

INVESTIGATION OF MECHANICAL PROPERTIES OF RECYCLED POLYVINYL BUTYRAL AFTER TENSILE TEST

Lucia Knapčíková

doi:10.22306/atec.v4i4.42

Received: 19 Dec. 2018

Accepted: 25 Dec. 2018

INVESTIGATION OF MECHANICAL PROPERTIES OF RECYCLED POLYVINYL BUTYRAL AFTER TENSILE TEST
Lucia Knapčíková

 Technical University of Košice, Faculty of Manufacturing Technologies with a seat in Prešov, Department of Industrial Engineering and Informatics, Bayerova 1, 080 01 Prešov, Slovak Republic, EU
 lucia.knappcikova@tuke.sk

Keywords: polyvinyl butyral, PVB, safety glass, windshield

Abstract: The paper is focused on experimental testing of mechanical properties of recycled polyvinyl butyral. After homogenization, the mixture polyvinyl butyral was compressed to the test pieces of prescribed shape and size under action of pressure and heat. Polyvinyl butyral foil is one of the most important parts of the windshield or safety glass as interlayer. Recycled polyvinyl butyral was investigated under tensile test. An important consideration is the environmental suitability of materials from recycled polyvinyl butyral and its negative effects on human's life and the environment.

1 Introduction

The implementation of materials from secondary raw materials and their application to possible components reduces the economic and environmental aspects that are also important today [1,2]. The aim of the work is to find areas of use of recycled polyvinyl butyral (PVB) product, which is the product of windscreens recycling. Nowadays, every car and its windshield is equipped with a polyvinyl butyral film that secures the safety of glass. Polyvinyl butyral [3] carries a large amount of chemically bonded energy. Less harmful vapors are released during combustion of PVB than when combustion of heating oil. However, the price of energy obtained from such a waste product is sometimes lower than the price of energy obtained from oil. Due to the way packaging of PVB waste (in the form of "big bags"), it is difficult to handle them. Given the global PVB waste production, the price for this attractive commodity is very reasonable. It ranges from 0,25 € to 0,50 € per kilogram of this thermoplastic. After the PVB separation itself, the waste still contains glass particles that reduce the extent of its use. External storage of PVB material is dissuaded because moisture and ultraviolet radiation generally degrades the properties of PVB [3]. In addition, the possibility of primary PVB contamination is increased. Due to the sticky and soft surface of the recycled PVB film, it is assumed that when unsuitable for storage, the amount of impurities will be easily adhered to the surface, thereby reducing the quality of the use of the recycled product [8]. PVB storage capacities are limited in many countries. Accordingly some countries are already increasing storage costs and are trying to make producers of PVB to encourage, that this type of waste to be reused; they returned it to the production process.

2 Material definition

Polyvinyl butyral (PVB) [4] is a special resin, mainly used as a raw material for laminated safety glass in cars and in the building construction industry (Figure 1). Application is mainly for sky scrapers. PVB currently produces several companies in Europe and the world, each under its trade mark. In addition to the main application and thus the use of PVB films, PVB resins are used for the production of paints, structural adhesives, dry toner paints, and as binders for ceramics and composite fibers [5].

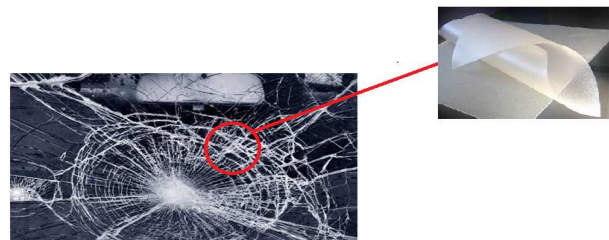


Figure 1 Polyvinyl butyral as a foil in the windshield [4]

The PVB foil has many of excellent features such as high tensile strength, impact resistance, transparency and flexibility, which is particularly useful in producing safety glass. Due to the alcohol, ester and acetate bond content, PVB foil [2] can hold the glass firmly, even if the glass breaks. The glass will adhere to the PVB film interlayer to prevent breakage. Sales of primary end-users of polyvinyl butyral are dependent on the performance of the general economy, especially for safety glass, which is so necessary in the automotive industry and in the construction industry - in architecture. In the market, polyvinyl butyral resins are highly concentrated and are the domain of four companies - Eastman, Sekisui, DuPont and Kuraray [5,6].

INVESTIGATION OF MECHANICAL PROPERTIES OF RECYCLED POLYVINYL BUTYRAL AFTER TENSILE TEST

Lucia Knapčíková

2.1 Recycled polyvinyl butyral

The key material is polyvinyl butyral, which was obtained after recycling windshields of cars (Figure 2). The material has been provided by Schirmbeck GmbH, Germany. The flakes have size from 2 mm to 20 mm and the thickness is from 0.5 mm to 1.5 mm.



Figure 2 Recycled polyvinyl butyral [7]

This recycled polyvinyl butyral is contaminated with dust, glass fragments, so it is important to thoroughly wash the material and dry it before starting laboratory work. Polyvinyl butyral as thermoplastic material is soluble in ethanol, butanol, ethyl acetate, butyl acetate, in a mixture of chlorinated hydrocarbons and insoluble in aliphatic hydrocarbons (in gasoline).

3 Material testing

Before to moulding, the thermoplastic material was homogenized using a double screw machine [8-10] Continuous mixing was used to prepare the homogenized mixture [11,12]. Homogenization (Figure 3) of the material was carried out on a Brabender Plasti-Corder W 350 E [13,14]. Laboratory investigations were performed at room temperature 22 °C and 60% humidity.

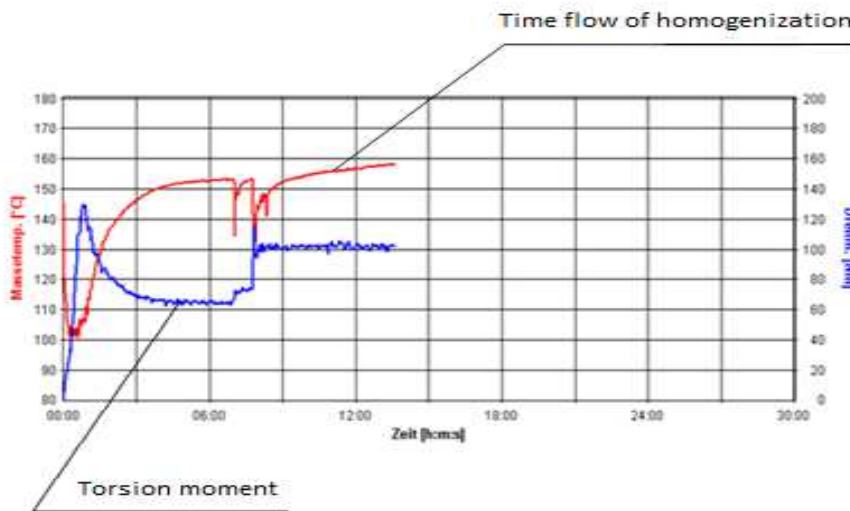


Figure 3 Polyvinyl butyral homogenization [9]

The homogenization process lasted 15 min. The material was thoroughly mixed and the formation of air bubbles that were undesirable during the molding process (occurring during compression, incomplete mixing, or incomplete filling of the thermoplastic mold cavity) was avoided. After homogenization of the recycled polyvinyl butyral on a Brabender Plasti-Corder W 350 E, the material was carefully selected and prepared for molding. The molding cycle [15] was composed of the following operations:

- mold form opening,
- filling the mold with a material,
- closing the mold,
- molding itself,
- mold form opening,
- selection of the mold,

- cooling the mold,
- cleaning the mold [11,12].

The following table (Table 1) shows the molding characteristics used Brabender W 350 mold equipment.

Table 1 Molding characteristics

Equipment	Brabender W 350
Molding temperature	190 °C
Pre-heating time	20 min
Molding time	20 min
Cooling time	20 min
Molding pressure	10 MPa

INVESTIGATION OF MECHANICAL PROPERTIES OF RECYCLED POLYVINYL BUTYRAL AFTER TENSILE TEST

Lucia Knapčíková

As mentioned above, after completion of the homogenization, the test samples were pressed according to DIN EN ISO 527-1 [12,13]. The tensile test (Figure 4) evaluated the tensile strength of the material (Table 1).

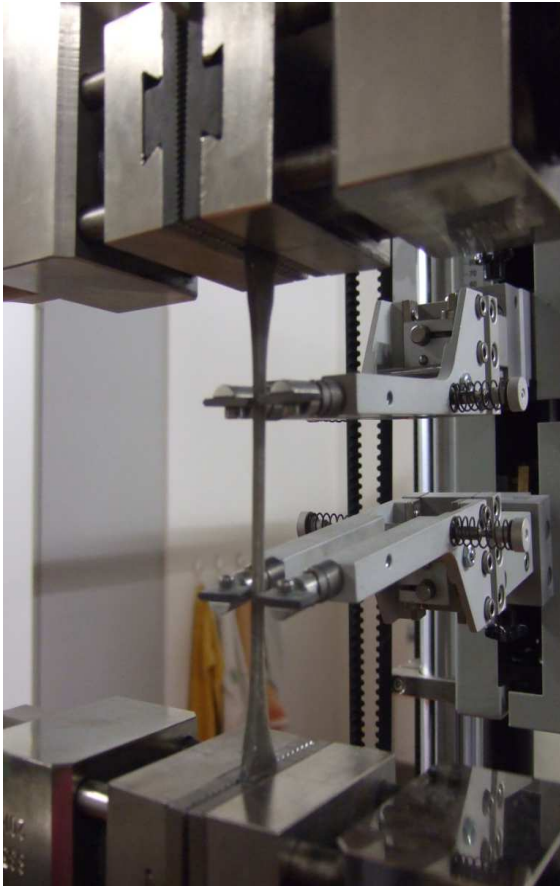


Figure 4 Tensile test of recycled polyvinyl butyral [9]

By tensile test it is important to know an external factors include:

- the frequency and condition of the load of the test material,
- medium stress when material is loaded,
- the stress state of the material,
- aggression and temperature of the environment in which the measurement is taking place,
- the material load history (whether initial testing of the material or repeated load cycles),
- samples geometry,
- test samples material,
- existence or assumption of cracks in materials,
- surface properties of the material,
- method of preparation of the test specimen [11].

Internal factors include:

- chemical composition of the material (FT IR method used),
- structural changes of material,

- method of material processing,
- method of storing the filler in the material matrix.

Table 2 Mechanical characteristics of recycled polyvinyl butyral after a tensile test

	E-modul [MPa]	σ_B [MPa]	ϵ_B [%]	σ_{max} [MPa]	ϵ_{max} [%]
\bar{x}	5,0	17,23	146,14	17,51	145,96
s	2,0	1,47	11,59	1,63	11,64
v	52,4	8,34	7,93	9,34	7,98

The test principle consisted of stressing the test body until the specimen breaks. Due to the constant speed, it has been stretched.

Conclusions

In the current work, the testing of recycled polyvinyl butyral was investigated under tensile test and material stress relaxation. Based on results it can be stated that the material had the max. values for a max. tensile stress of 17,51 MPa, the strain of the material subject to tensile strain was 145,96%. Recycled PVB is an important component in the production of new materials, characterized by very good:

- elasticity,
- adhesion to various surfaces,
- good water resistance.

The advantage of the material is high compatibility with other polymers and also very good possibilities in the manufacture of composite materials.

References

- [1] Schirmbeck GmbH, Online, Available: <http://www.schirmbeck.com/>, [13 October 2018], 2018.
- [2] Transparency market research, Online, Available: <http://www.transparencymarketresearch.com/polyvinyl-butylal-films-sheets.html>, [10 November 2018], 2018.
- [3] Polyvinyl butyral, Online, Available: <https://www.ihs.com/products/polyvinyl-butylal-chemical-economics-handbook.html>, [08 October 2018], 2018.
- [4] DHALIWAL, A.K., HAY, J.N.: The characterization of polyvinyl butyral by thermal analysis, *Thermochimica Acta*, Vol. 391, No. 1-2, pp. 245-255, 2002, doi:10.1016/s0040-6031(02)00187-9.
- [5] BARRY, C.M.F., ORROTH, S.A.: *Processing of thermoplastics*, Harper, CHA.: ModernPlastics Handbook, USA, 2000.
- [6] Sekisui chemical.com, Online, Available: www.Sekisuichemical.com, [20 November 2018], 2018.

INVESTIGATION OF MECHANICAL PROPERTIES OF RECYCLED POLYVINYL BUTYRAL AFTER TENSILE TESTLucia Knapčíková

- [7] Kuraray.eu, Online, Available: www.Kuraray.eu, [20 September 2018], 2018.
- [8] HUTYROVÁ, Z., ŠČUČKA, J., HLOCH, S.: Turning of wood plastic composites by water jet and abrasive water jet, *The International Journal of Advanced Manufacturing Technology*, Vol. 84, No. 5-8, pp. 1615-1623, 2016.
- [9] KNAPČÍKOVÁ, L., RADCHENKO, S., HUSAR, J., RADIC, P., BERNAT, A.: Experimental study of thermoplastics material reinforced by various types of high-strength fibres, *MM Science Journal*, Vol. 2016, No. October, pp. 1043-1046, 2016.
- [10] MORTENSEN, A.: *Concise encyclopedia of composite materials*, Elsevier, 2007.
- [11] VASILIEV, V.V., MOROZOV, E.V.: *Mechanics and analysis of composite materials*, Elsevier, 2001.
- [12] ZHANG, X., HAO, H., MA, G.: Parametric study of laminated glass window response to blast loads, *Engineering Structures*, Vol. 56, pp. 1707-1717, 2013.
- [13] HOOPER, P.A, BLACKMAN, B.R.K., DEAR, J.P.: The mechanical behaviour of poly(vinyl butyral) at different strain magnitudes and strain rates, *Journal of Materials Science*, Vol. 47, No. 8, pp. 3564-3576, 2012.
- [14] KNAPČÍKOVÁ, L., HERZOG, M., ORAVEC, P.: Material characterization of composite materials from used tires, *Výrobné inžinierstvo*. Vol. 2010, No. 4, pp. 31-34, 2010.
- [15] KNAPČÍKOVÁ, L., HUSÁR, J., ORAVEC, P.: *High- Strength Fiber in Polyvinyl Butyral Matrix*, Manufacturing Engineering and Management 2012, Proceedings of 2nd International Conference: December 5-7, 2012, Prešov, Slovak Republic, Prešov: FVT TU, pp. 91-93, 2012.

Review process

Single-blind peer review process.