Possibility Use of Plastic Materials Recycling Used in Rail Transport

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Summary
The repeated recovery of materials is synonymous with technical and economic maturity. Concern for the environment causes the amount of recycled and re-used plastic (polymer materials) constantly grows. All ecological activities associated with limiting environmental pollution and the maximizing used previously of materials. Regulations, EU directives oblige to recycle and have the effect on the amount of recycled materials on the market. It means that recycling is not only recovery of materials, but also a search for new applications of those materials. The re-use of materials is not without influence on their properties. Some polymeric materials are not suitable for re-processing, however, if such possibility exists, then we should take an advantage of it. This article contains results of mechanical changes in the properties of the polymer material subjected to multiple terms of the processing.

Keywords: recycling, polymeric materials, multiple processing, mechanical properties

1. Introduction

Thanks to their good properties polymer materials currently are one of the most popular and respected materials. They replace traditional materials such as: wood, glass or metal. Incorporated in almost all areas of the industry, it is hard to imagine the modern world without those materials. They possess a lot of advantages that make them become very attractive. They are resistant to corrosion and aggressive substances, have a low specific gravity of, low modulus and high specific strength (strength to weight ratio correct), good electrical insulating properties, and ease of shaping and processing. However, in terms of other properties of both mechanical, physical or chemical, is an individual matter, conditioned by the specificity of the material construction. Their processing is a real advantage. These materials need much less energy than traditional materials which is very important from the perspective of savings and ecology [1, 2].

From the environmental protection the most important thing is the ability to re-use these materials in many different ways Recycling is defined as the recovery relied on re-processing of materials or substances contained in waste production processes. Such activities are directed on obtaining materials or substances that have primary stage or completely different purpose [3, 4, 5].

Particularly interesting group of polymer materials that can be repeatedly processed are thermoplastics. Repeated processing is not without effect on the final properties of the finished product. It should be considered in the use of new original material is justified. For example from the economical point of view, because material derived from recovered (milling) may have such features and parameters are enough for the application [6, 7].

The purpose of this article is to present the possibilities of re-use of plastics in railway transport on the example of the multiple processing – polybutylene terephthalate (PBT).

2. Material Features

PBT – Polybutylene terephthalate is a semi-crystalline thermoplastic polymer derived from a family of polyester resins, placed on the market in 1970. It is similar in chemical structure and characteristics of the PET, but crystallizes faster and therefore it is more suitable for injection technology [4]. In contrast to the PET – ethylene-based molecules, PBT is based on polybutylene molecules. It is obtained by polycondensation of terephthalic acid or by using special catalysts of dimethyl terephthalate with 1,4-butanediol. Dimethyl terephthalate, 1,4-butanediol

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and terephthalic acid obtained from petrochemical feedstocks such as acetylene and xylene. Some varieties of PBT are acceptable for direct contact with food. The main processing method is an injection molding PBT with weight at 230–270°C. Forms temperatures are typically about 60°C, but the optimum surface appearance is obtained at 110°C. As in the case of PET, it is necessary to dry the granules before the injection process. PBT Methods than can be used for PBT connection are: friction welding ultrasonic, hot gas and heating of the mirror, and bonding with adhesives of the reactive resin [6–11].

Polybutylene terephthalate is used in many branches of industry. Most frequently PBT is used for the production of bearings, valve parts, screws, casing pumps used in the construction of rolling stock. In the transport (not only railwaytransport) it was applied to the production of: housing headlights, wipers, airbags, masking frames and other construction elements [7, 6]. This material is also used to produce household appliances, parts cooking appliances, coffee machines, hair dryers, vacuum cleaners, kitchenware and toasters.

3. Test Samples Preparation

The study used a screw injection molding machine UT90 series injection molding thermoplastics, horizontal, screw, has a five-point, dual lever locking system and direct injection mold screw drive.

The remaining laboratory equipment involved in the study are: injection mold, electronic weighing DARwag, dryer KC 100 / 200 mill for grinding plastics. Tests consisted of two parts: the processing of the material injection technology and the research of individual mechanical properties.

In the first part of the mechanical recycling process was carried out under laboratory conditions PBT (20% reinforced glass fiber). Input material was clean granular form Longlite PBT 3020 – 104Xs. PBT is hydrolyzed in a high temperature, for this reason it is important to dry the material in in a dryer (Type KC 100/200) before processing. Plastic drying parameters before the first injection cycle were:

- Drying time: 6 hours,
- Drying temperature: 110°C,
- The minimum moisture content before processing: <0.05%.

After drying the materials were subjected to the next step which was the injection test samples of mechanical properties. In the first cycle of processing performed about 100 samples, of which 20 samples were selected, for further testing strength material. Other samples were subjected to a process using a grinding mill to plastics in order to obtain granules for further processing. The next step was to re-injection of material obtained from a mixture of original material from the comminuted waste (up to 30% of the entire material) derived from previous attempts injection. Such actions were repeated five times – five times the recycled plastic responding PBT. PBT injection molding process parameters are shown in Table 1.

Table 1

Parameters of the injection molding process

Parameter	Value
Mold temperature [°C]	80
The injection temperature [°C]	260
Injection pressure [bar]	130
Downforce pressure [bar]	30
Plasticizing pressure [bar]	175
Time downforce [s]	5
Injection time [s]	5
Cooling time [s]	10

The final step was the weighing of the obtained samples (weighed together with the supply system to get the most accurate results) in individual recycling cycles by weight with an accuracy DARwag d = 0.01 g. Obtained and grouped samples were designated for further research of mechanical properties of PBT. The dependence of the mass of the processing times are summarized in Table 2 and the graph of Fig. 1. It should be emphasized that the same injection parameters were retained in all processing cycles. From Table 2 and Fig. 1, it is clear that the weight of the samples in the subsequent processing steps slightly increased.

Table 2

Dependance on the sample masses processing cycle

Processing / Sample number	I [g]	II [g]	III [g]	IV [g]	V [g]
1	26,51	26,92	26,92	26,97	26,97
2	26,52	26,89	26,94	26,95	26,98
3	26,50	26,88	26,95	26,97	27,00
4	26,50	26,89	26,96	26,98	26,99
5	26,52	26,88	26,95	26,96	26,97
The average value [g]	26,51	26,89	26,94	26,96	26,98

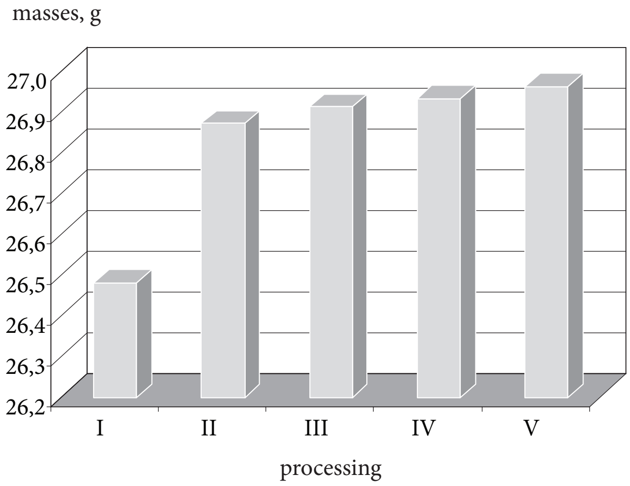

Fig. 1. Dependence on the sample masses processing cycle

Visual analysis of the obtained compacts in subsequent steps of the recycling gives the possibility to notice changes in the process. The main difference is a color change. The higher the step of processing, the darker samples are received reflecting the phenomena of degradation of the material, which affects the properties of the final products.

It is also worth to notice that multiple processing (more than five cycles of recycling) leads to substantial changes, which proves the existence of the PBT border according to subsequent processing processes. The detailed impact of the recycling PBT process on selected mechanical properties are shown in the rest of the article.

4. Research Methodology

1. Strength static stretching examination sample was performed in accordance with PN EN ISO 527-2: 2012 „Plastics – Determination of mechanical properties at static stretching. Part 2: Test conditions for plastic pressing, injection molding and extrusion".
2. Hardness identification was performed by a ball according to PN-EN ISO 2039-1: 2004 „Plastics. Hardness determination. Part 1: Method for pressing ball pressing method.
3. Determination of Charpy impact strength was carried out on the hammer swinging in accordance with PN EN ISO 179-1: 2010 „Plastics. Determination of Charpy impact strength. Part 1: non-instrumental impact test".

5. Research Results and Discussion

Material Strength

Strength determination and material deformation were performed in accordance with PN EN ISO 527-2: 1998. The measurement consisted of a stretch of constant standard speed in the form of dumbbell specimens made by the injection molding in accordance with applied respected relevant standards. During the trial stress and strain were recorded. The test results for next processing cycles are shown in Table 3 and Figure 2 and 3.

Table 3

Results of the static tensile strength test

Processing (plastic injection)	I	II	III	IV	V
Tensile strength [MPa]	113,3	105,0	100,0	93,7	91,7
Elongation at break [%]	3,75	3,30	3,10	2,75	2,70

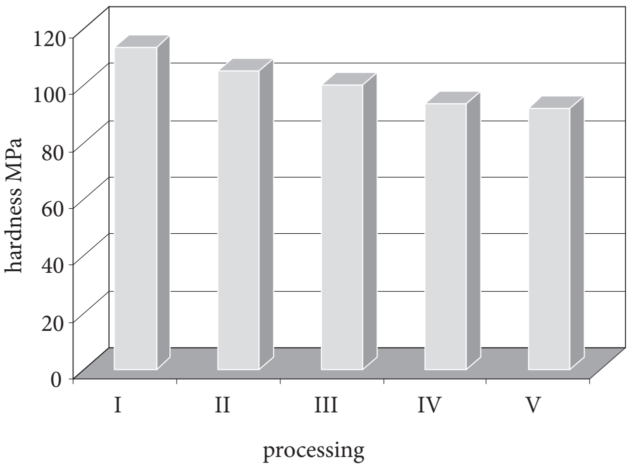

Fig. 2. Dependence on tensile strength of the next stage of processing

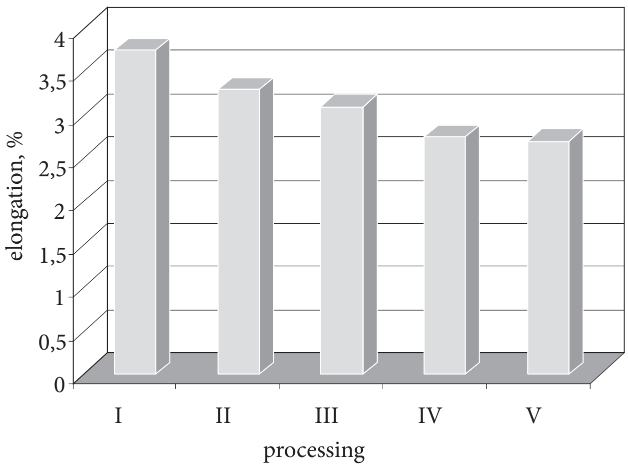

Fig. 3. Dependence on elongation break of the next stage of processing

Table 3 and Figure 2 show that within the following processing cycles decreases stress value. The same thing happens with stress. The conclusion is that successive processing result in the deterioration of these properties. Reduction of these values is not drastic. In the fifth cycle, the tension is maintained at 80 MPa and the elongation at 2.5% (Fig. 3). These are decent value and the material can be applied to structural elements that do not require moving large loads.

Material Hardness Determination

The study was carried out by a ball hardness according to PN-EN ISO 2039-1: 2004. The test consists in pressing down spherical indenter having a diameter of 5 mm for 30 seconds in the material. At steady state, in which the increasing surface of the recess balances the load, the force loading the indented surface determines the hardness of the material [1, 13]. The measurement results are shown in Table 4 and the graph of Figure 4.

Table 4

Average hardness PBT dependence next stage of processing

Processing (plastic injection)	I	II	III	IV	V
Hardness [MPa]	120,0	119,8	118,0	117,7	112,9

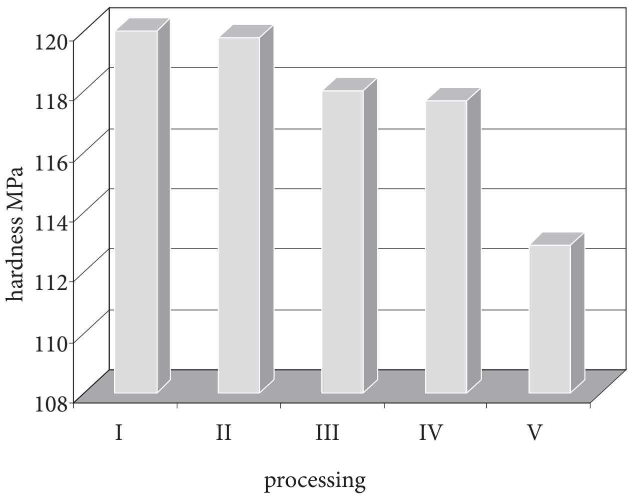

Fig. 4. Dependence of hardness PBT next stage of processing

Impact Strength

The study was carried out by Charpy impact strength (PN EN ISO 179-1: 2010), in a device called a hammer the pendulum. This method consists in the sample in the form of a standardized bar is based on a special bed near its ends and the hammer hits with the corresponding energy [1, 2]. Table 5 shows the average energy required to break the sample, the final toughness of the material after successive processing cycles.

Table 5

Charpy impact strength measurements for the samples following subsequent processing

Processing (plastic injection)	I	II	III	IV	V
Average energy required to break the sample [kJ]	2,03	1,75	1,58	1,54	1,47
Average impact strength [kJ/m²]	**50,8**	**43,8**	**39,6**	**38,6**	**36,7**

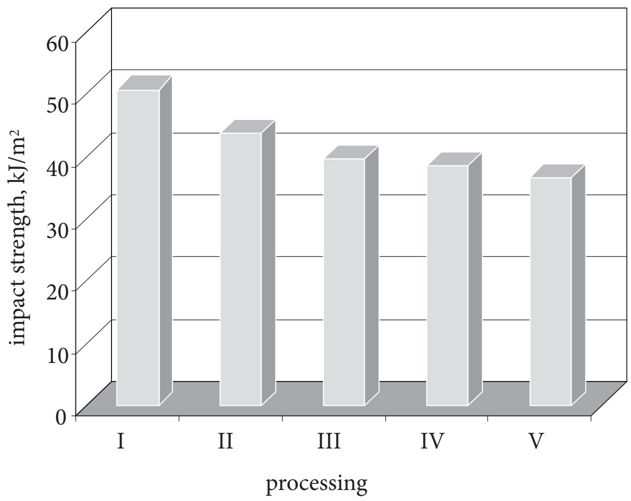

Fig. 5. Dependence of impact strength PBT next stage of processing

Figure 5 shows impact strength change material (PBT) at successive stages of processing. It falls to the value of 36, 7 kJ/m² after the fifth processing and is a decent result. The material of such parameters, the strength and hardness (Fig. 2, 3 and 4) can be successfully applied to the elements of machine parts that do not require significant load and performing not significant functions. Change impact strength for cycles III, IV and V is small, it can be assumed that in subsequent cycles, it will not be drastically deteriorated.

6. Summary and Conclusions

Plastic recycling process is the source of the material in most cases underrated and rarely used. This article is focuses on the advantages of using prevailing technology reuse plastic waste to produce new elements using the various branches of the economy. The study showed that repeated processing slows mechanical properties, however to the extent that it is possible to reuse this material. Table 6 presents the summary list of all parameter changes following subsequent processing.

Table 6

Summary of the results of the mechanical properties of PBT in successive processing cycles

Processing (plastic injection)	I	II	III	IV	V
Tension [MPa]	113,30	105,00	100,00	93,70	91,70
Elongation break [%]	3,75	3,30	3,10	2,75	2,70
Hardness [MPa]	120,00	111,80	118,00	117,70	112,90
Impact strength [KJ/m^2]	50,80	43,80	39,60	38,60	36,70

Performed studies and the results can be concluded that:

- on the basis of the results of the static tensile test, it can be noticed that the best tensile strength properties to the original material, but obtained from the next processing cycle (recycle) samples exhibit only a slight decrease in the strain and stress,
- hardness value processing in the subsequent cycles is reduced, the most pronounced decrease is observed only after the V cycle, if the hardness is determining the mechanical property of the PBT-designed product it can be safely used in its manufacture of recycled material derived from previous throughputs,
- PBT polymer impact strength decreases significantly after his re-processing of the values of 50.8 kJ/m^2 to the value of 36.7 kJ/m^2. This is due to the fact that the processing is repeated slightly reduces the viscosity of the material. It becomes more fragile, which is more prone to cracking.

In summary the study it can be concluded that the polymeric material (in this case thermoplastics) can successfully be used again for processing and for new applications if the chemical structure allows this. This gives great savings and economic benefits.

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Powtórne wykorzystanie tworzyw sztucznych stosowanych w transporcie szynowym

Streszczenie
Powtórne odzyskiwanie materiałów jest synonimem dojrzałości technicznej i ekonomicznej. Troska o ochronę środowiska naturalnego powoduje, iż ilość odzyskiwanych i ponownie wykorzystywanych tworzyw sztucznych (materiałów polimerowych) ciągle rośnie. Wszystkie działania proekologiczne wiążą się z ograniczaniem zanieczyszczenia środowiska i maksymalnym, ponownym wykorzystaniem materiałów użytkowanych wcześniej. Regulacje prawne dyrektywy Unii Europejskiej obligują do recyklingu różnych wyrobów i wywołują efekt polegający na zwiększaniu się ilości materiałów wtórnych na rynku. To oznacza, że wyzwanie, jakie stawia recykling tworzyw, nie polega tylko na samym odzysku materiałów, ale także na poszukiwaniu nowych zastosowań tych surowców. Powtórne wykorzystanie materiałów nie pozostaje jednak bez wpływu na ich właściwości. Niektóre materiały polimerowe wręcz nie nadają się do ponownego przetwórstwa, jednak jeżeli taka możliwość istnieje to należy ją wykorzystać.
W artykule zaprezentowano wyniki zmian mechanicznych właściwości materiału polimerowego poddanego wielokrotnemu przetwórstwu.

Słowa kluczowe: recykling, materiały polimerowe, wielokrotne przetwórstwo

Переработка синтетнческих материалов используемых в рельсовом транспорте

Содержание
Переработка синтетнческих материалов является синонимом технической и экономической зрелости. Забота о натуральной среде влечет за собой постоянный рост количества использованных повторно синтетнческих материалов (полимеров). Все экологические действия связаны с ограничением загрязнения натуральной среды и максимальной переработкой использованных раньше материялов. Правовые нормы, директивы Европейского союза заставляют перерабатывать разные изделия и производят эффект роста количества вторичных материялов на рынке. Это обозначает, что вызов, который бросает переработка синтетнческих материалов, не заключается лишь в их обратном получении, но также в поиске новых способов употребления этого сырья. Переработка материялов не остается без влияния на их свойства. Некоторые полимерные материалы вообще не подходят для переработки, однако если существует такая возможность, надо ее использовать.
В работе будут представлены результаты изменений механических свойств полимерных материялов подвергающих многократной переработке.

Ключевые слова: переработка, полимерные материялы, многократная переработка