TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
ELECTRICAL ENGINEERING | ELEKTROTECHNIKA

1-E/2015

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THE INFLUENCE OF GEOMETRIC DIMENSIONS ON TORQUE VALUE IN A COMPLEX MOTION COMMON MAGNETIC CIRCUIT ELECTRIMAGNETIC CONVERTER

WPŁYW GEOMETRII NA WIELKOŚCI MOMENTÓW OBROTOWYCH WYTWARZANYCH W ELEKTROMECHANICZNYM PRZETWORNIKU POŁOŻENIA O RUCHU ZŁOŻONYM OPARTYM NA STRUKTURZE RADIALNEJ

A b s t r a c t

The article presents the results of the impact of various geometric dimensions of torque in a complex motion electromechanical converter. The converter differs from the conventional radial structure motor in that it has two rotors, an inner and an outer, and excitation by a common stator which is located between them. The use of such a system introduces different size ratios relative to the normal external rotor motor. The result is that the shape of the torque curve of the outer rotor is different from the one in the internal rotor. This article presents a study on the impact of individual items in the course of time – this relied upon a comparison of several hundred configuration dimensions.

Keywords: *electrical machines*, *influence of geometric dimensions on torque value*

S t r e s z c z e n i e

W artykule przedstawiono wyniki badania wpływu poszczególnych wymiarów geometrycznych na moment obrotowy w elektromechanicznym przetworniku położenia o ruchu złożonym. Przetwornik różni się od konwencjonalnego silnika w strukturze radialnej tym, że posiada dwa wirniki, wewnętrzny i zewnętrzny, a wzbudzający je wspólny stojan znajduje się pomiędzy nimi. Zastosowanie takiego układu wprowadza inne proporcje wymiarów w stosunku do zwykłego silnika z zewnętrznym wirnikiem. Powoduje to, że kształt krzywej momentu wirnika zewnętrznego różni się od uzyskanego w wirniku wewnętrznym. W niniejszym artykule przedstawiono badania wpływu poszczególnych elementów na przebieg momentu, które polegały na porównaniu kilkuset konfiguracji wymiarów. Omówiono zasadę porównania rozbieżnych co do wartości wyników jedną zależnością kryterialną.

Słowa kluczowe: *maszyny elektryczne*, *wpływ geometrii na moment obrotowy*

DOI: 10.4467/2353737XCT.15.039.3839

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1. Introduction

The development of computerized numerical control technologies inspires the creation of new complex motion electromechanical converters. The device presented herein allows simultaneous, independent linear and rotary shaft motion. The applied solution with a common magnetic circuit allowed the replacement of two motors with one. Accurate information is described in [1–4]. The main target of the common magnetic circuit is a reduction of device dimensions compared to the dual motor application. This requirement forces a height reduction of the outer part of the device and different parameter values in comparison to the inner part which is presented in Fig. 1. The result of usage of different parameter values was a disadvantageous torque distribution. To find appropriate solutions, several studies were performed.

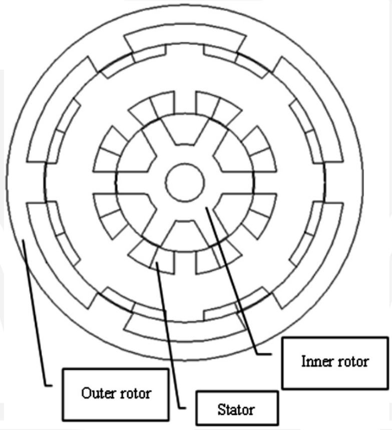

Fig. 1. Cross-section of the complex motion electromechanical converter

2. Research description

The study consisted of a 576 dimension configuration examination which was made on a filed model of a common circuit complex motion motor based on SRM philosophy. Every configuration test was to outer rotor torque registration, with energized proper coils in few rotor position from 0–0.5 range. Calculations were made in FEMM4.2 and Matlab software. The all parameter descriptions and range of change are shown in Table 1 and Fig. 3.

Table 1

No.	Coefficients	Description	Range
1	*kr*	Diameters coefficient	1.4–1.8 step 0.2
2	gamS2	Parameter specifying stator tooth width	0.2–0.5 step 0.1
3	*ks*2	Parameter specifying stator yoke height	0.2–0.5 step 0.1
4	*krr*2	Parameter specifying rotor yoke height	0.3–0.6 step 0.1
5	*kr*2	Parameter specifying the middle of air gap (in align rotor position)	0.4–0.6 step 0.1

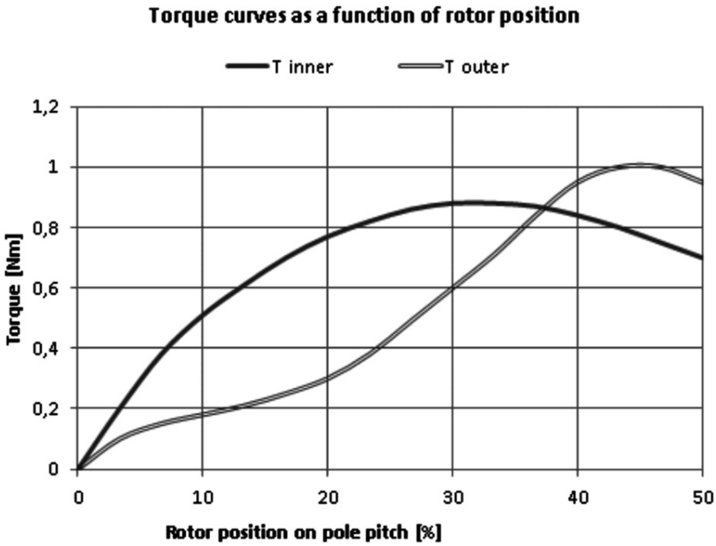

Fig. 2. Distribution of torques

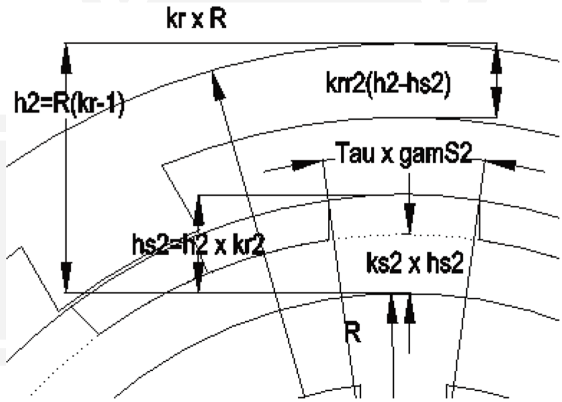

Fig. 3. Decision-making dimensions, and parameters

The result of the test was a torque matrix. For a qualitative comparison of the results, the average values were determined. In the next step, every configuration ripple factor was calculated. It was difficult to draw conclusions from data given in that form. Presentation of two related values as a function of five variables needs other form then spatial waveforms. It was considered that the mean value and ripple factor should be scaled by the maximum achieved values. For those values where the diameter coefficient was changed, should be scaled locally – this was to avoid comparing cases from different categories. Finally, it was decided to use a ratio of scaled coefficient of torque to ripple factor one, as a comparison criteria.

$$f_{\text{criterion}} = \frac{\dfrac{T_{\text{avg}}(n)}{\max(T_{\text{avg}})}}{\dfrac{k_t(n)}{\max(k_t)}} \tag{1}$$

Where:

n – number of case,

T_{avg} – torque mean value of case n,

$\max(T_{\text{avg}})$ – maximum value of T_{avg} for range constant *kr* factor range.

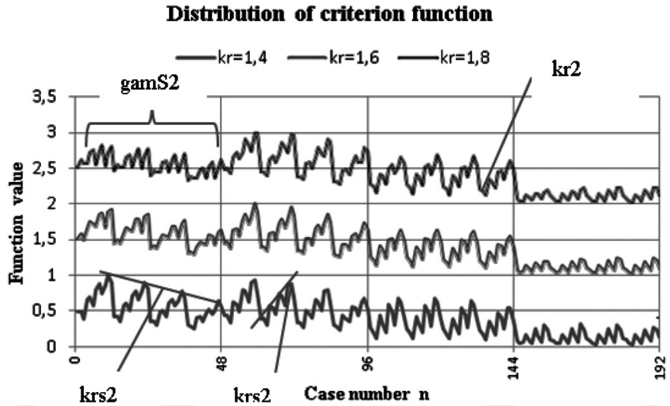

Fig. 4. Distribution of criterion function, for *kr* = 1.6 values increased +1, for *kr* = 1.8 values increased +2

There is course of criterion function presented in Fig. 4. There can be seen four areas of visible changes. The first is 1–48 range, where gamS2 parameter is 0.2, the second is 49–96 range for gamS2 = 0.3, the third is 97–144 for gamS2 = 0.4, the fourth 145–192 for gamS2 = 0.5. Based on this figure, the following conclusions can be drawn.

The pole width should be well-fitted to the diameter coefficient *kr*. This means that for small values of *kr*, the number of poles or phases should be increased. In every case, the number cycle per revolutions increases.

Too large a tooth width causes there to be too little space for winding and this results in a small torque value – this explanation is presented in Fig. 5.

Limited winding area comparing to stator tooth causes low flux distribution in the tooth core and too little reluctance change. The influence of the gamS2 parameter is shown in Fig. 6. The further analysis of Fig. 4 points other modulation of criterion function curve where 4 subareas can be found. Describing function fluctuation is caused by *ks*2 parameter. The *ks*2 parameter corresponds to the height of the stator yoke. The reduction of the criterion function is caused by the reduction of the stator yoke height. This situation is shown in Fig. 7. The stator tooth is significantly higher and the flux lines denser. It can also be seen in Fig. 4 that for increasing gamS2 values, *krs*2 parameter has no influence on criterion function.

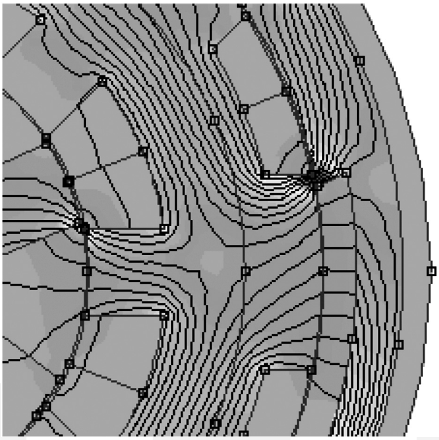

Fig. 5. Distribution of magnetic flux in pole tooth that is too wide. Unaligned rotor position

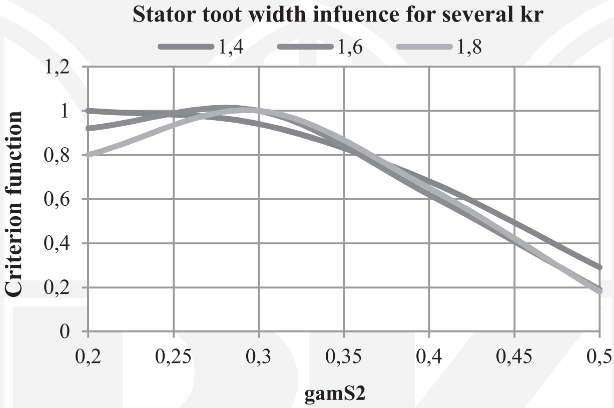

Fig. 6. The influence of stator width on criterion function for several *kr*

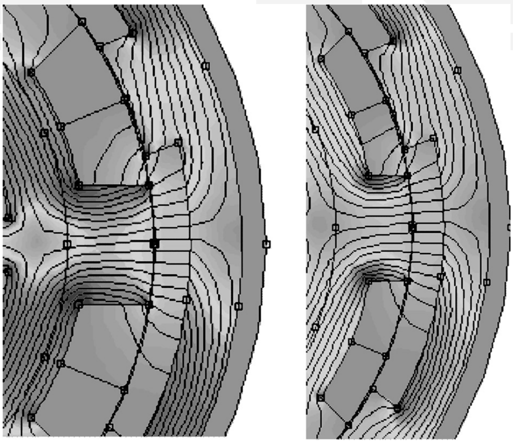

Fig. 7. Distribution of magnetic flux for different *krs*2 parameter values. Left *krs*2 = 0.2, right *krs*2 = 0.5

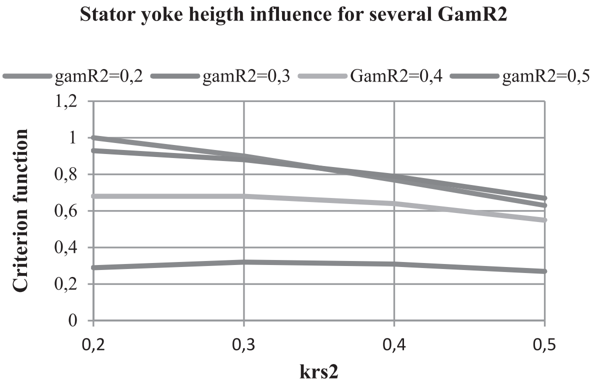

Fig. 8. The influence of stator yoke height for several GamR2

The parameter corresponding to rotor yoke height has a completely different effect on criterion function. The higher the value of *krr*2, the higher the criterion function value.

In Figure 8, the flux distributions in the magnetic core of two configurations are shown. Both constructions differ in the thicknesses of their rotor yokes. The influence of this parameter (*krr*2) can be seen in Fig. 11 where the saturation is shown.

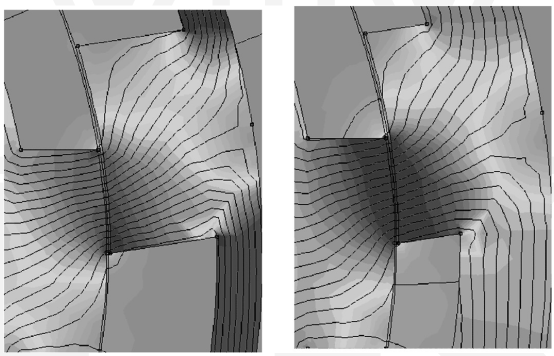

Fig. 9. Distribution of magnetic flux for different *krr*2 parameter values. Left *krr*2 = 0.2, right *krr*2 = 0.6

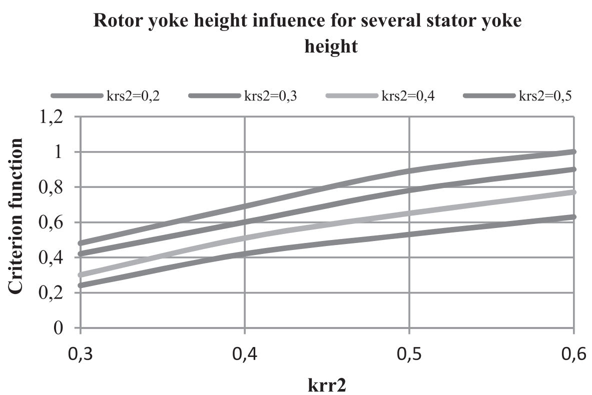

Fig. 10. The influence of rotor yoke height on criterion function for several stator yoke heights

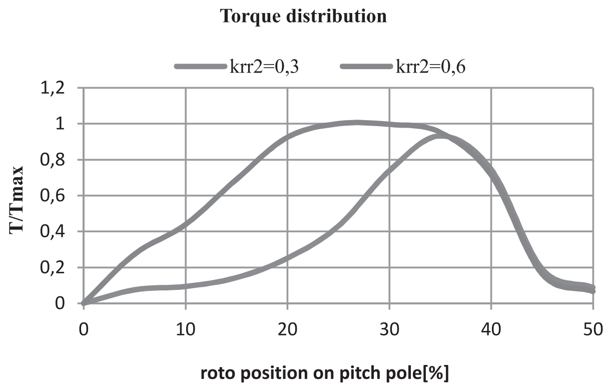

Fig. 11.Torque distributions for different stator yoke heights

It should be noted the description of moment problem by criterion function gives good results.

Another parameter resulting on outer rotor torque is the *kr*2 parameter. This coefficient defines the diameter of the air gap and scale dimensions controlled by krs2 and *krr*2. The influence of the *kr*2 parameter on criterion function is shown on Fig. 12.

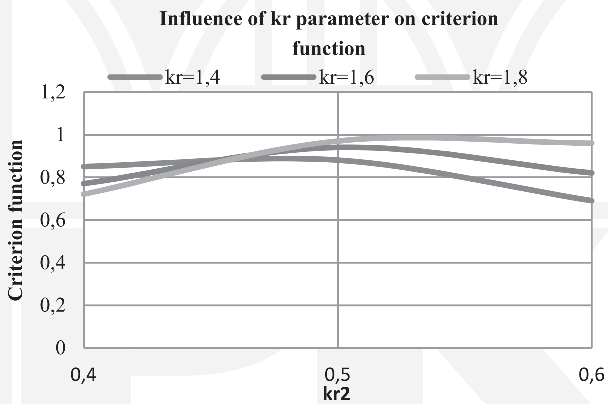

Fig. 12. The influence of *kr*2 parameter on criterion function

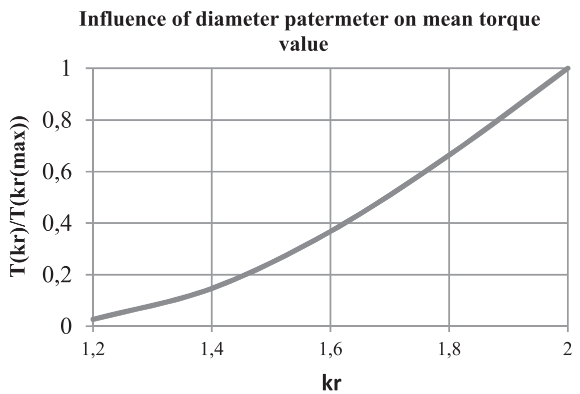

Fig. 13. The influence of *kr* parameter on torque mean value

Based on Fig. 12, it can be stated that the influence of the *kr*2 parameter is connected to the diameter coefficient. The optimum value is 0.5.

The reflections about influences of various parameter on torque ends diameter ratio discussion, which character is parabolic.

3. Summary

In this paper, the influence of various parameters on torque distribution was presented. Moreover, the efficient method of comparing and evaluating configurations was pointed out. A further step will be to analyze both the inner and the outer rotor. Then, in conjunction with criteria [5], the best possible solution for the set of requirements will be chosen.

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