Journal of mathematics and computer science 11 (2014), 209-217

Contents list available at JMCS

Journal of Mathematics and Computer Science

Journal Homepage: www.tjmcs.com

2D Shape optimization via genetic algorithm

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Article history:
Received May 2014
Accepted June 2014
Available online June 2014

Abstract

In this study, among different algorithms that have been introduced for obtaining optimal shapes and structures, an advanced optimization method for distinct shapes and also non-significant ones is illustrated. In order to investigate the efficiency of the method, a specific structural member (safety belt) is analyzed. The optimization process is to optimize the member via genetic algorithm, in order to have minimum weight; meanwhile having the ability to support the loading and also sustaining the generated tension stresses under the range of the allowable limit. The main goal of the present work is to focus on the existence of an optimal shape of the member optimized by genetic algorithm, having necessary conditions of optimality for a safety belt, and stability of optimal solutions under some prescribed perturbations.

Keywords: Belt, Optimization, Genetic Algorithm, FEM, Shape.

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1. Introduction

Nowadays, the technology footmark is easily seen in all mechanical systems. Consequently, optimization of industrial components is a vital concern to the designers. Today the traditional trial and error method is obsolete and has been replaced by other advanced methods. The current trend is to implement more and more numerical softwares that simultaneously analyze and optimize many possible designs and make optimal design in an automated process. Optimization enables management of energy and resources, saves time and costs, and ultimately, leads to greater accuracy in design of a device, and is easier to use [1-5].

In the daily progress of technology, human beings need precise accessories to make better and more efficient use of these technologies. One of the technologies that has made a significant change in human life is car. This means of transport eased a lot of human beings tasks and has become one of the most essential tools in the daily life. With the passage of time and increase of transportation vehicles and their variation, accuracy, convenience and safety of them has become a challenge. One of the devices which provide safety for the passengers of these vehicles is a safety belt.

In the present paper, a belt, which is one of the most essential parts of a vehicle security system, is reviewed. By measuring the dimensions of a sample one, the initial plan was drawn. Then, in order to have highly detailed analyses, Finite Element Method (FEM) was utilized, which had already been used in [5-7] as an accurate method. By the use of FEM, initial analyses were performed on the model, and the rudimentary results were classified and ready for optimization process. The schematics of the whole processes is depicted in Figure 1.

For the optimization process, Genetic Algorithm (GA), which was developed by John H. Holland [8] and has become one the most powerful methods, was chosen to have clear-out results. Although there are new optimization methods (such as the methods used in [9 and 10]), GA was emerged as a useful tool for the heuristic solution of complex discrete optimization problems which was based on the concept of biological evolutionary processes [11]. In this study, and during the optimization process, dimensions, fillets and stress concentrated points were investigated intently, so as to minimize the stress concentration and weight. Since one of the major concerns in the design of the mechanical parts is their weight, an appropriate range was considered for the weight change during the optimization process.

The present study is organized as follows: In section 2, the initial shape of the belt and its modeling is illustrated; in section 3, the GA optimization process and the optimized shapes is proposed; and finally in section 4, simulation results and concluding remarks are demonstrated.

2. Modelling

The objective of this study is to present an optimized shape for the vehicle safety belt. As a result, a hypothetical model of a vehicle safety belt was considered. First of all, the model was designed according to the dimensions pre-arranged, which is shown in Figure 2. Moreover, the scaled model is almost identical with the real dimensions (Figure 3 (a)), which leads to more precious results. The proposed 2D model was composed of two rectangular holes. All of the holes corners were filleted in order to decrease the stress concentration on the corners as possible. The forces that were imposed on the belt are shown in Figure 3 (b). The model is made of stainless steel with the properties that are tabulated in Table 1.

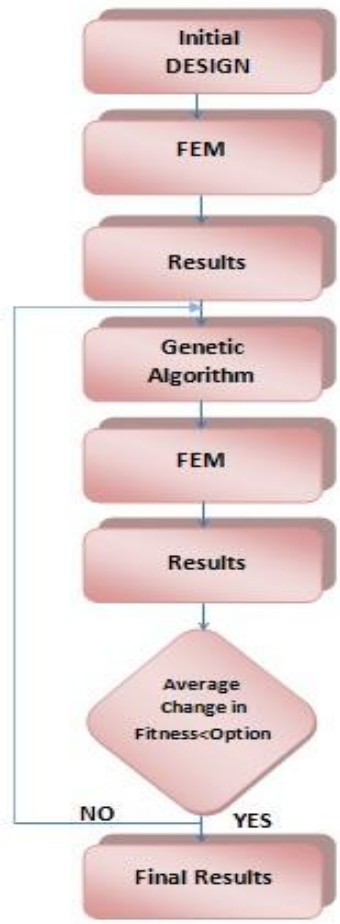
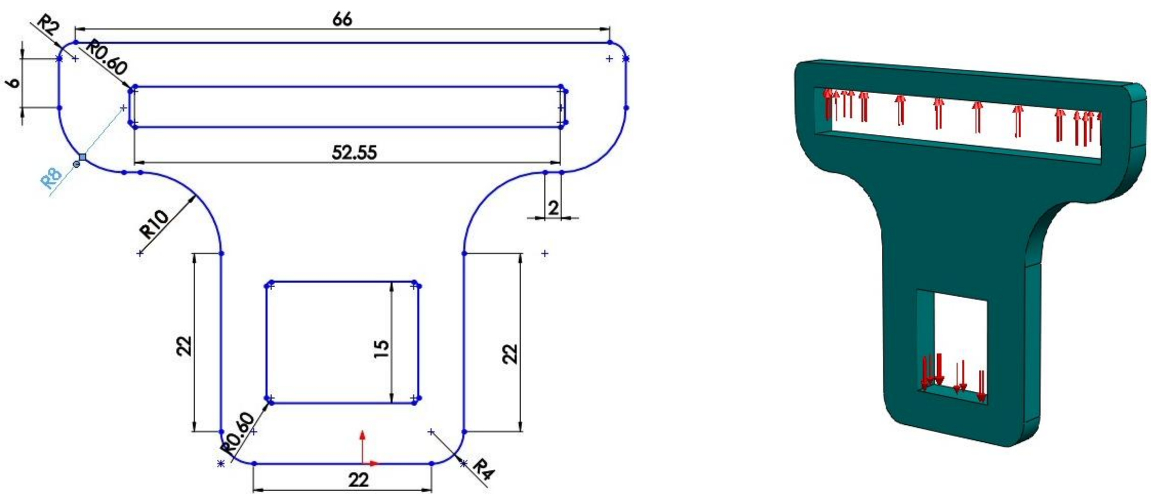


Figure 1. Overview of the whole process

Figure 2. The rudimental model



(a) (b)

Figure 3. (a) Scaled models dimensions; (b) Loads

Table 1: The physical properties of the model

Young Modulus	2.049e11 Pa
Poisson's Ratio	0.29
Thermal Expansion Coefficient	$1.20e^{-5}$ 1/K
Density	7858 kg/m^3

Traditionally, such complex problems which are governed by partial differential equations are largely solved using numerical methods, such as the FEM [12 and 13]. In these methods, the spatial domain is discretized and a finite element mesh is generated (Figure 4). In this study, triangular elements were used, which their properties are presented in Table 2.

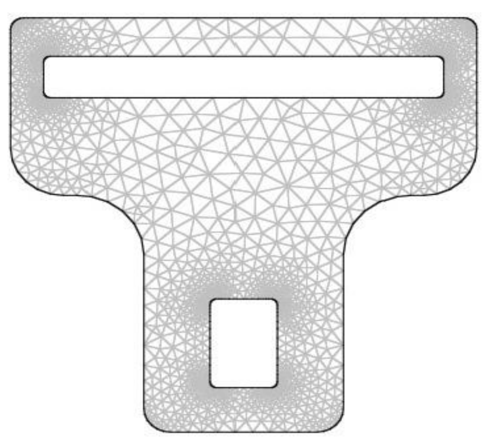


Figure 4. Schematics of triangular element

Table 2: Mesh properties

Number of degrees of freedom	14098
Number of mesh points	1837
Number of elements	3374
Triangular	3374
Quadrilateral	0
Number of boundary elements	302
Number of vertex elements	32
Minimum element quality	0.686
Element area ratio	0.001

Then, the proposed model was analyzed under static loading, by use of the FEM. This analysis was performed with specified initial conditions and a 5 kN tensile load. Results of the analysis will be presented in next section.

3. Results

Dimensions of the abovementioned model of the car safety belt was optimized with genetic algorithms. To achieve this goal, rectangular holes was assumed to vary in length, but with constant width. Additionally, the inside fillets were also assumed to vary. At each stage of the optimization process, variable parameters that were mentioned above will change in a certain predefined range. The aim of these changes in dimensions is to reduce, or in another way, to minimize the maximum stress. The Optimization results are reported in Table 3.

Table 3: The optimization results

	Before Optimization	**After Optimization**
Max. Von Mises Stress (Pa)	5.1081e9	1.9284e9
Min. Von Mises Stress (Pa)	4.1691e5	3.5714e5
Length of Hole Rectangle(1) (cm)	5.375	5.08825
Length of Hole Rectangle(2) (cm)	1.875	1.03175
Radius of Filet Rectangle(1) (mm)	0.6	1.8
Radius of Filet Rectangle(2) (mm)	0.6	1.4
Area (m^2)	0.0027	0.0028
Weight (Kg/m)	21.2166	22.0024

The results of optimization process are summarized in Figures 5 to 8. Figure 5 shows the average distance between individuals at each generation, which is a good measure of the diversity of a population. For the setting of initial range, there is too little diversity for the algorithm to make progress. Decay trends of cost function in optimization by GA of 2-D belt are depicted in Figure 6.

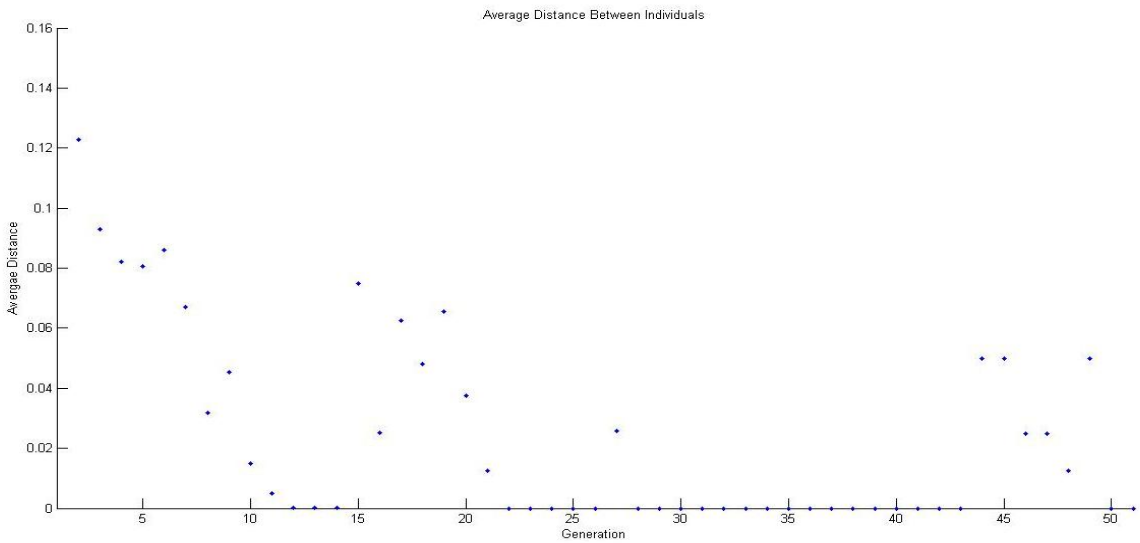


Figure 5. Average distance between individuals

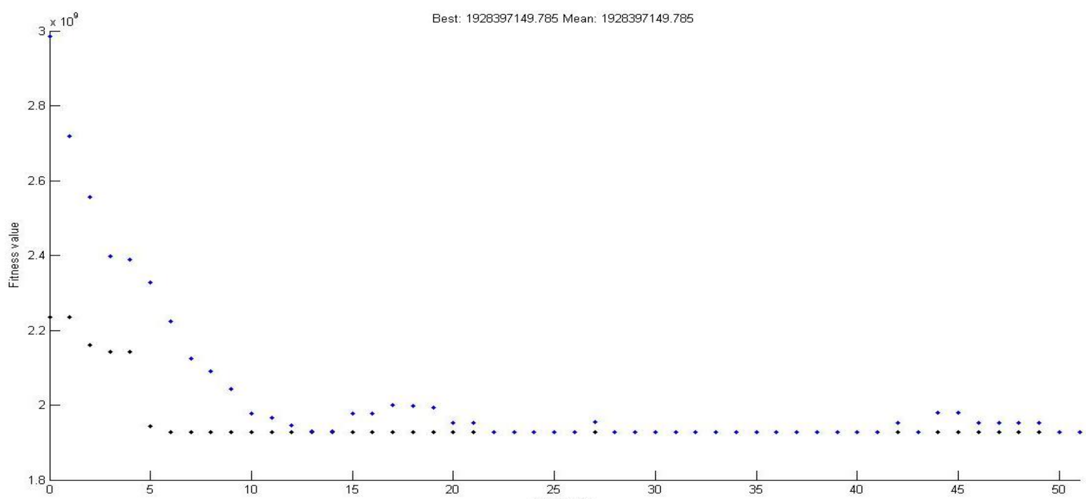


Figure 6. Decay trend of cost function in GA optimization of 2-D belt with 52 iterations

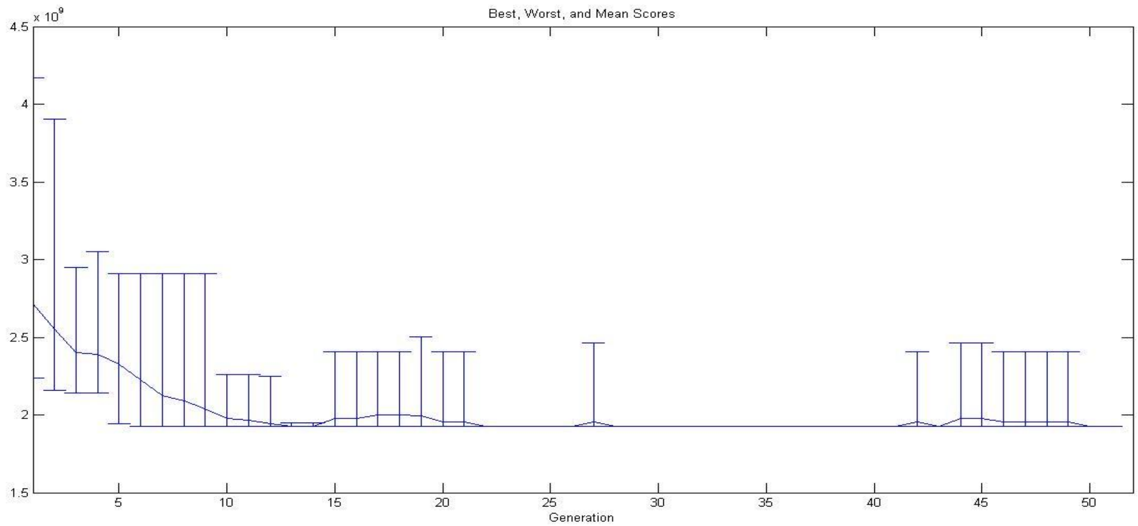


Figure 6. Range of fitness value

Figure 7 displays a vertical line at each generation, showing the range from the smallest to the largest fitness value, as well as mean fitness value. As the amount of mutation decreases, the range decreases too. These plots show that reducing the amount of mutation decreases the diversity of subsequent generations.

The final plot in this section, which is shown in Figure 8, is the inputs of the problem. These inputs are the bigger rectangular hole length, the smaller one, and their fillets and the final values (after the optimization process) are shown in the graph bar.

By using the optimization results shown in Table 3, the new shape of the model is shown in Figure 9. The stress analysis and displacement contours of the model are also shown in Figures 10 and 11, respectively.

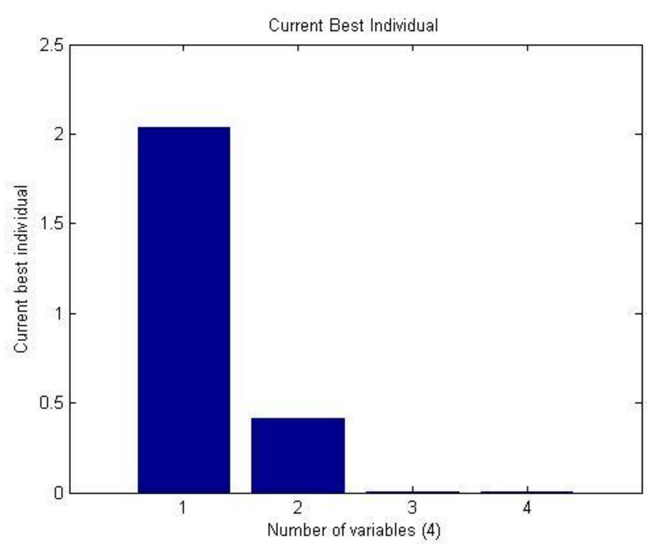


Figure 7. Best individuals

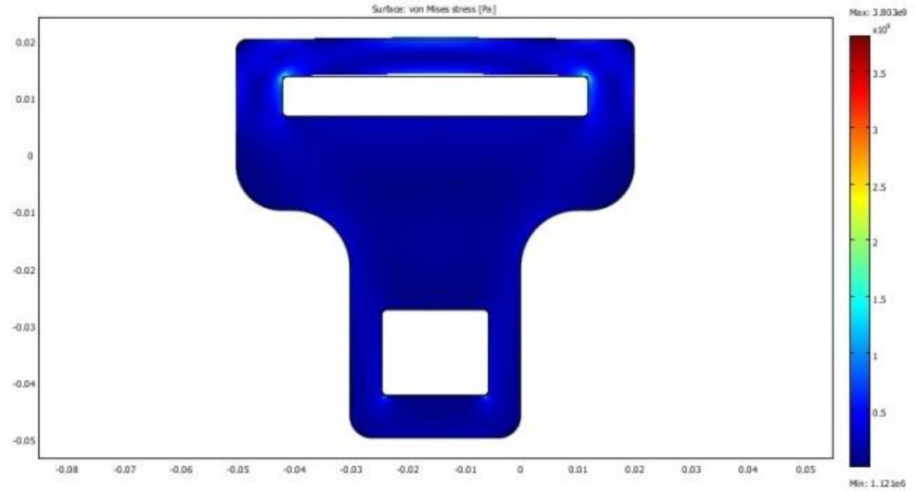


Figure 8. Von Mises stress; initial shape 1

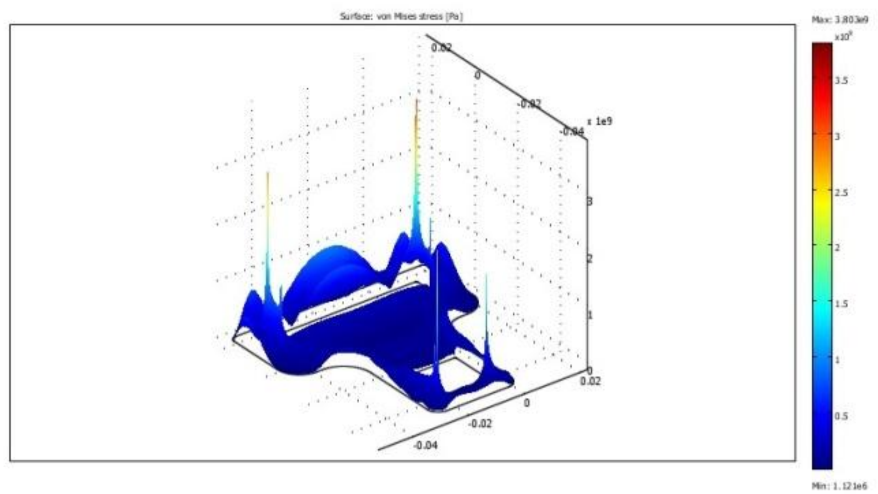


Figure 9. Von Mises stress; initial shape 2

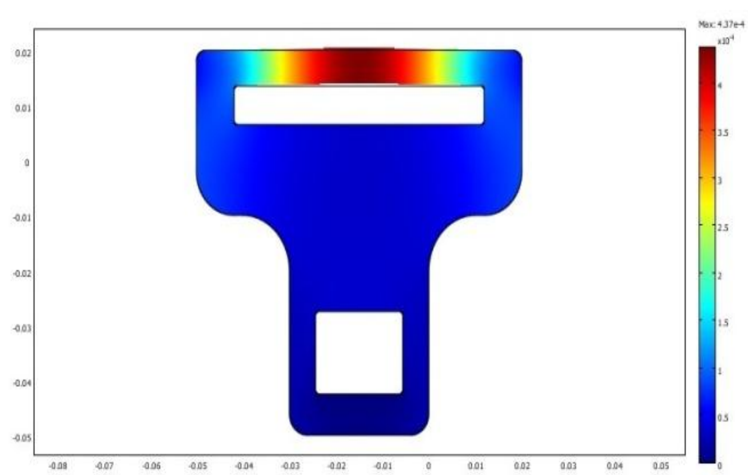


Figure 10. Displacement; initial shape 2

As is evident in Table 3 and Figures 7-10, in order to minimize the maximum stress, the rectangle size was made smaller after the optimization, which lead to a bit increase in the weight.

4. Conclusions

The purpose of this study was to optimize the shape of a safety belt to have the minimum range of weight parallel with the ability to put up with the loading while the generated tensile stress stands under the range of the allowable limit. To reach this goal, the model were designed, analyzed by the finite element method and optimized by the genetic algorithms. As can be seen in the result figures and tables, the holes become smaller after the optimization. As a result, the weight increases a bit, but not more than the range that were prearranged.

References

[1] A. Ketabi and M.J. Navardi, Optimization shape of variable-capacitance micromotor using seeker optimized algorithms, journal of electrical engineering and Technology, 7(2):212-220 (2012).
[2] S.K. Tiong, D.F.W. Yap and S.P. Koh, A comparative analysis of various chaotic genetic algorithms for multimodal function optimization. Trends Applied Sci. Res., 7: 785-791 (2012).
[3] A. Ketabi and M.J. Navardi, Optimization Shape of Variable Capacitance Micromotor Using Differential Evolution Algorithm, Mathematical Problems in Engineering, Volume 2010 (2010).
[4] B. Baumann, B. Kost, M. Wolff, H. Groninga, T. Blob and S. Knickrehm, Numerical Shape Optimization of Photoacoustic Sample Cells: First Results, Proceedings of the COMSOL Users Conference, October 23-24, 2007, Grenoble, France, 1-6 (2007).
[5] A. Manconi, P. Tizzani, G. Zeni, S. Pepe and G. Solaro, Simulated annealing and genetic algorithm optimization using COMSOL multiphysics: Applications to the analysis of ground deformation in active volcanic areas. Proceedings of the COMSOL Conference, October 14-16, 2009, Milan, Italy, 1-6 (2009).
[6] J. Shang and L. Zhang, Ant colony algorithm and genetic algorithm optimization for test vector reordering inform, Technol. J., 11:1786-1789 (2012).
[7] H. Strandberg, T. Makkonen and J. Leinvuo, Multi-objective optimization of a ball grid array using mode FRONTIER and COMSOL multiphysics. Proceedings of the COMSOL Conference, October 14-16, 2009, Milan, Italy, 1-7 (2009).
[8] J.H. Holland, Adaptation in Natural and Artificial Systems. 1st Ed., University of Michigan Press, Ann Arbor, Michigan, ISBN: 0472084607 (1975).
[9] M. Mashinchi Joubari, M. H. Pashaei and A. Fathi, Sizing optimization of truss structures under Frequency Constraints with Artificial Bee Colony Algorithm, Journal of mathematics and computer Science, 9:77-88 (2014).
[10] N.K. Naseri, A Hybrid Cuckoo-Gravitation Algorithm for Cost-optimized QFD Decision-Making Problem, 9:342-351 (2014).
[11] C.B. Cheng, C.J. Cheng and E.S. Lee, Neuro-fuzzy and genetic algorithm in multiple response optimization. Comput. Math. Appl., 44:1503-1514 (2002).
[12] W. Pao, X. Chen and L. Chao, Optimization of insulation padding for directional solidification, J. Applied Sci., 13:321-325 (2013).
[13] G.R. Liu, Mesh Free Methods: Moving Beyond the Finite Element Method, CRC Press, Boca Raton, FL., ISBN: 9780849312380 (2003).