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Calculation of temperature distributions in the rotors of oil-injected screw compressors

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ABSTRACT

A mathematical model and a calculation procedure are proposed in this study to efficiently calculate the temperature distributions in the male and female rotors of the oil-injected screw compressors. The solution of the transient heat conduction problem of the rotors, which is subject to a periodic convective boundary condition and five steady boundary conditions, is obtained by solving the set of Helmholtz equations derived from the partial differential equations for transient heat conduction without internal heat. During the solving process, the periodic convective and the five steady boundary conditions are calculated using the six empirical constants together with the ideal convective heat-transfer coefficient and the ideal steady heat fluxes. The six empirical constants are determined by minimizing the difference between the calculated and measured temperatures of the rotors. The average errors of calculated temperatures at three locations of each of the male and female rotors are 5.45% and 4.85%, respectively. Results indicate that the heat is mainly transferred from the bearings installed on the outlet shaft of the rotors into the screws. Then, the heat is transferred from the screws to the compressed air and the bearings installed on the inlet shaft of the rotors. The temperature gradient in the axial direction is different at different positions along the screw. The results of the sensitivity analysis show that the three empirical constants that are used to calculate the heat convection between the screw and the compressed air, the heat transfer between the rotor and the bearing at the inlet shaft of the rotor and the heat transfer between the rotor and the bearing at the outlet shaft of the rotor, have a stronger impact on the outputs of the mathematical model than the other three empirical constants. The reduced mathematical model, using only the three empirical constants with the strongest impact, can be used in the studies of the temperature distribution in the rotor. The calculated temperature distributions in the screws can be used to estimate the approximate thermal deformation of the screws and thereby improve the screw profiles and the design of the oil-injected screw compressor.

1. Introduction

An oil-injected screw compressor compresses air within the compression chamber formed by the casing and the screws of the male and female rotors of the compressor. As the rotors rotate, the volume of the compression chamber changes and thereby compresses the air. To cool the compressor and the compressed air and to lubricate the rotating meshing rotors, lubricant oil is injected into the compression chamber at the proper position during a compression cycle. Currently, the volumetric efficiency of screw compressors is higher than 90% due to the well-controlled clearances of the internal leakage paths achieved with modern precision-machining techniques [1]. When designing an oil-injected screw compressor, one of the major design goals is to maximize the volumetric and the isentropic efficiencies [2–5]. Thermodynamic analysis is usually performed at first, followed by the analysis of the loads exerted on the rotors. With the results of the thermodynamic and load analysis, the design of the screw profiles of the male and female rotors and of the geometric structure of the case are performed and optimized. Stosic et al. [5] compiled a list of all 5×6 screw profiles that had been generated since 1967 and the procedures to calculate these profiles.

Studies on the compression processes of oil-injected screw compressors can be classified into two categories, lumped parameter analysis and finite element/difference analysis. In the first category, a lumped parameter system is adopted to analyze the performance of the oil-injected screw compressor. The properties of the compressed air inside the compression chamber are

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