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Research on Wear Law of Rod String in Directional Well

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Abstract: The rod string wear in directional well deflecting section is the key problem to restrict the production efficiency of directional well, the finite element method is adopted according to vibration theory, contact theory and non-linear theory, then the distribution law of contact force between string rod and oil tube will be acquired under the condition of sucker rod actual well conditions. It analyses the relationship between deviation angle and contact force of rod tube and it also comparative analyses the change rule of contact force before and after installing centralizer in the deflecting section. That provides a theoretical basis to slow the wear of directional well sucker rod string and improve its lifetime.

Key words: Directional well, rod string, numerical simulation, contact force, wears

INTRODUCTION

Rod string will motion under oblique condition due to the effect of gravity in the slant well or directional well deflecting section, the friction force and wear of rod string in the oil tube of slant well and directional well deflecting section can be larger compared to the friction force and wear motions in Vertical Well. The method to change this situation is installed centralizer on the sucker rod. In this way, the friction between sucker rod and oil tube wall becomes a friction which between centralizer and oil tube wall, the motion resistance will change greatly. The friction and wear characteristics are different along with different lubricants between sucker rod and oil tube. The main problem of failure in directional well sucker rod pump is tubing leakage and sucker rod break off (Li *et al*., 1994; Wang *et al*., 2004; Xia *et al*., 2004). In this study, the nonlinear mechanics analysis is carried out on the rod string of rod pumping system for directional wells, we can find the distribution law of friction load between sucker rod and tubing through calculation and predict service life and corresponding design method is put forward.

MECHANICAL MODEL OF DIRECTIONAL WELL ROD SYSTEM

When the directional well sucker rod pump work it mainly bears the loads: Sucker rod weight, liquid column weight on plunger in oil tube, pressure on the liquid column to lower end of the plunger external oil tube, inertial load and vibration load are produced by the movement of sucker rod and oil cylinder, sucker rod and oil column wall mutual friction produce the friction load, sucker rod and liquid column, liquid column and oil tube mutual friction produce the friction load etc. The mechanical model of down hole rod tube in directional well rod pumping system, as shown in Fig. 1.

Sucker rod string belongs to a slender rod it exists contact impact behavior in the process of movement, so we commonly use numerical method to solve. The slender sucker rod and tubing are dispersed into several

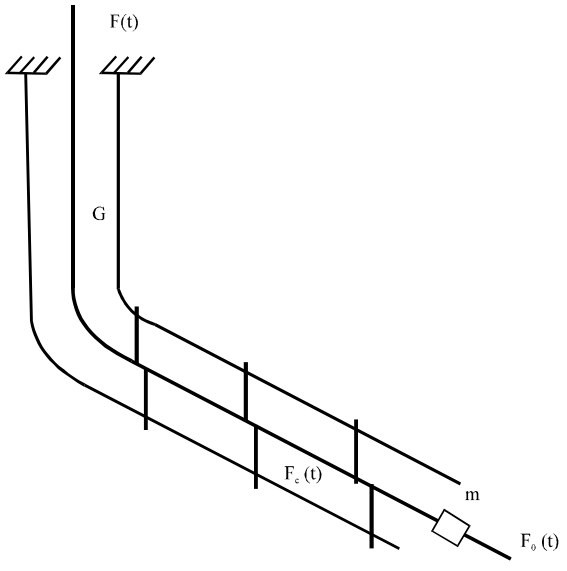

Fig. 1: Mechanical model of down hole rod tube in directional well rod pumping system

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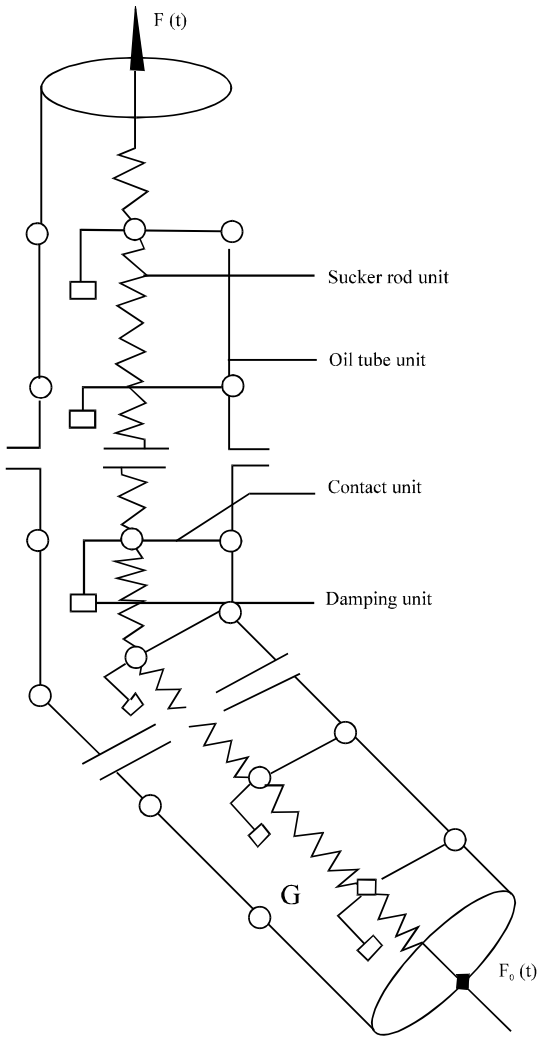

Fig. 2: Finite element model of down hole rod tube in directional well rod pumping system

"space beam element" and the contact element nodes are established. Then build equilibrium equation of beam element according to variation principle, get the balance equation of the whole rod through the process of coordinate transformation and combination assembly and put the contact load as the boundary condition, then solving equation can get rod node displacement, unit internal forces and rod tube contact force (Yang *et al*., 2011; Chen *et al*., 1999). Finite element model of vibratory rod string is shown in Fig. 2.

EXAMPLE CALCULATION

The finite element model is established according to structure parameter and working parameter of shu ping 1 well in Daqing oil field. All kinds of loads are calculated according to working parameters, applied it to the sucker rod; calculate the change rule of different pump depth and rod tube contact positive pressure. The working parameter of shu ping 1 well and the corresponding relations between pump and deviation angle is shown as Table 1 and 2.

Table 1: Working parameter of shu ping 1 well

Stroke (m)	Frequency of stroke (frequency min^{-1})	Pump diameter (mm)	Sucker rod diameter (mm)	Working fluid level (m)
4.2	5	44	19	1579

Table 2: Corresponding relation between pump and deviation angle of shu ping 1 well

Deviation angle (°)	10	20	30	40	50	60
Pump hanging (m)	1457	1579	1673	1747	1838	1859

Contact force of rod and tube under different deviation angle: Set the maximum pump hanging position of deviation angle: 10, 20, 30, 40, 50 and 60°. The contact state of deflecting section of rod string oil tube can be obtained through the displacement loading on the ground. The contact force distribution law of rod and tube under different deviation angle is shown in Fig. 3.

It can be seen from Fig. 3 (1) It's maximum in the deflecting section of rod string and oil tube without centralizer, the maximum contact force is 1600 N. The average contact force in the upper and lower deflecting section is 150 N due to the impact of deflecting section and (2) The distribution of contact force between rod string and oil tube is connected with deviation angle, the rod tube contact force is small when the angle is less than 30°, the contact force increases obviously when the angle is greater than 60°. Therefore, the deflecting section need avoid exceeding 30° in order to reduce the wear of rod string for directional well.

The comparison of contact force of rod and tube have centralizer or not have: The centralizer can be installed on the sucker rod in order to reduce the contact force between rod and tube, reduce the wear of rod string. Figure 4 and 5 are the comparison of contact force of rod and tube has centralizer or not has.

It can be known from the contrast: It can effectively reduce the contact force between rod and tube after the centralizer is installed in the deflecting section, the reduction extent of maximum contact force is about 40%. The interval will be decrescent between rod and tube after install centralizer in the rod, the flexibility can reduce as unstability. The contrast of contact force homogeneity between rod and tube under the different angles, (Table 3).

Table 3: Finite element analytical calculation results of each deviation angle

Maximum pump hanging position deviation angle (°)	Maximum positive pressure on each time mean value without centralizer (N)	Maximum positive pressure on each time mean value with centralizer (N)
10	-76.4	-36.7
20	-920.3	-278.1
30	-888.6	-261.8
40	-914.8	-216.9
50	-1010.3	-401.5
60	-1016.2	-420.6

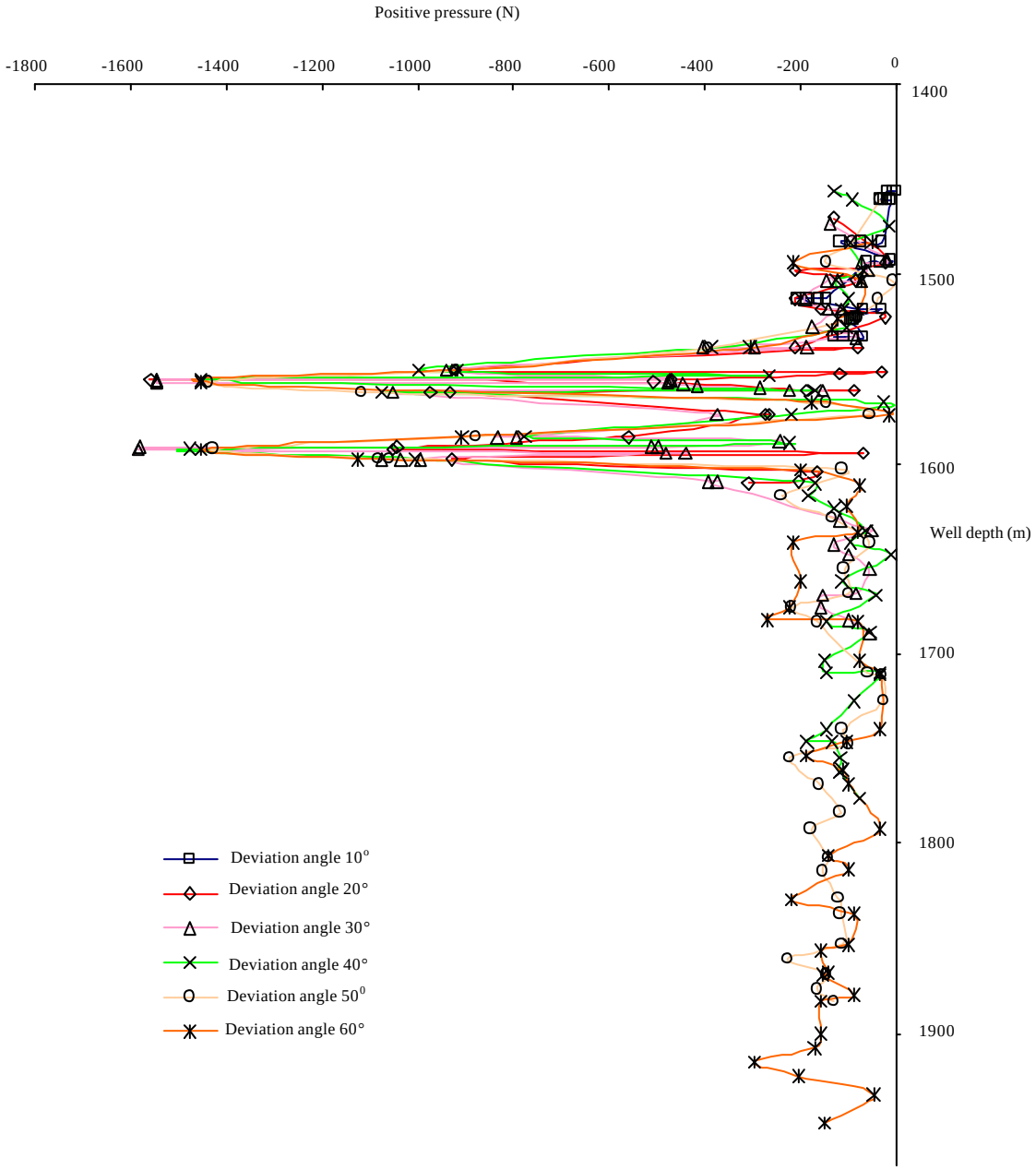

Fig. 3: Relation diagram between directional well oblique angle without righting ring and positive pressure

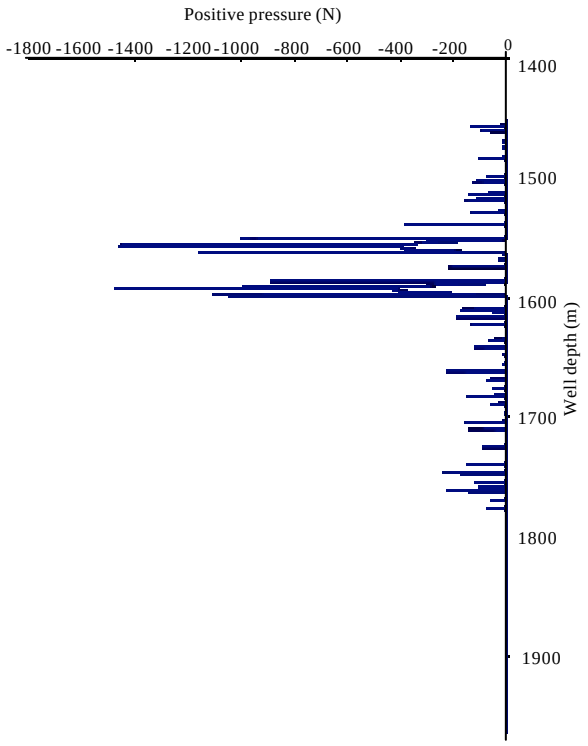

Fig. 4: Well depth and positive pressure relation diagram without righting ring when deviation angle is 40°

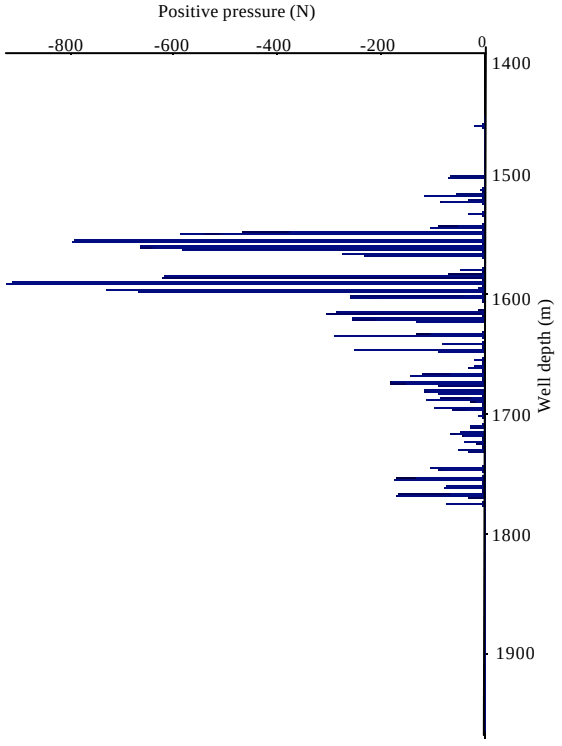

Fig. 5: Well depth and positive pressure relation diagram with righting ring when deviation angle is 40°

It can be seen from Table 3, the contact force of rod and tube decreases obviously after the centralizer is installed. In order to improve wear lifetime of rod and tube, we need install centralizer in the deflecting section of directional well.

CONCLUSION

- The finite element method is adopted according to vibration theory, contact theory and non-linear theory, then the distribution law of contact forcebetween string rod and oil tube will be acquired under the condition of sucker rod actual well conditions
- The directional well deviation angle is larger impact on the contact force between rod and tube. Calculation shows that, the rod tube contact force is small when the angle is less than 30°, the contact force increases obviously when the angle is greater than 60°. Therefore, the deviation angle should be controlled in the range of 30° when we design the hole
- It can effectively reduce the contact force between rod and tube and reduce the wear of rod string after the centralizer is installed in the deflecting section of directional well. The contact force of rod and tube has little change in the upper and lower parts of deflecting section

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