INFLUENCE OF FRICTION ON THE QUALITY OF INNER THREADS MADE BY PLASTIC DEFORMATION

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Abstract: An important aspect concerning the processing of metals by plastic deformation is related to the existence of the friction forces between tool and part. The friction forces can determine a great increase of the forming resistance. They are quite hard to measure and consequently, they represent one of the most insecure elements when an analysis of the deformation forces is performed. The friction surface is characterized by microgeometry under dimensional aspect and of distribution law and also under the aspect of asperities deformation. Regardless of the finish degree, the surfaces have asperities that are elastic or plastic deformed or even broken, under the action of a system of forces, velocities and a certain environment.

Keywords: friction surface, inner threads made by plastic deformation

1. INTRODUCTION

In the specialty literature [1, 2, 3, 4] the friction is treated like a complex process of molecular, mechanical and energetically nature, which appears between in contact surfaces that are in a relative movement. In this sense, there are many theories whose analysis emphasizes the following conclusion: the friction force represents in fact the sum of some efforts needed to: shear the potential microjunctions like the roughen of the harder material or the abrader products witch follow the fractures, develop the local elastic or plastic deformations, overcome the molecular interaction in the case of microsurfaces which are in direct contact, overcome the shear resistance in the lubricant layer.

The friction surface is characterized by microgeometry under dimensional aspect and of distribution law and also under the aspect of asperities deformation. Regardless of the finish degree, the surfaces have asperities that are elastic or plastic deformed or even broken, under the action of a system of forces, velocities and a certain environment.

The interaction between the friction process and the contact surface continues, as Caubet stated, in some conditions (related to the intensity of the friction process, its duration, some terminal aspects, environment or the material of the in contact parts) till a certain depth of the material. In figure 1, a model with four zones of depth, dependent on the in contact material nature and the nature of process, is shown.

From statistical point of view, three types of friction surfaces can be defined:
- the nominal surface, A_n, defined by the outline geometry of the small part A;
- the apparent contact surface, A_a, defined as a sum of the contact surfaces a_1, a_2, a_3, ... , a_n, constituted by the processing ripples, defined as a second degree asperities;
- the real contact surface, A_r, defined as the sum of the contact microsurfaces of the asperities by which the normal pressure force is transmitted.

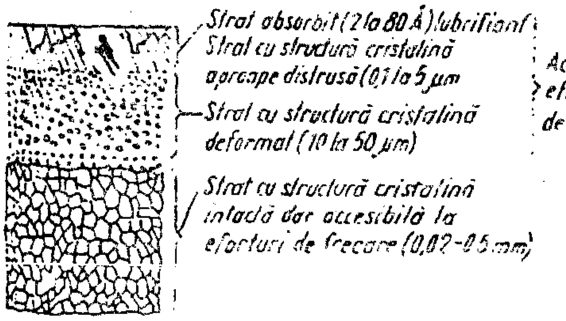


Fig. 1 Model of the friction surface in the substrate zone

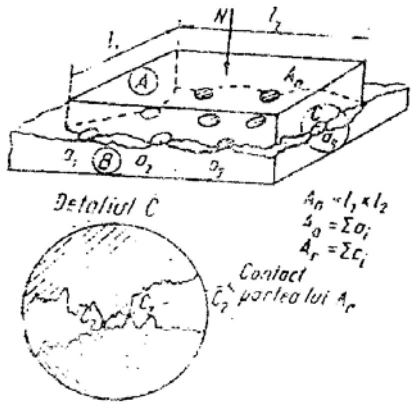


Fig. 2 The contact surfaces
A_n -nominal surface, A_a – apparent surface
A_r –real surface

The ratios of the mentioned contact surfaces allow the calculus of the relative non-dimensional units that define the class of ripples or asperities of the contact surfaces:

$$\eta_1 = A_r/A_a,\ \eta_2 = A_a/A_n,\ \eta_3 = A_r/A_n,$$

laid by the relation: $\eta_3 = \eta_1 \cdot \eta_2$

Under the action of normal efforts and function of their values, of accuracy degree of the surface and its chemical composition, the asperities are deformed elastically or plastically. The deformation regime of asperities can be determined according to Williamson I. B. and Hunt B.T by using the plasticity index, defined by the following relation:

$$\Psi = (E' / H)\ \sigma/r \tag{1}$$

where E' is the reduced elasticity module of the material of the contact surfaces, calculated with the relation:

$$E' = 2\left(\frac{1-\mu_{p1}^2}{E_1} + \frac{1-\mu_{p2}^2}{E_2}\right) \tag{2}$$

where: E_2, E_1 are the Young's modulus of the two materials of the contact surfaces, μ_{p1}, μ_{p2} are the Poison's coefficients, H is the hardness of the softer material, σ is the square mean error of the asperities height, r is the asperities radius given by the relation $r = s_R^2/8R$ (s_R – the asperities height, R – the roll radius).

It has to be mentioned that for ψ smaller than 0.6 the asperities deformation is elastic, even for the domain of the big efforts, for ψ bigger than 1.0 the deformation is plastic in the same conditions, while for ψ between 0.6 and 1, the deformation is elasto-plastic.

From the data presented in the specialty literature and taking into account the fact that the shear resistance and the yield strength limit of the material vary within limited borders as a function of the material characteristics, the friction coefficient can be defined as a physical constant of the material, independent on effort and the contact surface A_r. From the plasticity theory, for an homogeneous, isotropic and partial plastic material results:

$$\tau_m / p_c = 0.58 \tag{3}$$

where τ_m is the shear resistance of the material plastic deformed and p_c is the yield pressure of the same material.

More recent researches have proved that the friction laws elaborated by different authors (Dezaguillet, Hardy, Prandtl, Dereaghin, Davies, Coulomb-Amantons) are approximations and that, in reality, the friction coefficient varies with pressure and slide velocity. But friction are accompanied by other phenomena, too (heating, oxidation, wearing, etc); consequently, for an exact determination of the friction coefficient the temperature increments, the surfaces interaction, the molecular absorption, the deformation of the in contact materials are taken into consideration.

Based on the above considerations, results that the value of the friction coefficient is influenced by the following factors:

- the quality of the tool surface and the surface of the deformed material; in fact, the biggest influence rests upon the degree of roughness of the tools surface determined by scratches, accentuated irregularities, filings, hard oxides, etc.
- the temperature of the deformed material, respective the gradient of temperature between tools and deformed material;
- the slice velocity at the contact tool/material. The friction coefficient decreases with the slice velocity increasing. Practically, this happens in the case of deformation with high velocity.
- specific pressure on the contact surfaces of tool and material; as bigger is this pressure, as smaller is the friction coefficient;
- the chemical composition of the deformed material, especially in the case of warm plastic deformation, where the composition of oxides has a big influence on the friction.

The variation of friction coefficient with the relative movement velocity of material during deformation is shown in figure 3.

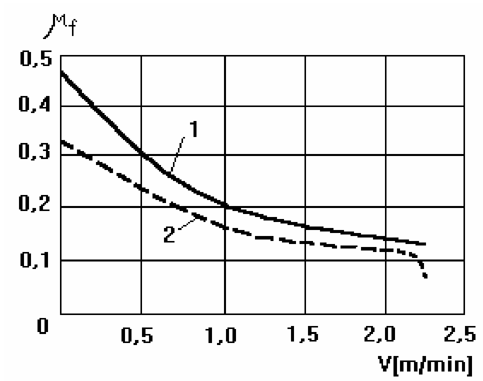


Fig. 3 The variation of the friction coefficient with velocity
1 – steel on steel
2 – steel on duralumin

Fig. 4 The sketch of semifluid friction regime

In the case of fluid friction, the contact surfaces are separated by a layer of lubricant. If the thickness of the continuum lubricant layer, liquid or gas is sufficient, the microasperities contact it is avoided, and, consequently, the fluid friction takes place.

An important role in this kind of friction has the adherence of the lubricant film on the in movement contact surfaces. Even if in the fluid lubrication theory the contact surfaces are considered smooth, during the last period the effect of roughness on the surface contact was emphasized. Even optimum roughnesses in terms of size, shape and orientation, which allow to obtain conditions of minimum friction it were established. The process of fluid friction can be performed in two ways:

- *hydrodynamic*, in which case the lubricant is introduced from the exterior between the contact surfaces without pressure or with a minimum pressure; the fluid film is obtained through phenomena related to the fluids dynamics laws, being conditioned by a needed relative velocity of the contact surfaces and a certain shape of the space between them;

- *hydrostatic*, in which case the lubricant is introduced from exterior with a pressure and a debit that assure the maintaining of fluid between the contact surface.

In practice, the semidry or semifluid friction is the most frequently used, even if in the frame of technological processes a series of lubricants as colloidal graphite or sodium chloride is used. The semidry friction occurs due to the inconstant repartition of the lubricant on the surface of tools and material. Therefore, the friction coefficient has the values between 0.04- 0.2.

The semifluid or mixed friction is a complex phenomenon that occurs at the limits of fluid friction in the case of existence on the contact surfaces of a certain degree of roughness. Even if the film of lubricant assures a fluid lubrication, it can break in some zones, such that on the same contact surfaces can appear both- the hydrodynamic friction and the direct contact as well (fig. 4).

The values of the friction coefficient in the case of semifluid friction depend on a series of parameters, such as: the physico-mechanical characteristics of the material of contact surfaces and of lubricant, velocity, load and temperature. In table 1 the informative values of the friction coefficient are given.

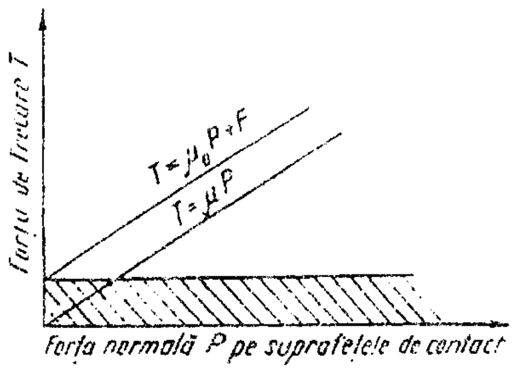
Tab. 1 The influence of material on the values of the friction coefficient in the case of semifluid friction

In contact material	lubricant	μ_f	Observations
Steel, cast iron, bronze, antifriction alloy	Mineral oil	0.10 – 0.16	Molecular layer
idem			
steel/steel	Fatty acids	0.05 – 0.12	Function of the aggregation state
steel/cupper	Stearic acid, lauric	0.10-0.11	
steel/magnesium	Stearic acid, lauric	0.09	
steel/cadmium	Stearic acid, lauric	0.07	
steel/zinc	Stearic acid, lauric	0.06	
	Stearic acid, lauric	0.05	

In order to characterize the supplement of force of dry friction that does not depends on the value of the normal force, the Coulomb used the following relation:

$$T = \mu_{f0}P + F, \quad (4)$$

where F is the molecular joining between the contact surfaces (determined in the case of P = 0, T = F)
The graphical representation of the relation (4) it is shown in the figure 5



In the case of plastic deformation processes, the researches emphasized that it must be also taken into account the supplementary force of friction F and therefore used the relation 4.
In the mean time, from phenomenological point of view, the molecular catching of the contact surfaces it has to be considered, as an element with play an important role.
In conclusion, the lubrication coefficient of the surfaces, noted with γ, can be determined by using the relation:

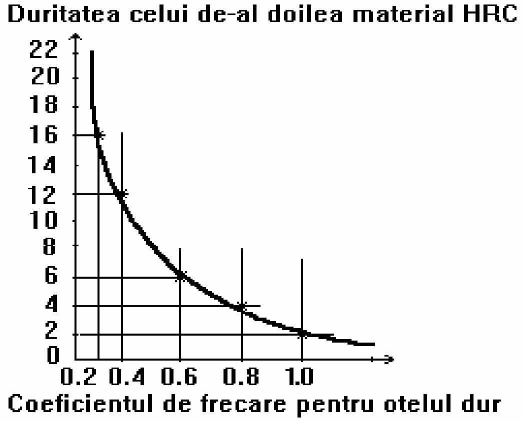
$$\gamma = A_l/A_{med} \quad (5)$$

where A_l is the lubricated surface and A_{med} is the total contact surface between tools and material.

Fig. 5. The graphical representation of the relation 4

A significant importance for the values of the friction coefficients has the physico-mechanical characteristics of the metallic materials.

In the diagram from the fig. 6, the dependence of the friction coefficient in the case of threading some materials having different hardnesses it is shown. From the diagram it can be observed how the values of the friction coefficient increase as the hardness of the threaded material decreases (the tool is made from rapid steel Rp5, having the hardness 63HRC constant during the threading process).



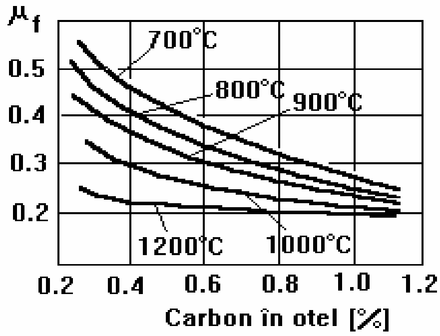


Fig. 6 Variation of the friction coefficient in function of the hardness of the second material

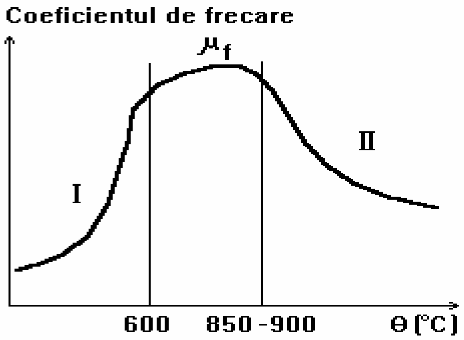
Fig. 7 Dependence of the friction coefficient by the carbon content in steel in the case of warm threading

In the case of warm threading, the chemical composition of the steel from which the tool is made influences on its wearing, on the appearance of the cracks network and on the contact effect of tool on the air-blown surfaces of the formed material.

Experimentally, the relationship between the value of the friction coefficient and the carbon percentage of the formed steel, for different threading temperatures it was determined (fig. 7). From the diagram it can be observed that once the content of carbon increases, the values of the friction coefficient decrease for the temperatures varying between 700^o and 1200^{o}C.

The study of the influence of the formed material temperature and tool on the friction conditions is very complex, because interfere in the same time a big number of factors. In fig. 8 the influence of the temperature of the formed material on the values of the friction coefficient it is shown.

In the case of warm threading the friction coefficient can be calculated in function of the forming temperature by using the Ekelund relation: $\mu_f = (1.05\text{-}0.00055\theta)K_1K_2K_3$, where θ is the threading temperature, expressed in ^{o}C and $K_1K_2K_3$ are constant that depend on the tool material, threading velocity and the structural class of the formed material.



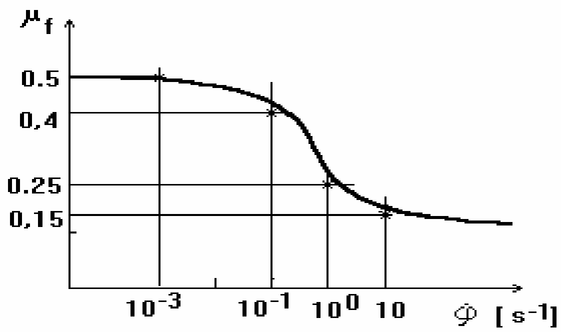


Fig. 3.21 Influence of the temperature of the formed material on the friction coefficient

Fig. 3.22 Relationship between friction and forming velocity in the case of warm threading

The diagram from the fig. 8 is characteristic for steels and for non-ferrous metals and alloys, too (the field I for non-ferrous metals and alloys and the field II for steels). It can be observed that in the field of temperature where the steels are plastic deformed the values of the friction coefficient decrease when the temperature increases. In field of temperature where the non-ferrous metals and alloys are warm plastic deformed (cupper – 850^{o}C, aluminium and its alloys – 500^{o}C), the values of the friction coefficient increase as the threading temperature increases.

The value of the friction coefficient is also significantly influenced by the velocity of tool on the contact surfaces. In the field of warm plastic deformation, the velocity of tool has a greater influence on the friction conditions. The relationship between the values of the friction coefficient, determined with maximum values of the angle of approach of turn of screw, in the case of warm threading (carbon steel and threading temperatures about 1000^{o}C) and the threading velocity it is shown in fig. 9. It can be observed that the limits of variation of the friction coefficient in function of the threading velocity are quite large.

In the case of alloys, the existence of a big coefficient of friction and an improper lubrication can determine the sticking of the tap inside the threading hole, which can lead to its fracture in the case when the machine-tool is not appointed with an overload filter device.

2. CONCLUSIONS

The anti-sticking function it is usually assured by the soft, ductile constituents (phases), capable to plastic flow, having a melting temperature much reduced compared to the other phases of the structure (those of the alloy, respectively) and close to the maximum temperature of threading. These phases must be uniformly distributed inside the structure at the microscopic level. Thus, the bronze CuPb20Sn5 has small friction coefficients even at big loads but small velocities; the alloy CuPb15Sn8 has also a reduce friction at very high local pressures and even when the lubricant is momentary absent while the alloy CuPbSn10 has the same behaviour in the same conditions and besides for big forming velocities (over 5 m/s).

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