

## ANALYSIS AND DESIGN OF REAR TWIN ELECTRIC POWERTRAIN MOUNTING SYSTEM IN E-UP BOOST

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**Abstract:** The paper focuses on analyzing and designing a mounting system for the modified rear powertrain of the E-up Boost. The initial section delves into the theoretical aspects, specifically examining the differing sources of vibration between internal combustion engines and electric powertrains. Following this, the subsequent section presents an in-depth analysis of the powertrain mounting system using ADAMS View. After the analysis is carried out, a robust mounting system is designed and verified through structural analysis.

**KEYWORDS:** Silentblocks, bushings, powertrain mounting, structural analysis, NVH

### 1 Introduction

Electric powertrains (EP) are specific due to the absence of the need for idling, so when designing the storage of the electric powertrain, it is not necessary to adapt the parameters of the silentblocks to low-frequency excitation, which would occur at low engine speeds, figure 1. Another factor comes from the fact that electric vehicles, they use one permanent gear, the absence of a step gearbox and clutch mechanism means that the flow of power is continuous and therefore the storage of the electric powertrain does not have to be sized for the repeated shocks that occur in the drive mechanism of vehicles with step gearboxes. Electric powertrains, unlike conventional combustion engines, can produce large torques at very low speeds, therefore higher stiffness of flexible members is expected from the installation of these powertrains, [1].

In internal combustion engines, vibrations arise primarily due to the rectilinear movement of the pistons in the cylinders. Since the cylinders in most vehicles are oriented almost vertically, this means that this excitation occurs primarily in the vertical direction. The second factor is the creation of vibrations due to the ignition of the mixture in the cylinders. The angular velocity of the crankshaft is not constant; it is affected by each ignition of the mixture and therefore depends on the number of cylinders in the ignition sequence[6]. These changes in angular velocity create excitation in directions perpendicular to the motor axis, [2].

In electric powertrain, vibrations can occur due to several influences. The most significant influence on the occurrence of vibrations can be the imbalance of rotating components in the drive mechanism. These components can be the rotors of the electric motors themselves, but also the components of the permanent transmission of the gearbox up to the output shafts. The second effect is the switching of poles in the electric motor, which controls the magnetic field in the motor, this results in torque oscillations. These oscillations create vibrations at high frequencies. The frequencies of these vibrations depend on the engine speed and the number of magnets. Vibrations of electric motors, whether caused by the imbalance of rotating components or the effect of switching the magnetic field, act primarily in directions perpendicular to the axis of the motor, [3].

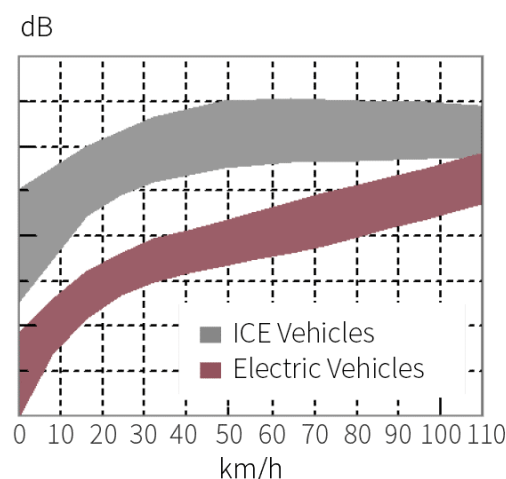


Fig. 1 Noise difference in the interior of a vehicle with ICE or EP, [4]

## 2 The E-up boost Vehicle powertrain

The E-up Boost vehicle is based on the VW E-up vehicle, the original front powertrain was supplemented with a rear powertrain consisting of two separate drive units for each wheel of the rear axle.

### 2.1 The current state of the E-up boost vehicle powertrain

For economic reasons, drive unit components from the front powertrain were used, such as gears and gear shafts, which were installed in a new gearbox housing. The entire powertrain is mounted on silenblocks in the rear axle frame, Figure 2.



Fig. 2 The original solution of rear powertrain E-up Boost

### 2.2 Modified rear powertrain of the E-up boost

For the needs of research and student projects, a modified rear drive unit was designed, where reduction gearboxes with spur gears were replaced by planetary reducers, Figure 3. The modified powertrain forms a compact assembly, which enables it to be efficiently mounted in the space of the rear axle. For this reason, the possibility of mounting the powertrain using silenblocks from EVs was analyzed.

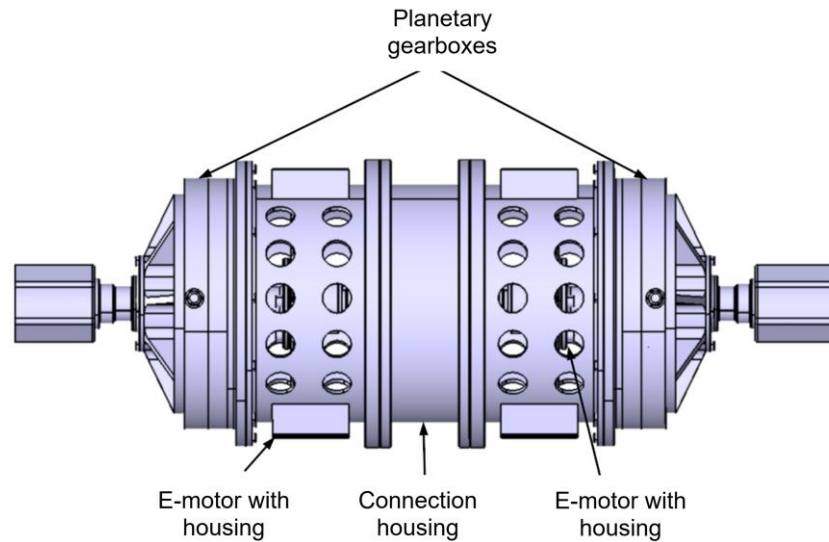


Fig. 3 Modified rear powertrain of E-up Boost

### 3 Analysing of the mounting system of modified powertrain

A solution with 3 silentblocks was chosen, these silentblocks will be distributed in one pair in the front part of the powertrain and one silentblock in the rear part of the powertrain. The silentblocks will be attached to the rear axle frame of the vehicle. Their axes will lie in the horizontal plane. The front silentblocks are oriented with the longitudinal axis of the vehicle, the rear one is oriented with the transverse axis of the vehicle, figure 4. This orientation of the silentblocks is necessary in order to achieve higher stiffness in the transverse and longitudinal directions. The characteristics of the selected silentblocks for the powertrain of the vehicle show that they have significantly higher stiffness in the longitudinal direction than in the transverse direction.

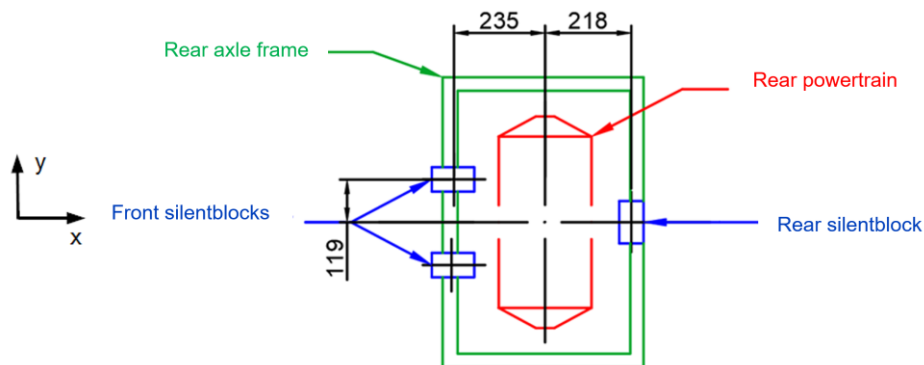


Fig. 4 The concept of the modified rear powertrain mounting system

#### 3.1 Analysis of powertrain mounting in MBS

The powertrain mounting analysis was performed in the MSC ADAMS.View environment.

A simplified but effective model of a rear-drive vehicle with appropriate vehicle parameters was built, figure 5.

A silentblock model was chosen for the analysis, which is represented by the general bushing element model, figure 6. The general gushing model consists of three basic parts that have been positioned parallel, a nonlinear spring, a Bouc-Wen element and one transfer function. The nonlinear spring is dedicated to capture the nonlinear effects that appear at the large deflection

amplitudes caused by the nonuniform shape of the bushing [4]. This part is dedicated to describing the frequency dependency of rubber bushings in terms of dynamic stiffness and loss angle. The Bouc-Wen hysteresis element is used to model the amplitude dependency at 'small' amplitudes of the excitation[5].

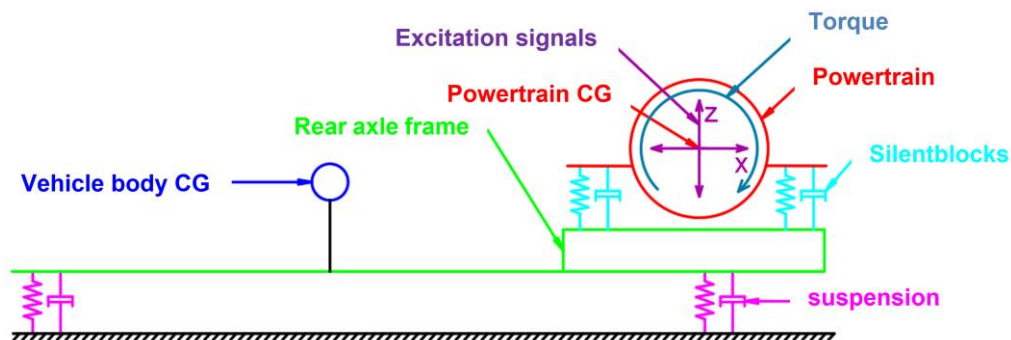


Fig. 5 The scheme of the simplified rear powertrain model in MBS

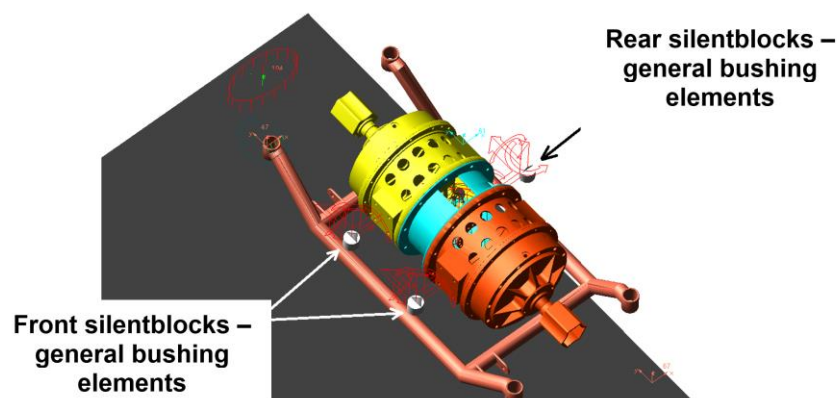


Fig. 6: The MBS model of the rear powertrain

The Isolator-Parameter Identification Tool (IPIT) has been used to identify the parameters of the nonlinear frequency and amplitude dependent bushing models in Adams View out of bushing measuring data in terms of dynamic stiffness and damping[6].

The output of the identification process, figure 7, is a bushing property file that contains all the parameters for the bushing so it can be used in your vehicle model.

### 3.2 Simulation of the rear powertrain mounting system

Series of simulations was performed after identification of silenblocks parameters. The excitation signal acted in the centre of gravity of the powertrain in the x, y and z directions.

The first part of the simulation was necessary to determine the frequency response of the mounting system of the powertrain [5]. The excitation signal was formed by a swept sine with different displacement amplitudes from 0.1mm to 3mm in the frequency band 0-2000Hz. Subsequently, the frequency response was calculated in the postprocessor, figure 8.

The second part of the simulations was carried out using max. torque of the drive unit to the storage system. Torque acts about the y-axis between the powertrain and the ground and results from the combined maximum torques of both drive units of rear powertrain.

## 4 Design of rear powertrain mounting system

The modified rear powertrain is mounted using silenblocks in the rear axle frame.

The rear subframe is made of a tubular frame and had to be supplemented with holders for silentblock brackets, figure 9.

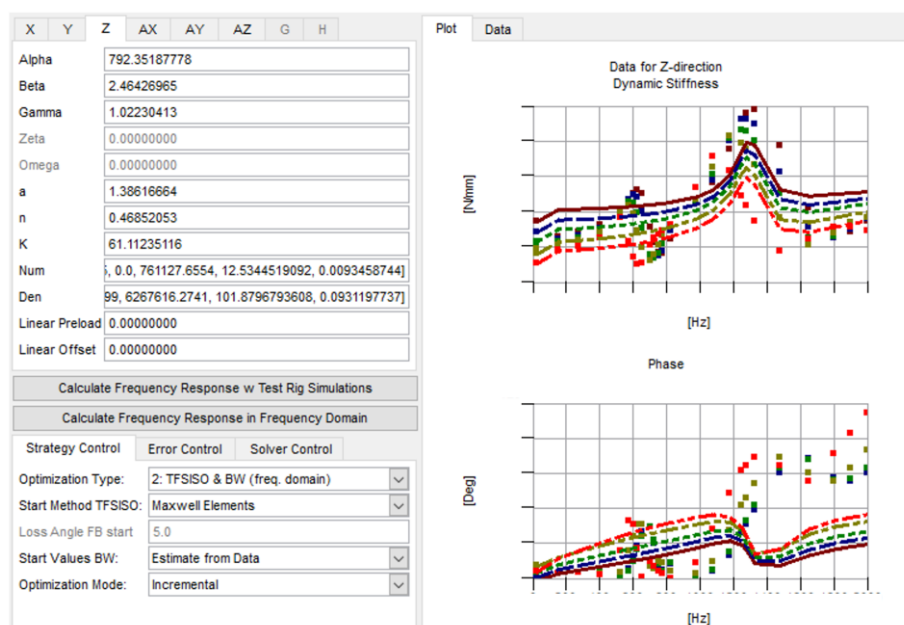


Fig. 7 The IPIT GUI

#### 4.1 Structural analysis of selected components

Structural analysis was performed in ADAMS View where selected rigid components were replaced with flexible body parts, figure 10.

After shape modification all of the selected components were satisfactory in terms of stresses and displacements. The worst safety coefficient was 2,5 which was more than rated minimal safety coefficient equal 2.

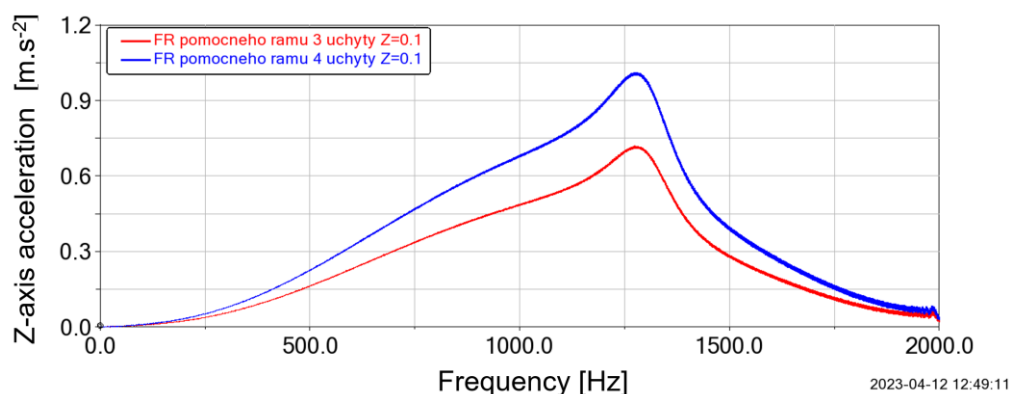


Fig. 8 Frequency response of rear axle frame, excitation amplitude 0.1mm

## CONCLUSION

The paper deals with analysis and design of mounting system of modified rear powertrain of E-up Boost. Analysis was performed in ADAM View. The silentblocks were modelled with general bushing element. An existing silentblocks with measured data from EV was used for the design process. IPIT was used for identification of silentblock parameters. The optimization process in IPIT was successful only partially because there is frequency limitation of identification tool. Also, time consumption is very high. The neural network model of silentblock for speeding the design process will be used in further work.

## ACKNOWLEDGEMENT

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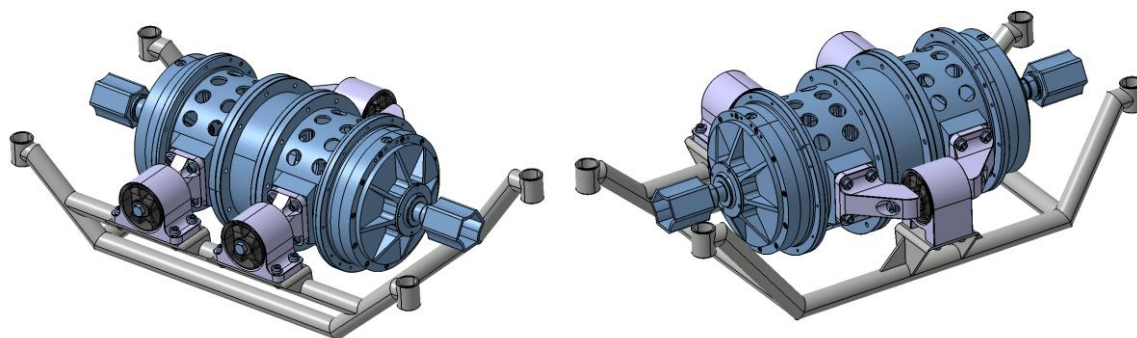


Fig. 9 The modified powertrain with mounting system on the rear axle frame

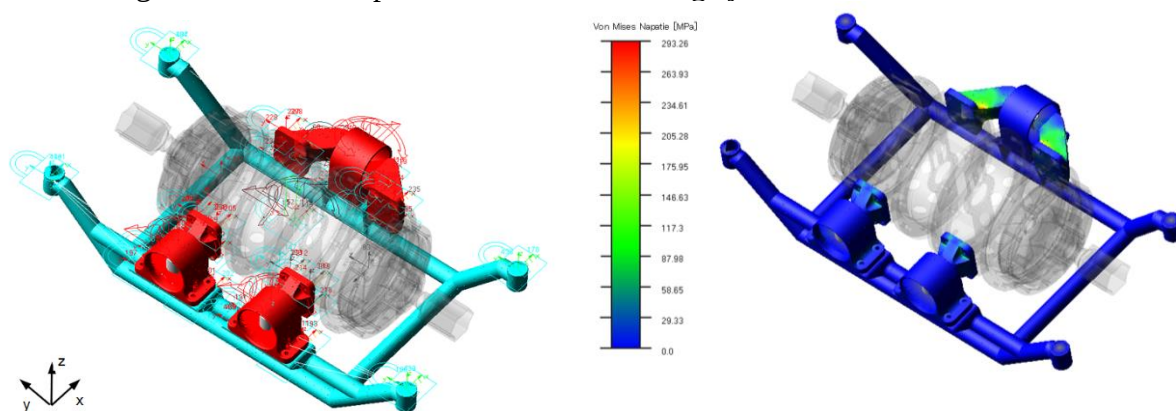


Fig. 10 Replaced flexible body parts model and stress distribution

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