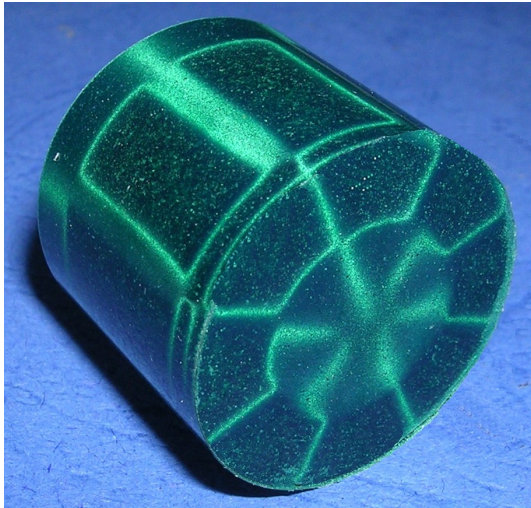


## Sm2Co17 ROTOR AND ENCODER MAGNETS MAGNETIZED AT THE SAME TIME

Imagine a brushless motor rotor, with permanent magnets, composed of a pattern of radial poles and a single axial ring on its top.

Radial poles induce the motor magnetic field, whereas the axial ring copies the radial polarities on a pcb board, where the position hall sensors take place.



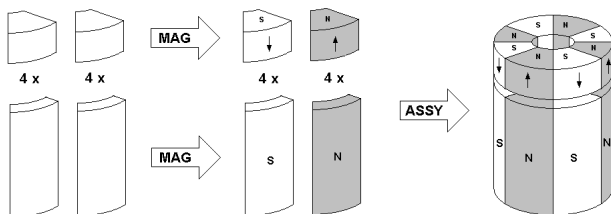
1: Magnetic viewer paper shows either radial and axial poles

The first and most intuitive way to assembly this kind of rotors is using magnets already magnetized, keeping aligned axial ring and radial poles, maybe using some mechanical references.

Single magnet magnetization warranties 100% of material saturation. Very high axial magnetic field is quite easy to obtain; it comes from winded iron-less cored solenoids or also by using that kind of solenoids called Bitter coils, fed with direct capacitor discharging units. Anyway quite high field is required because of

- the high demagnetizing factor of single magnets
- no iron cored fixture

Anyhow let us say that a 100mm diameter solenoid makes in its middle point a field of 4000kA/m with 30kJ and a duty cycle of 6 pieces per minute.



2: First Method: pre magnetized magnets are assembled together

As Melville said "dear Sir at this world it is not so easy to set so plain things, this intuitive way is not so easy of course, for many reasons:

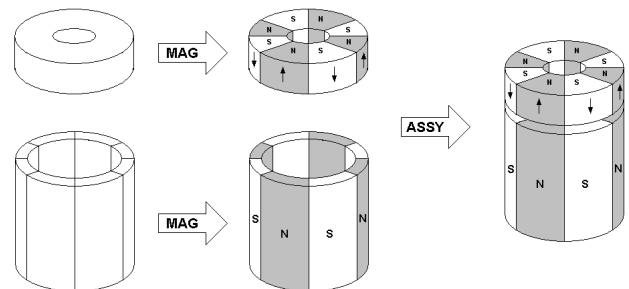
- pre magnetized magnets are more expensive,
- pre magnetized magnets are difficulty handleable, being

that they attract all the iron dust close to them or coming from them,

- sintered magnets are quite brittle and broke just at the least bending action or at the least collision,
- magnetized sectors are difficulty to assembly together because they repulse or attract each other, and they must be kept in their position for the glue long drying time.

So it is almost mandatory magnetizing all the radially oriented magnets after they have been properly fixed to the rotor, accepting a slightly lower saturation level (99%) due to the fact that the magnets are too close one each other.

This second method requires two different magnetization heads, one for the radial rotor and one for the axial ring.



3: Second method: magnets are assembled first then magnetized, then the two parts assembled together.

For what about the radial magnets, if the material is common hard esaferrite, everything is very easy; a 600-800kA/m magnetic field saturates. One builds an iron cored fixture, better if laminated in order to avoid eddy currents field reduction, with so many slots as many the poles to be obtained are; then one fits in the slots a certain number of varnished wires and glues everything in epoxy resin to warranty good insulation and mechanical strength; indeed on each wire act the electrodynamic forces, and they proportional to the square of the magnetizing currents .

The magnetization current is obtained using low voltage capacitor discharging unit, typically 600-800V, and few kJ of energy. Common electric current values are roughly 10000-30000A, lasting 0.1 to 1ms.

Whenever a more intensive production rate is required, where cycle time is minimum, solid copper rods are preferred, matched with the power unit by means of a lowering pulse transformer, with the aims to reduce the insulation space requirement and to radiate more heat from the transformer, where we have more cooling room. In those copper rods one gets electric currents up to 150000A, working with few thousands of Amperes on magnetizer side.

But if the material is NdFeB, magnetic field of 1600-2000 up to 2500kA/m is required, depending on magnet brand and fixture magnetic circuit. With rare earth, rotors dimensions are smaller, thus one has less space for proper wire to wire and wire to iron insulation. High voltage is required and some kJ of energy. The solid copper bars fixture matched with pulse transformer has now lower efficiency because:

- magnetic poles are not symmetrically closed, being that the copper bars cover only ¾ of the pole;
- the transformer connections are so long that the impedance increases too much;

- the required current is so high that saturates the transformer iron core;

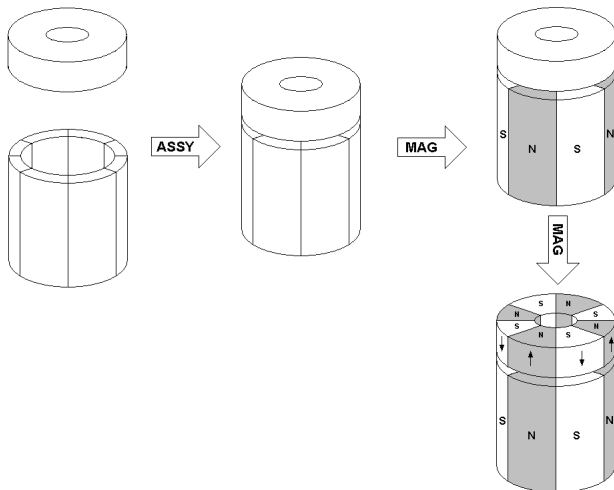
Sm2Co17 requires even higher field, let's say 3000-4000kA/m, so magneto-motive force required needs more wires, so that the slots become deep and the net current moves far from the magnets. This leads to

- less wires efficiency,
- polarity change areas (q axe) not well defined.

In 2005 LEE developed a new kind of magnetizing fixture core, named no one knows why SAT coil, which amplifies the electric current, thanks to a mutual linkage between magnetization copper rods and magnetizer side wires, with awesome results.

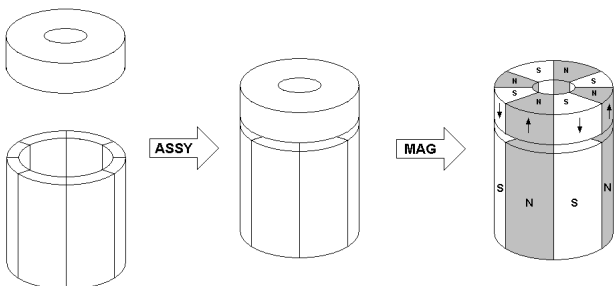
To magnetize the axial multipolar ring one uses a multipolar axial fixture. We can well repeat all the above mentioned concept, with more focus upon the small room in the middle.

It is not always easy, but even possible, a third method, assembling first the parts, then magnetizing the radial part first and then also the axial ring, but paying attention to do not magnetically damage the ring during the radial magnetization.



4: Third method: magnets are assembled, then radial sectors magnetized first, then axial ring is magnetized in a different station.

This time LEE moved even more forward with its product innovation. Combining good and bad results research of the past, anyway related with the concept above described, a single fixture has been developed, which magnetizes both radial rotor and axial ring at the same time, with a single shot, without other assembly process.



5: New System: assembling unmagnetized parts first, then single shot contemporary magnetization of both encoder and field magnets

the difference with the last three method is hidden under a skilful magnetic circuit design, linked with the capacitor discharging unit circuit. "Hidden" because all the geometrical and electrical parameters must be optimised solving a third order differential equation, which is the steady state circuit equation of the fixture equivalent electric circuit, with concentrated parameters, solved with numerical method. Finite element model has been used only at the end, with the aim to verify the project, adopting the more efficient and fast analytical method to find the optima parameters. The parameters we are speaking about are:

- wires number,
- conductor gauge,
- solid bars cross section,
- parallels ,
- iron cross sections,
- Capacitance and voltage.

In this way LEE solved the problem of an 8 poles 2mm diameter PM rotor magnetization, in Sm2Co17, using 7000J at 15s cycle time, utilizing a cheap turbofan as vacuum cooling system.

Even if magnetizing bars thickness is bigger than pole to pole distance, one finds a very good alignment between radial and axial poles.



6: Fixture

This new fixture is composed of two linked windings. One is made of a certain number of insulated wires whereas the other is a composition of solid copper rods, laser welding joined, with additional material. The first winding magnetizes the central part of the radial magnets, the second saturates the radial magnets edges and magnetizes the axial ring.

This fixture is a little bit bigger than a common high energy fixture, but quite smaller than two single different fixtures. The main constrain is obviously that axial and radial magnets must be of the same polarity and of the same poles number.