INVESTIGATING THE EFFECT OF IRON PRESENCE IN THE MAGNETIC CIRCUIT OF A DOUBLE HELICAL WINDING INDUCTION MOTORS

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ABSTRACT:

The paper presented a new type of double helical-winding tubular induction motor (DHWTIM). The proposed motor consists of double- layer helical windings primary arranged on the same circumference with a common secondary. By controlling the phase sequence of supply voltage for each of primary winding layers, the secondary conductor would be capable of producing pure rotary motion, pure linear motion, or helical motion. An appropriate multi-layer analysis using cylindrical geometry is presented. This has been used to study the effect of iron presence in the magnetic circuit of the machine on its performance.

KEY WORDS

Double helical windings, helical motion, induction machine, linear-rotary motion, linear induction machines.

الخلاصة

يتناول هذا البحث در اسه أداء محرك حثي اسطواني يمتلك طبقتين من الملفات ثلاثية الأطوار.المحرك المقترح يتكون من طبقتين من الملفات اللولبية (جزء الثابت)، و أن عدد الأقطاب المحيطية والمحورية متساوية في كلتا الطبقتين، مع الجزء الثانوي العام (الجزء المتحرك).

أن ألطريقه التي تم استخدامها نظريا لتحليل المحرك هي طريقه تحليليه صرفه تم استخدام أسلوب ألتغذيه الاعتيادي وتبعا لهذا تمت كتابة برنامج لهذا الغرض وتم التعرف على تأثير وجود الحديد في هيكل المحرك.

INTRODUCTION

Since the commercial motor produces only one dimensional (linear or rotary) motion, the two–dimensional motion generally requires more than two kinds of motors. The helical winding induction motor (HWIM) topology is such that the developed electromagnetic forces produce helical motion, and this would be a desirable asset to the fields of machine tools and robotic (such as valve-seat grinding).

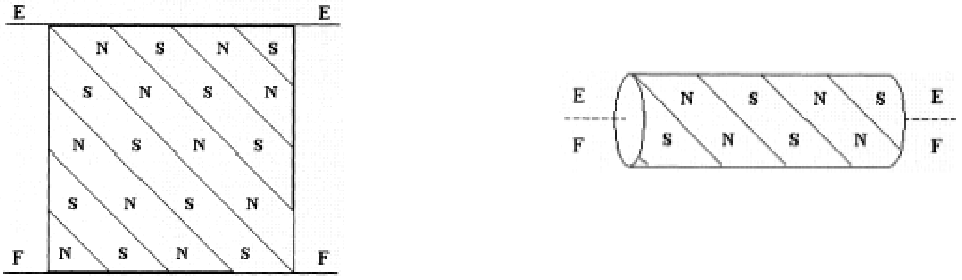
Massoud and Cathy [1988] had presented a helical winding induction motor (HWIM) that could be used in a tandem arrangement of two units to form a direct–acting, two degree of freedom a actuator. That was capable of producing pure rotary motion, pure linear motion, or helical motion, the analysis presented, however, made use of a rotating Cartesian Coordinate, and limited the analysis to the case where only two poles exist in the circumferential direction.

Alwash [2003] had presented a tubular motor with helical winding, together with a multi-layer mathematical model chosen for the analysis. Since then few, but significant, papers relating to helical motion machines have been published.

The primary object of this paper first to develop the winding layout for such model, and second to show the effect of the presence of iron in the magnetic circuit on the performance of the machine.

WINDING LAYOUT

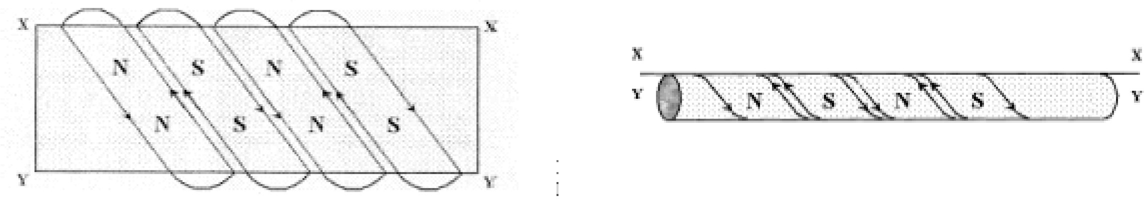
The basic development of the helical motion tubular induction motor can be explained with the aid of fig.(1.a). That shows a flat layout of the instantaneous pole pattern of a helical motion tubular induction motor. If this layout is rolled about an axis and applied (EE) to (FF), the result is a helical motion tubular induction motor, as shown in fig. (1.b).



(a) (b)

Fig.(1). Development of a helical motion tubular induction motor.
a. Instantaneous pole pattern of a planner motor.
b. planner motor rolled to form a tubular motor.

The primary coil construction of one phase of the winding may be explained with the aid of fig. (2.a), which shows the coil structure for the planner motor. To convert this into the tubular shape, it is rolled to produce the construction shown in fig. (2.b).



(a) (b)

Fig.(2). Coil structure of one phase of helical motion tubular induction motor.
a. Coil structure of a planner motor. b. Coil structure of a tubular motor.

Fig. (3) show the helical windings in the tubular form for two poles axially. The model shown in fig. (3.a) has two poles circumferentially while that shown in fig. (3.b) has four poles circumferentially.

(a) **(b)**

Fig. (3). A 3-phase helical motion tubular induction motor with 2-poles axially.
a. 2-Poles circumferentially b. 4-Poles circumferentially

Polyphase versions of the winding may of course be arranged, fig. (4) shows unrolled 3–phase configuration, with two poles circumferentially and axially.

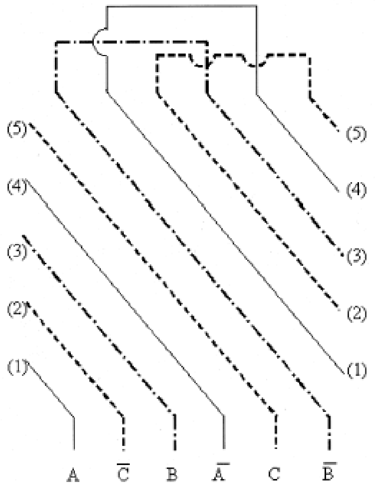


Fig. (4). An unrolled 3-phase helical motion tubular induction motor with two poles axially and circumferentially.

From this point, the developed 3-phase winding for the (DHWTIM) may be represented as shown in fig.(5).

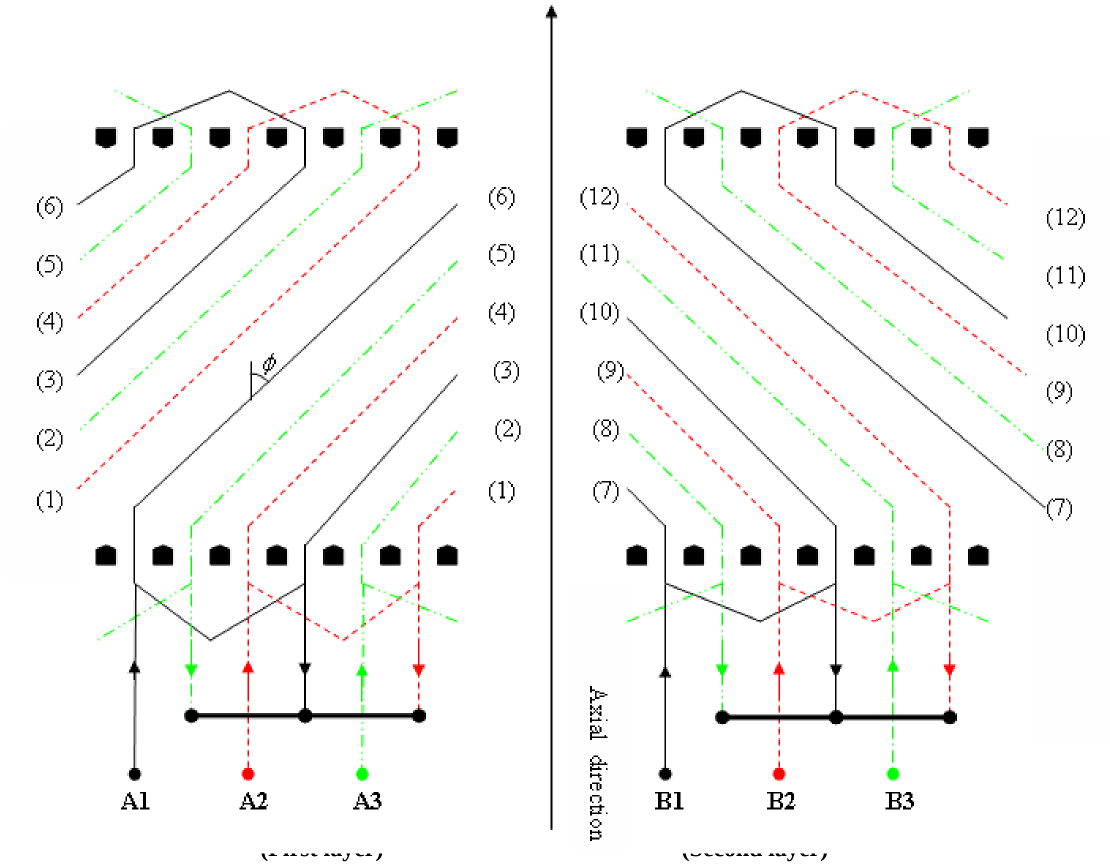


Fig. (5). An unrolled 3-phase double helical windings tubular induction motor with two poles axially and circumferentially.

THEORETICAL EVALUATION

The layer theory approach has been used to analyze this type of machines, Freeman [1968], Freeman and Smith[1970]. The mathematical analyzes of the model chosen is based on solution of Maxwell equations in a given region, with the continuity across the borders between the consecutive layers. The final governing equations are as follows:

$$E_{\theta,m} = \frac{K.r_m}{n}\left[A.I_n(\alpha_m r_m) + D.k_n(\alpha_m r_m)\right] \qquad (1)$$

$$H_{Z,m} = \frac{jr_m.K}{n\omega\mu_m}\left[\left(\frac{2r_{m.}K^2}{n^2 + r_m^2 K^2} - \frac{n}{r_m}\right)\left(A.I_n(\alpha_m r_m) + D.k_n(\alpha_m r_m)\right) + \alpha_m\left(A.I_{n-1}(\alpha_m r_m) - D.k_{n-1}(\alpha_m r_m)\right)\right] \qquad (2)$$

The details may be seen in the M.Sc. thesis, Saad [2007], it is thought to be useful to investigate the effect of rotor and stator iron cores on both the axial and circumferential force.

Table (1) gives the machines parameters for the model chosen for the analysis.

The model under consideration posses eight degrees of freedom. These are shown in table (2), it may be seen that cases **1** to **4** each represent a type of helical motion, while cases **5** and **6** each represent a linear type of motion, and finally cases **7** and **8** each represent a rotational type of motion.

Now a helical motion model, was chosen, and the analysis been applied to investigate the variation of first the axial force with axial speed and second the variation of the circumferential torque with circumferential speed. The results are displayed respectively in fig. (6.a) and fig. (6.b).

The effect of adding iron to the rotor circuit is seen to be apparent while adding iron to stator have a greater effect on the forces, and of course adding iron to both members of the motor, have the greatest effect on forces and this is expected because the magnetic circuit becoming ideal and closed.

As a second case in the study a linear type model has been chosen for the analysis, and fig. (7) shows the variation of axial force with axial speed, and again it is clear that adding iron to both primary and secondary member of the model would produce a model with the greatest possible values of forces.

A third case was then chosen for the analysis, this is to represent the rotational type of motion, and fig. (8) shows the result of the study for such model which again shows the effect of adding iron to the model both to the stator and rotor members.

It is clear that the presence of iron in the magnetic circuit of motor increases the speed at which the maximum developed force occur. This is also expected in the conventional rotating counter part of the machine. Also it is clear that the effect of presence of iron in the stator core on the magnetic circuit is more than that in the rotor core because of the limitation of the rotor core circumference.

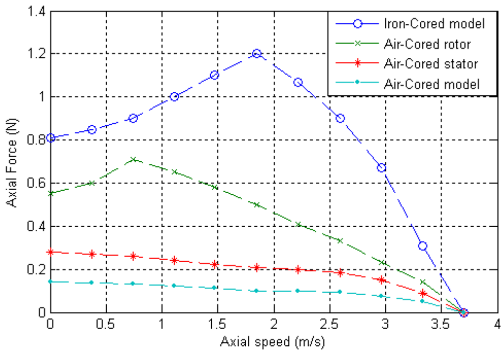


Fig.(6.a) Variation of axial force with axial speed for the mathematical model under investigation in helical motion.

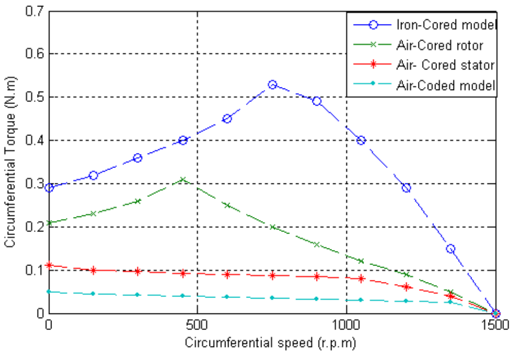


Fig.(6.b) Variation of circumferential torque with circumferential speed for the mathematical model under investigation in helical motion.

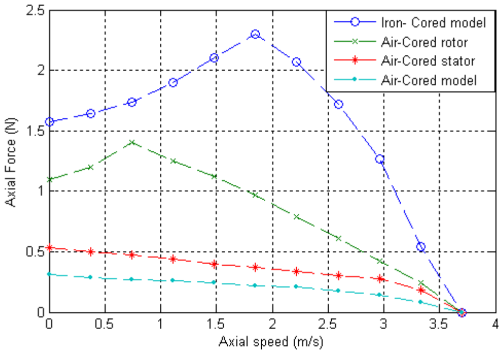


Fig.(7) Variation of axial force with axial speed for the mathematical model under investigation in linear motion.

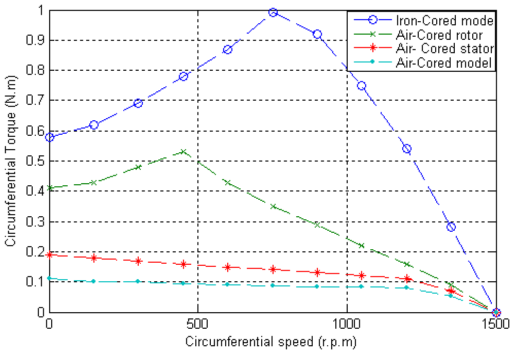
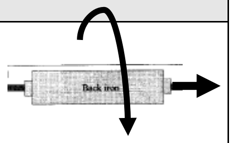
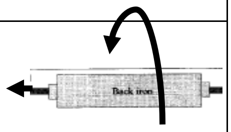
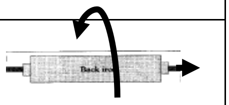
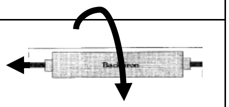
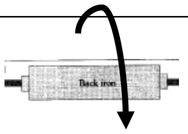
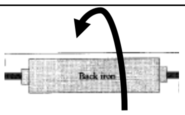


Fig.(8) Variation of circumferential torque with circumferential speed for the mathematical model under investigation in rotary motion.

Table (1)
Machine parameters

Stator length (mm)	300
Phases	3
Circumferential poles	4
Axial poles	4
Slot per pole per phase	1
Slot per pole	3
Slots, axial and circumferential	12, 12
Normal coil width (mm)	8
Normal slot pitch (mm)	12
Normal pole pitch (mm)	45.38
Helicoid angle at the average diameter of the winding (degree)	35.5
Turns per coil	140
R.M.S. stator phase current (Amp.)	1.8
Frequency (Hz)	50
Outer stator winding diameter (mm)	60.5
Air-gap length (mm)	4
Outer secondary conductor diameter (mm)	39.5
Outer stator back iron (if presence)diameter(mm)	95
Aluminum sleeve thickness (mm)	3
Iron (if presence) conductivity	5.8107

Table (2)
Eight motion of the secondary conductor by controlling the phase supply voltage for each layer

No.	Supply voltage with identical balance three-phase	Secondary conductor motion
1	**Positive sequence currents were supplied to first layer only.**	
2	**Negative sequence currents were supplied to first layer only.**	
3	**Positive sequence currents were supplied to second layer only.**	
4	**Negative sequence currents were supplied to second layer only.**	
5	**Both the first and second layer were excited by positive sequence.**	
6	**Both the first and second layer were excited by negative sequence.**	
7	**Positive sequence currents were supplied to first layer while negative sequence current were supplied to second layer.**	
8	**Negative sequence currents were supplied to first layer while positive sequence current were supplied to second layer.**	

CONCLUSIONS

The paper describes a way to investigate the effect of iron presence in the rotor, in the stator, and finally in both rotor and stator of the type motor described in the M. Sc. Thesis Saad [2007], and this represent a clear addition to what is included in the reference thesis, and shows clearly that addition of iron in the stator would posses a greater effect than that obtained in adding iron to the rotor circuit.

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LIST OF PRINCIPAL SYMBOLES

E	Electrical-field strength, V/m
H	Magnetic-field strength, A/m
K	Wave length factor, rad/m
I_n, k_n	Modified Bessel functions of order n
m	Subscript referring to region, m
n	Circumferential pole pairs
r, θ, z	Subscripts for cylindrical coordinates
ω	Angular velocity, rad/s