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Influence of temperature on friction coefficient of low density polyethylene

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Materials

ABSTRACT

Purpose: The article describes influence of temperature on friction coefficient of low density polyethylene in the aspect of loads occurring in a drawing die during free drawing of pipes.

Design/methodology/approach: Research was conducted on the basis of the PN-EN ISO standard.

Findings: The paper presents results of friction coefficient research. The research was conducted on a testing machine with a special design table for measurement of friction in different, set temperatures. The paper resulted in characteristics of correlation between examined friction coefficient and temperature.

Research limitations/implications: Research on dependence allows to evaluate thickness of the plasticized layer in free drawn PE pipes. Thickness of the plasticized layer depends on the value of friction coefficient. This is important in case of after-deformation returns which allows tight fitting of polyethylene lining during digless pipe reconstruction.

Practical implications: Results of conducted research allow to verify the mathematical model describing a process of free pipe drawing.

Originality/value: Research was conducted on exclusively prepared samples, which allows to reproduce conditions inside a drawing die.

Keywords: Engineering polymers; Properties of materials and products; Friction coefficient; Drawing die; Examined friction coefficient and temperature

1. Introduction

Polymer materials allow to meet growing requirements of modern technology, safety, ecology and economy. Good slipping properties, high resistance to abrasion, high operational temperatures, mechanical and chemical resistance, long durability and minimal cost of maintenance, increased noiselessness due to charring and noise attenuation, as well as dimensional stability contributed to the position of technical plastics as indispensable construction material. Unique features of modern plastics include good friction characteristics connected with tribology (especially in dry states).

In order to obtain additional characteristics, special strengthening impurities and strengthening materials are used, such as glass fibres and balls, carbon fibres and textile warps which increase thermal stability of shape, graphite and aramid fibres which increase sliding properties and abrasion resistance. Final selection and application of materials for a given sliding element with good properties should be based on the requirement it should meet.

Full evaluation of a given material is possible only after a series of tests. Those tests determine friction coefficient, wear intensity, friction temperature and other phenomena. This paper shows a detailed analysis of correlation between friction coefficient and temperature changes.

Friction has essential influence on after-deformation return of PE pipes drawn freely, which are used in reconstruction of pipelines [1-5].

1.1. Friction

Professional literature describes a number of different divisions of the phenomenon of friction, for example:

- internal (dry) friction – internal friction resistance depends on abrasive features of materials and surface features, especially its coarseness; it is accompanied with deformation of the outer layer, emission of heat and acoustic effects [6-9],
- internal (fluid) friction – typical internal friction occurs when friction elements are separated with a layer of lubricant susceptible to plastic strain and being in a liquid state [6,7,8].

Other division of friction, particularly essential for this paper, is division according to movements of working elements [9]:

- static friction – during rest (Fig. 1.),
- kinetic friction – during movement (Fig. 2).

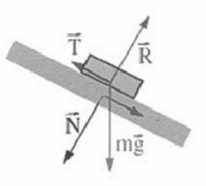

Fig. 1. Static friction, force occurring between surfaces that are motionless and pressed against each other with force N [10]

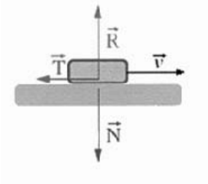

Fig. 2. Kinetic friction, force occurring between surfaces that are in movement and pressed against each other with force N [10]

The phenomenon of friction can be described in many ways, depending on the pairs of co-working elements, such as polymer/glass, polymer/polymer, polymer/steel, etc. This paper discusses co-work of a polymer/steel pair. Friction of a polymer element on steel is significant in case of free drawing of polyethylene pipes in digless pipeline reconstruction. In such case, a PE pipe is drawn through a steel drawing die [1-5].

Transmission of material to friction surfaces occurs no matter what type of friction surface we take into consideration. Oscillating samples may aggregate and then are trasferred out of the friction area as wear products. The process of moving them is initiated by local, strong adhesive grafting. Properties of the moved polymere material layer are as follows: thickness, form and measurements of moved chunks, degree of crystallinity and orientation [11,12,13,14]. They strongly depend on constructional characteristics of examined materials. Co-working conditions should also be taken into consideration during tests [6].

1.2. Temperature and friction coefficient

Research on the phenomenon of friction cannot include evaluation of various parameters which influence that coefficient. These are for example: pressure, sliding speed, coarseness, temperature. Unfortunately, the available literature does not provide us with evaluation of friction coefficient for free drawing of polyethylene pipes.

Tribological properties, as well as other characteristics of polymer materials, change with temperature (Fig. 3).

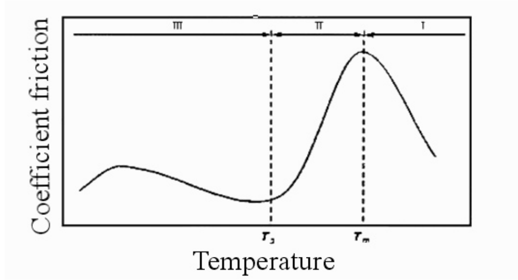

Fig. 3. Dependence between friction coefficient and temperature for thermoplastic polymers [9]

Three visible areas represent physical states in which the discussed polymer material can be during friction. Area I represents a state of high elasticity, area II – forced elasticity state, while area III shows vitreous state. Changes of physical state of a polymer are accompanied with changes of its friction mechanism. Mechanical losses during volumetric reorganisation of polymer outer layer have great importance in the fluid state area (III).

Participation of mechanical component near the glass transition temperature T_g is comparable with participation of adhesive forces. Minimal value of the friction coefficient occurs near that temperature [9].

With further increase of temperature, adhesive interaction between a polymer and a co-working surface (adhesive component of the friction force) play an increasingly important role. Value of the friction coefficient grows until it reaches its maximum around the softening temperature T_m. Thermoplastics are polymer materials most susceptible to changes of temperature in connection with tribological properties [11]. Conducted research on the friction coefficient of most polymers (excluding PTFE), allows us to form a motion that it decreases with increase of temperature, while wear intensity increases at the same time.

2. Own tests

Aim of the research was to determine influence of temperature of a material on its tribological properties. The property under examination was static and dynamic friction coefficients. Tests were conducted in various temperatures.

2.1. The test bed

Tests were conducted on a type FPZ 100/1 testing machine (Fig. 4.). The machine was simultaneously used as a force measuring head. The test bed was constructed on the basis of PN-EN ISO 8295:2005 [15] standard. It included a horizontal non-ferromagnetic table, a block, a measuring head, a heater and a mechanism which induced a relative movement between the test bed and the block.Tests were conducted in four temperatures: 22±2°C, 30±2°C, 40±2°C, 50±2°C.

Tested materials were low density polyethylene blocks with various meshing and surface. meshing was placed on each sample at 10%, 15% and 20% of its height correspondingly (Fig. 5).

Tests were conducted on samples with established friction surfaces and weight. Tare weight of a block was added to weight of each sample fastened to the block. Total weight of each block was 200g +/- 2g (exerting axial force of 1.96N +/- 0.02N).

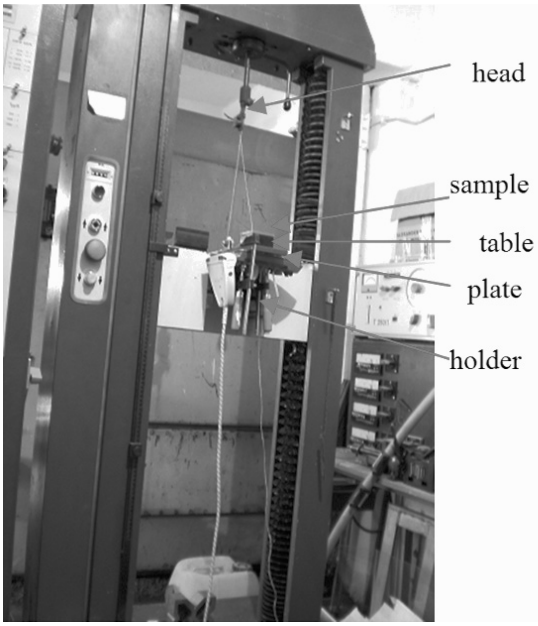

Fig. 4. The test bed

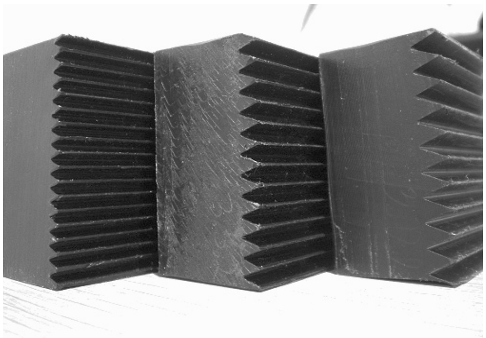

Fig. 5. Types of test samples

2.2. Results of the tests

Test show linear increase of force until it reaches maximum, which is equal to the static friction force F_S. Static friction coefficient μ_S, was calculated from the equation [9]:

$$\mu_S = \frac{F_S}{F_P} \tag{1}$$

where:
μ_S – static friction coefficient
F_S – static friction force, [N]
F_P – axial force exerted by a plate, [N]

Dynamic friction force F_D is mean force calculated from the travel path of a sample with omission of the static force peak. Value of the dynamic friction force was read from the graph resulting from the tests. The dynamic friction coefficient μ_D, is calculated from the dynamic friction force, using the equation [9]

$$\mu_D = \frac{F_D}{F_P} \tag{2}$$

where:
μ_D – dynamic friction coefficient
F_D – dynamic friction force, [N]
F_P – axial force exerted by a plate, [N].

Results of tests are presented on graphs (Fig. 6. and 7.).

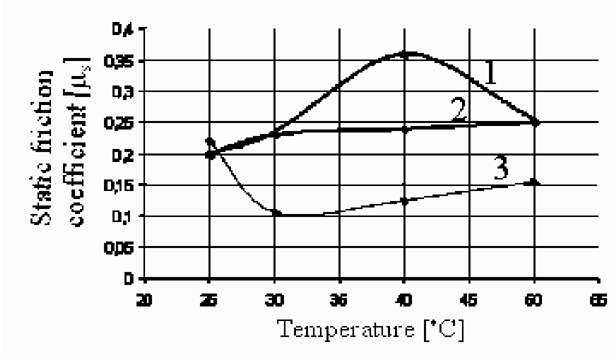

Fig. 6. Dependence between static friction coefficient and temperature

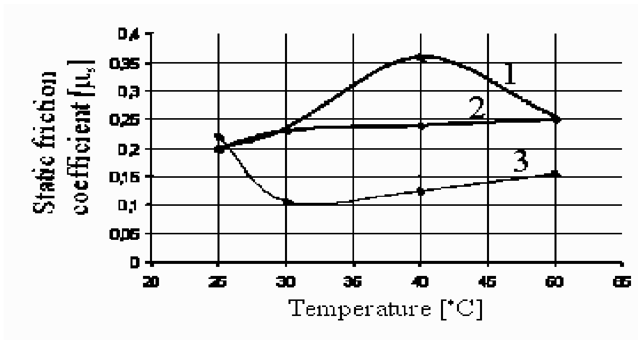

Fig. 7. Dependence between static friction coefficient and temperature

Conducted tests prove that the static friction coefficient reaches similar values as the dynamic friction coefficient.

In samples with high value of meshing, value of the coefficient increased until the temperature reached 40°C, and after that point it started to decrease. Static friction coefficient in samples with medium meshing increased at the beginning.

Dynamic coefficient of samples with the same meshing type showed falling tendency.

Biggest differences between static and dynamic coefficients could be observed in samples with low meshing. The dynamic friction coefficient decreased after temperature exceeded 30ºC, while the static friction coefficient increased at 30ºC and over.

While comparing dependences resulting from the tests with general dependence between friction coefficient and temperature of polymer plastics, a regularity emerges in case of samples with high meshing. Dependence among those samples approximately coincides with the line of general dependence in the range between the glass transition temperature and the softening temperature.

Dependence among samples with medium meshing only partially coincides with general dependence, that is for temperatures ranging from 25ºC to 30ºC. In case of tests with low meshing samples, dependence between the friction coefficient and temperature does not coincide with general dependence.

Influence of particular factors connected with supermolecular structure of polymers is still not fully known and is a subject to ongoing research. Polymers are materials much more susceptible to complex effects of processes that occur during friction and to environment conditions. General postulates of the theory of friction are also valid for polymers, however the analysis of the process of friction in their case is more complex and difficult. Therefore, tests described above are not enough to obtain a complete picture of correlation between temperature and both static and dynamic friction factors. Further research should be carried out in that field with wider range of material.

Another factor that could significantly influence the obtained results of tests is state of surface of the samples. The surface could have irregularities, scratches and impurities due to conditions in which the tests were performed.

3. Conclusions

The following conclusions result from the conducted research:

- The friction coefficient depends not only on the used material but also on its constitution and technological characteristics,
- Influence of temperature on the friction coefficient of polyethylene depends on its constitution and technological characteristics,
- Dependences between friction coefficients were similar in most cases,
- The static friction force (therefore the static coefficient) is always higher than the dynamic friction,
- Conducted tests are not sufficient to obtain the full picture of the influence of temperature on the friction coefficient of polyethylene.

References

[1] G. Wróbel, Ł. Wierzbicki, M. Szymiczek, Evaluation of influence geometric parameters of drawing die on after deformation, Proceedings of the 12th Scientific International Conference „Achievements in Mechanical and Materials Engineering”, AMME’2003, Gliwice – Zakopane 2003, 1049-1052, (in Polish).

[2] G. Wróbel, Ł. Wierzbicki, M. Szymiczek, Swagelining as a method of pipelines rehabilitation. Journal of Materials Processing Technology 157-158 (2004) 637-642.

[3] A. Pusz, G. Wróbel, M. Szymiczek, Expansive sitting internal linnig with PE in pipelines, Proceedings of the 14th Scientific International Conference „Achievements in Mechanical and Materials Engineering” AMME’2005, Gliwice – Wisła, 2005, 587-592 (in Polish).

[4] G. Wróbel, M. Szymiczek, Influence of temperature on the viscoelastic properties of draw PE pipes, Journal of Achievements in Materials and Manufacturing Engineering 20 (2007) 287-290.

[5] G. Wróbel, M. Szymiczek, Strenght of drawing polyethylene pipes, Progress in procesie of plastics, Publisher of Technical University Czestochowa, Częstochowa, 2002, 312-316 (in Polish).

[6] M. Hebda, A. Wahal, Trybology, WNT, Warsaw 1980 (in Polish).

[7] A. Gierek, Tribology wear, Silesia Technical University Press, Gliwice, 2005 (in Polish).

[8] S.W. Zhang, State-of-the-art of polimer tribology, Tribology International 31(1998) 49-60

[9] Z. Rymuza,Tribology of polimers, WNT, Warsaw, 1986.

[10] http://www.totalpolska.pl

[11] L.A. Dobrzański, Engineering materials and material design. Principles of materials science and physical metallurgy, WNT, Warsaw, 2006 (in Polish).

[12] A. Pusz, K. Michalik, Examining the hardness of the high density polyethylene with method of the cone, Archives of Materials Science and Engineering 28/8 (2007) 467-470.

[13] A. Pusz, Numerical modeling and evaluation internal stresses in moulding pipes with crystalline polymeric. Proceedings of the 14th Scientific International Conference „Achievements in Mechanical and Materials Engineering” AMME’2005, Gliwice – Wisła, 2005, 593-600 (in Polish).

[14] http://www.tworzywa.com.pl

[15] Polish Standard: PN-EN ISO 8295:2005.