Physical functional model of the SES solution for extending autonomy of the electric vehicles propulsion system

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Abstract. The theoretical analysis and the virtual model design of the SES (Secondary Energy System) outlined the usefulness of this kind of equipment. Therefore, by carefully examining the improvements brought by SES to electric-powered vehicles, we can easily conclude that they can be equipped with such an additional energy system, which will enable them to have impressive performances. This has led to the next stage, respectively the physical construction of the whole ensemble. In this paper, the main elements that are part of the SES are presented in a detailed manner. At the same time, the thermodynamic processes of the spark-ignition engine are showed, practically, caught on a camera during its functioning.

1. Introduction
In this paper we present the first steps leading to the achievement of the physical model of the SES. Based on the virtual model, where the possibilities of implementing the adopted solutions were analyzed, we advanced to the next stage, which is, the construction of the physical functional model. This step is absolutely necessary in order to optimize the system (SES).

The SES comprises the following elements:
- a small-liter internal combustion engine;
- two electric generators;
- transmission system;
- mounting bracket.

2. Component parts of the system
Having the theoretical analysis and a three-dimensional virtual design of the SES, its physical construction is not such a difficult work to do.

2.1. The thermal engine used in the SES
At first, it should be emphasized that an internal combustion engine was used, meaning a small cylinder spark ignition engine that can meet the functional requirements of the system. Specifically, the system is equipped with a Briggs & Stratton 4-stroke engine of 127 [cm³] which provides a maximum power of 2,20 [kW] at a rated speed of 3600 [rpm]. This engine was chosen for several reasons, the most important being the compact construction and the air cooling system [1].

In order to do a detailed analysis of the thermodynamic processes underlying the functioning of the engine, the standard cylinder head was replaced with a 30 [mm] quartz plate, shown in figure 1 [2].
Figure 1. Quartz cylinder head.

The thermal engine has the following technical characteristics:
- 4 stroke;
- displacement = 127 [cm³];
- maximum power $P_{\text{max}} = 2.2$ [kW] at the speed $n_{\text{pmax}} = 3600$ [rpm];
- maximum torque $M_{\text{max}} = 6.24$ [Nm] at the speed $n_{\text{mmax}} = 3100$ [rpm];
- bore $D = 60.33$ [mm];
- stroke $S = 44.45$ [mm];
- compression ratio $\varepsilon = 5.3$;
- air cooling.

2.2. The generators used within SES
Depending on the maximum power provided by the thermal engine, it was decided to use two electric generators which would produce a charging current of approximately 70 [A]/pcs, at a constant voltage of 12 [V].

The generators used in the SES, according to figure 2, are produced by BOSCH Company and are equipped with a wide belt roller with one way rotation mechanism, having a trigonometric rotation direction [3].

Figure 2. Electric generator used within – SES.
2.3. Transmission system within SES
As shown in figure 3, the priority is the simplicity of construction, as well as a quiet and low vibration functioning, the best answer to these requirements being a transmission system using a belt.

In order to carry out the training of the two generators by the thermal engine, the chosen variant was the one whereby a ribbon winding belt is used for each generator separately. Their tensioning is carried out by moving them on the mounting bracket [4].

![Figure 3. SES transmission system.](image)

2.4. The SES mounting bracket
The mounting bracket for the entire SES assembly is executed to be as compact as possible and to ensure the placement of all components parts within the system in the most efficient manner. At the same time, it was considered the possibility of fixing it to the metal part designed for fixing the spare wheel of a vehicle. Figure 4 shows the chosen mounting bracket:

![Figure 4. Mounting bracket for – SES.](image)
3. The thermodynamic processes of the engine within the SES

In the following figures, we can observe the four thermodynamic processes, directly from the combustion chamber. These processes underlie the operation of a 4-stroke engine, in this case a spark ignition engine [5]:

3.1. Intake

Figure 5. The intake process.

3.2. Compression

Figure 6. The beginning (a) and the maximum pressure point (b) of the compression process.
3.3. Combustion

![Figure 7. The combustion process.](image)

3.4. Expansion - Exhaust

![Figure 8. The process of expansion (a) and exhaust (b) of the burned gases from cylinder.](image)
4. Conclusions
Combining the theoretical results obtained previously with the practical realization of the SES system, it is obvious that this system offers a viable solution and that it comes with substantial advantages for vehicles equipped with electric propulsion system. The most important advantages are mentioned below:

- ensuring the movement of the electric vehicle, when the batteries run out of energy and there is no possibility to recharge it;
- ensuring the movement of the electric vehicle on longer routes, without the need for stops on to recharge the battery;
- extending the life of the battery;
- requires a small and light battery and therefore has lower deployment costs.

Following these steps: the theoretical study, the virtual design, the physical analysis, the selection and testing of the main elements within SES, the physical assembly of all the components on the mounting bracket was performed. At the first start-up of the system, its behavior was successful.

Last but not least, the most important thing in this step is that the confirmation of the previous results was achieved by effectively testing the physical model.

5. References
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