International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

A Review on Design Optimization of Rolling Contact Bearings

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Accepted 07 May 2017, Available online 13 May 2017, **Vol.7, No.3 (June 2017)**

Abstract

This paper represents a review on modification of Rolling contact bearing design using different optimization techniques. Most widely Rolling bearings are used in Construction Equipment, Traction Motors, Electric Motors, Pumps and Compressors, Plastic Forming Equipment, Blowers and Fans, Coal Pulverizers, Heavy Equipment, Machine Tool Spindle, Calender Rolls of Paper Making Machines, Printing Presses, Crushers, Table Rollers for Steel Mills, aero-space machines, etc. Rolling bearings are weakest components in any machine unit which impacts its remaining life. While designing of rolling bearings it has to satisfy various constraints while delivering excellent performance and long life. The two main primary objectives for rolling bearings, namely radial load capacity and rating life has been considered. All design variables corresponding to bearing geometry are considered. For efficient discrete optimization the nonlinear constrained optimization problem has been solved by using algorithms. Optimization is used to get optimum mechanical design and it will be revealed from comparing the methods of algorithms by satisfying all design constraints.

Keywords: *Optimization; Rolling contact bearings; Algorithms; Optimum mechanical design*

1. Introduction

Nowadays peoples are getting more conscious about effects on global environment which causes by use of natural resources. There are increasingly demands for improved fuel economy for its industrial and other engineering applications. There are needs arising for reduced running torque, weight and size for rolling contact bearings used in different mechanical applications. So bearing companies are trying to improve its design techniques for this main purpose (Daisuke Imada, *et al*, 2011).

Bearing used in engineering applications needs to meet various demands including rigidity, bearing life and safety factors. For improved fuel consumption bearings need to be overcome all needs by achieving lower torque and decreased weight and size for better design point of view (Tsujimoto T., *et al*, 2005).

To satisfies all needs for bearing design a methods of trial and error are repeatedly applied to the process of designing. This developing process of designing takes a lot of time and even cost more. There may be some cases where requirements of all design parameters is not satisfies under some conditions like size and weight. So it very difficult to establish a perfect bearing design that satisfies all requirements under combined loading (Kanamoto T., *et al*, 2007).

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As rolling contact bearings are widely used in engineering applications in field of Nano- micro machines, automotive, space technology, aeronautical applications, house hold appliances etc. the design engineers had come up with new design techniques to develop rolling bearings. So to get improved design there is need for optimization (Shantanu Gupta, *et al*, 2007).

In field of CAE, optimization analysis has been more commonly used recently (Nagatani H., *et al*, 2005). For optimization analysis to previous design problems all parameters which are important are set as constraints and there are objectives functions which are defined for minimum torque, long life, minimum size and high rigidity (Daisuke Imada, *et al*, 2011).

2. Basic Terminology of Rolling Bearings

2.1 Characteristics of rolling bearings

Rolling bearings comes in different forms and varieties with its own unique features. Rolling bearings have advantages when compare with sliding bearings they are as follows:

- Low starting friction coefficient.
- Easily interchangeable and readily available.
- Easy to lubricate and requires less lubrication.
- It can carry high radial load and some light amount of axial loads.

- It can be used in all temperatures applications.
- By preloading bearing rigidity can be improved.

2.2 Loading conditions

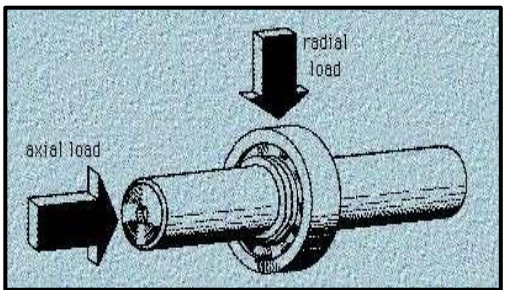

Fig.1 loads acting on rolling bearing

Rotary bearings can handle both radial loads and axial loads as it's shown in fig.1. Both load can act together or separately. Ball bearings make a narrow path of contact with both races so it can handle medium radial load and light axial loads. Cylindrical roller bearings have a wider contact with both races so it can handle high radial load but it's usually not preferred where axial load is high.

2.3 Cylindrical roller bearings

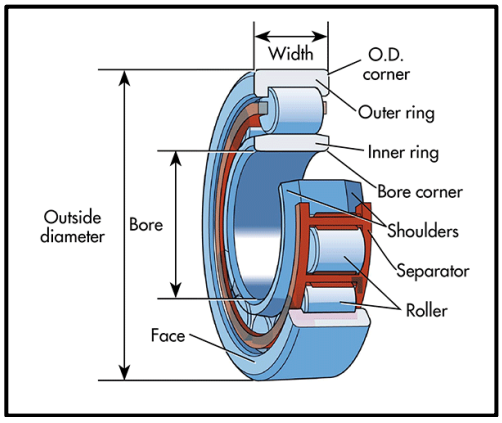

Fig.2 Basic type of cylindrical roller bearing

Cylindrical roller bearings have high radial load capacity upto 60% compared with ball bearings of the same size, it is because of the roller and both raceways are in line contact. That make them very suitable for applications where long life and high reliability is needed in conditions where impact loads and heavy radial loads acts. Due to its simplified structure when machined accurately then it can be used in high speed applications. Rolling bearings without cages with full complement show high loading capacities however, roller bearings with cages can be used for higher speeds. Guiding collars on inner and outer rings of bearings can withhold higher axial forces and also it allows some axial misalignment of the rings. Cylindrical roller bearings requires perfect alignment, the maximum allowable tilting angle is 3-4'. Basic type of single-row cylindrical roller bearing is shown in Fig. 2. Bearings having separable inner and outer rings can be easily mounted and dismounted. These bearings also needs less lubrication.

3. Need of Work

The main purpose of design optimization of rolling contact bearing is to increase its bearing life and its high reliability. These factors are improved by considering the parameters of radial load capacity and rating life of bearings and hence it will affect indirectly to other parameters and will able to reduced running torque, size and weight for rolling bearings etc. To achieve this lot of research is going on to get optimum design of rolling bearing. By modifying and optimizing its design by using algorithm techniques, that can improve its radial load capacity values and thus it can also reduce its forces acting on bearing surfaces which acts in radial and axial directions. Analysing and validating obtain results from that it can get optimal design solutions which will increase its bearing efficiency and also it will reduce its power losses and speed losses which occurred during transmissions.

4. Literature Review

Literature Review has been carried out to study the present status of bearings and its development in new bearing designs, and hardly any paper is available on the optimization of rolling contact bearings.

(Daisuke Imada, *et al*, 2011) has introduced a new optimization system which is unique in bearing design which improves bearing torque. This system will also improve size, life, weight and rigidity parameters. By this system time required for design is been also reduced. Due to this new process there would be no need of high experienced designer for designing of bearings.

(Shantanu Gupta, *et al*, 2007) has proposed a new procedure for the optimisation of bearing design. The optimisation problem are in nonlinear and multi-objectives nature. Objective functions are taken as Static capacities, dynamic capacities and the elasto-hydrodynamic minimum thickness. All Constraints are kinematics in nature. The non-dominated sorting based genetic algorithm (NSGA II) has been applied to solve design problem.

(Lucian Tudose, *et al*, 2011) has presented a report on RKB Advanced Calculations and its achievements. The optimal design and conventional design differences are pointed out in simplified manner. Multi–objective optimal design via Evolutionary Algorithms technique has been used for optimization of cylindrical roller bearing.

(Vikas Waghole, *et al*, 2014) have proposed different methods like the artificial bee colony algorithm, differential search algorithm, grid search method, and a novel hybrid method for optimizing needle roller bearing design. The dynamic capacity is

considered as objective functions. From Comparison of all methods Optimum designs it is seen that the hybrid method gives the best optimal value. Also convergence study is carried out to ensure the global optimum in the design. The fatigue life has been found to be improved than catalog life values also there is increase in the dynamic capacity.

(B. Rajeswara Rao, *et al*, 2007) has presented a Genetic algorithms optimization procedure for designing rolling bearings. Fatigue life has been considered as objective function. The design variables are bearing pitch diameter, number of rolling elements, the rolling element diameter and inner and outer-race groove curvature radii are taken into consideration. Fatigue life of the optimized design parameters have found to be improved than those listed in catalogues.

(Seung-Wook Kim, *et al*, 2016) have done research on a non-standard angular contact ball bearing of a grinder and it was optimized using a design optimization technique. The main aim was to maximize both the radial stiffness and axial stiffness of the bearing. Eight constraints are considered and six geometric variables and an axial preload were considered as design variables. All design variables were discrete so it should able to manufacture.

(Morteza Najjari, *et al*, 2015) has proposed that for uniform contact pressure distributions in bearing, the crowning modifications are needed and some changes in rounded corners. This paper also present a formulas for rapid design of optimal crowning profile corrections with rounded corners. Due to this process it maximizes the load capacity and make a constant film thicknesses. The developed formulas amalgamate effective results obtained from multi-objective particle swarm optimizations completed over a five-level dimensionless factorial design, with the factors being the slenderness and the load completed by the lubricant viscosity. The resulting design tool allows avoiding time consuming optimization procedures.

(S. Panda, *et al*, 2015) has proposed a use of method of a hybrid optimization algorithm PSO-TLBO and along with PSO. Its performance is compared by experimentation. The hybrid algorithms results show better performance over other optimization algorithms like GA and PSO.

(Feng Jilu, *et al*, 2016) has presented an optimized angular contact ball bearings results on the combination method of the Kriging model and PSO. By using these methods the design efficiency of the bearing can be improved and also number of design points are previously taken in consideration are reduced by these methods. The angular contact ball bearing NSK-7016A5 has been taken for experimentation in this method of work. The reduction in heat generation of the bearing is observed due to application of this methods.

(E. Dragoni, *et al*, 2015) in this report the tapered roller bearings are been optimized. Main objectives was to maximum static load capacity. Free optimization technique is considered in this process of work.

(Meduri Kalyan, *et al*, 2016) has worked on the multi-objective optimization techniques for Needle Roller Bearings. The two main objectives are the dynamic capacity and the elasto-hydrodynamic minimum film thickness are taken into consideration to optimize. Optimization problem has been solved using NSGA-II. The advantage of this methodology is that it can be used to design new non-standard bearings. Increase in life of bearings due to this method is observed.

(Indraneel Chakraborty, *et al*, 2003) have presented a method to solve the design optimization problem on ball bearings by using genetic algorithms. Due to this methods it's basically a guided by random search, so there is less chances of getting trapped in local maxima or minima values. The method has improved performance than those mentioned values in standard catalogues.

(Yao Qishui, *et al*, 2016) has studied a new Design Method for a New Type of Cylindrical Roller Bearing using genetic algorithm. Which is based on Edge Effects and two variables are considered in this process of design.

(K. Sunil Kumar, *et al*, 2009) has proposed a procedure for the optimization of the cylindrical roller bearing by consideration of logarithmic profiles of rollers. The design optimization is done using real-coded genetic algorithms. Fatigue life of bearing is taken as the main objective function and Constraints are mainly based on strength and geometrical parameters.

(K. Sunil Kumar, *et al*, 2008) has presented in this paper, a procedure for the optimization of the cylindrical roller bearing design by using real-coded genetic algorithms. Fatigue life of the bearing is taken as main objective function. The nominal diameter of roller, effective length of the roller, pitch diameter of the bearing and number of rolling elements are parameters which are selected for design optimization. The five design constraint are taken into considerations.

Conclusions

This paper gives short overview about need of the design optimization techniques on rolling contact bearings. As the bearing industry remained somewhat outside the concerns of professional workings in the field of optimization, there is hardly any research done on rolling contact bearings. But In last two decades the numbers of scientific papers have deals with an optimal design of bearings by using different types of optimization algorithm techniques. Although the revealed results have made us more confident, then also there is less research work done on optimal design of bearings. This study shows that there is necessity of optimization for getting optimal design of bearings to achieve goals for high performance bearings which will have high load capacities, low weight, low friction losses and high resistance to wear. These can be only accomplished by use of optimization algorithms

techniques which are robust, flexible and easy to solve and also able to give best solutions in less period of time than any other conventional techniques. In short this review concludes that the method of optimization using algorithms helps us to shorten the time period required to optimize bearing designs.

References

Daisuke Imada, Tsuyoshi Niwa, Takashi Ueno, Tomohisa Uozumi, (2011), Development of A System For Rolling Bearing Design Optimization, *NTN Technical Review,* vol. 79.

Tsujimoto, T., Mochizuki, J., (2005), High Capacity Tapered Roller Bearings-Super Low Torque, High Rigidity Tapered Roller Bearings, *NTN Technical Review,* vol. 73.

Kanamoto, T., Ueno, T., Katayama, A., Satou, M., (2007), Transmission Technology Trends and Product Developments, *NTN Technical Review,* vol. 75.

S. Gupta et al., (2007), Multi-objective design optimization of rolling bearings using genetic algorithms, *Mechanism and Machine Theory,* vol.42, pp. 1418–1443.

Nagatani, H., Niwa, T., (2005), Application of Topology Optimization and Shape Optimization for Development of Hub-Bearing Lightening, *NTN Technical Review,* vol. 73.

Lucian Tudose, Cristina Stanescu, (2011), Optimal Design of Rolling-Contact Bearings via Evolutionary Algorithms, *RKB Technical Review*.

V. Waghole, R. Tiwari, (2014), Optimization of needle roller bearing design using novel hybrid methods, *Mechanism and Machine Theory,* vol. 72, pp. 71–85.

B.R. Rao, R. Tiwari, (2007), Optimum design of rolling element bearings using genetic algorithms, *Mechanism and Machine Theory,* vol. 42, pp. 233–250.

S.-W. Kim et al., (2016), Design optimization of an angular contact ball bearing for the main shaft of a grinder, *Mechanism and Machine Theory,* vol. 104, pp. 287–302.

M. Najjari, R. Guilbault, (2015), Formula derived from particle swarm optimization (PSO) for optimum design of cylindrical roller profile under EHL regime, *Mechanism and Machine Theory,* vol. 90, pp. 162–174.

S. Panda, S.N. Panda, P. Nanda, D. Mishra, (2015), Comparative Study on Optimum Design of Rolling Element Bearing, *Tribology International* .

Feng Jilu, Sun Zhili, Sun Hongzhe, (2016), Optimization of structure parameters for angular contact ball bearings based on Kriging model and particle swarm optimization algorithm, *Proc IMechE Part C: J Mechanical Engineering Science,* pp. 1–11.

E. Dragoni, (2015), Optimal design of paired tapered roller bearings under centered radial and axial static loads, *Mechanics & Industry,* vol. 16, pp. 604.

Meduri Kalyan, Rajiv Tiwari, (2016), Multi-objective optimization of needle roller bearings based on fatigue and wear using evolutionary algorithm, *Proc IMechE Part J:J Engineering Tribology,* vol. 230, no. 2, pp. 170–185.

Indraneel Chakraborty, Vinay Kumar, Shivashankar B. Nair & Rajiv Tiwari, (2003), Rolling element bearing design through genetic algorithms, *Engineering Optimization,* vol. 35, no. 6, pp. 649-659.

Yao Qishui, Yang Wen, Li Chao and Yu Jianghong, (2016), A Design Method for a New Type of Cylindrical Roller Bearing Based on Edge Effect, *The Open Mechanical Engineering Journal,* vol. 10, pp. 98-108.

K. Sunil Kumar, Rajiv Tiwari, P. V. V. N. Prasad, (2009), An Optimum Design of Crowned Cylindrical Roller Bearings Using Genetic Algorithms*, Journal of Mechanical Design,* vol. 131, pp. 051011-1.

K. Sunil Kumar, Rajiv Tiwari, and R. S. Reddy, (2008), Development of an Optimum Design Methodology of Cylindrical Roller Bearings Using Genetic Algorithms, *International Journal for Computational Methods in Engineering Science and Mechanics,* vol. 2008, no. 9, pp. 321–341.