



Physics of failure analysis of power section assembly for positive displacement motor



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ABSTRACT

Power section assembly is the core part of positive displacement motor (PDM), and its mechanical behavior and service life determine the drilling efficiency and cycle. In this paper, fault tree of power section assembly was established, failure reasons were analyzed and improvement measures were put forward. Finite element models of conventional lining and uniform wall thickness lining of 5/6 PDM were established, and the mechanical behaviors were investigated. Working parameters such as drilling fluid pressure, rubber hardness, downhole temperature and pressure difference were discussed. The results show that wear and rust are the main failure modes of the rotor. Failure modes of rubber lining are wear, tear, rupture, peeling off, thermal failure and fatigue failure. Under the action of drilling fluid pressure, the maximum effective stress of rubber lining appears in the bottom of arc, and the minimum stress appears at the top of arc. But deformation distribution is opposite to the effective stress. Deformation of uniform wall thickness lining is more uniform. Effective stress of the lining increases with the increasing of drilling fluid pressure and rubber hardness, but it decreases with the downhole temperature increases. Deformation of the lining increases with the drilling fluid pressure increases, but it decreases with the increasing of rubber hardness and downhole temperature. Effective stress and deformation distribution of rubber lining are more uneven with the pressure difference increases. High stress area lies between the two smallest chambers.

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1. Introduction

Positive displacement motor (PDM) is a kind of downhole drilling tool, which has been widely used in oil drilling and workover for the advantages of its structure and performance in recent years. It is also used in the geological survey, coal-bed methane, construction pipelines and defense projects (Su, 2001). As shown in Fig. 1, positive displacement motor is composed of drive shaft assembly, universal coupling assembly, power section assembly, anti-drop assembly and outlet valve assembly. Power section assembly is the core part of the whole system. It is a displacement engine driven by drilling fluid. There are two core components (rotor and stator). The rotor is a steel screw that coated with wear resistant materials. The stator is a steel pipe, its inner wall bonded by vulcanized rubber lining. Spiral number of the stator is one more than the rotor, such as 1/2, 3/4, 5/6, 7/8, 9/10. The typical cross section contours of power section assembly as shown in Fig. 1. The less

spiral number, the speed is higher and the torque is lower. The more spiral number, the speed is lower and the torque is higher. In addition, the hollow rotor can be used to increase the hydraulic horsepower and mud return speed.

The usage of PDM increases gradually with the development of drilling technology. But premature failure of PDM may cause downhole accidents in poor working condition. According to the accident rate of drilling tools, failure of power section assembly is difficult to be controlled and has a great influence on the drilling. One of the main reasons is that mechanical behaviors of rubber material are more special. Han (Han et al., 2014) and Zhang (Zhang et al., 2014) only studied the thermal failure of rubber lining, but other failure reasons were not considered. In recent years, uniform wall thickness rubber lining was put forward. Uniform wall thickness rubber lining can work in high temperature condition, its pressure drop is 2–3 times than conventional rubber lining, and volumetric efficiency is 45%–50% (Miao et al., 2011). So, it can improve the service life and work efficiency of PDM. But its machining process is more complicated.

In this paper, fault tree of power section assembly was

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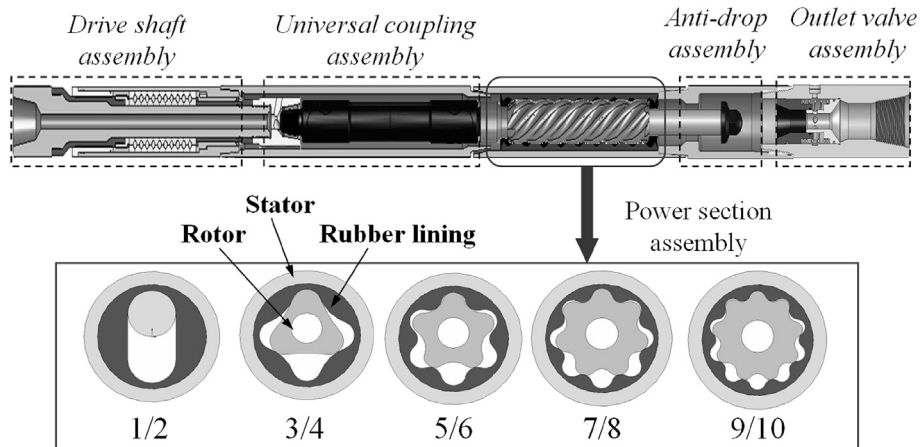


Fig. 1. Composition of positive displacement motor.

established, failure reasons were analyzed and improvement measures were put forward. Mechanical behaviors of conventional and uniform wall thickness rubber linings were investigated by numerical simulation. Effects of drilling fluid pressure, pressure difference, rubber hardness and downhole temperature on mechanical behavior of rubber lining were studied.

2. Failure analysis of power section assembly

2.1. Fault tree model

From a large number of field investigations and the relevant literature analysis, “Failure of power section assembly” is the top

event, and fault tree was established as shown in Fig. 2. The number of the basic events is 27 and the basic events are $X_1 \sim X_{27}$. Table 1 shows the basic events and codes. For the fault tree, if logic “AND” is more, the number of minimal cut set is less. If logic “OR” is more, the number of minimal cut set is more. Those cut sets can give a major reference for the weak link analysis of power section assembly in design and working process by considering all the aspects related to the top event. It can provide a reference for structure optimization and maintenance.

2.2. Failure analysis and improvement measures

As shown in Fig. 2, failure of rotor's surface and rubber lining are

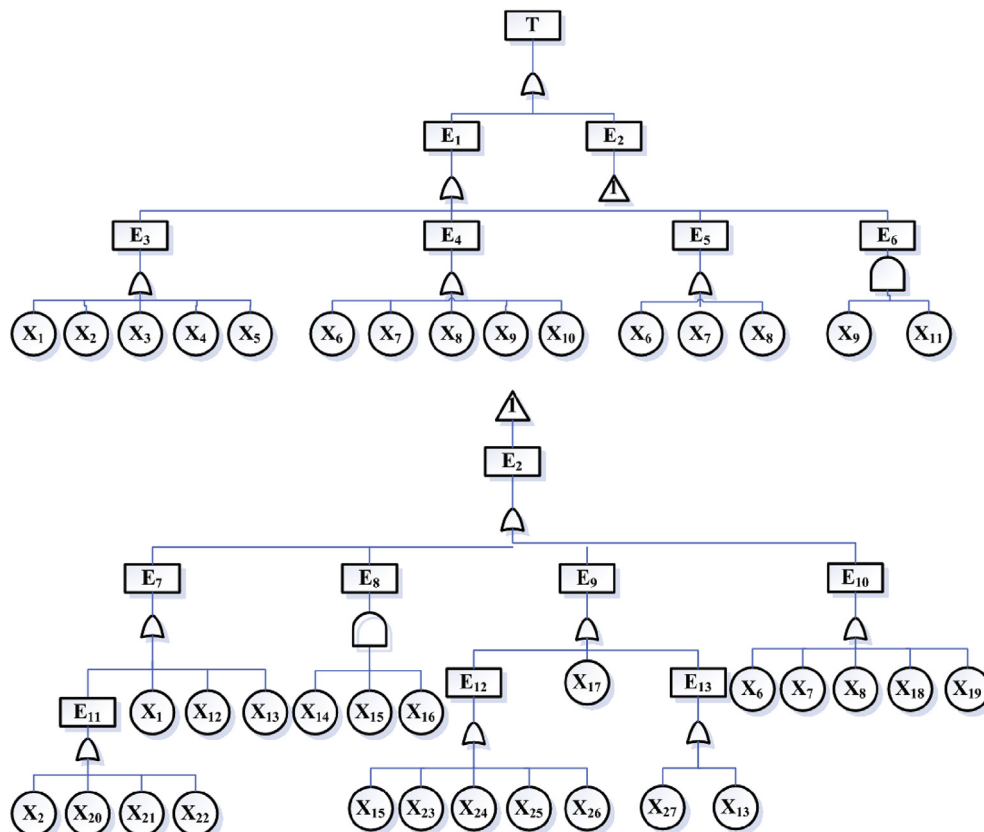


Fig. 2. Fault tree of power section assembly. □ Intermediate event ○ Bottom event △ Logic “OR” ▽ Logic “AND” ▴ Transfer symbol.

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