RESEARCH PAPER Engineering Volume : 5 | Issue : 4 | April 2015 | ISSN - 2249-555X

Numerical Investigation of the Influence of Gas Temperature upon the Characteristics of Flat Aerostatic Bearing using Cfd-Simulation

KEYWORDS characteristics of aerostatic bearings, numerical investigation, CFD-simulation

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ABSTRACT *This study concerns the numerical investigation of the influence of air temperature upon the characteristics of circular flat aerostatic bearing with central supply. One construction of gas bearing is examined by means of CFD-simulation based on the product Fluent.*

INTRODUCTION

A series of advantages of the flat aerostatic bearings (FASB) as small almost zero friction and insignificant heating impose the use of bearings in many measuring instruments, computer peripheral devices, and in new modern microelectronic mechanical systems (MEMS).

A perspective direction for the investigation of gas bearings is the numerical model examination by means of ComputationalFluid Dynamics(CFD) simulation [1, 2].

The influence of air temperature upon the characteristics of one construction of FASB by simulation based on the software product Fluent is the goal of this study.

1. AN EXAMINED MODEL AND FORMULATION OF THE PROBLEM

The examined design of circular FASB with central supply is presented in Fig. 1. FASBs are formed in practice from two hydraulic resistances, *a constant resistance* and *a changeable resistance* as a throttle type "diaphragm" and a flat gap with radial outflow, respectively. This design has the following geometric dimensions: a diameter of the bearing, D_o*= 100 mm;* a diameter of the supplying source, D_1*= 1 mm*; a depth of the supplying source,δ *= 1 mm*; a diameter of the diaphragm, $d_{б}$ *= 0.35 mm;* a gap, *h=10 μm.*

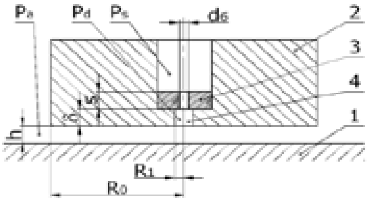

Fig. 1. A design of FASB with radial outflow from central source; 1 – base; 2 – bearing; 3 – throttle (diaphragm); 4 – central source; R_0- radius of the bearing; R_1 – radius of the central source; p_s – supplying (input) pressure; p_d – pressure in the central source; p_a – external pressure (atmospheric).

The flow in the gas bearing is examined for:

-four supplying pressures (over-pressure) as following p_s *= 100; 200; 300; 400 kPa(* p_a *= 0);*

-four temperatures of the working fluid (air) as following *T = 300; 400; 550; 700 K.*

2. A NUMERICAL SOLUTION – BASIC PRINCIPLES

The geometric building and cross-linking of the model is realized by means of the program product Gambit, while a detailed solution of this problem is presented in [3].The built model is solved by CFD-simulation using the software product Fluent. A detailed description of the steps, the building procedure and the in-stage-examination are applied in [3, 4]. In the mathematical model for the software solution of the flow in FASBs the following basic equations are set [4]:

-equation of conservation of momentum:

$$\frac{\partial}{\partial t}(\rho.\vec{v})+\nabla.(\rho.\vec{v}.\vec{v})=-\nabla p+\nabla.(\overline{\overline{\tau}})+\rho.\vec{g}+\vec{F} \quad (1)$$

where*p* is static pressure; $\overline{\overline{\tau}}$ is a tensor of stresses; $\rho.\vec{g}$ and $\vec{F}$ are gravity and external forces;

-equation of continuity:

$$\frac{\partial\rho}{\partial t}+\nabla\cdot(\rho.\vec{v})=0 \quad (2)$$

-equation for conservation of energy

$$\frac{\partial}{\partial t}(\rho.E)+\nabla(\ \vec{v}(\ \rho E+p)\ =0 \quad (3)$$

The flow character in the radial gap of FASB is predominantly laminar, which is proved in [4]. The criteria local Reynolds number is determined by the dependence:

$$\mathrm{Re}=\frac{q}{2\pi r\mu} \quad (4)$$

where*q*is the gas mass flow in the gap; *r*is the current radius of the gap; *μ* is the dynamic coefficient of gas viscosity.

Taking into account the changeable parameter *r* (at the gap entranceR_1 *= 0,5 mm*, and at the gap exitR_0 *= 50 mm*), the Reynolds number*Re* has an order change even in one examination, then the flow can be turbulent at the radial gap entrance *(r =* R_1 *)*, and laminar at the radial gap exit *(r =* R_0 *)*. Having in mind the small gap (*h = 10 μm*) the flow is definitely laminar (for all investigations*Re = 0,1…150*) during the concrete numerical examinations. On the grounds of this only a laminar model is used during the determination of the type of viscous model ***(Define / Viscous model***).

The numerical examination is done at different temperatures of the working gas (air).This is rendered into account during the introduction of the parametres of the working fluid - ***Define / Materials / fluid – air.***The concrete values of air parametressuch as specific heat capacity - c_p; coefficient of heat

Volume : 5 | Issue : 4 | April 2015 | ISSN - 2249-555X

conductivity - λanddynamic coefficient of viscosity -*μ* at the respective temperatures are presented at Table 1.

Parametresof air Table 1

Temperature / parametres	*300 K*	*400 K*	*550 K*	*700 K*
c_p (J/kg.K)	1006,43	1009	1043	1068
λ (W/m.K)	0,0242	0,0334	0,0444	0,0521
μ (Pa.s)	$17{,}9.10^{-6}$	$23{,}3.10^{-6}$	$29{,}1.10^{-6}$	$33{,}7.10^{-6}$

The iterative processes are short (the number of iterations is 150-160), and therefore, the convergence on the put criteria is quickly reached.

The numerical modeling suggests interest opportunities for the presentation of the solution results such as visualizations of the distribution of pressure, temperature and the speeds in different sectors of the flat gap. At the so set problem very important are the opportunities for the obtaining of solution for:

the effect of the flowing gas through the gap on the limiting surfaces, ***Report / Force Reports / Forces,*** which in fact is an important feature of FASB, i. e. the load-carrying capacity, *W*;

- the running mass flow*q*in the gap of FASB - ***Report / Flux Reports / Mass Flow Rate.***

3.RESULTS AND ANALYSIS

The results from the numerical solution prove the conclusions about the isothermal character of the flow in the flat radial gap. In Fig. 2 is evident that for each investigated case the temperature along the gap length (along *r*) remains constant equal to the set one during the examination (for four temperatures). On this scale the insignificant temperature derivations (ΔT = *-0,1…-1* K) from the set temperature at the radial gap entrance cannot be read in this figure.

The second analysis shows that the pressure distribution along the gap length (along *r*) does not depend on air temperature, but merely on the supplying pressurep_s.In Fig. 2b the dependences*p(r)*at p_s = *200 kPa*and at different temperatures*T = 300; 400; 550; 700 K* coincide almost completely. This explains also the results for the load-carryingcapacity of the investigated FASB at different

supplying pressures $p_s$and temperaturesT.*a.)*

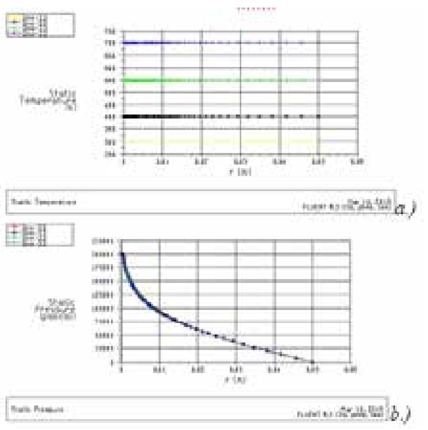

Fig. 2. A change of the gas temperature T (a) and the gas pressure P (b) along the radius of FASB for p_s = 200 kPa andT = 300;400;550;700K.

In Fig. 3 is evident that the load-carrying capacity*W* almostdoes not depend on the temperature of the working fluid, air, but only on the supplying pressure. For the different p_s = *100; 200; 300; 400 kPa*the load-carrying capacity of the bearing is $W_{100}\approx109$ *N* ; $W_{200}\approx254$ *N* ; $W_{300}\approx416$ *N* ; $W_{400}\approx585$ *N*, respectively.

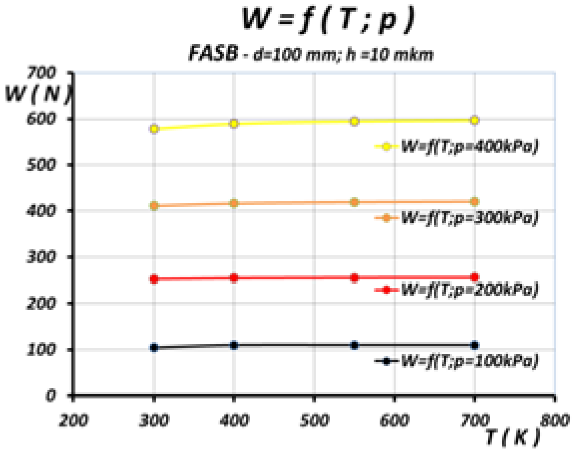

Fig. 3. A load-carrying capacity of the investigated FASB at different temperatures T and supplying pressures

The most considerable change is that is seen in mass flow characteristics of FASB with the increase of temperature *q=f(T;p)*, presented in Fig. 4.

The analysis of the results shows that with the increase of the temperature (at constant supplying pressure p_s =const.) the mass flow through the gap decreases. In the investigated temperature range (*T = 300…700 K*) this reduction is 4,3 times, and is almost independent on pressure. This could be explained with the increase of air viscosity at its heating (in deference with liquids), and the respective increase in the hydraulic resistance. At other equal circumstances (a constancy of the supplying pressure p_s),a little "heater" air should flow through the gap.

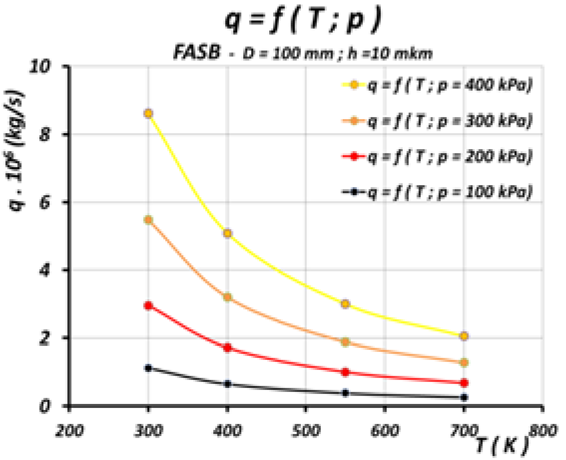

Fig. 4. A mass flow through the investigated FASB at different temperatures T and supplying pressuresp_s- q = f (T ; p)

CONCLUSIONS

A numerical investigation of the influence of the working fluid temperature upon the gas flow and the characteristics of one construction of FASB is done by means of CFD-simulation ofsoftwareproduct Fluent.The results demonstrate that the increase of air temperature does not influence the load-carrying capacity of the bearing, while during the air heating the gas mass flowthrough the bearing decreases.

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