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Supercapacitors and starting modes of a hybrid car engine**

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Abstract

Reducing the start-up time of internal combustion engines, especially at low temperatures and when the batteries are discharged, the use of supercapacitors leads to a

reduction in emissions into the atmosphere, improving the quality of life in large metropolitan areas.

Keywords: start-up time, battery, supercapacitor, starting current. hybrid engine.

Recently, experimental studies of combined current sources (KIT) for the electric starter start-up system (SEP) on the example of a hybrid engine MZ-4062.10 with a starter 42.3708 have shown that the use of a supercapacitor allows the use of rechargeable batteries (AB) with a higher degree of discharge [1], which is especially important at low air temperatures.

Figures 1-4 show the dependences of the currents of the AB and supercapacitors that are part of the KIT, and the speed of rotation on the time of rotation of the crankshaft of the engine ZMZ-4062.10 with the starter 42.3708 (the calculated dependences of the SEP parameters in the figures are shown in dotted lines). When the power supply to the starter motor only from AB type 6ST-75A, discharged to 50% at 25 °C for ten second attempt, the crankshaft of the engine rotates with a frequency of $n = 115-125 \text{ min}^{-1}$ (figure 1). Throughout time cranking amperage armature starter and power of the discharge current of AB were within 143-147 A. In ten seconds of discharge, the AB U_{AB} voltage dropped from 12.22 V to 10.48 V. At the next stage of experimental studies, a supercapacitor – energy storage (NE) with a capacity of 40 F was connected in parallel to the AB. The charge of the supercapacitor was produced from the AB, discharged by 50 %. The results of turning the engine crankshaft from the KIT showed that the initial speed increased to 145 min^{-1} (Figure 2). By the end of the tenth second, the supercapacitor discharge had stopped, and the crankshaft speed had dropped to 125 min^{-1} . The average armature current I_a remained at the level of 147-154 A, while at the initial moment ($\tau = 0.1 \text{ s}$) of rotation of the crankshaft, the armature current I_a was 610 A, of which the supercapacitor accounted for the current I_{HE} of the order of 365 A. By the end of the tenth second, the current of the I_{HE} supercapacitor decreased to zero, and the current of the AB I_{AB} increased to the value of the armature current I_a . The AB U_{AB} voltage at the tenth second of the discharge decreased from the initial 12.43 V to the value of 10.76 V, and the NE U_{BE} voltage was 10.50 V.

An even greater effect was obtained when connecting a more powerful NE with a capacity of 660 F to the AB (Figure 3). In the presented graphs, the change in the current and voltage of the AB and NE is of interest. In the presented graphs, the change in the current and voltage of the AB and NE is of interest. The average current of the armature I_a increased to the level of 190-240 A, while at the initial moment ($\tau = 0.1 \text{ s}$) of rotation of the crankshaft of the internal combustion engine, the current of the armature I_a was 489 A, of which the NE accounted for the current of the I_{HE} of the order of 350 A. Within ten seconds, the current strength of the NE I_{NE} was at the level of 142-146 A, and the current strength of the AB I_{AB} was at the level of 47-94 A. Thus, NE accounted for about 2/3 of the current load. The voltage of the AB U_{AB} at the tenth second of the discharge was 10.79 V (at the initial 12.6 V), and the voltage of the NE $U_{NE} = 9.79 \text{ V}$. The speed of rotation of the crankshaft of the internal combustion engine averaged 125 min^{-1} .

In previous experiments, energy storage devices were charged from a battery that is part of the KIT and is 50% charged. By increasing the initial voltage of the NE U_{NE} to 14 V (up to the rated voltage of the generator set), its role in the KIT when turning the crankshaft has increased even more (Figure 4). The value of the current strength of the NE I_{NE} was close to the current strength of the starter armature I_a almost throughout the entire attempt. At the initial moment ($\tau = 0.1 \text{ s}$) of rotation of the internal combustion engine crankshaft, the current strength of the armature I_a was 477 A, of which the NE accounted for the current strength I_{NE} of the order of 397 A. The average armature current I_a was at the level of 150-196 A, while

the current I_{AB} did not exceed 60A during the entire attempt. This indicates that in this case, the starter load was completely taken over by the NE, unloading the battery from the starter currents. At the initial value of 12.17 V, the U_{AB} voltage decreased by only 1 V to 11.16 V at the tenth second, and the NE U_{BE} voltage value changed from 14 V up to 10.24 V. The engine crankshaft speed remained at 125 min⁻¹.

Analysis of the distribution of current values between the AB and NE shows that in the first 2-4 seconds of turning the engine crankshaft, energy storage can significantly reduce the current flowing from the AB, which reduces the load on the batteries and extends their service life. It also follows from the experimental data that lower values of the current flowing from the AB when the NE is connected cause lower voltage drops on it. This increases the reliability of the system ignition (the minimum permissible value of the uninterrupted spark generation voltage of which should be 6 V).

Conclusions. Thus, the parallel connection of the supercapacitor-NE and AB allows you to:

- unload the AB at the initial time, which makes it possible to use a smaller battery capacity;
- increase the frequency of cranking of the engine crankshaft, especially during the initial start-up period;
- reduce harmful exhaust when starting the engine;
- perform cranking of the engine crankshaft in the case of a highly discharged battery;
- increase the voltage in the ignition system when the battery is very low (for gasoline engines).

The development of an optimized standard-size range of KIT with NE remains an important problem [2-6], the solution of which makes it possible to significantly improve the technical and economic indicators of KIT and speed up the process of their implementation on various samples of automotive equipment.

Figure 1-The average frequency of cranking of the crankshaft ZMZ-4062.10 and the average current of the starter armature 42.3708 when using AB 6ST-75A (50%)

Figure 2 – Change of average current of the armature starter 42.3708, AB 6ST-75A (50 %), NEM-40/14 (12 V) and the average frequency of rotation of a crankshaft of the engine ZMZ-4062.10

Figure 3-Change in the average voltage and current of the starter armature 42.3708, AB 6ST-75A (50 %) iMNE-660/12 (12 V) when turning the crankshaft of the engine ZMZ-4062.10.

Figure 4-Change in the average voltage and current of the starter armature, AB 6ST-75A (50 %) and NE MNE-660/12 (14 V) when turning the crankshaft of the engine ZMZ-4062.10

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