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Implementation of electric propulsion in small race car

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The paper deals with a new design method used in construction of pure electric vehicle based on the frame of the well-known Formula Student race car. The functional principles of the electric vehicles are first introduced. Then the main parts of the electric drive system are described. Optimal system components are proposed according to computed values of drive drags to meet required performance criteria. The whole concept of electric formula race car is verified by simulations in Matlab/Simulink computer code, where basic performance parameters of the electric formula are calculated.

1 INTRODUCTION

Transportation is a primary source of energy consumption and pollutant emissions worldwide. With the stricter restrictions on air pollution and shortage of fossil fuels, the advantages of electric vehicles (EV) are becoming more evident than ever. The technology has now been accepted by more and more vehicle manufacturers and users. However, the design of electric vehicles is difficult due to the large amount of inter-relating design parameters and conflicting design objectives. Electric vehicles (EVs) use an electric motor for traction, and chemical batteries or other appliances for their corresponding energy sources. The electric vehicle has many advantages over the conventional internal combustion engine vehicle (ICEV), such as an absence of emissions, high efficiency, independence from petroleum, and quiet and smooth operation. The operational and fundamental principles in EVs and ICEVs are similar (Ehsani, et al., 2005).

These basic principles are the same for common vehicles and for race vehicles. Designing the race vehicle with electric propulsion is something special because other priorities and requirements must be considered. That means that the vehicle should have low weight and very good dynamic performance parameters. Maximum driving range is not that important. Race car has to be good in cornering, acceleration and braking. Electric drivetrain can fulfill these requirements, because of optimal torque characteristics of an electric motor. Actual advanced power sources, e.g. chemical batteries based on Lithium, are offering enough power to supply electric motors.

1.1 Formula Student race car description

Formula Student race car is a small single seat formula race car built according to specified rules by university students from all over the world. The idea of the project is to improve engineering design and business skills of students and to participate at racing competitions. The formula race car could be driven by internal combustion engine, by hybrid drive or by electric drive. Its chassis could be constructed like monocoque made of carbon fibres or like strut-frame welded from high-tensile steel tubes. All four wheels have independent suspension and disc brakes. Front wheels are used for steering and rear wheels are driven. In front of the vehicle is situated impact attenuator to increase passive safety. The bodywork is usually made of carbon laminate. The race car must show very good driving characteristics such as acceleration, braking and handling.

Examined vehicle has electric drive system and its chassis are made of steel tubes. It was designed by students of STU in Bratislava (see Fig. 1).

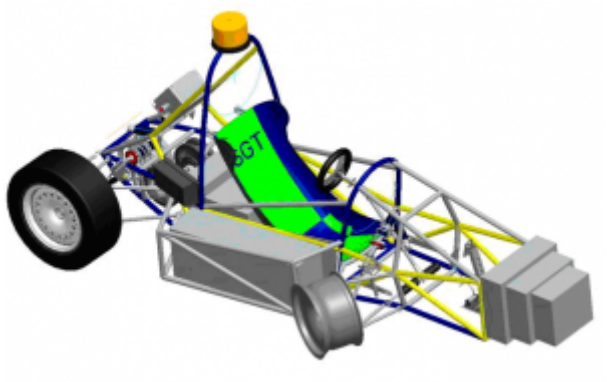

Fig. 1 Formula Student Electric race car chassis designed by Stuba Green Team Bratislava

2 PERFORMANCE PARAMETERS OF THE VEHICLE

There are several forces acting on a moving vehicle. The tractive effort in the contact area between tires of the driven wheels and the road surface propels the vehicle forward. It is produced by the power plant torque and is transferred through transmission and final drive to the drive wheels. While the vehicle is moving, there is resistance that tries to stop its movement. The resistance usually includes tire rolling resistance, aerodynamic drag, uphill resistance and forces of inertia (Ehsani, et al., 2005).

Motor vehicles use power of their powertrain system to get over tractive resistance. Power required on the drive wheels could be calculated by the sum of resistance power presented in this formula (Ferencey, et al., 2007):

$$P_k = \frac{M_k}{r_d}.v = P_m.\eta_c = P_f + P_v + P_z + P_s + P_h \quad (1)$$

Formula Student Electric race car was designed to meet sports requirements. That means that the race car should have maximum speed over 100 km/h and acceleration to this speed in 5 seconds. Important parameter is the vehicle mass, which affects the resistances. Maximum weight of the electric formula race car should not exceed 350 kg.

According to equation no.1, we were able to define dynamic requirements on tractive system, which are power, torque, max. rpm of the motors, etc. But to choose suitable components of the electric drive system, it is important to consider even more parameters, for example vehicle constraints, weight of the tractive system, electric current flow, type of power source (voltage) and last but not least the price of components. Defined requirements are power over 30 kW and torque about 70 Nm.

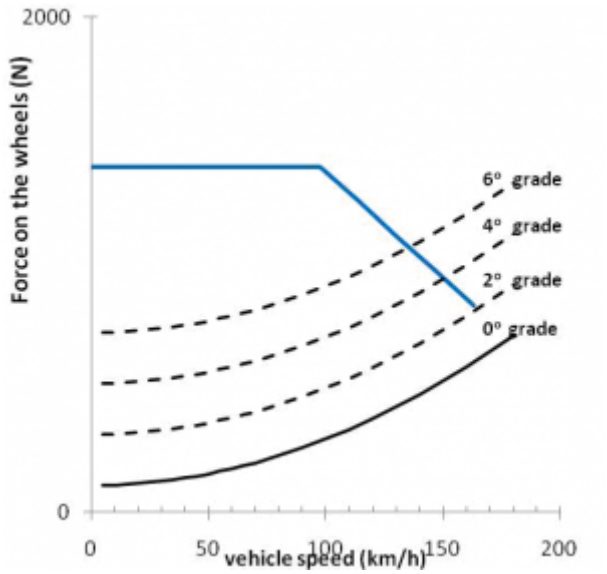

Fig. 2 Forces acting on formula race car (blue – tractive force, black – rolling resistance and aerodynamic drag, comma-shaped – uphill resistance)

3 TRACTIVE SYSTEM OF THE FORMULA RACE CAR

Main components of the electric tractive system are analyzed here. An automotive power train consists of a power plant (electric motors), energy source (batteries), transmission (final gear), differential (electronic differential), drive shaft and driven wheels.

Tractive system of the Formula Student Electric race car designed by Stuba Green Team consists of high voltage and low voltage part. The system operates at direct current – DC voltage, so there is no need to use inverters and converters.

Every circuit, which carries more than a nominal operation voltage of 60 V DC or 25 V AC RMS, is defined as part of the High Voltage system. High voltage part consists of three battery packs, six main contactors, two motor controllers and two electric motors. The Low Voltage part or the control system of the car is defined as every electrical part that is not part of the high voltage system.

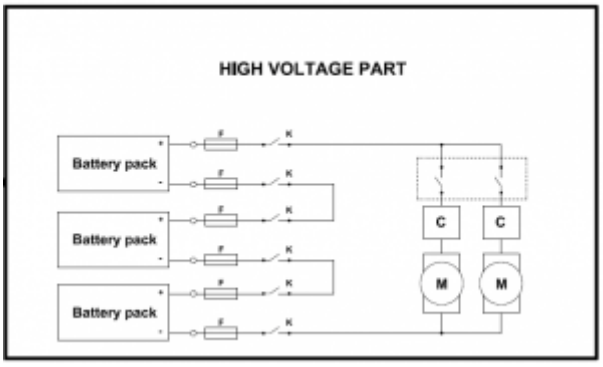

Fig. 3 High voltage part of the tractive system

3.1 Electric motors

Electric motors are the heart of the tractive system. The electric motor converts the electric energy into mechanical energy to propel the vehicle, or, vice versa, to enable regenerative braking. We have chosen Brush-Less DC motors with permanent magnets from company L.M.C. Ltd. There are two BLDC motors LEM-200 type D135 installed in the formula race car to fulfil requirements defined above.

Tab. 1 Motor specification