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The Method and Instruments for Induction Motor Mechanical Parameters Identification

A. Egorov,
Assistant Professor, Institute of Mechanics and Machine Building,
Volga State University of Technology, Yoshkar-Ola, Russian Federation
al.v.egorov@yandex.ru

V. Belogusev,
Research Assistant, Institute of Mechanics and Machine Building
Volga State University of Technology, Yoshkar-Ola, Russian Federation
vladimir.belogusev@yandex.ru

K. Kozlov,
Assistant Professor, Institute of Mechanics and Machine Building,
Volga State University of Technology, Yoshkar-Ola, Russian Federation
konstantin.k-e@yandex.ru

Abstract
Identification of the induction motor mechanical parameters and their control are important tasks to maximize the induction motor energy efficiency in all possible modes of operation. The purpose of this paper is a development of the method and instruments for identifying the moment of inertia of an induction motor (the rotating parts moment of inertia with respect to the rotation axis passing through the center of the rotor taking into account losses). This method allows identifying and controlling the mechanical parameters of an induction motor with high measurement rate within a wide range of operating modes. When determining the torque, the developed method is to be preferred because it not only has a sufficiently high measurement accuracy under dynamic modes, but also requires a minimal amount of additional equipment. The experiments showed the high reliability of the data obtained. In this work it was determined the proportion of each type of losses in the induction motor (mechanical and added losses) that is difficult to perform in the application of existing methods and measurement instruments.

Keywords: Induction motor, Reference body, Mechanical efficiency, Mechanical losses.

Introduction

In the course of the induction motors parameters check, it is required to have instrumentation of two types: for measuring electrical quantities (current, voltage, power) and for measuring non-electrical quantities (mechanical parameters). Unlike electrical appliances, equipment for measuring the non-electrical values is not developed quite well: the range of instruments produced centrally is low, the equipment is not always standardized and often not subjected to qualified metrological control [1-4].

The main non-electrical quantities of the motors are such mechanical parameters as the mechanical efficiency, the mechanical power, the motor shaft torque and the moment of inertia of an induction motor. Nowadays separate methods and instruments are applied to identify each of those parameters.

Analysis of the scientific literature [5-13] revealed that the existing methods for control and identifying the induction motor torque, efficiency and power are based on either both assumption and averaging (brake methods) or on the set of indirect parameters (e.g., input and output electrical parameters). Therefore, the most commonly used methods do not allow obtaining information of the mechanical parameters of induction motors in general with a high accuracy [12, 14].

Thus, there is the contradiction now. On the one hand, it is necessary to provide maximum power efficiency of the motors in all possible modes of operation; on the other hand, the existing methods and instruments do not allow cost-effective and easy-to-make measurement of the induction motor mechanical parameters with a high accuracy within a wide range of speed and load modes. Moreover, the problem of determining the mechanical losses and added losses in an induction motor has not yet solved. The value of added losses in the motor is often taken as zero value.

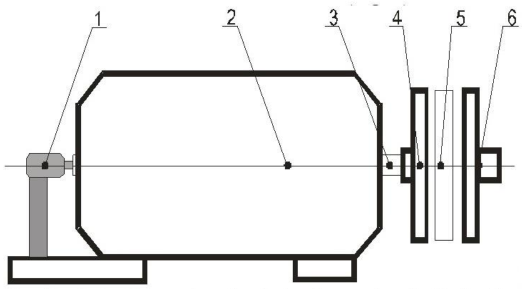
The purpose of this paper is a development of the method and instruments for determining the moment of inertia of an induction motor taking into account losses, which allows identifying and controlling the mechanical parameters of an induction motor with a high measurement rate within a wide range of operating modes.

Thereto we solved the following scientific and technical tasks: development of the method and instruments to determine the moment of inertia of an induction motor taking into account losses; comparison of the measurement results obtained using the developed method and by means of existing methods (in accordance with the State Standard); the practical application of the developed method to identify the mechanical parameters of the induction motors and to determine the proportion of each type of loss (mechanical and added) as parts of the total losses in induction motors.

Materials and Method

The method for Identifying the Moment of Inertia of an Induction Motor Taking into Account Losses

The implementation of the developed method we explain on the basis of a diagram of an induction motor, the shaft of which is attached to the shaft of an encoder (Fig. 1).



1 - encoder; 2 – induction motor; 3 – induction motor shaft; 4 – the first half-coupling, 5 – rotary body with a known moment of inertia J_{ref} (reference body); 6 – the second half-coupling

Fig. 1. A diagram of an induction motor

To determine the moment of inertia of the induction motor taking into account losses, we suggest using the following way. The reference body 5 is removed. The motor 2 with a half-coupling 4 starts, and the average value of the angular acceleration of the motor shaft within a selected speed range is defined as:

$$\varepsilon_1 = \frac{d\omega}{dt_1} \tag{1}$$

Where, $d\omega$ is the change of the angular velocity within a selected speed range, *rad/s*; dt_1 is the time needed to change the angular velocity within a selected speed range during the first start, *s*.

The speed range selection depends on the task and the angular velocity measurement instrument. The minimum value of the speed range depends on the measuring instrument; the maximum value may be equal to the rated value of the angular velocity.

The angular acceleration of the motor is measured by means of an incremental encoder. The torque M, which a system of rotating masses "induction motor 2; half-coupling 4" has, is defined as:

$$M = (k_{loss} \cdot J_{r.p.m.} + J_{h.c.}) \cdot \varepsilon_1 \tag{2}$$

Where, k_{loss} is the coefficient characterizing mechanical and added losses in the induction motor; $J_{r.p.m.}$ is the moment of inertia of the induction motor rotating parts without taking into account losses, $kg{\cdot}m^2$; $J_{h.c.}$ is the moment of inertia of the half-coupling 4, $kg{\cdot}m^2$.

Further, the motor 2 stops. The reference body 5 is attached to the half-coupling 4 with the fasteners. The motor 2 starts and the average value of the angular acceleration of the system of rotating masses "motor 2; half-coupling 4; reference body 5" is defined in the selected speed range as:

$$\varepsilon_2 = \frac{d\omega}{dt_2} \tag{3}$$

The torque M, which a system of rotating masses "induction motor 2; half-coupling 4; reference body 5" has, is defined as:

$$M = (k_{loss} \cdot J_{r.p.m.} + J_{h.c.} + J_{ref}) \cdot \varepsilon_2 \tag{4}$$

Since losses in the stator and the rotor, the input voltage, the power frequency, and the stator resistance do not change at the first and the second starts, therefore, the speed-torque curve of the induction motor is invariable. Hence, the right-hand parts of Eq. 2 and Eq. 4 are equal, and we can define the moment of inertia of the induction motor taking into account mechanical and added losses:

$$k_{loss} \cdot J_{r.p.m} = J_{ref} \cdot \frac{\varepsilon_2}{\varepsilon_1 - \varepsilon_2} - J_{h.c.} \tag{5}$$

To determine the average value of the moment of inertia of the induction motor taking into account mechanical and added losses in the speed range from zero to the rated value of the angular velocity, the Eq. 5 may take the form:

$$k_{loss} \cdot J_{r.p.m} = J_{ref} \cdot \frac{\overline{\varepsilon_2}}{\overline{\varepsilon_1} - \overline{\varepsilon_2}} - J_{h.c.} = J_{ref} \cdot \frac{t_1}{t_2 - t_1} - J_{h.c.} \tag{6}$$

Where, t_1 is the time needed to speed the motor up from zero to the rated angular velocity during the first start (without the reference body), *s*; t_2 is the time needed to speed the motor up from zero to the rated angular velocity during the second start (with the reference body), *s*.

Thus, knowing the values of the moments of inertia of the reference body and the coupling (can be calculated or determined by the torsional pendulum), we can determine the moment of inertia of the induction motor taking into account losses by controlling only one parameter, which is the acceleration time.

Having determined the moment of inertia of the induction motor, $J_{r.p.m.}$, (by the torsional pendulum and calculation), one can determine its efficiency (taking into account mechanical and added losses):

$$\eta_{im} = \frac{1}{k_{loss}} = \frac{J_{r.p.m.}}{J_{ref} \cdot \frac{t_1}{t_2 - t_1} - J_{h.c.}} \tag{7}$$

The coefficient characterizing mechanical and added losses in an induction motor can be defined as:

$$k_{loss} = (1 + k_1 + k_2), \tag{8}$$

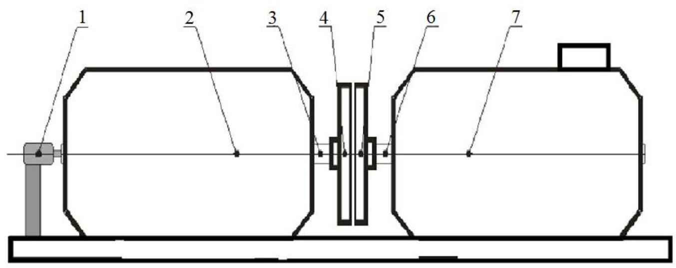
Where, k_1 is the coefficient characterizing mechanical losses; k_2 is the coefficient characterizing added losses in an induction motor (all kinds of difficult calculated losses caused by the influence of the higher harmonics of magnetomotive forces, magnetic induction pulsation, and other causes).
$k_1 = k_2 = 0$ if there are no mechanical and added losses in an induction motor.
The induction motor moment of inertia with respect to the rotation axis passing through the center of the rotor can be defined as:

$$J_{r.p.m.} = J_{rotor} + J_{bearings} + J_{fan}, \qquad (9)$$

Where, J_{rotor} is the moment of inertia of an induction motor rotor (can be measured by the torsional pendulum), kg·m^2; $J_{bearings}$ is the moment of inertia of an induction motor bearings (can be calculated), kg·m^2; J_{fan} is the moment of inertia of an induction motor propeller fan (can be measured by the torsional pendulum), kg·m^2.

Identifying the Coefficients Characterizing Mechanical and Added Losses in an Induction Motor

To determine k_1 and k_2, an induction motor needs to be off the line and its windings need to be demagnetized. It excludes added losses, and the coefficient characterizing mechanical and added losses for that induction motor can be defined as $k_{loss} = (1+k_1)$.
Let us determine the coefficient characterizing mechanical losses in an induction motor k_1.
To have the acceleration characteristic from zero to the rated value of the angular velocity close to the tested motor acceleration characteristic, it must be used an identical motor (the motor 2) to rotate it.
Figure 2 illustrates the joint of two identical motors, where the tested induction motor is used as the reference body.



1 – encoder; 2 – identical induction motor; 3 – shaft of the identical induction motor; 4 – the first half-coupling; 5 – the second half-coupling; 6 – shaft of the tested induction motor, 7 – tested induction motor

Fig. 2. A diagram of two identical induction motors joint

Since the tested induction motor is used as a reference body and has no added losses then it can be written:

$$J_{ref} = J_{r.p.m} \cdot (1+k_1) \cdot \qquad (10)$$

Let us make two induction motors starts to determine k_1:

1) The motor 2 without the tested motor 7 starts and the average value of the rotor shaft acceleration $\overline{\varepsilon_3}$ within the selected speed range is measured. The average value of the torque M is defined as:

$$M = (k_{loss} \cdot J_{r.p.m} + J_{h.c.}) \cdot \overline{\varepsilon_3}, \qquad (11)$$

Where, $\varepsilon_3 = \varepsilon_1 \cdot$

2) The motor 2 joined to the tested motor 7 starts and the average value of the rotor shaft acceleration $\overline{\varepsilon_4}$ within the selected speed range is measured. The average value of the torque M is defined as:

$$M = (k_{loss} \cdot J_{r.p.m} + 2 \cdot J_{h.c.} + J_{ref}) \cdot \overline{\varepsilon_4}. \qquad (12)$$

Taking into account that $J_{ref} = J_{r.p.m.} \cdot (1+k_1)$, Eq. 12 takes the form:

$$M = (k_{loss} \cdot J_{r.p.m} + 2 \cdot J_{h.c.} + J_{r.p.m} \cdot (1+k_1)) \cdot \overline{\varepsilon_4}. \qquad (13)$$

Since losses in the stator and rotor of the motor remains unchanged at the first and the second starts (as the input voltage, power frequency, and temperature of the motor (stator resistance) do not change), therefore, the speed-torque curve of an induction motor is invariable. Hence, the right-hand parts of Eq. 11 and Eq. 13 are equal, and we can define the coefficient characterizing mechanical losses k_1:

$$((k_{loss} \cdot J_{r.p.m.} + J_{h.c.}) \cdot \varepsilon_3 = (k_{loss} \cdot J_{r.p.m.} + 2 \cdot J_{h.c.} + J_{r.p.m.} \cdot (1+k_1)) \cdot \varepsilon_4$$

$$\frac{(k_{loss} \cdot J_{r.p.m.} + J_{h.c.}) \cdot \varepsilon_3}{\varepsilon_4} - k_{loss} \cdot J_{r.p.m.} - 2 \cdot J_{h.c.} = J_{r.p.m.} \cdot (1+k_1)$$

$$\frac{(k_{loss} \cdot J_{r.p.m.} + J_{h.c.}) \cdot \varepsilon_3}{\varepsilon_4 \cdot J_{r.p.m.}} - k_{loss} - 2 \cdot \frac{J_{h.c.}}{J_{r.p.m.}} - 1 = k_1$$

$$k_1 = \frac{k_{loss} \cdot \varepsilon_3}{\varepsilon_4} + \frac{J_{h.c.} \cdot \varepsilon_3}{\varepsilon_4 \cdot J_{r.p.m.}} - k_{loss} - 2 \cdot \frac{J_{h.c.}}{J_{r.p.m.}} - 1$$

$$k_1 = k_{loss} \cdot (\frac{\varepsilon_3}{\varepsilon_4} - 1) + \frac{J_{h.c.}}{J_{r.p.m.}} \cdot (\frac{\varepsilon_3}{\varepsilon_4} - 2) - 1 = k_{loss} \cdot (\frac{t_4}{t_3} - 1) + \frac{J_{h.c.}}{J_{r.p.m.}} \cdot (\frac{t_4}{t_3} - 2) - 1 \qquad (14)$$

Where, t_3 is the time needed to speed the motor up from zero to the rated angular velocity during the one-motor start, s; t_4 is

the time needed to speed the motor up from zero to the rated angular velocity during the two-motors start.
Knowing k_{loss}, $J_{r.p.m.}$ and $J_{h.c.}$ we can determine k_1 according to the Eq. 14.

The Instruments to Identify and Control the Mechanical Parameters of an Induction Motor

Figure 3 illustrates a hardware-software complex (hereinafter HSC) to identify and control the mechanical parameters of an induction motor. The HSC is for determining and control the mechanical parameters of induction motors (single-phase and three-phase); the motors power is up to 90 kW at a supply voltage up to 400 V.

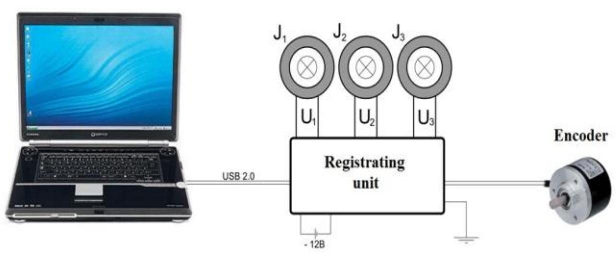


Fig. 3. A schematic diagram of HSC for identifying the induction motor mechanical parameters

Using the complex, one can determine the angular velocity and the angular acceleration of the motor shaft; the moment of inertia of induction motor rotating parts, which is respected to the rotation axis passing through the rotor center taking into account losses; the induction motor torque; the mechanical output; and the induction motor mechanical efficiency.
The HSC has three analog (voltages in three phases) and four digital (currents in the three phases and encoder signal) measuring channels. Upon rotation of the shaft, encoder generates a digital signal. The encoder generates 5,000 pulses per revolution of the motor shaft. The use of the encoder with such number of pulses per revolution provides the accuracy of higher order and a high frequency acceleration characteristic with all fluctuations of the angular velocity, which arise from transients during acceleration of an induction motor.
The HSC has an incremental encoder by Autonics; current sensors by Honeywell, which are based on Hall effect and form a digital signal (the current capacity is ±1,000 A). Voltage sensors are designed as resistors with a high resistance. Regardless of the voltage applied, the resistors input the voltage not exceeding 5 V to an ADC.
The digital signal from the sensors enters the registrating unit, wherein through galvanic isolation of signals and the filter enters the measuring microcontroller Atmega 640 with a clock frequency of 16 MHz (see Fig. 4). Galvanic isolation system consists of two units – power decoupling unit and signal line decoupling unit. The digital signal from the microcontroller enters the Flash-memory until the end of measurement. After completion of the measurement, data from the Flash-memory enters a personal computer (PC) and the terminal program installed on the PC hard disk processes it.
A mathematical processing of the data array and calculating the angular velocities, the induction motor accelerations, the total mechanical power and the mechanical parameters are carried out in terminal program on the PC using the procedure described above. According to the values of the angular accelerations obtained when accelerating motor with a reference body and without it, the moment of inertia of the induction motor taking into account losses, mechanical power and torque of the motor are calculated. The terminal program has built-in real time clock that allows you to save the time and date of the measured parameters.

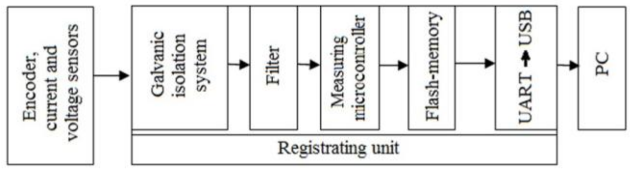


Fig. 4. A structure of the registrating unit for identifying the induction motor mechanical parameters

In order to ensure the identity of the input voltage and power frequency, we used a voltage stabilizer LIDER PS 7500SQ-E (the voltage error is 0.5%; the power frequency error is 0.1%). The multimeter AM-1152 monitored the stator resistance of an induction motor before each run.
In experiments, we used three types of induction motors manufactured by JSC "Eldin" (see Table 1) and a reference body with the moment of inertia of 0,002048 kg·m^2.

TABLE 1. Tested induction motors characteristics

Type of an induction motor	Rotary speed, rev/min	Efficiency at rated load, %			Moment of inertia, kg·m^2
		100	75	50	
A710B2	2820	79.6	79.6	77.5	0.0008
A71A4	1410	71.0	71.0	68.1	0.0010
A80A6	930	71.0	71.6	68.3	0.0035

Results

Measuring the Moments of Inertia of Induction Motor Rotating Parts by the Torsional Pendulum

For this purpose, we suspended rotating parts of an induction motor by a metal string with a diameter of 1 mm and a length of 0.88 m, which was attached to a rigid support. We placed a protractor on the horizontal projection of the rotating parts plane where string was fixed and attached a pointer on the measured bodies to determine the angle of deflection of measured bodies from the zero position. For a more precise determination of the period of torsional oscillations, a video camera captured the oscillation process.
Results obtained in the measurements are represented in Table 2.

Calculation of the Moments of Inertia of Bearings Rotating Parts

Two types of bearings (A71-6204 and A80-6205) are installed in the experimental motors, each bearing has 9 balls. For the experiment, we dismantled the bearings and determined geometric and mass properties of their rotating parts (Table 3).

TABLE 2. Results obtained in the measurements of the moments of inertia of induction motors rotating parts by the torsional pendulum

Parameter	Type of an induction motor			Reference body
	A71B2	A71A4	A80A6	
Torsional oscillations period (angle of deflection is 20 degrees), s	2.384	2.803	5.0679	7.010
Moment of inertia, $kg{\cdot}m^2$	0.000784	0.001084	0.003544	0.006781

TABLE 3. Geometric and mass properties of the bearings

Parameter	Bearing A71-6204	Bearing A80-6205
Number of balls	9	9
Diameter of balls, m	0.0080	0.0075
Weight of one ball, kg	0.00177	0.00189
Outer diameter of a race, m	0.028	0.033
Inner diameter of a race, m	0.020	0.025
Width of a race, m	0.014	0.015
Weight of a race, kg	0.037	0.038

The moment of inertia of a bearing is defined as:

$$J_{bearing} = J_{ir} + J_{roll} = J_{ir} + \frac{7}{80} m_{roll} D^2 n, \tag{15}$$

Where, J_{ir} is the moment of inertia of an inner race of a bearing, $kg{\cdot}m^2$; J_{roll} is the moment of inertia of bearing balls, $kg{\cdot}m^2$; m_{roll} is the weight of a bearing ball, kg; D is the diameter of an inner race of a bearing, m; n is the number of bearing balls.

The Total Moment of Inertia of Induction Motor Rotating Parts without Taking into Account Losses

At the next stage, in order to obtain the induction motor moment of inertia with respect to the axis passing through the rotor center without taking into account losses, we added the bearings moments of inertia with respect to the rotation axis passing through the rotor center to the moments of inertia of a rotor and a propeller fan. The results are represented in Table 4.

TABLE 4. The moments of inertia of induction motor rotating parts without taking into account losses

Moment of inertia, $kg{\cdot}m^2$	Type of an induction motor		
	A71B2	A71A4	A80A6
$J_{rotor}+J_{fan}$	0.000784	0.001084	0.003544
$J_{r.p.m.}=J_{rotor}+J_{fan}+2{\cdot}J_{bearing}$	0.000830	0.001130	0.003612

The Determination of the Moment of Inertia of Induction Motor Rotating Parts Taking into Account Losses

We identified the average values of the induction motors moments of inertia taking into account losses by the method described above. The average value of the induction motor acceleration was defined within the speed range from zero to the rated velocity of the induction motor A71B2 (900 rev/min). Since the speed range of the tested motors are the same, in order to determine the moment of inertia of an induction motor taking into account losses, we used the acceleration time as a measurand:

$$k_{loss} \cdot J_{r.p.m.} = J_{ref} \cdot \frac{t_1}{t_2 - t_1} - J_{h.c.}, \tag{16}$$

Where, t_1 and t_2 is the time needed for the induction motor acceleration from zero to the rated angular velocity without and with a reference body, respectively, s.
The obtained results are represented in Table 5.

TABLE 5. Identifying of an induction motor moment of inertia taking into account losses

Parameter	Type of an induction motor		
	A71B2	A71A4	A80A6
J_{ref}, $kg{\cdot}m^2$	0.002048	0.002048	0.003558
$J_{h.c.}$, $kg{\cdot}m^2$	0.001013	0.001013	0.001133
t_2, s	0.7866	0.4974	0.2341
t_1, s	0.3777	0.2594	0.1374
$k_{loss}{\cdot}J_{r.p.m.}$, $kg{\cdot}m^2$	0.000878	0.001219	0.003920

Identifying Added and Mechanical Losses as Parts of Total Losses in an Induction Motor

We defined the moment of inertia of mechanical losses $k_1{\cdot}J_{r.p.m.}$ and the moment of inertia of added losses $k_2{\cdot}J_{r.p.m.}$ according to Eq. 14 and Eq. 8. In order to define desired quantities, we measured the time needed to speed induction motors up from zero to the selected angular velocity at both starts (one-motor and two-motors starts) $\overline{t_3}$ and $\overline{t_4}$. For this purpose, we joined two identical induction motors together by means of a coupling, as shown above (Figure 2). A beat of the shafts relative to each other was 0.01 mm that was achieved by laser cutting of a frame and holes for the induction motors mounting. Experiments were conducted as described above.

The obtained results are represented in Table 6.
For clarity, we decomposed the energy consumed by the motor during its acceleration into energy parts that were taken to speed the induction motors rotating parts up and to deal with parasite forces (added and mechanical energy losses). The energy decomposition is represented in Figure 5.
Figure 5 shows that the average values of the efficiency of the induction motors are high (92% - 94%). Energy expenditures are mainly losses in ventilation and friction losses in the bearings.

TABLE 6. Obtained results of identifying added and mechanical losses in induction motors

Parameter	Type of an induction motor		
	A71B2	A71A4	A80A6
$J_{h.c.}$, kg·m^2	0.001013	0.001013	0.001133
k_{loss}·$J_{r.p.m}$, kg·m^2	0.000878	0.001219	0.003920
J_{rotor} + J_{fan} + $J_{bearings}$, kg·m^2	0.000830	0.001130	0.003612
t_4, s	0.7551	0.5185	0.2727
t_3, s	0.3781	0.2599	0.1374
k_2·$J_{r.p.m}$, kg·m^2	0.000006	0.000011	0.000077
k_1·$J_{r.p.m}$, kg·m^2	0.000043	0.000077	0.000233

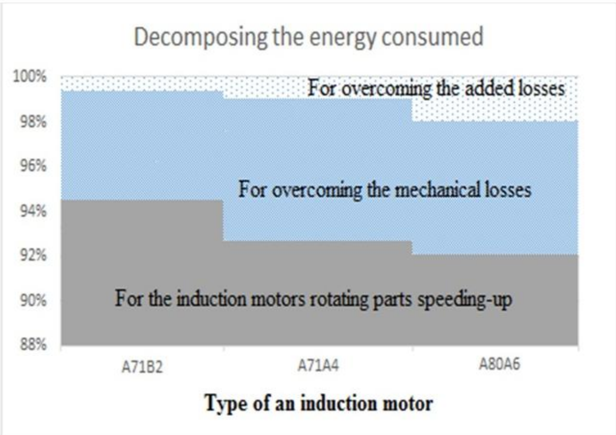


Fig. 5. Decomposing the energy consumed into energy parts that are taken to speed the induction motors up and to deal with parasite forces

Experimental Validation of Data Obtained with the Proposed Method

To check the reliability and validity of the results obtained by the developed method according to the present experiment we carried out two series of measurements. While using the average values of measurands within the selected speed range. First, we determined the moment of inertia of an induction motor taking into account losses, $k_{loss} \cdot J_{r.p.m.}$. Then we determined the moment of inertia of the induction motor with an additional rotary body (its moment of inertia, J_{true}, is 0.002465 kg·m^2) taking into account losses, $k_{loss} \cdot J_{r.p.m.+}$ = $k_{loss} \cdot J_{r.p.m.} + J_{add}$.

Knowing the average values of the moments of inertia of both systems of rotating masses (without additional rotary body and with it), we could easily calculate the average value of the moment of inertia of the additional rotary body and compare it with the calculated one.
Table 7 shows the values of errors of the moment of inertia measurement of the additional rotary body using the developed method.
According to Table 7, we obtained the convergence of the results obtained with the developed method and with the calculating with a maximum relative error of 1.22%. The resulting convergence is an evidence of high reliability of the data obtained using the developed method and the instrument for identifying the mechanical parameters of induction motors.

TABLE 7. The accuracy of determining the moment of inertia of the additional rotary body with a known value of the moment of inertia

Parameter	Type of an induction motor		
	A71B2	A71A4	A80A6
J_{true}, kg·m^2	0.002465	0.002465	0.002465
J_{add}, kg·m^2	0.002495	0.002443	0.002441
Accuracy, %	98.78	99.11	99.03

Conclusion

In this research, we determined the proportion of each type of losses in the induction motors (mechanical and added losses), which is expressed in terms of the moment of inertia with respect to the rotation axis passing through the rotor center. According to the experiments conducted, added losses in the test induction motors are from about 8% to 25% of total losses. Thus, the energy loss at overcoming added parasitic forces are from about 0.5% to 2% of the total energy consumed to accelerate the motors after electrical energy conversion. The obtained results suggest the possibility of determining the value of added and mechanical losses as parts of the total losses in an induction motor by using the proposed method.
A significant advantage of the method is the possibility to control the mechanical parameters of induction motors in real time with a high measuring frequency rate within a wide range of possible modes of operation as it uses the angular acceleration and the acceleration time as controlled variables.
This method can be widely applied in the manufacturing plants and companies that operate induction motor. In comparison with other methods the developed method reduces the time and cost for identifying and control of mechanical parameters due to the versatility of the method and less overall dimensions of the developed hardware-software complex, as well as the lack of need for calibration of measuring elements (resistance strain gauges).
At the level of technical control department of a manufacturer, having defined the tolerance to change the acceleration time of a particular type of an induction motor, as well as equipping the object under study with hardware-software complex, it is possible to respond rapidly to decrease of the energy performance of induction motors. That allows

improving the quality of their build and providing high efficiency of the equipment produced.

The main disadvantage of the developed method may be called a limited range of motors that can be studied, as at high powers there are difficulties in stabilizing the input voltage. So the further development of the method should be directed to the study of the possibility of identifying high-power motors mechanical parameters.

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