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Development of the recommendations on selection of glass-fiber reinforced polyurethanes for vehicle parts

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Abstract
Advanced polymer composites have essential features: high specific strength ratio, resistance to aggressive substances (water, fuel, oil, lubricants, weak alkalies and acids), wide operation temperature range (from -60 to +80 ^{0}C), sufficient durability (up to 10 years), high aesthetic qualities. The use of polymer composites for vehicle parts significantly reduces the curb weight of a vehicle, improves its dynamic behavior, increases its payload capacity, reduces its fuel consumption and emissions.
The research was focused on the parts made of rigid glass-fiber reinforced polyurethane. The samples were made using the system based on polyol component A and isocyanate component B in a ratio of 1,75:1 (A:B). As a filler the glass fiber roving was used in the amount of 25 weight parts per 100 weight parts of the matrix component. The glass-fiber reinforced polyurethane parts were manufactured by spraying.
The paper describes the comprehensive research of the glass-fiber reinforced polyurethane properties including the evaluation of thermal resistance, impact resilience, temperature resistance, Shore D hardness, acoustic absorption coefficient with the state-of-the-art test procedures and research equipment.
The recommendations were developed to select glass-fiber reinforced polyurethanes for vehicle parts: for parts where the material is under high load during operation (temperature, impact resilience, etc.) it is recommended, whenever possible, to use the materials with larger thickness; for the parts where hardness is subject to special requirements – the materials with smaller thickness; during part production it is necessary to precisely carry out the operations of part manufacturing process to avoid any defects which are stress raisers and reduce the material strength.

Keywords: Polymer composite, Glass-fiber reinforced polyurethane, Comprehensive research, Thermal resistance, Impact resilience, Temperature resistance, Shore D hardness, Acoustic absorption coefficient.

Body text
Today the use of polymer composites is growing steadily in the vehicle industry [1]. Polymer composites are used to manufacture vehicle exterior and interior parts, body and decoration items. Polymer composite parts have essential features: high specific strength ratio, resistance to aggressive substances (water, fuel, oil, lubricants, weak alkalies and

acids), wide operation temperature range (from -60 to +80 ^{0}C), sufficient durability (up to 10 years), high aesthetic qualities [2]. The use of polymer composites for vehicle parts significantly reduces the curb weight of a vehicle, improves its dynamic behavior, increases its payload capacity, reduces its fuel consumption and emissions.

All the world's large vehicle manufacturers require their vehicle component manufacturers to introduce ISO/TS 16949:2009 standards [3]. The Russian equivalent of ISO/TS 16949:2009 standard is GOST R ISO/TU 16949-2009 «Quality management systems. Particular requirements for the application of ISO 9001:2008 for automotive production and relevant service part organizations» [4]. According to the main provisions of GOST R ISO/TU 16949-2009 vehicle component suppliers should ensure that their products comply with the specification (TU) applicable in the vehicle manufacturing company.

The research was focused on the parts made of rigid glass-fiber reinforced polyurethane. The samples were made using the system based on polyol component A and isocyanate component B in a ratio of 1.75:1 (A:B). As a filler the glass fiber roving was used in the amount of 25 weight parts per 100 weight parts of the matrix component. The glass-fiber reinforced polyurethane parts were manufactured by spraying [5].

Six parts made of glass-fiber reinforced polyurethane were tested:

- Nos 1, 2, 3- 2 mm;
- Nos 4, 5, 6 - 4 mm.

The purpose of the research was to develop the recommendations on selection of glass-fiber reinforced polyurethanes for vehicle parts on the basis of the comprehensive research including evaluation of physical and mechanical properties (thermal resistance, impact resilience, temperature resistance, Shore D hardness) according to specification TU 2292-010-14682925-2014 [6] and acoustic absorption coefficient (K_s).

The following research equipment was used: multi-functional DigiTest durometer; electrical SNOL dryer; vernier caliper; BINDER climate chamber MKT 115; metal ruler, GOST 427-75 [7]; steel ball, weight 0,20±0,02 kg; steel ball, weight 0,90±0,02 kg and diameter 60±1 mm; special device (appendix B, Figure 1, TU 2292-010-14682925-2014); cradle; Brüel & Kjær Kundt's tube Type 4206; electronic GAS GBL-220H bench scales. All the testing was carried out at normal temperature plus 24±1 ^{0}C and humidity 50±1 %.

The electrical SNOL dryer, vernier caliper, metal ruler GOST 427-75, cradle were used to determine the thermal resistance.

Three samples of each part were tested at temperature plus 80±3 ^{0}C for 6 hours. The following parameters were determined:

- change in geometry:

$$L = \frac{(l_1 - l_o)}{l_o} \cdot 100\%, \quad (1)$$

where l_1 is the sample length (width or thickness) after treatment, mm; l_0 is the original length (width or thickness), mm;

- dimensions of possible defects.

The test results are given in Table 1.

TABLE. 1. The results of thermal stability testing

Sample No	L (%)	Remarks
1.1., 1.2., 1.3., 2.1., 2.2., 2.3., 3.1., 3.2., 3.3	0	In some areas the glazed material surface became mat
4.1., 4.2., 4.3., 5.1., 5.2., 5.3., 6.1., 6.2., 6.3.	0	The surface became brown-tinted. Insignificant thermal material degradation is possible.

All the samples passed the test:

- the geometry changes by no more than 5%;
- the material has no defects (layer separation, dents, bubbles, looseness).

The vernier caliper, metal ruler GOST 427-75, steel ball with weight 0,90±0,02 kg and diameter 60±1 mm, special device (appendix B, Figure 1, TU 2292-010-14682925-2014), cradle were used to determine the impact resilience.

Three samples of each part were tested. The steel ball with weight 0,90±0,02 kg and diameter 60±1 mm was dropped onto the part surface in three different points which had no planes of weakness. The appearance of the samples in the test areas was inspected. The test results are given in Table 2.

TABLE. 2. The results of impact resilience testing

Sample No	Appearance		
	Test 1	Test 2	Test 3
Sample 1.1.	A crack appeared	-	-
Sample 1.2.	A crack appeared	-	-
Sample 1.3.	No destruction	No destruction	No destruction
Sample 2.1.	A crack appeared	-	-
Sample 2.2.	A crack appeared	-	-
Sample 2.3.	No destruction	No destruction	No destruction
Sample 3.1.	No destruction	No destruction	No destruction
Sample 3.2.	No destruction	No destruction	No destruction
Sample 3.3.	No destruction	No destruction	No destruction
Sample 4.1.	No destruction	No destruction	No destruction
Sample 4.2.	No destruction	No destruction	No destruction
Sample 4.3.	No destruction	No destruction	No destruction

Sample 5.1.	No destruction	No destruction	No destruction
Sample 5.2.	No destruction	No destruction	No destruction
Sample 5.3.	No destruction	No destruction	No destruction
Sample 6.1.	A crack appeared	-	-
Sample 6.2.	No destruction	No destruction	No destruction
Sample 6.3.	No destruction	No destruction	No destruction

Samples 1.3, 2.3, 3.1-3.3, 4.1-4.3, 5.1-5.3, 6.2, 6.3 passed the impact resilience testing:

- their appearance did not change;
- their material has no defects (layer separation, dents, bubbles, looseness).

The vernier caliper, BINDER climate chamber MKT 115, metal ruler GOST 427-75, steel ball with weight 0,20±0,02 kg, special device (appendix B, Figure 1, TU 2292-010-14682925-2014 [6]), cradle were used to determine the temperature resistance of the material.

Three samples of each part were tested at temperature plus 80±3 ^{0}C for 12 hours and minus 60±3 ^{0}C for 6 hours. The steel ball with weight 0,20±0,02 kg was dropped from the special device (appendix B, Figure 1, TU 2292-010-14682925-2014 [6]) onto the part surface in three different points which had no planes of weakness. The appearance of the samples in the test areas was inspected. The test results are given in Table 3.

TABLE. 3. The results of temperature resistance testing

Sample No	Appearance		
	Test 1	Test 2	Test 3
Sample 1.1.	No destruction	No destruction	No destruction
Sample 1.2.	No destruction	No destruction	No destruction
Sample 1.3.	No destruction	No destruction	No destruction
Sample 2.1.	No destruction	No destruction	No destruction
Sample 2.2.	No destruction	A crack appeared	-
Sample 2.3.	No destruction	No destruction	No destruction
Sample 3.1.	A crack appeared	-	-
Sample 3.2.	A crack appeared	-	-
Sample 3.3.	No destruction	No destruction	No destruction
Sample 4.1.	A crack appeared	-	-
Sample 4.2.	No destruction	No destruction	No destruction
Sample 4.3.	No destruction	No destruction	No destruction
Sample 5.1.	No destruction	No destruction	No destruction
Sample 5.2.	No destruction	No destruction	No destruction
Sample 5.3.	No destruction	No destruction	No destruction
Sample 6.1.	No destruction	No destruction	No destruction
Sample 6.2.	No destruction	No destruction	No destruction
Sample 6.3.	A crack appeared		

Samples 1.1, 1.2, 1.3, 2.1, 2.3, 3.3, 4.2, 4.3, 5.1, 5.2, 5.3, 6.1, 6.2 passed the temperature resistance testing:

- their appearance did not change;
- their material has no defects (layer separation, dents, bubbles, looseness).

The destruction of samples 2.2, 3.1, 3.2, 4.1, 6.3 occurred in the defective material areas (thin areas of the material, pores, etc.).

Shore D hardness was measured with the multi-functional DigiTest durometer. The tests were carried out according to GOST 24621-91 (ISO 868-85) standard [8]. GOST 263-75 «Method for the determination of Shore A hardness» [9] which the TU specification refers to expired on January 1 1993.

Three measurements of Shore D hardness were taken in different points on the sample surface. Three samples of each part were tested. The test results are given in Table 4.

TABLE.4. The results of Shore D hardness testing

Sample No	Test 1	Test 2	Test 3	Arithmetic mean
Sample 1.1.	81,500	79,900	80,000	80,467
Sample 1.2.	80,600	77,300	83,200	80,367
Sample 1.3.	76,100	75,900	79,200	77,067
Sample 2.1.	71,000	68,200	67,600	68,933
Sample 2.2.	71,400	70,200	67,500	69,700
Sample 2.3.	69,800	74,900	69,200	71,300
Sample 3.1.	61,000	57,000	59,600	59,200
Sample 3.2.	59,100	59,300	56,300	58,233
Sample 3.3.	70,200	66,000	62,400	66,200
Sample 4.1.	48,200	45,500	54,000	49,233
Sample 4.2.	51,300	48,000	47,700	49,000
Sample 4.3.	44,400	46,800	42,200	44,467
Sample 5.1.	45,200	47,500	43,900	45,533
Sample 5.2.	50,400	54,800	48,400	51,200
Sample 5.3.	42,800	44,800	44,500	44,033
Sample 6.1.	61,600	61,900	64,800	62,767
Sample 6.2.	54,900	51,900	57,600	54,800
Sample 6.3.	61,700	66,900	57,900	62,167

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Specification TU 2292-010-14682925-2014 gives no recommended values of Shore D hardness. Samples 1.1., 1.2, 1.3 have the highest hardness. The thicker glass-fiber reinforced polyurethane samples have lower Shore D hardness than thinner ones that is likely to be linked to the scaling factor and a lot of defects per unit volume.

Brüel & Kjær Kundt's tube Type 4206 was used to determine the acoustic absorption coefficient according to GOST 16297-80 «Sound insulation and sound absorption materials. Methods of testing» [10]. Three measurements K_s were taken on each of parts 1-3, 5. The test results are given in Fig. 1-4.

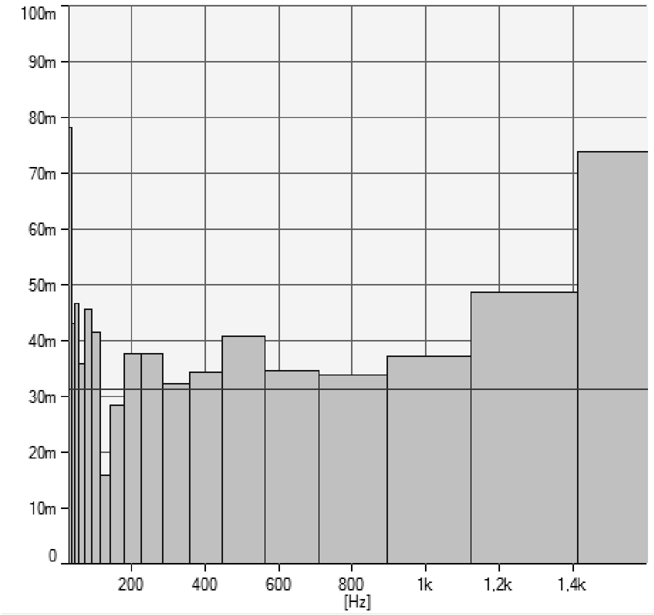

Fig.1. K_s for part 1

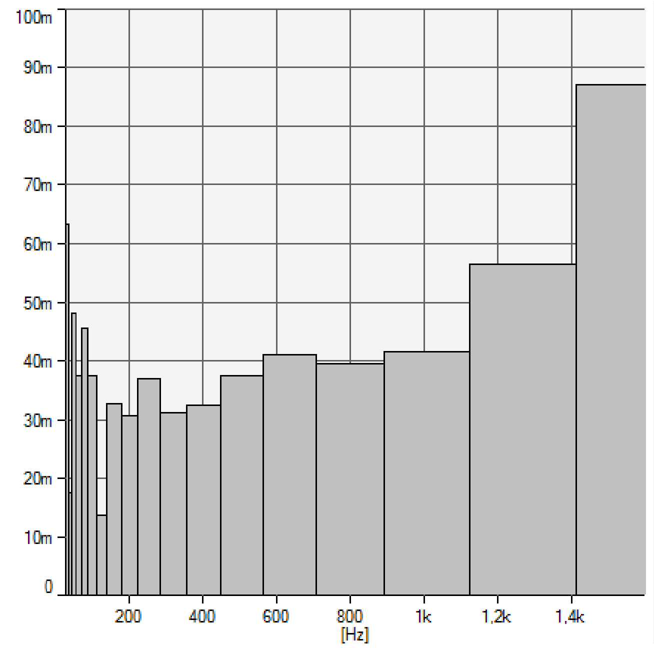

Fig.2. K_s for part 2

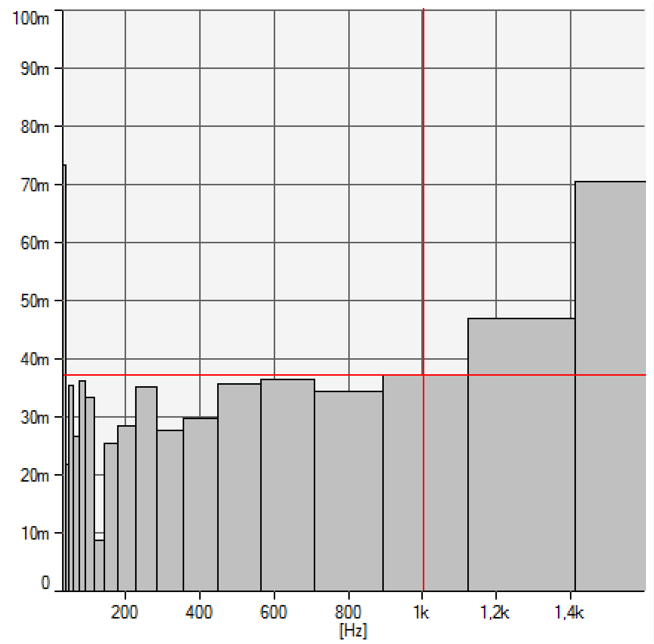

Fig.3. K_s for part 3

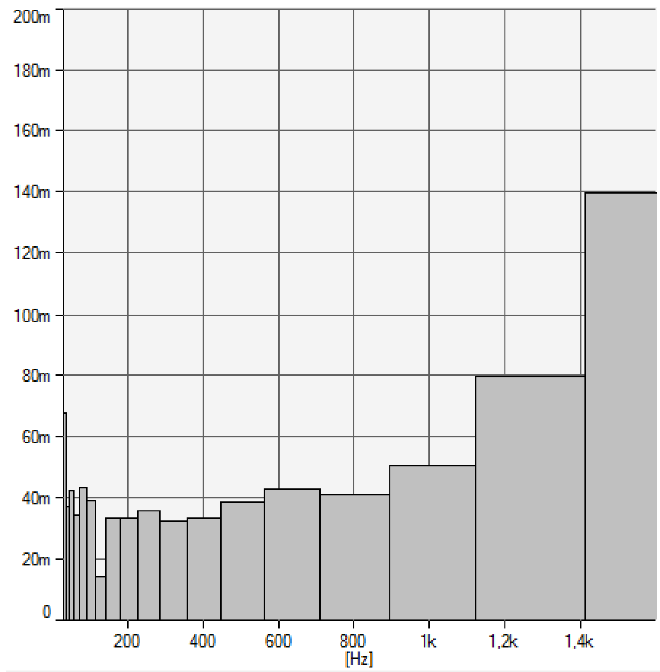

Fig.4. K_s for part 5

Conclusion

The samples have low K_s in the frequency range under study, maximum K_s values are reached in the medium frequency range - 1600 Hz.

Based on the comprehensive research of glass-fiber reinforced polyurethanes the recommendations were developed to select materials for vehicle parts:

- for parts where the material is under high load during operation (temperature, impact resilience, etc.) it is

recommended, whenever possible, to use the materials with larger thickness;
- for the parts where hardness is subject to special requirements – the materials with smaller thickness;
- during part production it is necessary to precisely carry out the operations of part manufacturing process to avoid any defects (variation in thickness, pores, cracks, etc.) which are stress raisers and reduce the material strength.

References

[1] VIAM [Official site]. URL: http://viam.ru/news/2108/ (date of the application: 14.11.2015)
[2] A.M. Adaskin, V.M. Zuev, "Materialovedenie i tekhnologiya materialov [Materials science and materials technology]", Forum, Moscow, 336 p., 2013.
[3] "ISO/TS 16949:2009. Quality management systems. Particular requirements for the application of ISO 9001:2008 for automotive production and relevant service part organizations (replaces ISO/TS 16949:2002)"; Introduced in 06.15.2009.
[4] "GOST R ISO/TU 16949-2009. Quality management systems. Particular requirements for the application of ISO 9001:2008 for automotive production and relevant service part organizations (replaces GOST R 51814.1-2004 (ISO/TS 16949:2002))"; Introduced in 01.07.2010.
[5] A.F. Nikolaev, et al., "Tekhnologiya polimernykh materialov [Technology of polymer materials]", Professiya, Saint Petersburg, 544 p., 2008.
[6] "Specification TU 2292-010-14682925-2014. Izdeliya iz zhestkogo steklonapolnennogo PPK [Parts made of rigid glass-fiber reinforced PPK]. Zavod avtomobilnykh komponentov «Avtokomponent»"; introduced in 10.04.2014.
[7] "GOST 427-75 Measuring metal rulers. Basic parameters and dimensions. Specifications", Izdatelstvo standartov, Moscow; Introduced in 01.01.1977.
[8] "GOST 24621-91 (ISO 868-85). Plastics and ebonite. Determination of indentation hardness by means of a durometer", Izdatelstvo standartov, Moscow; Introduced in 01.01.1993.
[9] "GOST 263-75. Method for the determination of Shore A hardness", Izdatelstvo standartov, Moscow; Introduced in 01.01.1977.
[10] "GOST 16297-80. Sound insulation and sound absorption materials. Methods of testing (replaces GOST 16297-70)", Izdatelstvo standartov, Moscow; Introduced in 01.01.1981.