Designing and verifying the concept of Silesian Greenpower electric bolide structure

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Abstract. The purpose of the following paper is to demonstrate the thought processes behind the design and verification of the electric race car structure. The developed structures were modelled in the CAD environment of Siemens NX 10.0 program. The main aim of inventing different solutions was to improve the characteristics of the car. These characteristics include, for instance, aerodynamic drag and gearbox friction. After the framework was established, work on the shape of the body began. The body alterations are understood as reducing the overall width of the car, decreasing the cross-section area and tilting the sides of the sheathing in order to minimise the generated aerodynamic drag. All elements were verified computationally to check whether they can be improved by altering their geometry. Main condition upon which every modification was made was to switch from the previous belt transmission to the newly designed chain transmission. The most significant change in the frame was reducing the back-section width in order to accommodate the chain transmission. Furthermore, it was required to enable easy switching of the transmission from chain to belt. Next step of the project was adding the mechanism enabling the tilting of wheels rotational axis in relation to the ground.

1. Introduction
Silesian Greenpower is an interdisciplinary student organization associating multiple faculties in process of designing, building and maintaining electric vehicles that compete in Greenpower races. In order to maintain its position among top teams, Silesian Greenpower improves and introduces new solutions to their vehicles. In previous years new solutions were introduced into old cars. The quantity and extent of these modifications made it impossible to further change the layout and forced the team to construct an entirely new vehicle.

1.1 Overview of the flaws of the previous car design
During the project there is a constant rotation of drivers. The old vehicle was designed specifically for a driver that no longer takes part in the project. In order to solve this problem, the new vehicle is required to be more suited for different body types. Additionally, several changes to the race rules were made.

One of the rule changes enforces the use of a new stainless steel rollbar. Due to the fact that the chassis of the car is mostly made of lightweight aluminum, introducing a new rollbar into previous builds proved to be a real construction challenge. Another feature of the previous design was the employment of a belt transmission for transferring torque from engine to drive wheel. This proved to be an efficient solution though it had a flaw, it had only one transmission ratio available for the entire
That caused the car's acceleration to be insufficient and very energy consuming. Lastly, the vehicles that were used in previous years were very wide, that caused increased aerodynamic drag which has the largest percentage share in the overall drag acting on the vehicle. All the flaws described, compelled the team to design a car differing in concept to the previous models.

2. New solutions
In order to fulfill all the requirements, a complete overhaul of the construction was necessary. Following changes were made:
- Ergonomics improvement
- New concept for the steering assembly
- Changing the rollbar to suit the regulation
- Introducing the new transmission
- Reducing the cross-section area

2.1 Ergonomics improvement
The Basic flaw of the previous car was that it was too short to accommodate a taller driver. This could be done by either adding more space in front of the vehicle or to move the seat further back. It was decided that the easier course of action is to proceed with the first option. In order to accommodate different drivers, an element regulating the seat position was introduced. This allows every driver to position the seat with his or her preferences. In order to better fit the drivers legs, the power cell slots were angled inward and rotated so that more space at the bottom was created.
2.2 New concept for steering assembly
On numerous occasions drivers reported that the previously employed steering was causing discomfort. This was due to a strand running through the midsection of the car, that limited the drivers field of movement considerably. New design eliminated that flaw by placing the connector strand below the drivers legs. Another possibility was to place the strand above the driver, however it was concluded that this design has insufficient stiffness and would not meet with the standards set by previous designs.

2.3 Roll bar change
Because of a regulation change, a new type of roll bar must be installed in all participating vehicles. The roll bar has to be made of stainless steel. This condition poses a great challenge because a simple bolt connection would not be strong enough to withstand the force of impact if the car should rollover. The final solution was to add an intermediary aluminum rod. First, the new roll bar is a “U” shaped, steel pipe with inner diameter of 21 mm. Then a 22 mm aluminum rod is turned to fit tightly into that pipe, and both are joined together by a thermocompression bond. Lastly the whole assembly is welded into the aluminum frame.

2.4 Transmission
Silesian Greenpower team had designed a new type of transmission for their cars last year. Extensive tests were conducted on the system and it was concluded that it has improved qualities over previous belt transmission [2][3]. Implementing the design into new frame meant significant changes to it and adding several new components. Adding an aluminum plate is necessary so the derailleur can
be mounted, it also serves as an additional support, improving the overall stiffness of the car. Next element to be subject to change was the shaft. Previously there was a single shaft that had both back wheels mounted on it. Because of the 8-degree angling, that will be described in more detail in paragraph 2.5, it was no longer possible. Instead of one shaft it was decided to implement two, with better gradation to reduce internal stresses. The shafts were also designed with mounting a cassette sprocket in mind.

![Figure 7. Previous design.](image1)

![Figure 8. Current design.](image2)

Due to the mentioned angling a new motor mount had to be installed as well. The new mount positions the motor directly in line with the derailleur and cassette sprocket. It also allows to quickly move the motor closer or further away from the cassette thus changing the chain tension. It is vital to change the tension because it has a direct influence on the transmission efficiency and stability. For example, on a track with a good surface quality, it is a good idea to lower the tension and make the transmission more efficient without the danger of losing stability during the race, whereas on track with lower surface quality, increased chain tension will improve stability at the cost of decreased efficiency. All changes made are depicted on pictures 11 and 12.

![Figure 9. Previous rollbar.](image3)

![Figure 10. Current rollbar.](image4)
The most important condition while designing the frame was to accommodate all newly added elements within and allow for easy movement of the driver. Several numerical simulations were conducted on the previous body design and an aerodynamic drag coefficient was determined as $C_x=0.2$. Aerodynamic drag being the largest share in overall drag acting on the vehicle. In order to further improve the coefficient, the cross-section area has to be reduced. This was done by angling the wheels by 8 degrees in relation to the ground. The 8-degree value is the maximum angle that can be used without causing major increase in rolling friction. As can be seen in pictures 13 and 14 a significant change in vehicle width in the back of the vehicle was made. Behind the driver only mounting elements and the transmission is located. These components are of low dimensions and that allows for an increased slope of the car body in the back section.
3. Conclusion

Every condition made at the beginning of the project was met. Vehicle ergonomics were improved, and the car is now able to accommodate different drivers. Steering assembly was made more comfortable in use. New, innovative roll bar mount was implemented according to the newest race regulations. Frame was designed so that a new type of transmission can be added. Lastly the cross-section area was reduced and by that the overall aerodynamic drag.

The bolide design is an ongoing, evolving process, solutions become obsolete and insufficient, that is why new changes are made. The project is a great opportunity for students of different faculties to improve their skills and become more proficient with problem solving and construction.
References
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