Claw Pole Brushless D.C. Motor for a Variable Speed Drive System

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Abstract: **The claw pole brushless d.c. motor offers the advantages of its robustness, low cost, high speed and controller simplicity. All these make this motor very attractive for low power variable speed drive systems. The claw pole brushless d.c. motor has quite a complicated 3D geometry and its design arises some difficult problems. Based on a developed design procedure some different claw pole brushless d.c. motors were built up and tested. The given results stand by to prove the design accuracy and motor usefulness.**

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See attached the scan of the paper

References

1. VIOREL, I.A. – KOVACS, Z. – SZABO, L.: *Sawyer Type Linear Motor Modelling*, Proceedings of the International Conference on Electrical Machines (ICEM '92), Manchester (UK), pp. 697-701, 1992.
2. BLOCK, R. – HENNEBERGER, G.: *Numerical Calculation and Simulation of a Claw Pole Alternator*, Proceedings of the International Conference on Electrical Machines (ICEM '92), Manchester (UK), pp. 127-131, 1992.
3. PAWLAK, A.M.: *Claw-Pole Rotary Actuators*, Proceedings of the International Conference on Electrical Machines (ICEM '92), Manchester (UK), pp. 122-126, 1992.
4. VIOREL, I.A. – BIRO, K. – SZABO, L.: *Transformer Transient Behavior Simulation by a Coupled Circuit-Field Model*, Proceedings of the International Conference on Electrical Machines (ICEM '94), Paris (France), pp. 654-659, 1994.

CLAW POLE BRUSHLESS D.C. MOTOR FOR A VARIABLE SPEED DRIVE SYSTEM

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ABSTRACT

The claw pole brushless d.c. motor offers the advantages of its robustness, low cost, high speed and controller simplicity. All these makes this motor very attractive for low power variable speed drive systems.

The claw pole brushless d.c. motor has quite a complicated 3D geometry and its design arises some difficult problems. Based on a developed design procedure some different claw pole brushless d.c. motors were built up and tested. The given results stand by to prove the design accuracy and motor usefulness.

INTRODUCTION

The usual d.c. motor has a field winding on the stator and a rotative armature winding excited via a commutator with brushes. In such a, let say, classic d.c. brushed motor the permanent magnets can replace the field winding on the stator. If the field winding, which can be replaced by permanent magnets will be on the rotor, the currents through the stator armature winding must be commuted electronically. The stator currents are controlled function of the rotor position in order to ensure a suitable direction of the resulting m.m.f. and to obtain a d.c. type torque. This is the basic concept of the brushless d.c. motor.

The availability of high-energy permanent magnet materials at quite low cost, the expansion of power electronics and the improvement of control technique have given rise to the wide application of the permanent magnet brushless d.c. motors in

variable speed drive systems because of their high power density, efficiency and great flexibility.

Among the several types of brushless d.c. motors the claw pole motor offers the advantages of its robustness, low cost, high speed and electronic controller simplicity. All this makes the claw pole brushless d.c. motor very attractive for low power variable speed drive systems.

The claw pole brushless d.c. motor consists of two parts, a claw pole type structure excited with rectangular current and a multi-pole permanent magnet ring. The internal ring permanent magnet rotor has radial magnetization with the number of poles equal to the number of stator claw poles. The shape and dimensions of the claw pole play an important role in the development of electromagnetic torque. The m.m.f. produced by claw poles armature is controlled via a rotor position Hall sensor.

The claw pole brushless d.c. motor has quite a complicated 3D geometry. Therefore its design arises some difficult problems. The design procedure utilized was based on a field-circuit model [1], and the results look quite satisfactory.

Different claw pole brushless d.c. motors were built up and the results of tests conducted on this prototypes prove the motor usefulness in low power variable speed drive systems.

CLAW POLE MOTOR DESIGN ASPECTS

The claw pole brushless d.c. motor consists of a claw pole type structure and a multi-pole permanent magnet ring. The external location of the claw pole type structure is preferred because of heat transfer reasons, such a location increasing the area of dissipation. Also, an external location being stationary, the control coil can be excited without slip rings.

The specific polarity of the claw pole sections depends on the direction of the excitation current through the excitation coil and because off this inherent homopolar features the claw pole sections polarity can be changed by simply reversing the excitation current. In order to avoid difficult commutation process which comes together with the excitation current reversal, the claw pole stator is provided with two identical coils, one coil for each direction of the excitation current.

The internal ring permanent magnet rotor has multi-pole radial magnetization with the number of poles equal to the number of stator claw poles. The size and geometry of the rotor ring corresponds to that of the stator claw poles. The permanent magnet is made as one piece and magnetized in a custom made, specially designed magnetizing fixture.

The claw pole's shape and dimensions play an important role in the development of the electromagnetic torque. Both the geometry (claw pole surface area and mean radius) and the number of teeth (poles) affects the total torque level which is a superposition of the torque developed by each pole pair section.

The total torque produced by the motor consists of two components: the permanent magnet variable reluctance cogging-type torque due to the interaction of the permanent magnet and claw poles with no current excitation, and the mutual synchronous type torque due to interaction of the stator coil M.M.F. and the permanent magnet. The torque variation with rotor position is a function of the claw poles geometry and permanent magnet field distribution.

In order to calculate the torque developed by the motor, the air-gap flux linkages function of rotor position should be known.

By design procedure it was also necessary to check the magnetic flux density through the ferro-magnetic circuit. All this were done via a magnetic equivalent circuit where the e.m.f. induced by the moving, at a constant speed rotor field was considered in determining the excitation m.m.f. In fact it is a circuit-field model developed on this particular motor case, which is quite complicated one because of the induced e.m.f. in the stator claw poles by the rotor magnetic field.

The stator excitation coils currents are controlled by the rotor position sensors which are based on Hall effect. The electronic controller is really uncomplicated one and can be entirely integrated within the motor-drive entity.

RESULTS AND CONCLUSIONS

Two claw pole brushless d.c. motors were built up, EM-8 and EM-16, and tested, first one with 8 poles and second one with 16 poles.

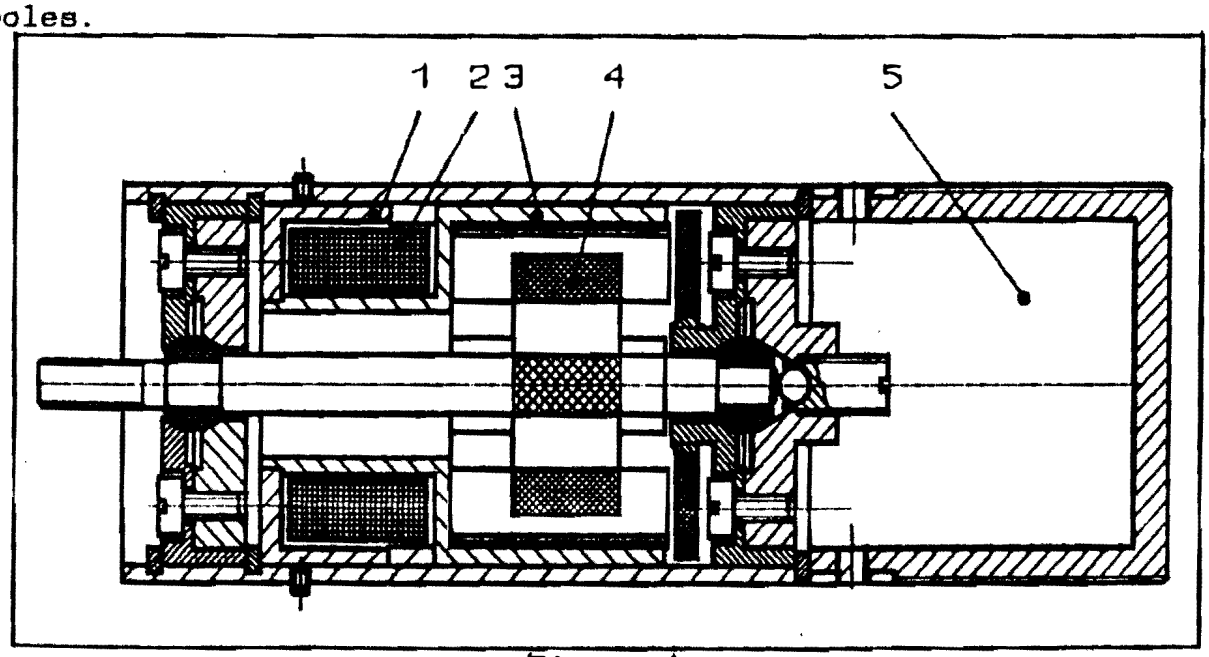

Figure 1

In figure 1. a longitudinal section through EM-8 is given. In this figure the meaning of the notations are:

1 stator magnetic core yoke
2 excitation coils
3 claw poles
4 multi-pole permanent magnet ring
5 integrated electronic controller room.

The permanent magnet ring is made of sintered ferroxdure with B_r=0.4T remanence and H_c=240kA/m coercivity in both cases. Sure, a higher energy density magnetic material, like Ni-Fe-B, should assure better performances, but will increase the cost.

The EM-8 motor has two excitation coils, each one with 380 turns and 10.781Ω resistance and its maximum designed input power was 15 Watts.

The speed-voltage and current-voltage characteristics are given in figure 2. and 3., respectively. The load torque was 2.1mNm for the curve number 1, 1.575mNm for the curve number 2, and 1.05mNm for the curve number 3.

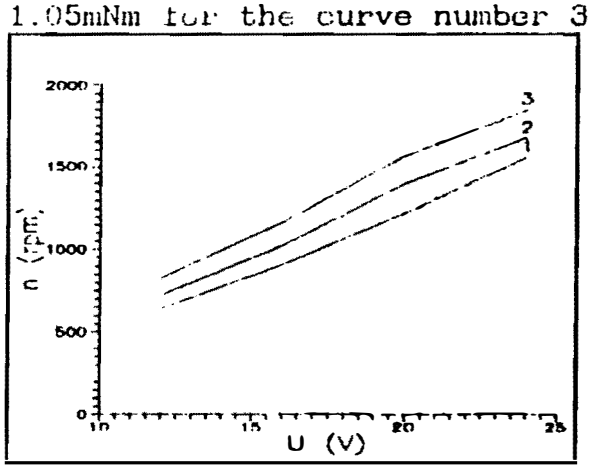

Figure 2

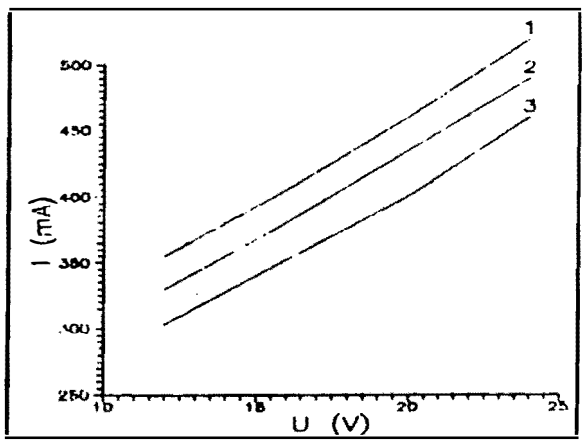

Figure 3

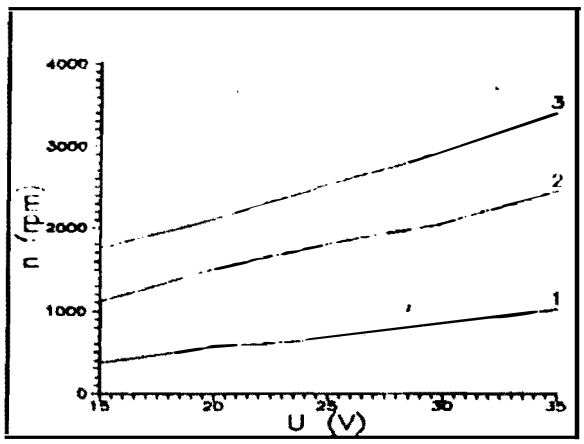

Figure 4

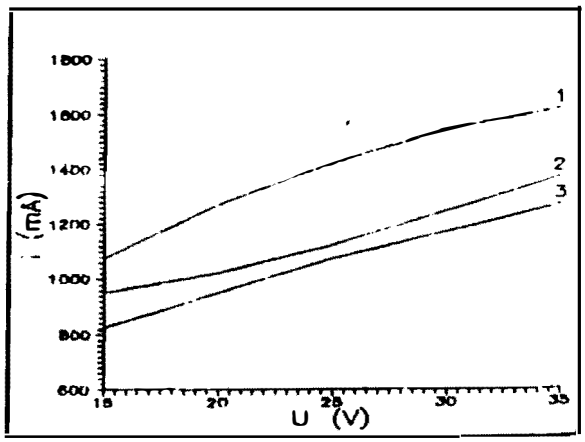

Figure 5

The EM-16 motor, which is almost two times greater than EM-8, has two excitation coils with 135 turns and 2.2175Ω resistance each. In this case the maximum input power is 80Watts. The speed-

voltage and current-voltage characteristics are given in figure 4. and 5., respectively, the load torque being 20mNm, 10mNm and 5mNm for curves 1, 2, respectively 3. This EM-16 motor has a total length of 0.109m and an external diameter of 0.086m. Because of some mechanical problems the highest efficiency was around 20% which is smaller than the calculated maximum of 28%. The rotor speed resulted also smaller than expected. In fact the calculated air gap magnetic flux linkages were greater than the reality and so was the electromagnetic torque computed with these values of flux linkages.

As one can see from the given results the speed is quite linearly varying with the input voltage and the voltage-speed plane is well covered. It means that the claw pole brushless d.c. motor is well suited for a uncomplicated, small power, variable speed drive system.

REFERENCES

1. VIOREL I.A. - KOVACS Z. - SZABO L.: *Sawyer Type Linear Motor Modelling*, Proceedings of the International Conference on Electrical Machines 1992, pp. 697-701.

2. BLOCK R. - HENNEBERGER G.: *Numerical Calculation and Simulation of a Claw Pole Alternator*, Proceedings of the International Conference on Electrical Machines 1992, pp. 127-131.

3. PAWLAK A.M.: *Claw-Pole Rotary Actuators*, Proceedings of the International Conference on Electrical Machines 1992, pp. 122-126.

4. VIOREL I.A. - BIRO K. - SZABO L.: *Transformer Transient Behavior Simulation by a Coupled Circuit-Field Model*, paper to be presented at the International Conference on Electrical Machines 1994.