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A study on the influence of oil film lubrication to the strength of engine connecting rod components

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ABSTRACT

Dynamic lubrication analysis of connecting rod is a very complex problem. Some factors have great effect on lubrication, such as clearance, oil viscosity, oil supplying hole and surface roughness. This work establishes the EHD characteristic of bearing and bush to analyze the peak oil film pressure, min oil film thickness and node force with consideration of deformation and cavitation; then create connecting rod components to calculate the stress distribution with consideration of film lubrication or not and finally contract the results of two conditions. The results show that the stress distribution of two conditions is different in individual positions, but the stress calculation method considering the oil film lubrication is more consistent with the actual working conditions.

1. Introduction

Connecting rod is an important component of engine which transforms the reciprocating piston motion in the cylinder into rotary motion of crankshaft, as well as converting the power from piston to crankshaft. In such operating condition, the connecting rod experiences complex dynamic loads as stretching, compressing and bending during the service. Therefore it is considered to be a critical component.

The majority of damages have been reported to take place at some parts of connecting rod, such as rounded filet of small connecting rod end, rounded filet of big connecting rod end and the connecting rod bolt. As shown in Fig. 1, the failure of connecting rod occurs and the crack was found at rounded filet of big connecting rod end. A number of efforts have been made to calculate the strength of connecting rod. The traditional way to calculate the strength of connecting rod simplified the 3D model into 2D stress problem. The dimensionless thickness of rounded filet and ribs are determined by the area equivalent principle [1]. Timoshenko et al. analyze the stress distribution of connecting rod by mathematic calculation [2]. M.N. Ilman identified the cause of failure and evaluated fatigue performance of a failed connecting rod by microstructural examination. The visual examination on fracture surface of the connecting rod shows that fatigue seems to be the main cause of failure as indicated by the presence of initial crack, crack propagation and final failure. M.N. Ilman also built FEM model of the failed connecting rod to calculate the stress distribution and find the stress concentration region [3] Zhu xiaoping and many other researchers create the piston pin, connecting it with bush by contact in connecting rod strength calculation. But these calculations do not consider bolt's preload and shell interference [4–7]. Recently many researchers consider the influence of bolt's preload and shell interference in connecting rod stress calculation, but few of them care the influence of lubrication.

Over the past decades, a considerable number of theoretical and experimental studies have been made on bearing performance. The effects of oil viscosity, bearing deformation and cavitation were taken into consideration gradually. He zhenpeng calculated the minimum oil film, maximum oil pressure and friction loss of connecting rod bearing with consideration of oil

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Fig. 1. The failed connecting rod.

hole location, oil supply pressure and surface roughness, but do not calculate the connecting rod stress distribution.[8] In this paper, we calculate the minimum oil film and maximum oil film pressure first, then transform the oil film pressure into node force to calculate the connecting rod stress distribution with consideration of bolt's preload and shell interference, and finally analyze the influence of oil lubrication to connecting rod component strength. The calculation model was built based on actual connecting rod of a diesel engine as shown in Fig. 1 and its parameters were listed in Table 1.

Nomenclature

U	the relative velocity of the contact surface
μ	viscosity of the lubricant in the film region
R	radius of journal
P_{ref}	the reference pressure
ρ_c	lubricant density
P_c	vapor pressure
a	a parameter, in full film area: $a = {}^{P-P_c}/_{P_{ref}-P_c}$, in cavitation area: $a = {}^{\rho-\rho_c}/_{\rho_c}$
c	the radial clearance
e	the eccentricity
$\delta(\theta)$	the bearing deformation caused by oil pressure
M	the mass of bearing
C	the damping of bearing
K	the stiffness of bearing
X_b	the deformation of bearing
m	the mass of web pin
$F(t)$	the oil film force
X	the deformation of web pin
$F_{out}(t)$	the outside force in web pin

Table 1
connecting rod and bearing dimension.

Connecting rod and bearing dimension	Value	Dimension
Piston mass	58.02	kg
Bearing radius	260	mm
Bush radius	230	mm
Radial clearance	0.13	mm
Bearing width w	79	mm
Fluid viscosity	0.0096	Pa·s
Fluid density	860	kg/m^3
Rotational speed	1000	rpm
Oil supply pressure	2.8	bar
Young's modulus	210	GPa
Poisson ratio	0.45	
Bolt preload	215	kN
Bearing interference	286	μm
Bush interference	78	μm
Connecting rod big end mass M_2	40.09	kg
Connecting rod small end mass M_1	74.85	kg
The length of connecting rod L	570	mm
The radius of crank r	155	mm
The gas force F	1240.25	kN
The rated rotation speed ω	1000	r/min