Novel Rotor Design to Improve Dynamic Performance of Axial Flux Hysteresis Motors

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***Abstract*— In high speed axial flux hysteresis motors, hysteresis material & hysteresis ring's holder have the main roles of producing steady state torque and induction torque respectively. Also it is clear that minimum air gap can cause better motor performance in steady state. In conventional AFHM, and especially in the high speed AFHM types, the hysteresis ring's holder is placed between the hysteresis ring and stator to make more induction (dynamic) torque at the time of starting. So exchange of the hysteresis ring place and its holder place can be useful despite the fact that simulation and experimental results show worse motor dynamic response. For resolving this issue a new model is proposed. A thin copper is used at the hysteresis ring bottom to improve the induction torque and consequently motor dynamic response. Then finite element analysis is done in order to acquire the accurate copper thickness and investigate the new proposed AFHM. Furthermore some experimental set ups are provided and AFHM results in all cases are measured. The obtained test and simulation results show that the new rotor configuration in the new proposed model make a better dynamic performance for the AFHM.**

I. INTRODUCTION

There are many publications devoted to mixed structures such as hysteresis permanent magnet motors, and hysteresis induction machines while a few are devoted to the axial hysteresis motors [1-5].

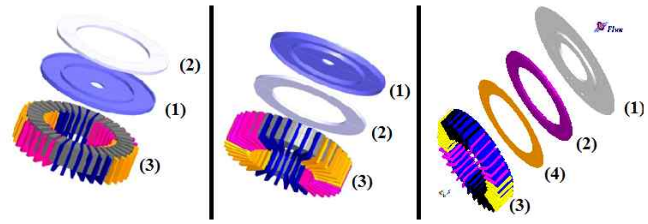
Furthermore, there are some literatures which consider equivalent electrical circuit of AFHM [1-2] but no literature considers the role of hysteresis ring's holder in the equivalent electrical circuit. However as it is investigated [3] hysteresis ring's holder has an important role in AFHM behavior in sub-synchronous speed.

In conventional AFHM a hysteresis ring's holder is placed between the hysteresis ring and stator. In this configuration nonmagnetic holder which is made of aluminum and its alloys is the major source of dynamic torque. But at synchronous speed where induction torque reduces to zero, hysteresis ring's holder act such as airgap. So, the effective airgap length is increased in this topology and the synchronous steady state output torque, efficiency and power factor is decreased. Meantime, mechanical constrains restrict designer to have lower airgap which affects directly on motor characteristics [4]. In previous research [3] effect of holder and hysteresis ring displacement on dynamic and steady state quantities of such motor was investigated. Furthermore, motor steady state torque is improved however drawback of that model is decreasing of induction torque.

In the same way, in this study displacement has been done. But two motors out of three experimental set-ups due to some mechanical resonance frequencies and consequently high Commissioning time are crashed. Thus for quickly passing of these mechanical resonance frequencies, we have to increase dynamic torque to decrease the starting time of this motor. Then we introduce a new proposed model to resolve this problem. In new proposed model a thin electrical conductive material underneath hysteresis ring, between hysteresis ring and stator, is used. Also displacement of hysteresis ring and its holder is done simultaneously. In addition a new electrical model presented which describe and consider hysteresis ring's holder role in steady state, starting point, and sub-synchronous speed. Finally, an experimental set up is done which has a reasonable agreement with simulation results.

II. AFHM STRUCTURE AND OPERATION PRINCIPLE

The conventional AFHM, the previous model [3], and new proposed model are illustrated separately in Fig. 1. Fig.1(a) shows the structure of a two pole conventional axial flux hysteresis motor. The rotor is made up of two parts. Firstly, hysteresis ring which is the basic element for providing torque and it is made of semi hard magnetic materials. Secondly, the hysteresis ring's holder; which is almost made of the nonmagnetic material such as aluminum and its alloys. This part of rotor does not have any effect on the steady state operation mode of motor [3,4]. In conventional AFHM, hysteresis ring holder produces the induction (dynamic) torque in sub synchronous speed.



(a)Conventional Model (b)Previous model [3] (c)New Proposed model
Fig. 1- different parts of axial flux hysteresis motor (1)-hysteresis ring Holder, (2)-Hysteresis ring, (3)-Stator and winding, (4) copper ring.

In previous research [3] after displacement of hysteresis ring and its holder the real airgap height is decreased from 3.6mm to 2.6mm. As can be seen from Fig. 1(b) hysteresis ring's holder is not between hysteresis ring and stator. So by displacing the hysteresis ring's holder and hysteresis ring the appropriate starting period of such machine is weakened [3], but we can attain a better power factor, efficiency and steady state (synchronous) torque due to airgap reduction [3]. The airgap length which flux pass to approach the hysteresis ring for these three models in Fig. 1(a),(b),(c) is 3.6mm, 2.6mm, and 2.8mm respectively.

Hysteresis motors act like induction motors at the time of run up. It means that hysteresis ring and rotor holder produce induction torque when motor does not rotate with synchronous speed, or when motor is not in steady state. Electrical equivalent circuit of axial flux hysteresis motor is shown in Fig. 2. Two bottom resistors of middle branch which are driven using induction machine equations show the role of hysteresis ring's holder on producing of induction torque. This electrical model can help to understand and analyze the dynamic behavior of AFHM.

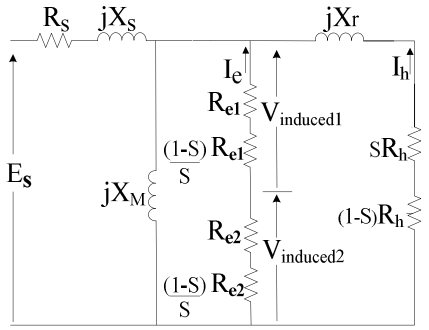


Fig. 2 - equivalent electrical circuit of axial flux hysteresis motor [3]

III. Characteristics of Motors

A. Simulation results

FEM simulation has been done for all configurations of the axial flux hysteresis motor. Because of the magnetic symmetry half of the motor is analyzed.

The proper value of copper thickness is calculated by sensitivity analysis of induction torque of the new proposed model of the AFHM versus copper ring's thickness. Fig. 3 shows the graph of induction torque versus copper ring's thickness.

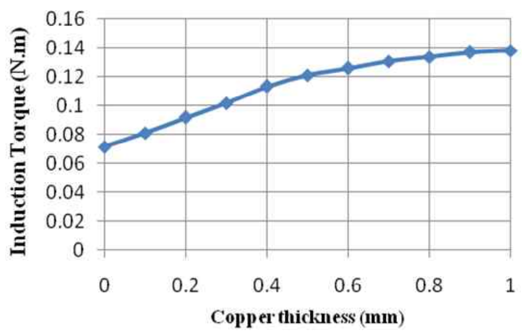


Fig.3- graph of induction torque versus copper ring's thickness

Based on these flux density distributions the output quantities of motors are shown in Table I.

Table I- simulation results for two configurations of AFHM

Quantity	Conventional motor	previous model [3]	New Proposed model
Maximum induction torque (Nm)	0.08325	0.07159	0.09179
Steady state torque (Nm)	0.01853	0.02228	0.02173
Steady state current (A)	1.58	1.45	1.48
P input(Watt)	78	70	71.5
P out (Watt)	41	49	47.8
Efficiency (%)	52	70	66.8

B. Experimental results

In this set up two investigations are done. In first test the induction (dynamic) torque is investigated. The inverter is set on 350 (Hz) and the time which last that each motor reach synchronous speed from 300(Hz) and 150(Hz) is measured. Table II shows the measured data which is extracted from motors [4].

Table II- Investigation of Dynamic Performance

Time last each motor reach synchronous speed	from 300 to 350(Hz)	from 150 to 350(Hz)
Conventional motor	55 sec	289 sec
previous model [3]	72.5 sec	342 sec
New Proposed model	47 sec	253 sec

In second test the output current of both motor in synchronous speed for defined load is measured. Table III shows the measured data which is extracted from motors.

Table III- Output current at synchronous speed

Steady state input current for	Conventional motor	previous model [3]	New Proposed model
at synchronous speed	1.55 A	1.40 A	1.44

IV. Conclusion

In this study, a new model emphasizing on rotor structure is proposed. An experimental set up provided and two test types are done in order to investigate the dynamic and static operation of motors. Meanwhile, a finite element analysis model for accurate analysis of the axial flux hysteresis motor is used. The simulation based on real dimensions of a typical motor is done. Also an equivalent electrical circuit for showing the role of hysteresis ring's holder is presented.

Furthermore, all simulation results and experimental tests show that new proposed model caused more rated steady state torque, better motor dynamic response, and consequently less run up time in the proposed model rather than conventional AFHM. The efficiency of new proposed model is considerably increased rather than that of a conventional model, However the efficiency of new proposed model decreased a little bit rather than the efficiency of previous model.

Also the drawback of previous model [3] which was about less induction torque and more run-up time is resolved using the new proposed model.

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