Engineering Failure Analysis 94 (2018) 239–248

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Failure analysis of general stator and uniform wall thickness stator

Changshuai Shi[a,b], Xiaohua Zhu[a,b,*], Yike Chen[a], Liping Tang[a]

[a] School of Mechatronic Engineering, Southwest Petroleum University, Chengdu 610500, PR China
[b] State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation, Southwest Petroleum University, Chengdu 610500, PR China

ARTICLE INFO

Keywords:
PDM Stator lining
Thermo-mechanical coupling
Thermal hysteresis
Thermal failure analysis
FEM

ABSTRACT

Stator lining of positive displacement motor (PDM) is prone to generate thermal fatigue failure because of viscoelastic hysteresis of the rubber material. Based on the thermo-mechanical coupling modeling and rubber material testing, finite element method was used to study the effect of environment temperature and thermo-viscoelastic hysteresis to the lining thermal failure of general stator and uniform wall thickness stator. The results show that the deformation and temperature field of general rubber lining has been less affected by the environment temperature than thermo-viscoelastic hysteresis whose distribution of temperature field appears oval-shaped and the temperature gradient is large. Stator lining's temperature increases with the increasing of motor interference and well depth, and the rubber lining's thermal failure modes observed in practice are consistent with the calculation results. The temperature field distribution of uniform wall thickness rubber lining is relatively uniform, and the highest temperature and temperature rise are less affected by the motor interference and well depth, especially with small motor interference and in the shallow well. Therefore, the uniform wall thickness rubber lining has very obvious advantages in prolonging service life and improving the work performance of PDM.

1. Introduction

Positive displacement motor (PDM) drill has become an indispensable tool for directional well and horizontal well operation, and has been widely used in the drilling operation of straight well [1–3]. The PDM installation position and motor structure are shown in Fig. 1. With the increase of drilling depth, the bottom hole temperature can reach 220–240 degrees centigrade, and the cycle temperature reaches 170–180, the performance stability and service life of the screw drill are higher [4]. During working, the lining rubber is more prone to heat aging, leading the efficiency of the motor declines sharply, even the failure of fatigue happens prematurely and the stator rubber falls off, which causes the motor to lose power and seriously affects the drilling speed [5, 6] Fig. 2.

According to the mechanical properties and deformation regularity of PDM stator lining under different working conditions, Jolihtzahanna et al. [7] studied the influence of working time and fuild temperature on the hydraulic characteristics of screw pump. Jose et al. [8] built the simplified model for the leakage of screw pump based on the experiment foundation. Bratu [9, 10] considered that the temperature rise which caused by the rotor friction was a function of the pressure gradient, revolutions per minute(RPM) and friction coefficient. Chen et al. [11] acquired the relationship between working pressure and lining stress, strain and deformation regularity by statics analysis. Zhu et al. [12] pointed out that rubber expansion is serious with the increase of downhole temperature, which leads to the increase of motor friction torque and braking torque, and the rubber lining is more vulnerable to fatigue aging. Zhang et al. [13] pointed out that the relationship between output torque, speed and pressure difference is the key to decide the

* Corresponding author at: School of Mechatronic Engineering, Southwest Petroleum University, Chengdu 610500, PR China.
E-mail address: zxhth113@163.com (X. Zhu).

https://doi.org/10.1016/j.engfailanal.2018.07.018
Received 11 April 2018; Received in revised form 20 July 2018; Accepted 20 July 2018
Available online 25 July 2018
1350-6307/

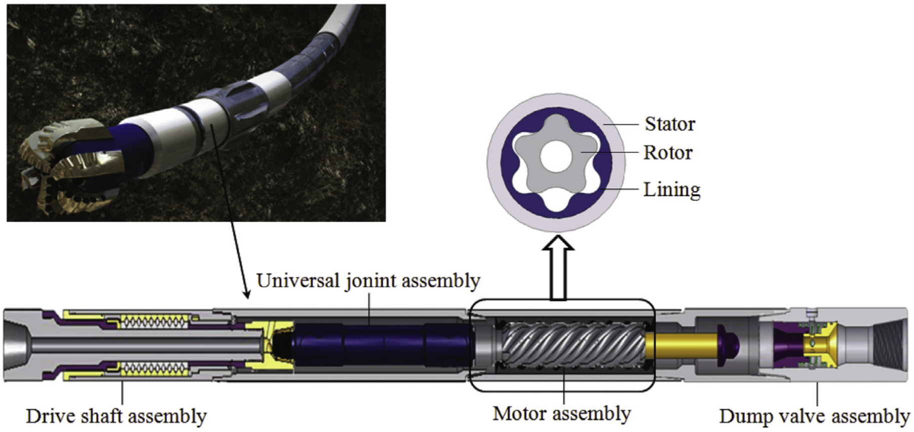

Fig. 1. The PDM installation position and general motor structure.

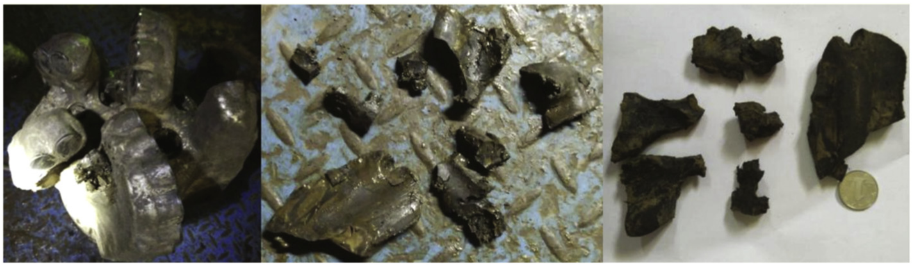

Fig. 2. Stator rubber falls off.

performance of PDM. Cao et al. [14] solved the thermal coupling problem of screw pump stator rubber lining which used the one-way decoupling analysis method. Wang et al. [15] got the conclusion that the volumetric efficiency of the equal wall thickness lining is higher than that of the conventional lining. Han and Zhang et al. [16–19] analyzed the temperature rise mechanism and temperature field distribution of PDM stator lining under the action of pressure and temperature.

At present, there are few papers on the systematic analysis of the performance of General Stator and Uniform Wall Thickness Stator. In this paper, the finite element method was used to establish the model of rubber lining based on the material testing, and the effect of environment temperature and thermo-viscoelastic hysteresis to the lining thermal failure of general stator and uniform wall thickness stator was discussed.

2. Material test and constitutive model of stator rubber

Compression test for stator rubber standard sample has been conducted with reference the standard of ASTM D575–1991(2012), so as to obtain the data which is needed for the finite element numerical simulation, such as stress-strain relationship and rubber's compression modulus, Young's modulus and so on (Which are obtained at room temperature).

The material of stator lining is nitrile rubber which is a highly nonlinear hyperelastic material, so numerical simulation is based on studying its mechanical property. Table 1 shows the experimental result of nitrile rubber elastic modulus at room temperature [20, 21].

Where E_e is the compression modulus; E_O is the elastic modulus under rubber strain 10%; and $\overline{E}_0$ is the AVG of E_O.

There are a variety of hyperelastic material constitutive model in finite element software. For great majority rubber, compared with other models, Mooney-Rivlin two-parameter model has higher accuracy in less than 100% strain (tension) and 30% (pressure)

Table 1
Modulus of compressibility and elasticity of test piece.

No.	Diameter/mm * height/mm	E_e/MPa	E_O/MPa	$\overline{E}_0$/MPa
N25-1	29.00*12.80	10.51	9.46	
N25-2	29.10*13.00	13.48	12.13	
N25-3	28.90*12.90	12.92	11.62	11.49
N25-4	29.00*12.80	13.21	11.89	
N25-5	29.05*12.80	13.72	12.35	