OPTIMUM DESIGN OF ROLLING ELEMENT BEARING USING TLBO ALGORITHM

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Abstract

This project represents the 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, aerospace 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

1.0 Introduction

NRB was incorporated in 1965 as an INDO-FRENCH venture with Nadella and pioneered the production of needle roller bearings in India. Today over 90% of vehicles on Indian roads run on NRB parts. It is India largest needle and cylindrical roller bearings producer head quartered in Mumbai. Its eight manufacturing facilities in India and Thailand produce needle roller bearings , special ball bearings The company setup a state of the art engineering and design centre at its manufacturing unit in thane in 2000.Today the facility has testing, validation and benchmarking capabilities.NRB acquired SNL Bearings in June 2000. Over the years NRB has expanded to five modern manufacturing facilities producing needle, spherical, cylindrical, wide–inner ring bearings, tapered roller bearings and ball bearings.

Manufacturing process of needle roller bearings:

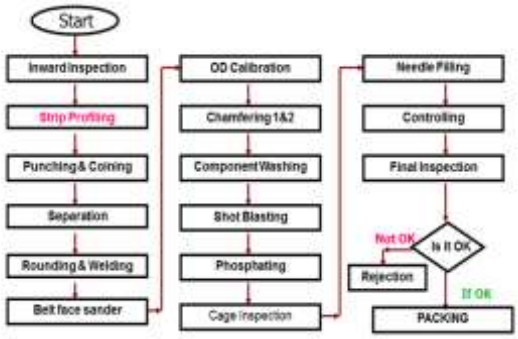

Figure 1.1 Manufacturing Processes of Needle Roller Bearings

Introduction to needle roller bearings:

Needle roller bearings have relatively smaller diameter cylindrical rolling elements whose length is much larger than their diameter.They serve also as a ready replacement for sliding bearings.The difference between a needle roller bearing and a roller bearing is the ratio of diameter and the length of the roller of a roller bearing is between the intervals of 0.1 to 0.4, that roller bearing is called a needle roller bearing.

Additional clarification of needle roller bearings:

According to "Marks' standard handbook for mechanical engineers', a needle bearing is a roller bearing with rollers whose length are at least four times their diameter. The surface area of the rollers and the high number of rolling, load – bearing elements provide needle roller bearings with exceptional load capacity and stiffness. All needle roller

bearings require some type of lubricant to help dissipate heat and reduce friction. This includes applications in which the bearing rotates at less than 10 rpm, has slow oscillations, or may experience points of rest. Operating temperature is the temperature range in which the bearing may be used.

Needle roller and cage assembly:

This assembly, a major component of a needle roller bearing, comprises needle rollers and a cage to support the rollers. Using the shaft and housing as raceway surfaces reduces the cross-sectional height: it is equal to the diameter of the needle roller bearing. This structure eliminating the outer and inner rings allows the bearing to be fitted more easily. The assembly is available in both single-row and double-row configurations. As long as the tolerance limit of the shaft and housing is satisfied, the radial internal clearance can be made adjustable.

.**Figure: roller and cage assembly**

Needle roller and cage assembly for connecting rods

This assembly, a major component of a needle roller bearing, comprising needle rollers and a cage to support the rollers, is used typically for connecting rods in reciprocating compressors and small- and mid-sized internal combustion engines such as those for motorbikes, light cars, outboard motors and versatile engines. This assembly features such a cage that is specifically optimized for severe operating conditions involving high impact loads, complicated motions, high speed revolution and/or high operating temperatures.

Needle roller and cage assembly for largeend:

This assembly, subjected to a cranking motion with a simultaneous action of the rolling elements' rotation and revolution, must be light but have a high rigidity, and must have a precise dimension of the outer diameter of the cage so that the guiding system can keep an appropriate gap. The cage is made of high-tensile special steel with a surface hardening treatment. The guiding system employed is an outer diameter guiding system.

Figure: roller and cage assembly for largeend

Machined ring needle roller bearings:

This bearing type comprises a machined outer ring and machined needle rollers, and a cage to guide properly the needle rollers. In the case of this bearing, the cage or the needle rollers are guided by the ribs of the outer ring or the face ring. Hence, this bearing is non-separable type. In addition, the type with no inner ring is also available for enabling a shaft to be used as the raceway surface. (Of course, the type with inner ring is available). Selectively available for both of the metric system and the inch system

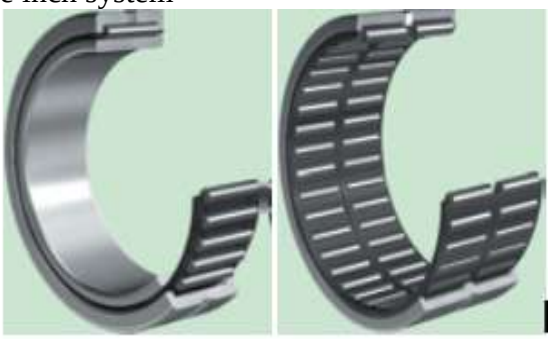

Figure: machined ring needle roller bearings

Applications:

Unlike rolling element bearings which are designed with finite lives in mind, plain bearings relying on full fluid lubrication are theoretically capable of running indefinitely and are used in very critical applications where failure of bearings might have severe consequences. Examples include many of the dozens of kinds of turbo machines, such as power plant steam turbines, compressors operating in critical pipeline applications, etc. Plain bearings are also frequently used in low speed shafting application such as ship propeller shafts. As mentioned, they are used almost exclusively in engines. Plain bearings also excel at the other end of the spectrum due to their low costs and simplicity, and are also well suited to intermittent motion applications and, of course, to linear motion.

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

2.0 literature review

Ueno, TomohisaUozumi, (2011),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. 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 has proposed a new procedure for the optimization of bearing design.

Tsujimoto, T., Mochizuki, J., (2005),have found new efficient optimization method, called „Teaching–Learning-Based Optimization (TLBO)", is proposed by them for the optimization of mechanical design problems. They tested on five different constrained benchmark test functions with different characteristics, four different benchmark mechanical design problems and six mechanical design optimization problems which have real world applications. has proposed an optimization method called Teaching–Learning-Based Optimization for large scale non-linear optimization problems for finding the global solutions.

Katayama, A., Satou, M., (2007),have considered mathematical models of three important casting processes namely squeeze casting, continuous casting and die casting for the parameters optimization of respective processes. They described each process with a suitable example which involves respective process parameters Has introduced and applied for the multi-objective optimization of a two stage thermoelectric cooler (TEC). They considered two different arrangements of the thermoelectric cooler for the optimization.

Nagatani, H., Niwa, T., (2005),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.

Methodology

TLBO is nature-based optimization algorithm. The main objective to of this type of algorithm is to solve various optimization problems efficiently. While using this algorithm, assumption can be taken as nature"s behavior is always optimal. TLBO is a population based method. It uses number of solutions to find the global optimum solution. In TLBO,

population is a class of students. In optimization methods, the population is made of various design variables. In this method, design variables are taken as different

Implementation of TLBO technique:

Step by Step Procedure The procedure for implementation of TLBO technique for Deep Groove Ball Bearing is as follows:

Step 1: Select any bearing & specify the following parameters of that bearing

D = Outside Diameter d = Bore Diameter

di = Inner ring ball race

Diameter do = Outer ring ball

race Diameter ri = Curvature radius of inner raceway groove

ro = Curvature radius of outer raceway groove

w = Width Dsign variables are diameter of the balls (Db), mean diameter (Dm) and number of balls (Z). 2)

Optimization Problem of Deep Groove Ball Bearing:

On the basis of the requirements of particular application, different objective functions for Deep groove ball bearings may be proposed; the most important of these is the requirement of the longest fatigue life of bearing. In normal operating conditions fatigue failure is the main mode of failure in rolling element bearings. If a bearing is clean and properly lubricated, is mounted and sealed against the entrance of dust and dirt, maintained in this condition, and operated at reasonable temperatures, then the metal failure will be the only cause of failure. Metal fatigue implies many millions of stress applications successfully endured, we need a quantitative life measures.

Inner ring:

For the needle roller bearings, usually a shaft is used as the raceway surface, but this inner ring is used where the shaft surface cannot be machined to the specific hardness and roughness. This inner ring is suited to space-saving design due to its low section height. This is made of high carbon chrome bearing steel, finished by high precision grinding after heat treated.

Figure: inner ring

Thrust roller bearing:

This bearing comprises needle rollers or cylindrical rollers, a cage to guide and retain properly the rollers, and disc-shaped rolling bearing ring. This is a bearing capable of supporting one-way axial load. Furthermore, this bearing can be used without rolling bearing ring, where the heat treated and ground bearing mount surface can be used as the raceway surface.

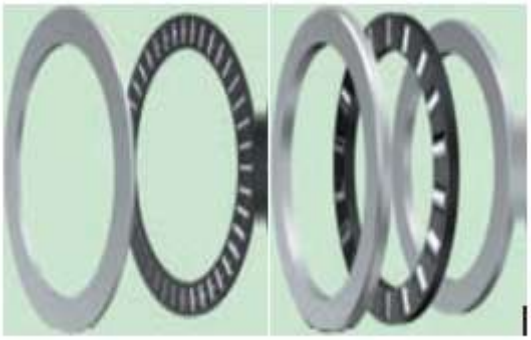

Figure: thrust roller bearing

Components:

The components described hereunder are for needle roller bearing. There are many different design types of needle roller bearings. Some may just contain a series of rollers in a cage

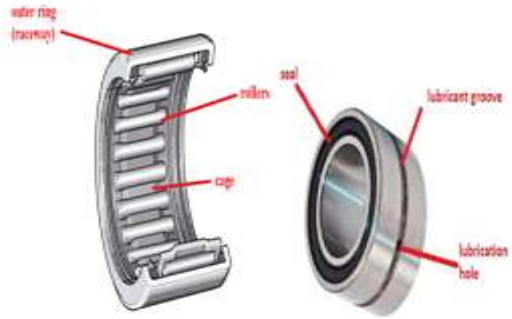

Figure:components

Needle rollers:

The needle rollers with flat end face and round end face are standard. These rollers are made of high-carbon chrome bearing steel, surface-finished by grinding and buffing after heat-treated. The standard accuracy of these rollers is "Precision Grade". A-Inter-diameter tolerance of the needle rollers is 2mm maximum. The roller type with crowned rolling surface is also available, which can damp edge load. These needle rollers are supplied as an individual for applications (pin, shaft) other than rolling element.

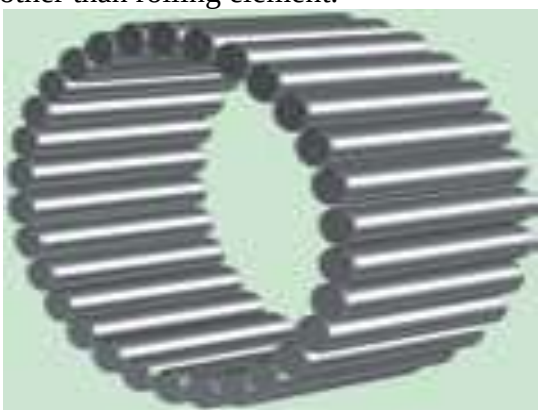

Figure: needle rollers

Lubrication:

Lubrication (not pictured above) is required for all needle roller bearings. Annular grooves and a lubrication hole are may be incorporated into the outer ring of most heavy-duty, machined needle roller bearings raceways to help the lubricant proliferate the circumference of the bearing.

1. Synthetic oils are most common for quality bearings. Mineral oils are appropriate for high-speed use. Synthetic oils are good for moderate to high speeds. Petroleum exhibits good lubrication under heavy-load/high-speed conditions. Silicone oils offer good heat resistance and do not corrode rubber, but are more appropriate for low speeds. Oils can be dripped, centrifuged, or impregnated into bearings.

Applications of needle roller bearings:

The general design trend today emphasizes continued reduction in weight, space, and energy consumption. With their light weight and thin cross section, needle roller bearings provide a compact solution to frictional problems.

Table: journal bearing ISO viscosity grade selection

Bearing Speed	Bearing / Oil Temperature (°C)			
(rpm)	0 to 50	60	5	90
300 to 1,500	-	68	100 to 150	-
~1,800	32	32 to 46	68 to 100	100
~3,600	32	32	46 to 68	68 to 100
~10,000	32	32	32	32 to 46

Bearing materials:

The bearing industry uses different materials for the production of the various bearing components. The materials are processed to achieve desirable properties to maximize bearing performance and life. The materials described here are the most commonly used. Since the rolling elements and the races are subjected to high local stresses of varying magnitude with each revolution of the bearing, therefore the material of the rolling element (*i.e.* steel) should be of high quality. The balls are generally made of high carbon chromium steel. The material of both the balls and races are heat treated to give extra hardness and toughness.

AISI316Austenitic Stainless Steel:

Bearing components made from 300 series stainless steel materials have greater corrosion resistance and are non-magnetic because of the low carbon content. However, the tradeoff is that this material cannot be hardened so the bearings can only operate under low loads and speeds. The surfaces of the bearing undergo a chemical reaction with the oxygen called a passivation process; the passive film developed on the surface protects the bearing from corrosion

4.0 Results

TLB algorithm is a newly developed advanced optimization algorithm. It consists a single phase process and quite simpler to apply but gives good results. This algorithm is based on the concept of moving the optimum solution of a problem

closer to the best solution and moving away from the worst solution. The algorithm can be applied in both constrained and unconstrained type optimization problem. This algorithm requires only some common control parameters and does not require any algorithm specific controls parameter. The description of Jaya algorithm is given below. Consider a problem where f(x) is the objective function which is to be maximized (or minimized). At any number of iteration „i", consider „d" is the number of design variables (i.e. j=1,2,…,d) and „p" be the number of candidate solution (i.e. population size, k=1,2,…p). In the past, rolling bearings were referred to as antifriction bearings, since they have much lower friction in comparison to sliding bearings. Many types of rolling-element bearings are available in a variety of designs that can be applied for most arrangements in machinery for supporting radial and thrust loads. The rolling elements can be balls, cylindrical rollers, spherical rollers, and conical rollers

Design optimization of ball bearing:

On the basis of operating requirements, different objective functions for rolling element bearings may be proposed, the most important of these being the requirement of the longest fatigue. Thus, the basic requirement for a ball bearing is the long fatigue life. In normal operating conditions of ball bearings, the main reason of failure is contact stress. The most frequent failure of bearing is due to surface fatigue or flaking phenomenon. Flaking is a phenomenon of removable of scaly surface particles from the bearing material which is due to surface fatigue that occurs between the rolling elements and the inner and outer rings.

Rolling element bearing design through genetic algorithms:

The design of rolling element bearings has been a challenging task in the field of Mechanical Engineering. Traditional approaches to the design optimization of such bearings have proved to be computationally time intensive and have yielded solutions that are yet to be theoretically proven optimal. While most of the real aspects of the design are never disclosed by bearing manufacturers, the common engineer is left with no other alternative than to refer to standard tables and charts containing the bearing performance characteristics..

Constraint defining the range of geometric design variables of spherical roller bearings:

Constraint 1 is used to find out the number and diameter of balls, for convenience of bearing assembly, first constraint must be satisfied. (= 4.7124 radians) is the maximum tolerable assembly angle which depends upon the bearing geometry. Constraints 2 and 3 are used to choose the bounds of diameter of ball. Constraints 4 and 5 are defined for running mobility of bearings. Bearing pitch diameter of bearing should fall in a certain range. Constraint 6 is defined to take care of thickness of bearing ring at the outer raceway, so that bearing ring not distorted under process of manufacturing and mounting.

Cylindrical roller bearings:

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.

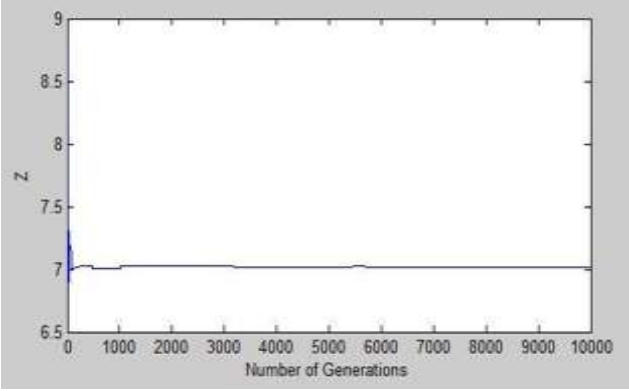

Figure: Variation of no. of balls versus no. of generations for a radial ball bearing

The design of ball bearings of various sizes was optimized using TLBO algorithm and their results compared with genetic algorithm, which obtained by previous researchers. The results obtained using TLBO algorithm is better than genetic algorithm and also fulfilling all necessary constraints. Convergence studies are also carried out and it shows very fast convergence towards than other algorithm. The analysis of the optimized design parameters and variablesindicatesthatD_r,D_m,l_e,Zarethekeyd esignvariables.Furthercasestudiescouldbec arriedoutonother types of bearings. Some more realistic constraints can be introduced for getting more precious result.

Future scope:

Ball bearings will be used for many years to come, because they are very simple and have become very inexpensive to manufacture. Some companies experimented with making balls in space on the space shuttle. In space, molten blobs of steel can be spit out into the air, and the zero gravity lets them float in the air. The blobs automatically make perfect spheres while they cool and harden. However, space travel is still expensive, so a lot of polishing can be done on the ground for the cost of one "space ball".Other kinds of bearings are on the horizon, though. Bearings where the two objects never touch each other at all are efficient to run but difficult to make.

Conclusions:

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 techniquesIn short this review concludes that the method of optimization using algorithms helps us to shorten the time period required to optimize bearing designs the roller bearings used to hey are used in heavy loading applications such as gears, transmission shafts and areas with high axial thrust. Again turning and facing operations are performed using this machine tools. The precision, size, accuracy and tolerances determine the type of equipment to use with CNC be favored for high precision work. They are applied in all internal combustion engines and forms the rotating parts of crank shaft. They are also used in large turbines, motors and heavy machinery where roller and ball types cannot be used. Essentially, this device is made of two rotating parts that slide along each other.

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