OPTIMIZING LEWIS BENDING STRESS AND TANGENTIAL TOOTH LOAD USING GENETIC ALGORITHM

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ABSTRACT

Genetic algorithm technique is applied for optimizing the Lewis bending stress and tangential tooth load for spur gear. In this thesis AGMA and GENETIC ALGORITHM are Compared for bending stress of spur gear .The design variables for the objective function are speed of pinion, number of teeth on pinion. The reason for using genetic algorithm is that it gives global optima instead of local optima. The genetic algorithm provides better results than conventional algorithm. The results are calculated for cast iron using turbo c..

Keywords : Spur Gears , Genetic Algorithm , LEWIS Bending Stress And TANGENTIAL Tooth Load; AGMA Bending Stress, TURBO C.

I INTRODUCTION

In engineering and technology the term “gear” is defined as a machine element used to transmit motion and power between rotating shafts by means of progressive engagement of projections called teeth. For mechanical power transmission, gears are generally categorized into three distinct types:

a) those transmitting power and motion between parallel shafts, namely, spur and ordinary helical gears;

b) those for shafts with intersecting axes, the angle between the shafts being generally 90^0, e.g. bevel gears; and

c) those where the shafts are neither parallel nor intersecting, the axes generally making 90^0 (or some other angle) to each other but in different planes, e.g. worm and worm-wheel, crossed-helical gears, and hypoid gears.

In recent times, the gear design has become a highly complicated and comprehensive subject. A designer of a modern gear drive system must remember that the main objective of a gear drive is to transmit higher power with comparatively smaller overall dimensions of the driving system which can be constructed with minimum possible manufacturing cost, runs reasonably free of noise and vibration, and which requires little maintenance. He has to satisfy, among others, the above conditions and design accordingly, so that the design is sound as well as economically viable.

Optimization is the task of finding one or more solutions which correspond to minimizing (or maximizing) one or more specified objectives and which satisfy all constraints (if any). A single-objective optimization problem involves a single objective function and usually results in a single solution, called an optimal solution. Traditional method gives one or two optimal solutions but non-traditional methods give more number of solution out of which the best solution is selected by fitness value.

In the present work, a spur gear design is optimized using genetic algorithm. Genetic algorithm is used as it gives global optima instead of local minima. In this paper LEWIS bending stress and TANGENTIAL tooth load were calculated by the application of genetic algorithm; AGMA bending stress is also calculated and compared with genetic algorithm.

1.1 Genetic Algorithm

A genetic algorithm (GA) is a stochastic search algorithm based on the mechanics of natural selection. Genetic algorithms, as Goldberg [1989] states and demonstrates, are theoretically and empirically proven to provide robust search in complex spaces. The GA performs its search balancing the need to retain population diversity 'exploration', so that potentially important information is not lost, with the need to focus on fit portions of the population

In computational terms, genetic algorithms are distinguished from other search methods by the following features:

- A *population of structures* that can be interpreted as candidate solutions to the given problem.
- The *competitive selection* of structures for reproduction, based on each structure's fitness as a solution to the given problem.
- Idealized *genetic operators* that recombine the selected structures to create new structures for further testing.

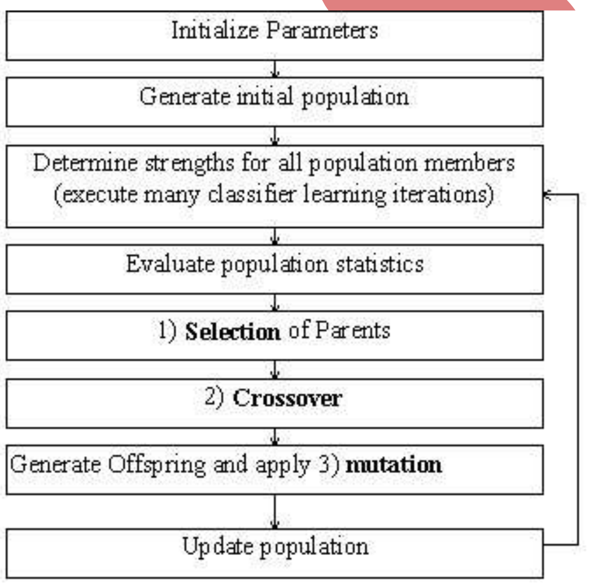


Figure 1: Simple Genetic Algorithm Flowchart

The basic genetic algorithm operators involved in reproduction are:

- Selection
- Crossover
- Mutation

The placement of these operators in the overall genetic algorithm is shown in Figure 1. In Figure 1.1 there is a box that reads, 'Determine strength for all population members', in the case of a classifier system this determination cannot occur during a single iteration. Classifier systems determine the ranking among the population members via multiple interactions with the environment whereby strength Changes occur via the apportionment of credit sub-system of the classifier system. Only after multiple interactions with the environment will the classifier strengths represent a measure of how well the classifier performs in the environment. The number of iterations that occur between each application 3 of the genetic algorithm is called an *epoch*. Therefore in Figure each loop represents one epoch.

Gears are the most common means of transmitting power in the modern mechanical engineering world. Gears are defined as toothed wheels, which transmit power and motion from one shaft to another by means of successive engagement of teeth

a. The center distance between the shafts is relatively small.

b. It can transmit very large power

c. It is a positive, and the velocity ratio remains constant.

d. It can transmit motion at a very low velocity.

GENETIC ALGORITHM technique is applied to optimize the spur gear in this paper work**.**

Spur gears: In a pair of mating spur gears, the axes of the component gears are parallel, that is, they are mounted on shafts which are parallel to each other.

II DESIGN OPTIMIZATION

The objective function is:

• Calculation of Lewis bending stress

• Calculation of Tangential tooth load

• Comparison of bending stress using AGMA AND GENETIC ALGORITHM

2.1 Calculation of Tangential tooth load

In Fig 2.0. a gear, not shown, exerts force *W* against the pinion at pitch point *R* This force is resolved into two components, a radial force F acting to r separate the gears, and a tangential component F , which is called the t *transmitted load.* Equal and opposite to force *W* is the shaft reaction *F,* also shown in Fig. Force *F* and torque *T* are exerted by the shaft on the pinion. Note that torque *T* opposes the force couple made up of F and F_x separated by the t distance *d/2.* Thus

T =F_t d/2 where *T* = torque, (N.m) W_t = F_t transmitted load, Newton

d = operating pitch diameter, (meter)

The pitch-line velocity v is given by Velocity (v) =π*d*N/60

A, operating pitch circle; *d,* operating pitch diameter; n_p, pinion speed; Ø , pressure angle; $W_t=F_t$ transmitted tangential load; $W_n=F_n$ radial Tooth load; *W,* resultant tooth load; *T,* torque; *F,* shaft force reaction.

F_t = F cos Ø , F_r = F sin Ø

F_r = F_t tan Ø , F_t = P/v Newton

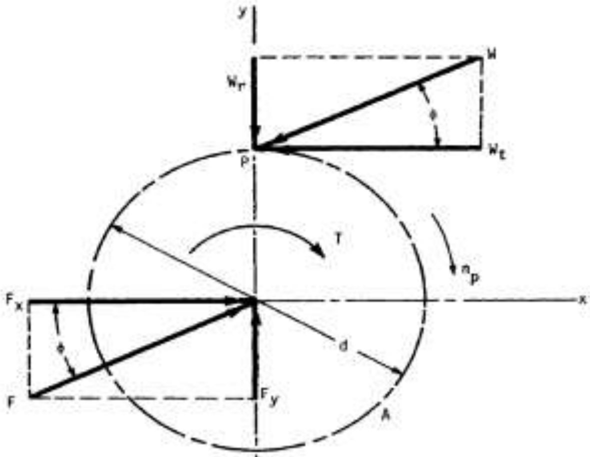


Figure 2.0 Force analysis of a pinion

2.2 Lewis's formula for gear strength calculation

The first problem faced by a gear designer is to find a design that will be able to carry the required power of the application. It is needless to say that the gear designed should be accurate enough, strong enough and big enough to perform the required job. Usually, failure by bending occurs when significant tooth stress equals or exceeds the yield strength or endurance strength of the material

However, it has to be said that the stresses calculated using gear design formulae will not necessarily be true stresses when compared to experimental results. This is mainly due to the gear tooth being idealized to a cantilever beam, and formulae being derived from this approximation.

Another factor making comparison between theoretical and experimental stress more difficult is the loading on the gear teeth. Even if the load that the gear teeth can be subject to is known, it is highly unlikely that this load is shared evenly between two or more pairs of teeth when meshing and also being evenly distributed across their face width. Errors in tooth spacing normally upset the load sharing between teeth causing accelerations and decelerations which cause a dynamic overload of the gear pair system.

Even taking into consideration the difficulties faced in calculating true stresses, gear stress formulae are valuable and a necessary design tool. When designing a new gear, the designer must take into consideration the stress limits, temperature limits and oil-film-thickness limits. Besides these first-order requirements, one must satisfy secondary considerations like vibration, noise and environmental effects. $\sigma_b = F_t /b*m*Y$ Where σ_b is the bending stress, b is the face width of the cantilever and F_t is the applied force, where $p = \pi m$, $Y = \pi y$ and m is the module of the gear.

2.3 Calculation using AGMA procedure

SPUR GEAR –TOOTH BENDING STRESS (AGMA)

American Gear Manufacturing Association (AGMA) came up with a refined form of Lewis equation as given below:

$\sigma =(Ft/(b*m*j))* K_v* K_o * K_m$

Where, J = Spur gear geometry factor. This factor includes the Lewis form factor Y and also a $_{stress}$ concentration factor based on a tooth fillet radius of 0.35/P. It also depends on the number teeth in the mating gear

$J = y / K_f$

Where, Y is the modified Lewis form

K_f is the fatigue stress concentration factor

Overload factor, K_O

Load distribution factor, K_m

III THEORETICAL CALCULATIONS RESULTS

Lewis bending stress and Tangential tooth load and AGMA bending stress are calculated with decision variables such as speed of pinion, number of teeth on pinion and are subjected to restrictions.

Input data:

Module =10mm

Teeth of pinion (z_1) =18

Pressure angle =20^0

The parameters below are obtained from a gear wheel used in a sugar cane crusher.

Power (P) == 1.5 KW =1500 Watts

(N)speed of pinion =140 to 1400 rpm

Variables	Conventional Calculations
Speed Of Pinion (RPM)	140
No. of Teeth on Pinion	25.00
Tangential Force (N)	1,136.82
Lewis Stress (MPa)	2.281523
Tangential Tooth Load (N)	1136.77
Agma Stress (MPa)	3.1205

3.1 Genetic Algorithm Results

Genetic Algorithm technique is applied to find Lewis bending stress, Tangential tooth load and AGMA with decision variables such as speed of pinion, number of teeth on pinion and are subjected to restrictions. Genetic Algorithm solutions are solved by using software TURBO C.

Input data:

Module =10mm

Teeth of pinion (z1) =18

Pressure angle =20^0

The parameters below are obtained from a gear wheel used in a sugar cane crusher.

Power (P) == 1.5 KW =1500 Watts

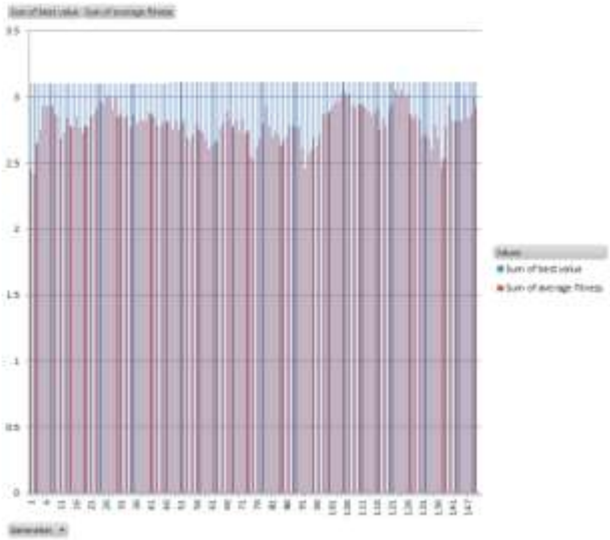
N=140 to 1400 rpm

Variables	**Genetic algorithm calculations**
Speed of pinion(rpm)	145.04
No. of teeth on pinion	24.94

Tangential force(N)	1132.884
Fitness value	**Genetic algorithm calculations**
Lewis Stress (MPa)	2.243
Tangential Tooth Load (N)	1097.318
AGMA stress(MPa)	3.113

Graph: Fitness(Tangential tooth load VS Generation number)

Graph: Fitness (Stress) Vs Generation Number



Graph: Fitness(Agma Stress) Vs Generation Number

IV CONCLUSION

By studying above cases we concluded that, while optimizing the complex problems of mechanical system a Genetic Algorithm is an important tool. So optimization of gear consisting of various parameters, objectives and constraints can be done easily using Non conventional optimization technique i.e. Genetic Algorithm as compared to conventional techniques. Finding Lewis stress and tangential tooth load using genetic algorithm and comparing AGMA stress with genetic algorithm for spur gear are taken as objective functions and subjected to constraints; the design variables are speed of pinion, number of teeth and tangential force. From the above study, the following inferences are drawn as follows: Genetic algorithm is random function search and optimization technique, the chance of getting global optimum is more. It does not require gradient information of the objective function. The performance of designed gear set using genetic algorithm is evaluated and compared traditional method gives one or two optimal solutions, but non-traditional methods give more number of solutions out of which the best solution is selected by fitness value.

Variables	Conventional cal.	Genetic algorithm cal.
Speed of pinion(rpm)	140	145.04
No. of teeth on pinion	25	24.94
Tangential force(N)	1136.82	1132.884
Fitness value	**Conventional cal.**	**Genetic algorithm cal**
Lewis Stress (MPa)	2.281523	2.243
Tangential Tooth Load (N)	1136.77	1097.318
AGMA stress(MPa)	3.1205	3.113

Table 3: Comparison between Conventional Calculations and Genetic Algorithm for Cast Iron

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