Physico-mechanical Properties and Electrical Conductivity of Conductive Plastic Materials

MILENA KUŠNEROVÁ[1,2]* JAN VALÍČEK[1,2], MARTA HARNIČÁROVÁ[1,3], BARBORA HALUZÍKOVÁ[1,2], PETR ŠKUBALA[4]

[1,2] Institute of Physics, Fac. of Mining and Geology, VŠB-TUO, Czech Republic; RMTVC, Fac. of Metallurgy and Materials Engineering, VŠB TUO, Czech Republic

[3] Nanotechnology Centre, VŠB-TUO, Czech Republic

[4] Petr Škubala, EBG plastics CZ, s.r.o., Ostrava, Czech Republic

The paper deals with the research of variety of non-standard samples of plastic material made by injection moulding. The samples were made of conductive plastic material (LNP Stat-kon Compound ZX05009). Brown Corundum F24 was used for blasting under different pressures. This conductive plastic material can be applied as a plastic electrode, it is therefore possible to make measurements and examination of electrical conductivity. The experiment is used in order to establish the extent, to which the pressure used at blasting measurably affects the electrical conductivity of plastic electrode.

Keywords: physico-mechanical properties, casting, plastic electrode, injection holding

Plastics are for more than 150 years a very important solid material used virtually in all industries. These are artificially produced polymers with such additives and fillers, which improve the desired properties of material. Namely the variability of mechanical and thermal properties of plastics, such as hardness, resistance, or temperature tolerance, in combination with the basic properties of plastics, i.e. with their plasticity and relatively low density, enables their extensive application [1, 2]. Plastics with different material and technological modifications thus gradually substitute traditional products, mostly metallic ones by plastic products in the form of cheap, lightweight, durable enough, sufficiently aesthetic and particularly satisfactorily functional [3, 4]. This article focuses on one interesting application, namely on the possibility of replacing metallic electrodes by plastic electrodes. The advantage of this non-standard substitution may be further enhanced by the possibility of regulation of its electrical conductivity, i.e. by the possibility of dimensioning the electrical conductivity to the desired value by adjusting the product surface. If the electrode surface is blasted by application of the air flow technology, the roughness of its surface would change. If we change pressure of the abrasive fluid, which is used for the blasting, the roughness of the blasted surface also changes. The aim of the research measurements was to determine, in what manner and how importantly the change of surface roughness [Haluzikova, B., Valicek, J., Skubala, P. et al. 2013]; [6] and (surface strengthening) would affect the change in electrical conductivity of plastics, i.e. in what way it would be possible to dimension the electrical conductivity of the product.

Experimental part

Materials and methods

Properties of plastic material used for manufacture of plastic component, which serves as plastic electrode (fig. 1) are determined by the manufacturer (table 1).

Plastic electrodes were produced by injection technology (fig. 2). The batch of the processed material was injected from the auxiliary pressure chamber of the

Table 1
PROPERTIES OF MATERIALS USED FOR MANUFACTURES OF PLASTIC ELECTRODE

	Noryl GTX GTX918W	LNP Stat-kon ZX05009
Mechanical properties		
Tensile strength [MPa]	60	81
Modulus of elasticity in tension [GPa]	2.4	10
Modulus of elasticity in bending [GPa]	2.2	7.6
Physical properties		
Density [kg·m^{-3}]	1 100	1 150
Linear shrinkage	0.016-0.020	0.002-0.004
Electrical properties		
Surface resistance [Ω]	not specified by the manufacturer	100-1000

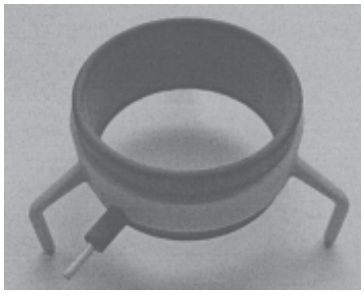

Fig. 1. Non-blasted plastic electrode

* *email: milena.kusnerova@vsb.cz; Tel.: +420597323178*

moulding machine at high speed into an enclosed cavity of metallic mould, where solidified into the desired final product.

The injection technology is the most widely used technology chosen for processing of plastics, because the products are characterized by very good dimensional and shape accuracy and high reproducibility of the properties, both mechanical and physical properties. Advantages of the injection moulding process are primarily - short time of production cycle, ability to produce even highly complicated parts with good dimensional tolerances and with very good surface finish, as well as structural flexibility that allows elimination of final surface finishing and assembly operations. The main disadvantage compared with other methods for processing of plastics consists in high investment costs and requirements to manufacture the moulds and of injection moulding machines.

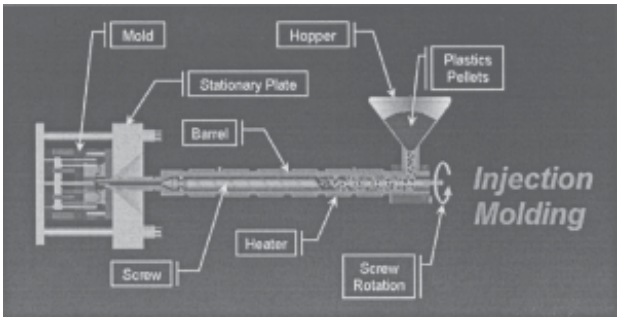

Fig. 2: Principle of injection moulding machine

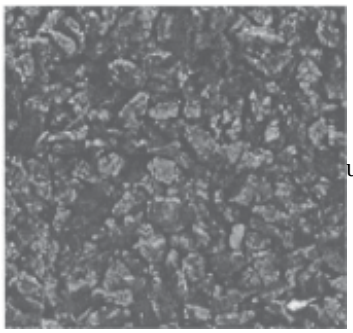

Fig. 3. Brown corundum used as abrasive material at blasting the surface of the plastic electrode

Surface of plastic electrodes was blasted by water with addition of abrasive material, i.e. brown corundum, at various pressures of liquid jet (fig. 3), at the company EBG plastics CZ, s.r.o. Brown corundum has high hardness as aluminium oxide, its most important component is Al_2O_3 (table 2) [7].

The subsequent electrical measurements of non-blasted and blasted plastic electrodes was performed in the laboratory IF HGF VŠB-TUO (F222) at the working site of the Institute of Physics at the Faculty of Mining and Geology of the VŠB - Technical University of Ostrava (HGF VŠB-TUO).

Electrical conductivity was measured on non-blasted and blasted plastic electrodes in the following way: the plastic rod was inserted into a simple electrical circuit as an appliance (fig. 4). The measurement concerned the terminal voltage by a voltmeter connected in parallel and also the electric current passing through it by an ammeter connected in series, at different powers. The database of results of partial direct measurements was then used for evaluation of the final results of indirect measurements dependence of electrical conductivity on the electric power source and on the fluid pressure at abrasive blasting. These

Table 2
MECHANICAL PROPERTIES AND CHEMICAL COMPOSITION OF THE USED ABRASIVE MATERIAL (BROWN CORUNDUM)

Mechanical properties	
Hardness [Mohs]	9
Density [$kg \cdot m^{-3}$]	4 000
Grain size [mm]	0.42 - 0.85
Chemical composition	
Al_2O_3	min. 95.50 %
SiO_2	max. 1.40 %
Fe_2O_3	max. 0.60 %
CaO	max. 0.40 %
TiO_2	1.80 - 2.80 %

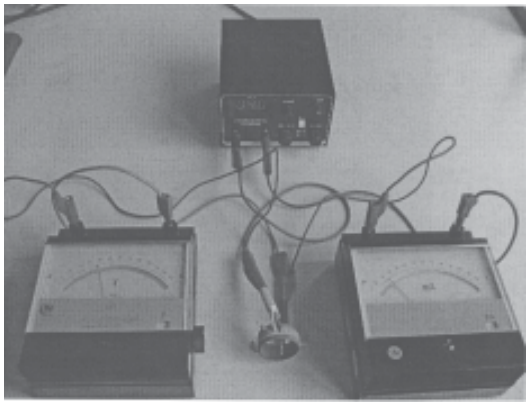

Fig. 4. Measurement of electrical conductivity of plastic electrode

dependencies were interpreted in the relevant required context, i.e. the dependence of the electrical conductivity on the fluid pressure at application of the air flow technology.

Results and discussions

Final results of measurements were summarised in table 3 and graphically illustrated in figure 5. These results may be for the needs of engineering practice interpreted quite unequivocally: non-blasted surfaces exhibit the highest electrical conductivity (the lowest electrical resistance), and with the increasing pressure of the liquid at abrasive blasting it is possible to strengthen the material surface and thus only reduce the electrical conductivity of the plastic electrode, or to dimension it to the adequately required, but always lower value, possibly down to a negligible value, when properties of the specific plastic material approach the properties of electrically non-conductive insulating materials. Change of the power supply for the circuit was performed only for control as a comparative case of measurement under similar conditions, and it did not confirm any significantly different trend.

Pressure [bar]	Sample No.	Voltage [V]	Current [mA]
4	1	5	0.09
3	2	5	0.18
1.5	3	5	9.00
1.3	4	5	9.20
1	5	5	14.80
0	6	5	22.00

Resistance [Ω]	El. conductivity [S]
58823.53	0.000017
28571.43	0.000035
555.56	0.001800
58823.53	0.000017
28571.43	0.000035
555.56	0.001800

Table 3
EXAMPLE OF MEASUREMENT OF 6 SAMPLE OF PLASTIC ELECTRODE, OF THE DEPENDENCE OF ELECTRICAL CONDUCTIVITY (AT IDENTICAL POWER SUPPLY) ON VARIOUS PRESSURES OF LIQUID AT ABRASIVE BLASTING

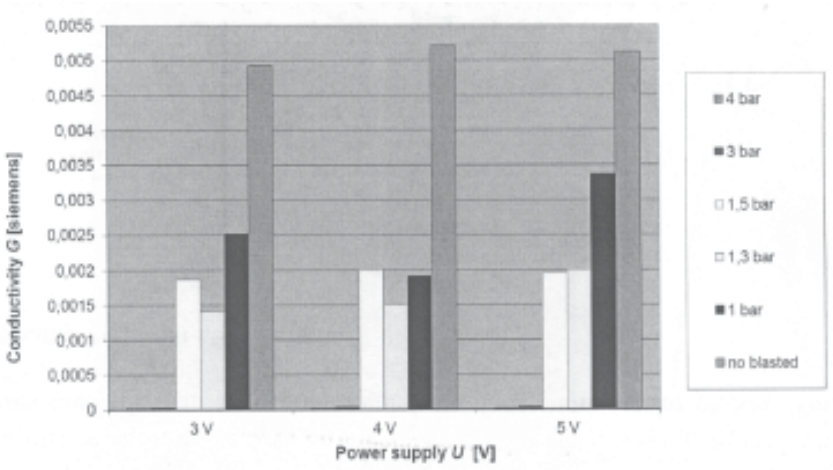

Fig. 5. Dependence of electrical conductivity of plastic on pressure at blasting

Conclusions

The electrical conductivity of plastics is therefore primarily determined from the perspective of macro-structure by material composition, and secondarily by technological change of material properties of the product, such as mechanical surface treatment (by abrasive blasting). Future research will be conducted at the micro-structural level, i.e. we will investigate the change of surface roughness in dependence on the change of electrical conductivity.

Acknowledgement: The contribution was supported by the projects RMTVC No. CZ.1.05/2.1.00/01.0040. Thanks also belong to the Moravian-Silesian Region project RRC/01569/2012 for financial support and the IT4 Innovations Centre of Excellence project, reg. no. CZ.1.05/1.1.00/02.0070 and to project Institute of Clean Technologies for Mining and Utilization of Raw Materials for Energy Use, Reg. No. CZ.1.05/2.1.00/03.0082.

References

1. JONAS, F., SCHRADER, L., Synthetic Metals, **41**, nr.3, 1991, p.831.
2.MELLALI, M., GRIMAUD, A., LEGER, A.C., FAUCHAIS, P., LU, J., J. Therm. Spray Technol., **6**, nr.2, 1997, p. 217.
3.SEOW, L.W., LAM, Y.C., J. Mater. Process. Technol., **72**, nr.3, 1997, p. 333.
4.GRZYBOWSKI, B.A., WILMER, CH.E., FIALKOWSKI, M**.,** J. Non-Cryst. Solids., **355**, nr. 24-27, 2009, p.1313.
5.KOSTIAL, P., VALICEK, J., ROKOSZ, K., HARNICAROVA, M., HALUZIKOVA, B., KUSNEROVA, P. SKUBALA, P., BRAZINA, D., SZARKOVA, V., TOMKOWSKI R., Diffusion in Solids and Liquids 8, Book Series: Defect and Diffusion Forum, **334-335,** Trans Tech Publications, Zurich, 2013, p. 71.
6.VALICEK, J., DRZIK, M., HRYNIEWICZ, T., HARNICAROVA, M., ROKOSZ, K., KUSNEROVA, M., BARCOVA, K., BRAZINA, D., Meas. Sci. Rev., **12**, nr. 5, 2012, p. 184.
7.KUSNEROVA, M., VALICEK, J., HARNICAROVA, M., HRYNIEWICZ, T., ROKOSZ, K., PALKOVA, Z., VACLAVIK, V., REPKA, M., BENDOVA, M., Meas. Sci. Rev., **13,** nr. 1, 2013, p. 1.
8.SOMSAKOVA, Z., ZAJAC, J., MICHALIK, P., KASINA, M., Mat. Plast., **49,** no. 1, 2012, p. 55

Manuscript received: 6.01.2014