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CALCULUS OF THE THREADING MOMENT WITH DEFORMATION TAPS

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ABSTRACT

In this paper, a simple relation of calculus of the threading moment with tap was obtained, starting from the Goubkine's relation and taking into account that the deformation of a whirl can be approximated with a compression test. The performed experimental tests demonstrated that the threading moments calculated with the obtained relation are very closed to the real (measured) moments.

Keywords: threading moment, deformation taps

1. SPECIFIC VARIABLES THAT DEFINE THE PROCESS OF MAKING THREADS BY PLASTIC DEFROMATION

In the case of process of inner threading by plastic deformation it is very difficult to supervise and to determine a range of specific parameters of deformation; due to this fact, different variables are used to define the process: absolute, relative and real strain and the degree of deformation, respectively.
For the special deformation states, Nadai introduced the notion of real strain or added relative strain:

$$\ddot{\varepsilon} = \int_{h_0}^{h} \frac{dh}{h} = ln(1+\varepsilon) = 2{,}303\, log(1+\varepsilon) \qquad (1)$$

where:

h_0, h are the initial, respective the current values of the height of the deformed part;
ε is the relative strain, in percentage.

The real strains have the addition property which means that the percentage strains can be added in order to determine the total strains. If the relative strain, ε, is smaller that 0.1, it can be approximated that $\overline{\varepsilon} = \varepsilon$. In the case of bigger strains, the value of ε is always superior to the relative strains.
The curves deformation strength – degree of deformation are often drawn in σ-ε coordinates, the value of the relative strains being expressed in percentage or unit cuts. They are generally recommended for strains smaller than 10-15%, case that perfectly characterize the process of threading by plastic deformation.
In the case of compression tests, for all deformation modes (plane or spatial), the notion of real strain is conveyable to introduce. Besides, the results of tests presented in σ-ε coordinates can be more easily compared and then used for the calculus of different deformation processes.
A big inconvenient of the all testing modes are represented by the small value of the real strain.
The extrapolation of the σ-ε curves is not possible when it is starting from a determined value of ε, the value of the deformation strength varying less or even decreasing with the increasing of the

deformation degree. This is a characteristic specific to the majority of metals and alloys in the case of warm deformation.

2. ASSIMILATION OF THE CONDITIONS OF THREAD GENERATION WITH THE PROCESS OF PLASTIC DEFORMATION BY COMPRESSION

The process of threads achievement by plastic deformation can be associated with the compression test. The advantages offered by the compression test are, on the one hand, the possibility to obtain important strains and, on the other hand, the compression specific load of the cylindrical specimens characterizes in a more precise manner the real deformation strength of the tested material.
An alternative for determination the results consists in recording the friction forces that determine an increasing of the threading moment with 10-15% and generate an irregularity of the stress state of material during deformation.
The theory and the experimental tests demonstrated that, in the case of plastic deformation of threads, due to the small degree of deformation, the specific pressure is closed to the deformation strength, taking into account that the relative reduction is small.
Bridgeman P. [1] drew the compression curves by using the same specimen, which, after each compression cycle, was worked in order to obtain the initial diameter-height ratio.
At the moment, different compression schemes that reduce the influence of the friction forces and allow to obtain large strains during testing are used. In [2], the successive deformation of a cylindrical specimen is presented. The process was approximated with an isotherm process. This kind of deformation allowed lubrication after each deformation cycle and a good approximation of the uniaxial state of stresses compared to the continuum deformation. Between successive tests, a material un-hardening occurred, such that the flow curve of the echeloned deformation is always situated under the ideal curve which expresses the isotherm deformation.
Many authors were tempted to diminish, through different means, the influence of the friction forces, by using lubricant and different antifriction materials. Thus, Silov [3] fixed the specimens between conical fishing taps, having an inclination angle that allows the conservation of the cylindrical form of the specimen during compression. However, in this case, it was difficult to create the conditions of a uniform deformation because it was necessary to vary the taper of the fishing taps during deformation.
In order to reduce the contact friction, Suzuki [4] and Soiarov [5] used specimens provided at extremities with circular lubrication channels.
Based on the analysis of the above mentioned literature of specialty, in order to determine the real values of the compression deformation strength for the cylindrical specimens, the following relations can be used:

$$\sigma = \frac{q}{1 + \frac{1}{3}\mu\frac{d}{h}} \tag{2}$$

$$\sigma = \frac{P}{S_{max}\left(1 - \frac{r_{max}}{4\rho} + \frac{\mu}{3}\frac{d_1 - h}{h}\right)} \tag{3}$$

where: d and h are the initial diameter and height of the specimen; q is the average pressure; p is the compression load; S_{max} is the transversal section of the swollen part; r_{max} is the radius of the swollen transversal section; μ is the coefficient of friction; ρ is the curvature radius of the generatrix of the compressed specimen:

$$\rho = \frac{h^2}{8(r_{\max} - r)} \tag{4}$$

Based on the literature of specialty, in order to determine the real values of the compression deformation strength for the cylindrical specimens, the Goubkine's relation (eq. 2) is recommended to

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be used, because it is valid for relative reduce strains (ε = 0.6 – 0.8), with the notice that, at high temperatures, technological lubricants (metal oxides, glass with different softening temperatures, etc.) must be used.

3. CALCULUS OF THE THREADING MOMENT WITH TAPS

Starting from the Goubkine's relation [6], the threading moment with tap can be calculated, taking into account that the deformation of a whirl can be approximated with a compression test and the unit load from the initial relation is represented by the yield strength of material, minimum necessary to fill up the space of a thread whirl. Under these initial conditions, the average pressure q is given by the ratio between the deformation load and the maximum section of a whirl (q = F/S). Thus:

$$q = \frac{F}{\pi d_1 p} = \frac{F}{\pi p\left(d - \dfrac{5p}{16tg\dfrac{\alpha}{2}}\right)} \tag{5}$$

because: $$d_1 = d - \frac{5}{8}H = d - \frac{5p}{16tg\dfrac{\alpha}{2}},$$

where: d_1 is the inner diameter of thread; p is the thread pitch; H is the theoretical height of thread; D is the exterior diameter; α is the inclination angle of the thread wings.
Replacing into the Goubkine's relation, the following equation results:

$$\sigma_c = \frac{F}{\pi p\left(d - \dfrac{5p}{16tg\dfrac{\alpha}{2}}\right)\left(1 + \dfrac{\mu H}{3p}\right)} \tag{6}$$

By replacing $\mathrm{H} = \dfrac{\mathrm{p}}{2\mathrm{tg}\dfrac{\alpha}{2}}$ into relation (6), the relations (7) and (8) results:

$$\sigma_c = \frac{F}{\pi p\left(d - \dfrac{5p}{16tg\dfrac{\alpha}{2}}\right)\left(1 - \dfrac{\mu}{6tg\dfrac{\alpha}{2}}\right)} \tag{7}$$

$$M_t = F d_2 = d_2 \sigma_c \pi p\left(d - \frac{5p}{16tg\dfrac{\alpha}{2}}\right)\left(1 + \frac{\mu}{6tg\dfrac{\alpha}{2}}\right) \tag{8}$$

Under these conditions, the threading moment is given by the multiplication of deformation force (which includes the friction force) with the average diameter of thread.
In the case of metric threads,

$$d_2 = d - \frac{3}{8}H = d - 0{,}3p \tag{9}$$

By replacing eq. (9) into eq. (8), the following relation results:

$$M_t = \pi p \sigma_c (d - 0{,}3p)\left(d - \frac{p}{\sqrt{3}}\right)\left(1 + \frac{\mu}{2\sqrt{3}}\right) \tag{10}$$

The experimental tests demonstrated that the moments calculated by using the eq. (10) are very closed to the real moments (measured). This aspect is show on fig. 1 (the test were performed by measuring the threading moment both, in the case of threading part fixed on a dynamometric table, by using resistive transducers, and also in the case of threading tap, by using a dynamometric key).
Different values of the threading moment are obtained by using different types of cooling-lubrication liquids. Thus, in the case of threads made by many passing, exceptional results are obtained by using the СОЖ chemical additive.
The threading method with the use of cooling-lubrication chemical additive allows the softening of the formed layer directly during the process of thread generation. At the base of the process is the Gutman’s mechanical effect, which supposes that the chemical reaction speed of the metal with the active environment in the case of plastic deformation process increases about several times. Before threading, the surface of tap and the bore hole are lubricated with a soft layer of grease composed of: bearing oil, sulphofrezol, oleic acid, fish grease (preferentially of cachalot, whale or shark).

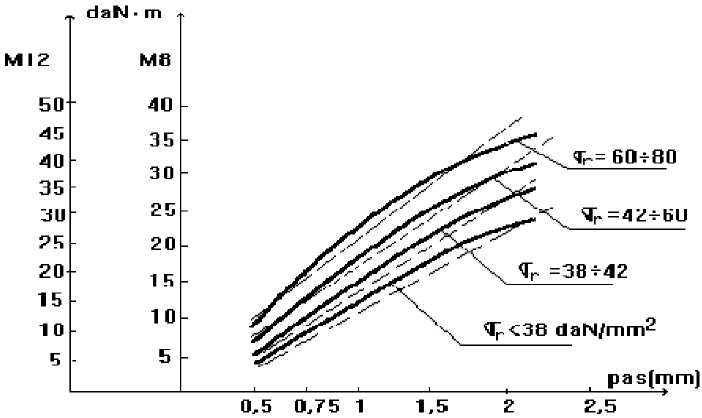

Fig. 1 Variation of the threading moment with the thread pitch
—— experimental values; ---- theoretical values

4. CONCLUSIONS

The process of threads achievement by plastic deformation can be associated with the compression test.
The threading moment with tap can be calculated starting from the Goubkine’s equation, taking into account that the deformation of a whirl can be approximated with a compression test. A good fit was obtained between the calculated threading moments and the results obtained from the experimental tests.

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