Tribological optimization of single and double slope marine stern tube bearings: A case study

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ABSTRACT

In the present study, the optimum geometric parameters of a double slope aft stern-tube bearing are sought, for (a) maximizing the contact area between the bearing and the propeller shaft, and (b) minimizing the maximum local pressure exerted on the bearing surface. Apart from generic geometric parameters (L/D, D, clearance, misalignment angle), additional design parameters are the two slope angles of the bearing surface and the longitudinal length of each sloped region. The computational approach used, evolves from the solution of the Reynolds differential equation in the oil domain between the shaft and the bearing. A general purpose optimizer based on genetic algorithms is utilized.

1. INTRODUCTION

High efficiency ship designs have reduced significantly the shafting system reliability of newbuild vessels according to Devanney and Kennedy [1]. Murawski [2] has studied the effects of hull flexibility and deformations on the shaft line, demonstrating a substantial effect regarding the stern tube bearing. Several failures of the shafting system have been reported and emphasis has been put on the severity of the stern tube bearing failures in modern VLCCs and ULCCs, as the one reported by DNV in [3]. Thereof, ABS and BV introduced the Elastic Shaft Alignment in [4]-[5], in order to improve the Shaft Alignment standards. ABS supports that the maximum absolute bearing-shaft misalignment allowed is 0.3 mrad, beyond which point, slope boring should be applied at the stern tube bearing.

2. METHODOLOGY

In this study, a single and a double slope optimum design of the stern tube bearing of a large container vessel were calculated and compared in terms of their tribological performance. The dimensionless bearing-shaft misalignment (Ψx) was set to 0.3 mrad in both cases and the loading condition was identical. A parametric model of the lubricant film thickness domain between the sloped housing geometry and the bent shaft was developed. The shaft curvature, for the given loading condition, was evaluated. The models were coupled to a shaft alignment calculation tool, to seek equilibrium between the externally loaded bent shaft and the required curvature of the bearing, in order to achieve optimal lubrication. The process was followed by optimization of the single and double slope geometry for the given load distribution. For the slope bearing design, the two slope angles and the respective region lengths were identified utilizing a genetic algorithm and a multiobjective Pareto Front optimizer. The results were compared with those of a single slope bearing design and the tribological performance of the two bearings were assessed.

3. CASE STUDY - RESULTS

In the present case study, the following input data were used:
Bearing Geometry: *Bearing length = 1.05 m , Bearing diameter = 0.52 m, Diametrical clearance = 0.0009 m*
Bearing loading: *Aft protruding edge = 0.407m, Fore protruding edge = 0.5412 m , Moment (aft end) = 409948 Nm , Force (aft end) = -202598 N , Force (fore end) = -107261 N*
Operational data: *RPM = 90, Lubricant Temperature = 40°C*
The design parameters for single and double sloped housing, optimised using the bent shaft model are:
Single slope non-dimensional parameters: *Slope = 0.3*
Double slope non-dimensional parameters: *Slope_Aft = 0.31 , Length_Aft = 0.61 , Slope_Fore = 0.11 , Length_Fore = 0.39*

In **Table 1** and **Figures 1 & 2**, the results of the comparison between: No Slope (NS), Single Slope (SS) and Double Slope (DS) housing models for Linear Shaft (LS) and Bent Shaft (BS) modeling are presented.

Slope Modeling	No Slope	No Slope	Single Slope	Single Slope	Double Slope	Double Slope
Sh. Model	**Linear**	**Bent**	**Linear**	**Bent**	**Linear**	**Bent**
h_{min} [μm]	79.1	**2.25**	175	**80.8**	145	**156**
p_{max} [GPa]	1.56	**16.1**	1.22	**1.13**	1.42	**1.28**
Angle of p_{max}	39.2	**53.7**	22.1	**26.5**	27.9	**27.2**
Ploss [kW]	2.40	**2.56**	2.34	**2.35**	2.35	**2.33**
*Ds.p. * [m]*	0.0744	**0.170**	0.00	**0.0315**	-0.0417	**-0.0162**
Ecc ratio	0.594	**0.506**	0.346	**0.301**	0.141	**0.106**
Att angle	48.31	**38.45**	37.34	**35.41**	30.90	**30.29**

Table 1. Computation results for: S = 0.0618 and Ψx = 0.3
** Ds.p. = Distance of Support Point from L/2 [m]*

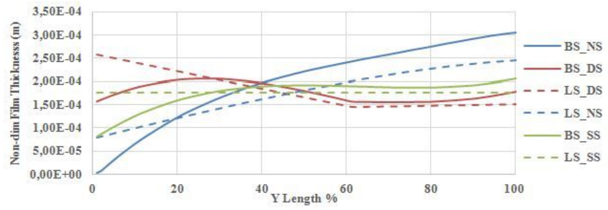

Fig1. Non-dimensional Film Thickness on the longitudinal direction, for (a) no slope, (b) single slope and (c) double slope bearing design.

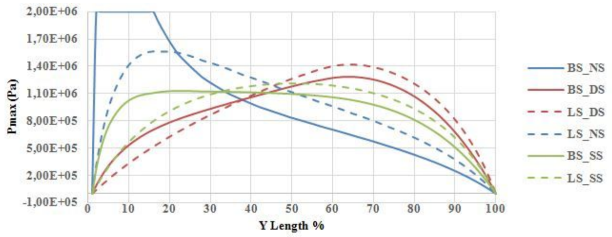

Fig2. Maximum pressure on the longitudinal direction, for (a) no slope, (b) single slope and (c) double slope optimized bearing design.

4. CONCLUSION

The effect of bent shaft modeling, in comparison to linear shaft modeling, was significant. Both the single and the double slope optimum designs improved the performance of the bearing by increasing the minimum film thickness and decreasing the maximum pressure. The double slope design altered the longitudinal location of the H_{min} position, by increasing significantly the pressure distribution towards the fore end of the bearing. The distance of the actual, one-point, support location from the bearing center was small in absolute size but positive for the double slope design (fore direction) and negative for the single slope one. Last but not least, a slight decrease on the lift of speed was observed in the double slope model.

5. REFERENCES

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