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A COMPARISON OF THE BREAKING STRENGTH OF SAMPLES OF PARTS MADE FROM PURE AND REGRIND POLYPROPYLENE

Summary

This paper presents the results of tests of selected mechanical properties of parts made from injection molded polypropylene (PP). Parts made from primary (pure) 100 [%] PP as well as parts made from 100 [%] regrind were used for the tests. Discussed was the problem of using reground material in injection molding. Attention was paid to the apparent lack of adverse influence of regrind on the assessed mechanical properties of injection molded polypropylene parts.
***Key words**: regrind, polypropylene parts, breaking strength, ultimate tensile strength, mechanical properties*

PORÓWNANIE WYTRZYMAŁOŚCI NA ZERWANIE PRÓBEK DETALI OTRZYMANYCH Z CZYSTEGO I WTÓRNIE MIELONEGO POLIPROPYLENU

Streszczenie

W pracy przedstawiono wyniki wybranych właściwości mechanicznych detali wykonanych z polipropylenu (PP) metodą wtrysku. Do badań wykorzystano detale wykonane w 100% z pierwotnego (czystego) PP oraz detale wykonane w 100% z przemiału. Poruszono problem możliwości wykorzystania tworzywa wtórnie mielonego w produkcji wtryskowej. Zwrócono uwagę na brak wyraźnego negatywnego wpływu przemiału na oceniane właściwości mechaniczne wtryskiwanych detali tworzywowych.
***Key words**: przemiał, detale z polipropylenu, wytrzymałość na rozciąganie, właściwości mechaniczne*

1. Introduction

One of the main indicators determining the quality of operation of any injection molding plant is efficiency [1], described by numerous inter-connected factors. Among the more important ones are, e.g. machine (injection molding machines) and device (injection molds) utilization/loading rates, or the amount of correctly manufactured parts [1, 2, 5, 6]. As far as parts themselves are concerned, their total amount is divided into good and defective (scrap) parts. Scrap is further divided into internal and external defects. External defects are the sore point of any production plant as their rate is the main indicator of the work quality of the production staff. In addition, injection molding plants aim to achieve the external defect rate of several ppm (parts per million) [1]. Internal defects are a lesser problem as deficient material can be simply sold or re-used in the injection molding process.

Re-using defective parts is connected with the necessity to grind them and usually prepare a composition with a specific proportional content of primary material [4, 5]. In this context, injection molding companies are constantly struggling with the problem of the amount of regrind that can be safely used for the production of parts, so as not to lower their operational and functional quality. As of yet, manufacturers of thermoplastic parts use in the production process either the amounts of regrind permitted by the ordering party or pure material [4]. The latter solution enables to avoid unnecessary complaint-related squabbles. The point is that seeking 'cost reductions', ordering parties often put the blame on the manufacturers for the parts that are 'deficient' due to regrind material having been used for their production. In this way they try to renegotiate the accepted asking price. At the same time, using pure material in the production process in the current economic situation is simply expensive and often unnecessary [7, 8]. For instance, in the case of parts for the food or medical industry, using regrind is absolutely out of the question (e.g. due to the requirements concerning the purity of material), however, in the case of parts which e.g. do not come into a direct contact with the human organism, or when the contact is negligible, returned defective material can be freely used [1]. Yet, ordering parties still believe that using such mixtures affects the general functional properties of the manufactured parts to a considerable degree.

2. Aim of the research

The aim of this paper is to present the results of tests of selected mechanical properties of parts made from pure PP and from 100 [%] defective parts regrind.

3. Research methodology

For the purpose of the tests, parts obtained directly from the process line of one of Bialystok's companies were used. These parts were called the lid (PK) and the plate (PD). The main aspect of the analysis was connected with a comparative assessment of the breaking strength of PP samples. The key issue, characteristic of the obtained parts, was the fact that some of them (marked as A) were made from 100 [%] pure PP, while others from PP regrind. A question was posed, as a technological issue, whether manufacturing parts from PP regrind has a significant influence on different types of mechanical strength, especially the ultimate tensile strength of the manufactured products.

Due to the fact that the test samples were obtained in the form of ready-made parts, it was impossible to prepare them pursuant to PN-EN ISO 1873-2:2002. For this reason, for the purpose of the tests, 100/4/2 [mm] samples (length/width/thickness) were cut out from the obtained parts (fig. 2a).

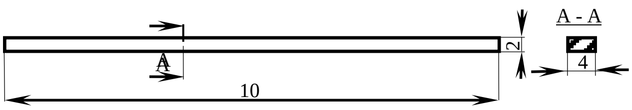
Source: own work / Źródło: opracowanie własne

Fig. 1. View of the INSTRON TM-SM 500 tensile strength tester: 1 - loading bar (traverse)
Rys. 1. Widok maszyny wytrzymałościowej INSTRON TM-SM 500: 1 – belka obciążająca (trawersa)

The tests were carried out on an INSTRON TM-SM 500-type tensile strength tester (fig. 1), at a loading bar velocity of v = 1 [mm/min] (pursuant to ISO 527) and a maximum tensile force of F_{max}= 100 [kG] (981 [N]). The tests were continued either until the sample was destroyed, or up to the point when, after exceeding the breaking strength R_m, the tensile force set at a constant, unchanging level.

Before commencing the tests, the samples were subject to 24 hours of conditioning in a climatic chamber at a humidity of 60 [%] and a temperature of 20 [°C]. Then, static tensile tests were performed (fig. 2). Each test was repeated three times in order to verify and average they obtained results.

a)



b)

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Fig. 2. View of a sample: a) dimensions of the samples prepared for the tests, b) mounted in the jaws of the tensile strength tester
Rys. 2. Widok próbek: a) wymiary próbek przygotowanych do badań, b) widok próbki zamocowanej w szczękach maszyny wytrzymałościowej

4. Research results

Fig. 3 shows an example graph of a static tensile test for the tested elements. Due to the manner of operation of the recorder, the graph is shown in a 'reversed' form.

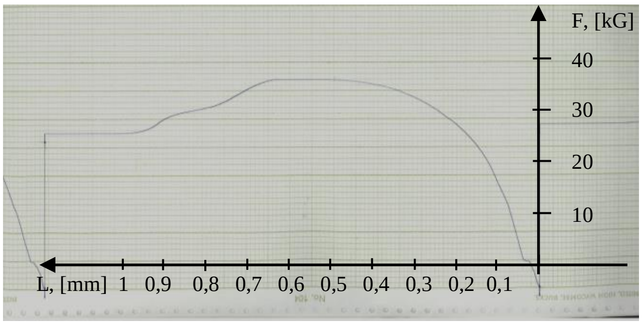

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Fig. 3. An example graph of a static tensile test
Rys. 3. Przykładowy przebieg statycznej próby rozciągania

Graphs for all the prepared samples as well as the values of maximum force, corresponding to the ultimate tensile strength, were obtained and read in the same way. Tables 1 and 2 illustrate the obtained test results. Fig. 4-6 show a graphic interpretation of the obtained test results in the form of graphs created by means of Statistica v. 10 software.

Table 1. Values of maximum tensile forces for the PD part (the values are given in [N])
Tab. 1. Wartości maksymalnych sił rozciągających dla detalu PD (wartości podane są w [N])

Type of material	F_{max} 1	F_{max} 2	F_{max} 3	Mean values
A	265	284.5	324	291
B	353	363	343	353

Source: own work / Źródło: opracowanie własne

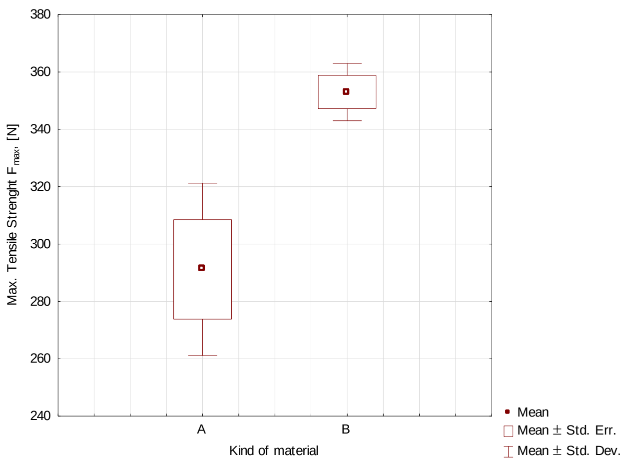

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Fig. 4. Maximum tensile strength depending on the material for the PD part
Rys. 4. Maksymalna siła rozciągająca w zależności od tworzywa dla detalu PD

Table 2. Values of maximum tensile forces for the PK part (the values are given in [N])
Tab. 2. Wartości maksymalnych sił rozciągających dla detalu PK (wartości podane są w [N])

Type of material	F_{max} 1	F_{max} 2	F_{max} 3	Mean values
A	353	348	363	355
B	383	392.5	358	378

Source: own work / Źródło: opracowanie własne

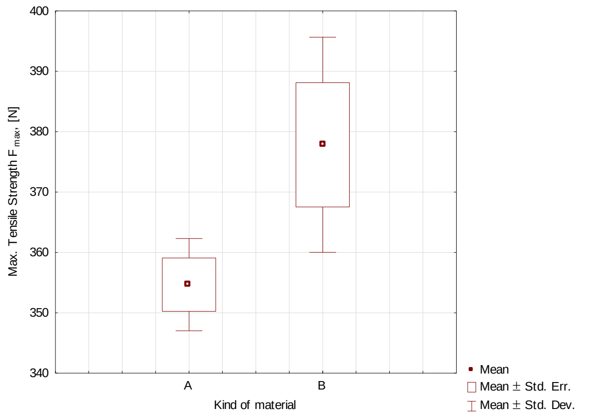

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Fig. 5. Maximum tensile strength depending on the material for the PK part
Rys. 5. Maksymalna siła rozciągająca w zależności od tworzywa dla detalu PK

The obtained test results may seem a little surprising. It can generally be stated that using regrind material (defective parts) does not have a negative influence on the value of tensile strength R_m. It may also be noticed that the values of R_m for individual parts and samples are repeatable, which eliminates the element of randomness from the obtained test results. For a better visualization of the obtained test results, fig. 6 shows a summary graph for all the tested samples.

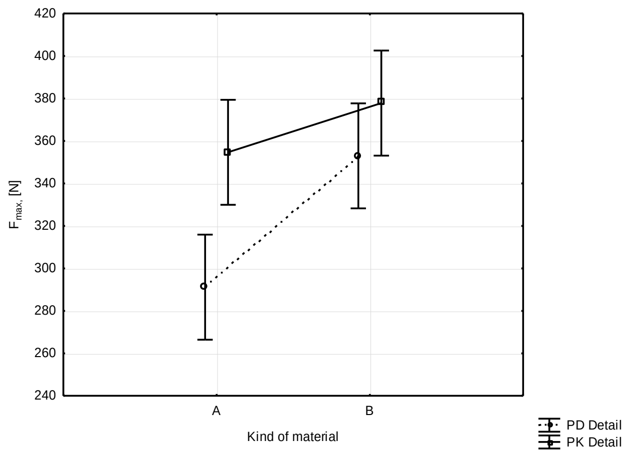

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Fig. 6. A summary of the tests results of changes of the maximum tensile force depending on the type of material and part
Rys. 6. Zestawienie wyników badań zmiany maksymalnej siły rozciągającej w zależności od rodzaju materiału i detalu

The graph presented above confirms the fact that regrind does not have a negative influence on the tensile strength of injection molded parts. It is an important aspect that these results are confirmed both in the case of the PK and the PD parts, which may indicate certain repeatable functional characteristics of this type of materials (regardless of the construction of the part). This is also an indication for manufacturers and ordering parties that in certain specific cases there is no need to worry about significantly worse mechanical properties of parts produced from mixtures with a regrind content. Obviously, a fully substantive inference in this area requires a supplementation of the tests with strictly relevant mechanical properties. The authors of this paper, however, wished to indicate that there is a possibility of using regrind, even in amounts of up to 100 [%], as a base material in injection molding, without worrying about the loss of mechanical or functional properties of parts produced from this kind of material.

As a complementary aside to the descriptions of the performed tests, it can be added that differences in the 'flow' of material during the static tensile test were observed. The illustrations presented in fig. 7 are an exemplification of these observations.

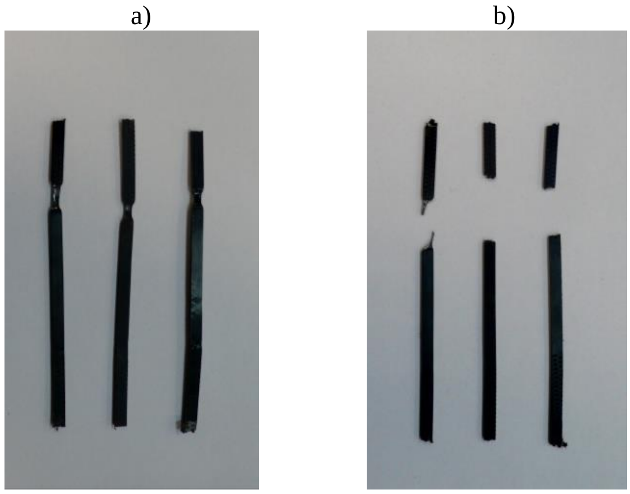

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Fig. 7. View of the tested elements after the static tensile test – PK part: a) 100 [%] pure PP, b) 100 [%] PP regrind
Rys. 7. Widok badanych elementów po statycznej próbie rozciągania – detal PK: a) 100% czysty PP, b) 100% przemiał PP

Referring to the photographs shown above, it can be stated that during the static tensile test, pure material is characterized by 'necking' (fig. 7a), as in the case of materials with a clear yield point. This may be caused by the structure of polypropylene (partly crystalline) and the partly disordered carbohydrate chains. When the material is subject to tensile forces, the chains stretch and arrange themselves in the direction of stretching, which is manifested in the lengthening and darkening of material, i.e. 'necking'. In the case of the sample made from regrind, polymer chains are to a certain degree mechanically, thermally and chemically degraded [3]. The process of grinding of defective parts also has an influence on mechanical destruction on polymer chains. For these reasons, the structure of regrind is 'finer', while the bindings in the chains are weakened. A finer structure, and thus a denser packing of molecules, may have an influence on the beneficial mechanical qualities of these materials. The weakened bindings of chains and the impossibility of their lengthening, on the other hand, manifest themselves in the effect of almost instantaneous breaking of material. Probably for the same reasons, a reduction of the impact strength of materials with a regrind content can be observed.

As proof of these claims, fig. 8 shows the results of other research studies conducted at Bialystok University of Technology. These studies were performed pursuant to PN-EN ISO 527-1, by means of the MTS 858 Mini Bionix machine [1]. The tests were carried out on samples made from pure PP and from a mixture of pure PP and PP regrind. Parts were prepared with 25, 50, 75 and 100 [%] regrind content. The presented data clearly confirms the earlier observations. It can be only added that at specific regrind contents, the obtained values of the assessed parameters are sometimes higher, at other times lower, though these differences are not substantial. Hence, a general conclusion can be formulated, namely that as far as the mechanical properties assessed in this paper are concerned, regrind content does not have a substantial negative influence on their values.

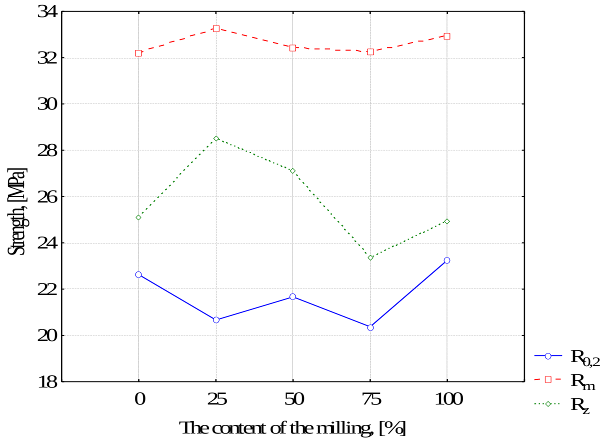

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Fig. 8. The influence of regrind content on the mechanical properties of parts made from plastics

Rys. 8. Wpływ przemiału na właściwości mechaniczne detali wykonanych z tworzywa

5. Conclusions

On the basis of the performed tests and their analysis, the following final conclusions can be formulated:

1. This paper presents a comparative analysis focused on the ultimate tensile strength of parts made from pure and regrind PP.
2. The obtained results do not indicate a negative influence of regrind on the tensile strength of samples taken from parts made from 100 [%] regrind. In addition, as it turned out, these results are confirmed regardless of the tested part.
3. Differences in the character of the behavior of samples during the static tensile test were observed. The samples taken from parts made from pure PP underwent necking when subjected to tensile forces, as is typical of materials with a clear yield point. The corresponding value of force was constant at first and then gradually decreased. In the case of the samples taken from 100 [%] regrind, on the other hand, breaking was almost instantaneous, yet at force values higher than in the case of pure PP.
4. On the basis of the performed tests, it is safe to suppose that using regrind for manufacturing injection molded parts can bring substantial economic and environmental benefits without the risk of a loss of the functional quality of the produced parts. In order to gain full knowledge in this field, research focused on fulfilling detailed requirements of parts made from regrind as well as pure material needs to be conducted.
5. For a fully substantive inference in this area, a more extensive experiment needs to be performed, e.g. one focusing on the behavior of parts in their natural conditions of operation. It is highly probable that other material characteristics, whose importance was omitted in this paper, would disqualify regrind as recycled material in injection molding.

6. References

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