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TRIBOMODELLING OF CONTACT DIE-TUBULAR GOODS WITH APPLICATIONS ON DRILLING-EXTRACTION

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Abstract
To do the screwing (unscrewing) of the tubular goods during the drilling-production work we use the tongs. The screwing (unscrewing) efficiency of the tubular goods is determined by the achieve of the functional role of the tong that means: tightening (ravelling) without sliding of the tubular goods with the prescribed moment of torsion (established depending on the diameter of the tubular goods on which we work).
The paper states the functioning criterion of the drilling tongs taking into consideration the influence factors: exterior factors (motive power, working medium etc.), constructive factors (tubular goods diameter, shape and sizes the die etc.) and superficial layer contact (die surface geometry, thermal treatment applied to the material etc.).

Key words: *Die, tubular, modelling*

1. GENERAL ASPECTS

The tubular material used in the drilling – extraction works is exposed in exploitation to the complex mechanic strains in the conditions of some aggressive environments. The tubular good is represented by: drill pipes, casings, tubing, assembly reducing etc.

The demands satisfaction concerning the safe exploitation of the well is realised by a complex constructive measures (the choice of the joining type, of the thread form etc.) and by exploitation type from which determinants are the resistance characteristics of the tubular good and the screwing – unscrewing size moment [3].

The screwing – unscrewing of the good material is done with some devices named drill pincers. The functional role of the pincers is to realize in certain exploitation conditions the screwing – unscrewing of the tubular good by transmitting the movement flux from the pincers screwing dies to the exterior surface of the tubular good on which it acts

During the operational process of the pincer the technical characteristics are emphasized by the following parameters [4]:

- the catch interval I_p, defined as the value set of the tubular goods diameter where it can be used the pincers;
- the torsion moment M_t, that can be applied with the help of the pincers; the size of the torsion moment depends on the tubular good diameter on which it acts.

In this paper it is considered as representative the multidimensional drilling pincers presented in the figure 1. The multidimensional drilling pincers is composed from three to five elements (jaws) that are articulated by link pins.

By acting the pincers shank with a force F_m the component elements are rotating around the link pins, are covering the exterior surface of the tubular good and are transmitting the torsion moment by friction forces that are developing.

In this context, in the paper there is proposed a calculation model for the functional dimensioning of the drilling pincers that consists in the validation of the geometrical solutions from the point of view of the functional role and of the tubular good protection.

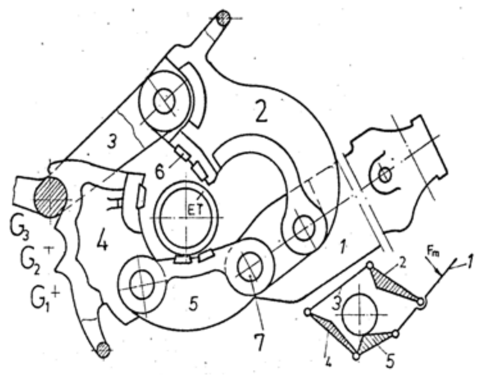

Figure 1: *The drilling multidimensional pincers*:
1 – *shank of the pincers*; 2 – *the long jaw*; 3 – *the locking*; 4 – the *jaw in steps*; 5 – *the short jaw*; 6 – *the die*; 7 – *the pin*; F_m – *the exterior force*; *ET – the tubular element.*

2. THE TRIBOMODELLING OF THE DIE – GOOD TUBULAR CONTACT

The tribomodelling of the die – tubular good contact is started by the factors identification that influences the pincers functioning (figure 2).

These factors may be grouped in accordance with their role in three categories:

a) Exterior factors (*E*) that define the system from the point of view of the functioning conditions (the size of the screwing – unscrewing moment), exploitation (working environment) and tests (the application system of the exterior force).

b) Constructive factors (*C*) that define the system from the point of view of the constructive principle (the mechanism geometry, the die geometry).

c) Interaction factors (*P*) that analyze the system depending on the accomplishment of the working system conditions – screwing – unscrewing without slip of the tubular good with the prescribed torsion moment.

The friction and the wear are considered consequences of a tribosystem working in which the input sizes are defined by exterior strains that by the structure of the tribosystem are transformed in output sizes represented by the exploitation characteristics of the tribosystem.

In these conditions, for determining the working criterion of the pincers it has to be established a dependence between the specified influence factors thus:

$$C_F = \mathrm{f}(E, C, P) \qquad (1)$$

To the contact die – tubular good, in the operation process there are not allowed permanent abnormalities. According to these restrictions there are imposed three conditions the die in functioning has to do:

- not to produce plastic abnormalities on the exterior surface of the tubular good;
- not to mark the exterior surface of the tubular good;
- not to slide on the exterior surface of the tubular good.

By acting with a force F_m on the pincers shank, its elements take contact with the exterior surface of the tubular good forming in final phase a rigid system able to transmit the torsion moment necessary to the screwing – unscrewing operation. In these conditions, the movement flux is transmitted in the die – tubular good contact zone existing complex interaction phenomena between the two elements concerning the: prescribed torsion moment size (in accordance with the tubular good diameter on which it acts), the tubular good diameter, the physical and mechanical characteristics of the tubular good and of the die, the environment etc. The strain system that is established in the region of the die – tubular good contact is presented in the figure 3 (there was considered the schematic representation of the pincers elements in a perpendicular plan on the geometrical axle of the tubular good).

As consequence of the normal forces that act on the jaws, it appears at the jaw – die contact and there are transmitted forward to the die – tubular element pressures specific that deform the superficial layer of the tubular element in the elastic field (figure 4).

Also, as consequence of the elastic abnormalities that are produced at the die – tubular material contact there appears material agglomerations that contribute to the increase of the active working moment.

The choice of the contact surfaces supposes the knowledge of the metallurgical material aspects (nature, chemical composition, structure).

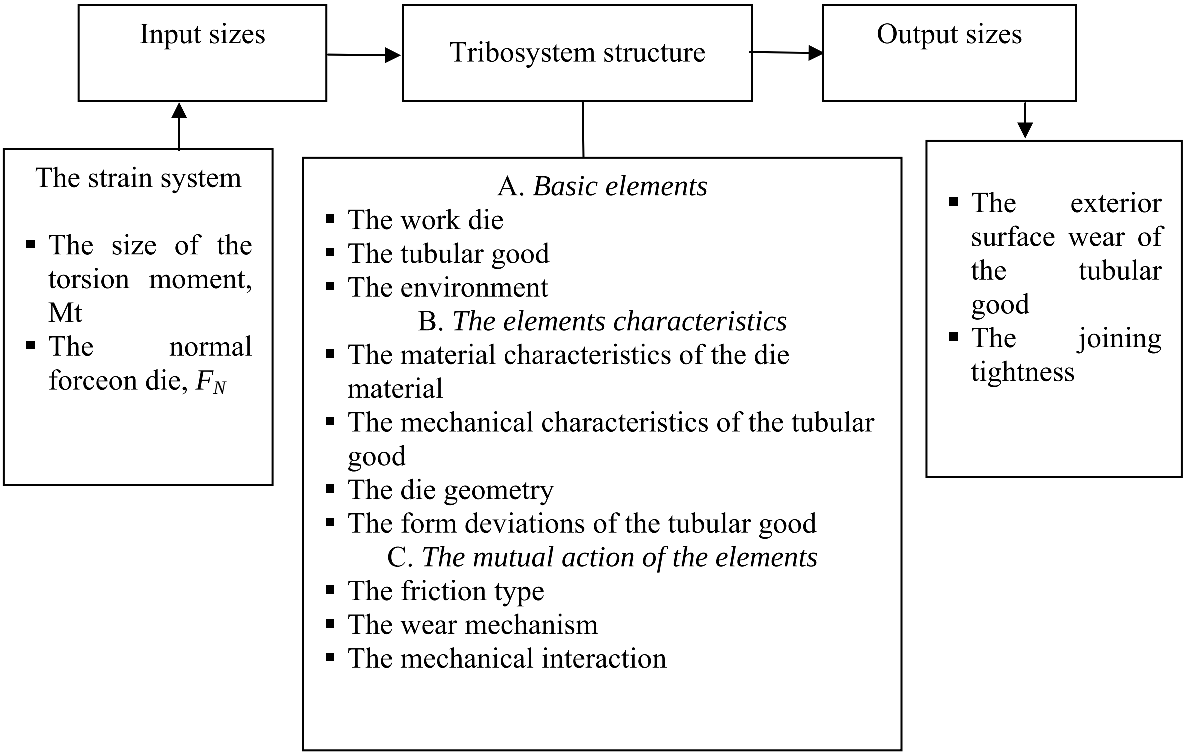

Figure 2: *The tribomodelling of the die – tubular good system.*

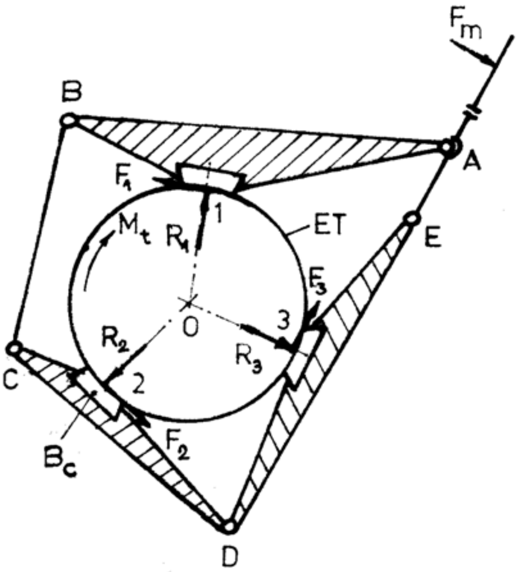

Figure 3: *Strain system at the die – tubular good contact*:
ET – tubular element; B_C *– die*; M_t *– torsion moment*; F_m *– exterior force*; F_1, F_2, F_3 *– tangential force*; R_1, R_2, R_3 *– radial forces.*

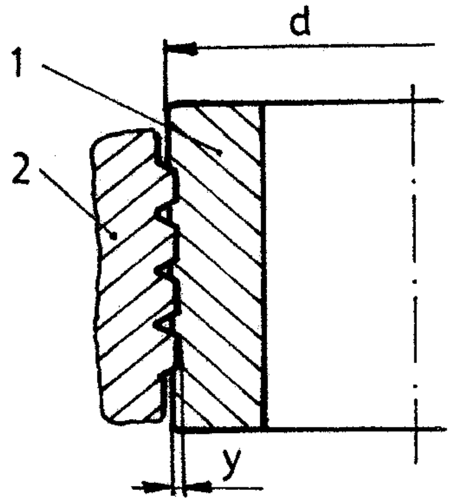

Figure 4: *The die – tubular good contact:*
1 *– tubular element*; 2 *– striated die*; *d – exterior diameter of the tubular element*; *y – abnormality*.

The exterior surface of the tubular element is covered with oxides or a liquid coating (water, crude oil, oil and drilling mud) that influence the pincers functioning. The transmitting of some important couples by the friction forces supposes accomplished the compatibility condition of the materials in contact. For the fiction couplers the material compatibility is appreciated in accordance with the capacity of leading from the welding at low sliding speeds and great contact pressures. In the analyzed situation one of the surfaces (the exterior surface of the tubular material) is made from thermal treated steel and the concerted element (die) has to present a strong gripping tendency on the steel. Thus it results that for making dies it has to retain the carbon steels with a more decreased content in carbon as the steels with the marks OLC10, OLC15, OLC20, 18MnCr11.

In conclusion on the functioning condition of the drilling pincers it will act the following factors [1], [2], [6]:

a) The position of the die – tubular material contact points refers to the disposition on the tubular good circumference of the contact points (contact area) that present a special importance on the pincers functioning. This aspect is tied on the pincers geometry.

b) The geometrical form of the used die; according to the experimental researches, the dies used for the equipment of the drilling pincer may be grouped form the point of the contact surface geometry view in three groups (fig. 5): cylindrical smooth dies (having the catch surface cylindrical - smooth), dies scratched dies (having the catch surface scratched) and curved dies (cylindrical or scratched).

In what it concerns the way of the die disposal on the tubular material circumference these may occupied the positions indicated in the figure 6.

c) The strain system that develops to the die – tubular material contact (fig. 7).

3. THE DETERMINATION OF THE PINCERS WORKING CRITERION

Between the die and the tubular material without existing a relative movement there appears the problem of determination of the limit starting conditions (at the contact between the two elements die and tubular material) of the relative slide phenomenon that constitutes the criterion through which the pincers does not accomplish the functional role.

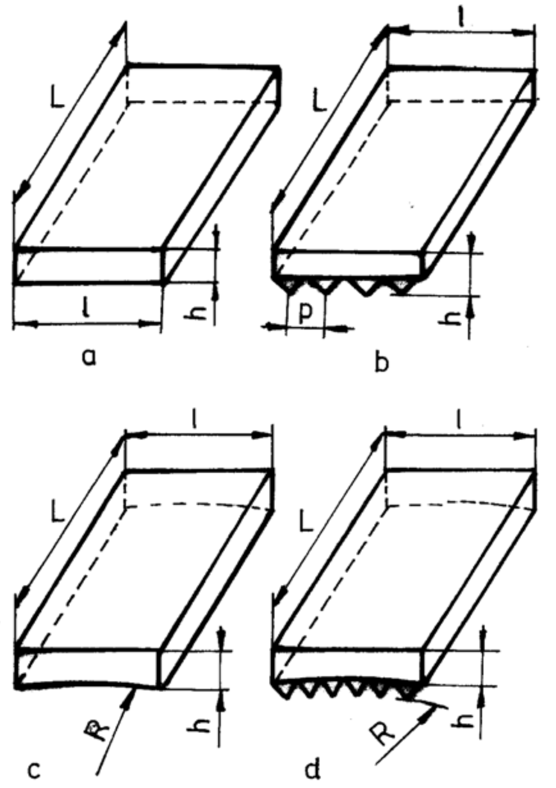

Figure 5: *Types of dies*:
a – flat die; *b – flat – scratched die*; *c – curved die*; *d – curved scratched die*.

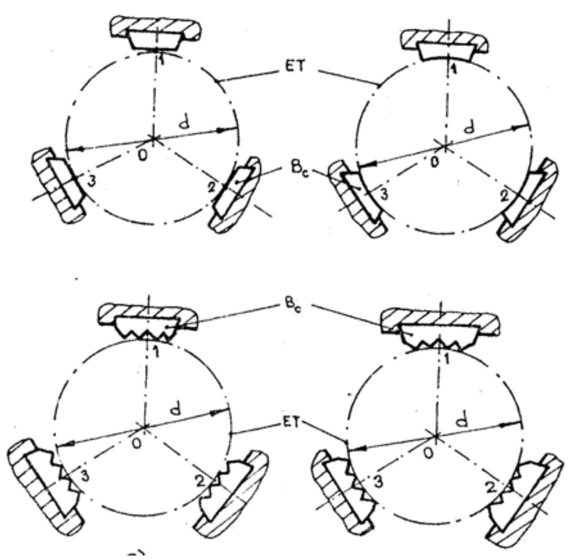

Figure 6: *The dies disposal on the tubular material circumference:*
ET – tubular element; B_C – die; *d – exterior diameter of the tubular material*; 1, 2, 3 – *die – tubular material contact points.*

The pincers functioning condition supposes the screwing (unscrewing) without slip of the tubular material. The acting exterior moment may be defined:

$$M_e = F_m \cdot b \qquad (2)$$

in which F_m represents the exterior force applied to the pincers and b the force arm.

The active moment (M_a) is produced by tangential forces that appear in the die – tubular good contact region:

$$M_a = (F_1 + F_2 + F_3) \cdot (d/2) \qquad (3)$$

$$M_a = \mu_0 \cdot (F_1 + F_2 + F_3) \cdot (d/2) \qquad (4)$$

in which μ_0 represents the friction coefficient to the adhesion slip, d – exterior diameter of the tubular material.

The resistant moment (M_r) is given by the friction forces that appear in the die – tubular material contact region (M_1) and by the material agglomerations from the front of the die tooth (M_2):

$$M_r = M_1 + M_2 \qquad (5)$$

$$M_1 = \mu \cdot (d/2) \cdot [R_1 \cos\varphi + R_2 \cos\beta + R_3 \cos(\varphi + \theta + \beta)]$$
$$M_2 = E \cdot p \cdot (d/2) \cdot (y_1 + y_2 + y_3) \qquad (6)$$

in which: μ represents the limit friction coefficient to the die – tubular element contact; E – longitudinal elasticity modulus of the tubular element material; p – the width of the die – tubular element contact region; y_1, y_2, y_3 – abnormality from the die – tubular element contact region; ϕ, θ, β – position angles.

The functioning condition will be:

$$M_r \leq M_a \qquad (7)$$

In the hypothesis of neglecting the material agglomerations effect, (the case of the dies with cylindrical smooth catch surface) the condition (7) becomes:

$$\mu \cdot [R_1 \cdot \cos\varphi + R_2 \cdot \cos\beta + R_3 \cos(\varphi + \theta + \beta)] / /(R_1 + R_2 + R_3) \leq \mu_0 \qquad (8)$$

Thus, the functioning condition of the multidimensional pincers is established by the value of the adhesion friction coefficient (μ_0) to the die – tubular good contact that has to be bigger than the value of the sliding friction coefficient (μ).

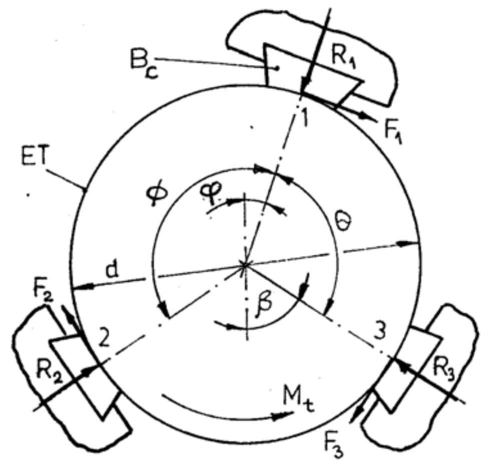

Figure 7: *The strain system to the die – tubular good contact*:

ET – tubular element; B_C *– die*; *d – exterior diameter of the tubular material*; 1, 2, 3– *die-tubular material contact points*; M_t – *torsion moment*; F_1, F_2, F_3 – *tangential forces*; R_1, R_2, R_3 – *radial forces*; ϕ, θ, β – *position angles*.

4. THE EXPERIMENTAL RESEARCH PROGRAM

4.1. The marks of the materials used for making dies

The materials used for making dies are: OLC10, OLC15, OLC20, 18MnCr11 [5]. The chemical composition of the steels studied for the delivery state (re-baked steel) is presented in the table 1.

4.2. The marks of the materials used for making tubular good

The tubular material that is assembled during the drilling – extraction works may be: drill –pipes, casings, assembly reducing etc. The marks and the diameters of the tubular material selected for the tests are presented in the table 2.

4.3. The types of dies

For the experimental researches it may be used dies flat – scratched type *A* or *B* (according to the figure 8).

4.4. Test piece for the tubular material

The form and the dimension of the test piece for the modelling of the tubular material are presented in the figure 9.

Table 1. Chemical composition

Steel mark	Chemical composition (%)			
	C	Mn	S	P
OLC 10	0.09	0.440	0.030	0.020
OLC 15	0.140	0.380	0.020	0.018
OLC 25	0.180	0.420	0.025	0.016

Table 2. The mark and the diameter of the tubular material

No.	The nominal diameter	Steel mark	Hardness (HB)
1	60.3	OLT65	105
2	70.6	26MoVMn26	202
3	89.0	26MoVMn26	202
4	104.0	43MoMn16	136

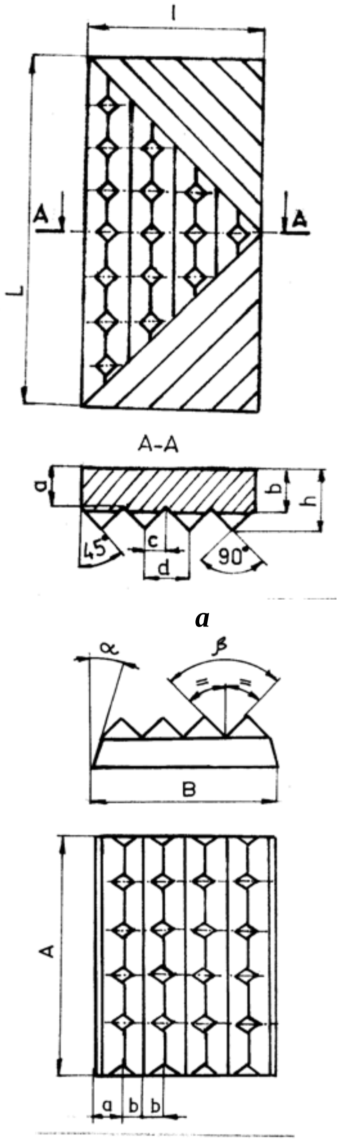

Figure 8: *Flat – scratched dies*:
a – type *A* ; *b* – type *B*

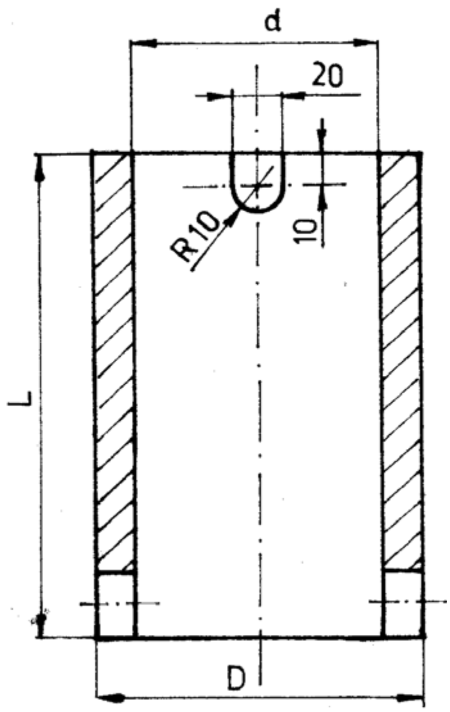

Figure 9: *The form and the dimensions of the test piece for the tubular material*.

5. CONCLUSIONS. DISCUSSIONS

The researches made established that the possibility of realizing the functional role depends on the strain system that is established in effective working conditions and on characteristics die – tubular material contact.

The experimental researches aims at the determination of the starting limit coefficient of the sliding conditions at the die – tubular material contact (μ). The conditions in which there are developed the researches have to take into account the following elements:

- The value of the radial force (pressure) on die (*R*);
- The exterior diameter of the tubular material (*d*);
- The mark of the tubular material;
- The geometry (type) of the working die (test piece);
- The mark of the die material (test piece);
- The environment: the dry regime, the drilling mud, the oil, the crude oil, the salt water etc.

The constructive form has a special importance thus on the pincers working condition so the realization of the screwing – unscrewing couple and on the surface state of the tubular material influencing the working period of time of the tubular material that is manipulate.

Knowing the field in which it varies the radial force (pressure on die – on the basis of the experimental determinations with the help of the tensometrical marks), the die type (the geometry of the active surface), the mark of the die material, the mark of the tubular element material, the value of the tubular material exterior diameter (on which it acts) and the working conditions determine the value of the adhesion friction coefficient (μ_0) to the die – tubular good contact that has to be bigger than the value of the sliding friction coefficient (μ).

Thus it may be drawn working diagrams – according to a great series of experimental determinations and the statistical data processing – establishing the verification criteria of the multidimensional pincers functioning condition.

Thos kind of diagrams may be used in the activity of drilling pincers projection renouncing at a series o tests enough expensive on the essay stands.

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