Hydraulic-Thermal Analysis and Optimization for a Circumferentially Grooved Seal Based on Bulk Flow Theory

†*Yuefang Wang[1,2], Xiaojian Cao[1,2]

[1]Department of Engineering Mechanics, Dalian University of Technology, China.
[2]State Key Laboratory of Structural Analysis for Industrial Equipment, Dalian, China

*Presenting author: yfwang@dlut.edu.cn
†Corresponding author: yfwang@dlut.edu.cn

Abstract

Grooved seals have been installed extensively on pumps and hydraulic turbines to prevent leakage of operation liquid. From its inlet to its outlet, a grooved seal enwraps a thin-film of the liquid in a very narrow clearance with varying inner and outer diameters bounded by the rotor shaft and the motionless stator of the machine. Inside the clearance, the liquid moves axially due to the pressure difference from upstream and spins with the rotor due to fluidal viscosity. Dragging forces can develop on the walls of the stator and the rotor, which generates both excessive heat and loss of power rate. Attention must be paid in seal design on overwhelmingly rapid heating by the seal liquid to the ambient stator.

In this paper, a hydraulic-thermal analysis is carried out for a circumferentially grooved seal filled with water. The bulk-flow theory along with the three-control-volume model is adopted to describe the flow of the thin-film seal liquid. The liquid is partitioned into three types of gap flows for which the equations of mass conservation, momentum and temperature are presented. The governing equations are then approximated with respect to the perturbation of the rotor offset, discretized through the difference scheme, and solved through the Newton-Raphson method. For the optimal geometry of seal clearance, a multi-objective optimization model is established considering reductions in both dragging force and heat generation of the liquid. For efficiency of the optimization, the dragging force and maximum temperature of the fluid field are explicitly approximated through two response surfaces created with the method of radial basis function. Afterwards, the method of moving asymptotes is used to determine the optimal dimensions of the seal geometry to achieve the minimum dragging force and the least temperature-rise of the seal liquid. Numerical examples show the effectiveness of the proposed approaches for hydraulic-thermal analysis and geometrical optimization of circumferentially grooved seals.

Keywords: liquid seal; hydraulic and thermal analysis; method of moving asymptotic; optimization