Real stress arising in the backrest frame of a car seat

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Abstract: At present lot of people spend still more of their life on the road. Vehicles have been becoming ever more sophisticated and the main direction of their development is placed primarily into the areas of environment, design, safety and comfort. The main current trend with regard to the environment, reducing emissions, fuel economy etc. is reduction of vehicle weight. A large amount of manufacturers and research works is concerned on a reduction of the weight of individual vehicle components primarily by application of unconventional materials. We've been finding highly sophisticated composite material which by targeted influencing of their properties can replace conventional steel materials with considerable weight reduction. As a long-time neglected part in this area we can generally mark the steel frames of car seats, especially their big mass which reduction can be a good challenge in future optimizations. In this work based on experiments with the normalized loading and numerical simulations we found how big stress and strain arise in the frame and especially their distribution. The experiment was based on loading of the back rest with a controlled torque relative to the R point of the seat. The overall deformation was monitored with using a laser and local deformation using strain gages. For a more detailed description of the emerging stresses, primarily about their distributions and directions a quasi static numerical model has been created. The found results will be applied mainly for the future construction of a composite backrest.

Keywords: car seat; real stress; Steel frame; experimental loading; simulation.

1 Introduction

Car seats are the one of very important parts of cars with a direct influence to subjective feelings, safety and ride quality. The important parameters of passenger comfort and safety are mainly properties of vibration isolation and their ability to a shock absorbing [1]. The standard seat frames are usually weldment from steel stampings and wires. The comfortable infill ensures parts from molded polyurethane foams which are being replaced with low the density foams, however, with even better properties. The properties of used foams are very important while driving a car lasting more hours, because they must sufficiently stabilize muscles especially in the area of pelvis and spine. With this requirement help us quite significantly the textile coating that doesn't have only an aesthetic role, as might appear at first, but also ensuring the rigidity of a cushion [2].

In the seats construction (Fig. 1) there are standardly some adjustable elements that can modify and set the position of the cushion, backrest, peripherals and entire position of the seat in a cabin of a car. The primary mechanisms provide longitudinally sliding guideways moving in the length of around 250 mm, controlled a rod on the lower front part of the seat. The body of the backrest is angularly adjustable via a control mechanism located on one side of the seat. For new and more luxurious types of cars all positions and angles have been controlled electronically by stepper motors typically with worm gears.

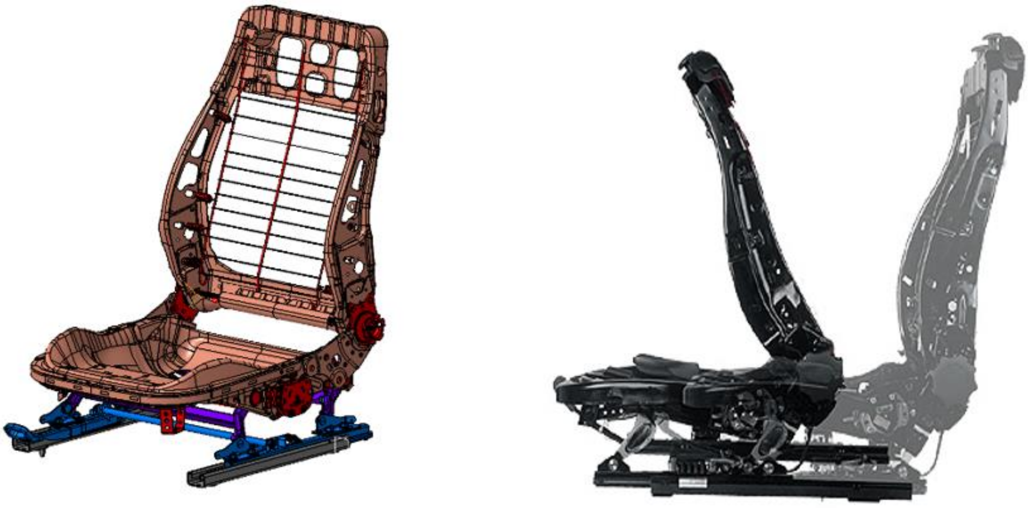


Fig. 1: The CAD model of a tested car seat in Catia and visualization of a seat shape adjustment.

2 Testing of car seats

Generally there are two group of tests. Tests that coming from the first "comfort group" like the damping, transfer function, specific pressures, breathability and thermal comfort are on safety involved indirectly, because their impact is primarily on the driver's person and his mental or physical condition. Then there is a second group of tests that cover direct mechanical testing of the seats, their parts and to the safety have an impact primarily at the time of an accident. The most commonly tested are particularly: Strength of seats, seat belts and their mounting into the floor, and static and dynamic tests of the steel frame.

2.1 Comfort - interaction with human

According to [1, 3] is driving a car action which has relatively high demands on the mental and physical capabilities of the human. A human weight and physique of each individual have a straight influence to the interaction of the body and seats. For a description of their interaction is usually used a parameter describing a distribution and size of the stress called Contact pressure, that size should not exceed the recommended health limits. According to physiological norms [4] and e.g. Vlk [5] a seat supports the driver in a relatively large contact area and transfers most of his weight. Ratios for individual parts should be approximately 64-72% on cushion, 4-16 % to backrest and the remaining approximately 15% goes as a reaction from the feet to the floor of a vehicle. It is very important, to support the lumbar spine and a minimum support in a popliteal part. Individual values were verified experimentally using X-sensor (Fig. 2) and subsequently by recalculation [6, 7] of the areas in which operate specific pressures to the resulting forces in dependencies of the cushion and backrest angle (Fig. 3).

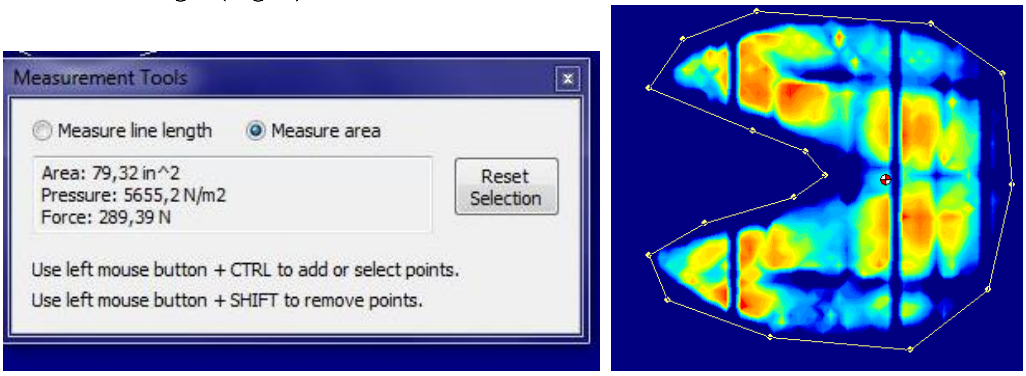
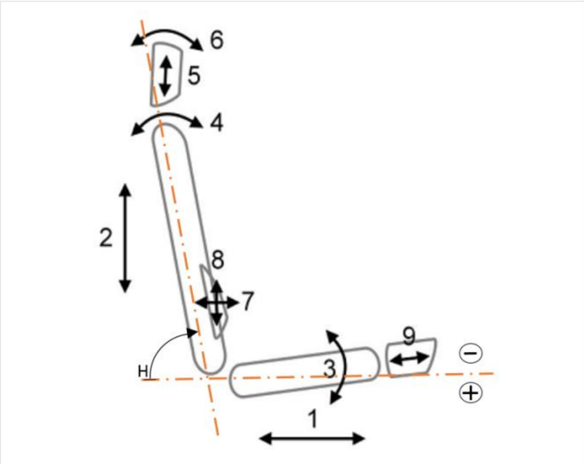


Fig. 2: Measurement of the specific pressures and subsequent determination of the forces using linear tracing of the contact region



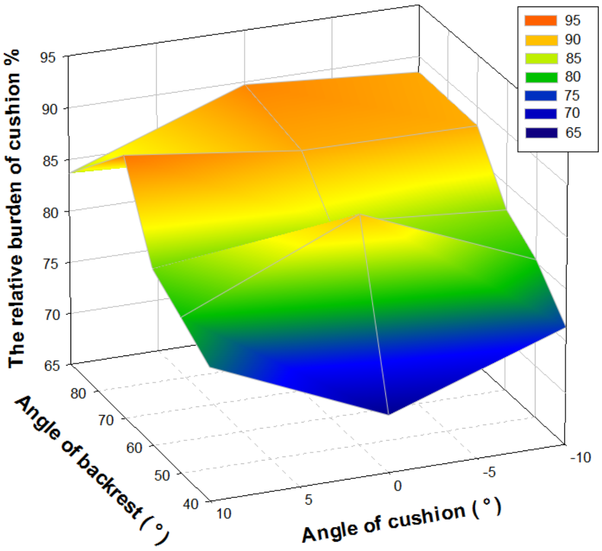


Fig. 3: The distribution of specific pressures on the seat while adjusting the angle of the seat and backrest

2.2 Mechanical tests

As already mentioned, this group includes tests that have primarily the influence to safety and in the event of an accident they should as much as possible eliminate its impacts, reduce damage to the health and save life of passengers. The most common and absolutely necessary are the tests according to [8, 9]:

Strength of seats and their fastenings to the floor. This are concentrated on a check of the angle adjustment mechanism and a frame of the backrest (Fig. 4) with torque 530 Nm relative to point H at a strain rate 150-300 mm/min. Due to the significant hysteresis of the entire structure, the loading perform several times consecutively is recommended. Then, there are static tests of the longitudinal sliding mechanism and rigidity test of the frames which are loaded 20 times the weight of the seat in the center of gravity. All this parts are also mostly checked with loads corresponding to 20 g. Further some tests on the headrest by a load-inducing the recommended torque with a maximum allowed deformation at the headrests less than 102 mm. For a dynamic test a spherical impactor with speed of 24.1 km / h is used that bump into the headrest when a deceleration on the impactor should not exceed 80 g for 3 ms.

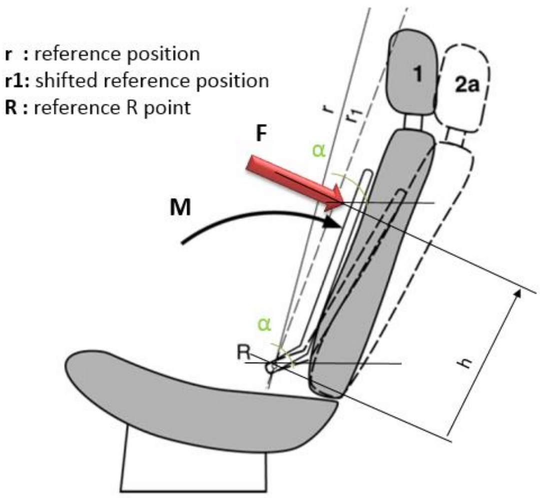


Fig. 4: Loading of the backrest (defined by a force or an equivalent torque) and position the strain gauges

3 Experiment

Considering the known dimensions of the tested seat and load from the normalized 95% male at the upper statistical percentile of weight we get, relative to the point R, a static torque about 23Nm. According to the safety standards [9], the load values ranging up to 700 N for the cushion and 400 N on the backrest, eventually a force that to the backrest cause torque 530 Nm relative to the axis of rotation.

Fig. 5: Scheme of the carried experiment

Loading on the backrest (Fig. 5) was carried out in sequence of three cycles as prescribed the standard with the feed rate of 10 mm/s. The testing force was up to 3000N (torque ~800Nm) which slightly exceeds the recommended values on that the backrests are tested. Two strain gauges were placed at the front and rear side of the frame. The front gauge (side to the steering wheel) measure elongation and the rear strain gauge measure a warping in the place of change the curvature of the frame. The entire experiment was also modeled through static contact analysis in software Ansys.

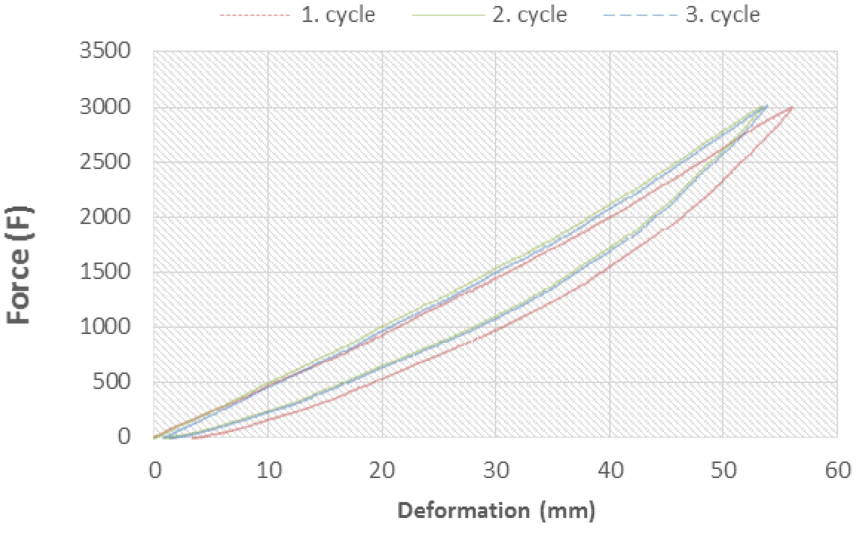


Fig. 6: Displacement in the upper part of the seat frame measured by a laser

As can be seen in the results (Fig. 6) under repeated loads was the first cycle always different and for other cycles seem the hysteresis loops to be almost identical. In the Fig. 7 there is possible to see the values of relative deformation at the front and rear side of the frame, which can help us to have at least an approximate idea about the rising deformations.

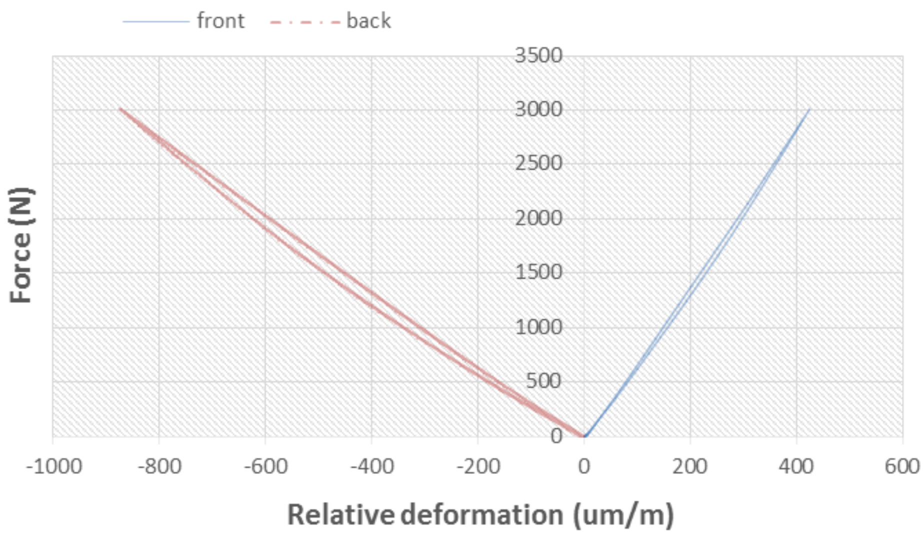


Fig. 7: The relatively deflection measured on the front and back strain gauges

4 Model

An analogical FEM model of the carried experiment carried out has been created in Ansys Software. Due to the rather complex geometry has been the CAD geometry of the backrest slightly optimized and solved as the shell element. This was especially suitable for creation the meshes and also due to time of calculation. Contacts at the connection the individual parts of the frame were formulated in multi-point constraint (MPC), which is generally suitable for “Bonded” and “No separation” behaviors. This approach is not based on the Penalty-base or Lagrange multiplier theory, it is direct and effective way for prescription contact two perfectly connected areas [10, 11]. The chosen detection method was Nodal-normal from contact with the constraint of Inside pinball radius with Couple U ROT and an automatic detection of region. The process of convergence during this model solution, has been smooth without chattering, which can sometimes appear in contact models because of used step functions. This problem is of course especially for frictional contacts.

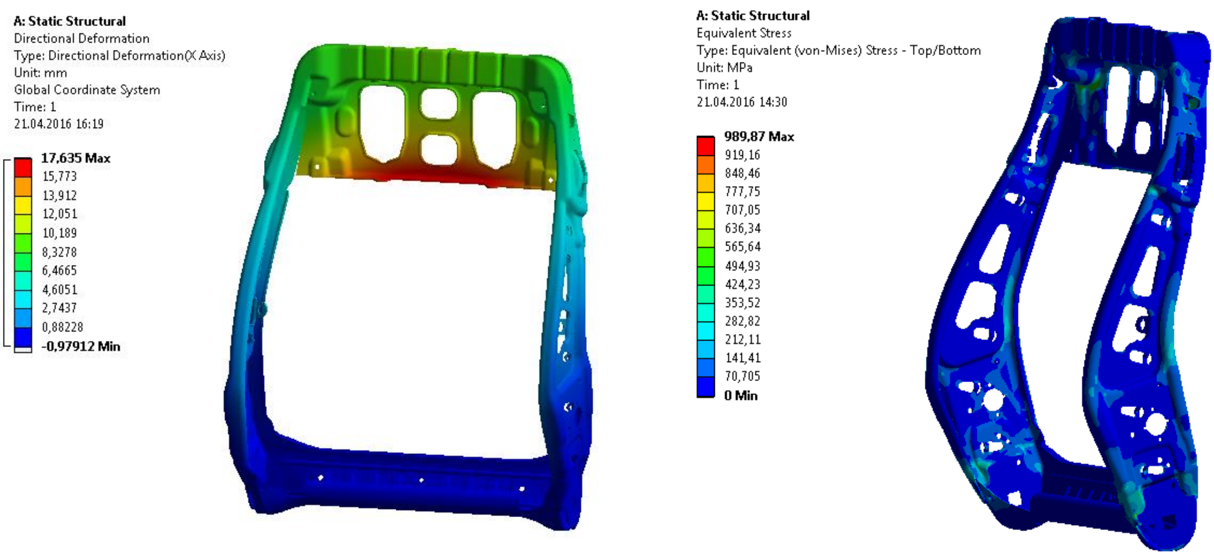


Fig. 8: FEM model of the strain and stress in the frame of backrest

5 Conclusion

The experimental results show that even with a significantly higher loading the size of the deformation on top of the frame is still just only around a half of the allowed value. Based on the FEM model results the deformations (Fig. 8), their distribution and simultaneously the individuals directions and character of stress could be clearer described. In comparison the experiment and model we could find a relatively smaller total deformation for the numerical solution. This is caused by the fact that a large portion of the deformation during experiment is caused by clearances in the backrest adjustable mechanism.

In technical literature can be found lot of works dealing with the areas of seat comfort, shock absorbing, biomechanics of human and the headrests during an impact etc. However, only several of them is devoted to a thorough description of deformations and stress in a such common part as is the frame of seater itself. The results of test conducted in this area by the car manufacturers are not easily achieved. For this reason this work has been aimed to making a sort of mapping of the fair values of stress and strain arising during the real and normalized loading. These results will be in future used primarily for comparison with proposal concepts of developed composite frames.

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