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RESEARCH

Reliability Evaluation for Improved Screw Dies of Coiled Tubing unit Injector

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A B S T R A C T

The paper considers improvement of screw dies of mobile coiled tubing unit injector through the change in screw die's design parameters with further mounting of metal-ceramic based friction material. Comparison of designs of unit injector screw dies was carried out and reliability evaluation of an improved coiled tubing transporter unit was executed.

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1. INTRODUCTION

The transporter of coiled tubing units is one of the most crucial component of mobile coiled tubing unit, which provides the movement of the coil tubing [1] and its fixation in a specified position with injector screw dies which provide movement of spooled tubes both upwards and downwards in the same reliable way and with no slipping of the working parts.

Today, designs are divided in two directions: with one and with two haulage chains (5 on Fig. 1) conjugated with screw dies (16 on Fig. 1), which interact with the spooled tube (17 on Fig. 1) by inner surfaces. Hydraulic cylinders (6 on Fig. 1) are drives of screw dies, which hold a tube in a specified position with the help of contact by concave surface with the tube surface. According to statistics, injector's screw dies are subjected, in the most intensive way, to mechanical wear due to the presence of high friction forces when interaction of screw dies with a coiled tubing unit.

2. PROBLEM ANALYSIS

Long-lasting operation of a coiled tubing unit due to the continuous contact with the drilling and borehole equipment results in the violation of tolerances for the mutual alignment of the operating surfaces, causing appearance of the cutting or more often out-of-roundness, which directly leads to the deficient contact of joining surfaces. In this case, tube shape accuracy is defined by the production accuracy and tube surfacing technology. In any case, the tube surface has many micro-roughness, which are invisible to a naked eye, but significantly effect on the surface roughness. Figure 2 shows the actual tube profile before and after deformation.

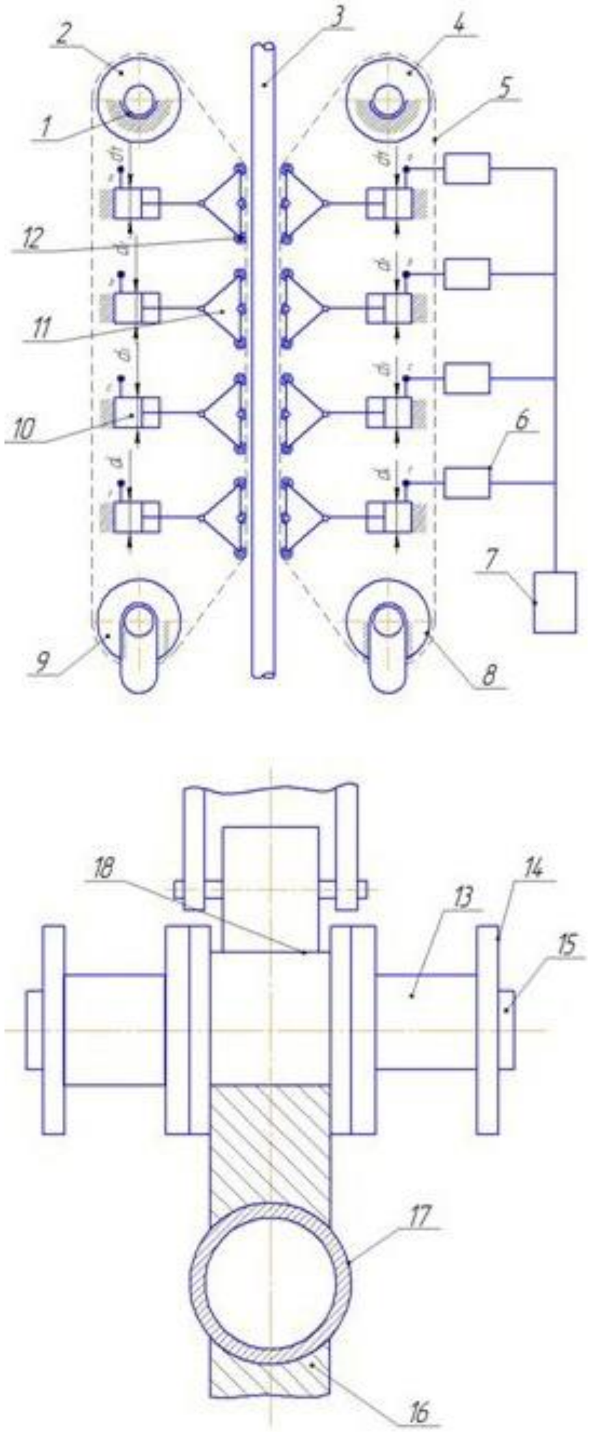
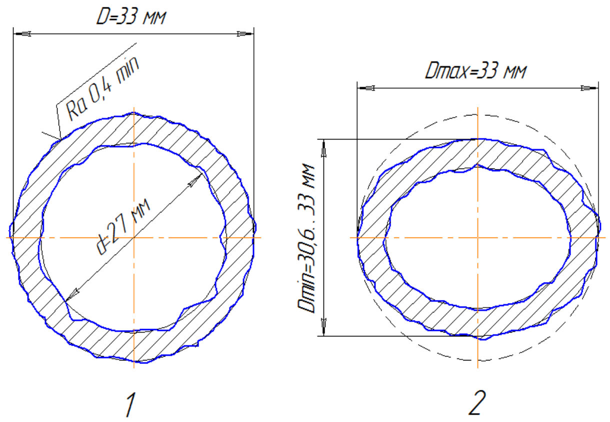


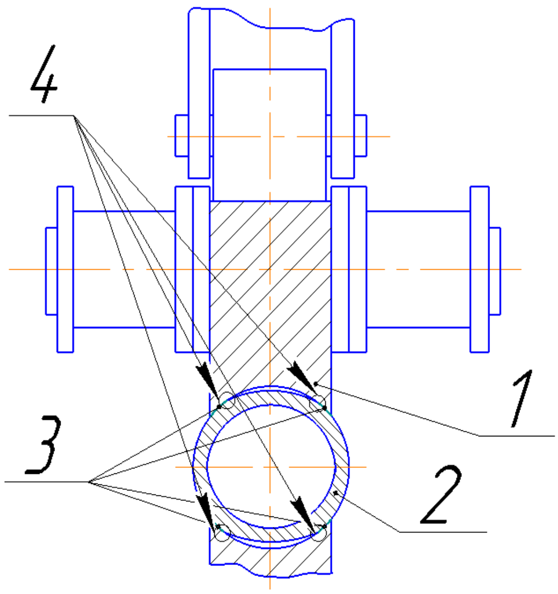
Fig. 1. Scheme of coiled tubing transporter



1 - actual tube profile before deformation;
2 - actual tube profile after deformation

Fig. 2. Tube profiles before and after deformation

Tube flattening during the screw dies contact with the tube causes 4 concentrated loads, effect of which causes the significant wear of the contact areas, labelled with arrows (Fig. 3).



1 – screw die; 2 – tube;
3 – surface contact areas; 4 – areas of sufficient wear

Fig. 3. Scheme of "screw die-tube" transition

Reliability and inter-repair period of the screw dies increase due to alloying screw die surfaces by case hardening, nitride hardening, gas cyanization and boriding. The spooled tube is made from steel 20, which yields in strength properties to the screw dies material [2] (steel 40X GOST 4543-71), as a result it is significantly more intensively worn-out than the screw dies material, that leads to incredible unit operation expenditures due to high tube cost [3].

Up to date, injector's screw dies are manufactured in two directions: with flat and corrugated inner surfaces. The latter found limited use in the drilling area since application of the corrugated surface leads to scoring and spalling on a tube surface. For this reason, the second design screw dies have less reliability than the first ones.

3. PROPOSED MEASURES

Wear resistance increase of screw dies and spooled tubes can be solved by the use of additional material which has capability to partially take the form the deformed tube, what leads to more full contact of adjoining surfaces.

That is why, the most optimal method to improve the construction is using iron-based friction material, which has the following properties:

1) high strength properties,
2) medium friction coefficient (independence from climatic conditions),
3) heat stability,
4) good conformability,
5) high wear resistance,
6) low cost.

In composition of injector's holding down device it is proposed to install two metal-based friction material linings in the inner hole of the screw die, which will be mounted with zero gap [4] and screwed to the main surface of the screw die.

Metal-ceramics based material which meets all the above mentioned requirements is selected among all friction materials [5,6].

The friction material FZh-10 with 102-131 HB hardness with microstructure consisting of perlite, ferrite up to 30 %, inclusions of cementite, graphite, phosphide eutectic, pores is the most optimum choice.

The chemical composition of the material is Fe (77 %), Cu (3 %), graphite crystal. (6 %), sulfurous nickel (2 %), chrysotile asbestos (3 %), silicocalcium (6 %), sulfurous ferrum (3 %).

Selected material [2] operates under extreme conditions of tear and wear-under high pressures (up to 6 MPa), at sliding speeds (up to 40 m/c) and temperature instantly increasing up to 1,000 °C. To fulfill its functions the friction material must have high and stable friction coefficient within a wide temperature range, minimal wear, high thermal conductivity and thermal resistance, good conformability and sufficient strength. Selection of the material is performed according to the extreme surface heat temperature and maximum pressure, which it withstands.

Friction material will be used in the form of linings (Fig. 4), which are screwed to the inner surface of the plates [7]. For this it will be needed to reduce the screw die radius by 6 mm.

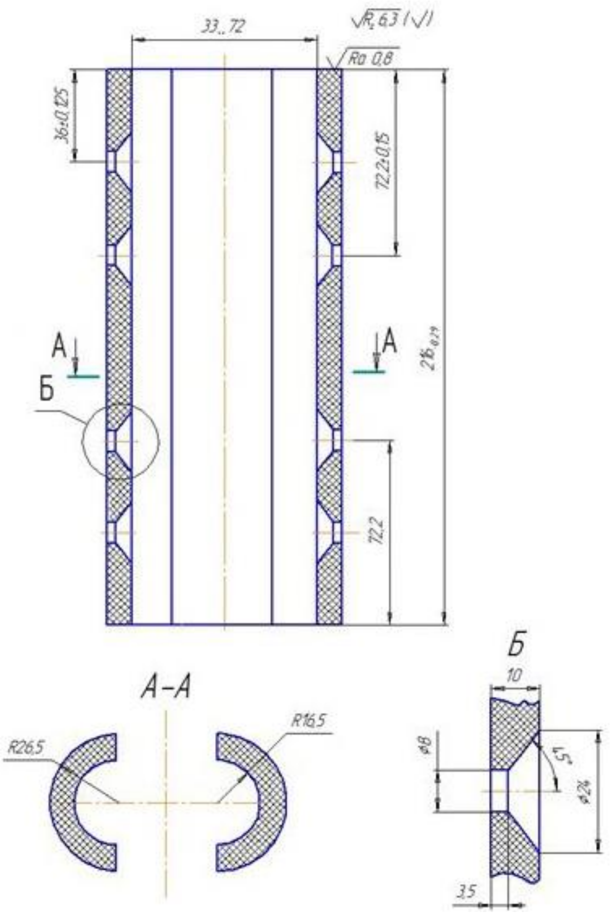


Fig. 4. Friction material lining.

Figure 5 shows the friction lining assembled with a screw die.

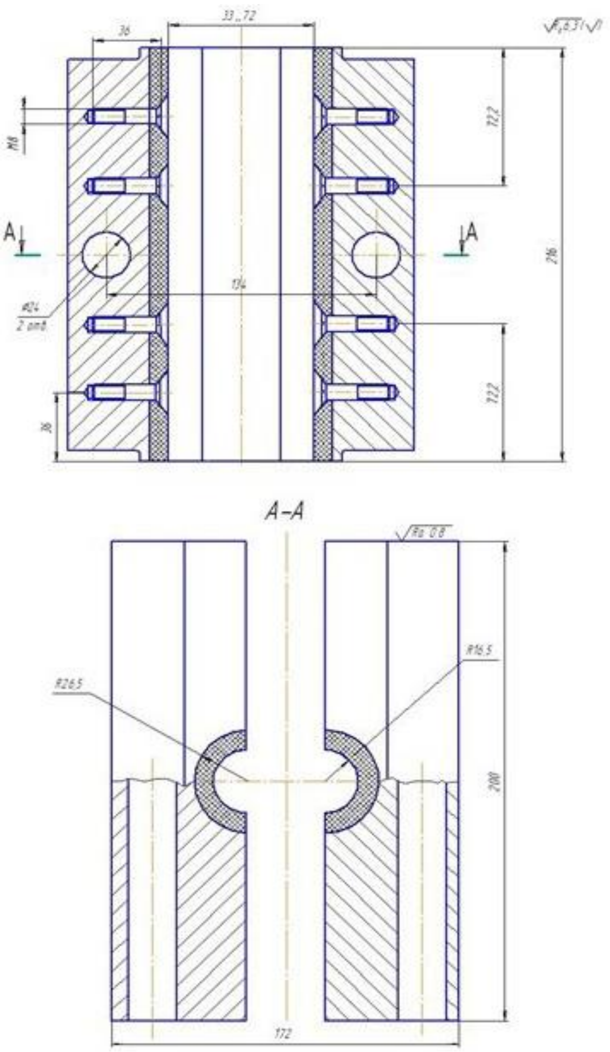


Fig. 5. Assembled lining and screw die.

4. RESULTS

To predict the reliability of the improved unit it is necessary to know the form and behavior of failure rate function λ(t) [8].

It is very important to know the form and behavior of failure rate function [9] λ(t) for theory and practice of reliability.

A typical failure rate function can be divided into three periods:

1. short period of time wherein significant decrease in failures is observed due to the parts and unit's components breaking-in,
2. constant value of failure rate,
3. period of catastrophic worn-out or regular gradual failures (the number of failures increases).

Probability of failure-free operation P (t) in the course of t, hours, depreciable mobile conjugation.

Wear life is determined by standard distribution law:

1. Quantile of normal distribution

$$u_p = \frac{t - m_t}{S} = \frac{26.78 \cdot 10^3 - 34.856 \cdot 10^3}{6.73 \cdot 10^3} = -1.2$$

where t is wear life, hours; m_t – mathematic expectation of operational equipment life, hours; S – mean square deviation of wear life, hours.

2. With the table of quantile values for normal distribution we find the probability of failure-free operation of improved screw die:

$$P(t) = 0.8849 = 88.49\ \%$$

3. Operational life of injector's screw die:

$$t = m_t + u_p \cdot S = 34.856 \cdot 10^3 + (-1.2) \cdot 6.73 \cdot 10^3 = 26.78 \cdot 10^3\ h = 3\ years\ 1\ month$$

5. CONCLUSION

Screwing the lining will provide quick and easy assembling-disassembling of connection, while the simplicity of friction lining design will provide the complete interchangeability of a unit. Application of friction material will allow protection of the screw die surface from tear and wear when contacting a deformed tube and significantly reduce the wear of the coiled tubing surface ensuring the breaking-in of the lining material to the shape of the outer tube surface. Along with that, it is necessary to carry out outer inspection of the screw die and linings to study wear behavior and rate. The success of friction material lining use is stipulated by their wide application in brake systems of trucks and cars. The calculation of failure-free operation probability of the improved injector's screw dies is carried out, their operation life is determined.

Summary:

1. Injector's screw dies are one of the unit elements which are subjected to mechanical wear in the most intensive way.
2. One of the main challenges in the field of engineering and technologies of oil and gas

wells drilling is the reliability improvement for the oilfield equipment.

3. Coiled tubing unit are subjected to a larger mechanical wear than the inner screw dies of coiled tubing transporter due to application in its production of low carbon steel (steel 30) , which yields by strength properties to steels alloyed [10] by the method of nitride hardening, gas cyanization and boriding [11].
4. The most expedient method to increase the wear resistance of the screw dies is application of friction material linings due to the optimality of physical properties of the friction material.
5. Improved screw dies are more reliable than the standard screw dies.
6. Use of friction material linings will prolong the service life of coiled tubing.

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