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Przemysław HADULA<sup>1</sup>, Łukasz KACZMARCZYK<sup>2</sup>, Paweł FABIŚ<sup>3</sup>

## POWERTRAIN DAMAGE ANALYSIS FOR FORMULA STUDENT CAR WT-02

**Summary.** This paper is a summary of the design and workmanship of a Formula Student transmission system vehicle. We conducted simulation research on transmission system damage. Damage occurred during the Formula Student competition, which is why we needed to improve the drivetrain system. The article proposes a variant of the change brackets and carrying out simulation studies on the new construction. For selected models, the transmission system, which is also determined by its impact on strength and reliability, is driven by a four-cylinder engine with a displacement of 0.6 dm<sup>3</sup>.

**Keywords:** Formula Student; transmission; driveline; MES simulation.

### 1. INTRODUCTION

Formula Student is an international competition between teams from universities and technical faculties around the world, which is organized by SAE International. The idea behind the competition is to design and produce a racing vehicle in accordance with the rules of the competition. The car created by each must be finished car in a given time and in line with the need to gain knowledge, strengthen discipline, cooperation and foresight, and often make compromises. Gained in such circumstances, experience and knowledge are invaluable and

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<sup>1</sup> Faculty of Transport Silesian University of Technology Krasinskiego 8 street 40-019 Katowice, Poland.  
Email: [przemysla.hadula@gmail.com](mailto:przemysla.hadula@gmail.com)

<sup>2</sup> Faculty of Transport Silesian University of Technology Krasinskiego 8 street 40-019 Katowice, Poland.  
Email: [lukasz.kaczmarczyk@gmail.com](mailto:lukasz.kaczmarczyk@gmail.com)

<sup>3</sup> Faculty of Transport Silesian University of Technology Krasinskiego 8 street 40-019 Katowice, Poland.  
Email: [pawel.fabis@polsl.pl](mailto:pawel.fabis@polsl.pl)

important aspects of training top-notch engineers. Undoubtedly, this is also a chance to test their skills in the real world, under the pressure of time and project requirements. What matters is not only the maximum speed of the car, but the balance between a number of important elements, namely, speed, economy of operation, aesthetics, functionality and safety. Victory in the competition only goes to those teams that are able to present a complete project and receive the highest number of points. With the Formula Student competition, students have the chance to establish contacts with local industry, while the industry has the opportunity to support the development of its potential future executives. The basis for the competition is undoubtedly to support the development of technical thought, while emphasizing how important it is to create technical universities. As engineering students and professionals play a huge role in human development, they are of great value to society.

## 2. CHARACTERISTICS OF THE FORMULA STUDENT COMPETITION

Formula Student is the largest international event organized by the Institution of Mechanical Engineers and directed mainly at students of technical universities. The patronage of the cycle of competitions includes the most distinguished engineers associated with the automotive industry and motorsport (including F1). The aim of the competition is primarily to find talented students and compare the design of vehicles from all over the world. The competition consists of two stages: the first is to present a vehicle design and the second is to build the vehicle according to a detailed specification from SAE International. During the competition, the judges strictly evaluate each project in terms of its design and engineering approaches. Furthermore, the vehicle is tested from static and dynamic perspectives, which is why the notion that this is a typical sport competition recedes into the background.

The static part is devoted to the broader business side and involves preparing a cost production schedule, developing a business plan and presenting on the special features of the project (i.e., design). The second part is directly related to the dynamic competitions involving the designed and manufactured vehicles. Admission to the dynamic part of the competition is possible after the painstaking verification of the technical research aspects of each vehicle:

1. Verification as to whether the vehicle complies with the provisions of SAE International's procedural rules (scrutineering)
2. Verification of the centre of gravity (tilt)
3. Measurement of engine noise (noise test)
4. Verification of the brakes system (brake test)

The positive completion of all of these tests enables the dynamic events to start, which are concerned with time measurement and include:

1. Driving on the track in the shape of a figure eight (skid pad)
2. Accelerations of the car at a limited distance (accelerations)
3. Driving on parts of the track (autocross)
4. 20 km main race (endurance)

Points are allocated in the course of these event by professionals, with the totals determining whether the vehicles will receive specific investments at the end of the competition.

### 3. TRANSMISSION SYSTEM CONSTRUCTION FOR THE FORMULA STUDENT CAR

The object of the research is a racing class Formula Student WT-02 vehicle equipped with a four-cylinder, four-stroke SI engine, with a capacity of 600 cm<sup>3</sup>. Originally, this engine was powered by a carburetted system, which, in the course of adapting the engine to the vehicle, was converted to a multipoint injection system.

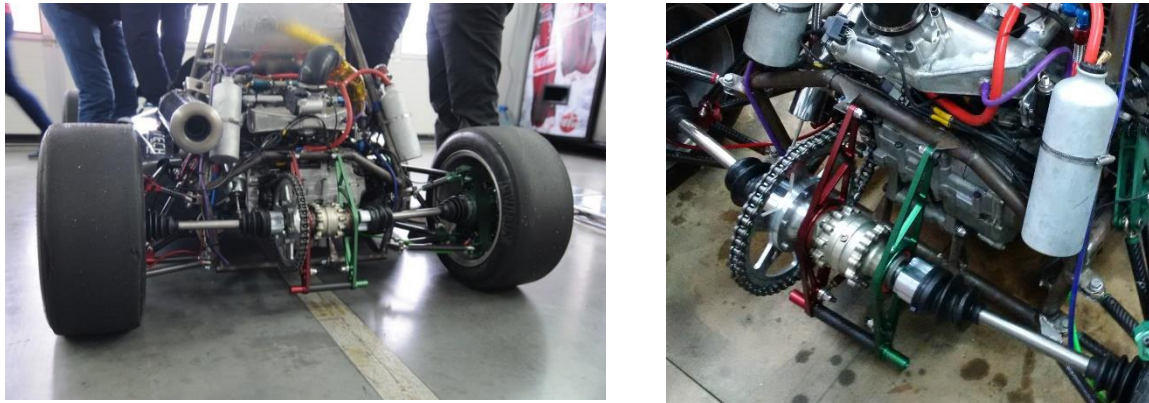


Fig. 1. View of the car and its transmission system

During the project construction, in order to increase the dynamic qualities of the vehicle, a charging system was applied using a turbocharger. The test transmission and the vehicle are shown in Fig. 1.

The car was equipped with a torque transfer from the engine to the wheels via a chain motorcycle. Torque distribution between the wheels is possible through the use of Drexler's differential (Fig. 2).

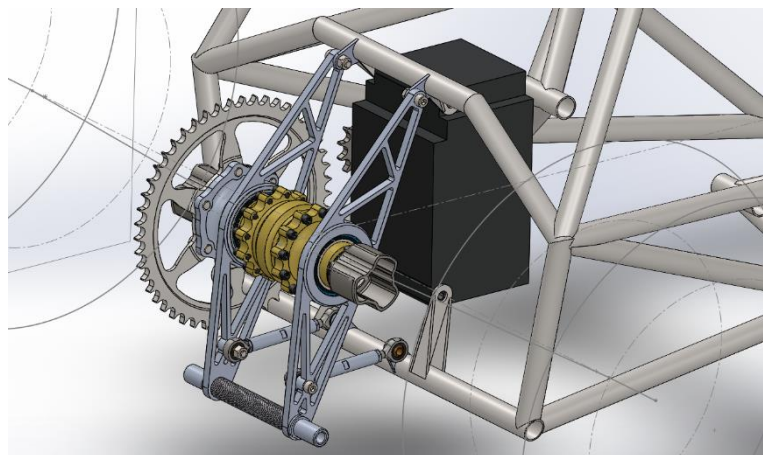


Fig. 2. Visualization of the Formula Student car's the transmission system

A differential mechanism, including a main gear, was attached to the vehicle frame, irrespective of the engine and the gearbox. This allowed the separation of the drive system of the vibration from the engine.

#### 4. TRANSMISSION SUPPORT MESH SIMULATION RESULTS

When designing the drive system of the vehicle and its attachments, the weight of the vehicle was reduced in line with the adopted criteria. Every element of the vehicle, including the powertrain, was subjected to the optimization of weight. The result of these assumptions was the need to simulate important endurance elements affecting the safety and operation of the vehicle systems.

During test drives carried out under track conditions, the bracket of the main gearbox and the differential broke down. The damaged components are shown in Fig. 3.



Fig. 3. Transmission support damage of the Formula Student car

On these photographs, a visible rupture can be seen, along with the broken part of the bracket located on the main gearbox of the vehicle.

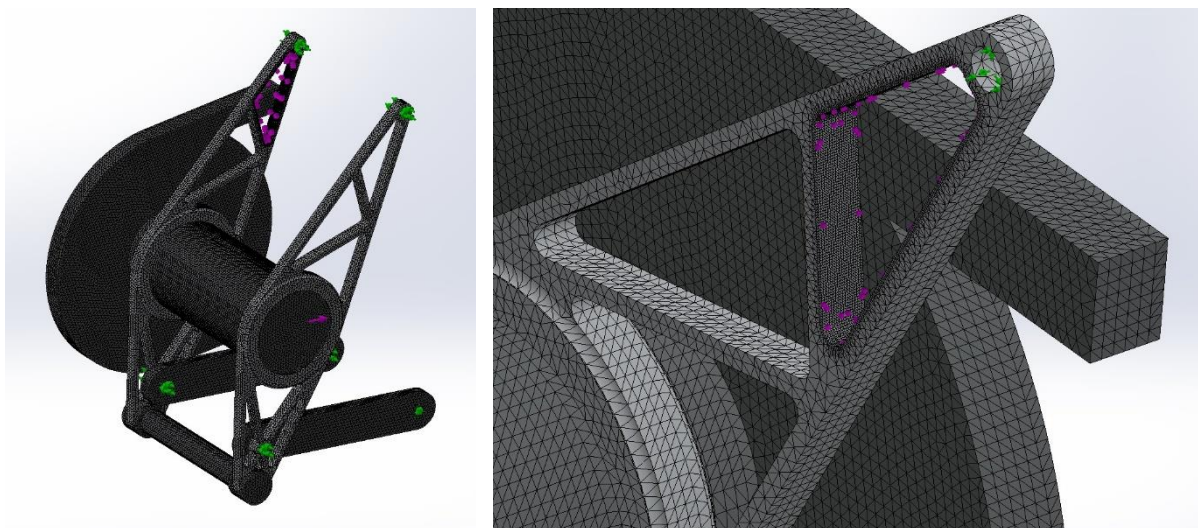


Fig. 4. Transmission system mesh of the Formula Student car

Simulation testing in SolidWorks 2016 was carried out in order to determine how to fix the problem, as well as improve stability in terms of securing and increasing the vehicle's strength. Fig. 4 shows the grid as applied to the powertrain components.

The differential was modelled and simplified in order to obtain the most real values of stresses in the material during drive operations. The upper part of the fixing devices was fitted to the frame's lower part by the steel brackets. The simple interface between the fasteners reflected the differential gears, which transmit force to the clamping differential. Applying the force has a direction and a return consistent with the operation of the drive chain. A force of 10 Kn was applied to the model, which reflected the strength with which the engine torque was transmitted through the chain to the differential. The original fitting of the differential stress values significantly exceeded the value of the elastic limit.

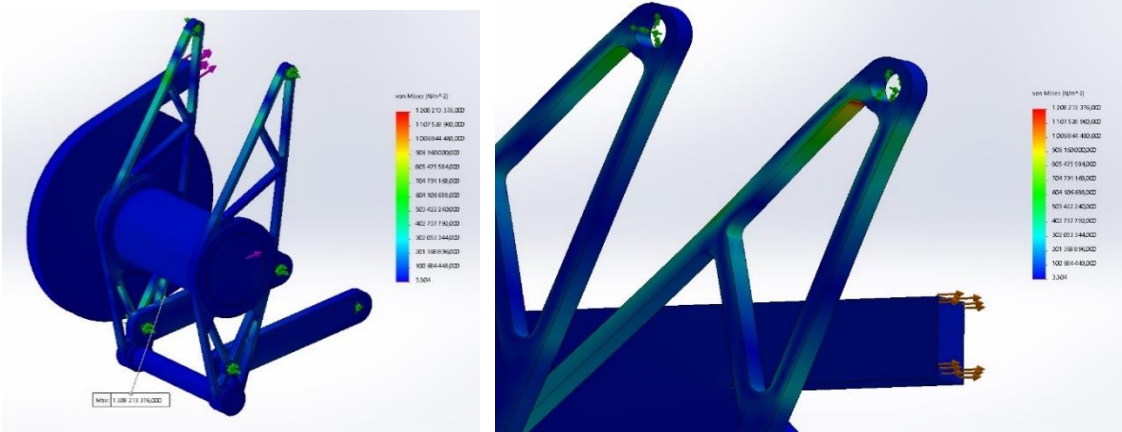


Fig. 5. Transmission system simulation of the Formula Student car

Modified support for the differential helped to significantly increase the rigidity and strength of the structure; at the same time, there was hardly any increase in the mass of the system. Tests exactly reflected the point of possible damage to the original structure. By applying force to the new support, the differential had a value of 20 kN, which is twice the value assumptions. During the test, in addition to the classic mesh, possible damage was caused to the local thickening grid. The results of simulation testing are shown in Fig. 5.

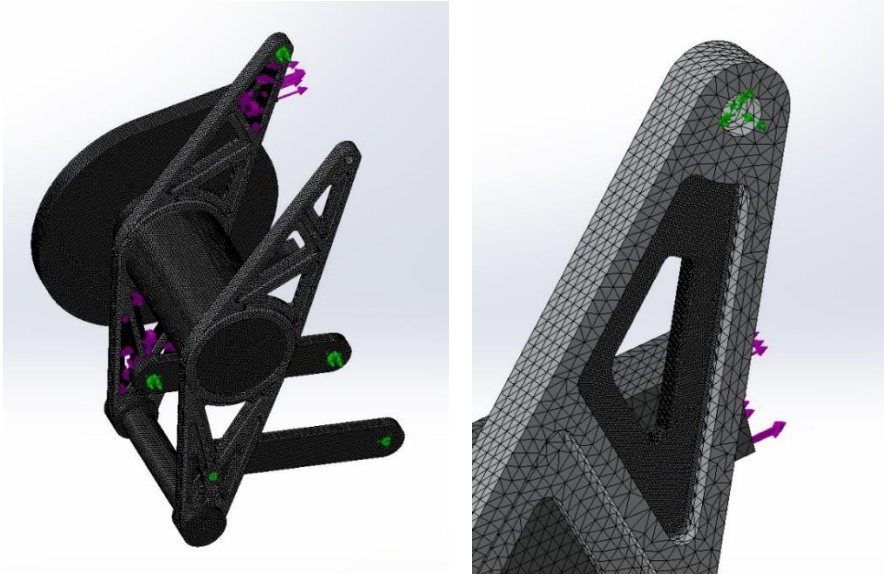


Fig. 6. Improved transmission system mesh of the Formula Student car

On the basis of the simulation, the place of greatest deformation was determined, as well as the loads that corresponded to the site of injury during the test drives. Appropriate modifications were carried out in order to increasing the vehicle's rigidity, again by simulating the FEM. Results of the simulation are shown in Fig. 6 and Fig. 7. The modifications consisted of changing the profile of the external support and partial filling of the parent material. These changes effectively improved the rigidity and strength of the bracket.

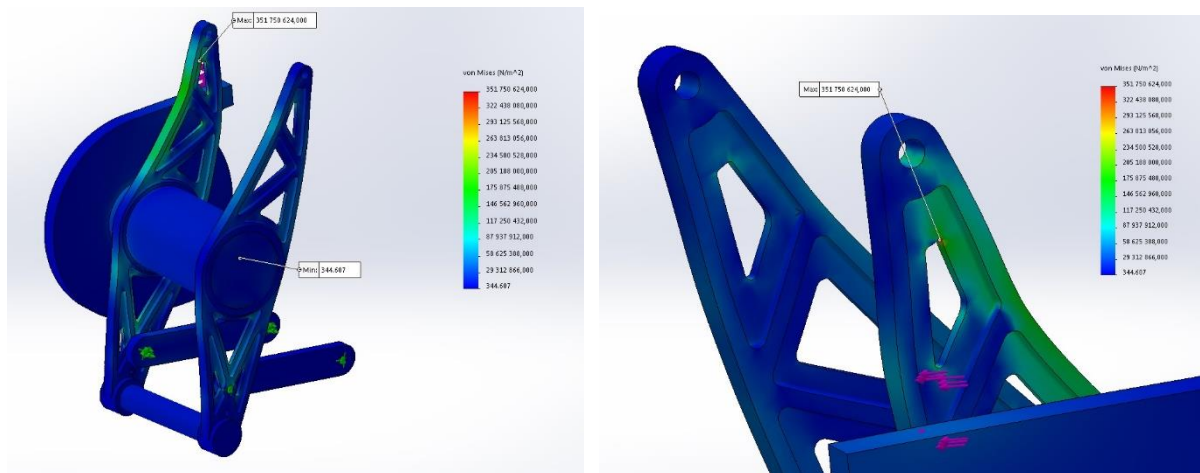


Fig. 7. Improved transmission system simulation of the Formula Student car

The value of the maximum destructive forces to support the revised powertrain was 20 kN.

## 5. CONCLUSIONS

In this study, the powertrain simulation allowed for an increase in the reliability of the vehicle. A strength analysis was carried out using SolidWorks 2016, which precisely defined the location of the damage. The research led to the following conclusions:

1. Changes in the structure of the bracket resulted in increased stiffness and mechanical strength
2. Design changes necessitated an increase in the weight of the bracket, while the reliability of the vehicle increased under track conditions
3. Changing the construction of the transmission support provided an increase in the force by 200%

It seems reasonable to continue research on the optimization reliability of the car and find some way in which to reduce weight.

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