Performance characteristics’ study of a submersible electric motor based on the bench tests results

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Abstract. Currently, the majority of electric centrifugal pump installations are equipped with submersible induction motors. The simulation models’ development and the study of operating modes based on them should be accompanied by verification of the data obtained with experimental results. It is due to the design features of this electric motors’ type. Therefore, the aim of the article is to study the performance of submersible induction motor with a power of 70 kW. The performance is obtained on simulation model and their verification with experimental results. The simulation model of SEM-YA 70-117 M5B5 submersible induction electric motor is developed in the MATLAB/Simulink software environment during the research. The performance characteristics are also built. It is established that the relative error of the values obtained during simulation to the experimental data does not exceed 10%.

1. Introduction

Currently, submersible induction electric motors (SEM) are the main drives of electric centrifugal pumps for oil production [1-5]. The widespread SEM’s use is due to the design simplicity, the ability to operate the engine during short-term mechanical overloads, the ability to connect directly the stator winding to the network (direct start) and the automation ease.

The existing methods for determining the parameters of equivalent circuits and building on their basis the performance characteristics of the electric motors in some cases do not always accurately reproduce the electromechanical processes in the engine. It is due to the design features of submersible electric motors.

At the moment, there are a number of fairly accurate methods in the scientific and technical literature [6-13] for determining the parameters of equivalent circuits for submersible induction motors. They use catalog data from manufacturers. However, the catalog data of the electric motor is given during its operating in the nominal mode. There is a possibility of discrepancy between the mathematical modeling results and the experiment when the motor is not operating in the nominal mode.

The description of the MATLAB/Simulink standard block "asynchronous machines quirrel cage" is given in the study [14]. It is a simulation model of an asynchronous machine with a short-circuited rotor. The initial conditions can be defined using the powergui block. However, a number of authors claim that the standard block "asynchronous machines quirrel cage" is intended for the operation modes’ modeling for the general industrial electric motors. The standard block does not consider the design features of the SEM. Therefore, it is necessary to study the performance characteristics of
submersible induction motors obtained on the simulation model and their verification with the experimental results [15-18].

2. Materials and Methods
A submersible induction electric motor of the SEM-YA 70-117 M5B5 brand is selected as the object of research. Its technical characteristics are given in table 1.

**Table 1. Technical characteristics of SEM-YA 70-117 M5B5**

| Characteristic                  | Value |
|--------------------------------|-------|
| Rated voltage $U_{nom}$, V     | 1190  |
| Rated power on the shaft $P_{nom}$, kW | 70    |
| Rated speed $n_{nom}$, rpm     | 2910  |
| Rated efficiency $\eta_{nom}$  | 0.845 |
| Rated power factor $\cos \varphi_{nom}$ | 0.84 |
| Rated current $I_{nom}$, A     | 51    |
| Nominal torque $M_{nom}$, N·m   | 222   |
| Starting current multiplicity $k_I$ | 5.1   |
| Multiplicity of starting torque $m_I$ | 1.5  |
| Multiplicity of the maximum moment $m_{max}$ | 2.3 |
| Moment of inertia $J$, kg·m$^2$ | 0.46  |
| Nominal slide $s_{nom}$, %     | 3.0   |
| The critical slide $s_{cr}$, % | 23.8  |
| Resistance of stator windings $R_{1m}$ at 84 °C, Ohm | 1.35 |

It is necessary to determine the initial conditions of the simulation model for the investigated submersible induction motor in MATLAB/Simulink, build performance characteristics and verify the experimental results.

The standard blocks of electrical devices in the SimPowerSystem library are used to build the model. They are: three-phase programmable voltage source and asynchronous machines squirrel cage (asynchronous machine with a short-circuited rotor).

The initial conditions are calculated using the method [14] and are given in table 2.

**Table 2. Initial conditions of the simulation model**

| Parameter                                | Value |
|------------------------------------------|-------|
| Active resistance of the stator winding, Ohm | 1.35  |
| Inductance of the stator winding, mH     | 4.3   |
| Reduced active resistance of the rotor winding, Ohm | 1.0   |
| Reduced inductance of the rotor winding, mH | 4.3   |
| Inductance of the magnetization circuit, mH | 70    |
| Moment of rotor’s inertia, kg·m$^2$      | 0.46  |
| Coefficient of friction, N·m·s            | 0.04  |

3. Results
A simulation model of the submersible motor is shown in figure 1.

![Simulation Model](image1.png)

**Figure 1.** A simulation model of the SEM

The operating characteristics of the submersible motor obtained by the simulation model are shown in figure 2. Construction of performance characteristics is obtained with a static moment applying from 0 N·m to 77 N·m relative to the nominal moment in 10% pitch.

![Performance Characteristics](image2.png)

**Figure 2.** Performance characteristics of SEM-YA 70-117 M 5B 5 (simulation)

Experimental performance characteristics of the brand SEM-YA 70-117 M 5B5 submersible electric motor received during acceptance tests are shown (Minutes No. 30001 of 01.09.2015) in figure 3. Tests are carried out at the factory LLC "Almaz", Radugniy city.
4. Discussion
The performance characteristics analysis shows that the relative error of the simulation data to the experimental data does not exceed 10% for all measured values. In the nominal mode, the deviation of the current, power factor, efficiency and motor speed is less than 5%.

Therefore, the simulation model of general industrial motors can be used to model the electromechanical processes of submerged induction motors after its verification.

5. Conclusions
The initial parameters for the simulation model of a submersible induction electric motor SEM-YA 70-117 M5B5 brand are determined. In the course of simulation, the operating characteristics for the submersible motor are constructed and verified. It is established that the relative error of the simulation results to the experimental data does not exceed 10%. Therefore, the simulation model adequately displays the electromechanical processes of the investigated submersible induction motor.

References
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