ASPECTS RELATED TO THE TUBULAR MATERIAL WEAR CAUSED BY ITS CONTACT WITH THE SUSPENDING DEVICE TEETH

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SUMMARY
The tubular material belonging to the drilling string, casing string and tubing string, during its use, is periodically suspended by means of the suspending devices (slips) so that the respective job causes traces on a certain length of the tubulars. The constructive and functional optimisation of the tubulars suspending devices presumes two aspects: the research of the contacts between the tubulars and suspending device teeth and the research of the slide between the above-mentioned two components. This is the reason why a test stand was designed and manufactured to allow the study of the tracing depth variation in case of the strips gripping the tubulars. The research result permits the manufacturer to select the optimum geometric parameters of the tubulars suspending device as well as the material and heat treatment for the slips and tubulars depending on the depth of the tubulars traces.

Keywords: tubulars suspending device, traces, teeth

1 INTRODUCTION
The tubulars belonging to the drill string, casing string and tubing string shall resist the heavy-duty conditions generated by the type and intensity of their mechanical stresses as well as the phenomena of wear, erosion and corrosion caused during the drilling and production. The quality of the tubular material becomes an element of the product performance under such circumstances, one of those factors really determining the good development of the production and drilling processes. During its use, the tubular material is periodically suspended by means of the suspending devices so that the respective job causes traces on a certain length of the tubulars. The shape and dimensions of the traces vary depending on the geometry of the slips having been utilised and, of course, the axial stress intensity. The said traces may generate breakage phenomena whose economical and technical consequences are really significant, such as: stopping or abandonment of the production and drilling jobs or recovery of the well-remained string under great-expense conditions. So, the slips suspending the drilling, casing or tubing strings have to be designed in order to develop such stresses that do not cause traces that can become breaking inductors.

This is the reason why a test stand was designed and manufactured to allow the study of the contacts between the teeth and tubulars. The mentioned test stand reproduces the suspending device requested test. The study of the said contact was made on the basis of various slip length, slip’s tooth apex radius, slip tapering, wall thickness-to-tubular OD ratio, slip back roughness, yield strength of the tubular material and axial stress of the tubulars.

2 THEORETICAL RESEARCHES
The specialty literature [1, 6] shows that the dimensional calculation of the suspending slips of the tubulars is effectuated by determining the stresses that occur in the zone where the tubulars are gripped. So it was possible to determine a theoretical relation that permits the calculation of the tubulars weight depending on the suspending device geometrical and material parameters, using the hypothesis that there are no slide and tracing between the teeth and tubulars:

\[
G = \frac{R}{2\pi \left[ \frac{t}{D} \left( \frac{1}{D^2} \right) \right] D \cdot l \cdot \tan(\alpha + \rho) + \frac{\pi}{4} \left( D^2 - D_i^2 \right)}
\]

(1)

where:
- \( G \) is the tubulars weight;
- \( R \) - yield strength of the tubular material;
- \( t \) - tubulars wall thickness;
- \( D \) - tubulars outside diameter;
- \( D_i \) - tubulars inside diameter;
- \( l \) - suspending device (slip) length;
- \( \alpha \) - suspending device tapering angle;
- \( \rho \) - friction angle.

3 EXPERIMENTAL RESEARCH
In order to effectuate the experimental determination 15 slips were used with different mechanical and geometrical properties. The test stand elements are described in Figure 1. The traces were studied using pipe groups that have the same mechanical properties as the materials used for manufacturing drilling, tubing or casing strings.
Figure 1. Test Stand: 1) Pipe; 2) Slip; 3) Safety Ring; 4) Adapter; 5) Screw; 6) Nut; 7) Body; 8) Bushing; 9) Pipe Displacement Measuring Device; 10) Slip Displacement Measuring Device; 11) Plate.

4 EXPERIMENTAL RESULTS

The slip capacity of suspension was analysed by defining the tracing coefficient C.

\[ C = \frac{A}{t} \cdot 100\% \]  

(2)

where:

- \( A \) is the trace depth;
- \( t \) – tubular wall thickness.

The variation of the tracing coefficient with each studied parameter was effectuated by means of regression functions calculated with the Jandel Scientific program according to [2].

\[ C = 0.035 - 0.062 \cdot \sigma + 0.001 \cdot \sigma^2 - 7.786 \cdot \sigma^{2.5} + 1.483 \cdot 10^{-6} \cdot \sigma^3 \]  

(3)

\[ C^2 = 47.20 - 73005 \cdot (\nabla H)^{-2} \]  

for slips made of 10Cr130

\[ \ln C = 0.193 - 0.0138 \cdot t^{2.5} \]  

for \( F=100kN \)  

(12)

\[ \ln C = 11.96 - 0.21945 \cdot t^{2.5} \]  

for \( F=100kN \)  

(13)

where:

- \( \sigma \) is a tubulars axial stress;
- \( l \) – slips length;
- \( r \) – slips tooth apex radius;
- \( R_z \) – slips back roughness;
- \( H \) - slips tooth material hardness;
- \( \nabla H \) - differences between the tooth material hardness and the pipe material hardness;
- \( F \) – axial pipe load.

The correlation coefficient of the regression function is \( R=0.944 \). That indicates a determined relation between the parameters taken into consideration and the value of the tracing coefficient. The remaining dispersion around the regression line of the tracing coefficient is \( S^2=0.526 \).

According to [3] each independent variable influences the tracing coefficient value significantly, the partial correlation coefficients are:

\[ R_{L,C} = -0.021; \quad R_{\sigma,C} = 0.281; \quad R_{HR,C} = -0.05 \]

(15)

\[ R_{l,C} = 0.349; \quad R_{T,C} = -0.27; \quad R_{H,C} = 0.459 \]

The study of the standards governing the amplitude of the admitted defaults of the tubular results in the following conclusions: the traces whose depth range between 5 and 12.5% of the pipe thickness can be repaired; the traces whose depths are under 5% of the pipe thickness can be neglected.
Taking into consideration those above, a maximum tracing coefficient of 3% was proposed to be an acceptance criterion of the slip performances. Those values did not determine significant increase of the stresses in the area of the default, the most solicited zone remaining that of the inner diameter of the casing end. That was the result of the finite element analysis carried out by means of the MSC/NASTRAN program and applied to those pipes that had been applied a tensile force \( F = 150 \text{kN} \) before tracing (Figure 2a) and a coefficient \( C = 3\% \) (Figure 2b) after tracing.

Some specimens were taken from the traced pipes and applied a tensile test according to [2], that permits the above acceptance criterion to be verified experimentally. The results gained after the specimen study did not differ from the values gained before the pipe tracing.

5 CONCLUSIONS

The theoretical calculations pointed out that the use of an axial stress of 47% of the yield strength specific to the tubular material did not generate any tracing and caused only elastic strain of the pipe; in this case the experimental value of the tracing coefficient was smaller than 2%.

Axial stress smaller than 60% of the yield strength of the tubular material determined a tracing coefficient smaller than 3% and modifications of the outer tubular diameters under the limit conditions accepted by the standards governing the tubulars manufacture.

Figure 2. The Stress and Strain Distribution: a) before tracing; b) after tracing when the tracing coefficient is \( C = 3\% \).

The length of the slip does not have a significant influence on the tracing coefficient, the partial correlation in the regression function being \( R_{l,c} = -0.021 \); but, if the ratio between the length of the slip and tubular diameter is smaller than 1.3 the suspending of the pipe is hard to be done.

### Table 1: Experimental Results

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The tooth apex radius has a great influence on the tracing coefficient \( R_{r,C} = 0.349 \); but, it is recommended to be less than 1 mm in order to avoid the slide of the tubulars.

The roughness of the taper slip surface has a great influence on the tracing coefficient \( R_{Rz,C} = -0.331 \) but, greater values than 12.5 \( \mu \text{m} \) can cause the slide of the tubulars.

The hardness of the tooth of the slip is the determining parameter that influences the tracing coefficient \( R_{H,C} = 0.459 \) but, if the difference between the tooth hardness and tubular hardness is less than 200HV the suspending of the tubulars can be difficult.

The tubular material hardness and yield strength have a small influence on the tracing coefficient, \( R_{Hp,C} = -0.05 \); \( R_{Rp,C} = -0.145 \) but, according to [5] the weight of the tubulars that can be suspended is determinated based on the yield strength of the tubulars.

The slip tapering angle, the wall ovality in accordance with the tolerances and working condition of the slip and tubular do not influence the tracing coefficient or suspending capacity of the slip significantly.

The research results are:

- an acceptance criterion of the slip performance, experimental validated is the \( C=3\% \) value of the tracing coefficient;
- elaboration of a selective guide permitting the optimum couple of suspending device and tubulars to be selected; the above specified couple is optimum regarding the material and heat treatment having been applied [2];
- elaboration of a guide for design and geometrical verification of the suspending device; the said elaboration is based on the acceptance criterion having been proposed.

6 REFERENCES