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Crankshaft-bearing evolution indexes investigation and asperity contact identification based on neural network ☆

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ABSTRACT

The dynamic and lubrication characteristic analyses of the crankshaft–bearing system is quite a complex problem, and it is important to avoid asperity contact which may lead to bearing wear and increase of friction loss significantly in dynamic lubrication condition. In this paper, the dynamic characteristic that has an essential impact on lubrication was investigated over an inline six-cylinder engine. Multi-body dynamics method, tribology, finite element method (FEM), finite difference method (FDM) and component mode synthesis method (CMS) were combined to analyze the dynamic characteristic of crankshaft, oil leakage, oil film pressure, asperity contact pressure and friction loss. Then the orthogonal experiment that included 5 levels and 6 factors was conducted to obtain the training sample sets for neural network, and the probabilistic neural network (PNN) was employed to identify weather the asperity contact happened or not according to its nonlinear characteristic. The analyses which can provide the guidance for the design of main bearing, and avoid the asperity contact in the lubrication are significant to the design of the bearing at the development stage of the engine.

1. Introduction

Crankshaft–bearing is the key system of the engine, and it has great effect on the durability, economics, security and performance of the engine. The change fee for the wear crankshaft and bearing contributes 20–25% of the engine, when the wear happens, the friction loss increases significantly. Market and legislative pressure on engine call for smaller size, higher power density and improved fuel economy. Also, efforts to reduce friction loss while improving durability and reliability have become increasingly important to engine industry due to more stringent requirements for higher performance, sophisticated analysis can greatly enhance the understanding of tribology mechanism associated with dynamic characteristics, so it is an important technique to make sure working condition of the crankshaft–bearing to be safety for engine design.

The crankshaft–bearing is a very complex system which includes: bearing, crankshaft, damper, flywheel, connecting rod and piston. The load of system comes from in-cylinder pressure and piston system inertia, the in-cylinder pressure applies on the piston is transmitted to the crankpin, and then the crankpin loads are transmitted to the engine block through the main bearing hydrodynamics. The asperity contact is a common phenomenon which may happen in the hydrodynamic lubrication of the main bearing, the serious asperity contact are shown to lead a significant increase of bearing

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Nomenclature

u	is partitioned into
u_i	internal degree of freedom
u_r	retained degree of freedom
M	the mass matrix of the crankshaft or bearing
C	the damping matrix of the crankshaft or bearing
K	the stiffness matrix of the crankshaft or bearing
F	the load vector
U_1	the velocity in the circumferential direction of the bearing ($U_1 = 0$)
U_2	the velocity in the circumferential direction of the crankshaft
h	the oil film thickness
p	the oil film pressure
η	the lubricant viscosity
x	the coordinate axis along the horizontal direction
y	the coordinate axis along the axial direction
φ_x	the pressure flow factors
φ_z	the pressure flow factors
φ_s	the shear flow factor
σ	the composite rms roughness
θ'	filling factor
c	represents the original radical clearance at the underformed state
ε_x	the crankshaft deformation in x direction
ε_z	the crankshaft deformation in the z direction
$\delta(\beta', z)$	radical deformation of the bearing
β'	measured from bearing crown
E'	the composite elastic modulus, $E' = ((1 - \upsilon_1^2)/E_1 + (1 - \upsilon_2^2)/E_2)-1$
υ_i, E_i	the Poisson ratio and Young's modulus of the adjacent surfaces
η_s	the asperity density
β	the radius of curvature of convex peak
H	the dimensionless clearance parameter, $H = H/\sigma$
Q_1	flow-rate from the front-end plane of the bearing
Q_2	flow-rate from rear end of the bearing
Q	total end leakage flow rate of lubricant
τ_a	asperity contact shear force
τ_h	fluid shear force
f_i	the friction force of every mesh point
u_i'	the velocity of every mesh point
$f_A(x)$	the value of PDF
n	the number of training vectors in category
m	the dimensionality of the training vectors
σ'	the smoothing parameter
T	the transpose matrix
x_i	the ith variable of the test pattern to be classified
$w_{i,j}$	the ith variable of jth training pattern

Abbreviations

FEM	finite element method
FDM	finite differential method
CMS	component mode synthesis method
DOE	orthogonal experimental design
DOF	degree of freedom
FMEP	friction mean effective pressure
PNN	Probabilistic neural network
HD	hydrodynamic lubrication
EHD	elasto-hydrodynamic
PDF	probability density functions
°CA	crank angle
ROB	roughness of bearing
ROJ	roughness of journal
ISC	initial shafting clearance