

Research on the Influence of Bench Installation Conditions on Simulation of Engine Main Bearing Load

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ABSTRACT

The simulation of main bearing load plays an important role in engine multi-body dynamics simulation, seemingly influencing the simulation of strength, vibration and acoustics. It is necessary to conduct engine bench test to validate the result of simulation. More attention has been paid to the flexibility of engine blocks and crankshafts, but not on the installing conditions of engine test bench, such as the stiffness of mounts, the presence of the connecting flange and the elasticity of shaft coupling, which are easy to ignore. The work presented here focuses on the influence of bench installation conditions on the multi-body dynamics simulation of an engine. A flexible multi-body dynamics model of a 4100QB diesel engine is built by employing the modal synthesis technique in the software ADAMS. By comparing the simulation results of different models, the effects of the connecting flange, the stiffness of mounts and the elasticity of shaft coupling are discussed. The result show that: Firstly, the inclusion of the connecting flange is important in the main bearing load calculations, when the engine is flexibly installed on the bench. Secondly, the difference of main bearing load caused by the changing of mounting stiffness is limited and can be neglected when the accuracy is not strictly demanded. Thirdly, the influence of elastic shaft coupling is negligible in main bearing load simulation. At the end of this paper, the simulation is validated by the measurement of

INTRODUCTION

Virtual design [1,2] is one of the trends of modern engine designs. Recently, the combination of finite element software and multi-body dynamics software has been widely used for simulation accuracy [3, 4, 5]. The main bearing load is very important in engine multi-body dynamics analysis. For fine accuracy, flexible bodies are getting more and more popular in multi-body dynamics simulation rather than rigid bodies. It is very difficult to establish a full flexible-body engine model because of the limitation of the computing cost, so that rigid-flexible hybrid models are often used. Rigid-flexible hybrid models including rigid engine blocks, connecting rods and pistons and flexible crankshaft [4,6] were applied. Flexible engine block and crankshaft were adopted in [3,7], but rigid models were used for other parts. How to keep balance between accuracy and efficiency is a tricky situation that the researchers have to face, but only a few observations done [6,8]. The difference between the bearing load from flexible engine block, crankshaft and that from rigid engine block, crankshaft was studied[7, 8], but the influence of the installing conditions of engine test bench, such as the stiffness of mounts and the elasticity of shaft coupling, was not considered.

It is necessary to study the influence, because the multi-body dynamics simulation of main bearing load is significantly affected by the installing conditions of

simulation method adopted in this paper is ADAMS/Engine, as well as HYPERMESH and ANSYS.

THE ESTABLISHMENT OF MULTI-BODY DYNAMICS MODEL

Limited by the computation cost, it is very difficult to simulate a fully flexible-bodied engine model. So the parts which have more influence on bearing load are chosen to be built as flexible bodies, while others as treated as rigid bodies. The ADAMS/Engine module is employed to complete parametric modeling when modeling rigid bodies; the modal neutral files are made by ANSYS, and then forwarded into ADAMS to replace the parts of rigid body when modeling flexible bodies.

Flexible engine block-cylinder head parts - The positions where engine mounts (adopted four-point supporting) directly influences the stress and deformation of the engine block, so that the parts of rigid body include: engine block, cylinder head, gear chamber, wheelhouse, and engine bracket. For the calculation accuracy, hexahedral units are generated by HYPERMESH. There are 119248 nodes and 90291 units in the parts of engine block and cylinder head.

Flexible bodies interact with other parts through boundary points in ADAMS, such as being applied constraint and force. By the generation of the modal neutral files, 28 boundary points are set up, located at the center of cylinders, inner wall of main bearing holes (4 boundary points every bearing hole), and engine mounts (four-point supporting). In order to keep balance between accuracy and efficiency, the modal neutral files whose frequency is less than 3000 Hz are reserved.

Flexible shafting - The flexible shafting model, including the crankshaft, the flywheel and the connecting flange, is made of hexahedral units, and 13 boundary points are set up, and the modal neutral files whose frequency less than 3000 Hz are reserved.

Parts of rigid bodies - Pistons, connecting rods, piston pins and other parts are generated as rigid bodies.

Damping setup - The engine block and crankshaft adopt non-linear damping, and the parameters are referred to reference [10]. The modal damping ratio of 300 Hz is 0.03, and the modal damping ratio of 1000 Hz is 0.05.

Boundary condition and motion pairs - There are two installation methods, flexible (with mounts) and rigid (without mounts), in the engine bench test, and these can be achieved by setting up different stiffness of mounts in ADAMS. The main bearing is hydrodynamic lubrication bearing, simulated by solving Reynolds oil film equation [11], with bearing clearance 0.05 mm and oil supply pressure 0.4 MPa. The connections between other parts are simplified to ideal constraint in ADAMS: The connection between the crankshaft and the connecting rod is cylindrical pair, the connection between the piston and engine block is translational pair and the connection between the piston and the connecting rod is hinged pair. The rated speed of the engine is 3200 rpm, and the gas pressure is obtained by experiment. The setup of the coordinate system: X-direction -- the center line direction of the cylinder (Vertical direction); Y-direction -- horizontal direction; Z-direction -- axial direction of the crankshaft. The multi-body dynamics model is shown at Figure 1.

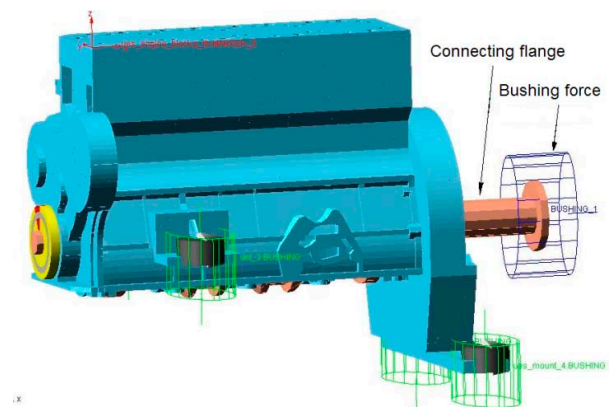


Figure 1: The model of 4100qb diesel engine