VOL. 15, NO. 10, MAY 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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INVESTIGATION FRICTION AND WEAR OF CONSTRUCTIONAL PLASTICS BASED ON AROMATIC POLYAMIDE

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ABSTRACT

Tribotechnical properties of aromatic polyamides named polyparaphenylene isophthalamide and polysulfonamide had been studied. It had been founded the optimal value of load and velocity for friction pair aromatic polyamide-steel while the grinding process of it. The influence of loadings and velocities on the main tribotechnical parameters of investigated friction pairs had been studied. It had been founded maximum value of load and velocity, which a friction pair aromatic polyamide-steel work in normal friction mode. It had been studied the physical-mechanical and thermal properties of aromatic polyamide. It was found, that accordingly to the level of strength characteristics aromatic polyamide is close to metals and their alloys. Thermal properties of investigated materials have a higher level than in other large-capacity polymers.

Keywords: constructional plastics, physical-mechanical characteristics, friction and wear, coefficient of friction.

INTRODUCTION

The intensification of the development of society leads to the growth of its consumption requirements. For their satisfaction is needed to force into application new production capacities or modernize pre-existing capacities. Launching new capacities is a very scientific and energy-intensive process and takes a good spell and demand for vast investments. Development of pre-existing capacities is delivering on the basis of operating concerns, for a considerable small period of time and doesn't require a lot of money for their realization. For this reason modernization of pre-existing production capacities for the growth of their productivity is the most appropriate way to develop or improve the technological processes in comparison with creating new capacities. As for the modernization of enterprises, in turn, it's maybe done by implementing into production new materials, along with them the engineering plastics with a high level of strength and tribotechnical characteristics, are taking rightful place. Frictional and tribological conjugations are the most critical elements in the question of equipment reliability [1]. It's known, that up to 80 % of technical failures happen exactly with them [2], that's why investigations of tribotechlical characteristics of new construction plastics are an actual task.

During the work of friction pair one of the main factor, which characterize their further stable work and durability is working out of tribotechnical elements. It's known, that the biggest wear of elements of the tribotechnical conjugations is observed in the initial operating period (working out period), when materials, which rub, with different geometrical parameters on the surface enter into interaction [3]. So far, the question of studying and justifying the process of working out is an actual task.

Tribotechnical conjugations of modern equipment work in the conditions of high loads, slip velocity and temperatures, that's why parametrization, in which tribotechnical conjugations work in nominal mode is a present-day task.

LITERATURE REVIEW

In modern mechanic engineering developing durability frequently resolved by using lubricants, including without limitation, those which are modified with fullerene-containing component parts [4, 5]. As the matter stands, in machinery manufacturing, there are some construction movable connections, which on the strength of, construction and operation features cannot be greased with liquid and non-fluid oils. Those connections are made open or in such a way, that they have not protected against the ingress of dust, dirt, technological materials, so they are free breathing. In this case polymer composites (PC) are used. In recent years was developed many constructions plastics with high physical and mechanical features, from them machine spare parts are made, withstanding high loads, slip velocity and temperatures. Applying this kind of PC gave an opportunity to raise the power work of components [6, 7]. One of these materials is PC based on polyamide [8-10]. Details made of it may work during the friction without greasing, under the condition of aggressive and abrasive mediums, under alternating loads. There are studies, which aimed at recycling structural plastics to the spare parts, which can be implemented at lower loads in tribosystems [11]. The disadvantages of such materials their relatively low level of thermal resistance and mechanical strength should be related. However this disadvantage is compensated by filling or modification of polymeric matrix with different materials, with aid of them it's possible to direct a particular level of polymers features [12, 13].

Nowadays the most promising polymer matrixes are aromatic polyamides [14, 15]. Thanks to their high level of physical-mechanical and thermal properties, these polymers may replace "traditional" construction materials (steel and their alloys) in the tribological conjugations of machines and mechanisms, due to a dramatic increase in power work, reliability, and durability. Consequently, using the aromatic polyamides as polymer matrixes for the manufacturing of machine parts and mechanisms, with a view to developing the equipment is relevant.

MATERIALS AND METHODS

The most common aromatic polyamides in the function of polymeric matrices were selected: polyparaphenylene isophthalamide (PPFIF) and polysulfonamide (PSA), structural formulas are given below on Figure-1.

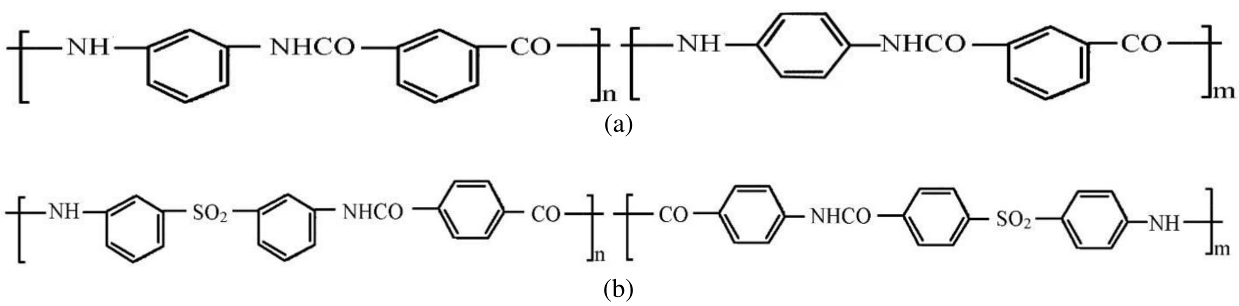

Figure-1. Structural formulas for aromatic polyamides: a – PPFIF; б – PSA.

PPFIF and PSA are press powders with particle sizes 20-40 μm. They are recycled into finished products by compression pressing in heat up press-form [16].

The investigation of properties was being conducted on the friction machine "SMC-2" by scheme «disk- block». We're using steel samples from steel 45 with roughness Ra = 0.32 μm with a hardness of 45-50 HRC. The density of polymers was determined by the hydrostatic weighing method according to ISO 1183-1. Compressive stress at yield (σ_y) of polymers was determined on the cross-functional tensile-testing machine 2167 P-50 in accordance with ISO 604. Hardness (H) of polymers was detected with the aid of the ball hardness testing machine "2013 ТШСП" in accordance with ISO-2039-1. Vicat softening temperature T_{VC} was determined to devise FWV-633/10 in accordance with ISO 1183-1. Resistance to the temperature of polymers was determined by thermogravimetric analysis in accordance with ISO-11358 on the derivatograph Q1500D.

RESULTS AND DISCUSSIONS

The defining moment at the beginning of the exploitation of any tribological conjugations is a grinding process, which passes with a high level of friction and wear of investigation tribotechnical connections. A grinding process is needed for its future normal and stable exploitation. It lasts until, friction force (the coefficient of friction) and the wearing of materials, which stay in the friction interaction, they won't fall and won't be steady. Duration of the Grinding process of materials in tribological conjugations is determined by the vast number of factors, the most significant are loadings and velocities. For this reason, it's of scientific interest to determine the impact of these parameters on the duration of grinding in the materials, investigated at their friction interaction. The period of work out was measured sticking to the frictional coefficient of friction pair, which was under test. On the Figure-2 are shown dependencies between the coefficient of friction (F_{TP}) during the friction interaction of materials, investigated, and the slide path of steel disk (L) with stable velocity and variable loadings.

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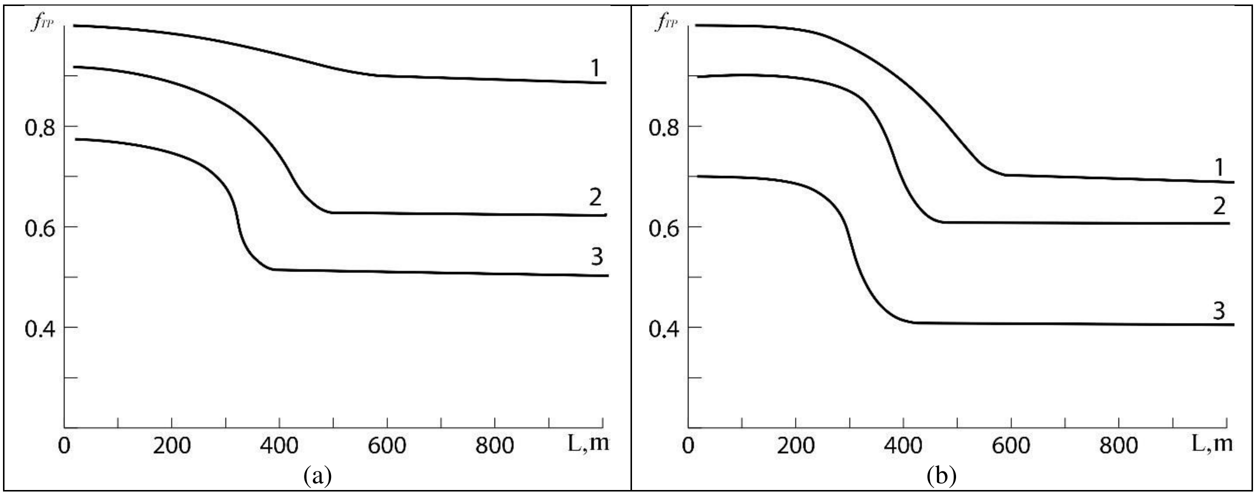

Figure-2. Dependencies between the coefficient of friction (f_{TP}) PPFIF(a) and PSA (b) while friction interaction with steel disk from slide path (L) with stable velocity (V = 1.25 m/s) and variable loadings (P, MPa): 1 - 0.50; 2 - 0.75; 3 - 1.00.

From the dependency diagram, it can be seen, that in the initial period of friction pairs work is observed the quite high value of the coefficient of friction - up to 0.95. Further reduction and stabilization of them are in connection with the finish of the grinding process in the friction pair. Thus for materials, studied, the minimum values of the coefficient of friction at the velocity V = 1.25 m/s consist of .0.85 to 0.41 depends on loadings, which is being worked on. It was found, that rising of load, at the wear in is required less slide path. So far, for investigated materials at the minimum loads slide path is 550-600 m, and at the maximum is within 350-400 m.

It was determined to influence of velocities on the grinding period of friction pairs, which were investigated. On the Figure-3 have taken dependencies of the coefficient of friction (F_{TP}) at the friction interaction of materials, studied, with steel disk from slide path (L) in the condition of stable load and variable velocities.

From received graphic dependencies was found decreasing in the coefficient of friction value with increasing in slide path, it connects with the finishing of the grinding process in studied friction pairs. The minimum value of the coefficient of friction at the load of P = 1.00 MPa consist of 0.5 to 0.41 depends on velocities.

It has been established, that along with an increase in velocity in the process of grinding of studied friction pairs is required less slide path. Thus for studied materials at the minimum velocities consists of 400-500 m, and at the maximum - 300-400 m.

Coming from conduct tests changed of the coefficient of friction from slide path of studied friction pair from changing of loadings and velocities (Figures 2, 3) was noted, that growing load and velocities lead to the reduction of required slide path in the grinding process in studied friction pair. Furthermore, it’s necessary to admit, that the biggest impact on changing the coefficient of friction makes a load, rather than velocity. That is for the speeder grinding process of tested materials is ought to use loads in the amount of 1.0 MPa and velocity in the amount of 1.25 m/s.

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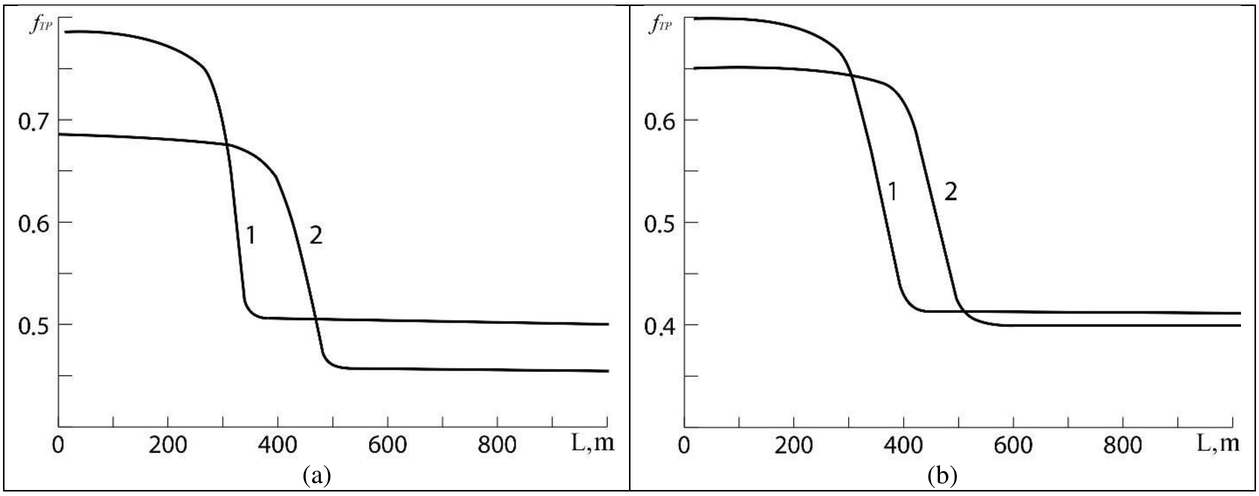

Figure-3. Dependencies of the coefficient of friction (f_{TP}) PPFIF (a) and PSA (b) while friction interaction with steel disk from slide path (L) in the condition of stable load (P = 1.00 MPa) and variable sliding speed (V, m/s):1 - 1.25 m/s; 2 - 0.75 m/s.

While the exploitation of tribological pairs one of the key factor, which influences its working efficiency is loading and velocities [17, 18]. That's why the tests were done by us, they describe an impact on these factors on the basis of tribological features of materials while their friction engagements with steel. On the Figure-4 are taken dependencies of changing the coefficient of friction, temperature on the friction surface and the intensification of linear wearing of aromatic polyamides, which are investigated from load action and velocities in the condition of friction engagement with steel.

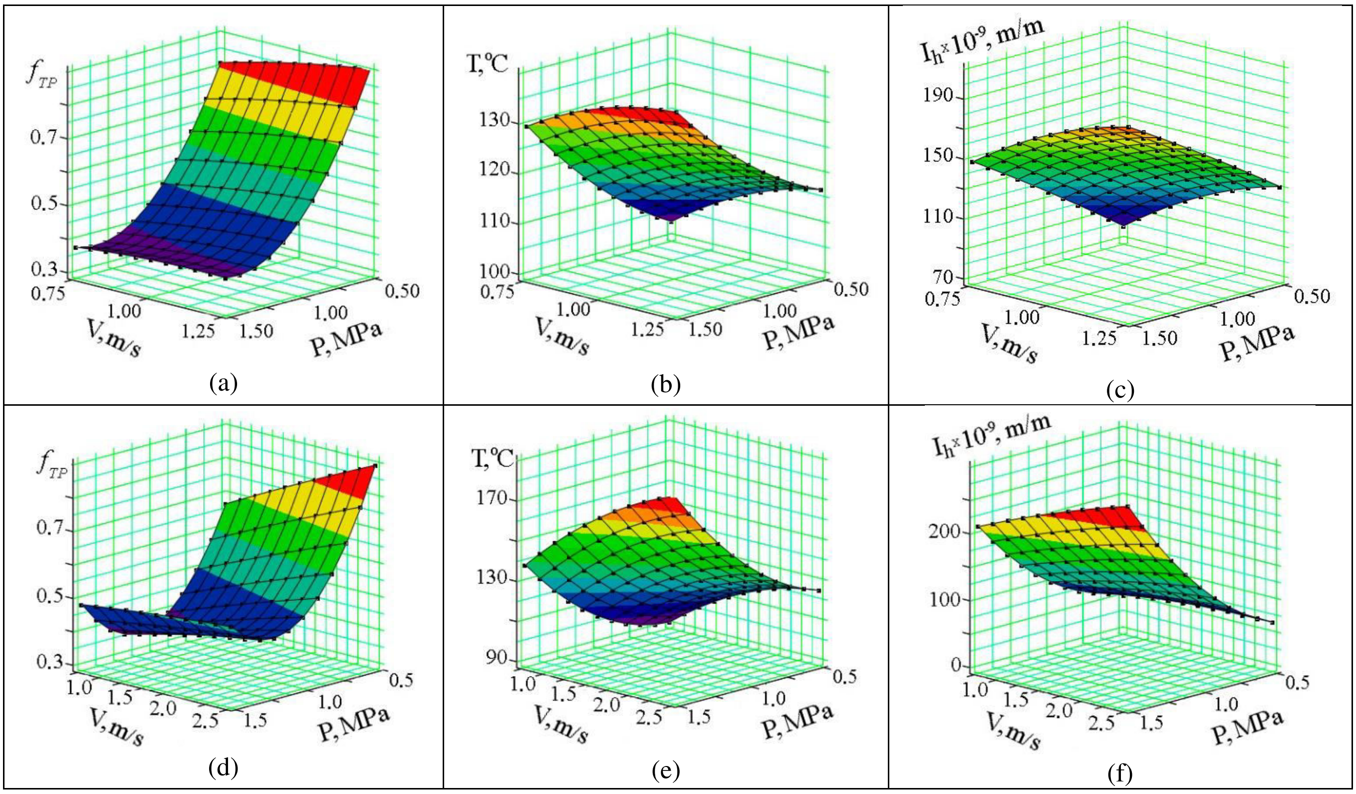

Figure-4. Dependencies between (a, d) coefficient of friction (f_{TP}), temperature (b, e) on the friction surface (T) and (c,f) an intensification of linear wear (I_h) PPFIF (a, b, c) and PSA (d, e, f) and loadings (P), velocities (V) at their frictional interaction with steel.

It was found that with the increase of the loadings from 0.5 to 1.25 MPa, there is a decrease in the coefficient of friction in the friction pairs to 0.4÷0.45. It's a characteristic feature of materials with pronounced

VOL. 15, NO. 10, MAY 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

antifriction properties [19]. The further growth of load leads to the upturn of this index. The upturn of velocities results in a sharp increase in the friction coefficient over the entire range of studied velocity, which is driven by its friction heating, an intensification of the interaction of the operating surfaces.

While increasing the load and velocity is observed growing of temperature on the friction surface and intensification of linear wear of the polymeric samples. In the meanwhile, the largest growth of these parameters experienced at the loads more than 1.25 MPa and velocity more than 1.5 m/s.

It's investigated, that loads have a bigger impact on the coefficient of friction, the temperature of friction surface and intensification of linear wear of polymers, which were being under investigation.

Proceeding from the nature of received dependencies, it can be concluded, that friction pairs, which were fixed in the range of loads from 0.5 to 1.25 MPa and velocities from 1.0 to 1.5 m/s while working in the operating mode. Future increasing of these parameters leads to significant growth of the coefficient of friction and intensification of wearing, it's the identification of the beginning of emergency friction mode, while can be seen rapid destruction of materials and possible catching in the tribological connections.

With the aid of the program, MathCAD was found the main tribotechnical parameters of investigated friction pairs. Received mathematical dependencies of frictional coefficient, the temperature on the friction surface and intensification of linear wear from loadings and velocities in the friction joints:

- for PPFIF:	
$f_{TP} = 0.594 \cdot P^2 - 0.128 \cdot V^2 - 0.144 \cdot P \cdot V - 1.517 \cdot P + 0.512 \cdot V + 1.164$	(1)
$T = 11.05 \cdot P^2 - 35.2 \cdot V^2 - 7.2 \cdot P \cdot V + 10.04 \cdot P + 101.6 \cdot V + 41.3$	(2)
$I_h \times 10^9 = -5.33 \cdot P^2 - 105.6 \cdot V^2 - 6.4 \cdot P \cdot V + 85.3 \cdot P + 319.2 \cdot V - 140.5$	(3)
- for PSD:	
$f_{TP} = 0.853 \cdot P^2 - 0.005 \cdot V^2 - 0.104 \cdot P \cdot V - 1.815 \cdot P + 0.198 \cdot V + 1.255$	(4)
$T = 44.57 \cdot P^2 - 8.549 \cdot V^2 + 10.46 \cdot P \cdot V - 49.24 \cdot P + 42.24 \cdot V + 73.18$	(5)
$I_h \times 10^9 = 139.05 \cdot P^2 - 6.1 \cdot V^2 + 44 \cdot P \cdot V - 157.03 \cdot P + 2.96 \cdot V + 85.4$	(6)

Formulas (1-6) can be used not only for determination of frictional coefficient, temperature of friction surface and intensification of wear of the materials, which were investigated under the condition of frictional engagement with steel in the examined intervals of loadings and velocities (P = 0,5÷1,5 MPa; V = 0,75÷2,6 m/s) but also for prediction of behavior of the friction pair during operating mode, which is out from examined interval.

It was found the physical-mechanical and thermal properties of investigated aromatic polyamide PPFIF. The results have taken in the Table-1.

Table-1. Physical-mechanical and thermal properties of PPFIF.

Properties	Value
Density ρ, kg/m^3	**1330**
Hardness HB, MPa	206
Compressive stress at yield σ_y, MPa	242
Modulus of elasticity E, MPa	3000
Impact resistance a_n, Dj/m^2	45
The onset temperature of active thermal destruction (thermal resistance), T_K°C	350
Vicat softening temperature T_{VC},°C	272

It was found that accordingly to the level of strength characteristics aromatic polyamide PPFIF is close to metals and their alloys, it has a density 4-7 times lower. It's promoted decreasing in the mass of machines and mechanisms, where it will be using, that's relevant to rocket and aircraft manufacturing. At the level of thermal properties, PPFIF has an advantage against the vast number of polymers. In reference to conduct tests the details made from these materials can work at the temperatures up to 270°C, without changing of its geometric shape and with no visible thermal destruction at the temperatures up to 350°C.

CONCLUSIONS

Tribotechnical properties of aromatic polyamide (PPFIF and PSA) had been studied. It had been founded optimal value of load (P = 1MPa) and velocity (V = 1.25 m/s) for the grinding process of friction pair aromatic polyamide-steel. The influence of loadings and velocities on the main tribotechnical parameters of investigated friction pairs had been studied. It had been founded maximum value of load (P = 1.25 MPa) and velocity (V = 1.5 m/s), which a friction pair aromatic polyamide-steel work in normal friction mode. It had been studied physical-mechanical and thermal properties of aromatic polyamide PPFIF. It was found, that accordingly to the level of strength characteristics aromatic polyamide PPFIF is close to metals and their alloys but has a density 4-7 times lower, which allows using aromatic polyamide as a constructional material for units of aircraft and rockets. Thermal properties of investigated materials have a higher level than in other large-capacity polymers. The detail from aromatic polyamide can work at the temperatures up to 270°C without changing of its properties.

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