Minimization of Gear Power Transmission Error using Genetic Algorithm

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Abstract— Helical gears have been used for a wide range of engineering and technological applications especially in automobiles, ship building, aircraft and marine applications. The rapid increasing demand for high speed ratio, highly efficient cum light weight engines, with quite power transmission have led to the need for optimization of helical gears being used till today. For optimization of any engineering design initially problem function is formulated then variable parameters are decided which would minimize or maximize the objective function so as to give an optimal system performance. Today's competitive market required to optimize Weight and Volume of the gear design. Weight and Volume optimization of gear pairs is difficult to solve because it includes various objectives and large number of variables. Therefore, to solve such difficulty robust optimization technique will be useful to get optimal solution. Genetic algorithm will be useful to solve such difficulty using MATLAB. In this work a helical gear pair design optimization problem is solved. It is a multi-variable, complex non-linear problem with derived objective function and constraints. The objective is to minimize the volume of the gear. The design parameters considered are module, face width, number of teeth on drive and driven and helix angle. Results indicate that GA algorithm gives the best results for all design variables and objective function in helical gear design.

Keywords: MATLAB, Helical Gear, Genetic Algorithm, Constraints

I. General

Gear design is a complex phenomenon requiring consideration of several items such as gear geometry, material heat treatment, manufacturing, etc., to satisfy. Functional requirement, of high strength, high accuracy, low noise, and compactness of the drive. Traditionally, gear designers have been concerned with requirements of strength, noise, life, and accuracy of kinematic transmission. The recent focus of research however is the optimal design of compact gear pairs (gear boxes) for minimum weight and space requirements

Designing a new product consists of several parameters, which differ according to the depth of design, input data, design strategy, procedures, and results. Mechanical design includes an optimization process in which designers always consider certain objectives such as strength, deflection, weight, wear, corrosion depending on the requirements. Among these objectives the weight of a new product is one of the best considerable design parameter.

II. Helical gears

Helical gears are similar to spur gears except that their teeth are cut at an angle to the hole (axis) rather than straight and parallel to the axis like they are in the teeth of a spur gear. Helical gears are manufactured as both right and left-handed gears. The teeth of a left-handed helical gear lean to the left when the gear is placed on a flat surface. The teeth of a right-handed helical gear lean to the right when placed on a flat surface. In spur gears Fig.1.1 (a), the teeth are parallel to the axis whereas in helical gears Fig.1.1 (b) the teeth are inclined to the axis. Both the gears are transmitting power between two parallel shafts. [19] At any time, the load on helical gears is distributed over several teeth, resulting in reduced wear. When two helical gears are engaged as, the helix angle has to be the same on each gear, but one gear must have a right-hand helix and the other a left-hand helix. In helical gear the line contact is diagonal across the face of the tooth.

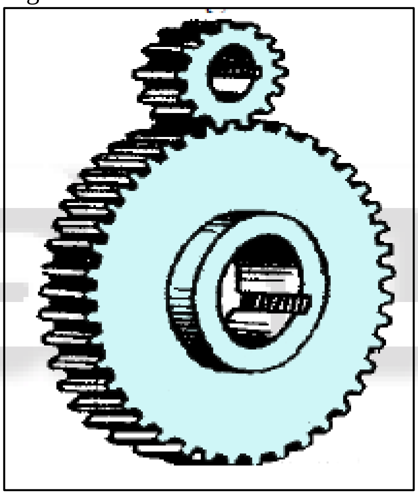

Fig. 2.1: (a) spur gear

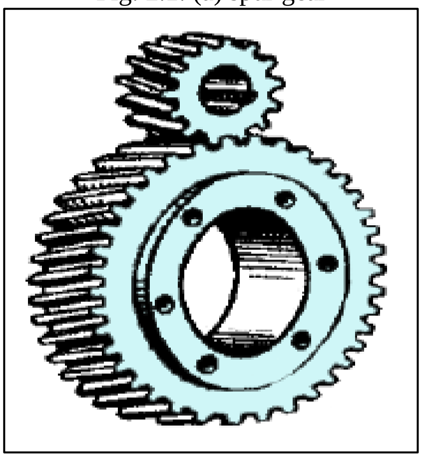

Fig. 2.1: (b) helical gear

III. Optimization techniques for optimum design problem

Modeling and optimization of process parameters of any manufacturing process is usually a difficult work where the following aspects are required: knowledge of manufacturing process, empirical equations to develop realistic constrains, specification of machine tool capabilities, development of an effective optimization criterion, and knowledge of mathematical and numerical optimization techniques. A human process planner selects the proper machining parameters using his own experience or from the handbooks. Performance of these processes, however, is affected by many factors and a single parameter change will influence the process in a complex way. Because of the many variables and the complex and stochastic nature of the process achieving the optimal performance, even for a highly skilled operator is rarely possible.

A. *Objectives of Present Work*

In this work a helical gear pair design optimization problem is solved. It is a multi-variable, complex non-linear problem with derived objective function and constraints.

– The main objective is to minimize the volume of the gear.
– The design parameters considered are module, face width, number of teeth on drive and driven and helix angle. MATLAB solvers fmincon and GA will be used.
– Simulation results will be analysed and compared to ParidhiRai et al. 2018.

IV. STEPS IN BASIC GENETIC ALGORITHM

1) [Start] Define the fitness function f(x) according to the problem definition.
2) [Initialise] Generate random population of n chromosomes – each chromosome being the potential solution.
3) [Fitness] Evaluate the fitness f(x) of each chromosome x in the population.
4) [New population]Repeat the following steps to create the new population of chromosomes:
a) [Selection] Select some parent chromosomes from a population according to their fitness to form mating pool.
b) [Crossover] Mate the selected chromosomes as per given crossover probability to form new off-springs.
c) [Mutation]Mutate new chromosomes as per given mutation probability.
d) [Replace] Replace the old population of chromosomes with the new population.
5) [Convergence check] If the maximum number of generations is reached, then stop, and return the best solution. 6. [Loop] Go to step 3.

V. GA RESULTS

The procedure described in the previous sections has been applied to the design helical gear pair. It presents an approach for combining mechanical component design models with non-traditional optimization techniques namely Genetic algorithms and Fmincon procedures. It is shown that the problem may be posed as a non-linear optimization problem, wherein the fitness function changes over successive generations. Results are presented for the optimal design problem of a helical gear set, where its volume as the objective functions is subjected to constraints.

Table 5.1 shows the results recorded after implementing the optimization process on the input data. The MATLAB program for GA has been run on i7 Intel(R) Core(TM) processor with 4 GB RAM and 64-bit operating system. Overall, 100, 200 300, 350 and 500 generations are experimented to check the validity of results.

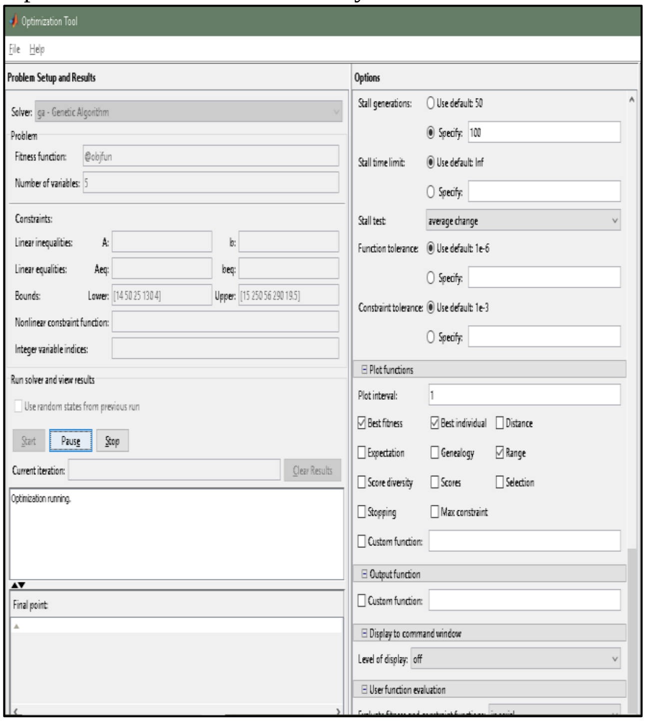

Fig. 5.1: GA implementation

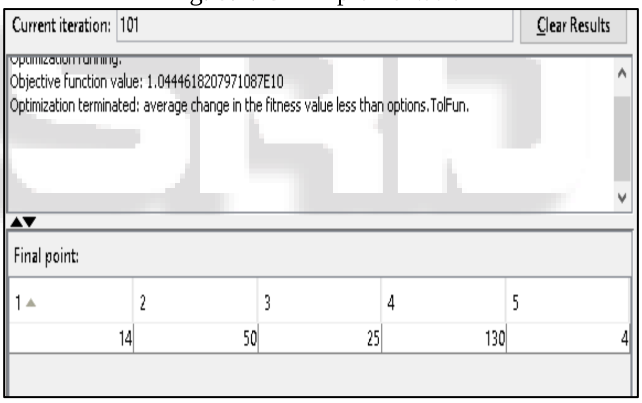

Fig. 5.1: Optimized results at 100 iteration

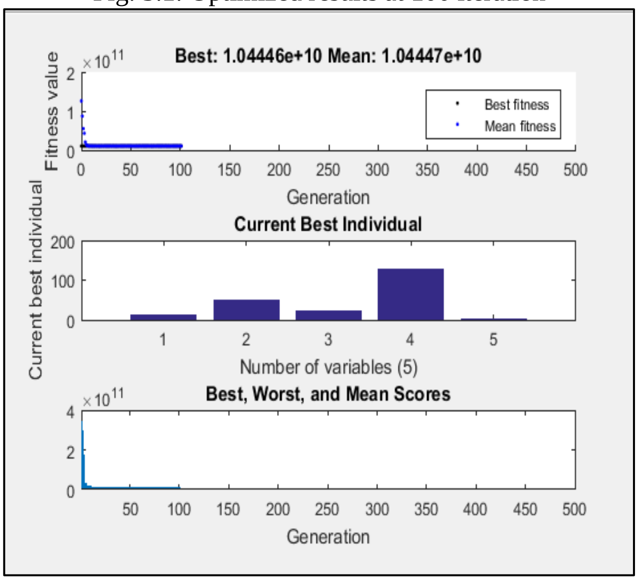

Fig. 5.2: Function value at 100 iteration

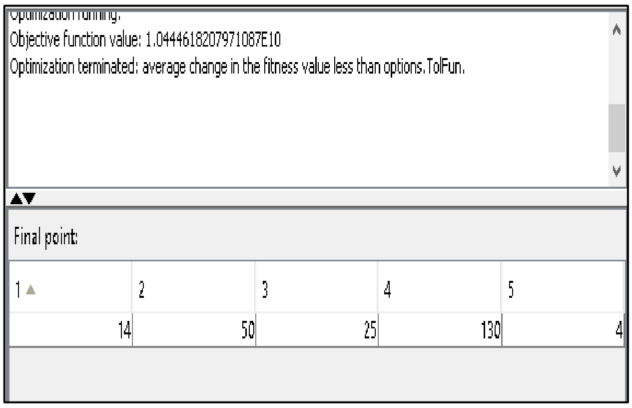

Fig. 5.3: Optimized results at 200 iteration

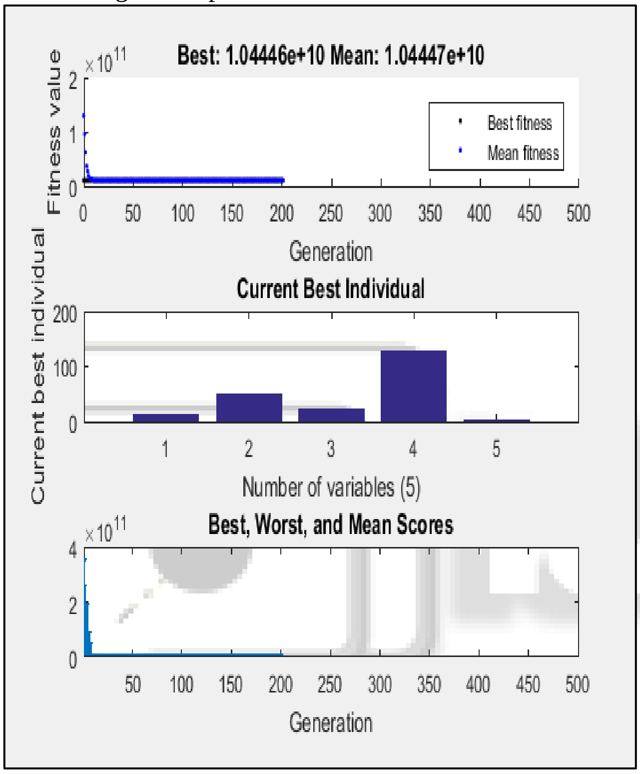

Fig. 5.4: Function value at 200 iteration

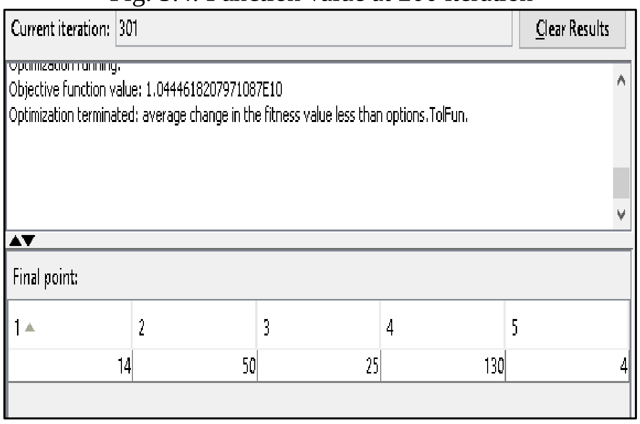

Fig. 5.6: Optimized results at 300 iteration

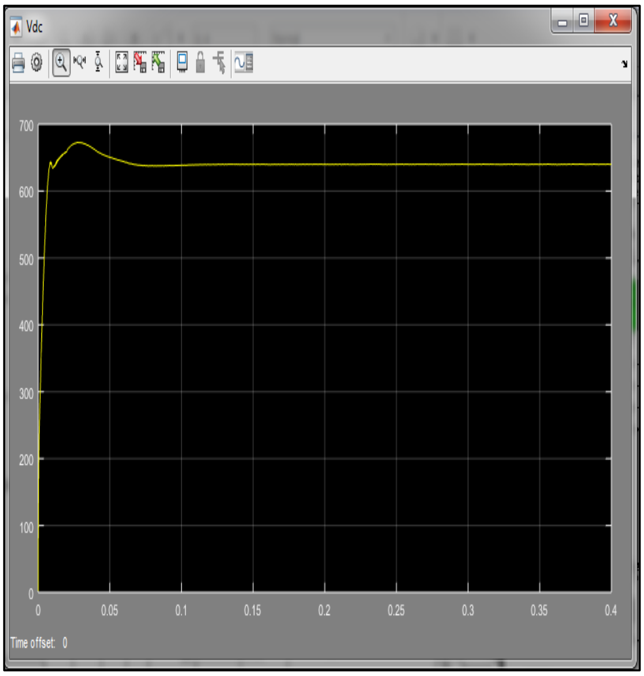

Fig. 5.7: Transmission error response.

This graph is represent Transmission error minimization using GA algorithm iteration this is shows 0.05 Second is denoted by Power regulation with respect to time now these are also identified Error is 0.098% with respect to maximum overshoot like as 650. The control design process begins by defining the performance requirements. Control system performance is often measured by applying a step function as the set point command variable, and then measuring the response of the process variable.

VI. Conclusion

In this work, a heavy duty helical gear pair is optimized. Objective functions and all constraints are well satisfied. Nature inspired algorithms GA and MATLAB solvers fmincon are successfully applied. The following are the important findings:

1) Results obtained by genetic algorithm technique for all generations are almost same for our problem.
2) By using GA value of decision variable is module (m_n) = 14 mm, face width (b) = 50 mm, No. of teeth on pinion (Z_1) = 25, No. of teeth on gear (Z_2) = 130 and Helix angle (β) = 4º. Value of objective function that is volume = 1.044 x 10^{10} mm^3.
3) By using Fmincon value of decision variable is module (m_n) = 14 mm, face width (b) = 50 mm, No. of teeth on pinion (Z_1) = 26, No. of teeth on gear (Z_2) = 132 and Helix angle (β) = 5º. Value of objective function that is volume = 1.044 x 10^{10} mm^3.
4) ParidhiRai et al. (2018) minimized the volume of helical gear pair by including profile shaft coefficients as design variables along with module, face width and number of teeth using RCGA and optimized volume achieved is 5.50560 x 10^{10} mm^3. However in our work we have used two techniques namely GA and fmincon and our improved optimised results are 1.044 x 10^{10} mm^3.
5) GA algorithm gives the best results for all design variables and objective function in helical gear design.

VII. FUTURE SCOPE

Global market has brought increasing awareness to optimize gear design. Current trends in engineering globalization require results to comply with various normalized standards to determine their common fundamentals and those approaches needed to identify best practices in industries. This can lead to various benefits including reduction in redundancies, cost containment related to adjustments between manufacturers for missing part interchangeability and performance due to incompatibility of different standards.

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