Dynamics of the fluid-structure coupling model of a direct-acting relief valve

Wen Song*, Maolin Liao**

*China Shipbuilding Industry Corporation 705 Research Institute, Xi'an, China

**School of Mechanical Engineering, University of Science and Technology Beijing, Beijing, China

Abstract. To explain the sudden jump of pressure for a direct-acting relief valve used by torpedo pump as the variation of water depth, a 2-DOF fluid-structure coupling dynamic model is developed. A nonlinear differential pressure model at valve port is applied to model the axial vibration of fluid, and the nonlinear wake oscillator model is used to excite the valve element in the vertical direction; meanwhile, the contact nonlinearity between the valve element and valve seat is also taken into consideration. Based on the developed dynamical model, the water depths for the sudden jump of pressure can be located precisely when compared with the experimental signals, and the corresponding vibration conditions of the valve element in both the axial and vertical directions are explored. Subsequently, in order to eliminate the sudden jump of pressure, the result of numerical simulation suggests to decrease the pump inlet pressure from 0.8MPa to 0.4MPa, which is verified to be effectiveness by the corresponding experimental test, and thus the proposed dynamical model is further verified.

Introduction

Direct-acting relief valve is widely applied for pressure adjustment in fuel pump; however, as the pressure fluctuation at the relief valve due to the influences of external environment, the valve element can lose its stability via Hopf bifurcation, and which can further enter into chaos via grazing bifurcation due to the axial impact between the valve element and valve set [1]. In addition, when the fuel flows through the valve element in a narrow space with high speed, the vortex-shedding behind the valve element can excite it vibration in the vertical direction [2], which further triggers its vertical impact with the valve set. Therefore, a 2-DOF fluid-structure coupling dynamic model is proposed in the present work, to investigate the correlation between the vibration condition of valve and the sudden jump of pressure of the pump observed in experiments.

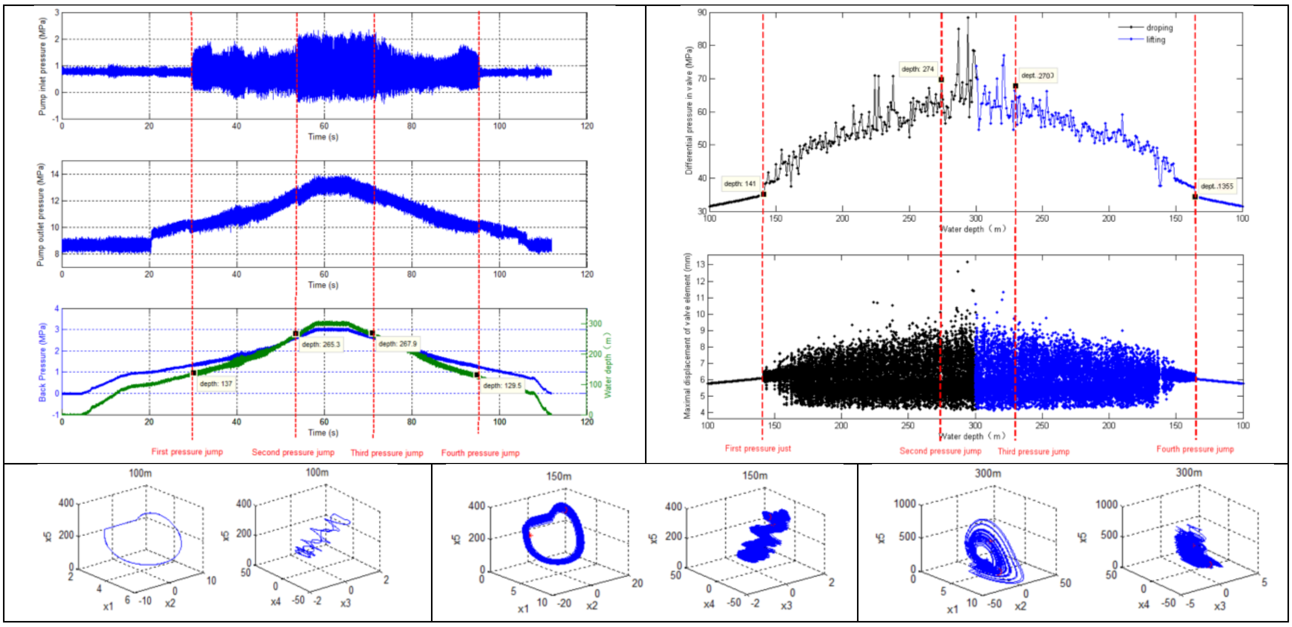

Figure 1: Comparison of experiments (top left) and simulations (top right), and three phase portraits for different depths (bottom)

Results and discussion

Fig.1 shows the comparisons between the experimental measurements and numerical simulations for the case by setting the pump inlet pressure 0.8MPa. Four pressure jumps appeared during the process of dropping and lifting the pump with relief valve are marked in both the top plots, and the errors of their corresponding positions are limited in 5%. In addition, the phase portraits about the axial and vertical vibrations of the valve element in three representative depths 100m, 150m, and 300m are compared, and the vibration condition of the valve element changes from limit circle to chaotic motions as the variation of the water depth, which is expected to be the main reason for the sudden jump of the pump pressure.

References

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