

Calculating the mobile electronic charge unit operating performance in COMSOL software

T. Petrov¹, V. Basenko^{1*}, A. Safin¹, and A. Tsevtkov¹

¹Kazan State Power Engineering University, 51 Krasnoselskaya St., 420066, Kazan, Russia

Abstract. The development of numerical analysis methods and, first of all, the finite element method (FEM), makes it possible to obtain accurate solutions for quite complex objects. Such objects include mobile electric vehicle charging units (MCUs). The MCU under development will have a rather complex design, experiencing significant static and dynamic loads in operation, so their reliable calculation is possible only with the help of FEM, which allows multivariant calculations with identification of weak points of the design. **Key words:** mobile electric vehicle charging device, design operability, COMSOL software.

1 Introduction

Mobile electric vehicle charging units have peculiarities in the transportation process by different modes of transport. Considering multimodality of MCU design, the problem of ensuring durability due to the difference of the current regulatory loads on sea, road and rail transport comes to the fore. At the design stage, much attention should be paid to calculating the stress-strain state (SSS) to ensure the safety, safety of the MCU while reducing metal intensity to increase competitiveness. All this requires a detailed study of the behaviour of the MCU and the determination of loads that act in operation to improve the calculation and testing methods.

As part of the agreement with the Ministry of Education and Science of Russia No. 075-11-2021-048 dated June 25, 2021 on the organization of high-tech production of mobile high-capacity electric charging units with an integrated energy storage system, it is necessary to perform strength analysis of the developed MCU design to assess its performance and resistance to external influencing factors (EVF). General view and technical characteristics of the investigated container are shown in Fig. 1.

* Corresponding author: vasiliybas123@mail.ru

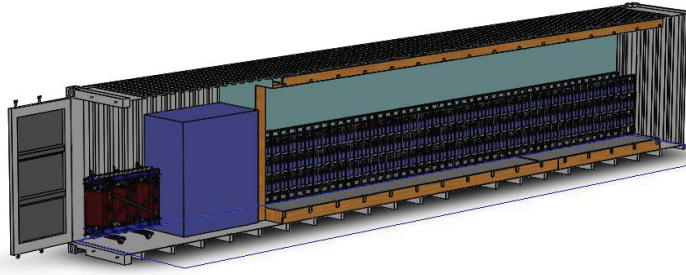


Fig. 1. General view of the MCU.

The COMSOL software package is used to solve strength problems using the finite element method.

Construction of the finite element model of the MCU. The developed MCU is referred to the group of mechanical version 3 (M3), for which according to GOST 3063199 the level of mechanical external influences has the following limits:

- frequency range of sinusoidal vibration in the range from 0.5 to 35 Hz;
- maximum amplitude of sinusoidal vibration acceleration - 5 m/s^2 ;
- peak shock acceleration for multiple impacts - 30 m/s^2 ;
- action duration for the shock acceleration for the shocks of repeated action - from 2 to 20 ms.

The process of strength calculations using FEM in COMSOL software can be divided into several stages:

- creation of a geometric model of the object;
- creation of a physical model of the object;
- superimposing of a finite-element mesh;
- assignment of external connections;
- modeling loads;
- solving a system of equations and calculation of stresses in nodes;
- result analysis.

To conduct strength analysis in the COMSOL software package, a geometric 3D model of the MCU under development was constructed, which is shown in Figure 2.

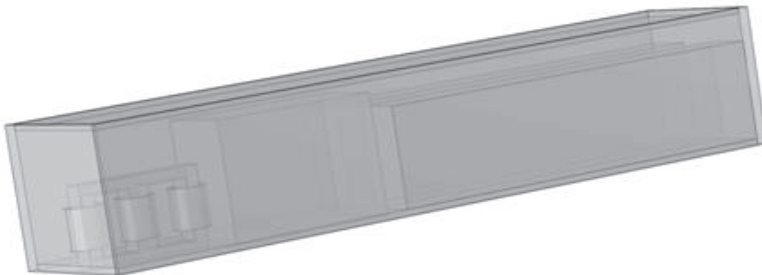


Fig. 2. Design geometric model of the MCU.

After construction, the geometric model of the MCU was divided into nodes according to its key elements, viz:

1. MCU container;

2. Dry transformer TSZ 10/0.4 kV;
3. Bidirectional inverter;
4. Power storage unit.

Next, a physical unit was created in COMSOL software package to perform strength analysis. The creation of the physical model begins by filling the geometric model with materials that have properties that reflect the mechanical characteristics of the MCU under development.

The basic materials for strength analysis were selected Structural Steel, Soft Iron, Copper

Table 2. Parameters of Structural Steel MCU material.

Parameter	Parameter value
Density	7850 kg/m ³
Young's modulus	200*10 ⁹ Pa
Poisson's ratio	0.31

For the TSZ transformer, Soft Iron and Copper magnetic core and winding materials were selected, the mechanical parameters of which are presented in Tables 3 and 4.

Table 3. Soft Iron material parameters.

Parameter	Parameter value
Density	8300 kg/m ³
Young's modulus	205*10 ⁹ Pa
Poisson's ratio	0.33

Table 4. Parameters of Copper material.

Parameter	Parameter value
Density	8960 kg/m ³
Young's modulus	110*10 ⁹ Pa
Poisson's ratio	0.35

After generating the physical model, a grid was overlaid on the simulated MCU (Figure 3) to perform finite-element simulations.

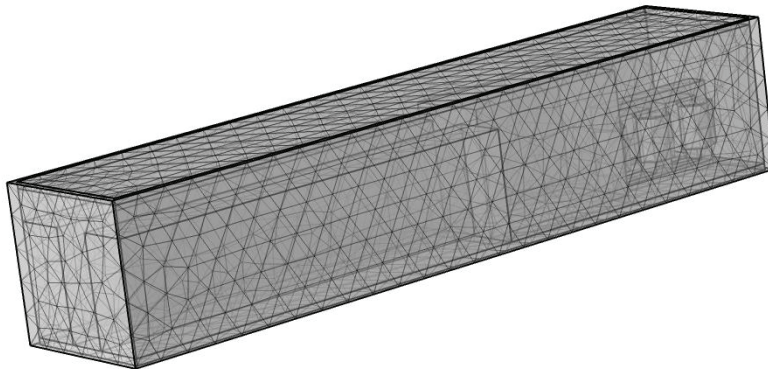


Fig. 3. Mesh overlay on MCU geometric model.

The maximum size of the mesh element is 30 cm, the minimum size is 3 cm, the maximum height of the mesh element is given by a factor of 1.5, and the curvature factor is 0.6.

2 Calculation of MCU stress-strain state

The task of this study will be to simulate the mechanical parameters of the MCU design nodes under the WSF. Solid Mechanics physics with the solution of second-order differential equations in the time domain in Time Dependent mode was chosen. This mode calculates stress tensor equations for the MCU with time variation. The time range was set from 2 to 20 ms with a step of 1 ms (Figure 4), which corresponds to the parameter GOST 3063199.

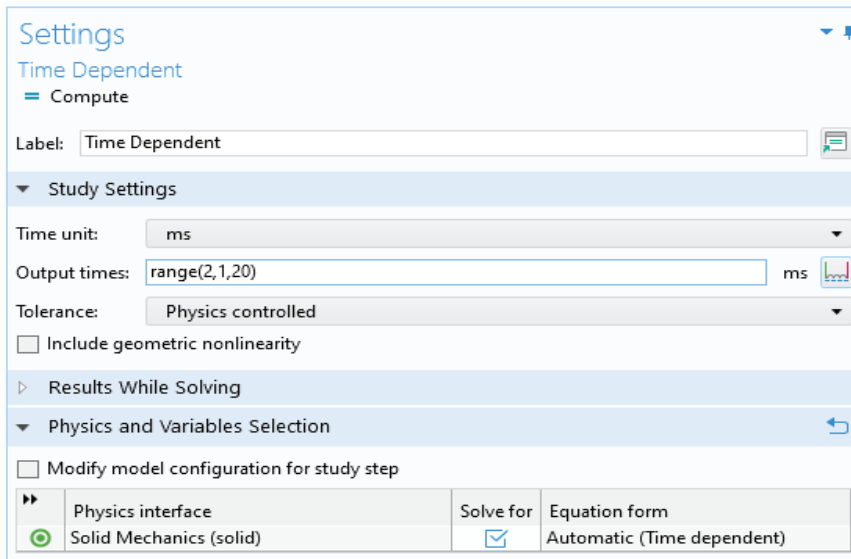


Fig. 4. Parameters for calculating the mechanical characteristics of the MCU in COMSOL for the time domain.

The stress-strain state of the MCU was calculated using the Cauchy stress tensor function, which is described by second-order differential equations (Figure 5).

Figure 5. Computational equations for determining the MCU stress-strain state

The mechanical stress tensor describes the maximum deviation of a point from its equilibrium position, which corresponds to the physical concept of vibration displacement. By determining the value of vibration displacement, it is possible to estimate the value of vibration velocity experienced by the MCU structure under the action of the HVF using the equation 1:

$$a = \frac{du^2}{dt} = -u_{\text{peak}}(\sin\omega t) \quad (1)$$

3 Results

As a result of the calculation the data on equivalent stresses, displacements were obtained, the zones of stress concentration, as well as zones with large relative difference of stresses in adjacent elements were identified. Calculation results on the impact of VVF on the MCU are shown in Table 5.

Table 5. Calculation results of WWF impact on MCU.

node number	Node name	Maximum acceleration amplitude according to GOST 3063199 m/s ²	Peak impact acceleration by GOST 3063199 m/s ²	Calculated maximum acceleration amplitude of MCU m/s ²	Calculated peak impact acceleration of MCU m/s ²
1	MCU container	5	30	2.13	9.87
2	Dry Transducer TSZ 10/0.4 kV			2.43	13.2
3	Bidirectional inverter			2.18	11.12
4	Electricity storage unit			3.21	19.43

The stress-strain state of the simulated MCU with indication of these zones is shown in Figure 6.

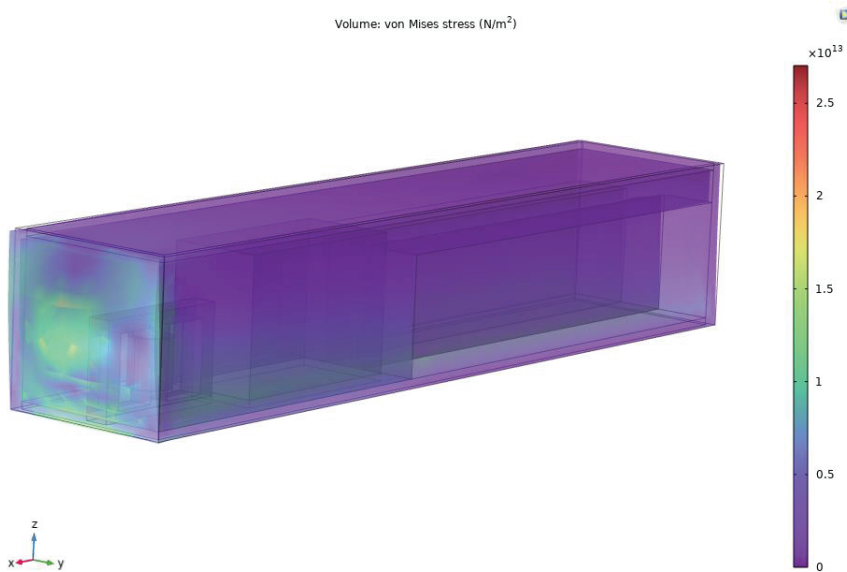


Fig. 6. Areas of the MCU stress-strain state.

According to the results of the strength calculation for the structure of the developed MCU by means of finite-element modeling in COMSOL software, the results were obtained, which confirm the mechanical reliability of the developed structure to the VVF according to GOST 3063199.

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