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Research Article

SELECTED PHYSICAL PROPERTIES OF EXTRUDED COMPOSITES TYPE OF POROUS PVC-METAL

Aneta Tor-Świątek[1]

[1] Department of Polymer Processing, Lublin University of Technology, Nadbystrzycka 36, 20-618 Lublin,Poland, e-mail: a.tor@pollub.pl

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ABSTRACT
The article presents studies of selected physical and mechanical properties of hybrid materials type of polymer-metal. In the frame of this work modification of PVC with the iron and copper powder in amount of 0, 1.5 and 3% and blowing agent in amount of 0, 0.5, 1% was done. Extrudates in a form of pipe were tested to determine density, porosity, maximum tensile stress, stress at break, modulus of elasticity and elongation with break. The samples were also observed in a microscope. The studies have shown significant influence of the added components on the properties tested.

Keywords: poly(vinyl chloride), extrusion, fillers, metallic powders.

INTRODUCTION

Polymer composites are now widely used in construction. They form a group of materials whose properties depend on the characteristics of individual components, the degree of miscibility, volume fraction, technology and processing conditions. A commonly used method of physical modification is the addition to polymeric materials auxiliary agents in the form of powder of fibrous fillers (e.g. calcium carbonate, magnesium oxide, beryllium oxide, talc, chalk and metal oxides such as aluminum, brass, nickel, copper, iron) and also blowing agents (porophors). Fillers in the form of powders are added to polymers to improve mechanical, dielectric, thermal, chemical and processing (better flow, decreased shrinkage) properties.

A new, interesting solution is hybrid materials type of polymer-metal. They are mostly produced by injection molding [1] and metal components usually take form of mould insert. Hybrid elements combine the advantageous properties of metals, such as high rigidity and mechanical strength with the preferred features of polymeric materials, such as easy processing, low specific gravity and corrosion resistance [1, 2]. Another method of preparing polymer –metal composites is adding a metal powder in the extrusion process.

Adding metallic powders to the polymer causes significance changes in properties and structure of the composition. Adding aluminum and brass increases acoustic conductivity, nickel powder improves impact resistance, whereas copper improves stability. Adding metallic powders also causes different specialist properties, such as electric, magnetic and tribological properties. They also increase barrier properties and strength properties such as hardness and tensile strength [3]. Conversely, changing the physical structure of the polymer materials form solid to porous results in a significant reduction of gravity of the product [6], the change of individual properties [4] and physical and geometric structure [5, 6], what have an influence on lower manufacturing costs.

Literature analyses have shown that research of hybrid materials containing polymer – metal compositions concern polymer in solid form [4, 8, 9]. In all analyzed cases the metal had a form of fibers [10, 3, 11] and was usually made in injection moulding process or plating [4, 12, 13, 14].

The aim of the study was to analyse the influence of adding a blowing agent and the filler in the form of a powder iron and copper on selected physical properties of the obtained composite.

MATERIALS AND METHODS

A modification of plastified PVC Alfavinyl GFM/4-31-TR was done. The plastic has density 1210 kg/m^3 (in 23 ºC) and tensile strength 21 MPa. The plastic was modified with iron and copper powder, which was added in the amount of 0% and 3% and mixture of Fe i Cu in the amount of 1.5%. The characteristic of metallic powders used was shown in Table 1. In addition, the PVC was modified with a blowing agent (BA) in a form of Hydrocerol 530 granulate (prod. Clariant). Porophor was dosaged in the amounts of 0%, 0.5% i 1%. The prepared mixtures were extruded in a technological line of a profile extrusion (by free cellular method) fitted with a single screw extrusion T32-25, extrusion head to pipe extrusion, cooling device and receiving device. The process was done with a constant screw rotational speed of 70 rpm. The other process conditions were: temperature of selected plasticizing system zones amounting to 110, 120, 130, 150 ºC respectively, the temperature of extruder head equal was 165 ºC and the temperature of cooling factor amount 18 ±2 ºC. In the frame of extrusion the pipe with 19 mm external diameter and 3 mm thickness wall was obtained.

In the framework of the research program of physical properties the measurements of density, porosity, tensile strength and elongation at break was done. The visualization of the structure of the surface and cross section of the obtained extrudates was also done. The research of density and porosity was done in accordance to PN-EN ISO 845:2000. The research of mechanical properties was made on tensile machine Zwick/Roel Z010 according to PN-EN ISO 527-1:1998 and PN-EN ISO 1798:2001. The structure observations of the extrudates was made in a passing light on metallographic microscope Nikon ECLIPSE LV100ND with DS-U3 Digital Camera Control Unit.

RESULTS AND DISCUSSION

Results of selected research was show in Table 2 and 3. The studies have shown the effect of the mechanical properties of metal powders added to the measured factors. The addition of metal powder resulted in an increased density by about 3% for the solid extrudates with an iron content of 3% and 5% for the solid extrudates with 3% of copper. Further adding a blowing agent resulted in a significant decrease in the density of the

Table 1. Characteristics of powder fillers used (producer data)

Type of filler	Chemical composition, %	Bulk density, kg/m^3	Granulation	Geometrical form
Copper powder (Cu) Lt 16 (Stanchem Sp. j.)	Cu – 99.7 O_2 – 0.3	1660	>63 μm – 2% >45 μm – 10% <45 μm – 88%	Irregular
Iron powder (Fe) (Stanchem Sp. j.)	O_2 – 0.1 C – 0.007 S – 0.01 Fe – 99.8	3200	+0,150 mm – 19% +0,045 mm – 98%	Irregular

Table 2. Mean values (from 10 measurements) selected physical properties of obtained composite PVC porous-metal

Dosage of porophor BA, %	Dosage of iron Fe, %	Dosage of copper Cu, %	Density, kg/m^3	Porosity, %
0	3	0	1247.10	0
0.5	3	0	1017.37	18
1.0	3	0	1013.25	24
0	0	3	1265.77	0
0.5	0	3	1019.37	19
1.0	0	3	1017.82	26
0	1.5	1.5	1260.32	0
0.5	1.5	1.5	1018.13	19
1.0	1.5	1.5	1016.63	25

Table 3. Mean values (from 10 measurements) of mechanical properties at tension of composite PVC porous-metal

Dosage of porophor BA, %	Dosage of iron Fe, %	Dosage of copper Cu, %	Maximum tensile stress, MPa	Stress at break, MPa	Modulus of elasticity, MPa	Elongation with break, %
0	3	0	14.9	14.8	8.01	170
0.5	3	0	12.2	13.7	12.6	140
1,0	3	0	8.55	8.34	6.75	120
0	0	3	19.9	19.8	13.6	180
0.5	0	3	9.85	9.57	8.76	130
1.0	0	3	7.34	6.96	6.54	120
0	1.5	1.5	17.4	17.4	11.4	150
0.5	1.5	1.5	14.7	14.2	10.9	140
1.0	1.5	1.5	7.60	7.09	6.22	120

extrudates with Fe from an average of 16% for dispensing 0.5% BA, and 17% for 1% BA. The values obtained for the density and porosity of the extrudates containing the blowing agent and Cu are greater average of 2%, which may be due to the larger size of the copper particles. In contrast, a slight decrease of the density of the extrudates with 1% BA in relation to the extrudates of 0.5% BA may result of insufficient expansion of the pores, which prevented the added metal powder.

The study of the mechanical properties showed a significant decrease in the tested factors by the addition of auxiliary agents. Tensile stress and stress at break decreased by 30% after the addition of Fe and 5% after the addition of Cu. Adding a blowing agent resulted in a further reduction of the mechanical strength of the extrudates by 42% for samples with 0.5% BA and 3% Fe and about 53% for samples with 1% BA and 3% Cu. The lowest values of mechanical examined is observed with the addition of 1% of blowing agent and 3% of copper.

Modification of PVC with a mixture of iron and copper powder allowed to obtain intermediate values in relation to the results of the extrudates and with iron and the extrudates with copper.

In the result of microscopic observations images of surface and cross sections morphology of polymer composite type of porous PVC-metal was obtained. Sample images of selected extrudates are shown in Figures 1 and 2. The observations showed the homogeneity of the physical structure of the resulting product. Visible is a relatively uniform distribution of added blowing agent in the entire cross-section of the pipe. Distribution of added metal powders is not so uniform. The largest amount of fillers is located directly on the surface of the section. It is also unsatisfactory that the surface of the extrudate, which is due to the addition of the foaming agent significantly increased its roughness. Therefore, it becomes necessary to use more intensive cooling of the extrudates, e.g. through the use of a calibration device.

CONCLUSIONS

When combining and processing components with known properties it is difficult to predict all the properties of the obtained composite porous polymer-metal. The study indicates the possibility of simultaneous modification of polymeric recipients in a form of blowing agent and powder metals. The studies have shown that the addition of the aforementioned ingredients significantly change the characteristics and structure of the resulting polymer composition. Adding a blowing agent significantly reduces the molecular weight of the material, which is reduced by the addition of copper and iron powder. Noteworthy is the fact that the highest distribution of the metal powder takes place mainly on the outer surface of the composite, while the porous structure exists in the whole cross-section of extrudates. The analyzed results show that properly selected ingredients and processing technologies allow to obtain composites with modified physical and mechanical properties.

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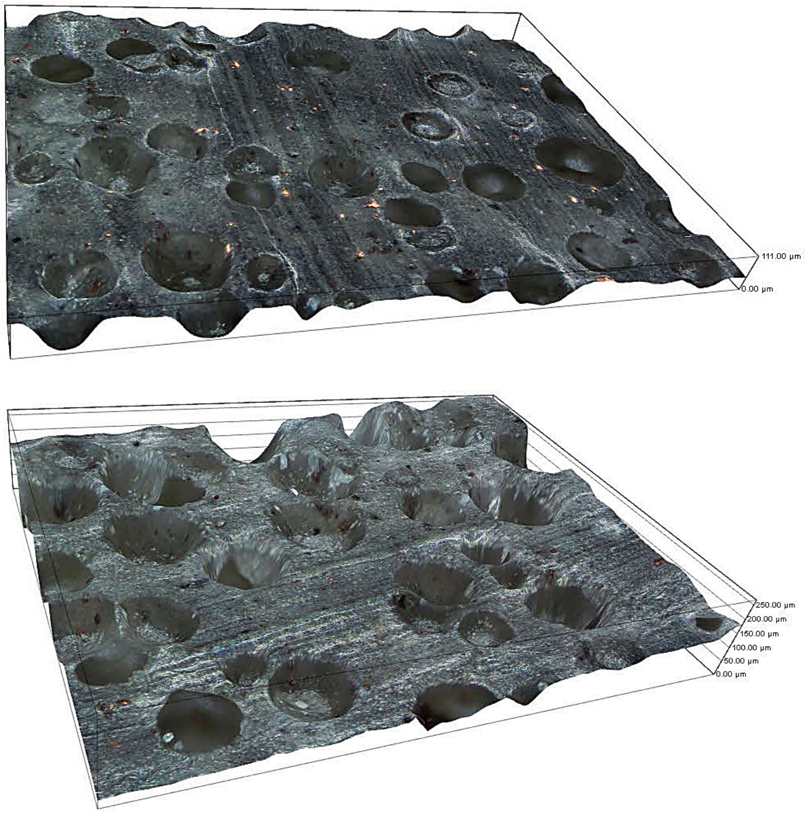

Fig. 2. Topography of cross section of composite PVC porous-metal: a) composite with 0.5% BA and 3%FE, b) composite with 1% BA and 1.5%Cu and 1.5 %Fe

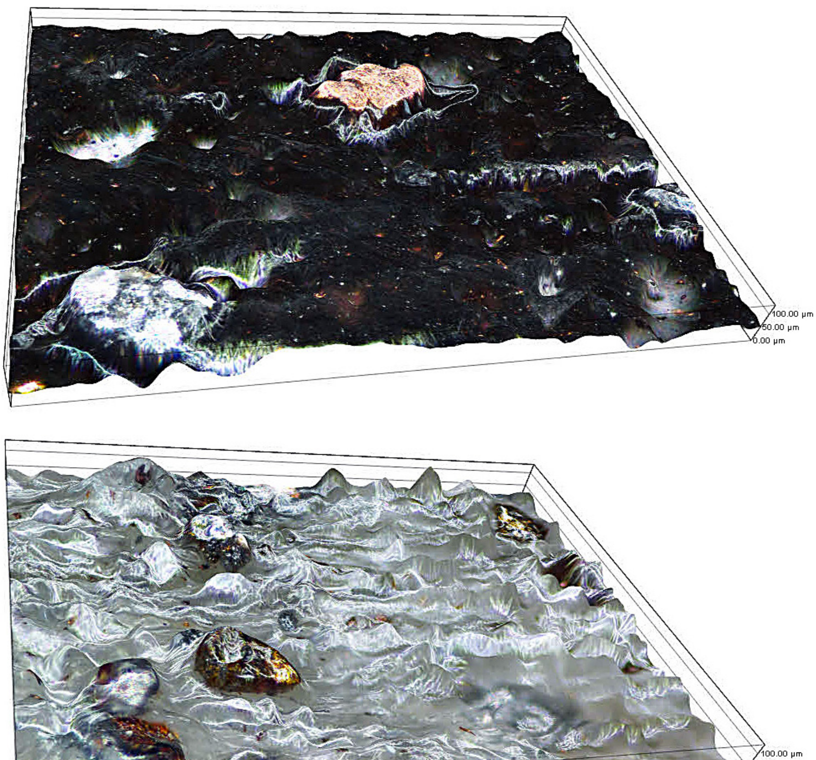

Fig. 1. Image of surface morphology and shape of powder iron and copper: a) composite with 0% BA and 1.5%Fe and 1.5%Cu, b) composite with 0.5% BA and 3%Fe c) composite with 1% BA and 1.5%Cu and 1.5%Fe

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