Clearance Optimization of Piston/Cylinder Pair Based on Virtual Prototype of Axial Piston Pump

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***Abstract*—The virtual prototype of axial piston pump is discussed in details through its application in the investigation on piston/cylinder pair. Three sub-models are introduced firstly. The data are transferred between three sub-models through the software interfaces. The liquid-solid coupling and rigid-flexible coupling of piston/cylinder pair model are achieved through the co-simulation model. Then several related test rigs are mentioned. The comparisons of simulation results and experimental results demonstrate that the virtual prototype of axial piston pump has a satisfying accuracy and a great potential in axial piston pump design. At last, the influence the average clearance height of piston/cylinder pair is analyzed. The simulation results indicate that the reduction of the average clearance height between piston and cylinder bore contributes to the reduction of leakage and friction force of piston/cylinder pair, and the improvement of the carrying ability of the lubricating oil film.**

Keywords; axial piston pump; piston/cylinder pair; virtual prototype

I. INTRODUCTION

Axial piston pump is widely used in hydraulic systems because of its advantages, such as high power density, high limit pressure and long service life. The designs of the friction pairs are the most important and difficult parts in the axial piston pump design, including the piston/cylinder pair, the cylinder/valve-plate pair, and the slipper/swash-plate pair. The pump realizes oil suction and delivery with the reciprocation of the piston in the cylinder bore. The piston tilts in the cylinder bore. Therefore, the clearance of the piston/cylinder pair is an important parameter that determines the carrying ability of the lubricating oil film, friction and leakage. Inappropriate clearance can lead to solid contact between piston and cylinder bore. The clearance optimization is helpful to improve the mechanical efficiency, volume efficiency and reliability of an axial piston pump.

In the earlier researches on the friction pairs of axial piston pump, some simulation models of the oil films were built with programming languages [1-4]. The most famous independent simulation tool is CASPAR developed by M. Ivantysynova. It was a nonisothermal model and took the elastic deformation of friction pairs into consideration [5-6]. However, in the programming of this kind of simulation models, the solving of the nonlinear equations and the convergence of model took most part of the work. What's more, the software maintenance and updating of the independent program was very time-consuming and expensive.

With the progress of the computer computation and multi-body dynamic theories, the virtual prototype developed with several commercial softwares is more and more widely applied in the researches of axial piston pump [7]. The mechanical and hydraulic characteristics are simulated with widely used commercial software. Therefore, more work can be done to realize liquid-solid coupling and rigid-flexible coupling of the axial piston pump which is helpful to improve the model accuracy. Roccatello analyzed the influence of different contact models on the accuracy of virtual prototype [8]. Deeken added the tribological sub-model to the main program in the form of a dynamically linked library for the first time [9]. The virtual prototype model is more similar to the practical pump and can simulate more characteristics.

In this paper, a virtual prototype of axial piston pump built with MSC.Adams, AMESim and MATLAB is introduced in details. Some related experiments are conducted to verify the simulation model. Based on this simulation model, the clearance of piston/cylinder pair is optimized to improve the carrying ability and to reduce the energy dissipation of the lubricating oil. Some conclusions are made that can be used in the design of high-performance axial piston pump.

II. MODEL CONSTRUCTION

The virtual prototype of axial piston pump is composed of several different sub-models，including mechanical modes, hydraulic system and oil-film model, which are built respectively and connected with each other through their co-simulation interfaces.

A. Mechanical Model

The mechanical model of axial piston pump can be portrayed as a multibody system. Mechanical properties such as inertia, elasticity and force are assigned to individual discrete element. And individual massy bodies are joined to one another via links or forces.

The mechanical model is built using the commercial software MSC.ADAMS because of its advantage on multibody dynamics simulation and co-simulation capability with AMESim. Firstly, the necessary components of axial piston pump are built in the three-dimensional modeling software

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