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The effect of wood filler behaviour on structure and fracture of polyethylene

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Materials

ABSTRACT

Purpose: The aim of this paper was to investigate the effect of wood filler additions on the microstructure, fractographic features and cracking mechanism of low density polyethylene (LPDE).
Design/methodology/approach: For the tests, waste polyethylene from industrial and common films and Lignocel CB 120 wood fibers have been used. Three types of compositions (composites) with 10, 20 and 30% of wood flour have been prepared for the tests. To evaluate the role of used filler conducted it's quantitative analysis by linear method. Parameters like volume fraction of the filler, the number particles of wood flour per surface area and mean wood fiber diameter, were determinated.
Findings: The results of microscopic observations of the etched sections and fractures obtained at room temperature and at liquid nitrogen temperature indicate good matching between the filler particles and the structure of basic polymer, due mainly to bonding of the individual lamellae in spherulites. The reinforced polymer reveals a cracking micromechanism which is called crazing.
Research limitations/implications: The further research are required to solve the problem of the filler contrast.
Practical implications: From practical point of view, this research can be used to project composites (wood flour – polyethylene).
Originality/value: Originality of this work is the fact that stereological measurements shown usefulness this method to estimate filler's influence of forming microstructure and properties of the investigated composite.
Keywords: Engineering polymers; Low density polyethylene (LDPE); Wood filler; Microstructure; Fractography; Fracture

1. Introduction

An issue of particular concern, specially in large urban agglomerations, is the increasing volume of waste polymer products. Therefore a lot of attention and numerous publications are devoted to the problem of their utilization [1-3].

A separate problem is how to make the polymers cheaper and improve some of their properties. Recently, a growing interest has been observed in the possibility of modifying the polyolefines with fillers of natural origin, like cereals, stems of plants, nut shells, cotton, cellulose, or wood flour, specially of the conifers [2-4].

The products fabricated from such compositions are easy in utilization by both energy and material recycling [2].

The main advantages of products based on wood flour are: improved mechanical properties, increased stiffness, and water-proof behaviour (compared with wood), as well as reduced material cost and appearance of natural wood [3,5-8].

Another and quite difficult problem is the injection of materials with natural fillers.

Therefore, the aim of these studies was to examine the effect of wood fillers on changes of microstructure, on fractographic features, and on the cracking mechanism of low density polyethylene.

2. Procedure

The tests were carried out on virgin polyethylene and waste polyethylene (LLDPE + LDPE) from industrial and consumption films which were reinforced by LIGOCEL CB 120 wood fibers supplied by J. Rettenmaier & Söhene Gmbh + Co [9]. For the tests, original LDPE and composites of LDPE with wood fibers of 10, 20 and 30 per cent mass fraction were prepared. The original LDPE and the reused one with wood fibers were prepared as granulated compositions for injection, using standard lines for granulation operating in Plastics Processing Plant in Kłaj. Specimens for the tests were injected by ZA Tarnów S.A [3].

The investigations were focused on the microstructure, and especially on the fracture surfaces of the original and reinforced materials. The microstructure was investigated on sections (perpendicular to injection axis) and fracture surfaces. The fracture surfaces were obtained by tensile test performed at room temperature on Instron testing machine (by using standard dumbbell specimens, type 2, according to PN-81/C- 89034) or by breaking at liquid nitrogen temperature (- 196 0C).

The microstructure and fracture surfaces of plastics under investigation were examined with aJSM 5510 LV scanning microscope after coating the samples with thin films of carbon and gold. The secondary – electron mode was used to detect the image contrast. The microstructure and fracture surfaces were evaluated qualitatively by using magnification 500x to 2000x, while recording photographically their most characteristic features. As a result, the cracking mechanism of virgin and modified with wood fiber additions LDPE was established.

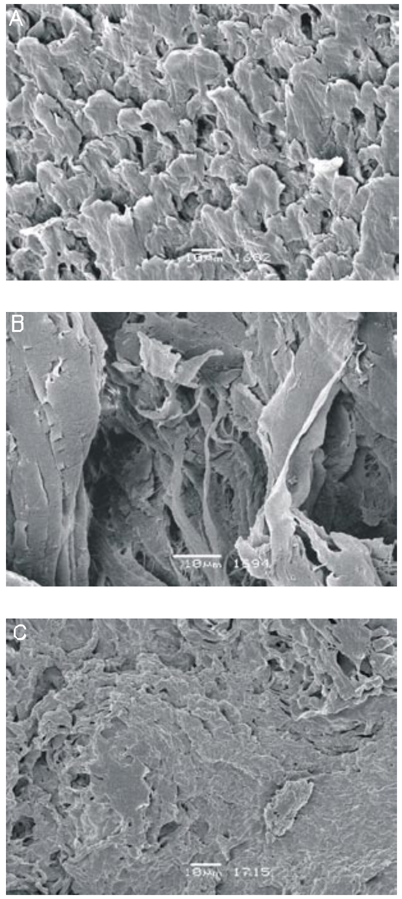
The quantitative analysis of wood fibers was carried out on unetched sections – perpendicular to injection axis. The linear method [10] was used to evaluate the effects of LPDE reinforcement. The effects of modification were evaluated by determining the volume fraction (V_v) of the used filler, the number of particles of wood fibers per surface area (N_a), and the mean wood fiber diameter (l_m).

3. Results and discussion

An analysis of microstructure and fractography (at ambient temperature and at liquid nitrogen temperature) of basic polyethylene has indicated that its crystalline part is built of spherulites of lamellar packing of fine monocrystals (Fig.1). The photographs of basic polymer taken at -196 [^{0}C] have indicated a brittle cracking mechanism – the cracking path runs between lamellae – indicating spherulite boundaries; this confirms its fine-crystalline structure (Fig.2A).

Table 1.
The results of stereological parameters of the filler measured on LDPE sections

Material + filler [%]	V_v [%]	l_m [mm] x 10^{-3}	N_a [mm^{-2}]
LDPE + 10%	24,6	1,205	583
LDPE + 20%	29,3	1,431	664
LDPE + 30%	43,5	1,183	1602



A
B
C

Fig.1. Etched section of LDPE: A - base polymer; B - with 10% of the filler; C - with 30% of the filler

The results of quantitative analysis of wood flour used as a polymer filler – of typical shapes presented in Fig.3A - LDPE (made from wastes) are listed in Table.1. An increasing filler weight fraction leads to increasing its volume fraction in the composite. The average filler particle size – determined from perpendicular sections at specimen axis (Fig.3B) - is within limits of error of the method. However, the content of N_a is rapidly increasing in the composite containing 30% of wood flour. This may result from the fact that filler segregation occurs in the first two composites.

The increasing filler volume fraction is accompanied by an increase of the measured mechanical composite properties. This refers especially to Young's modulus that increases four fold (Fig.5). This is of special significance for LDPE, as low Young's modulus of the unmodified polyethylene constrains its industrial use. The increase of LDPE measured properties is strictly related to the filler used. Its particles of well developed surface (Fig.3A) and average length of 70 to150 μm [9] bond individual lamellae in LDPE spherulites. The effect of wood flour is well illustrated in fracture fractographs taken at both liquid nitrogen (Fig.2B,C) and ambient temperatures (Fig.4B,C). The etched sections confirm an effect of wood flour mentioned above that can be described as a clip bonding individual LDPE blocks (Fig.1).

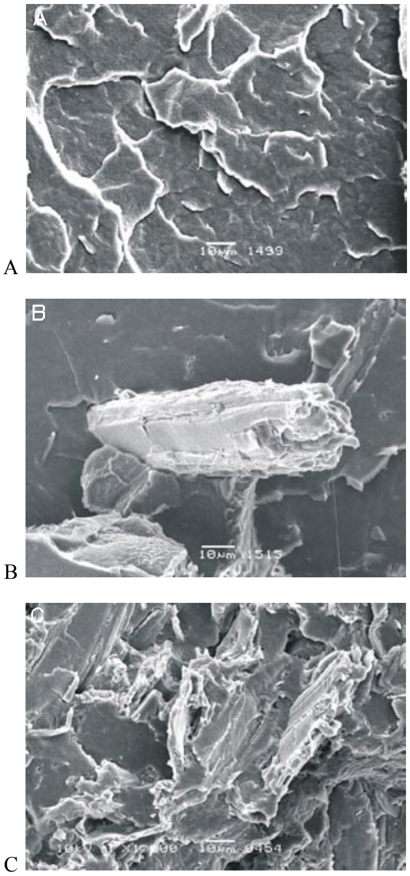


Fig. 2. Fracture surfaces of LDPE obtained at – 196 ^{0}C: A - base polymer; B - with 10% of the filler; C - with 30% of the filler

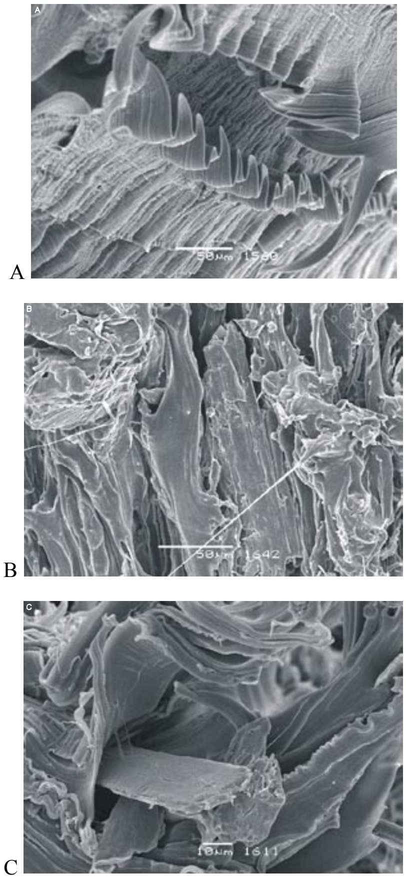


Fig. 4. Fracture surfaces of LDPE obtained at room temp.: A – base polymer; B – with 10% of the filler; C – with 30% of the filler

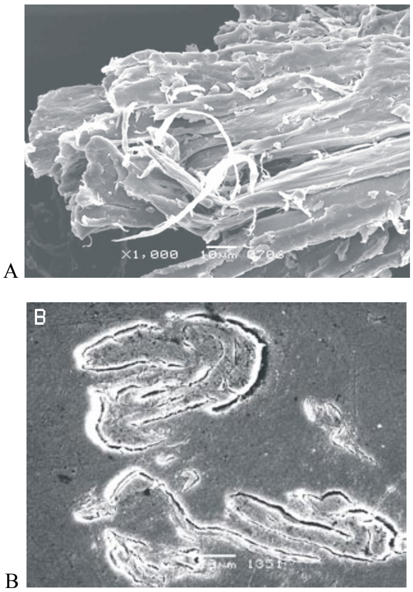


Fig.3. Typical Morphology of wood filler: A - 3-D image; B – section

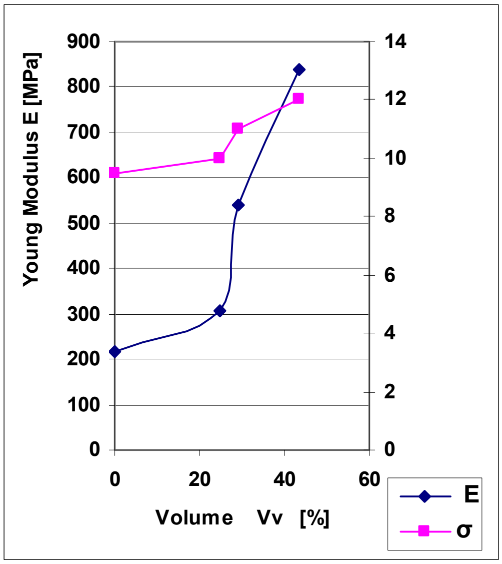


Fig.5. The influence of wood filler additions on measured mechanical properties of LDPE

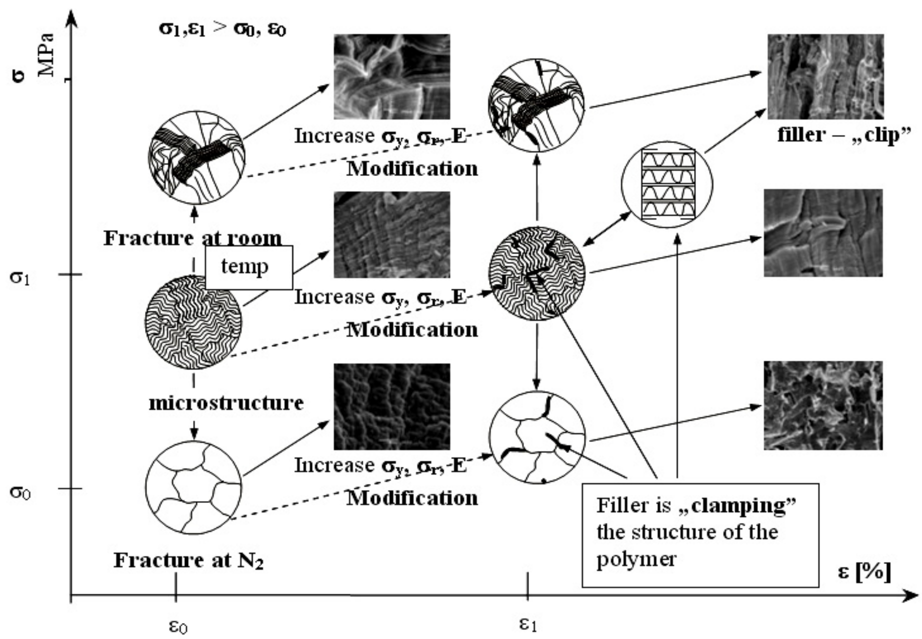


Fig. 6. Scheme shows the role of the wood filler in the changes of microstructure and mechanical properties of the investigated LDPE

The effect of wood flour on selected mechanical properties is presented schematically in Fig.6.

The fractures obtained at ambient temperature clearly indicate the features of crazing (Fig.4A, B and C). This process is observed especially for basic polyethylene (Fig.4A). The most striking feature of such fractures are numerous corrugations, some of them are comb-shaped. The crazing is a complex process that consists not only in inducing crystalline phase in the form of fibrils. It should be noted that this phenomenon, typical of some thermoplastics, increases their strength, while causing no ductility drop [11, 12].

4. Conclusions

The applicability of stereological method in determining the volume fraction of loose filler and its parameteres in wood flour - LDPE composite has been proved.

The examination of the etched LDPE sections and of the respective composites confirm their diphase structure and an important role of wood flour in microstructure formation.

The examination of fractures at room temperature indicates that crazing plays an important role in the mechanism of decohesion of the examined composites.

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