MAVILOR
INFRANOR GROUP COMPANY

EXPRESS

JULY 2006

MLL Series

New Mavilor series with elongated configuration and slotless stator that prevents reluctance variation in the rotor movement, which is translated as:
No cogging torque
Minimal ripple torque
Almost no losses in magnets
Increased efficiency
Possibility for high-speed rotation

Introduction

Ivan Flotats will explain us the numerous advantages of the absence of these slots in the stator, in the MLL motor, the latest in long geometry.

Our technical article written by Mr.J.C Compter where we find a simple explanation about the cogging torques in iron armature motors, effect that occurs if a rotor is equiped with several teeth.

The Mavilor Distributors network has been extended by our new distributor ECS, s.r.o. in Bratislava-Slovaquia. It has participated in the Trade Fair in Bratislava with a big exposition of our motors and drives.

Thank you very much, Mavilor Team.

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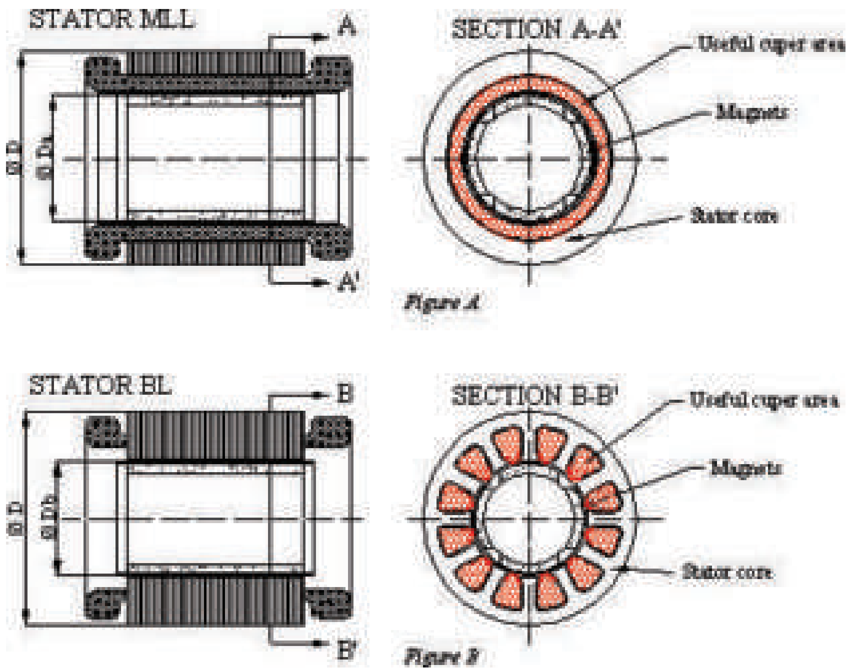
MLL Motor Philosophy by Mr. Ivan Flotats

The most standardize configuration of brushless electrical motors with permanent magnets consists in a cylindrical rotor where there are the permanent magnets already mentioned (in general rare earth) and a stator made of electrical steel with some teeth among which the motor coil is placed. (See picture B). While the presence of these stator "teeth" is very useful to hold up the coil and carry the flux through its coil, it presents key inconvenient for applications, where efficiency, precision and a high performance of the motor are necessary.

Mavilor has been manufacturing since some years ago a range of motors characterized by the absence of such a slots in the stator and has named them MLL Motors. As such slots do not exist, there is no reluctance variation around the 360° mechanical degrees of a rotor turn. That is to say that the magnetic flux will face the same difficulty in passing through, from the rotor magnets to the stator all alongside the rotor circumference length.

The advantages given by the absence of slots to improve the motor performance are numerous. A brief summary of them would be:

- Complete disappearing of the motor cogging. The magnets do not have a preferential situation of static equilibrium any more being in front of the existing teeth of the classic stators. Situations where it is needed a high level of precision of the rotor placing are the most favored ones by this technology, because all the positions along the turn of the rotor are equally stable, getting a better precision and a lower cost of the amplifier which controls the motor, because to place the rotor is not necessary such a complex control.



- The ripple torque is minimized because the stator teeth do not modulate the magnetic flux and consequently the value of the torque constant Kt is constant in each point of the rotor turning in front of the stator. This allows that every position through which the rotor goes through in a turn, the transmitted torque will be as homogeneous as possible.

- Consequently, the motor efficiency increases. The current fluctuations due to the cogging and the ripple disappear and consequently the losses derived from them (unnecessary heating).

- As the stator does not have any teeth, the coil wire can be distributed all alongside the circumference which permits to place the magnets at a bigger diameter (Da > Db in pictures A and B) and so the motor torque will be bigger because the torque definition is: strength per radio.

- The Cu filling factor is much bigger because all the space is occupied by this one and does not have to be shared with polar teeth. The more quantity of copper inside a motor for a certain external diameter D we can use, the more capacity of obtaining torque we will have.

- The magnetic losses in the magnets are almost null because the eddy currents in the magnets produced by the teeth in the stator disappear, permitting to obtain a bigger torque.

- The absence of heat sources produced by eddy currents permits the magnets to work at high speed without reducing any field of the magnetic field or any risk of demagnetization of these ones. In high-speed applications, where the turn frequency can be very important since the produced losses by eddy currents vary in an exponential way to the frequency, the resulting heating is much lower.

Cogging torques in iron armature motors

In iron armature motors a phenomenon not previously mentioned, that is cogging torque, comes into play. The cause of this torque is the positional dependence of the reluctance of a magnetic circuit. Let's say that a rotor has the form shown in Fig.3.15. Without further knowledge of magnetic fields it is clear that the rotor will try to align with the axis of the magnets.

This effect of preferred positions also occurs if a rotor is equipped with several rotor teeth; then we speak of, cogging effect or reluctance torques. On average this positionally dependent torque does not make any torque contribution over a rotation; in a certain position it strengthens or weakens the expected motor torque K*I. The standard method for reduncing this interference torque is to skew the rotor slots in relation to the rotor shaft (skewing, see Fig. 3.16).

Fig. 3.15 Cause of cogging torques Fig. 3.16 Iron armature motor   Fig. 3.17 Theory behind cogging torques

If a motor is running fast, the motor moment of inertia acts as an effective filter. With slow running servo systems the control loop can usually absorb this disturbance satisfactorily, because cogging torques are a "soft" disturbance. Yet it remains a disturbance, one that leads to an additional positional error. These cogging torques are discernible when turning the motor shaft by hand.

Theoretical analysis of the phenomenon is possible with reference to Fig. 3.17, in which the magnet is shown as a source with magnetic voltage $-H_c.1_m$ and an internal resistance R_m (assuming that $\mu_{r.m} = 1$). The magnet is loaded with a positionally dependent reluctance R_{ext}. To arrive at a determination of the torque we must start by remembering that no energy is lost. If in the case of an angular displacement $\Delta\theta$ a torque T is needed, the following is supplied to the

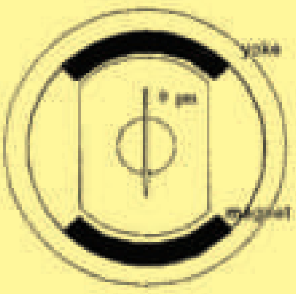


Fig. 3.15 Cause of cogging torques

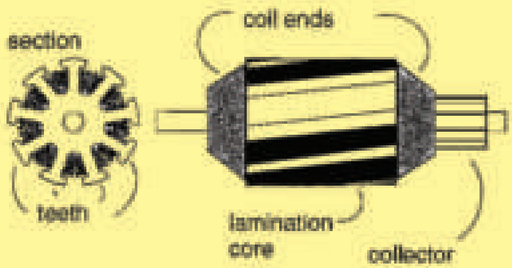


Fig. 3.16 Iron armature motor

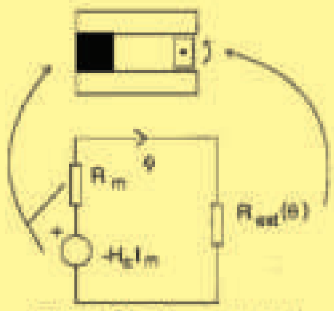


Fig. 3.17 Theory behind cogging torques

system:

$$\Delta E = T.\Delta\theta$$

This energy is stored in the magnetic field; if we know the change in the magnetic field energy, we can determinate the torque. We shall now work it out.

First of all the magnet is shown as a coil with one turn and current I equal to -H_c.1$_m$ and $\mu_{r.m}$ = 1. This gives us: N.i = -H_c.1$_m$ with N=1.

The magnetic field energy (for these linear systems) is given by:

$$E_{magn} = \frac{1}{2} L_m i^2 = \frac{1}{2}\phi.i$$

The definition of reluctance given previously:

$$R = \frac{H.l_m}{\phi} = \frac{N.i}{\phi}$$

gives us:

$$E_{magn} = \frac{1}{2}\phi^2.R = \frac{1}{2}\phi^2.(R_m + R_{ext})$$

In Fig. 3.17 the flux is given by:

$$\phi = -\frac{H_c.l_m}{R_m + R_{ext}}$$

The total magnetic field energy is therefore:

$$E_{magn} = \frac{\phi^2}{2}.(R_m + R_{ext}) = \frac{(H_c.l_m)^2}{2.(R_m + R_{ext})},$$

so that the adhesive torque is given by:

$$T = \frac{d\,E_{magn}}{d\theta} = -\frac{(H_c.l_m)^2}{2.(R_m + R_{ext})^2}.\frac{d\,R_{ext}}{d\theta}$$

In many cases it seems that R_{ext}, by which the cogging torque is known, can also be determined reasonably well. The torque is now easy to derive, if the permanent magnet is replaced by a coil with the self-inductance L (see Fig. 3.18).

H_c.1m is replaced by N.i ang R_m = 0, After substitution of:

$$L = \frac{\phi.N}{i} = \frac{N^2}{R_{ext}(\theta)}$$

we have:

$$T = \frac{1}{2}.i^2.\frac{d\,L}{d\theta}$$

To above formula is applicable to motors that work on the basis of reluctance forces, reluctance motors.

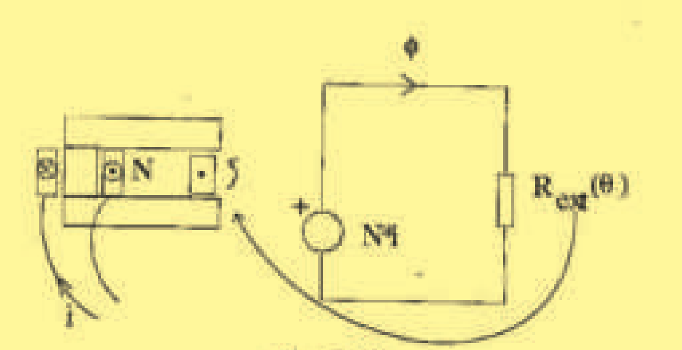


Fig. 3.18

Mavilor has at your disposition, in your own language, the publicity that you need, please send us your requests : mavilor@mavilor.es

Distributor in Slovaquia: ECS Služby s.r.o.

Last March, Mavilor Motors, S.A. has increased its distributing network in Europe. From March 2006 we have a distributor in Slovakia, the company ECS Služby s.r.o.

Since the very beginning ECS Služby s.r.o. has been very active, participating at the International Engineering Fair in Nitra from 23rd to 26th May 2006 and editing a two pages article at the AT&P Journal on its number 5/2006 promoting Mavilor servomotors and Infranor drives.

ECS Služby s.r.o. was created in 1995 always working on the automation sector, having a big experience and knowledge on it, being able to offer our costumers all the support that they could need on their automation applications.

On the other hand, Slovakia is a country with a very important industrial activity (in 2003 was the 30,4% of the national GDP) and in an economical expansion process, attracting very important foreign industrial investments.

All this data just can make us think that this new partnership will be a success, increasing our market share on the high level movement control applications.

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