DESIGN OF TUBULAR SPACE FRAME FOR FORMULA STUDENT RACE CAR

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ABSTRACT

Objective of this research was to design tubular space frame which satisfies rules defined by Formula student competition. Features of designed frame were clearly specified. Low weight and high amount of torsional stiffness were basic monitored parameters. Usage of CAD software with interconnection of FEM methods leads to design of unique tubular space frame. CAD software was used for design of basic shapes of the frame and FEM method software was used for calculation of torsional stiffness. Each step in frame design was tested by this way. Also package of reinforcements was developed. Their locations were found through FEM analysis of torsional stiffness. In comparison with frame which was used in Dragon 1 race car new evolution of frame had higher amount of total and sub-region torsional stiffness. Another part of whole research was tubular space frame production. Specific methods were used, for example laser cutting of pipes endings. This technological process brings higher manufacturer precision. Also TIG method for lowering of heat-affected zone was used. Finally designed and manufactured tubular space frame was used in Dragon 2 race car.

Key words: tubular space fame, formula student, FEM, torsional stiffness, construction design

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INTRODUCTION

Main nature of this research is about developing of tubular space fame for Formula Student race car. There are several basic types of conceptions used in FS competition. Tubular space frame is one of the fundamental constructions. Another option is usage of aluminium honeycomb monocoque or carbon fibre monocoque which is the top in this event. Main purposes of above-mentioned constructions are to protect driver, hold parts of suspension and engine and other construction units in its place. Also main goal of bodywork is to transfer and absorb forces generating from driving. One of the essential parts during construction is to fulfil predefined rules of FS competition. Also torsional stiffness of frame is important. High value of this parameter is desirable. In the one hand high value of torsional stiffness lowers elastokinematic effect of suspension in the other hand high amount of it can leads to cracking of frame´s weak spots. Usage of 3D software brings advantage of rules verification in preprocessing of whole frame production. Reasons of choosing tubular space frame as main bodywork of race car were: acceptable price for its manufacture, comparatively simple production, easy maintain and great variability of construction. Research was finished by producing of tubular space frame and its usage in Dragon 2 race car of TU Brno Racing team.

MATERIAL AND METHODS

Design of tubular space frame was constructed in 3D software Pro Engineer Wild Fire. Placement of all race car components was easier due to this. All tubes were designed by its profile dragging along the curves. This method was chosen due to computing of total torsional stiffness in FEM program which worked with wireframe model. Also series of reinforcements were developed for torsional stiffness increase. There were 2 mm thin plates used in specific locations of the constructed frame. For placing of reinforcements computation of sub-region torsional stiffness was necessary.

For torsional stiffness analysis (total and sub-region) ANSYS 12.1 program was used. For this evaluation three different principles could be applied. It is a volume, surface and beam method. Fast and sufficiently accurate beam method was used. This brings computer time lowering but in the other hand more complex model preparations. Specific BEAM189 elements were used for tubes replacement and LINK8 elements for suspension substitution. Linear, elastic, isotropic material model with Young´s modulus $E = 2{,}1.10^5$ MPa and Poissons ratio $\mu = 0{,}3$ was used for tubular profiles. Same material model with different Young´s modulus of $E = 2{,}1.10^{15}$ MPa was used for suspension substitution. The reason of this requirement is to transfer load forces through arms without their deformation influence. Configuration of coordinate system in ANSYS 12.1 environment was plotted on Fig.1. X axis of designed frame points along frame axis. Y axis points perpendicular to axis of the vehicle. Last one axis Z points up from the frame ground.

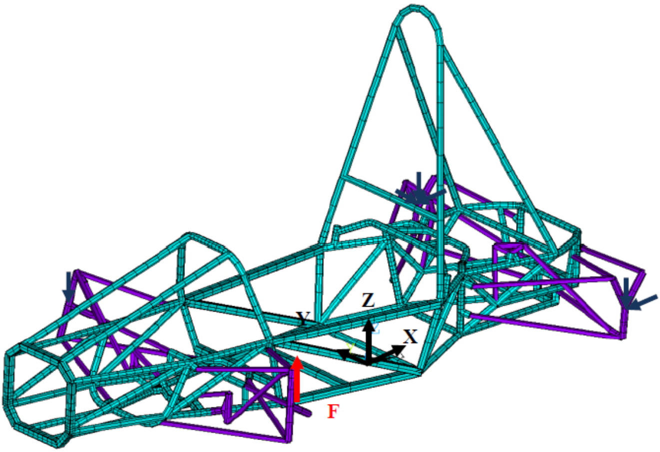

Fig. 1 – Coordinate system configuration

Loading conditions were applied and they were specified in table 1. Force was applied on front left wheel. Other wheels were restricted in the movement in specific conditions which represents real state of loading.

Table 1 – Displacement restrictions and force application

Axis displacement / Wheel	X	Y	Z	Force F = 1000 N
Front left	-	-	-	Z axis
Front right	-	-	X	-
Rear left	X	-	X	-
Rear right	X	X	X	-

Total torsional stiffness was calculated by equation no.1 where M_k was marked as loading torque and a as twist degree. For evaluating of loading torque equation no.2 was used where F was loading force applied on front left wheel and L_b was wheel track in mm. Equation no.3 was used for twist degree computation. In this equation U_z marking was used for point displacement in Z axis and U_y for displacement of Y axis.

RESULT AND DISCUSSION

Total and sub-region torsional stiffness were calculated. For comparison tubular space frame of Dragon 1 race car was used. Fig. 2 represents torsional stiffness of sub-region of the designed frame and frame upgraded with reinforcements also with results of Dragon 1 frame.

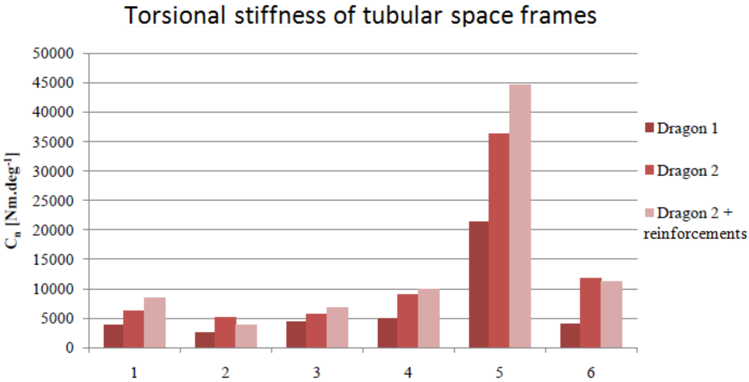

Fig. 2 – Sub-region torsional stiffness

As can be seen, new design of tubular space frame brings increase of torsional stiffness in all sub-regions. This was due to better triangulation of frame and aditional reinforcemnet of engine frame cover. With 2 mm steel sheet reinforcements higher amount of sub-region torsional stiffness wasachieved. Also total of torsional stiffness was increased as can be seen on fig.3.

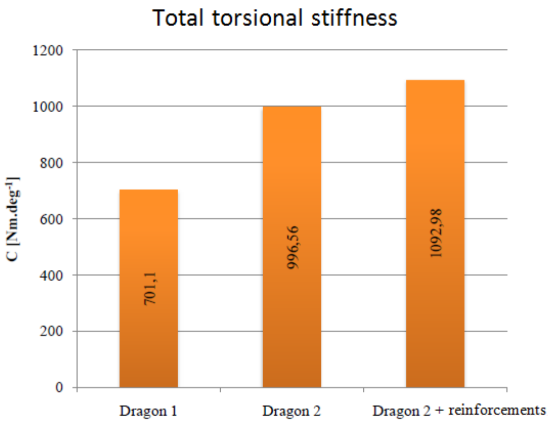

Fig. 3 – Sub-region torsional stiffness

CONCLUSIONS

The research of tubular space frame design was created. Major role in designing was interconnection between 3D design and to FEM method analysis. This approach leads to new design of bodywork with high amount of total and sub-region torsional stiffness which is essential in Formula Student competition. Also package of reinforcements was designed and carefully calculated. Due to bodywork conception, pure frame can be reinforced by welding of 2 mm thick metal sheets into specific locations arising from this work. In total, frame was designed, verified for Formula Student rules, computed for torsional stiffness analysis and finally manufactured. Specific technological methods were used, for example laser cutting for higher accuracy in production and TIG welding for lowering of heat-affected zone. Designed frame was used in Dragon 2 race car of TU Brno racing team.

Tubular space frame made from steel tubes could use future optimization in FEM methods. This approach can obtain preferable geometrical configurations of used tubes which leads to higher amount of torsional stiffness of whole frame.

Another future option for race car bodywork is usage of aluminium tubes with aluminium honeycomb reinforcement or usage of carbon fibres as monocoques. This brings in the one hand higher amount of torsional stiffness and weight reduction, but in the other hand it brings greater financial burden of the team budget.

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