8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

FINITE ELEMENT METHOD APPPLIED TO AEROSTATIC BEARINGS FOR INVESTIGATION OF THE DISCHARGE COEFFICIENT EFFECTS ON THE OPERATING PARAMETERS

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Key Words: *Aerostatic, Journal Bearing, Discharge Coefficient, Load Capacity.*

ABSTRACT

Aerostatic journal bearings operate mainly at either zero or low speeds. Thus, externally pressurized air must be supplied to the bearing clearance through feeding orifices, in order to generate a load carrying capacity. The discharge coefficient C_D, which is the correction factor employed to obtain the real air mass flow, is usually assumed constant $C_D = 0.8$ for design calculations, either for sonic ("choked") and subsonic flow conditions. This approach is adopted by Su and Li [1], Sorin et al. [2], Renn and Hsio [3] and Cheng-Ying [4]. However, Belforte et al. [5] from experiments on an aerostatic thrust bearing developed an empirical formula for C_D as a function of Reynolds number. Powell [6], also observed that C_D is variable, as a function of the pressure ratio p_d/p_s, i.e., $C_D = f\left(p_d/p_s\right)$, where p_s is the gas supply pressure and p_d is the discharge pressure at the feeding orifice throat. The present study is a theoretical investigation of the discharge coefficient influence on the performance of aerostatic journal bearings under two approaches for the C_D values, i.e., $C_D = 0.8$ and $C_D = f\left(p_d/p_s\right)$. The Reynolds equation for compressible fluids is solved by the finite element method with isoparametric triangular linear elements. The bearing main dimensions are: $L = 50.80\,mm$, $D = 50.80\,mm$, $C = 19.05\,\mu m$. Two rows of eight feeding orifices, located at $l_2 = 12.70\,mm$ from the bearing ends, were employed. Orifice and pocket diameters are $d_o = 0.150\,mm$ and $d_p = 0.750\,mm$, respectively. Air absolute supply pressure is $p_s = 0.51708\,MPa$. The calculated bearing gauge pressure ratio $k_{go} = \left(p_d - p_a\right)/\left(p_s - p_a\right)$, for $\varepsilon = 0$, was found to be 0.453 for $C_D = 0.8$ and 0.464 for $C_D = f\left(p_d/p_s\right)$, giving a 2.43% relative difference. A sample of results, for $\varepsilon = 0.5$, for the two C_D cases are given in Tables 1 and 2. As can be seen from Table 1, the total air mass flow differs by only 0.28% relative to the case of $C_D = 0.8$, although, at the minimum film thickness (orifice 5) the difference is about -12%. For the orifices 4 and 6, due to a C_D value reduction, the difference is -4.45%. On the other hand, for the orifices 1, 2, 8, 3 and 7, the difference is positive since C_D is slightly higher than

$C_D = 0.8$. From Table 2, the bearing load carrying capacity is about 6.6% lower for the case of $C_D = f\left(p_d / p_s\right)$, although the bearing total mass flow difference is only 0.28%.

Table 1 – Air mass flow for the two C_D approaches, for $\varepsilon = 0.5$.

Orifices of Row 1	$C_D =$ constant		$\frac{p_d}{p_s}$	$C_D = f\left(p_d/p_s\right)$		$\frac{p_d}{p_s}$	Difference (%)
	Flow *g/s*	C_D		Flow *g/s*	C_D		
Orifice 1	0.016698	0.8	0.378	0.017024	0.816	0.381	1.95
Orifices 2 and 8	0.016577	0.8	0.412	0.016993	0.820	0.416	2.50
Orifices 3 and 7	0.016054	0.8	0.545	0.016620	0.829	0.549	3.50
Orifices 4 and 6	0.012093	0.8	0.799	0.011555	0.744	0.783	-4.45
Orifice 5	0.007499	0.8	0.922	0.006601	0.578	0.877	-11.97
Total flow	0.113645		---	0.113962		---	0.28

Table 2 – Bearing characteristics for the two C_D approaches, for $\varepsilon = 0.5$.

Operating parameters	$C_D = 0.8$		$C_D = f\left(p_d/p_s\right)$		Difference (%)
Load carrying capacity	320.99	*N*	299.65	*N*	-6.65
Dimensionless load $W/\left(p_s L D\right)$	0.299	---	0.279	---	-6.65
Bearing total air mass flow	0.227290	*g/s*	0.227924	*g/s*	0.28

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The authors greatly acknowledge the support given by FAPEMIG and CNPq.