Advances in Engineering Software 123 (2018) 13–24

Contents lists available at ScienceDirect

Advances in Engineering Software

journal homepage: www.elsevier.com/locate/advengsoft

Optimizing presetting attributes by softcomputing techniques to improve tapered roller bearings working conditions

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ARTICLE INFO

Keywords:
Data mining classification techniques
Finite elements method
Design of experiments
Model parameter tuning and evaluation
Double-row tapered roller bearing

ABSTRACT

Double-row Tapered Roller Bearings are mechanical devices that have been designed to support a combination of loads that are fixed on an optimal presetting to ensure correct working conditions. The emergence of high contact stresses, fatigue spalling and pitting on the bearing railway makes it important to have a tool that enables knowing in advance whether certain presetting loads will lead to excellent working conditions or the opposite. This work proposes a methodology to classify the working condition on the basis of the values of presenting loads on four classes. To achieve this goal, a three-dimensional Finite Element (FE) model was generated. Later, a design of experiments was designed to provide the greatest amount of information by reducing the computational cost of the simulations based on FE models. Then, one of the four classes of working conditions was assigned to each of the experiments. Later, a statistical analysis and machine learning techniques were used to create classification models. Feature transformation and reduction, algorithm parameter tuning and validation methods were used to achieve robust classification models. The best results were obtained based on flexible discriminant analysis. As it provided acceptable accuracy, both the methodology and final model were validated.

1. Introduction

Double-row Tapered Roller Bearings (TRBs) are designed to support the preload (P), axial load (F_a), radial load (F_r) and torque (T) in static and dynamic conditions. TRBs are formed by a pair of inner raceways with a gap of width that are separated by a gap of constant width (δ) between them, an outer raceway and a set of tapered rollers. The gap that separates the inner raceway into two equal parts enables the TRB to be disassembled for maintenance, as well as to be able to apply P. F_a, F_r and T are applied on the outer raceway. The tapered rollers form two columns between the inner and outer raceways. This combination of loads produces contact stresses (S) and local deformations (α) on the bearing raceways, as well as its own rotation and a variation of δ, that are very difficult to predict and validate experimentally. In addition, if the combinations of loads on the TRBs differ from the manufacturer's recommended values, the bearing may malfunction. For example, the combination of a greatly reduced P and a very high F_r and T, could create an S in excess of 1000 MPa and significant local deformations (α_{max}) on the raceway. This could cause harmful defects like pitting and fatigue spalling [1]. In addition to these undesirable tribological problems, a reduced P may cause result in greater stresses in some contact areas of the outer raceway. This could cause the rollers to disengage from the outer raceways [2]. Thus, determining the optimal combination of loads on mechanical devices of this type is normally undertaken by analytical techniques or, alternatively numerical methods like the Finite Element Method (FEM). Although using the FEM provides obvious advantages, it does have some disadvantages. They include high computational expense, especially when the Finite Element (FE) model involves problems in mechanical contact, large displacements and material nonlinearities. A major drawbacks in using FEM for problems of mechanical contact is the mesh size and convergence of the model. Then, if the contact surface between the tapered rollers and raceways is reduced and the mesh size between the two contact bodies is large, the calculation of the contact stresses will be inaccurate [3]. Following this approach, some researchers [4,5] analyzed the influence of the mesh size of the contact bodies on the contact stresses between tapered rollers and raceways when several P and F_r were applied. It is well know that using FEM in isolation (i.e., without

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https://doi.org/10.1016/j.advengsoft.2018.05.005
Received 8 February 2018; Received in revised form 3 May 2018; Accepted 13 May 2018
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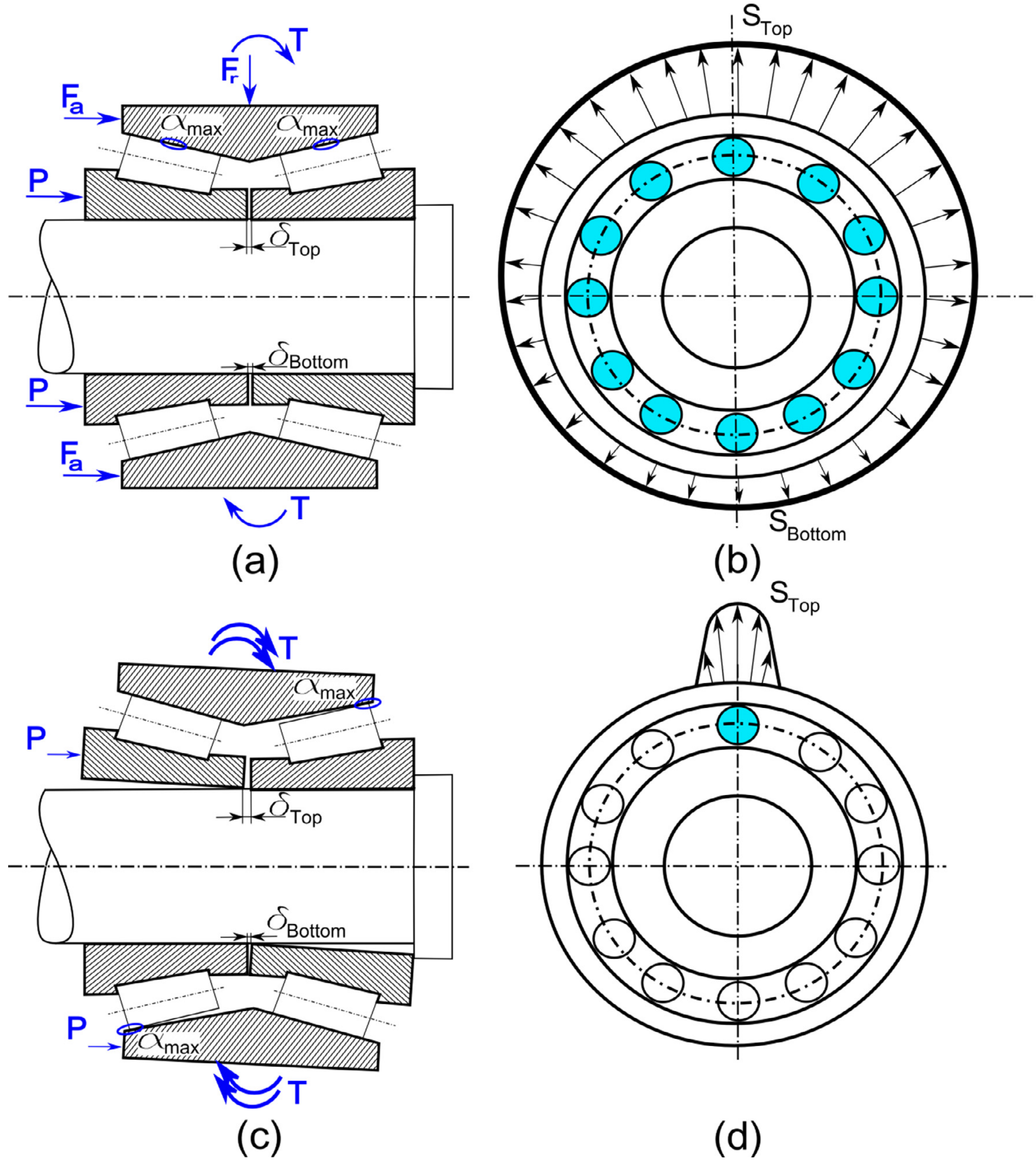

Fig. 1. Main components and the loads on the studied TRB when the external loads on it have standard values: (a) Values of gap δ_{top} and δ_{bottom} that are similar. (b) Contact stress distribution on the outer raceway when there is no roller takeoff. The external loads on the TRB have values that are correct: (c) Different values of gap δ_{top} and δ_{bottom}. (d) Outer raceway contact stress distribution when there is roller takeoff [1].

soft computing or Data Mining (DM) techniques) for a design to optimize the operating conditions or predict bearing failures involves a computational cost that is unacceptable. For example, to predict the distribution of contact stresses on a hub that was mounted on a double-row TRB, Lostado et al. [6] used various types of regression models on the basis of DM techniques. The distribution was determined as a function of *P*, F_r and the friction coefficient. The regression models obtained could be used as viable alternatives in the design phase of this type of mechanical device. Also, Lostado et al. [7] used a combination of FEM and DM to determine the maximum load capacity of double-row TRBs in order to optimizing the operating conditions of these devices. In this case, the work focused on finding a combination of input loads (*P*, F_a, F_r and *T*) in which the contact stress ratio of both rollers rows was close to 25%, and F_r was the maximum. Other researchers have used classification techniques based on machine learning methods in order to determine in advance the failure and malfunction of bearings. Most of these works that are based on classification techniques for predicting bearing failure have been based solely on experimental data. For example, for a fault diagnosis of roller bearings, Sugumaran et al. [8] used a decision tree and a kernel-based neighborhood score, multi-class, Support Vector Machine (SVM). In this case, the conditions of the roller bearings that were studied had good bearing, bearings with inner race faults, bearings with outer race faults, and bearings with inner and outer race faults. Other authors including Gryllias and Antoniadis [9] used SVM approach for an automated diagnosis of rolling bearing fault detection. The effectiveness of this method produces promising results and has the potential use in fault diagnosis of rolling bearings. More recently, Kankar et al. [10] used artificial neural networks (ANN) and SVM to detect and diagnose mechanical faults in ball bearings. The vibration response that was obtained and analyzed for the various