

# Topography Optimization of Automobile Seat Belt Bracket

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**Keywords:** Topography Optimization, Belt Bracket, Finite element analysis.

**Abstract.** A finite element model of automobile seat belt bracket was built by Hyper Works. Through computer-aided analysis, it carried out that the original model maximum stress was 347MPa, which was more than the material yield strength 340Mpa. The original model needed to be optimized. The best distribution scheme of the ribs was determined by the topography optimization technique. After optimization, the maximum deformation of the automobile seat belt bracket was reduced by 36.7%, the maximum stress was reduced by 17.6%, and the strain energy can be reduced by 32.9%. The mechanical performance of the automobile seat belt bracket was improved and the optimization effect was achieved.

## 1. Introduction

Automobile seat belt bracket is a piece of sheet metal that fastens the seat belt to the car body which bear the main role of the seat belt tension. Seat belt bracket is frequently used and directly related to the safety of driver and passengers. So the seat belt bracket should be designed with sufficient rigidity and strength.

The traditional structural optimization design is mainly based on the experience of the designer [1]. Some basic scenarios are presented empirically, and then according to some judging methods to optimize until satisfied. Disadvantages of traditional method is unreliable and always changing the installation environment of the original design. In order to make the optimization fast and efficient, the seat belt bracket is optimization designed with the topography optimization technique [2].

Topography optimization is an advanced form of shape optimization in which a design region for a given part is defined and a pattern of shape variable-based reinforcements within that region is generated using OptiStruct. The design region is subdivided into a large number of separate variables whose influence on the structure is calculated and optimized over a series of iterations. The large number of shape variables allows you to create any reinforcement pattern within the design domain instead of being restricted to a few [3, 4].

## 2. Mathematical principles and optimization process

Topography optimization is one of the most commonly used structural optimization (topology optimization, shape optimization, topography optimization, size optimization) [5, 6]. Optimization has three essential factors which are design variable, Objective function and constraint condition. OptiStruct solves topography optimization problems using shape optimization with internally generated shape variables. One or more design domains are defined using the DTPG card. Mathematical model of topography optimization can be expressed as:

$$\text{Minimize: } U=W \tag{1}$$

$$\text{Subject to: } g_j(X) \leq 0 \quad j=1, \dots, m \tag{2}$$

$$g_h(X) \leq 0 \quad k=1, \dots, m_k \tag{3}$$

$$X_i^l \leq X_i \leq X_i^u \quad i=1, \dots, n \tag{4}$$

$U$  is Strain energy and  $W$  is external force. The functions  $g(X)$  in the constraint function is structural response obtained from a finite element analysis. The selection of the vector of design

variables  $X$  depends on the type of optimization being performed.  $l$  and  $u$  represent the minimum and maximum values. Application of product optimization design process is shown in Figure 1:

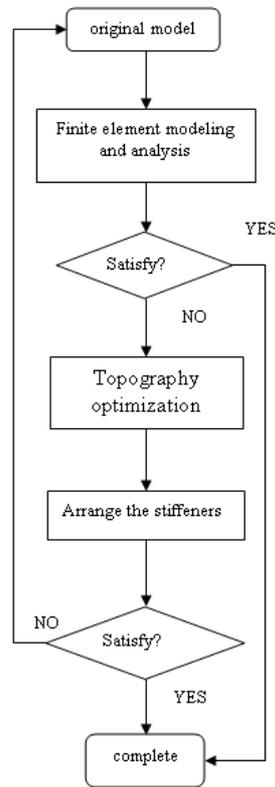


Fig. 1 Topography Optimization Product Design Flowchart

### 3. The original model structure analysis

#### 3.1 Finite element modeling.

The finite element pre-processing of the original vehicle seatbelt bracket geometry was performed using hypermesh. The basic unit size was 2mm, and the unit thickness was 1.1mm. Quadrilateral shell elements were used for meshing. The final number of units was 21119 and the number of nodes is 20837. The finite element model was shown in Figure 2.

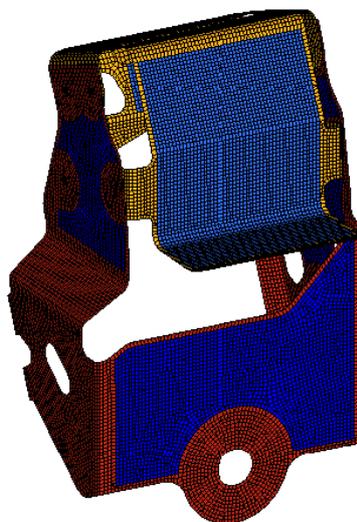


Fig. 2 The Original Model

### 3.2 Mechanical properties of materials.

The material used for the belt bracket was cold rolled dual phase steel with good strength and ductility characteristics. The thickness was 1.1 mm. The specific mechanical parameters of the materials were shown in Table 1.

Table 1. Mechanical properties of materials

Material	Elastic Modulus (GPa)	Poisson's Ratio	Yield Strength(MPa)	Tensile Strength(MPa)
CR340/590DP	210	0.3	340	590

### 3.3 Calculation results.

The finite element model was solved by RADIOSS solver. The overall strain energy of the support was 0.78J and the maximum displacement was 2.07 mm, which was shown in figure 3. The maximum stress was 493.4 Mpa which was more than yield strength 340 Mpa. The mas stress was shown in figure 4. To increase the safety factor, the original structure design must be optimized to improve its stiffness and strength.

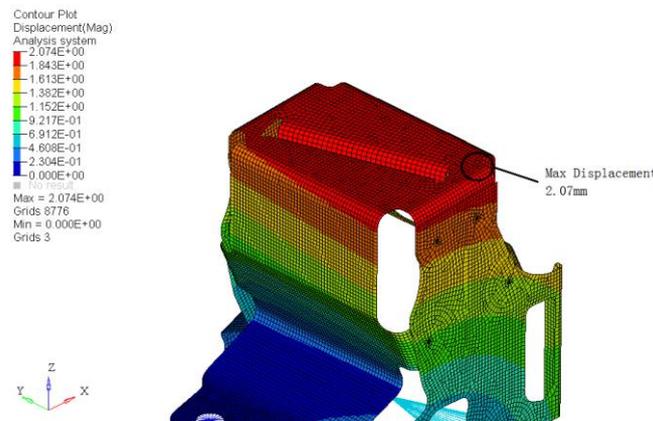


Fig. 3 The Original Model Max Displacement

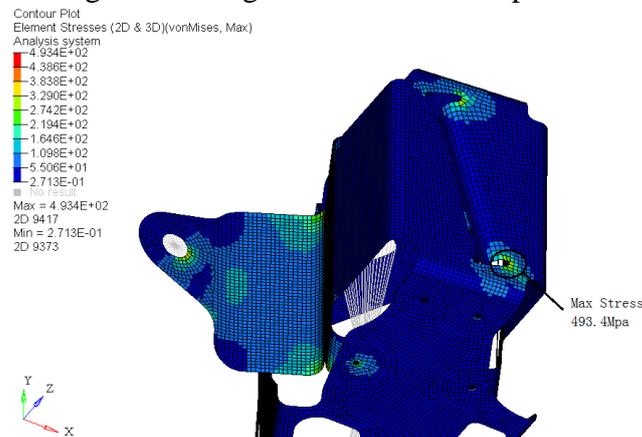


Fig. 4 The Original Model Max Stress

## 4. Optimization Analysis

Through the above analysis, it can be determined that the original design of the seat belt bracket decided to be optimized to improve its safety factor. In order not to change the material cost of the bracket and installation conditions, topography optimization technology was used to optimize the original structure by OptiStruct. The location of the ribs should be determined to increase the strength of the bracket and reduce the maximum stress.

### 4.1 Optimization Variables

Under the condition of ensuring the original design material cost and the basic assembly relation, the flat area was selected as the design variable area.

#### 4.2 Optimization Objective

Strain energy was the potential energy stored in the form of strain and stress. Strain energy could reflect the overall stress and strain of the object. The optimization goal was the minimum strain energy.

#### 4.3 Optimization constraints

Manufacturing methods can place constraints on the types of reinforcement patterns available for a given part. Some examples of this are: channels, which must have a continuous cross-section; discs, which must be turned on a lathe; and stampings, which cannot have the die lock conditions.

These constraints can be accounted for in topography optimization by using Pattern Grouping Options, and a design with a manufacturable reinforcement pattern can be generated.

The main constraint for the topography optimization was the setting of the stiffener parameters. The minimum rib width was 5 mm, the angle of the tendons was 60 degrees, and draft height was 2 mm.

#### 4.4 Optimization Results

The automobile seat belts bracket was optimized to obtain the optimal distribution of stiffeners, and the topography result was shown in Figure 5. The relative weakness of the structure resulted in the creation of a number of differently shaped ribs. The maximum deformation of the node was 2mm and the appearance was very regular.

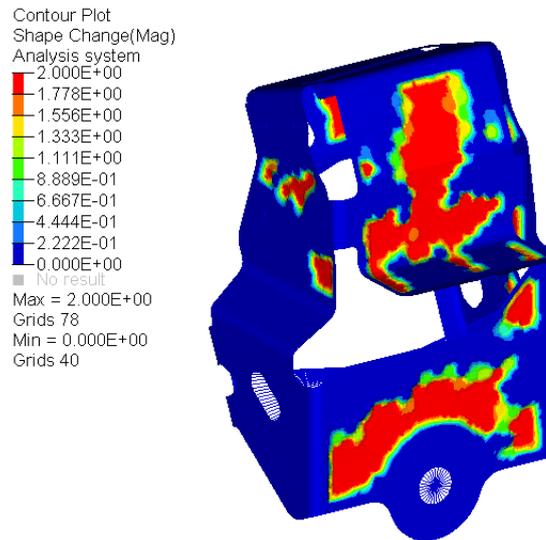


Fig. 5 Topography Optimization Cloud Picture

Comparison of parameters before and after optimization was shown in table 2.

Table 2. Comparison of parameters before and after optimization

Heading	Strain energy (J)	Maximum displacement (mm)	Maximum stress (Mpa)
Before optimization	0.780	1.57	347
After optimization	0.523	0.993	285.9
Percentage	-32.9%	-36.7%	-17.6%

#### 5. Summary

In this paper a vehicle seat belt bracket finite element model was established and optimization designed by HyperWorks software. Through the topography optimization technique, the original structure model was optimized. After optimization, the maximum deformation of the automobile seat belt bracket was reduced by 36.7%, the maximum stress was reduced by 17.6%. This paper provided a reference for improving the safety of the vehicle seat belt bracket.

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