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Optimal Design of Gear Based on Quantum Genetic Algorithm

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Abstract. Quantum Genetic Algorithm (Quantum Genetic QGA) is produced by combining Quantum computing and Genetic Algorithm. And it is got enormous attention because of its small population size, higher ability to find the global optimal value, fast convergence rate and time-saving. Take reducer that is widely used in mechanical for example, and study the application of RQGA in the mechanical structure optimization design. Establish the optimization model, adopt RQGA to solve it, and analyze by comparison to the solution of SA and QGA. And the comparison shows the validity and feasibility of the RQGA. *Copyright © 2012 IFSA.*

Keywords: Genetic algorithm, Quantum genetic algorithm, Real number coding, Reducer optimal design.

1. Introduction

Optimal design is a very effective design method, ensure the excellent performance of product, reduce its weight and volume, and reduce the cost. Optimal of mechanical design is the optimal design transplanted and used in the mechanical field. Its basic idea is: firstly, transform the engineering design problem into an optimization problem; then, select an appropriate optimization method; last, uses the computer automatically finds the optimal design achieve the desired goals from the meet requirements feasible design schemes. Optimal design is used in mechanical design, which not only adapts to the requirements of modern production, but also conform the needs of the actual situation of building energy-saving society. So optimal of mechanical design is increasingly got the attention by the scientists and the engineering technicians, and has got considerable progress. So far, optimizing algorithm is the foundation and core of optimal design, and has developed to hundreds.

In general, optimizing algorithm can be divided into traditional optimization and modern optimization algorism. With the promotion and application of computer technology, modern optimization algorism has been gotten a great deal of development. Modern optimization algorism mainly includes Simulated Annealing (SA), Genetic Algorithm and Ant Colony Algorithm (ACA) etc. Genetic Algorithm is an important branch of evolutionary algorithm, been widely used for its better robustness and extensive adaptive. And the iterative times of Genetic Algorithm is much, slow convergence and easy to fall into local extremism. By the development of Quantum Computation, and base on the idea of quantum bit and quantum superposition state, the idea of Quantum Genetic Algorithm is put forward. Quantum Genetic Algorithm (QGA) is an optimizing method by probability search that combining the quantum computation theory and Genetic Algorithm. Practice shows that Quantum Genetic Algorithm is efficient in the population diversity, the solving stably and the solution speed than Quantum Genetic Algorithm.

2. The Reducer Optimal Example

The gear reducer is used widely in every walk of life. It is an indispensable mechanical transmission. Currently, reducer ubiquity has many disadvantages such as big volume, heavy weight, large ratio and low mechanical efficiency. In order to meet the requirements of energy saving, today's reducer should towards develop in those directions as high power, large ratio, small volume, high mechanical efficiency and long service life. So, we not only continuously improve the quality of materials and the level of technology, but also use advanced optimizing methods in the optimal design of gear reducer, which is extremely necessary.

Shown in Fig. 1 is the two-grade helical cylindrical gear reducer. Let the input power of high-speed shaft is 6.2 kW, the speed of high-speed shaft is 1450 r/min, the resultant gear ratio is 31.5, the coefficient of tooth width is 0.4, the material and thermal treatment of large gears is normalizing 45 steel and HB=187-207, the material and thermal treatment of small gears is quenching and tempering 45 steel and HB=228-255, and the total operating time is not less than 10 years. According to the minimum of general center distance, determine the main parameters of the general scheme.

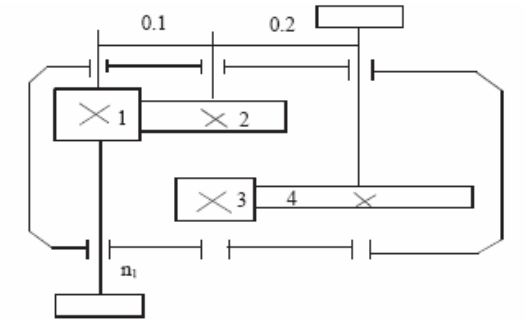

Fig. 1. The two-grade helical cylindrical gear reducer.

3. Establish the Optimization Model

3.1. Optimization Objective

Select the general center distance of this reducer as optimization objective. The specific formula:

$$f(x) = \sum a = a_1 + a_2 \frac{m_{n1} z_1 (1 + i_1) + m_{n2} z_3 (1 + i_2)}{2 \cos \beta}, \quad (1)$$

where m_{n1} is the high-speed tooth surface normal modulus; m_{n2} is the low-speed tooth surface normal modulus; i_1 is the high-speed transmission ratio; i_2 is the low-speed transmission ratio; z_1 is the high-speed pinion tooth number; z_3 is the low-speed pinion tooth number; b is the gear helical angle.

3.2. Design Variables

In this case, the parameters used to calculate general center distance involve $m_{n1}, m_{n2}, z_1, z_3, i_1$ (obvious $i_2 = 31.5/i_1$), because $i_1 = z_2/z_1$, for easy to handle, so let design variables as:

$$X = [m_{n1}, m_{n2}, z_1, z_3, z_2, b]^T = [x_1, x_2, x_3, x_4, x_5, x_6]^T .$$

Based on power transmission, we can guess $2 \le m_{n1} \le 5$, while standard value is (2, 2.5, 3, 4, and 5). Then $2 \le m_{n2} \le 6$, standard value is (3, 4, 5, and 6). Considering various factors such as steady transmission, axial force can not too large, and meet short-term overload. The immersion depth of large bears on high-speed level and low-speed level are roughly the same. And the size of shaft gear reference circle can not too small, $14 \le z_1 \le 22$, $16 \le z_3 \le 22$, $82 \le z_2 \le 154$, $8^0 \le \beta \le 15^0$.

3.3. Constraints

In this case, comprehensive consideration, the contact strength condition of tooth surface, the contact strength condition of tooth root, and the high-speed larger gear can not produced interference with the low-speed axial etc. Set the relevant parameters, can get the following constraints:

$$\begin{cases} g_1 = 3.098\times10^{-6} x_1^3 x_3^2 x_5 - \cos^3 x_6 \ge 0 \\ g_2 = 1.017\times10^{-4} x_2^3 x_4^3 - x_5^2 \cdot \cos^3 x_6 / x_3^2 \ge 0 \\ g_3 = 9.939\times10^{-5} \cdot (1 + x_5/x_3) \cdot x_1^3 x_3^2 - \cos^3 x_6 \ge 0 \\ g_4 = 1.076\times10^{-4} \cdot (31.5 + x_5/x_3) \cdot x_2^3 x_4^2 - x_5^2 \cdot \cos^2 x_6 / x_3^2 \ge 0 \\ g_5 = x_2 x_4 \cdot (31.5 + x_5/x_3) - x_5/x_3 \cdot [2(x_1 + 50) \cdot \cos x_6 + x_1 x_5] \ge 0 \\ g_6 = 1.116\times10^{-4} \cdot (1 + x_5/x_3) \cdot x_1^3 x_3^2 - \cos^2 x_6 \ge 0 \\ g_7 = 1.171\times10^{-4} \cdot (31.5 + x_5/x_3) \cdot x_2^3 x_4^2 - x_5^2 \cdot \cos^2 x_6 / x_3^2 \ge 0 \end{cases}, \quad (2)$$

Because g_6 , g_7 are more negative constraints than g_3 , g_4 , so can be omitted. g_1, g_2, g_3, g_4, g_5 are taken as five constraints.

3.4. Optimization Model

From the above, we know this optimization example is a constraints optimization problem. But Genetic Algorithm, Quantum Genetic Algorithm and Real-coded Genetic Algorithm just can solve the unconstrained optimization problem. So we should use a special method to transform constrained optimization problem to unconstrained optimization problem.

Internal penalty function method is called interior point method. By the method, new objective function is defined in the feasible region, the sequence iteration point in the feasible region gradually approaching the most advantage point on the constraint boundary. Interior point method is just used to solve the

optimization problem with inequality constraints.

$$\begin{cases} \min\ f(x) \\ s \cdot t \qquad g_j(x) \le 0,\ j = 1, 2, \cdots m \end{cases}, \tag{3}$$

Transformed into

$$\Phi\ (x, r) = f(x) - r\sum_{j=1}^{m} \frac{1}{g_j(x)}, \tag{4}$$

or

$$\Phi\ (x, r) = f(x) - r\sum_{j=1}^{m} \ln[-g_j(x)], \tag{5}$$

where r is the penalty factor, which is the series descending and approach 0: $r^0 > r^1 > r^2 > ... > r^n \to 0$.

The role of the penalty factor is important. Because interior point method only can iterate in the feasible region, but the most optimal solution may near the boundary in the feasible region or on its border. Although the value of the functional is large, the punishment factor is diminishing positive value. So after several iterations close to the optimal solution, the penalty term is a very small positive value. By transformed the unconstrained optimization problem is boiled down to the same optimal solution of original constrained problem.

Use Internal penalty function method to establish the optimization model of optimized instance shown as equation (6):

$$\begin{cases} \min: \quad \Phi(x, r) = f(x) + r\sum_{j=1}^{5} \frac{1}{g_j(x)} \\ \qquad g_1 = 3.098 \times 10^{-6} x_1^3 x_3^2 x_5 - \cos^3 x_6 \ge 0 \\ \qquad g_2 = 1.017 \times 10^{-4} x_2^3 x_4^3 - x_5^2 \cdot \cos^3 x_6 / x_3^2 \ge 0 \\ s.t.: \quad g_3 = 9.939 \times 10^{-5} \cdot (1 + x_5 / x_3) \cdot x_1^3 x_3^2 - \cos^3 x_6 \ge 0 \\ \qquad g_4 = 1.076 \times 10^{-4} \cdot (31.5 + x_5 / x_3) \cdot x_2^3 x_4^2 - x_5^2 \cdot \cos^2 x_6 / x_3^2 \ge 0 \\ \qquad g_5 = x_2 x_4 \cdot (31.5 + x_5 / x_3) - x_5 / x_3 \cdot [2(x_1 + 50) \cdot \cos x_6 + x_1 x_5] \ge 0 \end{cases}, \tag{6}$$

SGA, QGA and RQGA can be used to optimize the volume of reducer.

4. The Optimization Solution and Analysis of Results of SGA, QGA and RQGA

4.1. Control Parameters and Control Strategies

Genetic algorithm to choose the operating parameters of the size of the major groups M, the crossover probability p_c, and mutation probability p_m, the selection of these parameters to a greater impact on the operating performance of the genetic algorithm.

The size of the major groups M: The range of the general recommendations is 10~160. When the value of M is small, although it can improve the computational speed of the genetic algorithm, but reduces the diversity of the population, easily lead to premature convergence of genetic algorithms; when the M value whichever is greater, will seriously affect the genetic algorithm operating efficiency.

The crossover probability p_c : The crossover operation is the main method of genetic.

Algorithm to generate new individuals, but Crossover probability controls the frequency of use of the crossover operator, therefore, Crossover probability value larger. If the value is too large, it will destroy the group in fine mode. And it is not conducive to the evolution of computing; If the value is too small, it will reduce the new speed of the individual, so that the algorithm will fall into a slow state. The range of the general recommendations is 0.4~0.99. Other, you can determine the crossover probability based on adaptive thinking.

Mutation probability p_m : The mutation operator in genetic algorithm is a new helper method.

Generate new individuals supporting. Therefore, If this probability value is too large, it may damage the good mode, the performance of GA is similar to the performance of the random search algorithm; If the mutation probability value is too small, it will reduce its ability to produce new individuals and the ability to inhibit premature; The range of the general recommendations is 0.0001~0.1. It may also be based on adaptive thinking to determine the mutation probability.

1) Optimal solution to retention policies: whether the current best individual's fitness is greater than so far the best individual fitness, all with the best individual so far to replace the current worst individual.

2) Termination of algebraic T: It is an important parameter to control the end of the genetic algorithm run conditions, algorithm run this algebra to stop running after, and output is the optimal solution and the best individual in the current group. The range of the general recommendations is 100~1000. Of course we can also use some kind of criterion to control the termination of the algorithm. The judgment criteria are:

a) Successive generations of the average individual to adapt to a very small degree of difference are smaller than some threshold;

b) All individual fitness variance in groups is smaller than some threshold value.

Optimal solution. The standard genetic algorithm uses binary encoding, roulette selection algorithm, single-point crossover and gene 0-1 variation, including population size M = 10, crossover probability = = 0.5, mutation probability = 0.01, the optimal solution retention policy maximum Diego on behalf of the number of T = 500 as the convergence condition.

Quantum genetic algorithm and real-coded Quantum Genetic Algorithm two optimization methods which are used randomly generated initial coding, the use of the optimal solution to retain the mechanism to update the chromosome, using the maximum number of iterations T = 500 as the convergence conditions, and the population size M = 10.

Using JAVA programming language achieve program , using the standard genetic algorithm, quantum genetic algorithm and real-coded Quantum Genetic Algorithm conduct optimal solution each 20 times, the obtained optimal solution shown in Table 1.

Table 1. The optimal solution obtained by three algorithms.

Parameter \ Algorithms	SGA	QGA	RQGA
m_{n1}	2.0	2.0	2.0
m_{n2}	4.0	3.0	3.0
Z_1	20.0	21.0	21.0
Z_3	16.0	18.0	18.0
Z_2	100.0	87.0	87.0
β	12.0	13.0	13.0
$F(X)$	361.5	349.2	349.2

Three algorithms, the optimal solution got after each running, which shown in Fig. 2.

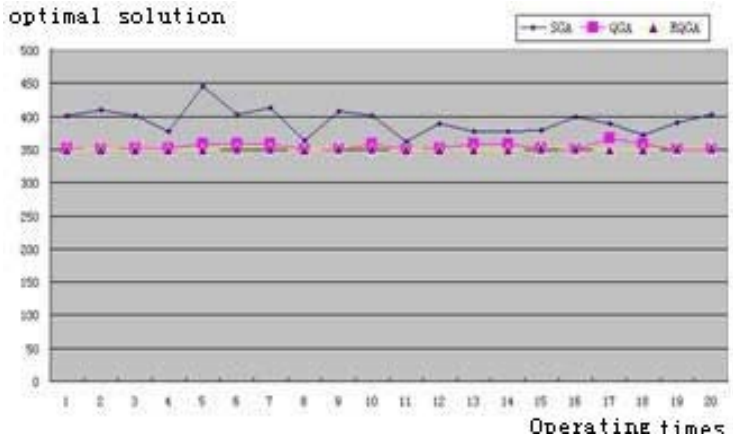

Fig. 2. The distribution of optimal solution.

4.2. Analysis of Results

Statistics on operating results shown in Table 2.

Table 2. The statistical results of run 20 times.

Algorithms	SGA	QGA	RQGA
Average	392.517	353.865	350.527
Optimal value	361.5	349.244	349.244
Standard deviation	4.386	2.181	1.007
Average time/20 times	2.5734 [s]	17.349 [s]	0.4797 [s]

The conclusion of analysis the statistical results are following:

1) Optimal value: The obtained optimal value of RQGA and the QGA is equal, it is superior to that obtained by the SGA of the optimal solution, it shows quantum genetic algorithm has better optimization ability.

2) The average: the average of RQGA is superior to QGA, QGA is better than t SGA in every 20 times.

3) The standard deviation: the standard deviation of RQGA is superior to QGA, the QGA is better than the SGA in every 20 times. Which can show the solving stability of RQGA is superior to the QGA's, QGA's is better than SGA's.

4) The average running time: when running 20 times, the average speed of RQGA is better than SGA's, SGA's is better than QGA's. It shows using real-coded can avoid the codec operation so that saving computing time.

5. Conclusion

Impressing on standard genetic algorithm, the basic quantum genetic algorithm and real-coded quantum genetic algorithm to optimize the volume of the two helical gear reducer, the results show that the optimal solution obtained by the real-coded quantum genetic algorithm, real-coded quantum genetic algorithm for solving speed and solution stability are better than the standard genetic algorithm and quantum genetic algorithm

References

[1]. Han K. H., Kim J. H., Quantum-inspired evolutionary algorithm for a class of combinational optimization, *IEEE Trans Evolutionary Computation*, Vol. 6, Issue 6, 2002, pp. 580-593.

[2]. Mikki S. M., Kishk A. A. Quantum particle swarm optimization for electromagnetics, *IEEE Transactions on Antennas and Propagation*, Vol. 54, Issue 10, 2006, pp. 2764-2775.

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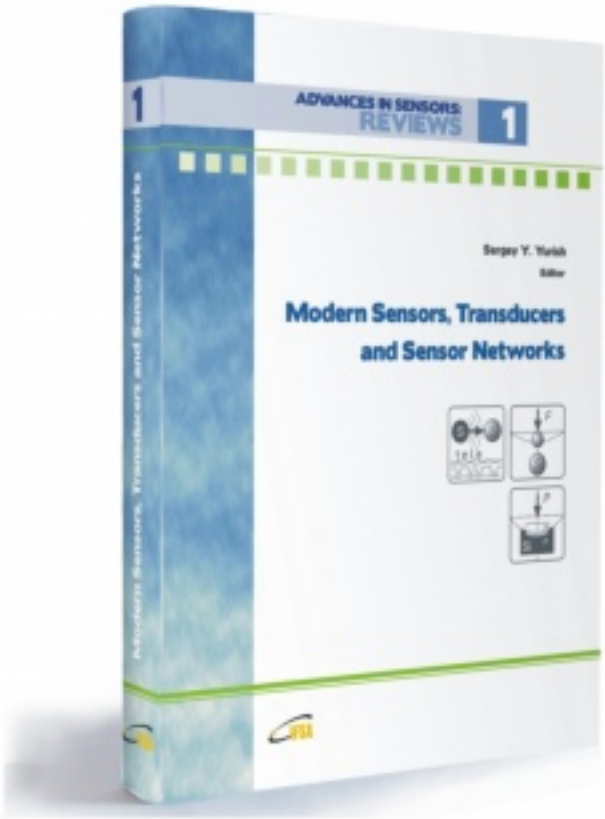

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