Engineering Failure Analysis 29 (2013) 12–26

Contents lists available at SciVerse ScienceDirect

Engineering Failure Analysis

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

# Experimental research on the surface strengthening technology of roller cone bit bearing based on the failure analysis

Zhiqiang Huang [a,*], Qin Li [a], Yi Zhou [a], Shuang Jing [a], Yachao Ma [a], Wengang Hu [a], Yongtao Fan [b]

[a] *MOE Key Lab of Oil and Natural Gas Equipment, Southwest Petroleum University, Chengdu, Sichuan 610500, China*
[b] *MOE Key Lab of Petroleum Engineering, China University of Petroleum, Beijing 102249, China*

## ARTICLE INFO

*Article history:*
Received 22 August 2011
Received in revised form 13 August 2012
Accepted 23 August 2012
Available online 6 October 2012

*Keywords:*
Roller cone bit
Failure analysis
Bearing life
Surface strengthening
Experimental research

## ABSTRACT

The roller cone bit is one of the most important rock breaking tools used in the oil–gas drilling industry. Its performance directly influences the drilling quality, efficiency and cost. As the world's oil–gas resource exploration continuously developed, the drilling speed accelerated, accelerating the failure speed of the bearing. The roller cone bit's service life was almost directly dependent on that of the bearing. In this paper, a bearing failure analysis, and an experimental research on the surface strengthening technology of the bearing with field applications etc. were carried out. The results showed that the bearing's main failure modes included fracture, plastic deformation and wear. The main reasons were overload and uneven distribution of the load; elevated temperature due to friction caused property and structure change in material; wear increased the fit clearance between the bearing and the cone, increasing dynamic impact load etc. The bearing surface strengthening technology, employing plasma-arc surfacing DH-60 wear resistance alloy, could prolong the service life of the bearing. Experimental research and field tests showed that the wear and impact resistance of the enhanced bearing increased by 30% with an increased service life of 12% on average.

## 1. Introduction

Roller cone bit is a major tool of rock breaking in oil–gas drilling engineering. Its performance directly influences the drilling quality, efficiency and total cost. With the increment of the world's demand for oil and natural gas, oil–gas resources exploration and production had been developing continuously and the exploitation scope shifted from inland to desert and deep-sea, from shallow strata to deep strata. This directly led to the difficulty in drilling mechanisms. The drilling technology directly influenced the global economic development and security. Therefore, the higher request for working performance of the roller cone bit would be put forward [1–4].

At present, with drilling speed acceleration, the failure velocity of the conventional high-velocity roller cone bit bearing became much too high, resulting in short service life, low drilling efficiency and high drilling cost. The failure analysis on roller cone bit indicated that the bearing damage was the major failure mode. The bit's service life almost directly depended on that of the bearing. Whenever one of the bearings damaged prematurely, soon followed the bit's failure. Through statistical analysis of field test results, bit failure due to early stage bearing damage accounted for 80% of total failures [5–10]. Therefore, improving the bearing's life was the key to improve the life of the high-speed roller cone bit. It had became an urgent need in drilling engineering industry.

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* Corresponding author. Tel.: +86 13981896898.
*E-mail address:* huangzq@swpu.edu.cn (Z. Huang).

1350-6307/$ - see front matter © 2012 Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.engfailanal.2012.08.018

The prime focus of international research on prolonging the service life of the bearing were in structural design, finite mechanical force analysis and improvements in lubrication etc. Furthermore, the theoretical research accounted for most. In 1990, Pearce designed a kind of thread locking device, which extend the service life of bearings to a certain extent, but it was not the fundamental solution to the rapid wear of the bearing [11]. In 2003, Smith Company developed a new kind of roller bearing cone bit, which contained a repair convex for the roller bearing and extended the service life of roller cone bit. But there was a much higher standard for material properties. Smith and Hughes company developed a new bearing called SPINODAL2, using copper–nickel-tin alloy, which improved the strength and the toughness and reduced the friction. It could be used in higher speed drill [12]. In 2005, Kaisong Wu studied the influence on the bearing strength from the carburized layer and inlaid copper alloy of rock bit bearing surface through the application of finite element software ANSYS. The research results was used in the design of the bearing cone bit. It showed that its peak contact pressure could be reduced by 34.6% and its contact pressure distribution was more reasonable [13]. In 2006, Qingyou Liu invented a roller cone drill bits ball bearing locking system, which equipped the bearing system with a higher carrying capacity, better lubrication and more reasonable load distribution. Simultaneously, this structure also increased the area and quality of the welding wear on the nose of the teeth, which effectively improved the performance and service life of the roller cone bit. But there was no relevant report of the field application [14]. However, there were no deep research and analysis on the failure mode, the failure mechanism and the failure cause of the roller cone bit bearing, not to mention of developing the research on the bearing surface strengthening technology based on the failure analysis of the roller cone bit bearing. The field test had reported little. Precisely, these were the key of increasing the roller cone bit bearing life and improving its application and popularization.

Therefore, the analysis of the roller cone bit bearing failure had been developed. We found the main failure modes and grasped the failure mechanism of the roller cone bit bearing. Through experiment researches on different surface strengthening technologies and materials, we found the matching technology and material of the surface strengthening technology that could prolong the life of bearing and roller cone bit, reduce drilling cost and improve drilling efficiency.

## 2. The load analysis of the bearing

Bearing friction pairs system is a major component of the roller cone bit bearing. It has the following main parts: two radial bearings (one large, one small), a plane thrust bearing with an outward thrust force, and a ball bearing which is to prevent the cone dropping due to its push force.

The ball bearing with a function of locking cone suffered a small load. Accordingly, the distributed force of the bearing from the cone could be simplified as a concentrated force. The radial force on the large journal was $P_{r1}$, and on the small journal was $P_{r2}$. The force on the thrust bearing was $P_a$ (Fig. 1). Based on theory advanced by professor Xianpu Zhang, we got the following formulas for calculating the above-mentioned force [15].

$$P_{r1} = 9800 \times \alpha_{123} \times 0.9 \times \sin\beta \times w = 8820\alpha_{123} w \sin\beta$$

$$P_{r2} = 9800 \times \alpha_{123} \times 0.1 \times \sin\beta \times w = 980\alpha_{123} w \sin\beta$$

$$P_a = 9800 \times \alpha_{123} \times \cos\beta \times w = 9800\alpha_{123} w \cos\beta$$

The friction torque along the circumferential bearing:

$$M_n = P_{r1} \times f \times R_{j1} + P_{r2} \times f \times R_{j2}$$

Among the above-mentioned formulas:

$\beta$: the angle degree between bearing axis and the roller cone bit axis.

$w$: the external load of the roller cone bit.

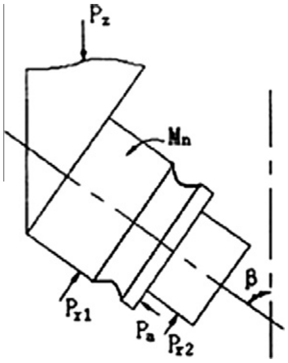

**Fig. 1.** Schematic diagram of the bearing force.