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IDENTIFICATION OF THE MECHANICAL BEHAVIOUR LAW OF POLYETHER-ETHER-ETHER KETONE COMPOSITES

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ABSTRACT

The mechanical properties of neat polyetherether ketone (PEEK), and reinforced PEEK with 30 (wt%) carbon fibre (PEEK CF 30) and 15.8 (wt%) carbon nanotube (PEEK Nano) was investigated for compression tests at different strain rate. The G'Sell – Jonas phenomenological model was used to describe the mechanical behaviour of the composite materials.

Keywords: Mechanical law, polyether-ether-ketone, polymer composite, parameters identification

1. INTRODUCTION

Polyether-ether-ketone (PEEK) is a semi-crystalline thermoplastic polymer with good mechanical properties (high modulus and high strength) [1]. The carbon fibres are the most used reinforcing material into the composite materials with PEEK matrix. The mechanical behaviour of PEEK composite depends on the filler reinforcement that is used [2].

2. EXPERIMENTAL DETAILS AND MATERIALS

In this study, the authors used the quasi-static compression test, to determine the mechanical behavior.

The testing machine (INSTRON 3369) (Fig. 1.) was connected to a computer using Blue Hill software that allows for the user to enter the test data and to record the acquired data. The bottom compression module remains fixed during the test and the specimen will be placed in its middle.

The test specimens were cylindrical, with a diameter of 6 mm and 9 mm height, the ratio height/diameter (*=1.5*),

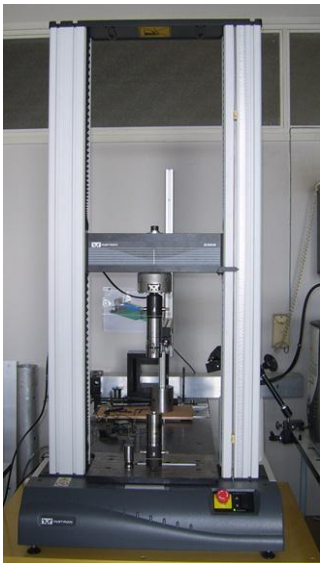

Fig. 1. Compression test device (INSTRON 3369)

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avoiding the specimen buckling [4]. The tests were performed for all three materials, at different compression speeds (0.5 mm/min, 5 mm/min, 10 mm/min), at constant temperature (*T=23°C*). The specimens before and after compression test were presented in Fig. 2.

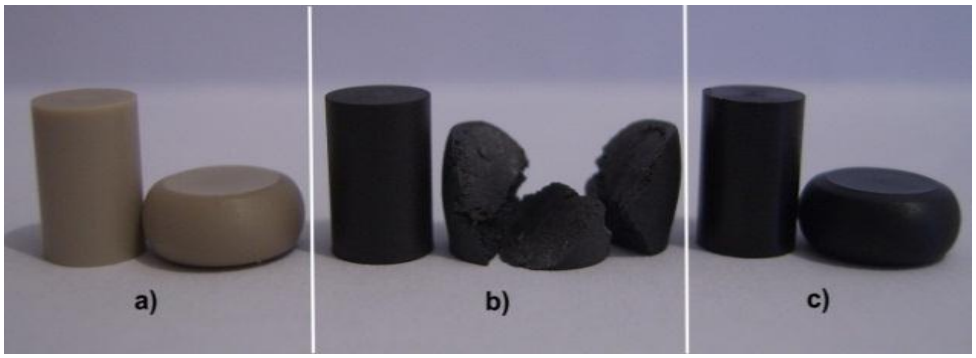


Fig. 2. Specimens before and after the compression test: a) Neat PEEK (v=0.5 mm/min); b) PEEK CF30 (v=5 mm/min); c) PEEK Nano (v=10 mm/min) [6]

The materials were assumed to be homogeneous and isotropic. During the compression test, the stress-strain curve of PEEK is influenced by the strain-rate and the temperature.

3. RESULTS AND DISCUSSION

The complex mechanical behaviour of PEEK matrix materials cannot be described by a simple law of behaviour. Many researchers have tried to describe the mechanical behaviour of the semi-crystalline polymers by equations that take into account a range of parameters: displacement, load, time and temperature [3, 4, 5].

A global relationship that describes as good as possible the rheological behavior of semi-crystalline polymers was developed by G'Sell and Jonas [4]. In this study, the authors used a multiplicative model for semi-crystalline polymers, proposed by these two researchers. This equation can be expressed as follows:

$$\bar{\sigma} = K \times f(\bar{\varepsilon}) \times g(\dot{\bar{\varepsilon}}) \tag{1}$$

where $\bar{\sigma}$ is the true stress, $\bar{\varepsilon}$ is the true strain and $\dot{\bar{\varepsilon}}$ is the strain-rate.

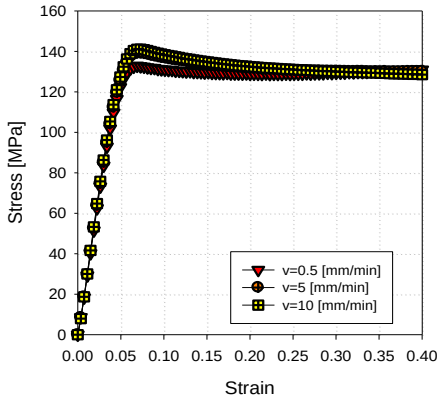
$$f(\bar{\varepsilon}) = \left(1 - e^{-w\cdot\bar{\varepsilon}}\right) \times \left(1 + a \cdot e^{-b\cdot\bar{\varepsilon}}\right) \times \left(e^{h\cdot\bar{\varepsilon}^{n}}\right) \tag{2}$$

$$g(\dot{\bar{\varepsilon}}) = \dot{\bar{\varepsilon}}^{m} \tag{3}$$

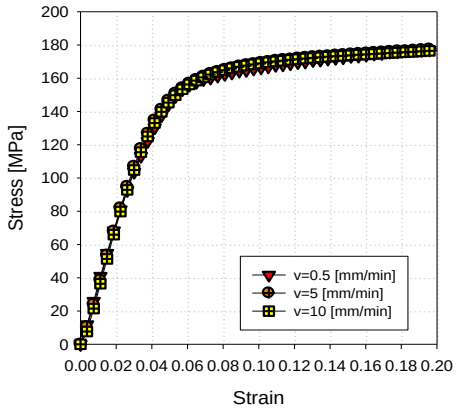
In equation (1), *K* is a material constant.

The equation (2) introduces the following terms: *w* – the viscoelastic parameter, *a*, *b* – are the softening coefficients and *h*, *n* – are the hardening coefficients. The equation (3) describes the strain-rate $g(\dot{\bar{\varepsilon}}) = \dot{\bar{\varepsilon}}^{m}$, where m is the sensitivity coefficient to the strain- rate.

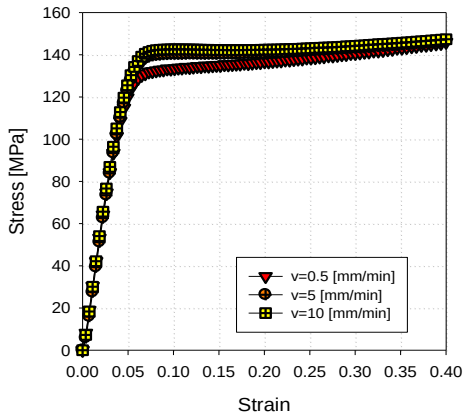
After the compression test, there were calculated the stress–strain curves for all three tested materials: neat PEEK (Fig. 3a), PEEK CF 30 (Fig. 3b), PEEK Nano (Fig. 3 c).



a) Neat PEEK

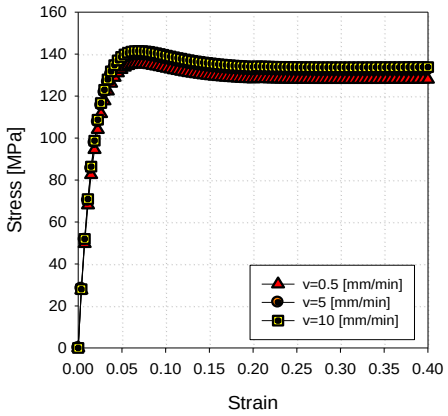


b) PEEK CF 30

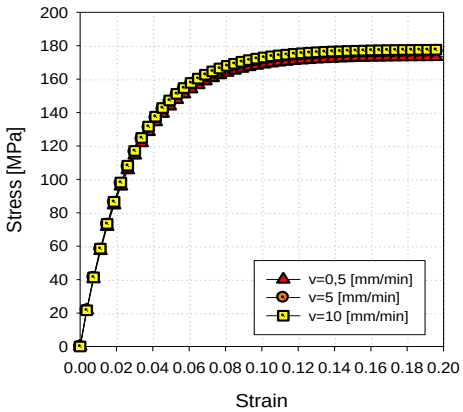


c) PEEK Nano

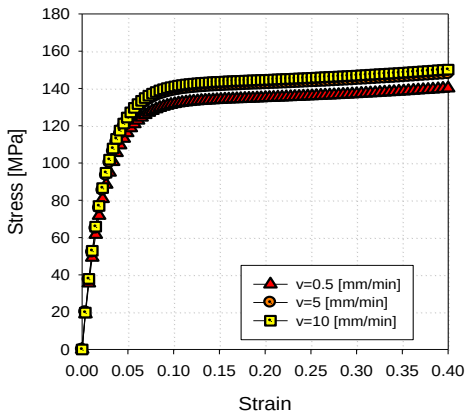
Fig. 3. Experimental data for stress–strain curves



a) Neat PEEK



b) PEEK CF 30



c) PEEK Nano

Fig. 4. Theoretical results for the stress–strain curves

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It was found that by adding the reinforcing materials the rheological behaviour of the composites is positively influenced, increasing their compressive strength. In the experimental stress-strain curves (Fig. 3), the authors observed that, for all three studied materials, the real stress is directly proportional to the test speed, meaning that increasing the test speed, the flow stress is increasing, too.

After the identification of G'Sell-Jonas parameters law, the flow curves for neat PEEK, PEEK CF 30 and PEEK Nano were calculated (Fig. 4). The values for these coefficients of the behaviour law are presented in Table 1.

Table 1. Constitutive parameters of the flow curve [6]

Materials	Parameters of G'Sell-Jonas model						
	K	w	m	a	b	h	n
PEEK	143.8	25.38	0.015	0.39	14	-	-
PEEK CF 30	183.4	35.7	0.008	-	-	-	-
PEEK Nano	156.3	41.4	0.023	-	-	0.3	2 [4]

CONCLUSION

The tested composite materials presented different types of mechanical behaviour, due to the reinforcing material.

The neat PEEK presented a yield–drop subdomain, described by the softening coefficients *a* and *b*. PEEK CF 30 presents the typical mechanical behaviour of a semi-crystalline material and the PEEK Nano composite presents a hardening domain, described by the coefficients *h* and *n*, up to the value 0.4 of the strain.

The composite reinforced with 30% carbon fibers presented the best mechanical behaviour of the three studied materials.

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