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Heat transfer study of mechanical face seal and fin by analytical method

M. Mosavat [a], R. Moradi [b], M. Rahimi Takami [c], M. Barzegar Gerdroodbary [d,*], D.D. Ganji [d]

[a] Department of Mechanical Engineering, Amirkabir University of Technology, Tehran, Iran
[b] Department of Chemical Engineering, School of Engineering & Applied Science, Khazar University, Baku, Azerbaijan
[c] Niroo Research Institute (NRI), P.O. Box 14655-517, Tehran, Iran
[d] Department of Mechanical Engineering, Babol University of Technology, Babol, Iran

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ABSTRACT

Heat transfer investigation of the mechanical device such as fin and mechanical face seals is crucial for the development of these elements in different applications. In this study, two analytical approaches (collocation and numerical methods) are used to study the thermal performance of fin and mechanical face seal in various operating conditions. In the mechanical face seal, the influence of significant parameters (thermal conductivity, operating temperature and heat convection coefficient) are investigated. In the fin study, the stretching and shrinking of the fin with different cross section are comprehensively discussed. Our findings reveal that the performance of these elements significantly varies in different operating conditions.

1. Introduction

Enhancement of the mechanical element such as fin is crucial for the heat transfer study and obtained knowledge could increase the performance of this element as heat sink. In addition, the mechanical face seal is one of the crucial equipment of industrial machinery such as pumps, turbines and compressors. The main role of the mechanical face seal is the preventing of fluid leakage that can cause a significant economic and environmental disorder event.

In order to study mechanical seal, Fig. 1 illustrates the schematic of this element. Among various materials, the most common material used in primary rings is carbon graphite. Ceramic, stainless steel, tungsten carbide and silicon carbide are popular materials for use in mating rings [1,2].

It is clear that both conduction and convection heat transfer play a significant role in the performance of a mechanical seal. Since high heat transfer rate occurs between the primary and the mating rings, the thermal conductivity of these materials is important. Moreover, heat generation at the interface between the mating and the primary rings is dissipated into the flush fluid through the process of convective heat transfer. In order to remove the heat generated at the faces effectively, a high heat transfer coefficient and/or a larger wetted area is needed. Doane et al. [3] studied how the wetted area influences the rate of heat transfer and noted that heat transfer from the seal face is mostly dissipated through the axial and radial directions. Thus, increasing the wetted area in the axial and radial directions can be considered for improving heat transfer. However, an increase in the surface area is not always possible due to space limitations. Therefore, new heat transfer augmentation techniques are needed to reduce interface temperature.

In order to preserved the performance of the mechanical face seal, several heat augmentation techniques such as pin fins, rib tabulators and dimpled surfaces have been employed in the engineering field. In this work, the role of the thermal radiation is investigated to improve the performance of the device. Then, analytical approaches are applied to study the fin (Fig. 2) with various cross sections when shrinking or stretching.

In recent years, the applications of the analytical approaches have been widely increased due to simplicity and low cost [3–10]. Several researchers and scholars applied these techniques for solving complicated various engineering problems with different applications [11–17]. In the heat transfer study, the nonlinear terms are the main challenge for the solving of the current problems [18–24]. Hence, scientist presents various approaches for transforming the complicated nonlinear equations to simple problems [3,18,25–29]. Among these approaches, DTM, ADM, HAM and CM are recognized as the most robust method for the heat transfer analysis of the engineering problems [23,30–37]. Besides, numeri-

* Corresponding author.
E-mail address: mbarzegarg@yahoo.com (M. Barzegar Gerdroodbary).
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Nomenclature

a	thickness of mechanical seal(m)
r	radius(m)
T	temperature (K)
Ti	temperature of inner surface
h	heat coefficient of convection
T_{out}	Ambient temperature(K)
ro	radius of outer surface
ri	radius of inner surface
$\acute{e}_{gen}$	heat generation
K	thermal conductivity coefficient
t	dimensionless parameter of Temperature
R	dimensionless parameter of radius
K	constant

Greek symbols

ε	emissivity
σ	Stefan-Boltzmann constant
β	constant
δ	ratio of outer radius to inner radius

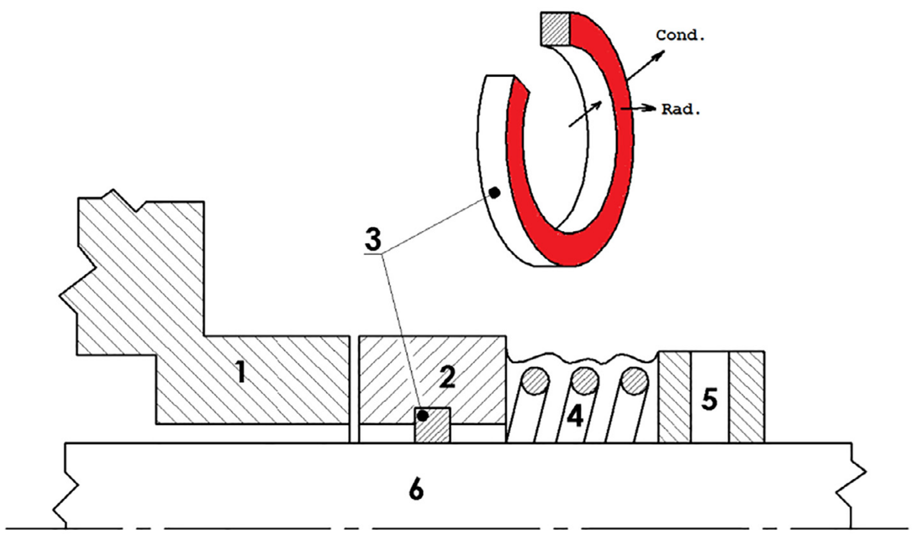

Fig. 1. Schematic of mechanical seal: 1-Stator, 2-rotor, 3- ring, 4-spring, 5-steady pin, 6- shaft.

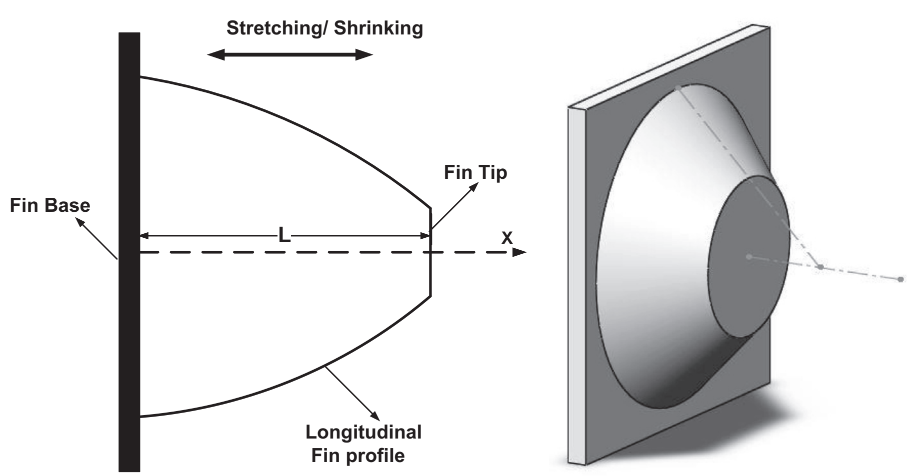

Fig. 2. Schematic of fin.

cal methods also applied for the simulations of the complicated problems [38–54].

In this study, the temperature distribution of the fin and mechanical face seal with/without thermal radiation is investigated. In section two, the problem is defined and the governing equation and boundary condition are presented. In the third section, the two main methods of solution are described. Moreover, the approach of these methods for this problem is discussed. In the fourth section, various parametric studies are conducted to investigate the efficiency of thermal radiation for different operating conditions. Finally, the results are concluded in the last section of the paper.

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