Applied Thermal Engineering 105 (2016) 217–224

Contents lists available at ScienceDirect

Applied Thermal Engineering

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

Research Paper

Jet cooling for rolling bearings: Flow visualization and temperature distribution

Wei Wu *, Chenhui Hu, Jibin Hu [1], Shihua Yuan

Collaborative Innovation Center of Electric Vehicles in Beijing, Beijing Institute of Technology, Beijing 100081, PR China
National Key Laboratory of Vehicular Transmission, Beijing Institute of Technology, Beijing 100081, PR China

HIGHLIGHTS

- Simulated and measured flow behaviours inside jet cooling ball bearings are given.
- The higher temperature appears at the lower oil volume fraction position.
- Average oil volume fraction in bearing cavity rises with a larger nozzle number.
- Temperature decreases with a larger nozzle number due to better cooling effect.

ARTICLE INFO

Article history:
Received 1 March 2016
Revised 23 May 2016
Accepted 24 May 2016
Available online 25 May 2016

Keywords:
Ball bearings
Jet cooling
Efficient cooling
Two-phase flow
VOF
CFD

ABSTRACT

To achieve an efficient cooling for the rolling bearing, a further investigation on cooling methods is necessary. The oil-jet cooling for high-speed ball bearings was investigated. The two-phase flow inside the ball bearing 7210 were analysed and verified through tests. The heat transfer was also considered. The circumferential air-oil distribution inside the bearing appears a periodic variation between two adjacent nozzles. The bearing temperature distribution is deeply affected by the air-oil distribution. The higher temperature always appears at the lower oil volume fraction position. The average oil volume fraction increases with a larger nozzle number. The nozzle number should be no more than four considering its effect on the oil volume fraction and the oil supply mechanism complexity. The nozzle number and the jet velocity have larger influences on the oil volume fraction when bearing speed is lower than 20,000 r/min. When bearing speed is larger than 40,000 r/min, the bearing speed affects the oil volume fraction much more than the multiple-nozzle oil-jet cooling mechanism parameters. The results are useful for the advanced precision cooling mechanism design of the rolling bearing.

1. Introduction

Many industrial applications use impinging liquid jet to provide an effective mode of heat transfer, such as electrical motor [1], gearbox [2] and steel rolling [3]. For high-speed transmission systems, such as aircraft engines, turbomachinery, and drive trains, oil-jet is applied to the ball bearing cooling [4]. The automotive transmission is now focused toward higher efficiency and greater power density [5]. A higher rated speed is beneficial to the greater power density. However, it makes the ball bearing speed become higher. Further, coupled with the compact design of the automotive transmission, there is always no bearing chamber which has been commonly used in aero engines [6]. They put increasing demands on the operation condition maintenance of the ball bearing for the automotive transmission.

The oil-jet cooling method of the rolling bearing is mainly used for the high-speed operation. The placement and number of nozzles, the jet velocity, the flow rate, and the removal of lubricant from the bearing and immediate vicinity are all important for satisfactory operation [7]. Through a small-diameter nozzle, the lubricant oil is injected into the bearing. The nozzle aims at the inner race and locates near the side face of the bearing. The lubricant oil is absorbed back to the oil tank and circulated by the hydraulic system.

For the oil-jet ball bearing, some of the oil is used to lubricate the ball bearing and form lubricant film in ball raceway contacts. The film formation behaviour has been investigated by single-phase method [8,9]. A larger film thickness is useful to reduce the friction and the heat generated. However, the total energy that

* Corresponding author at: Room 412, Building 9, Beijing Institute of Technology, Beijing 100081, PR China.
E-mail addresses: wuweijing@bit.edu.cn (W. Wu), hujibin@bit.edu.cn (J. Hu).
[1] Address: Room 412, Building 9, Beijing Institute of Technology, Beijing 100081, PR China.

http://dx.doi.org/10.1016/j.applthermaleng.2016.05.147
1359-4311/

Nomenclature

d	section circle diameter of bearing (m)
n	rotary speed of the inner ring (r/min)
N	number of nozzles (–)
p	pressure (Pa)
r	radial position (mm)
t_w	unit tangent vector (–)
Q	flow rate (L/min)
T	temperature (°C)
φ	volume fraction (–)
υ	velocity (m/s)
ω	circumferential azimuth angle (degree)

Subscript

air	subscript of the air phase parameter (–)
inner	subscript of the inner ring parameter (–)
oil	subscript of the oil phase parameter (–)
outer	subscript of the outer ring parameter (–)

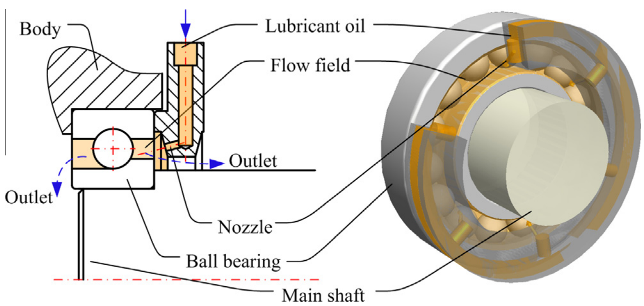


Fig. 1. Multiple-nozzle oil-jet mechanism for the high-speed rolling bearing.

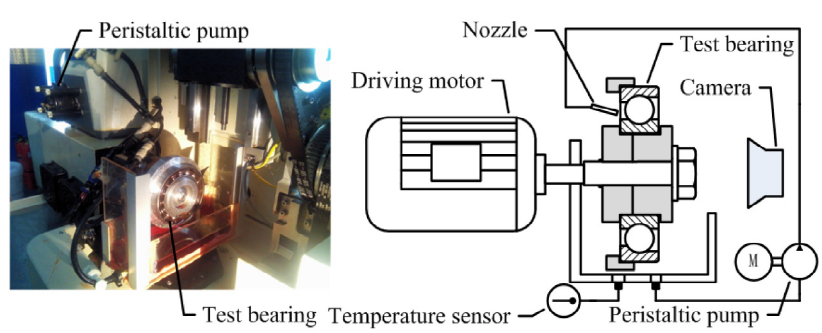
is dissipated by the friction is largely determined by the load and speed of the bearing [10]. For the high-speed and heavy-load operation, the bearing is at a higher temperature and larger amounts of lubricant oil flow are required for the cooling of the bearing [11]. The increase in flow requirements leads to larger capacity pumps and a higher agitation torque. A higher power loss of the engine

Table 1
Technical data of the test apparatus.

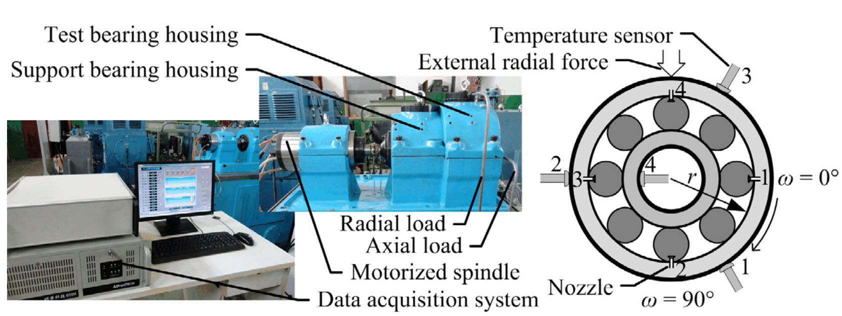
Apparatus and sensor	Technical data
Motorized spindle	0–15,000 r/min
Temperature sensor	Pt1000, −70 to 500 °C
Oil flow transducer	FT-110, 1.0–10 L/min
Vibration transducer	JHT-II-B, ±15 g
External radial force	Hydraulic loading, 0–30 kN
External axial force	Hydraulic loading, 0–30 kN

Table 2
Specifications of the test ball bearing.

Bearing type	SKF 7210
Inner diameter (mm)	50
Outer diameter (mm)	90
Width (mm)	20
Ball diameter (mm)	12.186
Number of balls	14
Contact angle (deg.)	40



(a) Rolling bearing flow behaviour experimental apparatus.



(b) Rolling bearing temperature distribution experimental apparatus.

Fig. 2. Experimental apparatus.