The influence of plasticizers on mechanical and optical properties of recycled Polyvinyl butyral

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Abstract: - The increasing costs of polymer materials and pollution of the environment make the usage of recycled materials more important. PVB is mainly used in laminated safety glass. It is quite difficult to reach the uniform control of polymer properties of recycled material from this application. Unused commercial PVB film for glass lamination, recycled material recovered from the delamination of car windshields and blends of PVB were used in this study. It is focused on evaluation optical and mechanical properties. It was found that recycled PVB has similar mechanical and optical properties as commercial PVB.

Key-Words: - Polyvinyl butyral; Recycling; Laminated safety glass; Light transmission; Tensile test

1 Introduction
Polyvinyl butyral (PVB) is an industrially important polymer widely used in laminated safety glass and surface treatments because it exhibits a very high adhesion to glass [1-5]. The main use of PVB is in safety glass laminates, particularly in automotive and architectural glass. Worldwide 65% of all PVB is used in automotive applications [6]. With increasing material costs and demands for pollution control becoming more important there is an incentive to recycle plastic waste [6-8]. PVB is extensively used in glass lamination, but it is not recycled in the Europe because the process is too demanding in requiring uniform control of polymer properties [6, 9]. Instead PVB from automotive sources is disposed off in landfill [10]. This is a waste of an expensive, valuable and non-renewable commodity as well as energy and land. While the glass is recycled PVB is not. It is a disposable by-product of the glass recycling industry and available in quantity with no additional collection charges [6, 9]. An alternative to disposal in landfill is to recycle by mechanical means but central to this is an appreciation of the variation in molecular structure of PVB and its effect on material properties and end use [6, 9]. PVB is also highly plasticized and different plasticizers could be present to different extents [6]. In recycling PVB from different manufacturers the different plasticizers present may interact in a deleterious way and alter the properties of the PVB [6]. Finally, weathering of the recycled PVB could hydrolyze the butyral groups, remove plasticizer by leaching and alter the nature of the functional groups of the polymer [6]. All of these will change the final properties of the recycled PVB.

PVB is a polyacetal prepared by reacting polyvinyl alcohol with butyraldehyde in an acid medium [11]. Substantial amounts of unreacted vinyl alcohol units typically remain in the chain and so PVB is best regarded as a random copolymer of vinyl butyral and vinyl alcohol units [1]. The vinyl alcohol unit is polar and hydrophilic and the vinyl butyral unit is hydrophobic [1]. The hydroxyl and acetate groups act as promoters of polymer adhesives in the glass surface [12]. The decomposed reaction mechanism of PVB is not simple because PVB is a copolymer and the decomposed products are very complicated [12]. The relative proportions of hydroxy groups, acetate groups and acetal groups are controlled by the conditions of the acetal reaction [12]. The final structure can be considered to be a random ter-polymer of vinyl butyral, vinyl alcohol and vinyl acetate, typically 76, 22 and 2%, respectively [13]. Variations in chemical composition can occur between manufacturers and the recycled products could vary in composition and properties depending on the original source [6].
In this article, the laminated safety glass from automotive was recycled by NaOH solution. From both recycled and commercial PVB were prepared samples. The optical and mechanical properties of recycled PVB were measured and compared with commercial PVB.

2 Experimental

2.1 Materials
Recycled material was recovered from the delamination of car windshields from company HS Laminated. The process technology for preparation recycled PVB from waste laminated safety glass contains two-step glass grinding and water separation. The purpose of the recycling of laminated safety glass is to separate PVB from the glass. The laminated safety glass was firstly grinding by hammer and secondary it was warming in NaOH solution. The distilled water contend 0.5, 1 and 2% sodium hydroxide.

The commercial PVB film was obtained from Retrim-CZ, under name Butacite G and it was also highly plasticized. The plasticizer amounts at 28 % of the total weight PVB. The plasticizer is under name 3GO, it is triethylene glycol di(2-ethylhexoate).

2.2 Preparation of samples
All samples were homogenisation by kneading. The roll mill used was a Collin W100T. The composites were prepared at 95 °C for 10 min at 10 rpm. The gap between the rolls was 0.35 mm. The samples were then pressed to a thickness of 125 × 125× 1 mm by heating in a table press them for 5 min to 130 °C, sample mass was 19 g, and then cooled in a cold press.

2.3 Instrumentations
Optical transmittance of the PVB films was measured on a spectroscopy Ultrascan PRO (HunterLab). The transmittance for the visible (400–700 nm) were evaluated for D65.

The tensile test was carried out at room temperature tensile testing machine Tensometr 2000. The crosshead speed was 500 mm/min and the initial gauge length was 20 mm. This method was provided under the test standard ČSN EN ISO 527-1, 3.

3 Results and discussion
In order to compare recycled and commercial PVB samples it is important to note that these samples were not same.

The optical properties of both recycled and commercial PVB samples were measured by spectrophotometer. Fig. 1 shows the light transmission of commercial PVB and recycled PVB in distilled water with 0, 0.5, 1 and 2% sodium hydroxide. It can be concluded that the transmittances of the samples are slightly decreased with increasing temperature of sodium hydroxide. The lowest light transmission was achieved in the case of commercial PVB. This result suggests that plasticizer was perhaps washed from PVB by sodium hydroxide.

The mechanical properties of plasticized PVB samples were measured at room temperature on standard dumbbell-shaped specimens cut directly from the films. All the samples were amorphous and above their glass transition at room temperature.

Fig. 2 shows the break stress obtained from the tensile stress. The values of break stress show that the strength was very similar for all recycled PVB. As you can see in Fig. 3 shows elongation of recycled and commercial PVB.

![Fig. 1 - Light transmission of commercial PVB and PVB recycled in 0.5, 1 and 2% sodium hydroxide.](image1)

![Fig. 2 - Break stress of commercial PVB and PVB recycled in 0.5, 1 and 2% sodium hydroxide.](image2)
Fig. 3 - Elongation of commercial PVB and PVB recycled in 0.5, 1 and 2% sodium hydroxide.

No marked differences were observed between the mechanical properties. However, commercial PVB appeared to less tensile strength and elongation than the recycled products.

4 Conclusion

The optical and mechanical properties have been extensively used to characterize the PVB obtained from a wide range of sources. These properties of recycling PVB are very important because the polymer is widely used for laminated safety glass. Our work shows that recycled PVB – could be used to laminated safety glass. The recycle materials and the original polymers have similar mechanical and optical composition. There were measured no significant difference between concentrations of sodium hydroxide during recycling of PVB. This indication that the most suitable concentration for recycling PVB is half percent of NaOH. It was apparent that recycled PVB could be used to laminate without loss of optical clarity and mechanical properties.

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