OPTIMUM DESIGN OF ROLLING ELEMENT BEARINGUSING 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 Nadellaand pioneered the production of needle roller bearings in India. Today over 90% of vehicles on Indian roads run on NRB partsIt 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 , thrust bearings and other anti-friction solutions such as planetary shafts.Since its inception, NRB has grown beyond its signature product to offer a wide range of high-precision friction solutions in the automotive sector.NRB is the global benchmark for quality and innovative design in high-precision friction solutions. NRB Bearings is a recognized leader in needle roller bearings, conventional cylindrical roller bearings and has developed a new generation of lightweight drawn cup bearings.

Roller bearings:

Needle roller bearings have relatively smaller diameter cylindrical rolling elements whose length is much larger than their diameter. Compared with other types of rolling bearings, needle roller relative to their volume Also, because the inertial force action on them is limited, they are ideal choice for oscillating motion. Needle roller bearings contribute to compact and lightweight machine designs. 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. They are used to reduce the friction of a rotating surface. The typical structure of a needle roller bearing consists of a needle cage which orients and contains the needle rollers, the needle roller themselves, and an outer race.

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.

.**Figure: Roller and cage assembly**

Cup needle roller bearing

This bearing comprises an outer ring and needle rollers, which were both drawn from special thin steel plate by precision deep drawing, and a cage intended to guide precisely the needle rollers. This bearing is the type of the lowest section height, of the rolling bearings with outer ring, best suited to space-saving design. A hardened and ground shaft or inner ring (IR Series) is used as the raceway. This bearing needs no axial locking due to easy installation and press-fit in the housing. The close end type to close shaft end is available in addition to the open end type. Furthermore, the type with seal fitted in at single side or double sides is also available. The standard type comprises a needle roller and cage assembly. In addition to this type, special type comprising full complement rollers is available at option.

Figure: Cup needle roller bearing

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 consequencesPlain bearings are often cast in bronze or pressed in powdered metal and impregnated with oil that provides film lubrication. Plastic bearings in nylon, PTFE, Vespel, etc. are available where the strength and performance of metal bearings are not needed

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

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.

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.

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.

3.0 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. This method is intended to achieve global solutions for continuous non-linear functions with very less number of iterations and high constancy. The method works on the effect of the impact of a teacher on the outcome of students in a class. Outcome is considered as results or grades of students. 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 Design variables are diameter of the balls (Db), mean diameter (Dm) and number of balls (Z). 2)

Step 2: Verify all the parameters of selected bearing using constraint equation g6(X).

Step 3: Find the range of Design variables - Constraint equations g2(X), g3(X) are used to find the range of Db. - Constraint equations g4(X), g5(X) are used to find the range of Dm. - Step 4: Verify all design variables for all constraint equations gn(X) 5) Step 5: Select those variable which satisfies all constraint equations and put values of these variables in Objective function Cd 6)

Step 6: Select those variables which give maximum values of Objective function Cd. 7)

Optimization 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.

Figure: Groove Ball Bearing

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

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

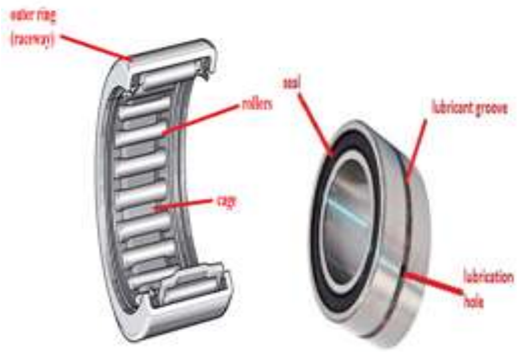

Figure: Components

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.

Forging & Annealing

Forging is a metal shaping treatment that works through the forces of heat and impact to give the desired shape to the metal. The process is performed on SAE 52100 Steel so as to deliver a perfect shape. Anneling is an association of heating and cooling treatment performed on the bearings so as to enhance the ductility of the bearings. This makes the bearings more workable with regards to molding them to any desired shape.

Figure: Bearingforging & annealing

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. 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.

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. Table shows the various optimized design variables of ball bearing obtained through TLBO algorithm and comparison of dynamic capacity obtained using Jaya algorithm with Genetic algorithm obtained by past researchers. The results obtained using Jaya algorithm is found better than other algorithm

Rotary bearings can handle both radial loads and axial loads as it's shown in fig.. 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.

Optimum design of radial ball bearing using TLBO algorithm and comparison with otheralgorithms

D	*d*	D_b (mm)	D_m (mm)	*Z*	f_i	f_o	C_d (GA) (N)	C_d (TLBO) (N)	increment %
30	10	7.85	20.586	7	0.515	0.515	7306.6	8312.722	13.77
35	15	8.00	25.400	8	0.515	0.515	9553.7	10631.9672	11.28
47	20	10.80	34.040	8	0.515	0.515	16213.4	18117.3040	11.74
62	30	12.80	46.640	9	0.515	0.515	25785.0	28158.0334	9.20
80	40	16.00	60.800	10	0.515	0.515	38979.1	43609.0014	11.87
90	50	16.00	70.800	11	0.515	0.515	45161.4	49073.2518	8.66
110	60	20.00	86	11	0.515	0.515	64542.3	71822.0417	11.28
125	70	22.00	98.60	11	0.515	0.515	81701.2	87885.5382	7.57

140	80	24.00	111.20	12	0.515	0.515	95915.9	105237.88	9.71
160	90	28.00	126.40	12	0.515	0.515	121401.9	131190.78	8.06

Convergence study is carried out by plotting graphs between design variables and number of generations. Convergence graph of dynamic capacity of ball bearing shows fast increment in its value, Dynamic capacityattends convergence at 44th generation with a value of 8312.722 N and become constant for rest of generations. shows variation of basic design variable with number of population.

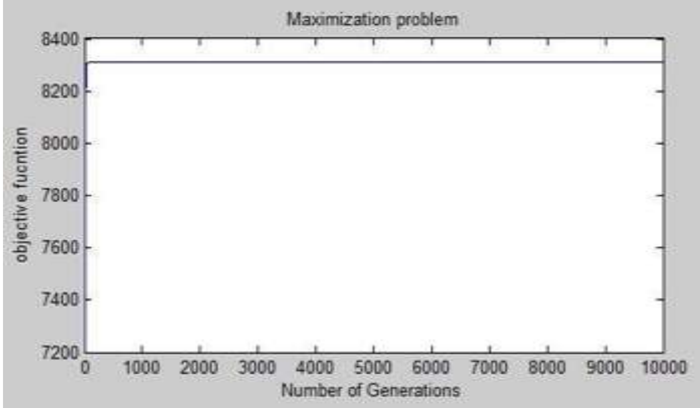

Figure: shows the variation of dynamic capacity with no. of generation for radial ball bearing 6200 series.

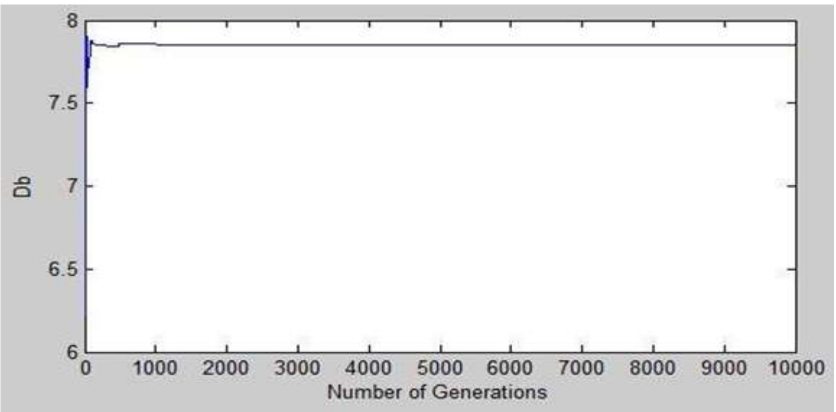

Figure: Variation of ball diameter versus number of generations for a radial ball bearing

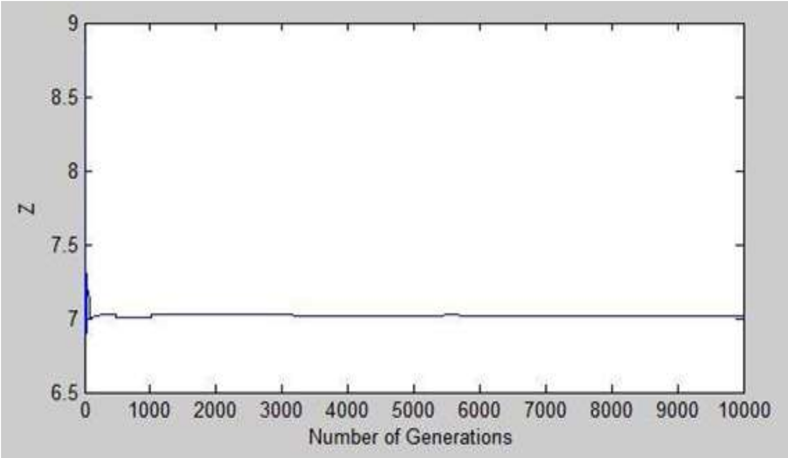

Figure: Variation of no. of balls versus no. of generations for a radial ball bearing

Selection of the optimal values of different design variables is of chief importance for designing of any kind of bearings. Design optimization has to yield maximize dynamic capacity while considering various design parameter and constraints. In the present paper, TLBO algorithm has used successfully for obtaining optimized design of ball bearing, which is taken from literature. The analysis of the optimized design parameters and variables indicates that$D_{r,}D_{m,}l_e$,Zarethekeydesignvariables.Furthercasestudiescouldbecarriedoutonother types of bearings. Some more realistic constraints can be introduced for getting more precious result.

Quality Control

Bearing making is a very precise business. Tests are run on samples of the steel coming to the factory to make sure that it has the right amounts of the alloy metals in it. Hardness and toughness tests are also done at several stages of the heat treating process. There are also many inspections along the way to make sure that sizes and shapes are correct. The surface of the balls and where they roll on the races must be exceptionally smooth. The balls can't be out of round more than 25 millionths of an inch, even for an inexpensive bearing. High-speed or precision bearings are allowed only five-millionths of an inch.

Heat treatment of bearing steels:

When bearing steels are in their soft (unhardened) state, metallurgists refer to their structure as being in the pearlite state. In order to harden the steel it must be heated to a very high temperature and then cooled very rapidly. When heated in the heat treat furnace to 1,750°F, the structure transforms from pearlite to what is known as austenite. After quenching (very rapid cooling), the structure then transforms from austenite to martensite. Once transformed to martensite, the steel becomes very hard. However, at this point it is not considered "thermally stabilized". This is because not all of the austenite transforms into martensite during the quenching process. This phenomenon is called "retained "austenite".If the steel is not thermally stabilized, the retained austenite will over an extended period of time (possibly years) transform into martensite.

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.

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.Specially designed turret and capstan lathes are used in mass manufacture of these journals. These reduce the diameter (turning) to suitable inner and outer diameter. This is followed by parting-off or cutting the concentric cylinder to accurate lengthor journal to function effectively, they must be smoothened. This is achieved using lapping operation. The cylindrical work piece is rotated against smooth abrasive material to remove a very small layer of materials and achieve high quality and extra smooth surface

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, both of these bearings are much more expensive to build and operate than the humble, trusted ball bearing

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