Bohdan Kopey*, Volodymyr Kopey*, Mykhailo Lyskanych*

TOOL-JOINT THREAD MODELING BY FINITE ELEMENT METHOD

1. INTRODUCTION

Tool-joints of drill pipes are very loaded elements of drill column. They are exposed to the action of longitudinal loads due to the proper weight of column, transversal forces and bending moments, axial vibrations, internal pressure and corrosion destruction of metal by drilling mud.

Tool-joint threaded connection is tightened usually by optimal torque, determined by full-size fatigue tests when mean stress in pin measuring plane achieves 0.3–0.4 of yield strength [1].

2. FEM ANALYSIS OF TOOL-JOINT

To learn the nature of stress distribution in the tool-joint thread of drill pipes we have developed computer FEM axisymmetric model of the standard thread 3-66 of tool-joint 3H-80 with the normal pass opening (GOST 5286-75).

A material of tool-joint's details is a steel 40CrNiMo after normalization (E = 2.1·10^{11} Pa, = 0.28). The computations were conducted taking into account the friction between the contact surfaces (nonlinear task). For the effort simulation in tool-joint between the supporting end of nipple and basic part of box the area of material able to the thermal expansion in the axial direction was used and this thermal expansion was equal to the nipple alongation in case of screwing the details together [2]

$$d_i \quad \frac{p\, d_c}{D_f} \tag{1}$$

* Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine

where:

p – thread pitch,

d_c – circular displacement of box in regard to nipple in case of screwing together,

D_f – diameter of circle on which the displacement of d_c was realized.

The Figure 1 shows the stress– deformation state of 3H-80 tool-joint without external loading (a) and in case of action of the external loading of 1 MN (b). On the Figure 1 the deformation is conditionally enlarged in 100 times. Local stresses of such large sizes (about 1 GPa) are explained by application of FEM model, where the plastic deformations were not taken into account.

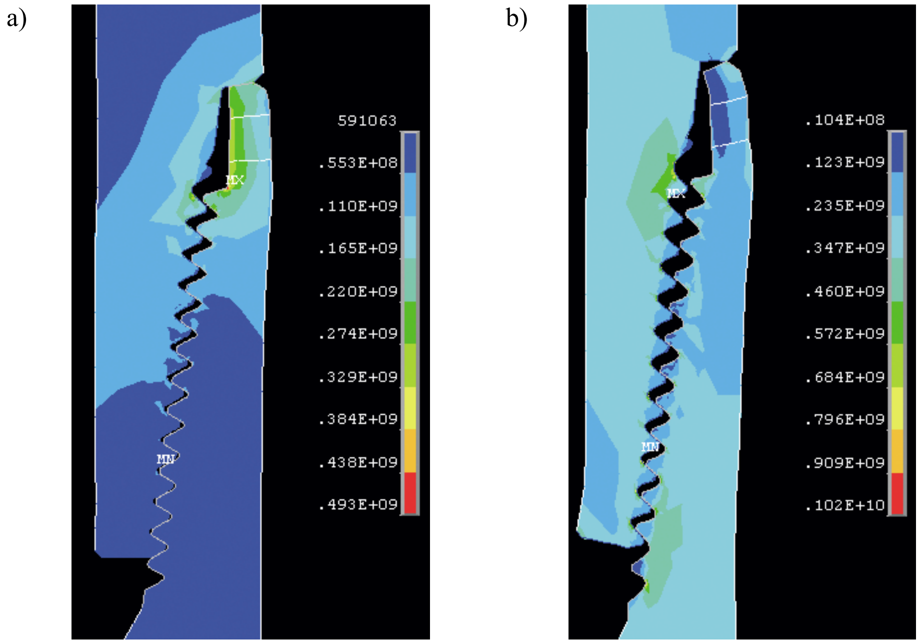

Fig. 1. Stress distribution after the Mises criteria (Pa) in the tool-joint 3-66, screwed together by the optimum torque in case absence and presence of the external loading: 0 N (a), 1 MN (b)

Evidently, that in case of absence of the external loading the highest srtesses exist in the first thread of nipple, and in case of action of the external loading by 1 MH – in the first thread of nipple and the last thread of box.

Proper frequencies of 3H-80 tool-joint screwed together are found by method of FEM: first – 7480 Hz, second – 22 925 Hz, third – 37 191 Hz. The harmonic analysis of tool-joint in case of loading was conducted under the action of variable external force of 150 kN in range of the frequencies 5000–30 000 Hz.

Computer simulation using finite element method (FEM) shows that action of longitudinal vibrations caused by rock bit teeth contact with well bottom may minimize and even open the shoulder connections in tool-joint's pin and box (Fig. 2).

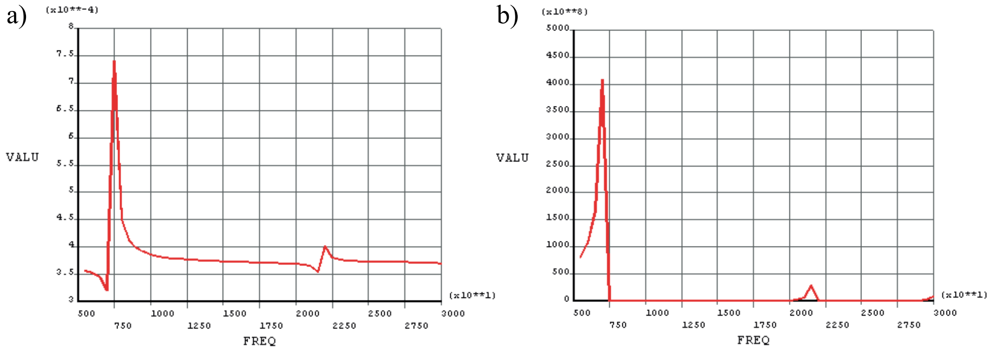

Fig. 2. Frequence descriptions of tool-joint 3H-80: a) amplitude of the relative moving in the joint place (m); b) amplitude of contact pressure in the joint place (Pa)

For example, the action of 150 kN amplitude axial force, applied to 3H-80 tool-joint (GOST 5286-75) having proper frequency equal to 7.48 kHz, may open pin and box shoulders and destroy the hermetic seal of connection.

a) b) c)

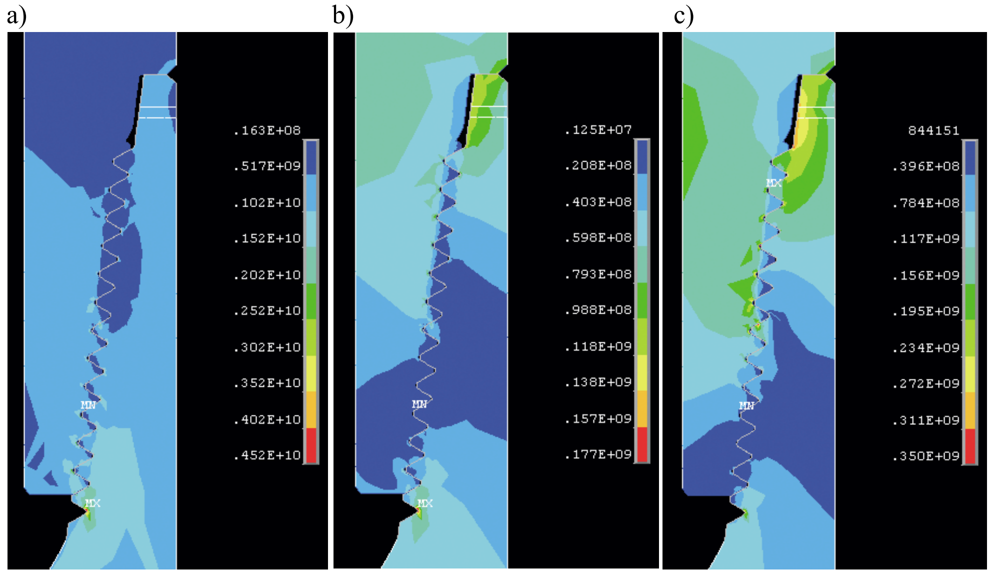

Fig. 3. Amplitude of stresses after the Mises (Pa) criterion at frequencies of the forced external loading by 150 kN: a) 7500 Hz; b) 19 000 Hz; c) 23 000 Hz

Distribution of stresses of von Mises criteria shows that fatigue failure of tool-joint thread is possible in pin first engaged groove (Fig. 3a), so it is necessary to eliminate such thread damage applying a bigger torque, which creates in pin measuring plane stress equal to 0.5–0.6 of yield strength (for steel with $_y$ = 600–800 MPa) and 0.6–0.8 $_y$ (for steel with $_y$ > 800 MPa). The second proper frequency is more favourable for the fatigue destruction of pin in the first thread (Fig. 4b).

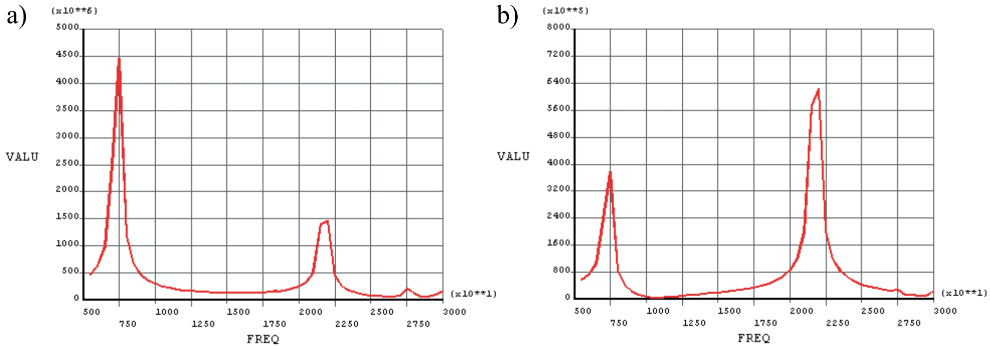

Fig. 4. Amplitude of stresses after the Mises (Pa) criterion in the dangerous sections of box (a) and pin (b)

3. CONCLUSION

On the basis of the given researches it is possible to do the conclusion, that the tool-joint thread in case of the large axial loading and action of vibrations can be involved in resonance, that conduct to reduction of compression stresses in the shoulder ends of pin and box and possible loss of monolith and screw-thread impermeability .

Experimental data conducted on vibration machine approve computer simulation of tool-joint 3H-80.

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