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A STUDY OF TANGENTIAL DISPLACEMENT OF ULTRA HIGH MOLECULAR WEIGHT POLYETHYLENE AND ITS COMPOSITES

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Abstract
The tangential displacement of neat UHMWPE and UHMWPE based composites with Fe, graphite, glass spheres and oil is explored in the present paper. The hysteresis of elastic, viscoelastic and plastic deformations is shown. It has been found out that Fe most efficiently reduces displacement, while the addiction of oil increases viscoelastic deformation in the contract.

Key words: *tangential displacement, UHMWPE, composites, viscoelastic deformation*

1. BACKGROUND

In the engineering calculations, it is assumed that the joints remain at rest until the external tangential forces become equal to the static frictional force F_z. In fact, under the effect of the uncomplete frictional force F_z ($0 < F_z < F_{to}$) in contact, elastic and plastic displacement may occur, the value of which should be taken into account in most of the cases. Some authors call them preliminary displacements [1]. Their role for the static and dynamic joint stability is well-known [2]. They determine to great extent the ease of movement and the accuracy of the positioning in the nodes, guides, supports, rotating dividing tables, etc. The preliminary displacements affect the toughness of the press, pin, bolt and other joints.

The typical dependence of the tangential displacement δ on the stress $\tau = F_z/A$ for a metal contact is illustrated on Figure 1.

Until the achievement of the stress τ_e, the deformations remain elastic, and then follow plastic deformations (δ_p) and strengthening of the contact. After further applying of pressure, the displacements that occur are purely elastic (δ_e). The stress τ_e corresponds to approximately the half of the frictional force at rest. The value of the preliminary displacements depends on the normal and tangential stress, the loading speed and the time of the contact at rest.

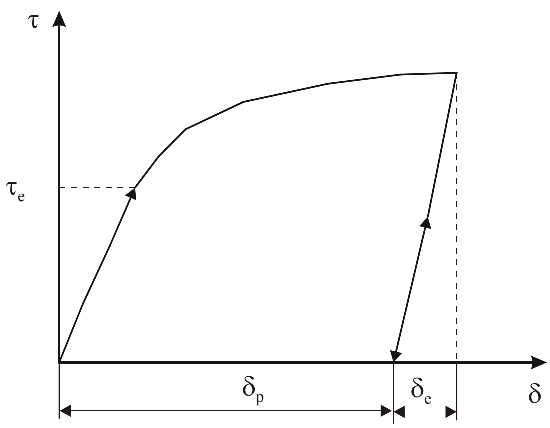

Figure 1: *Dependence of the tangential stress on the metal contact displacement.*

The last two factors have a great effect on the tangential displacements of the metal-polymer pairs. This fact can be explained by the strongly reological nature of the mechanical behavior of the polymers. The existence of creep effects and relaxation owing to their viscoelastic properties has a significant effect on the preliminary displacement [3]. It can be assumed that the variation of deformations δ with the time for polymers and their composites has, according to [4], a viscoelastic-plastical nature – Figure 2. The total deformation δ, formed during creeping (τ = const) after the load releasing (τ = 0), has elastic δ_e, viscose δ_v, and plastic component δ_p.

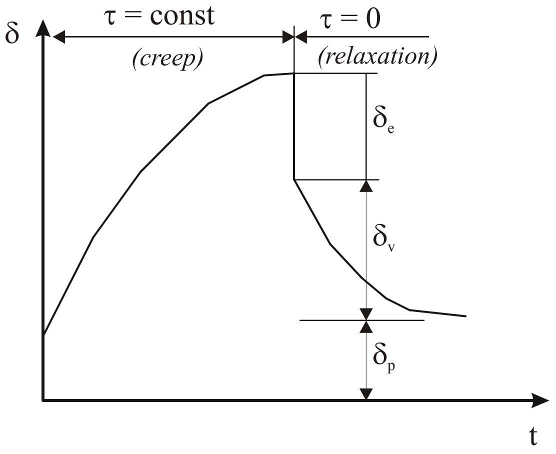

Figure 2: *Variation of deformations δ in the time for polymers and their composites.*

2. EXPERIMENTAL

Test rig

For determination of the preliminary displacements in the contact pairs with participation of the UHMWPE composites, a test rig is used as shown on Figure 3.

The variation of force F_t is realized by means of the pneumatic cylinder 11, in which dry and purified air is being supplied by means of the pneumatic preparation group 15. In its upper part, the pneumatic cylinder has an extension chamber, and in its bottom part – a calibrated opening, where the role of the piston is played by a sphere (ball) 13. The seals placed between the piston, cylinder and rod, are of a contact-free type, with a small tolerance guaranteed.

Materials

The tests are carried out on a neat UHMWPE and on its composites, shown in Table 1. The composites are created in view of the improvement of their loading capacity through the improvement of the heat conductivity, frictional coefficient and compression strength [5].

The steel counterbody is C15E, with a roughness R_a=1,5 μm.

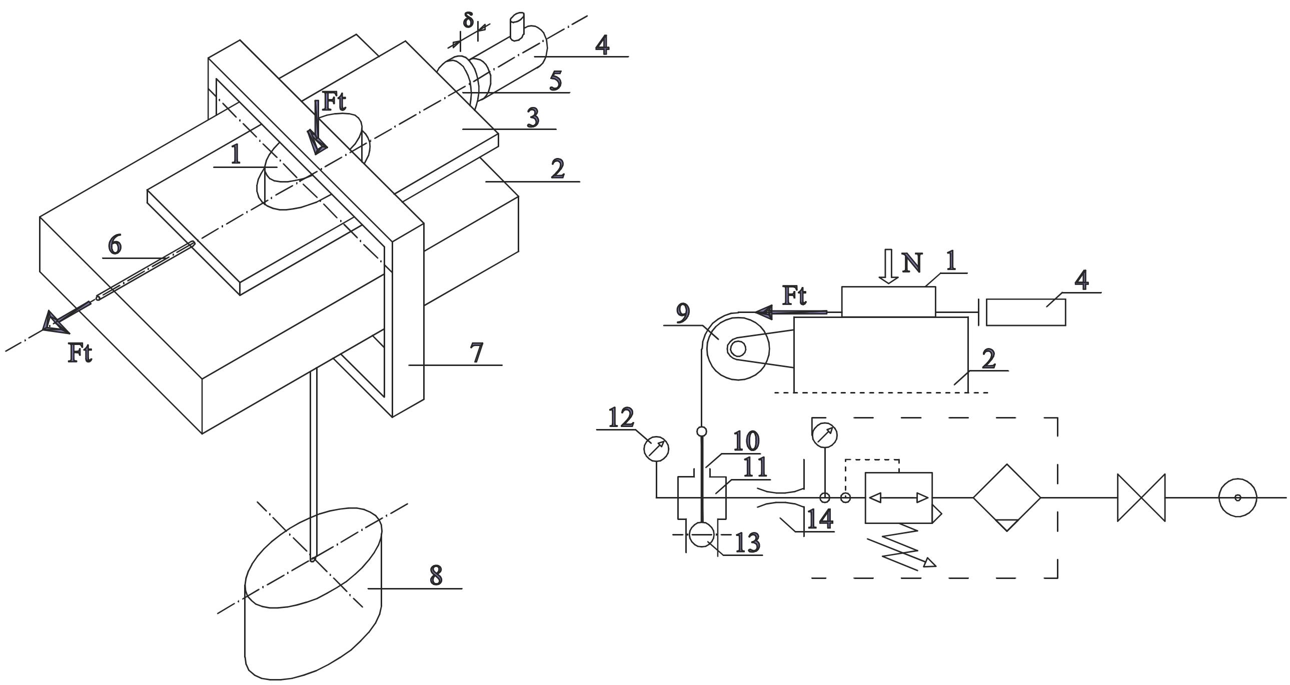

Figure 3: *Test rig used for determination of the preliminary displacements: 1 – sample; 2 – counterbody; 3 – plate, 4 – inductive transducer; 5 – plate; 6 – flexible thread; 7 – frame; 8 – weights; 9 – pulley; 10 – rod; 11 – pneumatic cylinder; 12 – manometer; 13 – sphere (ball); 14 – throttle; 15 – pneumatic preparation group.*

Method

The tests are conducted in the following sequence. The static frictional force F_{to} is determined for each pair: For all tests, the and the same stress τ_o = 0.9F_{to}, where F_{to} is the

No.	Type of the matrix	Type of the filler	Wt. % of the filler	Particle size, µm
1.	UHMWPE	-	-	80 -200
2.	UHMWPE	Fe powder	50	80 -200
3.	UHMWPE	Graphite	50	60 -120
4.	UHMWPE	Hydraulic oil	30	-
5.	UHMWPE	Glass sphere	28	120

Table 1: Materials

contact is loaded in tangential direction to one

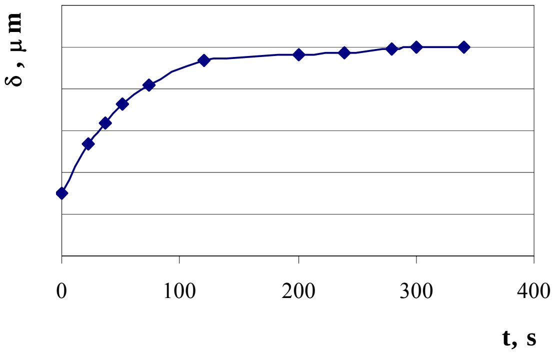

Figure 4: *Dependence of the tangential displacements δ on the time t for the pair UHMWPE – steel, τ_o = 0, 24 MPa, q = 2,5 MPa*

smallest frictional force among the all composites (that of UHMWPE/graphite composite). The normal load is q = 2 MPa. The time intervals between two consecutive loadings are determined. For this purpose, the dependences of the tangential displacements δ on the time t are taken (Figure 4). According to this, the interval between loadings is assumed to be 5 minutes. The loading speed is 0,24 N/s. After reaching t = t_o, the contact is reloaded by the tangential force under the same procedure. Second and third cycles of loading-unloading are carried out.

3. RESULTS AND DISCUSSIONS

The dependence of the preliminary the test materials are shown on Figures 5, 6, 7, 8 and 9. The average results of 10 tests show a typical and specific course of the dependence δ = f (τ).

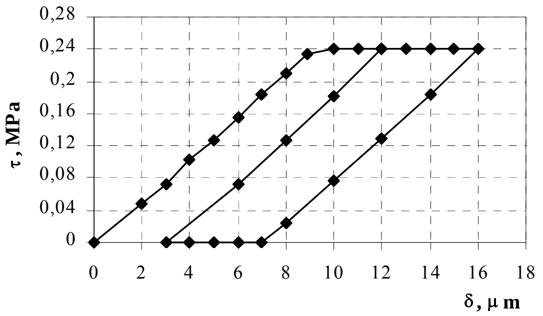

Figure 5: *Dependence of the preliminary displacements δ on the tangential stresses τ for neat UHMWPE, τ_o = 0, 24 MPa, q = 2,5 MPa*

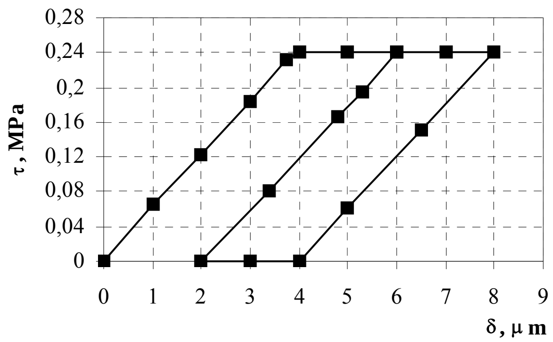

Figure 6: *Dependence of the preliminary displacements δ on the tangential stresses τ for UHMWPE/Fe composite, τ_o = 0, 24 MPa, q = 2,5 MPa.*

The total displacements are several times higher then those for the metal pairs. Both elastic and highly elastic displacements have their contributions.

It can be generalized that at the first cycle of loading-unloading, the displacement are formed as a result of the (Figure 10):

- Linear elastic deformation – (I)
- Non-linear strengthening – (II)
- Creeping – (III)
- Elastic recovering – (IV)
- Viscoelastic relaxation – (V)

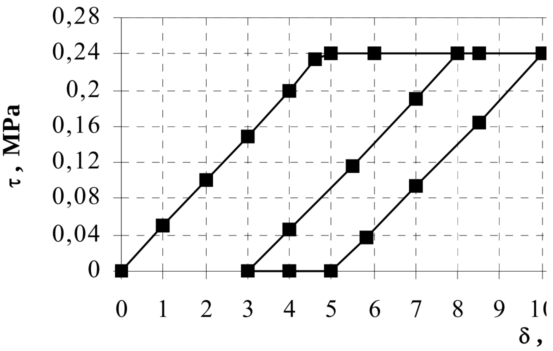

Figure 7: *Dependence of the preliminary displacements δ on the tangential stresses τ for UHMWPE/graphite composite, τ_o = 0, 24 MPa, q = 2,5 MPa.*

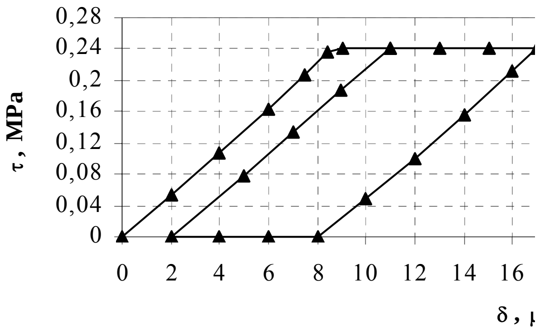

Figure 8*: Dependence of the preliminary displacements δ on the tangential stresses τ for UHMWPE/oil composite, τ_o = 0, 24 MPa, q = 2,5 MPa.*

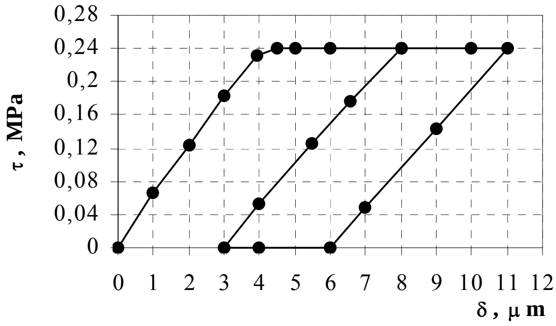

Figure 9: *Dependence of the preliminary displacements δ on the tangential stresses τ for UHMWPE/glass shperes composite, τ_o = 0, 24 MPa, q = 2,5 MPa.*

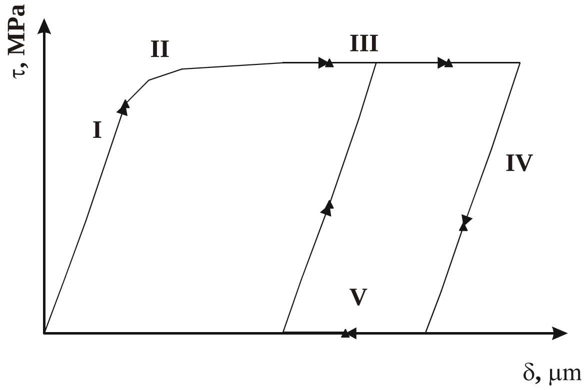

Figure 10: *Generalized appearance of the cycle of loading-unloading.*

During the next cycles, the plastic displacements nearly disappear, and the lines of loading and unloading are parallel to those in the first cycle. The creep value and the viscoelastic relaxation remain almost constant. It corresponds to the assumed model of the viscoelastic-plastic deformation in the contact (Figure 2).

4. CONCLUSIONS

If the behavior of the UHMWPE - steel pair is assumed for comparison purposes, the results show that the modification that is made by ferrous powder, glass spheres and graphite reduces the elastic and viscose displacements. This result has a strongest effect in the case of the ferrous powder (by 2 times) and it is the most suitable material for decreasing of the tangential contact pliability (improvement of toughness).

The modification, which is made by using oil, increases considerably the viscose displaceme-nts and reduces slightly the plastic ones. On the other hand, the increase of the viscoelastic deformations in the contact is probably resulting from the slight plastification effect of the oil, occurring at a micro level.

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