical tip (radius 10 mm). This test causes multiaxial stress inside tested specimens. Different potential energies were used in this study which can simulate falling parts of these materials on the ground from different heights. Two parameters (maximum force and all consumed work) were statisticaly evaluated.

3.1 Evaluation of ABS and SAN maximum impact force

The first maximum impact force was used for evaluation of ABS and SAN impact behaviour. In Tab. 2 and 3 there is possible to see statisticaly evaluated data which was recorded on drop-weight impact test machine. Maximum impact force 4,367 N for ABS and 1,237 N for SAN was measured at set potential energy 30 J. Maximum impact force of ABS is almost 4 times higher than maximum impact force of SAN. Measured values of maximum impact force at every higher set potential energy lie inside range of standard deviation for both materials except 100 J. In Fig. 1 percentage change of maximum force with dependence on set potential energy can be seen. The highest change was detected at potential energy 100 J, ABS maximum force rise is about of 27 % in comparison with the value measured at 30 J. On the other hand SAN maximum force decrease is about of 22 %.

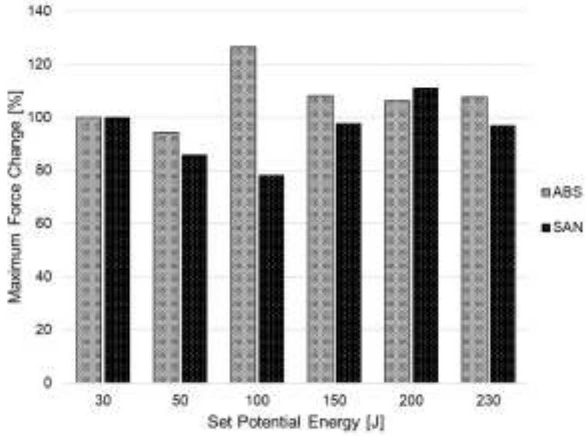

Figure 1: Percentage change of maximum force at potential energy

3.2 Evaluation of ABS and SAN all consumed work

The second all consumed work was used for evaluation of ABS and SAN. In Tab. 4 and 5 there is possible to see statistically evaluated data which was recorded on the drop-weight impact test machine. All consumed work 32.2 J for ABS and 2.4 J for SAN was measured at set potential energy 30 J. All consumed work of ABS is almost 10 times higher than all consumed work of SAN. In Fig. 2 percentage change of all consumed work with dependence on set potential energy can be seen. The biggest change was detected at potential energy 100 J, ABS maximum force rise is about of 31 % and 33 % for SAN in comparison with value measured at 30 J.

Table 4: Statistical evaluation of the all consumed work at the potential energy – ABS

Set energy of fall [J] / Statistical characteristics [J]	30	50	100	150	200	230
Number of measurements	15	15	15	15	15	15
Arithmetic mean	32.2	31.6	42.1	32.9	33.9	34.6
Type error A	0.4	1.0	0.7	0.8	1.0	1.1
Standard deviation	1.3	3.2	2.3	2.6	3.1	3.6
Minimum value	30.5	27.7	38.8	29.0	28.8	29.9
Median	32.2	30.4	41.9	32.4	33.5	35.0
Maximum value	34.0	38.7	45.9	37.7	38.2	41.0
Variation range	3.5	11.0	7.2	8.7	9.4	11.2

Table 5: Statistical evaluation of the all consumed work at the potential energy – SAN

Set energy of fall [J] / Statistical characteristics [J]	30	50	100	150	200	230
Number of measurements	15	15	15	15	15	15
Arithmetic mean	2.4	2.9	3.2	2.7	2.3	2.2
Type error A	0.1	0.1	0.2	0.2	0.2	0.1
Standard deviation	0.4	0.4	0.7	0.7	0.5	0.3
Minimum value	1.8	2.3	2.0	1.9	1.6	1.9
Median	2.4	2.9	3.3	2.6	2.1	2.1
Maximum value	2.9	3.7	4.1	3.8	3.1	2.6
Variation range	1.0	1.4	2.1	1.9	1.5	0.7

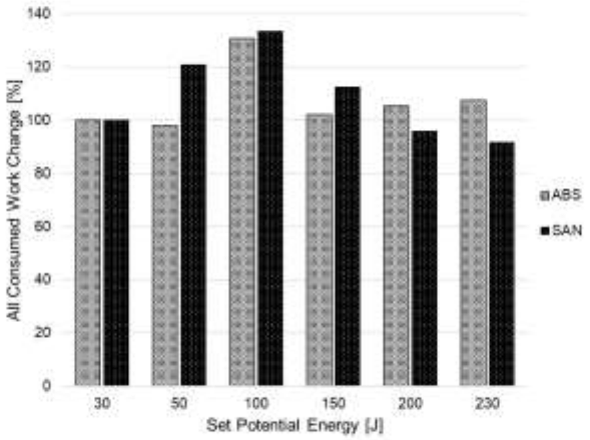

Figure 2: Percentage change of all consumed work at potential energy

3.3 *Failure of ABS and SAN during and after the test*

The course of impact force in the dependence on time is completely different for these two tested materials. ABS is a tough material where crack is gardually growing. On the other hand SAN is brittle material where the crack growing is very fast and not predictable. The SAN material crashes into a few small pieces. Records of both materials are depicted in Fig. 3 and 4.

In Fig. 5 and 6. can be seen failure of ABS and SAN, respectively, at set potential energy 30 J. ABS crack is growing from the center to edge of clamping rings and then around them (Fig. 5). SAN crack is brittle with sharp edges as it is displayed in Fig. 6. From this point-of-view SAN is not suitable for impact applications.

In Fig. 7 ABS failure at set potential energy 50 J is shown, in comparison with potential energy 30 J, the crack is through whole material which is inside the clamping system (clamping rings). In Fig.8 can be seen failure of SAN at set potential energy 50 J which is simillar with set energy 30 J. However, hole after the penetrator is larger then at 30 J.

With increasing set potential energy is deformation of both materials similar with set potential energy 50 J. ABS is used for covers because of good impact properties without crashing the material. This material is tough and fit together. Crack is stepwise growing. On the other hand, SAN is material which smash into many smal pieces. Failured edges are sharp as smashed pieces.

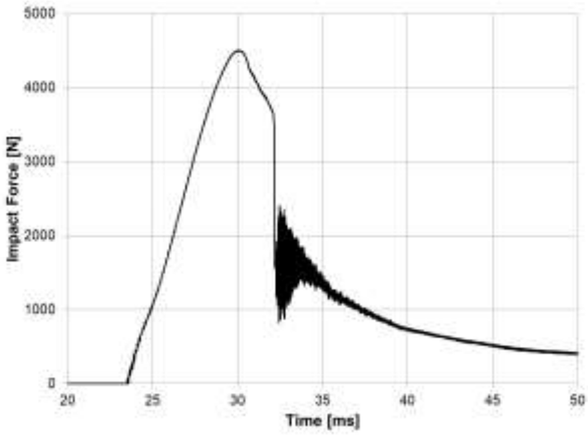

Figure 3: ABS force record at set potential energy 30 J

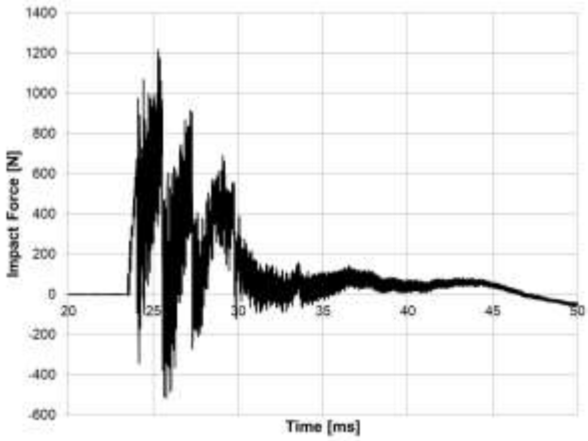

Figure 4: SAN force record at set potential energy 30 J


Figure 5: ABS failure after the test at set potential energy 30 J


Figure 6: SAN failure after the test at set potential energy 30 J

4 CONCLUSIONS

In this study injected ABS and SAN specimens in shape of plates with dimensions (100x100x3) mm were measured on the drop-weight impact tester from the company Zwick. From evaluated data follows that SAN is not suitable material for impact applications, on the other hand ABS has very good impact properties. ABS maximum impact force is 4 times higher than SAN one and ABS all consumed work is 10 times higher than SAN one. Suitable transparent material for impact applications is for example polycarbonate. Relative humidity of environment can cause different behaviour of ABS and also have influence to crack growing and all failure of parts from this material.

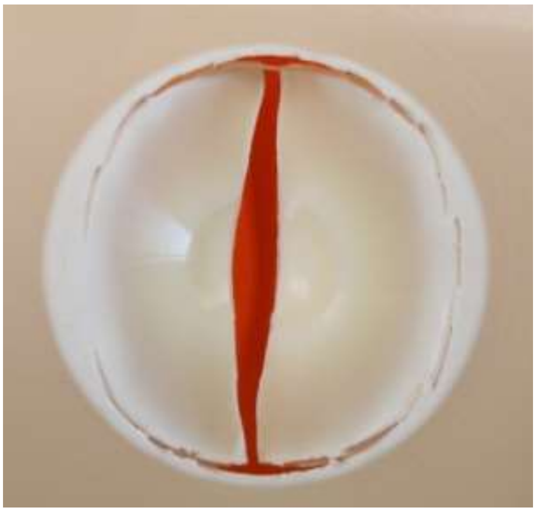
Figure 7: ABS failure after the test at set potential energy 50 J


Figure 8: SAN failure after the test at set potential energy 50 J

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REFERENCES

[Hylova 2017] Hylova L. and Manas M. Impact behaviour of acrylonitrile-butadiene-styrene after temperature and humidity load. MATEC Web of Conferences, 2017, Vol. 127, pp 1-4. ISSN 2261-236X

[Jin 2010] Jin F.L., et al. Effect of rubber contents on brittle-tough transition in acrylonitrile-butadiene styrene blends. Materials Science and Engineering A, 2010, Vol. 527, pp 3438-3441. ISSN 0921-5093

[Jung 2014] Jung H.J., et al. Influence of Acrylonitrile Content in Styrene-Acrylonitrile Copolymer on the Phase Morphology and Interfacial Tension in Blends of Polycarbonate/Styrene-Acrylonitrile Copolymer. Macromolecular Research, 2014, Vol. 22, No. 2, pp 146-153. ISSN 1598-5032

[Ohishi 2001] Ohishi H. and Nishi T. Application of Styrene-Acrylonitrile Random Copolymer-Polyarylate Block Copolymer as Reactive Compatibilizer for Polyamide and Acrylonitrile-Butadiene-Styrene Blends. Journal of Applied Polymer Science, 2002, Vol. 83, No. 11, pp 2300-2313. ISSN 0021-8995

[Senkerik 2016] Senkerik, V., et al. Effect of recycled particle size to micro-hardness properties of styrene acrylonitrile. Defect and Diffusion Forum, 2016, Vol. 368, pp 154-157. ISSN 1012-0386

[Wellen 2012] Wellen R.M.R., et al. Effect of Styrene-co-Acrylonitrile on Cold Crystallization and Mechanical Properties of Poly(ethylene terephthalate). Journal of Applied Polymer Science, 2012, Vol. 125, No. 4, pp 2701-2710. ISSN 0021-8995

[Xu 2005] Xu X.F., et al., Effects of polybutadiene-g-SAN impact modifiers on the morphology and mechanical behaviors of ABS blends. European Polymer Journal, 2005, Vol. 41, No. 8, pp 1919-1926. ISSN 0014-3057

[Xu 2011] Xu X.Y. and Xu X.F. Mechanical Properties and Deformation Behaviors of Acrylonitrile-Butadiene-Styrene Under Izod Impact Test and Uniaxial Tension at Various Strain Rates. Polymer Engineering and Science, 2011, Vol. 51, No. 5, pp 902-907. ISSN 0032-3888

[Zhu 2017] Zhu J., et al. Effects of styrene-acrylonitrile contents on the properties of ABS/SAN blends for fused deposition modelling. Journal of Applied Polymer Science, 2017, Vol. 134, No. 7, pp 1-5. ISSN 0021-8995

[Zorc 2015] Zorc B. and Nagode A. Analyses of a leaking styrene-acrylonitrile water-filter housing. Engineering Failure Analysis, 2015, Vol. 57, pp 156-163. ISSN 1350-6307

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