Journal for Technology of Plasticity, Vol. 31 (2006), Number 1-2

THE RELIABILITY OF USE OF RECYCLED THERMOPLAST

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ABSTRACT

In this work we presented the possibility of re-use of already used polymer materials by their recycling from the point of view of the change of mechanical characteristics.
In the experimental part, the standard test tubes of basic material of polyethylene, polystyrene and polypropylene as well as secondary materials were tested through five recycling cycles. The measurement of the values characteristic for testing by the process of tension, removing, and impact was performed as well as the measurement of hardness.
Scientific part presents the results of change of the most important mechanical characteristics and laws of their changes depending on the recycling cycles.
Key words: recycling, thermoplast

1. FOREWORD

Characteristic of modern society is a large amount of the public utilities waste. Materials that have a very long period of decomposition as well as non-biodegradable materials represent a great problem for an environment because they are polluters of the nature for the long time.
The manufacturers of new products should satisfy several requirements.

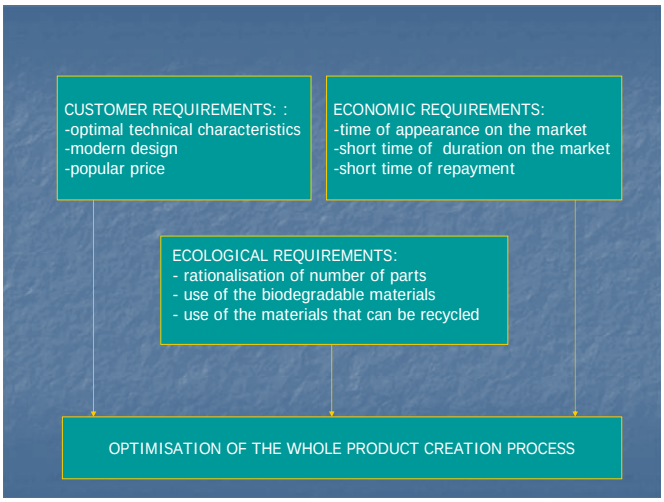

Figure1. *Important requirements that should be satisfied for the product creation process*

Today is common to replace a product by a new, more modern, more functional and attractive one before expiry of its exploitation duration. An example is mobile phone.

Figure 2. *Several generations of "NOKIA" mobile phones*

In order to create a new product which has satisfactory technical characteristics, interesting design, short duration on the market and low price, it is necessary to optimise all phases of the process, from its creation to its sale.
One of the optimisation measures is use of cheaper technical materials. The plastic masses are widely used as technical materials because of their favorable relationship between characteristics, quality and price, widespread possibility of use and great processing capability.

2. PLASTIC RECYCLING

The plastic mass recycling method is determined by the type of polymer, its structure and economic indicators.
The recycling of polymer waste is performed in order to obtain[4]:

- materials
- raw materials
- energy.

The simplest way to recycle thermoplast in order to obtain new material is by using thermoplast of the greatest cleanliness. This group comprises surplus materials in final product that are mechanically removed from it, and parts of final product with defects. It is very important for this group that it is not mixed with any dirt. The use of this polymer waste has long tradition. Procedures for thermoplast recycling of great hardness and procedures for recycling of dirty thermoplast are shown in **Figure 3**[4].

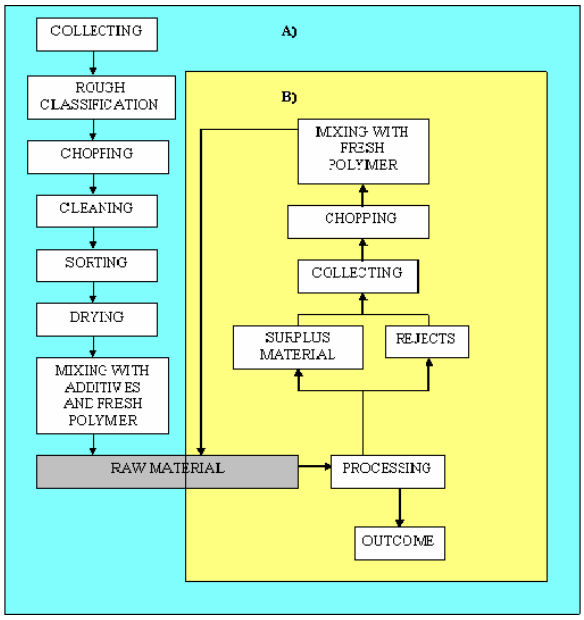

Figure 3. *Recycling of A) Clean B) Dirty thermoplast*

Recycling in order to get raw materials, in other words chemical recycling, is procedure for production of raw materials which after cleaning and finishing operations, can be used for synthesis of new polymers in processes of pyrolysis, hydrogenisation or gasification.
Outcomes obtained as a result of chemical recycling process are furthermore processed in oil refineries.

The total amount of oil energy is preserved in polymers. If there is no other way for recycling of polymers, they can be combusted in heating plants and can be used for heating and energy production. Also the presence of polymers improves combustion of utility waste.
All over the world there is already a huge number of heating plants in which utility waste is used as fuel. The presence of polymer waste in utility waste is great contribution to its combustion.

2.1. Experiment

An experiment was performed in order to research the impact of multiple thermoplast recycling on change of the mechanical properties through cycles.
The aim of the experiment was to draw conclusions about possibilities, quality and reliability of use of recycled materials. The changes of mechanical characteristics are observed on three materials at the same time through five cycles of recycling.
Three basic materials are used for the experiment:

- polyethylene
- polystyrene
- polypropylene

All materials were processed using the same machine:" ARBURG-MASCHINENFABRIK, HEHL & SOHNE, D 7298 LOSSBURG 1"
After every processing cycle some amount of material was retained and the rest of it was chopped and prepared for the next processing phase. In this way we obtained the tubes made of basic material as well as those made of materials from first, second, third, fourth and fifth recycling cycle.

***Figure 4**. Machine for finishing operations*

***Figure 5**. Industrial mill*

***Figure 6**. Cast*

***Figure 7**. Tube*

The processing temperature was constant and it amounted to 190°C, 210°C, 220°C for first, second and third heater respectively.
Cooling of tubes was done slowly at room temperature without use of any additional means.
The chopping of materials (preparation for reprocessing) was done by industrial mill.
Material was used for production of tubes for tension testing. The hardness was also tested and the samples were cut out for measurement of toughness and shearing strain.
The tubes were cast in special moulds.

An experiment included the following measurements:

1. maximum streching forces
2. maximum shearing forces
3. Rockwell hardness
4. toughness

Other mechanical values were calculated according to the measured values.

Table 1. *Experimental values*

POLYETHYLENE						
RECYCLING CYCLE	**0**	**I**	**II**	**III**	**IV**	**V**
Tension solidity R_m[N/mm^2]	22,93	23,544	23,789	24,402	23,97	23,667
Shearing solidity τm[N/mm^2]	31,08	29,44	28,6	28,6	27,63	27,29
Hardness HRC(Rockwel)	75-80	80	77	78-80	75-81	76-79
Breakage energy E_L [J]	1,635	1,962	1,962	1,962	1,308	0,981
POLYSTYRENE						
Tension solidity R_m[N/mm^2]	17,352	22,931	20,91	20,049	20,908	20,478
Shearing solidity τm[N/mm^2]	36,88	35,58	34,99	34,49	34,07	31,63
Hardness HRC(Rockwel)	90-93	90-92	87-92	85-90	85-91	85-90
Breakage energy E_L [J]	1,308	0,981	0,981	1,635	1,308	0,981
POLYPROPYLENE						
Tension solidity R_m[N/mm^2]	29,307	29,43	29,614	29,675	30,288	30,656
Shearing solidity τm[N/mm^2]	36,0	35,41	35,54	34,95	34,65	33,1
Hardness HRC(Rockwel)	83-84	85-86	82-86	80-82	80-83	82-87
Breakage energy E_L [J]	0,981	1,635	1,962	1,962	0,981	0,981

2.2. Table of Change Functions

Change functions for each recycling cycle are presented by polynomial of 4th or 5th degree. The recycling cycle is marked with the letter "N". The coefficient of determination (R) shows the extend to which experimental results are explained by the approximate results (3).

Table 2. Matrixes obtained by analysis

CHARACTERISTIC	CHANGE MATRIX	„R“
POLYETHYLENE		
Tension solidity R_m[N/mm^2]	$R_m = 0{,}0085N^4 - 0{,}1003N^3 + 0{,}2466N^2 + 0{,}3553N + 22{,}949$	$R^2 = 0{,}9234$
Shearing solidity τm[N/mm^2]	$\tau m = 0{,}0325N^4 - 0{,}3831N^3 + 1{,}5411N^2 - 2{,}9557N + +31{,}101$	$R^2 = 0{,}9882$
Hardness HRC(Rockwel)	$R = 0{,}25N^5 - 3{,}2708N^4 + 15{,}125N^3 - 28{,}979N^2 + 19{,}375N + 77{,}5$	$R^2 = 1$
Breakage energy E_L [J]	$E_L = 0{,}0136N^4 - 0{,}1241N^3 + 0{,}2225N^2 + 0{,}1527N + 1{,}6454$	$R^2 = 0{,}9683$
POLYSTYRENE		
Tension solidity R_m[N/mm^2]	$R_m = -0{,}2452N^4 + 2{,}7596N^3 - 10{,}17N^2 + 13{,}124N + 17{,}37$	$R^2 = 0{,}9948$
Shearing solidity τm[N/mm^2]	$\tau m = -0{,}0308N^4 + 0{,}1817N^3 - 0{,}0867N^2 - 1{,}2999N + + 36{,}869$	$R^2 = 0{,}9981$
Hardness HRC(Rockwel)	$R = -0{,}0833N^4 + 0{,}9167N^3 - 3{,}0417N^2 + 1{,}9226N + 91{,}464$	$R^2 = 0{,}9797$
Breakage energy E_L [J]	$E_L = 0{,}0381N^5 - 0{,}4632N^4 + 1{,}8802N^3 - 2{,}8067N^2 + 1{,}0246N + 1{,}308$	$R^2 = 1$

POLYPROPYLENE		
Tension solidity R_m[N/mm^2]	$R_m = -0{,}0128N^4 + 0{,}1323N^3 - 0{,}3741N^2 + 0{,}4331N + + 29{,}298$	$R^2 = 0{,}9846$
Shearing solidity τm[N/mm^2]	$\tau m = -0{,}0021N^4 - 0{,}0423N^3 + 0{,}2932N^2 - 0{,}7197N + + 35{,}98$	$R^2 = 0{,}9808$
Hardness HRC(Rockwel)	$R = -0{,}0625N^4 + 1{,}0417N^3 - 4{,}8125N^2 + 6{,}0476N + 83{,}464$	$R^2 = 0{,}979$
Breakage energy E_L [J]	$E_L = 0{,}0409N^4 - 0{,}3664N^3 + 0{,}7857N^2 + 0{,}1159N + 0{,}994$	$R^2 = 0{,}965$

3. CONCLUSION

Based on conducted analysis and experimental research, the following conclusions may be drawn:

- By reusing of waste the quantities in dumping site and environment are reduced. Rejected quantities of material are used for production of new materials, raw materials or energy production by recycling.
- All observed values have relatively small and limited change in value through cycles. These changes can be described by adequate mathematical function.
- Statistic analysis of results obtained by the experiment showed that the changes in observed values in function of the recycling cycle can be represented by polynominal functions of 4th or 5th degree with satisfactory accuracy.
- Matrixes describing the change of value through recycling cycles allow their analytical calculation, which in turn gives the possibility to recommend multiple use of material.
- By analysing the experimental results it may be concluded that the observed polymer materials can be reused up to the 5th recycling cycle. That is to say that recycled thermoplast is reliable for use and has stable mechanical characteristics.

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POUZDANOST PRIMENE RECIKLIRANIH TERMOPLASTA

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REZIME

U ovom radu opisuju se mogućnosti ponovnog korišćenja već korišćenih polimernih materijala reciklažom, pri čemu je akcenat stavljen na promenu mehaničkih karakteristika u toku procesa reciklaže.
U okviru eksperimentalnog dela korišćene su standardne epruvete izrađene od: polipropilena, polistirena i polietilena, kao i iste takve epruvete izrađenje od istih materijala, samo dobijenih postupkom reciklaže i to u pet ciklusa. Epruvete su bile ispitivane na zatezanje, udar, postojanost. Takođe je merena njihova tvrdoća.
Dobijeni rezultati pokazuju da zakonitosti promene najvažnijih mehaničkih karakteristika direkno zavise od broja ciklusa reciklaže.