An Approach to Design of Cotter Joint Using Genetic Algorithm Optimization Technique

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Abstract

Cotter joint is use to pull the heavy load and there are many chances of failing because of many variables and failing conditions so genetic algorithm is used here to make design easy. In the present study we evaluated different constants which can help to find other dimensions of cotter joint for safe design and minimum material requirement or minimum mass.

Keyword: *Cotter Joint, Genetic Algorithm, Engineering Design, MATLAB*

1. Introduction

Genetic algorithm is an optimization technique based on evolution. It is very useful for design optimization in engineering. Genetic algorithm is a tool which can optimize any equation with constraint or without constraints. Algorithm starts with encoding. Here a set of solution represented by chromosomes that is population. Population size is constant in all iteration. This chromosome generates new chromosomes with help different operators that are crossover and mutation. After using operators new population comes and better chromosomes or set of solution will be select for next iteration. After number of iteration algorithm converges to best solution and it may be optimal or sub optimal. Surendra et al (2015) optimized Helical gear for beam strength of helical gear and gave influencing factors in beam strength like contact ratio, gear ratio, helix angle, face width, module, pressure angle and their combined effects that enhance the effectiveness and performance of the helical gear. Ovidiu et al (2012) optimized a single-stage helical gear unit for minimum weight and presented an optimal design with the sizing of shafts, gearing and housing using genetic algorithms Chapman et al (1994) presented genetic algorithm optimization technique based on the theory of natural selection and applied to problems of structural topology design. Tae et al (2000) proposed a genetic algorithm based gear design system applied for the geometrical volume minimization problem of the two-stage gear train and the simple planetary gear train, showed that genetic algorithm is better than the conventional algorithms for solving the problems. Atish et al (2014) focused on reducing the weight and stresses keeping into considerations the various critical points. The spring designed to operate with tension load discussed about the application and problem formulation using genetic algorithm which is one of nontraditional methods. Zhou et al (2015) optimized a Dongfanghong-LA3004 tractor shifting clutch and optimized results verified the rationality and validity of the proposed optimization method. Raghuvarma et al (2017) worked on minimization of weight of flywheel of multivariable and non-straight conditions. Barbieri et al (2017) investigated the effect of tooth profile modification on single stage spur planetary gear vibrations and proposed genetic algorithm to improve planetary gear dynamic performances toward vibration reduction.

2. Problem Formulation

The cotter is usually made of mild steel or wrought iron. A cotter joint is a temporary fastening and is used to connect rigidly two co -axial rods or bars which are subjected to axial tensile or compressive force. It is usually used in connecting a piston rod to the cross head of a reciprocating steam engine. A piston rod and its extension as a tail or pump rod, tarp end of connecting rod etc. There are many chances of failure in cotter joint like Tension failure of rod at diameter, Tension failure of rod across slot, tensile failure of socket across slot, Shear failure of cotter, Shear failure of rod end, Shear failure of socket end, Crushing failure of rod or cotter, Crushing failure of socket or rod, Crushing failure of collar, Shear failure of collar and Bending failure of cotter. All failure conditions converted in constraints.

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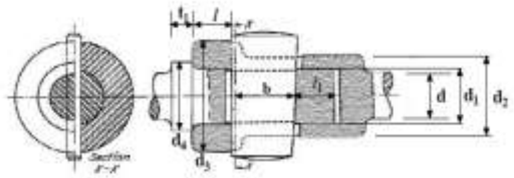

Fig 1 Schematic view of Cotter Joint

Table1 Different variables of cotter joint in term of constant and rod diameter

d1	d2	d3	d4	t	b	l	l1	t1
x(1)*d	x(2)*d	x(3)*d	x(4)*d	x(5)*d	x(6)*d	x(7)*d	x(8)*d	x(9)*d

Table2 Notations for force and different stress

Force	Tensile Strength	Shear Strength	Crushing Strength	Bending Strength
p	s_t	s_s	s_c	s_b

Here we find diameter of rod with the help of Failure of rod in tension condition given by equation (1) and then we find all other dimensions in correlation of rod diameter,

d=((4*p)/(pi*s_t))^0.5;   (1)

The objective function (equation (2)) is summation of all constant, these constants give different dimensions values by multiplying the rod diameter as shown in table 1.
Objective function=f(x)=x(1)+x(2)+x(3)+x(4)+x(5)+x(6)+x(7)+ x(8)+x(9);   (2)

Gx1 to Gx10 are different constraints which made under different failure conditions.
Gx1=((0.25*pi*((x(1)*d)^2)-x(1)*d*x(5)*d)*s_t)/p-1;
Gx2=(s_t*(0.25*pi*((x(2)*d)^2-(x(1)*d)^2)-(x(2)*d-x(1)*d)*x(5)*d))/p-1;
Gx3=(2*s_s*x(6)*d*x(5)*d)/p-1;
Gx4=(2*s_s*x(8)*d*x(1)*d)/p-1;
Gx5=(2*s_s*x(7)*d*(x(3)*d-x(1)*d))/p-1;
Gx6=(s_c*x(5)*d*x(1)*d)/p-1;
Gx7=(s_c*x(5)*d*(x(3)*d-x(1)*d))/p-1;
Gx8=(s_c*(0.25*pi*((x(4)*d)^2-(x(1)*d)^2)))/p-1;
Gx9=(s_s*pi*x(1)*d*x(9)*d)/p-1;
Gx10=((s_b*x(5)*d*((x(6)*d)^2)*0.3333)/((x(3)*d-x(1)*d)/6+x(1)*d/4)/p)-1;

Table 3 Parameters selected for Genetic Algorithm

Number of populations	No. of bits in one chromosome	Type of coding	Type of crossover	Crossover probability	Probability of mutation	Type of selection	Number of Iterations
90	10	Binary	Single point crossover	0.8	0.06	Rolette Wheel	300

Table 4 Load and Material property for cotter joint

P(KN)	s_y (MPa)	s_s (MPa)	s_c (MPa)	s_b (MPa)
50	150	110	110	150

Table 5 Constant values after applied Genetic Algorithm for safe Design

x(1)	x(2)	x(3)	x(4)	x(5)	x(6)	x(7)	x(8)	x(9)	f(x)
1.8768	2.5024	3.1281	2.5024	0.9482	2.5024	0.6256	0.3128	0.3177	0.3177

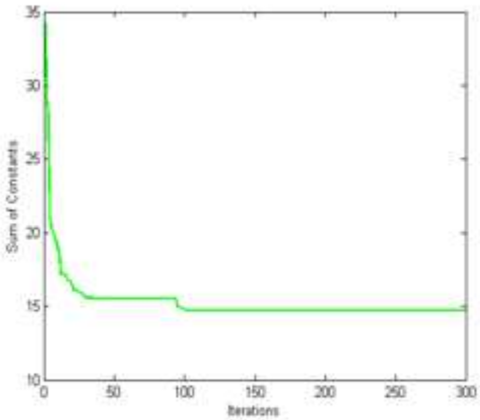

Fig 2 Change in objective function w.r.t. iteration

3. Results and Discussion

The correlation constant from x (1) to x (9) are optimized for safe design under all constraints. The objective function is minimized after 160iteration as shown in figure. This result minimize the dimensions of Cotter Joint and due to dimensions weight and volume also optimized, now we have variables or dimensions in the term of diameter of rod with different constant and it makes easy to design cotter joint under all safe conditions. These correlation constants value will be same for all load value but it may differ if material changes. Generally design of cotter joint does under table 4 specifications.

4. Conclusion

Cotter joint optimized for minimum dimensions under safe design and genetic algorithm helped to find correlation constants. An easy relations generated without taking much factor of safety. It must be used in engineering to save material and money.

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