Influence of the Fibre Macromorphology on the Adhesive Strength

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The paper deals with macromorphological structure of the fibres in composite material with rubber and its influence on the adhesive strength.

In the technical practice of the chemical and man-made fibres the reinforced materials are widely used. They are applied in the construction industry, agriculture, textile and rubber industry, *etc*. In composite materials, where fibres are one of the functional components, there are requirements on their mechanical, dynamic, and adhesive properties. It is possible to secure the mechanical and dynamic properties by the chemical composition of the fibres and by the macromolecular and morphological structure of the fibres, which are gained during the process of preparation.

It is possible to secure the properties of adhesion of fibres on rubber by the chemical composition of fibres and vulcanized mixtures, or by the chemical activation of the fibre surface and of vulcanized mixtures with adhesive agents, and by geometrical modification of fibres.

The application of intentional geometrical modification of fibres for the enhanced adhesive strength may be explained according to the theory of the mechanical adhesion. The latter is based on the penetration of one polymer into the surface irregularities and surface pores of the other polymer. In general this is valid for fibre and porous materials, the surface of which is irregular and articulated [1].

The application of unfolded surfaces of geometrical profiled fibres in combination with rubber is used in practice only in a small scale.

Recently information in special papers about the economical and advantageous application of oval profiled fibres in combination with rubber was published [2]. From this viewpoint it is relevant to characterize the macromorphological fibre structures for the explanation of the dependence between the geometry of the fibre surface and the adhesive strength of the composite materials.

The geometrical fibre modification is based on the fibre preparation during the spinning process, where special dies with noncircular die orifices are used. In correlation of the profile orifices of the spinning die and the controlled rheological regime in the spinning process a geometrically modified fibre is formed, the cross profile of which is different from the circular one.

The geometrical fibre modification has several advantages:

1. Substantially it is a physical modification, which does not change the chemical composition of the fibre.

2. By the application of geometrically modified fibres in a composite system a chemical change of the rubber mixture is not required.

3. With regard to the unfolded fibre surface during its treatment by adhesive agents the chemical activation of the fibre is increased.

4. The geometrical fibre modification ensures an increased adhesive strength to rubber.

5. The geometrical fibre modification improves some mechanical and dynamic fibre properties.

Potentially a great number of various profiled spinning dies can be used for the preparation of special fibre types.

In Fig. 1 some typical profile orifices of spinning dies are illustrated.

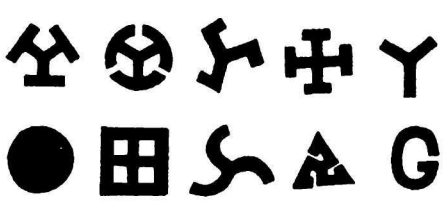


Fig. 1. Orifices cross-sections of spinning dies enabling the production of geometrically modified fibres.

EXPERIMENTAL

In the frame of our experimental work aimed to the verification of the influence of fibre macromorphology on the adhesive strength to rubber we used spinning dies of ●, Y, and ✿ shape. Poly(ethylene—

terephthalate) fibres with the mentioned profiles were prepared under the same technological conditions as circular fibres.

Spinning conditions: A semi-matted polyester with η_{rel} = 1.646 was used. The temperature of the melted polymer was on the nozzle 288 °C, polymer pressure was 15.0 MPa, air blowing beneath the nozzle was 300 N m^{-2}. The reeling rate was 2500 m min^{-1}. As spinning nozzles for fibre preparation ●, Y, and ☢ nozzle profiles were used. The fundamental linear density of fibres during spinning was 84 dtex. The fibres were further processed by drawing and joining to the required linear densities. The model fibres were evaluated according to their various macromorphology on the basis of their physical and mechanical properties and the composites with vulcanized rubber according to their adhesive strength.

RESULTS AND DISCUSSION

Cross profiles of final PET fibres are illustrated in Fig. 2.

The different articulation of the profile can be seen from electron microscopic pictures in Fig. 2. The degree of articulation of the fibre profile is expressed by the coefficient R

$$R = \frac{O^2}{S}$$

where O^2 is the square of the profile circumference and S is the profile area. The value of R is in the range from 12.5 to 20, whereby the highest value has the profile of the trefoil in Fig. 2*b* and the smallest one has the circular profile.

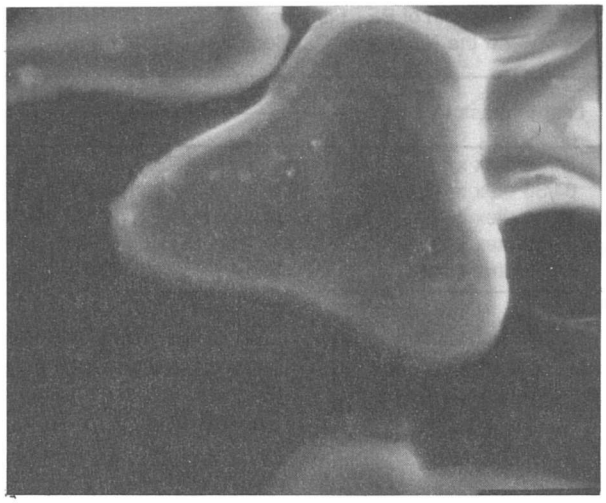
The basic physicomechanical properties of profiled and circular fibres are in Table 1.

Table 1. Basic Physicomechanical Properties of Profiled and Circular PET Fibres

Number of capillaries (profile)	Length mass	Tensile strength	Elongation
	dtex	N	%
288 (●)	495	18	106
216 (Y)	492	19	108
102 (☢)	498	18	106
72 (☢)	500	16	102

According to the values in Table 1 the basic strength and elastic characteristics are not changed in dependence on the cross profile. With the change of the fibre geometry it is possible to substitute the fibre fineness (titre) and so to lower the technological demands during the fibre preparation.

Model fibres were applied in a standard rubber mixture. According to the standard method [3] the adhesive strength of fibres to rubber was determined (Table 2).



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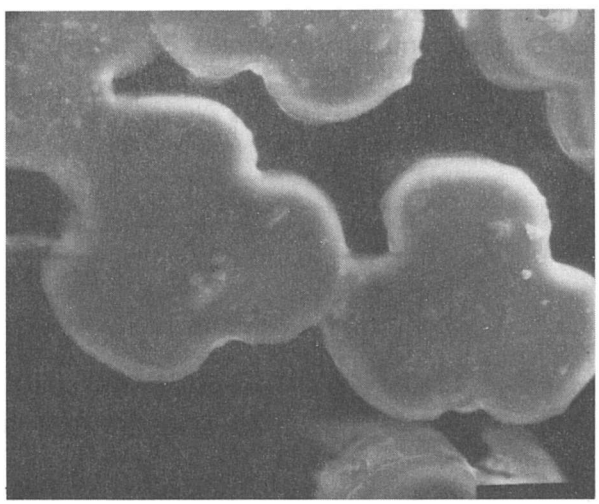

b

Fig. 2. Cross profiles of geometrically modified fibres. *a*) Y; *b*) ☢.

Table 2. Adhesive Strength of Fibres to Rubber

Number of capillaries (profile)	Adhesive strength
	N
288 (●)	9.5
216 (Y)	13.6
102 (☢)	12.7
72 (☢)	11.3

The fibre adhesive strength to rubber is highly dependent on the geometry of the fibre profile. The more is the fibre profile articulated the higher is the value of the adhesive strength of fibres to rubber (Table 3).

While the tensile strength is a growing function of the number of capillaries, the adhesive strength does not exhibit such dependence. The adhesive strength of fibres to rubber depends above all on the contact areas of the components in the system. From the viewpoint of the macromorphological fibre structure such fibres are on the surface of the fibre bundle. In

Table 3. Strength of PET Fibres with Y Profile in Dependence on the Number of Capillaries

Length mass (Y)	Tensile strength N	Adhesive strength N
84/36 dtex x 1	3.1	–
84/36 dtex x 3	9.5	10.3
84/36 dtex x 6	19.0	13.6
84/36 dtex x 9	28.1	13.4
84/36 dtex x 12	37.8	13.1

this fibre position it is possible to utilize the geometrically modified profile for increasing the contact area of fibres with rubber.

CONCLUSION

The fibre macromorphology secures a number of their functional and utility properties. By enlarging the fibre area by means of intentional geometrical modification of the fibre profile the parameter of adhesion of fibres to rubber is considerably increased. With regard to the optimum value of the adhesion of fibres to rubber by intentional change of the macromorphology of fibres it is possible to decrease the economical demands on the fibre mass or consumption of adhesive agents.

REFERENCES

1. Bischof, C. and Possart, W., *Adhäsion. Theoretische und Experimentale Grundlagen*. Akademie-Verlag, Berlin, 1983.
2. Henning, G. N. and Venkatachalam, T. K., *Elastomerics 12*, 25 (1990).
3. ST SEV 1765-79, *Adhesion Determination of Rubber to Cord.*

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The Possible Application of Dissolution Measurements to the Study of Composite Films

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The dissolution rheoviscometric measurements were used to evaluate dissolution of films based on gelatin upon the addition of nonionic hydroxyethylcellulose and ionic carboxymethylcellulose. The method is very useful for the interpretation of the dissolving process by the quantitative parameters and can be used for a more complex evaluation of composite films.

The solid layered systems based on water-soluble polymers have many applications [1]. The study of composed polymer films is of interest with regard to many practical aspects oriented to solubility, flexibility, and other technically important properties. In this paper we want to show the possibility of study of composite polymer films using rheoviscometric dissolution measurements. A laboratory device for continuous dissolution measurements of polymers by solution viscosity recording was described earlier [2]. The nonlinear viscosity dependence on the polymer content in the solution is utilized to measure a dissolution by recording the driving motor power of the discs rotating within the solution.

Gelatin, which was used as the binding agent for photographic layers 100 years ago is still very common polymeric component in many layered materials. Mixing the gelatin with water-soluble appropriate polymers we can obtain layers with combined properties of individual components. In case of gelatin which is an ionic polymer we have to consider different types of interactions with different polymer components depending on their chemical nature. However, between two ionic polymers we can ex-