

Feasibility Analysis of Running High-pressure Packers in Curved Wells

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Abstract

When the packer enters the deflection section, due to the complexity of the horizontal well borehole trajectory, excessive plastic deformation of the packer parts will result in packer failure, pre-setting or even jamming of the borehole. Based on the principle of virtual work and the theory of elastoplastic deformation, this paper establishes a three-dimensional finite element model of a fully-structured integral packer running into the curved wellbore; for the packer running into the curved wellbore, the stress situation and structure of the parts when loaded along the Y direction are determined. The ultimate working curvature is analyzed. The research results show that the weakest link in the process of running the whole structure into the curved well is the setting pin 1, and the remaining parts are safe; when loaded in the Y direction, the allowable and ultimate displacements of the pin to ensure safe work are 0.805mm and 0.924 mm respectively. mm; For casings with different wall thicknesses, the build-up rate when running into the wellbore should not be greater than the allowable limit value when the pins are loaded in the Y direction under each wall thickness.

Keywords

Packer; Curved Wellbore; Feasibility Analysis; Slope Building Rate; Finite Element.

1. Preface

Horizontal well technology has become a mature drilling technology, which can greatly improve the comprehensive economic benefits of exploration and development of various oil and gas reservoirs and improve the operating conditions of the petroleum industry. It has become one of the most important technical means for oilfield exploration and development [1]. Generally speaking, the wellbore profile of a horizontal well includes three parts: a vertical section, a tilting section and a horizontal section [2]. In the buildup section, the wellbore trajectory is curved, and the packer located in the buildup section bends along with the wellbore trajectory. The packer can safely and smoothly pass through the bending section of the horizontal well. This is the prerequisite for the packer to work further. Plastic deformation of a part of the packer due to excessive stress during the bending section will cause the packer to fail, set in advance or even jam the wellbore, causing serious safety hazards and bringing great inconvenience to subsequent operations. Therefore, it is necessary to evaluate and analyze the feasibility of running the packer into a curved wellbore.

Some scholars have done a lot of research on the smooth running of tools into curved boreholes. CAJohancsik [3] proposed a mathematical model for calculating torque and friction when running in curved boreholes; Qin Xing [4] established a local model. The passability of downhole tools in curved boreholes in buckling tubing was studied; Gao Deli [5] analyzed the buckling behavior of tubing strings constrained by various wellbore shapes based on the differential equation of tubing string buckling; with the development of finite element technology Dong Yonghui [6] established a drill string model in a curved borehole, taking into

account factors such as gravity, radius of curvature, borehole trajectory, etc.; Liu Chunquan [7] et al. established a calculation including curvature and deflection by simulating and calculating the borehole trajectory 3D wellbore casing lifting and lowering hook load calculation model.

At present, most scholars mainly focus on the research on the passability of downhole tools in the normal curvature curve [8-14], and enter the feasibility analysis in order to consider the overall structure. In this paper, the finite element simulation of the overall structure of the packer in the curved borehole will be carried out, the stress distribution of the components and the weakest link of the overall structure will be obtained, and the reference curvature of the curved borehole will be given. This result can guide the packing of the packer into the curved wellbore, and provide theoretical support for optimizing the strength of packer parts.

2. Finite element model

Based on the theory of virtual work and the theory of elastoplastic deformation, a three-dimensional finite element model of a full-structure integral packer running into a curved wellbore is established. The pin material in the structure is iron brass HFe59-1-1, with a yield strength of 170MPa; the liner, anchor body, connecting body, upper and lower rubber cylinder seat, upper vertebral body and slip sleeve materials are all 42CrMo, with a yield strength of 950MPa; rubber cylinder The material is HNBR and the Shore hardness is 90; the penalty contact is adopted in the structure, the friction coefficient between steel and steel is 0.1, and the friction coefficient between steel and rubber is 0.3 [15].

The component is simulated by an eight-node linear hexahedral element reduced integration unit (C3D8R), and its mesh model is shown in Figure 1. To fix the upper end face of the anchor body part, all threaded connections are transformed into binding constraints.

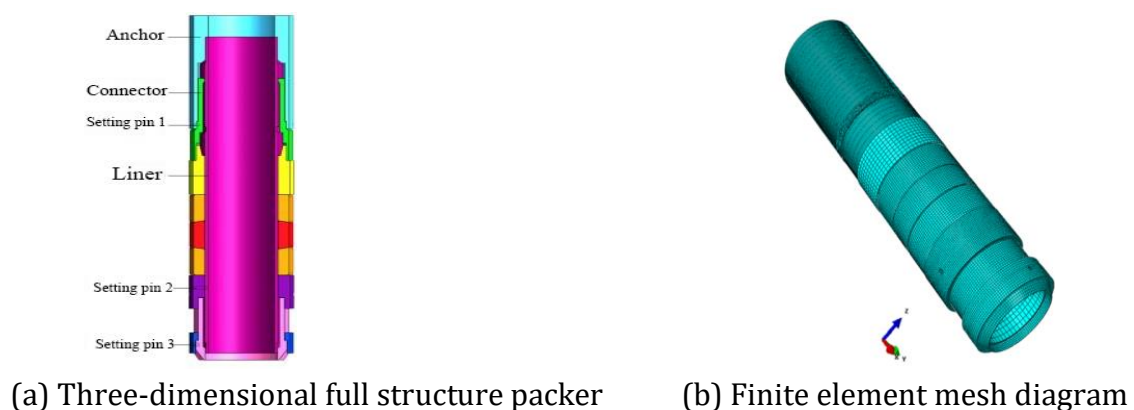


Fig. 1 High pressure packer

3. Part strength check and operation reliability analysis

3.1. Stress distribution of each part when loading in Y direction

Set the displacement loading direction to the Y direction in Figure 1(a), set the displacement loading amount to 1mm, and extract the stress cloud map of the parts with greater stress based on the structural orientation view, as shown in Figure 2.

Figure 2 is the stress cloud diagram of each part under the Y-direction displacement of 1mm. The stress is mainly concentrated at the connection between the parts. The connection between the liner, anchor body, connection body and setting pin is the maximum stress value of the system, In order to better express the comparison of the maximum component stress, draw the component stress histogram in the Y-direction loading direction as shown in Figure 3.

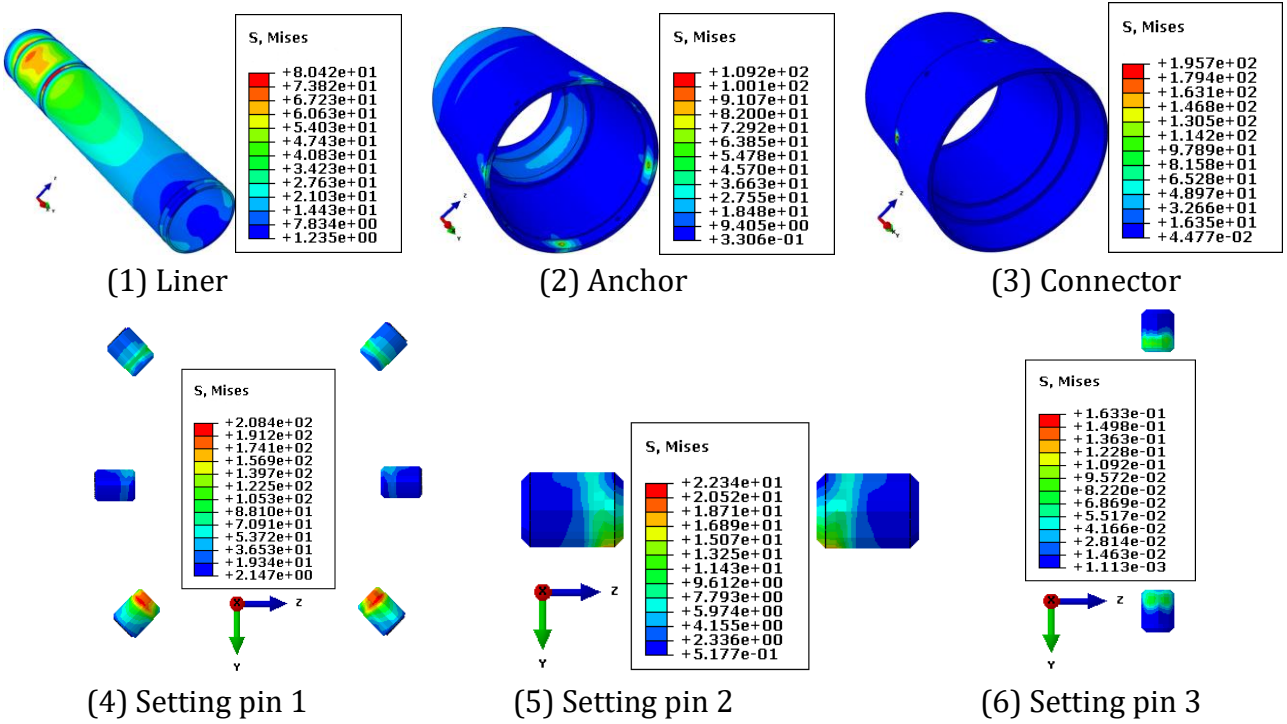


Fig. 2 Stress cloud diagram of parts

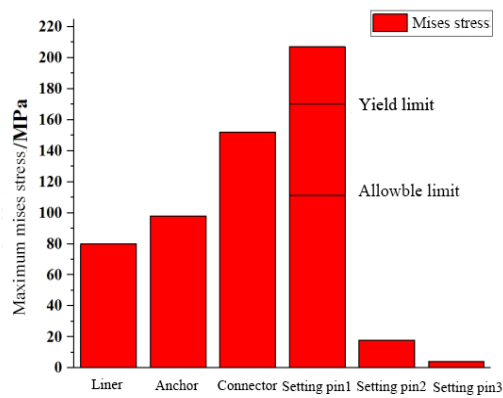


Fig. 3 Load 1mm along Y direction

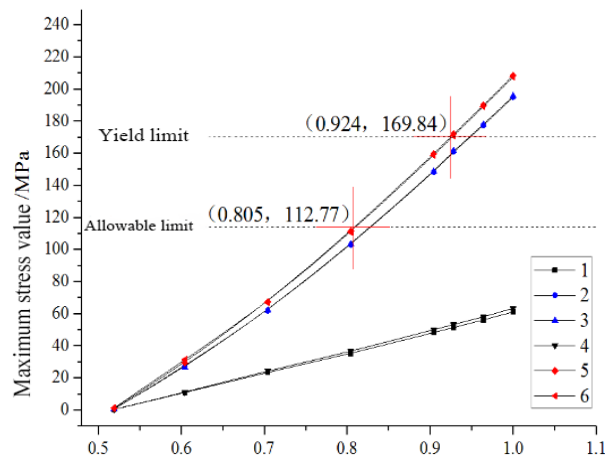


Fig. 4 Fitting curve diagram of the maximum stress value of 6 setting pins 1 with the change of Y-direction displacement

In Fig. 3, the stress value of the setting pin 1 is the largest, and the maximum value exceeds the yield limit of the material during the loading process, and it will fail when running into the curved wellbore section. The maximum stress value of the liner, anchor body, and connection body rises step by step, the strength is much lower than its yield limit, and the structure is safe. The maximum stress value of the remaining components is negligible compared to the above components.

Based on structural safety, the setting pins are extracted and analyzed separately. When loading along the Y-direction, the maximum stress value of each setting pin changes with the Y-direction displacement as shown in Figure 4.

As shown in Figure 4, when the displacement is less than 0.5mm, since the relative position of the anchor body and the connecting body does not change significantly, the maximum stress value of each pin is approximately equal to 0; when the displacement is greater than 0.5mm and less than 1mm, each The change of pin stress is similar to linear growth, so the method of obtaining the maximum stress value under a specific displacement in the interval by taking a point is highly reliable. Due to the symmetry of the pin force distribution along the longitudinal symmetry plane XY when loading in the Y direction, it can be seen that the change curves of pins 1, 4, 2, 3 and 5, 6 basically coincide, and the maximum stress appears at 5. No. 6, No. 6 pins; Among them, No. 2, 3, 5, and 6 pins will bear the additional tensile and compression stress caused by the bending of the liner, while the distribution of No. 1, 4 pins and the longitudinal symmetry plane XZ will be less affected. The maximum stress value of No. 1 and No. 4 pins under the same displacement is smaller than that of the other pins.

Based on the safety factor method, the displacements when the maximum stress value in Fig. 4 is close to its allowable limit and yield limit are 0.805mm and 0.924mm, respectively.

3.2. Maximum working curvature

In order to better express the ultimate working curvature of the packer in casings with different wall thicknesses, the 2 types of limit displacements obtained in the Y direction and the initial gaps of the 6 types of wall thickness casings are now subjected to finite element analysis to obtain the limit curvatures The results are shown in Table 1.

It can be concluded from Table 1 that for each casing wall thickness, the limit borehole curvature allowed by each loading method is not much different. Taking into account the safety of the structure and the displacement of the maximum borehole curvature, the build-up rate in the borehole should not be greater than the build-up rate shown in Y Xu.

Table 1. The curvature table of the packer under each wall thickness casing and each ultimate stress

Casing wall thickness(mm)	Initial gap(mm)	Equivalent build rate under each ultimate stress(°/30m)	
		Y allowable limit	Y yield limit
7.04	14.7	11.99	12.14
8.04	12.7	10.50	10.65
9.04	10.7	9.01	9.17
10.03	8.7	7.52	7.68
11.05	6.68	6.02	6.17
11.99	4.8	4.62	4.78

4. Conclusion

Based on the theory of finite element analysis, this paper systematically conducts finite element analysis on the structural components of the packer in the Y-direction loading direction, obtains the stress distribution of each component, and conducts strength check and safety and reliability evaluation. ,Concluded as follow:

- (1) The weakest link of the whole structure during running into the curved borehole is the setting pin 1; the strength of the other parts is safe;
- (2) When loading in the Y direction, the allowable and limit displacements of the pins to ensure safe work are 0.805mm and 0.924mm respectively;
- (3) For casings with different wall thicknesses, the build-up rate when running into the wellbore should not be greater than the allowable limit value when the pins are loaded in the Y direction under each wall thickness.

Acknowledgments

Fund Project: Sichuan Science and Technology Innovation Seedling Project: (No. 2021118).

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