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ScienceDirect

Procedia Engineering 176 (2017) 628 – 635

Procedia Engineering

www.elsevier.com/locate/procedia

Dynamics and Vibroacoustics of Machines (DVM2016)

Choice of Structural Parameters of Rotary Seal Made from MR-Material

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Abstract

The structural parameters of an elastic porous material MR used for perspective rotary seals, are analyzed in this article. The porosity value range, also as the wire diameter and the thickness of the elastic sealing element were determinated. It is clearly justified the necessity of additional research of flow characteristics of porous elastic sealing elements made of MR-material. The results of experimental studies of characteristics of rotor seals made of an elastic porous MR- material are also given.

Peer-review under responsibility of the organizing committee of the international conference on Dynamics and Vibroacoustics of Machines

Keywords: Rotary seal, Brush seal, MR-material, porosity, structural parameters, wire, flow characteristics

Nomenclature

V –velocity of liquid flow
d_p –diameter of the wire
ρ – density
μ, ν – dynamic and kinematic viscosity factors
P – porosity
Re - Reynolds' value
p_1, p_2 – inlet and outlet pressure in the porous element
h – thickness of the porous element
F (α) – gamma-function, α and β are parameters of distribution defined by relations

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Peer-review under responsibility of the organizing committee of the international conference on Dynamics and Vibroacoustics of Machines
doi:10.1016/j.proeng.2017.02.306

1. Introduction

Providing the required reliability, economy and ecology of modern turbo machinery is due to the necessity of solving scientific and technological problems of creating high-performance rotary seals.

One solution to this problem is the use of brush seals. They are an alternative to conventional labyrinth seals. The brush seals can significantly reduce the leakage of the working substances [1 - 6]. Brush seals can operate at significant radial movement of the rotor, which ensures them a significant advantage over other types of seals. Brush seals have an impact on the dynamics of the rotor, ensuring its damping. Another advantage of these seals is their small size, especially in the axial direction.

Brush seals are used for the separation of gas and liquid environments, at a pressure up to 2000 psi, temperatures up to 1000K, and the circumferential speed of 500 m/s [1].

Brush seals are contact seals with anisotropic porous fibrous structure. The disadvantages of such seals should include technological complexity and high cost. Furthermore, brush seals do not work with reciprocating motion of the rotor. A special feature of the brush seals is heating of the contact zone.

Currently, brush seals are actively developed and applied by Rolls-Royce, MTU, Pratt & Whitney and other companies, creating turbomachines and their elements. The MTU Company develops brush seals since 1983 and produces them for various engines (PW1500G, PW1000G, EJ200 and others).

Pratt & Whitney annually produces up to 4,000 units of seals for PW2000 and PW4000 engines family, and for PW545 [6]. They are also used in the design of V2500 turbofan, which has several brush seals.

Rolls-Royce employs brush seals in RB199 and EJ200 engines. Thanks to the use of BS in AE 2100, T406 and AE 3007 engines, Rolls-Royce / Allison have reduced specific fuel consumption by 0.25%. Brush seals are also applied to the General Electric turbofan engine GE90. [2, 6]

An lot of work was devoted to the Brush seals research by B. M. Steinetz, R.C. Hendricks, J. Munson, T.A. Griffin, T.R. Kline [1 - 3, 5, 6] (NASA); J.G. Ferguson, A.G. Fricker, C.G. Moore (Rolls-Royce); V.E. Reznik, V.I. Cibizov, V.R. Vekhov, N.K. Aksenov, A. Antonov, E.K. Mezhzil, A.A. Strukov, A.V. Goryachev, V.G. Zhulin, V.N. Polegaev, V.A. Geykin, V.M. Krainev, S.V. Falaleev, S.A. Pugachev [7, - 14] (Russia).

M.C. Sharatechandra and D.I. Rhode numerically determined velocity field and pressure in an idealized model of the brush seals [15]. This is the first study of the vortex flow's influence in the seal on its characteristics. Analysis of axial and radial flow of the sealed medium, caused by the rotation of the rotor, showed a leakage reduction with an increasing of the rotor speed. Determining parameters of this process are Reynolds number values, corresponding to the direction of flow, as well as the size of the distance between the wires. The "separation" of the bristles is observed and which is caused by the vortex flow motion, and occurs in a very thin layer between the bristle tips and the rotor surface.

M.J. Braun, V.A. Canacci and R.C. Hendricks obtained flow rate characteristics of the brush seals and experimentally analyzed the flow of the medium in the brush seal's elements [16]. For the first time in the research of brush seals study, a model of a porous medium was used.

For their use in aircraft turbines, the properties of Brush seals material were studied in the following works [17]. Here are the experimental results of the wire's contact interaction with the shaft surface and the determined friction coefficients.

A mathematical model of brush seal and the results of calculations of sealing parameters are presented in the following work [18]. It is recommended to set the brush at an angle of 70°.

Brush seals are very complex and expensive. According to MTU company price of the brush seals for aviation gas turbine engine is $ 7,000 compared to the price of a labyrinth seal - S 650[1, 13].

2. Design scheme of seal with the "metal rubber" (MR-material) porous elastic element

Rotor seal with the sealing element of the MR-material is a consumable seal [26, 27]. Its sealing effect is provided by a hydraulic resistance of the elastic porous structure. It replaces the brush elements in the seal.

The MR-material is a porous substance. It is obtained by cold pressing of stretched wire helix. This spiral, dosed by mass, in placed into a mold and pressed till the final product size [27 – 29]. The manufacturing technology of