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Dynamic analysis of the reheat-stop-valve mechanism with revolute clearance joint in consideration of thermal effect

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Abstract

The dynamic analysis of the reheat-stop-valve mechanism with revolute clearance joint is presented in this work. The effect of joint clearance variation induced by the manufacturing tolerance of components is analyzed combined with the thermal influence of the high temperature steam in working condition. It is shown that by increasing the combined clearance of the revolute joint, a favorable reduction of the friction torque between the bush and the valve shaft can be obtained for normal operation conditions of the reheat-stop-valve mechanism. However, if the temperature of steam reaches to 650 °C, the friction torque between the bush and the valve shaft becomes larger and the sticking phenomena exists. Based on the numerical results, several design recommendations to the partitioning engineer are advanced at the end of the paper.

Keywords: Reheat-stop-valve mechanism; Revolute clearance joint; Multibody dynamics; Contact analysis; Thermal behavior

1. Introduction

The reheat-stop-valve mechanism, which controls the high temperature and large pressure inlet steam, is a vital component of steam turbine. The schematic graphic of the reheat-stop-valve is shown in Fig. 1. The input motion applied by the driver at the handspike is transmitted through the connecting lever and the motion control linkage (i.e. the pole link, pin link, connecting rod, connecting tie-in, springs assembly) to the valve shaft and bush-that is the revolute joint with clearance.

In working condition, there is a thermal effect on the mechanism induced by the inlet high temperature steam. The significant failure of valve journal bearing with clearance will be developed with the mechanism and high temperature steam. As a result, the dynamic performance of the reheat-stop-valve mechanism in the working situation is greatly degraded.

The subject of the modeling and dynamic analysis of mechanical systems with joint clearance, especially the representation of real joints, draw the attention of a large mount of researchers that produced several

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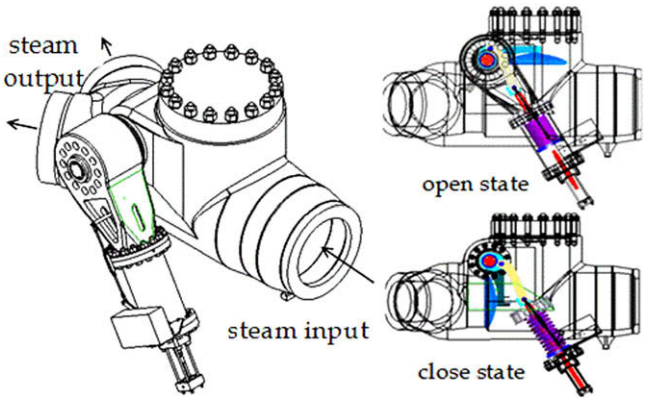

Fig. 1. The schematic graphic of a steam turbine valve.

theoretical and experimental works [1–7]. Some of these works focus on the planar mechanical systems with only one clearance joint [5,8–11]. Some researchers also include the influence of the flexibility of the components in the dynamic performance of multibody systems besides the existence of clearances in the joint [6,12]. Reports on the dynamic analysis and simulation of the mechanical systems including joints with clearance and lubrication are also available in a number of publications [11,13–15]. Continuous contact force model was presented by Lankarai and Nikravesh [16] and Flores and Ambrosio [17] and applied for the dynamic analysis of a slider-crank mechanism. Orden [18] presented a study of joint clearance with rigid cave model. In the work of Castelli and Venanzi [19], there was a novel local model of the mechanism kinematic pairs defined for the analysis of clearance effects on the mechanism configuration.

For dynamic performance of multibody systems with joint clearance, the effect induced by environmental factors on multibody systems, especially the clearance joint, also had been taken into account by some researchers. Lin and Liu [20] presented a study of a closed-loop planar mechanical system that takes in consideration the effect of thermal disturbance. However, most of solutions adopted conventionally are essentially designed on structure and thermal question, respectively. Their inadequacies in representing overall influence may present problems during engineer design or analysis process. A virtual prototyping based multi-physics modeling and analysis method is described in the work of Bing and Ye [21]. In that work, the authors proposed a framework of virtual prototyping environment for the design and analysis of reheat-stop-valve mechanism with revolute clearance joints in working situation. The main emphasis of the present work is on the modeling valve revolute clearance joints in consideration of the steam thermal behavior. The contact between the journal and the bearing is modeled by using a non-linear continuous contact force model. The contact forces are then introduced into the mechanism's equation of motion in order to analyze its dynamic performance.

In order to reveal the effect of high temperature steam thermal behavior effect on the revolute clearance joint, the thermo-structural coupled analysis [21] of the revolute clearance joints with related components is also used.

2. The configuration of the reheat-stop-valve mechanism in working condition

The configuration of reheat-stop-valve mechanism and its operating environment have vital effect on the dynamic behavior of reheat-stop-valve. The mechanism under consideration can be modeled as a slider-crank mechanism, which is made of four bodies, two ideal revolute joints, one perfect translational joint and one revolute clearance joint that connects the valve shaft and the fixed bush. The configuration schematized in Fig. 2, where the connecting lever is linked on the valve shaft with bonds, is the closed state of valve in working situation. There are four support bushes along the length of valve shaft. Therein, the right end bush works in the high temperature steam environment with the valve shaft. Due to the deformation of the valve shaft, the clearance distribution between the out face of the shaft and the inner face of the bush will be changed.