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COMPARISON OF PROPERTIES OF SINGLE-PHASE LINE START PERMANENT MAGNET SYNCHRONOUS MOTORS WITH *W* AND *VV* SHAPE PERMANENT MAGNET ARRANGEMENTS. EXPERIMENTAL RESULTS

PORÓWNANIE WŁAŚCIWOŚCI JEDNOFAZOWYCH SILNIKÓW SYNCHRONICZNYCH Z MAGNESAMI TRWAŁYMI O UŁOŻENIU MAGNESÓW W KSZTAŁCIE *W* I *VV*. BADANIA EKSPERYMENTALNE.

Abstract: The paper deals with comparison of properties of single-phase line start permanent magnet synchronous motors with different permanent magnet shapes. The motors have the same stators, stator windings, rotor bars and different permanent magnets arrangements inside the rotor. The comparison is based on the experimental results.

Streszczenie: Praca przedstawia porównanie właściwości jednofazowych silników synchronicznych z magnesami trwałymi o rozruchu bezpośrednim. Silniki te mają identyczne magnetowody i uzwojenia stojanów, pręty klatki wirników oraz różne ułożenia magnesów trwałych wewnątrz wirników. Porównanie silników wykonano na podstawie badań eksperymentalnych.

Keywords: *single-phase motor, synchronous motor, permanent magnets, high efficiency*
Słowa kluczowe: *silnik jednofazowy, silnik synchroniczny, magnesy trwałe, wysoka sprawność*

1. Introduction

The norm IEC 60034 part 30 orders the electrical motor producers to produce electrical motors with minimum efficiency factor. The goal of this command is to minimize electrical energy consumption by minimization of electrical motor power losses. Nowadays this norm ranges low-voltage electrical motors with rated power 0,75 kW≤P_n≤375 kW and number of pole pairs 2p=2; 4; 6. The new project of the norm assumes widening of the electrical motor rated power range up to 0,12 kW≤P_n≤1000 kW, number of pole pairs up to 2p=2; 4; 6; 8 and including multi-phase motors (single-phase motors in it).
Polish and World producers of electrical motors responded to the norm requirements by designing and producing high-efficiency three-phase motors which fulfil the norm by achieving the minimum factor of the efficiency. The electrical motor producers respond did not include single-phase motors which are not included by the norm yet.
If the new norm project IEC 60034 part 30 is valid no produced now single-phase motor will fulfil the norm requirements.
In articles [2, 8, 11] possibility of building of single-phase line start permanent magnet synchronous motor was proven. The single-phase line start permanent magnet synchronous motors achieve much better running properties than single-phase induction motor running properties. Taking into account the modern electrical motor development we can suppose that in case of restricted new requirements of producing electrical motors producers of single-phase motors will be forced to design and produce single-phase line start permanent magnet synchronous motors.
The price of permanent magnet is still going up. Due to that the goal of designing of permanent magnet synchronous machines is to obtain good running performances (efficiency, power factor) and simultaneously to minimize the permanent magnet mass of the machine.

2. Constructions of single-phase line start permanent magnet synchronous motors

In Maxwell version 14 programme two circuit-field models of single-phase line start permanent magnet synchronous motor were built.

The models are based on the mass production single-phase induction motor type SEh 80-4B with rated power P_n=0,75 kW supplied by the voltage U_n=230 V. Neodymium magnet N38SH with remanence induction B_r=1,24 T and magnetic field coercivity H_{cb}=990 kA/m was chosen for the excitation. Methodology of single-phase line start permanent magnet synchronous motor designing was revealed in articles [1, 3]. The papers [4, 5, 6, 7, 9, 10] were also helpful for the designer.

The motor needs two capacitors- run-capacitor and start-capacitor. The best running properties for both motors were obtained for C_{run}=50 μF. C_{start}=100 μF has enough capacitance for the motor self-starting with centrifugal switch, which switches off start-capacitor during starting (in case of fan-type load torque characteristic).

After optimization of the circuit-field model the motor was built. The built motor is shown in Fig. 1. Draws and photos of the model cross-sections and rotors are presented in Fig. 2 and 3. Centrifugal switch is shown in Fig. 4.

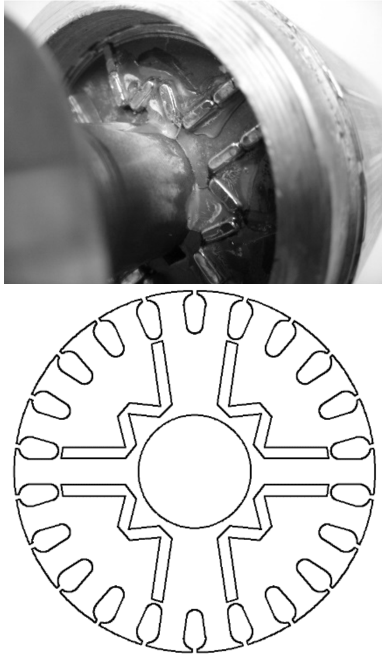

Fig. 2. Rotor and its cross-section of single-phase line start permanent magnet synchronous motor with ***W*** *shape permanent magnet arrangement*

Fig. 1. Single-phase line start permanent magnet synchronous motor and its typical application (pump)

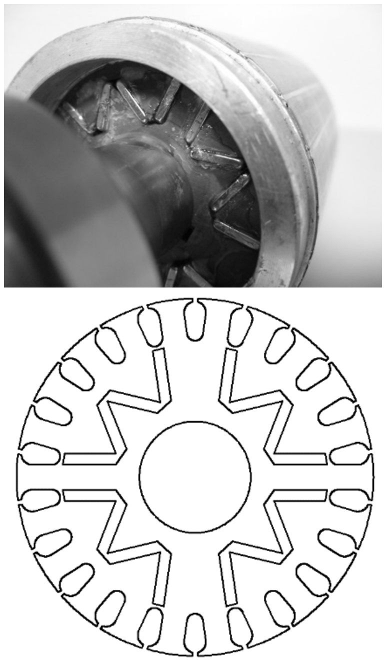

Fig. 3. Rotor and its cross-section of single-phase line start permanent magnet synchronous motor with ***VV*** *shape permanent magnet arrangement*

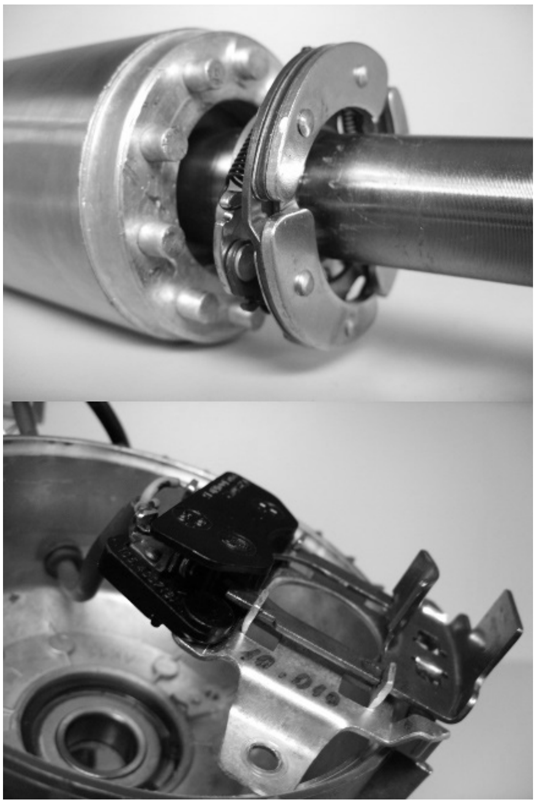

Fig. 4. Mechanism of centrifugal switch

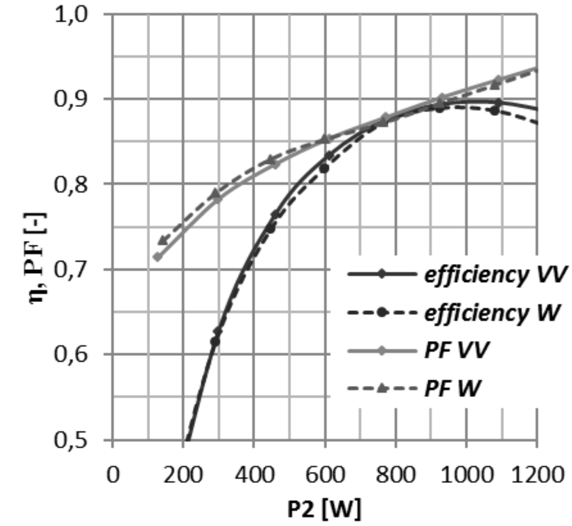

*Fig. 6. Efficiency and power factor curves of single-phase line start permanent magnet synchronous motors with **W** and **VV** shape permanent magnet arrangement*

*Tab. 1. Comparison of single-phase line start permanent magnet synchronous motors with **W** and **VV** shape permanent magnet arrangement*

quantity	unit	W	VV
P	W	1100	1100
η	%	88,5	89,5
PF	-	0,920	0,925
I	A	5,9	5,8
E	V	167	178
$\Delta T_{enclosure}$	K	21,2	20,3
$\Delta T_{winding}$	K	27,1	26,3
T_{max}/T_n	-	1,34	1,37
m_{magnet}	g	173	192
$k_{E/m}$	V/g	0,965	0,927

3. Comparison of single-phase line start permanent magnet synchronous motors with *W* and *VV* shape permanent magnet arrangements

Two types of single-phase line start permanent magnet synchronous motor were measured in laboratory of electrical machines at Wroclaw University of Technology (Fig. 5). The results of investigation of the motors properties are presented in Fig. 6 and Tab. 1.

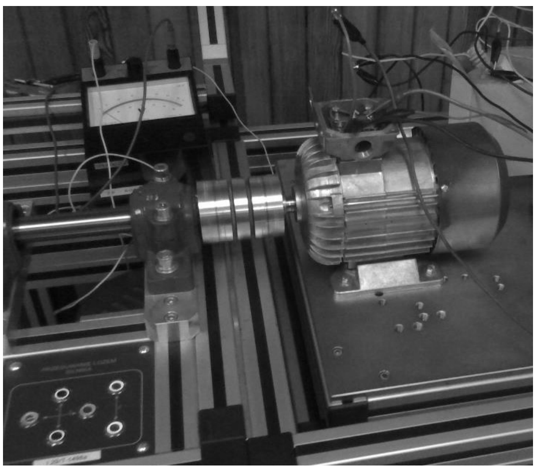

Fig. 5. Measurement test stand

According to the obtained results ***VV*** shape permanent magnet arrangement gives better running properties of the motor in comparison with ***W*** shape permanent magnet arrangement: efficiency is 1 % higher, back EMF is 9 V higher, temperature rise is almost 1 K lower. It is caused by the stronger magnetic field inside the machine due to higher volume of the installed permanent magnets inside the rotor. However, single-phase line start permanent magnet synchronous motor with ***W*** shape permanent magnet arrangement has better $k_{E/m}$ coefficient (proportion back EMF to the permanent magnets mass). ***W*** shape permanent magnet arrangement is better because permanent magnets are more utilized and permanent magnets volume is saved (10 %).

4. Conclusions

Permanent magnets arrangement has significant influence on the single-phase line start permanent magnet synchronous motor properties. Due to optimization of the synchronous motor magnetic core permament magnets volume can be saved and also price for the motor can be decreased. In case of narrow rotor yoke, like in case of the motor type SEh 80-4B, there is a conflict between obtainig the best motor running properties and minimization of permanent magnets volume.

5. Literature

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