STUDY OF IMPROVEMENT POSSIBILITIES OF A START-UP MOMENT OF LOW POWER ASYNCHRONOUS SINGLE-PHASE ENGINE WITH ASYMMETRIC STATOR

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Annotation

One of the biggest low power engines drawbacks is that created magnetic field in a single-phase electric machine is pulsating, thus its start-up moment is equal to 0. This article presents improvement possibilities of a low power asynchronous single-phase electric engine with asymmetric stator's magnetic circuit. This engine stator's walls are different in diameter. Because of different magnetic resistances of stator, rotary magnetic field has an ellipse form in this type of engines. Since a rotary magnetic field is not circular, it has a negative effect on the moment of starting the engine.

Key words: *small capacity engine, electric motors, asymmetric stator.*

Introduction

Single-phase asynchronous electric motors are often used because of their reliability and wide application possibilities. However, these machines, besides their advantages have some shortcomings too. One of the shortcomings is that magnetic field created in a single-phase electric machine is pulsating, thus its start-up moment is equal to 0.

Single-phase asynchronous electric motor with asymmetric stator's magnetic circuit has been analyzed. The stator's walls of this engine are of different diameter, thus rotary magnetic field for this type of engines has ellipse shape. Since a rotary magnetic field is not circular, it has a negative effect on the moment of starting the engine. It is the main of problem of this type of engines, which is analyzed in the study (Smilgevičius, 2005; Hughes, 2009; Kiong, Putra, 2011).

Aim of the study is to find out improvement possibilities of a start-up moment of asynchronous single-phase engine with asymmetric stator's magnetic circuit In order to achieve this objective following tasks are being resolved: 1) to measure and analyze coils placed on asymmetric stator's magnetic circuit wide walls effect when briefly turned on for magnetic flow phases and amplitudes at various engine power supply voltages. 2) to measure engine torque at different magnetic flow phases and power supply voltages (Katkevičius, Gečys, Kalvaitis, 2011). There was a circuit set up to study engine starting moment – voltage converter (autotransformer 0 - 250 V) → engine with asymmetric stator's magnetic circuit (AD-10-2/45A1Y4 220 V 10W) → moment meter (Figure 1). The tests were carried out at different engine power supply voltages using autotransformer. Following devices were used to take measurements: voltmeter, ammeter, watt-meter, oscilloscope, moment meter.

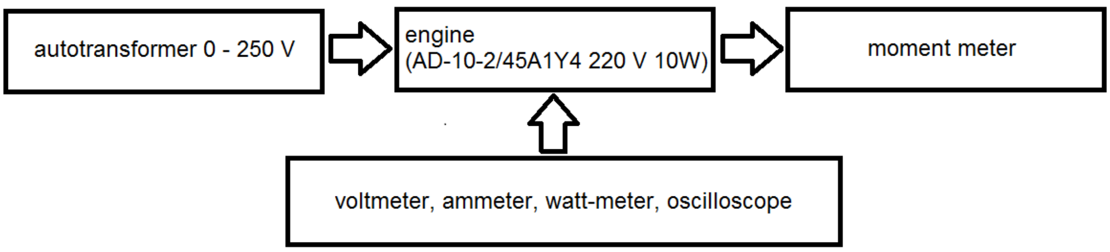

Fig. 1. Engine analysis scheme

Magnetic flows were measured indirectly by placing measuring coils on engine stator's pole, little pole and narrow and wide walls (Figure 2). Internal flows on them were measured using oscilloFig.. Engine starting moment was measured using moment meter.

Measurements were carried out in three stages by measuring magnetic flow phases (Balbonas, Kernagis, 2011) and starting moments.

1. Internal voltages induced in the coils of pole, little pole, narrow and wide walls of the standard engine have been measured (Figure 2a). Internal currents were also measured on measuring coils on narrow and wide stator's magnetic circuit walls at different power currents (140V, 160V, 180V, 200V, 220V). Engine torques were measured at start-up at different power supply voltages (140V, 160V, 180V, 200V, 220V).

2. Briefly turned on coil was placed on the engine wide stator's walls (Figure 2b). Internal currents of measuring coils of pole, little pole, narrow and wide walls of stator's magnetic circuit were taken. Internal currents were measured on measuring coils on narrow and wide stator's walls at different power currents (140V, 160V, 180V, 200V, 220V). Engine torques were measured at start up at different power supply voltages (140V, 160V, 180V, 200V, 220V).

3. Two briefly turned on coils were placed on the stator's magnetic circuit wide walls at the third measurement stage (2c figure). Internal currents of measuring coils of pole, little pole, magnetic circuit's narrow and wide walls were measured. Internal currents of measuring coils of magnetic circuit's narrow and wide walls were measured at different power supply voltages (140V, 160V, 180V, 200V, 220V). Engine torques were measured at start up at different power supply voltages (140V, 160V, 180V, 200V, 220V).

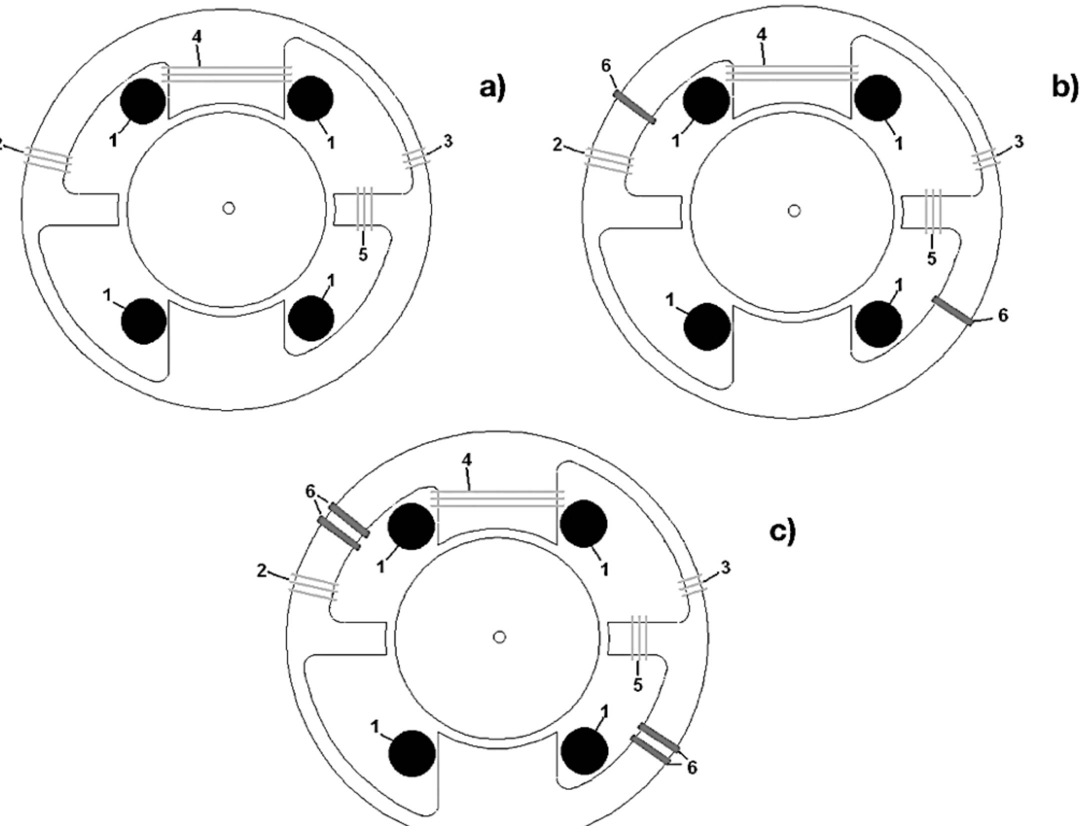

Fig. 2. Low power single phase asynchronous electric motor with asymmetric stator's magnetic circuit a - standard engine; b - engine with briefly turned on coils placed on wide stator's walls; c - engine with two briefly turned on coils placed on wide stator's walls. 1 - engage coils; 2 - measuring coils on wide stator's wall; 3 - measuring coils on narrow stator's wall; 4 - measuring coils on pole; 5 - measuring coils on little pole.

Calculations of magnetic flows in engine's magnetic circuit

Internal currents were measured on measuring coils on pole, little pole and narrow and wide stator's walls, with the engine connected to 220 V, 200 V, 180 V, 160 V and 140 V currents (Balbonas, Kernagis, 2011). Obtained characteristics of internal currents with the oscilloscope were split into harmonics (furje line):

$$u_0(\omega t) = U_0 + U_{01m}\sin(\omega t + \varphi_1) + U_{02m}\sin(2\omega t + \varphi_2) + ... + U_{0k}\sin(k\omega t + \varphi_k) + ... \quad (1)$$

w - angular frequency rad/s; t - time, s; U_{0K} - k-th harmonics' amplitude , V, φ_k - k-th harmonics phase; U_0 - permanent voltage component, V.

Internal currents' Fig. is presented in Figure 3.

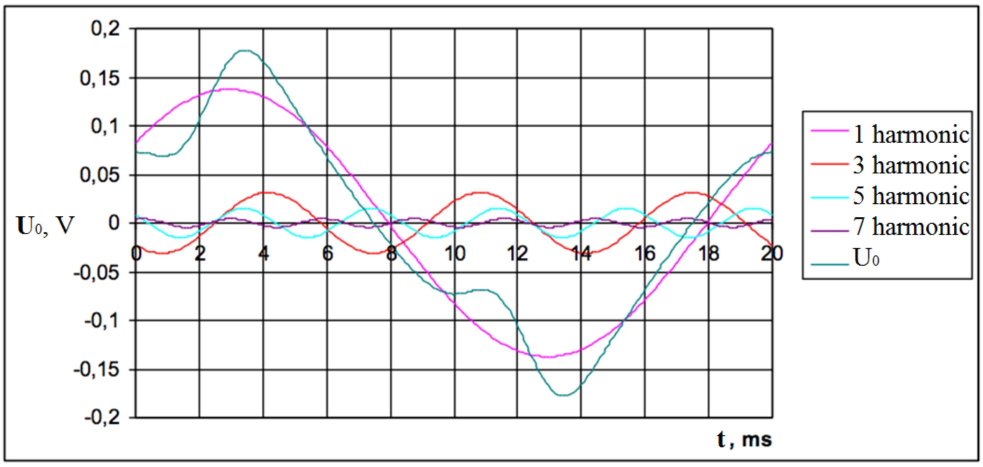

Fig. 3. Internal current harmonics of the measuring coils of wide wall (voltage of 220 V)

Internal current harmonics were recalculated into magnetic flow harmonics:

$$\Phi_{km} = \frac{u_{0k}}{4{,}44 \cdot kf \cdot N}. \qquad (2)$$

U_{0K} - k-th harmonics current effective value, V; f - the main harmonics frequency in Hz; N - number of coils; k - harmonics row; Φ_{Km} - k-th harmonics magnetic flow amplitude, Wb.

A function has been written for each magnetic flow harmonics:

$$\Phi_1(\omega t) = \Phi_{1m}\sin(\omega t + \varphi_1 + 90^0);$$

$$\Phi_3(3\omega t) = \Phi_{3m}\sin(3\omega t + \varphi_3 + 90^0);$$

....

$$\Phi_k(k\omega t) = \Phi_{km}\sin(k\omega t + \varphi_k + 90^0). \qquad (3)$$

Magnetic flow has been split into harmonics according to the functions (Figure 4).

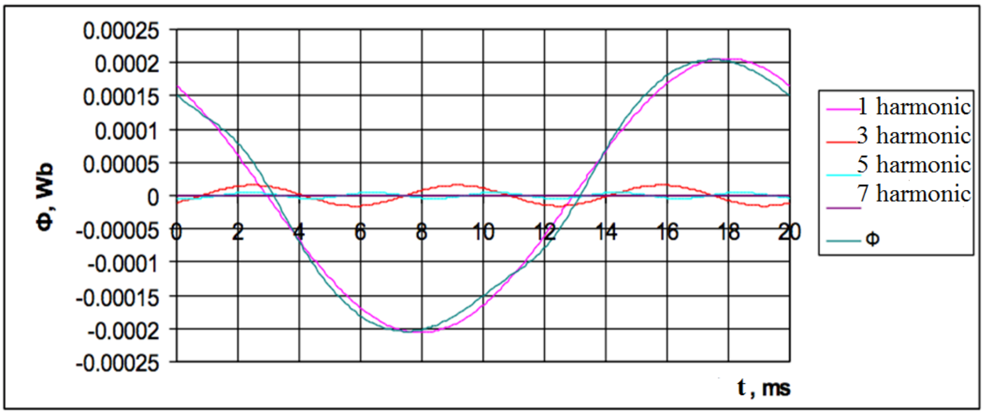

Fig. 4. Magnetic flow of a wide wall split into harmonics (voltage of 220 V)

Analogous measurements were taken for narrow wall of the magnetic circuit.

Analysis of flows showed how initial phases and amplitudes of harmonics change. Harmonics' first and third indicators of amplitudes of magnetic circuit's narrow and wide walls are presented in Table 1. Aggregated data shows that placing briefly turned on coils on magnetic circuit's wide walls increased phase corners between first harmonics (from 19.8 to 25.83 degrees) as well as between third harmonics, in particular, from 121.46 to 127.94 degrees. When placing two briefly turned on coils on stator's wide walls this angle increased even more, i.e. between first harmonics – from 19.80 to 29.88 degrees and between third harmonics – from 121.46 to 145.01 degrees. Additionally connected coils had little effect on harmonics' amplitudes.

Table 1

Magnetic flow amplitudes of the narrow and wide walls of stator's magnetic circuit and phase differences when engine voltage of 220 V was connected

Wide stator's wall		
Harmonics	1	3
Magnetic flow amplitudes, Wb (without briefly turned-on coil)	0.00021	$1.5 \cdot 10^{-5}$
Magnetic flow amplitudes, Wb (without briefly turned-on coil)	0.00019	$1.7 \cdot 10^{-5}$
Magnetic flow amplitudes, Wb (with two briefly turned-on coils)	0.00019	$1.6 \cdot 10^{-5}$
Narrow stator's wall		
Magnetic flow amplitudes, Wb (without briefly turned-on coil)	0.00029	$3.6 \cdot 10^{-5}$
Magnetic flow amplitudes, Wb (with briefly turned-on coil)	0.00028	$3.6 \cdot 10^{-5}$
Magnetic flow amplitudes, Wb (with two briefly turned-on coils)	0.00028	$3.5 \cdot 10^{-5}$
Phase differences fo magnetic flows		
Phase difference (without briefly turned-on coil)	-19.80	-121.46
Phase difference (with briefly turned-on coil)	-25.83	-127.94
Phase difference (with two briefly turned-on coils)	-29.88	-145.01

Dependencies of harmonics amplitudes have been drawn at different power currents (Figure 5 and Figure 6).

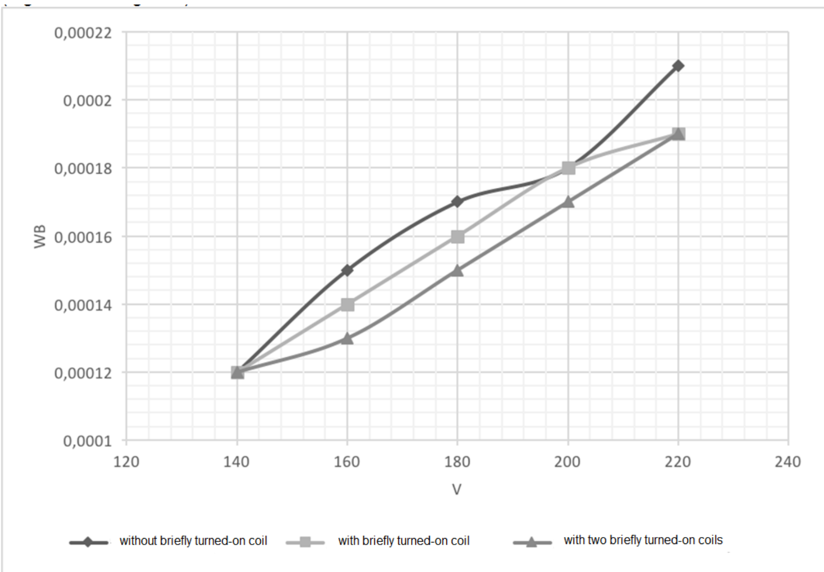

Fig. 5. Dependency on power current of the stator's wide wall magnetic flow first harmonic amplitude

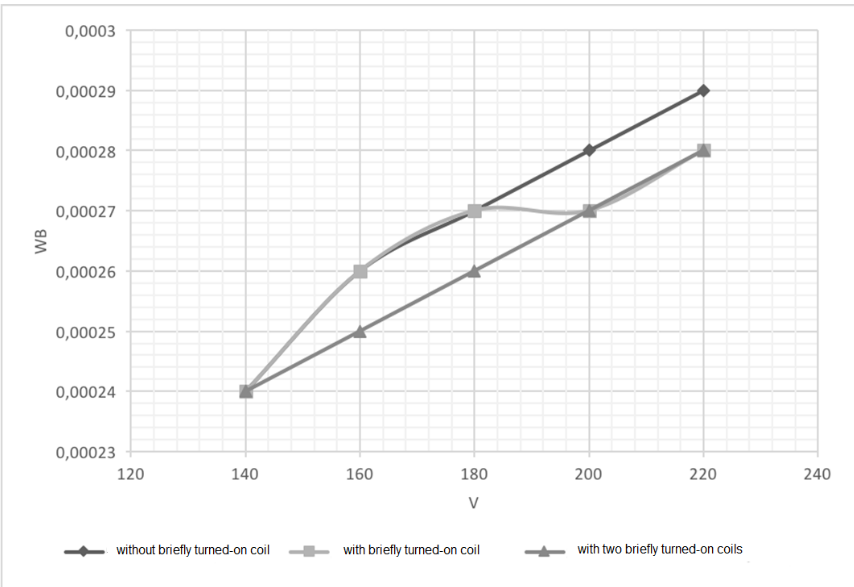

Fig. 6. Dependency on power current of the stator's narrow wall magnetic flow first harmonic amplitude

The measured engine torque dependence at different engine power supply voltages and different magnetic circuit magnetic flow phases

Start-up moment measurements of standard asynchronous engine and engine on which asymmetric magnetic circuit wide walls briefly turned on coils were placed showed, that the highest start-up moment was reached at the standard supply voltage (220 V) and by placing one briefly turned on coil on stator's magnetic circuit wide walls (Table 2) (Figure 7). In this case, start-up moment increased from 0,017 N·m to 0,022 N·m i.e. increased by 31% while power consumption increased from 104 W to 106 W, i.e. by about 2 %.

After taking measurements of two briefly turned on coils placed on wide stator's walls ambiguous data was received. When the engine power voltage is between 160 V and 200 V start-up moment increased compared to the test when one briefly turned on coil was placed on stator's wide walls. However, start-up moment was higher at rated engine voltage than of a standard engine but smaller when the engine was tested by placing one coil on the stator's wide walls. This shows that in order to reach maximum start-up moment an optimal resistance briefly turned-on coil needs to be selected.

Table 2

Dependence of engine start-up moments on supply voltage and magnetic flow phase angles

Test	Voltage, V	Current, A	Power, W	Torque, N·m
Without briefly turned on coils	220	0.7	104	0.016674
One briefly turned on coil on stator's wide walls		0.7	106	0.021954
Two briefly turned on coils on stator's wide walls		0.71	108	0.020287

Engine start-up moments at different supply voltages presented in Figure 7.

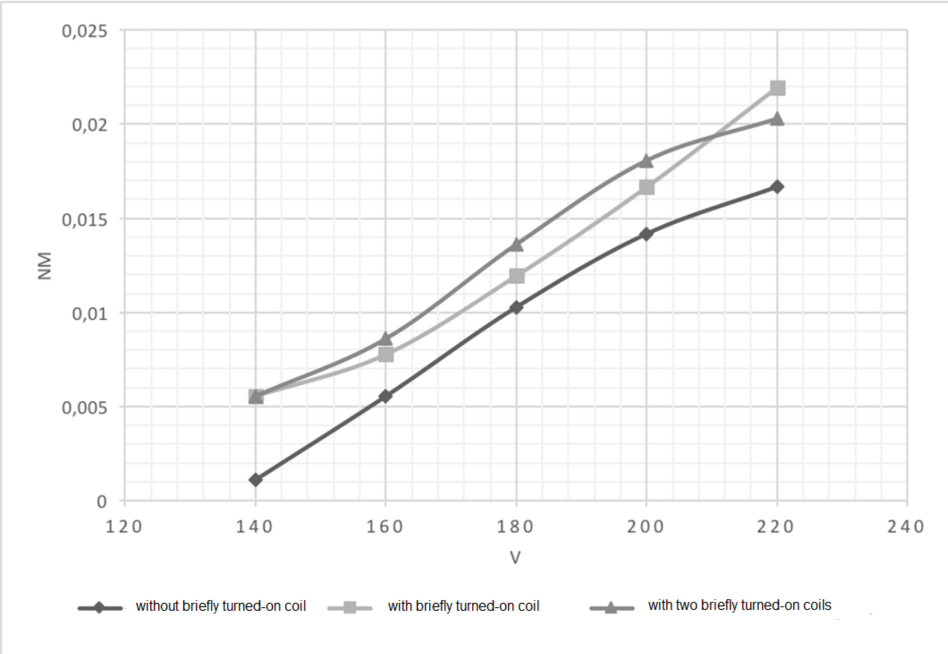

Fig. 7. Start-up moment dependence on voltage

Summary of the data obtained shows that placing briefly turned on coils on magnetic circuit's wide walls increased phase angles between first harmonics as well as between third harmonics of magnetic flow. Placing two briefly turned on coils on stator's wide walls, this angle has increased even more. This had a very little impact on harmonic amplitudes. Taking into account the above mentioned moment measurement results (Figure 7) it can be stated that this increase in phase difference increased engine starting moment.

Conclusions

1. Briefly turned on coils placed on asymmetric stator's wide and narrow walls influence closing magnetic flow on magnetic circuit and increase phase difference between these flows, however, these flows have little influence on amplitudes.
2. Briefly turned on coils placed on asymmetric stator's wide wall increased engine's start-up moment and increased the engine's power consumption. The highest start-up moment was reached after placing one briefly turned on coil on stator's magnetic circuit wide walls. In

this case, start-up moment increased from 0,017 N·m to 0,022 N·m i.e. increased by 31% while power consumption increased from 104 W to 106 W, i.e. by about 2 %.

3. In order to reach maximum start-up moment additional study is needed to be carried out and an optimal resistance briefly turned-on coil needs to be selected.

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