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# Engineering Design of Safe Automobile Front Strut Tower Brace with Predetermined Destruction

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# Engineering Design of Safe Automobile Front Strut Tower Brace with Predetermined Destruction

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**Abstract.** This paper shows the developed design of an automobile front strut tower brace instantly breakable on reaching a predetermined value impact load, which allows the impact load not to be transferred to the opposite strut. An automobile front strut tower brace with the directed destruction V-shaped element using the SolidWorks and SolidWorks Simulations software complex was developed, designed and analyzed. The obtained data were confirmed experimentally. By changing geometric features of the V-shaped element, it is possible to change the impact load value required for its destruction.

## 1. Introduction

All car bodies are welded structures made of various components. There are two types of car body construction: a framed body and a unitized body. The unitized body means that all suspension components are attached to the welded structure, and it absorbs all impacts, torsions and deformations. Frame cars present a frame with fastening suspension elements and a body attached to the frame. The framed body cars represent a frame to which are attached all suspension components and a car body. The frame is made of 4 mm metal, and the body is made of 1 mm metal. Thus, framed body cars are less prone to fatigue deformation and retain their factory strength for a longer time, which is not possible to say about cars with a unitized body. Most all manufactured car models are now with a unitized body, for reasons of better handling, smooth ride and savings on the manufacture costs. The cars as they come off the production line have the necessary stiffness, but within 3 or more years of operation, due to rough roads, aggressive driving, excessive loads and time, the metal accumulates fatigue cracks, the gaps vary in size and the body loses its strength to 30%. The loss of strength and stiffness leads to deterioration of vehicle control and reduced safety [1]. By installing the automobile front strut tower brace, it is possible to increase the useful life of a car through preventing premature fatigue-crack nucleation, to improve passive safety through the ability to control the car even in extreme situations, and to significantly improve vehicle steerability. The automobile strut tower brace extends the operation life of a new car and returns the factory stiffness to an old one [2,3,4]. The strut tower brace is a metal structure linking together the two attachment points of shock absorbers to a car body. It is a load-bearing structure [5].

Depending on the emplacement of the strut tower brace, it is able to reduce movement of the rear shock absorber towers by 20%, to reduce the total torsional stiffness of the body by more than 2.5%, as well as movement of the front suspension arm bracket - more than three times, to reduce the stresses arising in the arm bracket and the connector of the longitudinal side member with the floor - by 35% and the stresses arising in the area of the right steering gear bracket - by 8.5% [1,5,6].

The main interest in strut tower braces is shown by motorsports. Especially they are in demand in closed-circuit races and drift competitions, as car bodies are constantly subjected to extreme stresses, which affects the fatigue crack growth rate. In order for a sports car to withstand more races, to have better car handling, to easily pass the most difficult superelevations, as well as to be safe for a driver, car mechanics install different types of strut bars on the cars.

At the present time, very many civil vehicle owners are aware of the existence of the strut tower brace and its benefits, but very few of them use it on their cars, for fear of its only drawback. The additional rigidity of the car significantly increases its damage in a road traffic accident [7,8,9].

The automobile front strut tower brace works as follows: while cornering the increasing load on one of the front suspension struts strives to move them relative to one another, which is prevented by the strut tower brace, taking the load and evenly distributing it between the front suspension struts. All this improves steering response and reduces deformation of the body in torsion and in compression, thereby reducing the probability of microcrack initiation and fatigue [1, 2].

The automobile front strut tower brace ensures:

- increasing vehicle stability when driving on a straight road;
- significant increase in steering control accuracy in curvilinear motion. The car can enter into a turn at a higher speed without lurching and drifting;
- reducing deformation of the car body during driving on low-quality and rough roads, as evidenced by disappearance of squeaks in the cabin.
- preservation of suspension members. The suspension of the car is less exposed to wear due to complete disappearance of free play. The load is distributed more evenly.
- reducing the probability of body crack nucleation due to operation (age defects);
- increasing the car body stability under high loads and in aggressive driving;
- protection of the driver and passengers from getting the engine into the cabin in the event of a frontal collision.

Despite all the benefits, the automobile strut tower brace has a disadvantage making many people forgo this structural modification of the car:

- in case of a strong lateral impact on one of the vehicle parts, the opposite part connected to the damaged part by a strut tower brace will also be subjected to deformation, since the shock wave is distributed through the brace. That will lead to the repair of the entire forecarriage of the car, which threatens with great economic costs.

Many distinguished car-makers constantly carry out research and develop various designs of strut tower braces that would not have this drawback, but none of the currently known designs of strut tower braces does not provide the necessary rigidity of the structure during operation and the minimization of damage to the car body in case of a lateral impact at the same time.

Alternatively to the presented analogues, the proposed design of the front strut tower brace combines the necessary rigidity increasing the vehicle controllability, but at the same time, its installation will not lead to increased car repair costs even in the event of a side collision, due to a brittle V-shaped element acting as a safety appliance designed specifically for preserving the car behaviour factory parameters in a road traffic accident.

## 2. Materials and Equipment

For obtaining an instant brittle fracture of the V-shaped element of the designed strut tower brace, gray cast iron of the grade SCH-20 was chosen which does not have plastic deformation. For simulation and preliminary analysis of the proposed construction of the designed strut tower brace and its brittle element, the SolidWorks and SolidWorks Simulations software complex was used [10]. Tests for static loading and low-cycle and high-cycle fatigue were carried out using the Instron 8801 machine, impact tests were carried out using the impact testing machine. For cyclic load tests, the prototype of the developed strut tower brace with the directed destruction brittle V-shaped element has been installed on a unitized body passenger car with a service life of more than 18 years. The prototype has been used for 6 months.

### 3. Analysis of Simulation Results in SolidWorks and Experimental Data.

Considering the only disadvantage of automobile front strut tower braces, a strut tower brace with a V-shaped element made of gray cast iron (Fig. 1) was designed, which makes it possible to avoid transmission of impact loads from the damaged part to the opposite one, breaking under a predetermined load value.

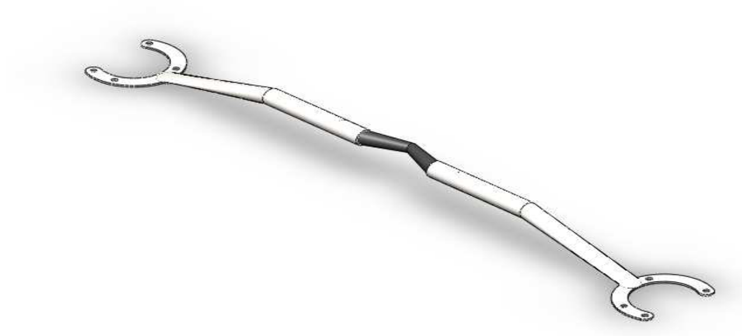


**Figure 1.** 3D-simulation of the automobile front strut tower brace in SolidWorks.

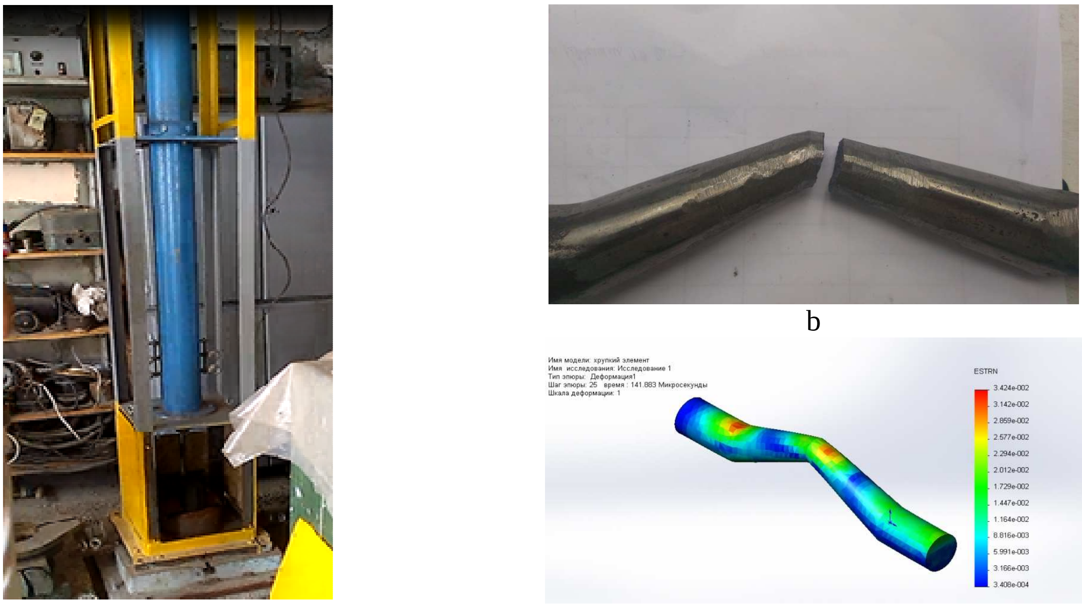
Gray cast iron has been chosen as it does not have a yield point, and as a result it does not yield, and when the ultimate stress limit is exceeded, it has brittle fracture which is characterized by instantaneous velocity [3]. The angles of the V-shaped element, as well as its dimensions, are calculated so that it breaks at a load value less than the load value at which the car body can undergo serious deformation.

All calculations and development were carried out in the SolidWorks and SolidWorks Simulation software complex.

The developed brittle element was investigated for strength characteristics, such as impact, static and cyclic loads that the strut tower brace undergoes during operation.

1. Impact loading. The impact load value, at which the brittle element will break, should be lower than the load capable to deform the car body and higher than the shock stress transmitted from potholes and road irregularities. After analyzing the data presented in the specialist literature and the data derived from crash tests, it was found that the impact load of 3000N transmitted through the strut tower brace from one strut to another does not damage the strut opposite to the impacted one. If the impact load value of 3000 N is exceeded, the opposite strut is damaged. Impact tests were carried out using the impact testing machine. The V-shaped elements were tested at the impact load values of 2600 N, 2800 N, 3000 N. At the impact load value of 3000N, the test specimens were destroyed, at the other values, only crack nucleation appeared [4].

Figure 2 shows the data obtained through process simulation of impact loading on the brittle V-shaped element of the automobile strut tower brace in SolidWorks Simulation. The data obtained during the simulation were confirmed experimentally. The plane through which fracture passed is shown, the cross section analysis shows that the fracture is brittle [3]. Thus, using the SolidWorks and SolidWorks Simulation software complex, it is possible to predict the destruction direction of the V-shaped element, and also to determine geometric characteristics of the V-shaped element depending on the specified destructive load.

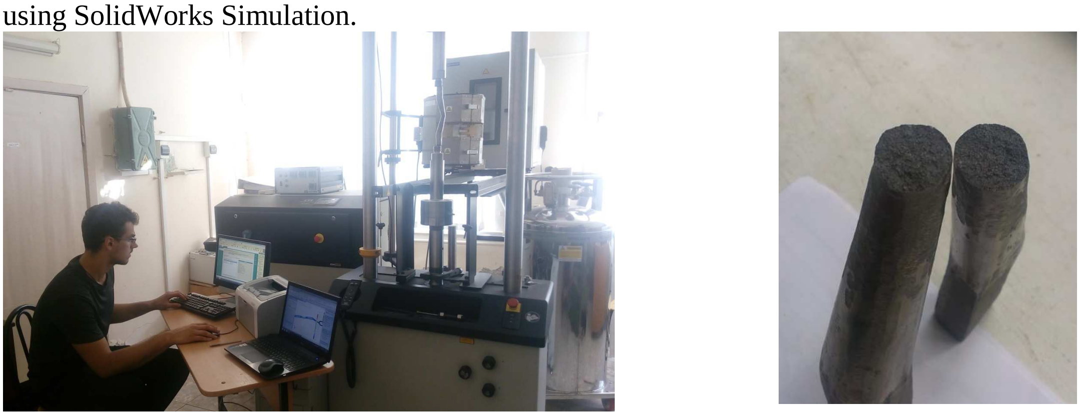


a b c

**Figure 2.** a - tests for impact load with the impact testing machine; b - the brittle element after impact tests; c - impact load simulation on the brittle element in SolidWorks .

2. Static loading. The static load value taken by the strut tower brace must exceed the impact load value. Static loading occurs only during cornering of the vehicle and cannot critically deform the car body. According to the theory of fracture mechanics, complete destruction occurs when the arising stress over the entire cross section exceeds the ultimate strength of the material. If the arising stress exceeds the ultimate strength of the material in a certain sectional area, that leads to crack nucleation [4]. The static load analysis is standard. The strut tower brace undergoes the given type of loading under cornering. During simulation in Solidworks Simulation, it was predicted that the V-shaped element would break at 30000N, which is significantly greater than the load transmitted through the strut tower brace from one strut to another.

The tests for static loading were performed on the Instron 8801 testing machine. The load value, at which the specimens were fractured by compression, was 30000N, which confirms the data obtained using SolidWorks Simulation.



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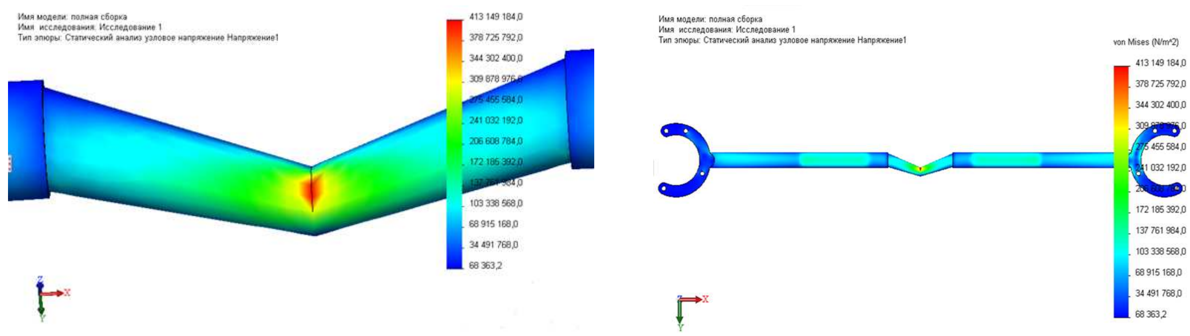

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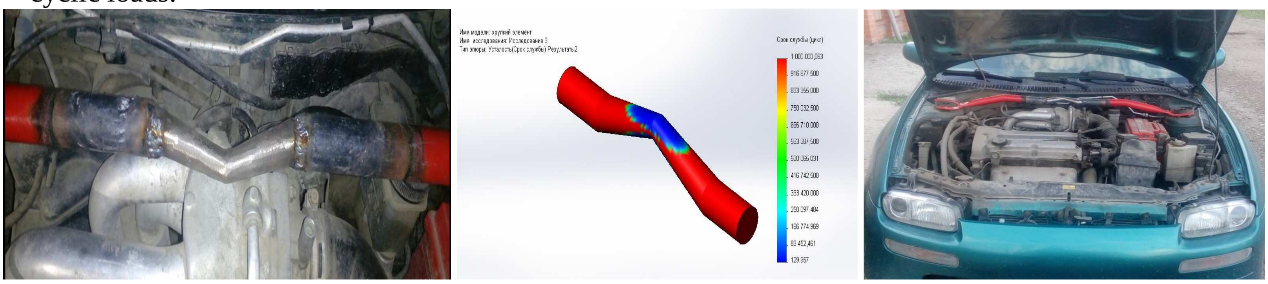
**Figure 3.** a - tests for static loading of the brittle element with Instron 8801; b - the brittle element after tests for static loading; c - simulation of the static load on the brittle element in SolidWorks; d - simulation of the static load on the 3D simulation of the strut tower brace in SolidWorks.

3. Cyclic loading. The number of cycles that the brittle element can withstand is a very important indicator. During movement under cornering and on a rough road, the strut tower brace undergoes cyclic loads.



a b c

**Figure 4.** a - simulation of cyclic loading on the brittle element in SolidWorks; b - the brittle element installed in the strut tower brace by means of a press fit and a welded seam; c - the automobile front strut tower brace installed on the car during the testing period.

The cycling tests were carried out using SolidWorks Simulation and experimentally by installing a front strut tower brace with a brittle element on a real car. The authors have tested the car with the installed strut brace on a car-testing track in extreme conditions, with sharp turns, hard braking and brick accelerations. The strut-braced car has been operating on unsurfaced roads and roads of the city till the present day with periodic control of the V-shaped element. So during the intensive operation of the car, no fatigue crack nucleation was found on the V-shaped element.

## 4. Conclusion

The developed design of the automobile front strut tower brace with the brittle element is safe when used on a car. This strut tower brace retains all the advantages of analogues, but at the same time it is able to instantly break when reaching the predetermined value impact load.

In the course of the study, the design of the strut tower brace with the V-shaped element demonstrated combination of such properties as integrity and rigidity, as well as safety, minimization of damage to the car body in case of an accident. The tests confirmed the data obtained with the use of SolidWorks. The V-shaped element of the strut tower brace withstands static loading of 30000N and breaks on impact above the predetermined value of 3000N, withstands the cyclic and static loads that the strut tower brace undergoes during the operation of the vehicle.

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