DESIGN AND OPTIMALIZATION OF RACING CAR'S STEERING COLUMN

Lukáš Horňáček[1]

Summary: Article describes the design of racing car's steering column. First part describes legislative issue of safety cages in light of operation of vehicles on roads and in terms of technical regulations. In the next part are described design of variants, calculation of stresses and deformations using finite element method, the materials used in design of racing car's steering column and production technology of the steering column selected variant for a racing car.

Key words: rollcage, technical requirements, welding, finite elements method

INTRODUCTION

The holder is part of a steering column of the vehicle, which serves to support the steering wheel and its accessories. For civilian vehicles steering column bracket serves as a holder of dashboard. The holder of the steering column is for civilian vehicles robust than for racing cars. For civilian vehicles is necessary that the holder, including the steering column, must meet the technical requirements for approval of vehicles. Racing car steering column bracket is a separate unit, which carries only the steering wheel, or its accessories due to weight reduction. Post holder must be sufficiently rigid and light. Vehicle weight and the stiffness of individual units is very important for racing cars. Bracket steering column in racing vehicles is homologated separately within the body, when the body is connected by permanent joints. Or it's homologated separately if it is mounted detachably.

1. THE USE OF DESIGN SOLUTIONS

The design of the steering column at civilian vehicles relates to regulation ECE and ED. For these vehicles the steering column also serves as a handle - Anchor Point - for the dashboard. Placed on it other claims and demands than the racing vehicles. The holder of the steering column is an element of passive safety. According to the regulations, in frontal impact situation, the downward deformation of steering column is necessary, due a contact of driver's body with steering wheel. Malfunction of required downward deformation results to serious injury of the driver, or his death. The steering column is designed as a sliding mechanism with a perforated metal cylinder (tube). Inside this tube is placed a drive shaft bearings. Cylinder of perforated sheet metal is the most important deformation element and together with a sliding mechanism allows movement of the steering wheel downward. The sliding mechanism of the steering wheel is also important ergonomic component for driver comfort.

[1] Ing. Lukáš Horňáček, VŠB – Technical University of Ostrava, Faculty of Mechanical Engineering, Institute of Transport, 17.listopadu 15, 708 33 Ostrava-Poruba, e-mail: lukas.hornacek.st@vsb.cz

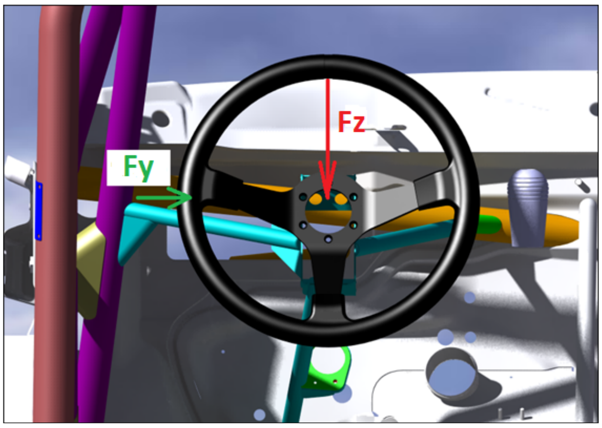
Source: Author

Fig. 1 – Holder + steering column of Škoda Octavia III. generation

Racing vehicles are special vehicle category and a changes in vehicle structure according the rules are allowed. Modifications of the steering column bracket can be realized under the supervision of NSC FIA. The structure must be able to operate also in fault, after the impact. Driver safety is primarily ensured by the design of the protective frame and by 6-point seat belts with anatomically shaped seat shell. The downward deformation of steering column is not necessary, beside a civil vehicles. Due this reason the safety aspects of a steering column for racing cars are insignificant. Design of steering column is different for different manufacturers of racing cars, but meets the same requirements. (1)

2. DETERMINATION OF ENTRY CONDITIONS OF THE PROPOSAL

The input conditions are important for the column design. For static analysis of the problems I came out with the steering and control forces on the steering wheel. Conditions are determined by ECE No. 79. Bracket is loaded by forces F_Y = 60 [N] in the horizontal plane and F_Z = 600 [N] in the vertical plane of the wheel according to the scheme. The force F_C represents a dynamic impact after the vehicle jump. Force F_Y represents driver's resting on the steering wheel by embarking or disembarking.



Source: Author

Fig. 2 – Load diagram of holder

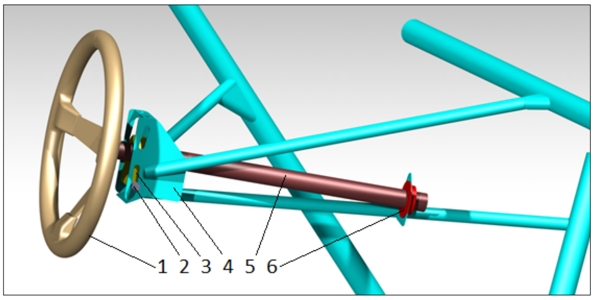
Dynamic analysis of the issue mainly deals with vibrations. From the perspective of a person is suitable steering column frequency between 30 and 40 [Hz]. Vibration of the steering column is a superposition of oscillations excited by different parts of the vehicle, such as engine (30 [Hz]), chassis (15 to 17 [Hz]) etc. The dynamic load of the steering column bracket will not be solved. Can be supposed, that the resulting will meet the demands of safety as previously tested design. Also is assumed, than if the structural design will be similar to the original, waveforms loading forces will be also similar. Eigenfrequencies and inertia also will not be solved.

Regulations International Automobile Federation FIA set, what materials and what structures can be holders steering columns. They may in particular be made of steel or composite materials such as carbon materials. It is always given a prescription for rally cars and for a given class or group of vehicle. They can also be securely welded to the frame MAG or screwed to the frame. The regulation stipulates that the management mechanism and its parts must be made of steel. Thus, steering rod, bearings, joints, steering gear, connecting rods, levers and steering pins. (2)

In terms of ergonomics, an important role have in drivers position for all day sitting in a racing car. The bodies of the crew absorb vertical vibrations caused by vehicles on uneven surfaces (gravel) or a bumpy road and also move sideways (cornering or even controlled shear). Persons absorb forces during acceleration or deceleration of the vehicle. Bad ergonomics leads to backache, so-called Injury of repetitive motion (in the UK known as RDI - Repetetive Driving Injury). Because of these reasons the proposed holder is designed as adjustable, respecting the driver requirements. (3)(4)

The technical requirements for the design were following: minimal possible weight, maximal possible rigidity, MAG welding and using the holder material eg alloy steel 25CrMo4, 15CdV6, T45, 4130, Docol.

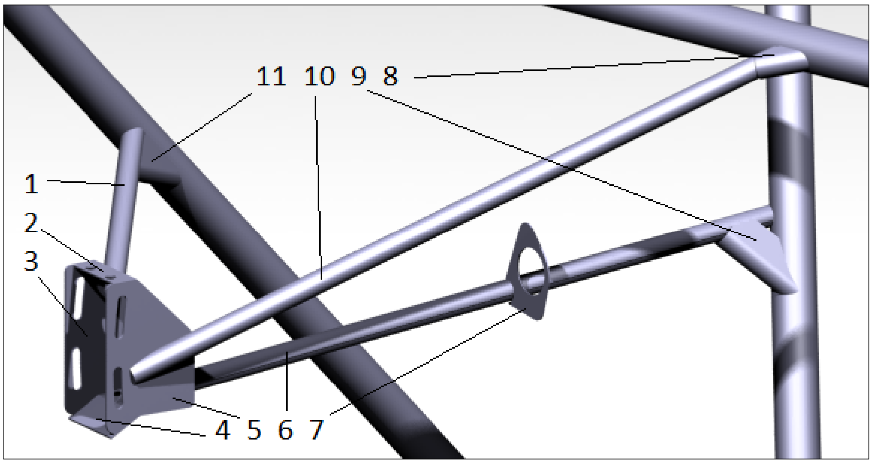
New design came from the original design and the original attachment points to the parts of the car have been kept. Attachment is realized to the same restraints and struts as in the original version. This fact relates to the validated holder attached at these places to the protective frame of the racing vehicle. Furthermore, the steering column is installed as shown in Fig. 3, together with the steering. It consists of a steering wheel, wheel bearings, steering rod and others. It is entry restriction for the holder design, this restriction must be included in the design of the steering column bracket. Steering column bracket was designed for this steering mechanism and it was not the aim to modify it.



Source: Author

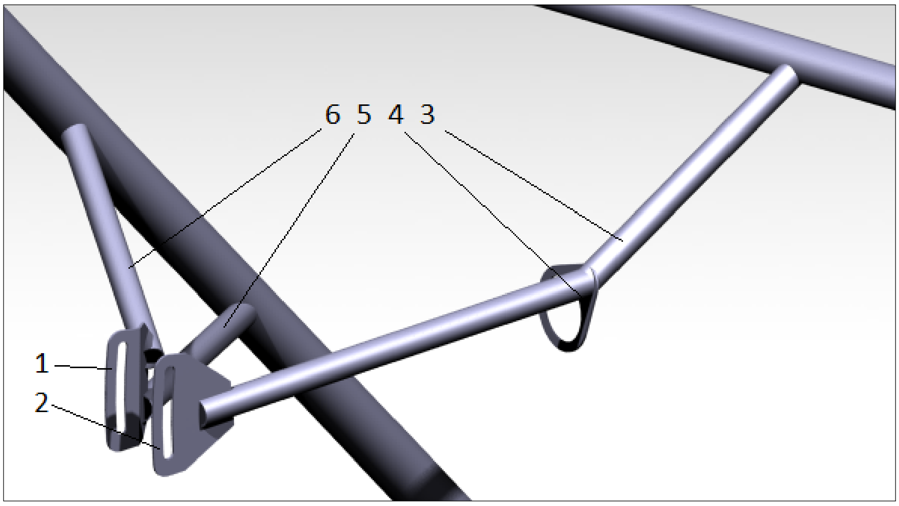
Fig. 3 – The installation of steering, 1 – steering wheel, 2 – mounting screw, 3 – wheel housing, 4 – steering column bracket, 5 – steering rod, 6 – Teflon bearing

Software CATIA for design variants of steering column bracket has been used. we're 8 variants of bracket have been created, 5 basic variants and 3 variants have been optimized.



Source: Author

Fig. 4 – The original version of the steering column bracket, 1 - left brace, 2 - upper brace, 3 - left side of the steering house, 4 - bottom stiffener, 5 - right side of the steering house, 6 - bottom strut 7 - house bearings, 8.9 - corner brace, 10 - right brace, 11 - corner brace



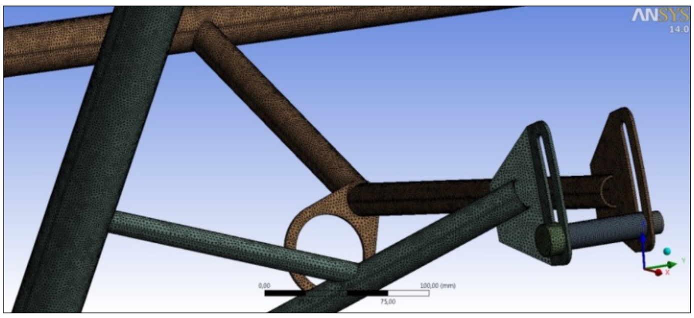
Source: Author

Fig. 5 – Variant E3, 1 - left side of steering house, 2 - right side of steering house, 3 - right brace, 4 - house bearing
5 - left bottom brace, 6 - left upper strut

Material of steering column should be chosen with regard to the material used for the race car protective frame. This choice is important because of strength, stiffness, and prices, and especially because of manufacturability and final assembly. Manufacturability of bent parts is ensured by ductility of the material, ductility must be greater than 10 [%]. The reasons mentioned above leads to following material choice, pipe material 25CrMo4 and 15CdV6 for sheets.

3. STRESS ANALYSIS

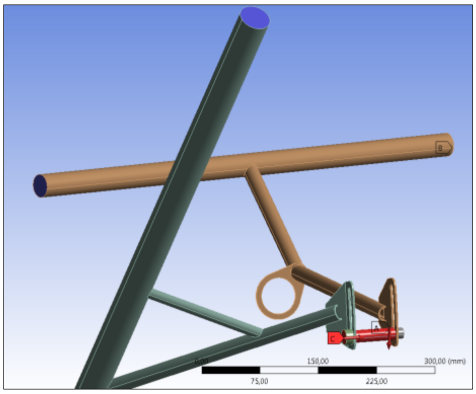
Finite element mesh with element size 1 [mm] using created model has been generated. Network density affects the calculation accuracy and calculation time. Mesh and shape of mesh elements have been chosen as a software-controlled. Part divided into 500,000 finite elements is shown in Fig. *6*.



Source: Author

Fig. 6 – The finite element mesh on the computational model

First boundary conditions are fixed supports, which serve to fix the product in the test environment space. Fixed supports ("Support") on blue marked areas of solid rods have been created (see Fig. 7.). A further boundary conditions are the component loads, thus, forces, pressures, etc. allowable displacements. Forces were chosen according to the diagram in Fig. 3. Forces are shown in Fig. 7 as a red colored.

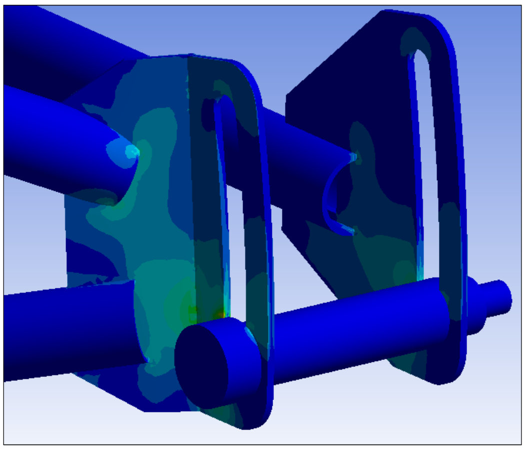


Source:Author

Fig. 7 – Boundary conditions, red - load,
blue - support

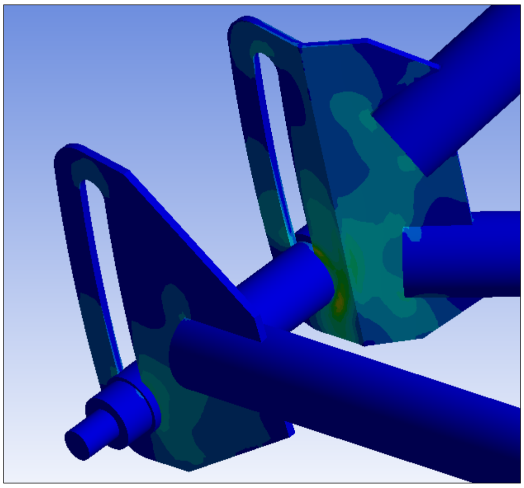
Analysis results can be displayed in the form of a written report. For users, however, a graphical outputs are friendly. In our case, for a results evaluation of reduced stress a HMH hypothesis has been chosen. General Three-axis stress is reduced to that equivalent stress. Other suitable presentation of components in the simulation load is presentation of deformations, thus shifting the elements after loading.

In variant E3 the bigger deformation is on side of the steering column and also in areas of welding. Maximal stress is about 350 [MPa] on the inner side of the bent metal plate of left steering house (see Fig. 8 and Fig. 9.).



Source: Author

Fig. 8 – Detail of strain option E3



Source: Author

Fig. 9 – Detail of strain option E3

CONCLUSION

Variant E3 gives maximum weight savings. In comparison to the original variant, it is an approximately of 62 [%] weight saving. The design of variant E3 is relatively simple, increase time and price savings by simple holder completion and by reduction of the welders working time. Deformation of the bracket under same load increased about 22 [%]. Maximum stress of bracket is about 350 [MPa], which may constitute a significant increase of stress in comparison with the original holder, but it is still enough under the yield strength of the selected material, where Re = min. 600 [MPa]. Safety factor is about k = 1.7. This represents a 70 [%] reserve in stress, which should provide enough space for dynamic stress or strain at once. The bracket has been successfully optimized and specified requirements have been met.

REFERENCES

(1) EHK/OSN č. 79, *JEDNOTNÁ USTANOVENÍ PRO SCHVALOVÁNÍ TYPU VOZIDEL Z HLEDISKA MECHANISMU ŘÍZENÍ.* [online], last revision 10.4.2014 [cit. 10-4-2014]. Avaliable from WWW: <*http://eurlex.europa.eu/ LexUriServ/LexUriServ.do?uri=OJ:L:2008:137:0025:0051:EN:PDF*>

(2) *Příloha J mezinárodního sportovního řádu* (překlad) FIA, Federace Automobilového sportu AČR, 2014

(3) *Ergonomie | autolexicon.net:* [online], last revision 10.4.2014 [cit. 10-4-2014]. Avaliable from WWW: <http://cs.autolexicon.net/articles/ergonomie/>

(4) Ing. DRESLER, Pavel. *Consultation with the vehicle crew.*