Comparison of Surrogate Models for Modeling Island-Type Hydrostatic Bearings

Nenzi Wang$^{1*}$, Shih-Hung Chang$^1$ and Hua-Chih Huang$^{2*}$

$^1$Department of Mechanical Engineering, Chang Gung University, Taiwan
$^2$Mechanical and Systems Research Laboratories, Industrial Technology Research Institute, Taiwan
Corresponding author: nenzi@mail.cgu.edu.tw

1. Introduction

A suitable surrogate model can be used to replace computationally intensive numerical models for quick solution. An effective surrogate model, therefore, can be applied in many tribological applications, such as representing the bearing performance (load capacity is obtained by integrating the film thickness). The corresponding load carry capacity of the input data set is $1.2$. The orifice diameter is the most sensitive factor [1]. The use of bilinear or bicubic interpolation as a surrogate model is straightforward. However, the performance of various ANNs can be much different [2]. As a result, several configurations of ANNs were tested and the result obtained by the best ANN is listed in Table 1. Also, the poor performance of RSM as a surrogate model is clearly shown in the same table.

2. Island-type hydrostatic bearing

Fig. 1 shows the schematic diagram of an island-type hydrostatic bearing. The width of the bearing is $B$. The recess size is $b$. The channel width of the recess is $a$ and the diameter of the orifice is $d$. The film thickness is $h$. The recess pressure is $P_r$ and the supply pressure is $P_s$. The bearing performance is affected by the aforementioned factors and among them the orifice diameter is the most sensitive factor [1]. The load capacity is obtained by integrating the film pressure obtained from the Reynolds equation. In order to have a converged solution, an accurate $P_r$ is required for a given film thickness. As a result, an iterative solution of Reynolds equation was conducted.

3. Surrogate models

The surrogate models compared in this study are bilinear interpolation, bicubic interpolation, artificial neural network (ANN), and response surface methodology (RSM) of second-order. The design factors are the orifice diameter and the film thickness. The input data set used to prepare the surrogate models is uniformly sampled in the design space. The corresponding load carry capacity of the input data set is then obtained from the numerical model of the bearing. To verify the accuracy of a model, a set of validation data is uniformly generated from the numerical model of the bearing. And the accuracy of a surrogate model is determined by the root-mean-square error (RMSE).

4. Results

Figure 2 shows the load carry capacity of the bearing. The range of the orifice diameter is 0.5 mm to 1.5 mm and that of the film thickness is 30 $\mu$m to 80 $\mu$m. The grid size of the input data is 20 by 20 and that of the validation data is 100 by 100. Table 1 shows the accuracies of the surrogate models. Using the ANN can obtain the lowest RMSE. And the worst result is obtained by using RSM.

5. Discussion

The use of bilinear or bicubic interpolation as a surrogate model for modeling island-type hydrostatic bearings is a promising approach. However, the performance of various ANNs can be much different. As a result, several configurations of ANNs were tested and the result obtained by the best ANN is listed in Table 1. Also, the poor performance of RSM as a surrogate model is clearly shown in the same table.

6. References