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Single-phase line start permanent magnet synchronous motor rotor designing

Streszczenie. *W artykule przedstawiono konstrukcję jednofazowego silnika synchronicznego z magnesami trwałymi. Wykorzystując konstrukcję mechaniczną i magnetowód stojana jednofazowego silnika indukcyjnego masowej produkcji zbudowano model polowo-obwodowy jednofazowego silnika synchronicznego z magnesami trwałymi z wykorzystaniem programu Maxwell w. 14. W modelowaniu polowo-obwodowym uwzględniono różne konstrukcje wirnika. Zbadano wpływ konstrukcji wirnika i rozmieszczenia magnesów na właściwości silnika. (**Projektowanie wirnika jednofazowego silnika synchronicznego z magnesami trwałymi**).*

Abstract. *The paper deals with constructions of single-phase line start permanent magnet synchronous motor. Circuit-field single-phase line start permanent magnet synchronous motor models based on the mass production single-phase induction motor was applied in Maxwell ver. 14 program. Various rotor constructions were taken into account. Influence of the rotor construction on the motor properties was examined.*

Słowa kluczowe: silnik synchroniczny, silnik jednofazowy, magnesy trwałe, układ magnesów, analiza
Keywords: single-phase motor, synchronous motor, permanent magnets, permanent magnets assignment, analysis

Introduction

There is one significant difference between construction of three-phase induction motors and single-phase induction motors – the rotor diameter of the single-phase induction motor in comparison with the three-phase induction motor rotor diameter is noticeably lower. It causes difficulties during single-phase permanent magnet synchronous motor designing due to constraint of the rotor volume to install permanent magnets in the rotor interior [9, 10]. The proper volume of the permanent magnets is needed to induce sufficient back EMF during the permanent magnet synchronous motor running [11]. In case of the limited rotor volume it can be achieved by application of the permanent magnet material with high energy density [NdFeB] or through the optimization of dimensions and way of arranging of permanent magnets.

Permanent magnet shape in the permanent magnet synchronous motor rotor interior has influence on the back EMF and the motor properties. Magnitude of the back EMF has influence on the steady state and starting motor properties and back EMF higher harmonics have influence on the motor additional power loss. The design of the single-phase permanent magnet synchronous motor can be divided into two stages – the first stage is to design permanent magnet shape taking into account magnitude of the back EMF and its higher harmonics, the second stage is to select proper number of the auxiliary winding turns and running capacitor capacitance. The goal of these two stages is to obtain maximum efficiency and rated power of the designing motor [1, 3, 4].

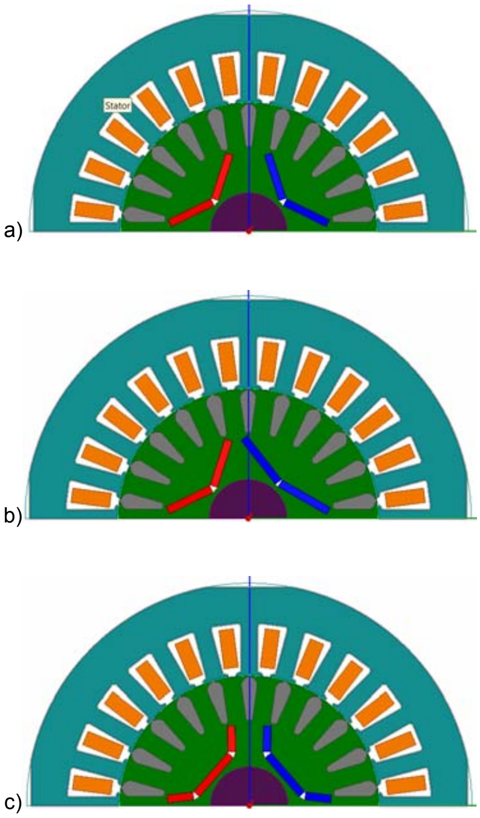
Analyses of the single-phase permanent magnet synchronous motor steady state performances by investigation of its back EMF is an efficient approach because it does not take much time during investigation and (with some assumptions) it is sufficient to obtain the best motor properties.

Investigated motor

The mass production single-phase induction motor SEh 80-4BF type with P_n=750 W, U_n=230 V, f_n=50 Hz, n_n=1370 rpm, η_n=73 %, $\cos\varphi_n$=0.92, I_n=4.9 A, C_{run}=20 μF, was a basis of the investigated single-phase permanent magnet synchronous motor models. All synchronous motor models have assumed P_n=1100 W. Main winding was left without any changes. The number of auxiliary winding turns was decreased from 94 turns down to 50 turns and run capacitor capacitance was increased from 20 μF up to 40 μF.

Back EMF investigation

Eight permanent magnet shapes (V symmetrical, V unsymmetrical, U symmetrical, U unsymmetrical, W symmetrical, W unsymmetrical, VVV symmetrical, W-VVV) were taken into account during back EMF investigation. In symmetrical permanent magnets cases permanent magnets arrangement for each pole is the same, in unsymmetrical permanent magnet cases is not the same. The volume of the permanent magnets in all models is the same. All Maxwell v.14 program motor models are shown in Fig. 1. The obtained results from this investigation (RMS value of the back EMF 1st harmonic and THD coefficient) are presented in Fig. 2.



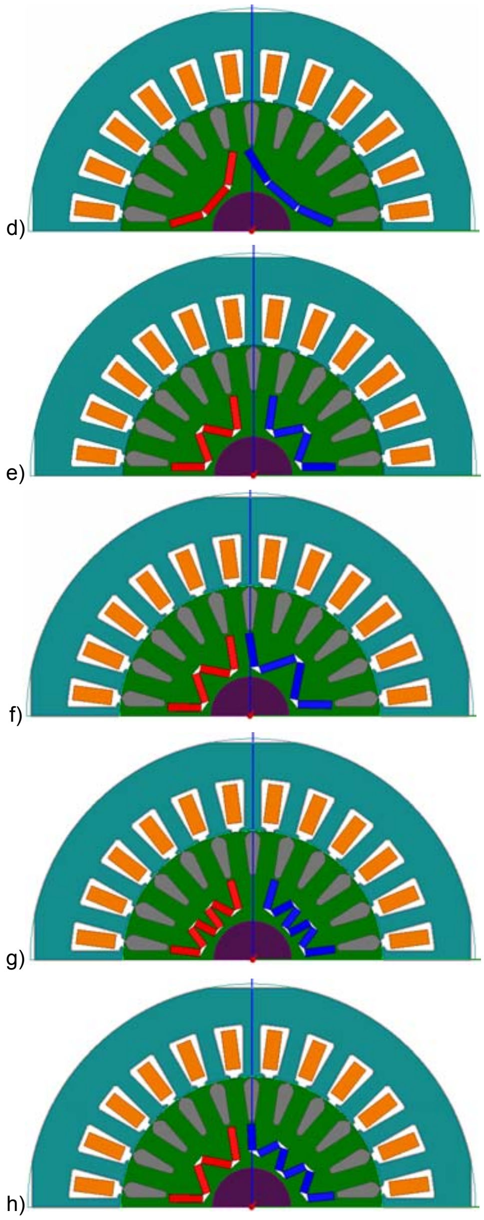


Fig. 1. Single-phase permanent magnet synchronous motor models with different permanent magnet shapes: a) V_{sym}, b) V_{unsym}, c) U_{sym}, d) U_{unsym}, e) W_{sym}, f) W_{unsym}, g) VVV_{sym}, h) W-VVV

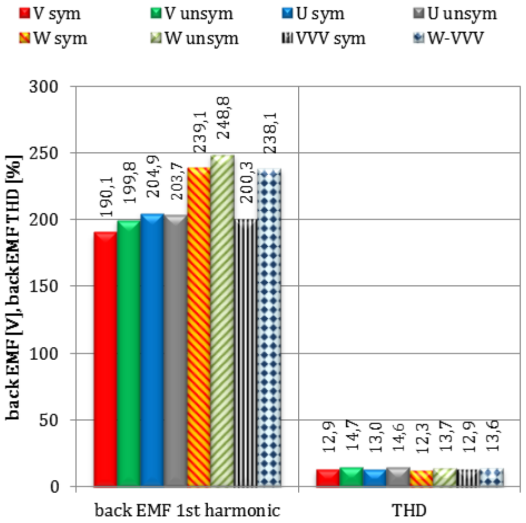


Fig. 2. RMS value of the 1^{st} back EMF harmonic and THD coefficient for various single-phase permanent magnet synchronous motor models

According to the obtained results W shape of the permanent magnets in the single-phase permanent magnet synchronous motor rotor seems to be optimal due to the highest RMS value of the back EMF. For further investigations W symmetrical permanent magnet shape was taken into account because of lowest value of the THD coefficient.

Efficiency and power factor investigation

Six rotor constructions with W shape permanent magnets were taken into account during single-phase permanent magnet synchronous motor running properties investigation. The size of the permanent magnets in all models is the same. All Maxwell v.14 program models are shown in Fig. 3. The obtained results from this investigation (efficiency and power factor) are presented in Fig. 4.

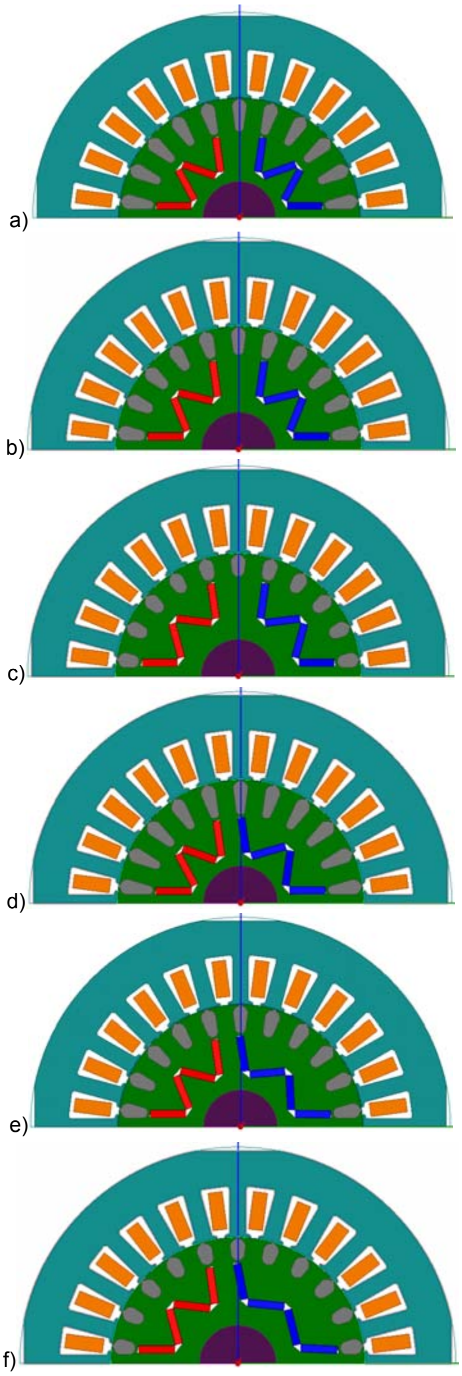


Fig. 3. Single-phase permanent magnet synchronous motor models with different rotor bar size and permanent magnets arrangement a) W_{sym}, h_{s2}=6 mm, b) W_{sym}, h_{s2}=4 mm, c) W_{sym}, h_{s2}=2 mm, d) W_{unsym}, h_{s2}=6 mm, e) W_{unsym}, h_{s2}=4 mm, f) W_{unsym}, h_{s2}=2 mm

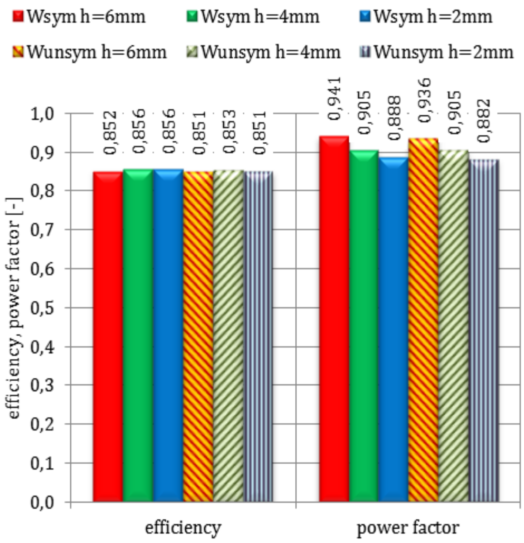


Fig. 4. Circuit part of the motor models

According to the obtained results influence of the rotor bars on the single-phase permanent magnet synchronous motor is strongly noticeable. Enlarging of the rotor bars causes increase of the motor efficiency and decrease of the motor power factor. The rotor bars with height equal to 4 mm seems to be optimal due to obtain both high efficiency and high power factor. Starting properties of the single-phase line start permanent magnet synchronous motor starting properties are analyzed in [2, 5].

Conclusions

Permanent magnets arrangement and rotor bars size in line start permanent magnet synchronous motor have significant influence on the motor running properties. Volume of the permanent magnet can be significantly reduced due to permanent magnets arrangement optimization.

Optimization of the single-phase permanent magnet synchronous motor by investigation of its back EMF seems to an efficient approach because it can reduce time during the motor investigation.

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