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Permanent Magnet temporary demagnetization temperature rise technique and their application for soldering[1].

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Abstract

The use of soldering in permanent magnet (PM) assemblies can be often more efficient than mechanical attachment or gluing. Compared to mechanical fastening, soldering takes less space which can be critical for high density compact assemblies. It is more resistive to radiation and has less out-gassing rate than gluing. The latter characteristics are especially important for in–vacuum type assemblies operating in an elevated radiation environment.

The biggest disadvantage of soldering in comparison to mechanical attachment and gluing is the necessity to raise the temperature of the PM to above the solder melting point when making the connection. This can easily demagnetize the PM.

The presented note describes a method for increasing the temperature at which PM demagnetization occurs. Simple model analysis and experiments show that ***the demagnetization temperature can be increased by arranging ferromagnetic (steel) pieces around the permanent magnet. The magnetic field generated by these pieces decreases demagnetization forces inside of the permanent magnet. This results in a rise in demagnetization temperature. The arrangement can be done just for the period of PM temperature rise necessary for soldering or for other high-temperature processes.***

In the note, first, the method is described based on a simple theoretical model. Then, the experimental setup and results of the method application are presented.

Model

Let us estimate and compare demagnetization temperatures of single PM blocks in two scenarios. The first one is just the block on its own, and the second is the block surrounded by steel plates.

The left plot of Figure 1 shows the profile of magnetic field calculated by program POISSON for the stand-alone rectangular PM block with dimension 0.5x0.25". A residual induction corresponding to NdFeB N40 grade material Br = 12.6 kGs was assumed. Data indicates that the minimum magnetic field ~3.88kGs will be in the middle of block, the region with minimal field line density. The given minimum field implies

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existence of ~10.5 kOe of demagnetizing force at this location (see 20degC curve of Fig. 2). Taking into account demagnetization curves for different temperatures depicted on Fig. 2, one can predict demagnetization temperature ~128degC.

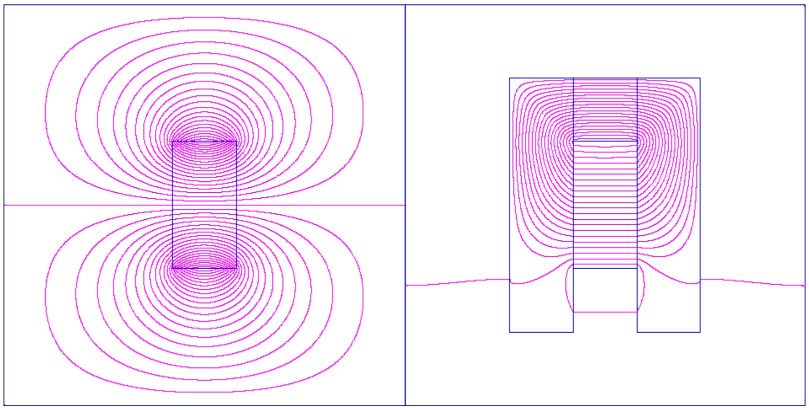

Figure 1. Magnetic field lines for stand-alone PM block (left) and PM block surrounded by a steel plates (right).

Plot on right side of Fig. 2 shows magnetic field for the same block, but surrounded by 0.5” thick steel plates. In this case magnetic field inside of the block is very uniform and its amplitude does not go below 11.2kGs. This means that demagnetizing forces everywhere inside PM will be ~1kOe or less (see 20degC curve of Fig. 2). For 1kOe of demagnetizing force, approximation of the Fig. 2 data for higher temperatures gives demagnetizing temperature ~ 217degC. This temperature is sufficiently higher than 128degC, the demagnetization temperature for the stand-alone PM block.

The effect of increasing demagnetization temperature by surrounding the PM block with ferromagnetic plates was confirmed in experiments described in the next section.

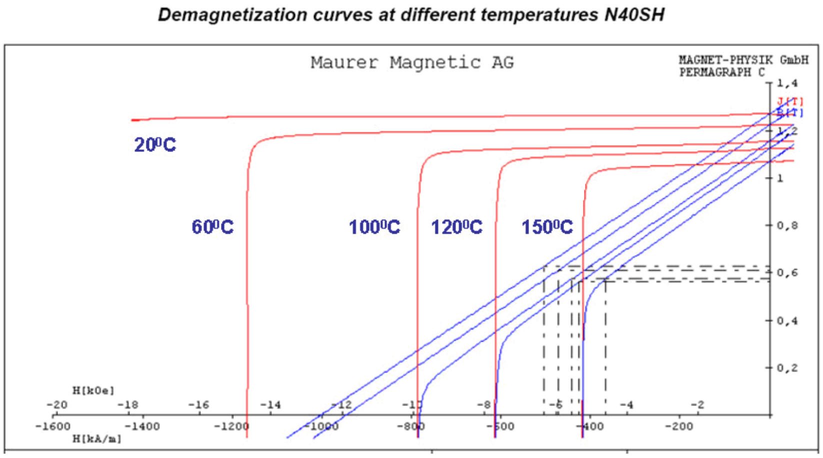

Figure 2. Demagnetization curves for different temperature for N40SH NdFeB permanent magnet material (copied from web site: www.maurermagnetic.ch)

Experimental setup and results

The above method for temporarily increasing the demagnetization temperature was applied in order to solder NdFeB PM blocks to copper bases.

PM blocks were rectangular magnets with dimensions 1x0.5x0.25” of 40SH grade magnetized in 0.5 (“V”) and in 0.25in (“H”) directions. Their demagnetization temperatures (estimated and confirmed in previous experiments) were 129 degC and 145 degC respectively. Blocks were coated by ~12 microns of Ni-Cu-Ni. The employed solder was widely used 63/37 Sn/Pb alloy with rosin component and with melting point 183degC. For copper bases were used 0.25x0.25” rectangular bars ~2” long. Note, that the direct soldering of these PM blocks to bases would result in their full demagnetization.

During soldering procedure, each PM block was placed in “steel jacket” consisting of three 0.25” thick steel plates and copper base (see photos on Fig. 3). The solder wire was flattened and inserted between PM block and base. PM block, copper base, and upper steel plate were fastened together with C-clamps. The whole assembly was placed in oven for 2 hours at 195degC.

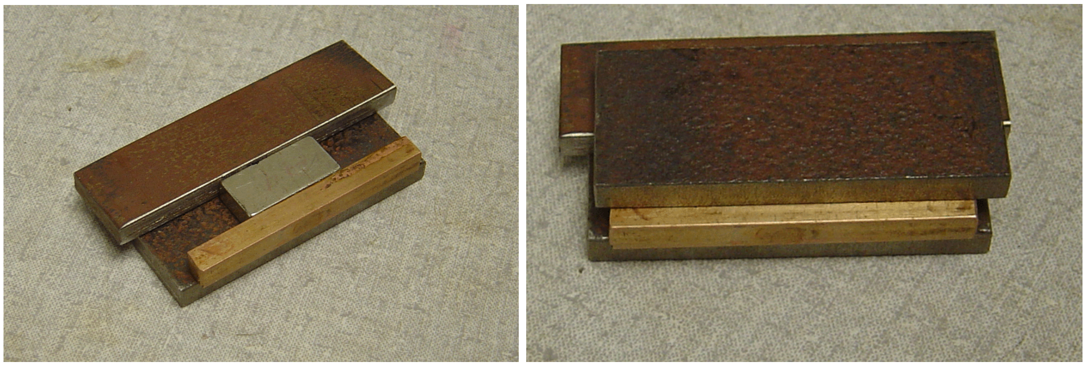

Figure 3. Right: two steel plates with PM block and copper base, the third steel plate is removed. Left: whole package.

After cooling down to room temperature, the package was disassembled, and the PM block soldered to copper base, see Fig. 4, was tested for magnetic, geometrical and mechanical properties:

- ***Magnetic properties test***. The magnetic moment of PM block/base assembly was measured using Helmholtz coils apparatus and compared with pre-soldering value. In the case of “H” block, measurements indicated ~ - 0.05+-0.02% relative magnetic moment change. In case of “V” block the relative change was ~ -1.39+-0.02%. Both decreases are very small and tolerable for most applications.
- ***Geometry test***. Measurement of the total dimension of PM block with copper base gave the thickness of *soldering layer ~ 1/1000”* which is quite satisfactory.

- ***Mechanical sterngth test***. The strength of the bond was tested by applying load to PM block while holding the assembly by the copper base. Calculation shows that the load on single PM block due to magnetic forces in our application (undulator magnet) will not exceed 70N. In the test we applied successfully 760N load, ~10 times more, without soldering joint broken. Note that for the tested sample 760N implies ~ 9.4MPa of tensile stress. The tensile strength of the used alloy given in database, www.efunda.com/materials/solders/tin_lead.cfm, is 54MPa. This ensures the mechanical strength of soldering will satisfy any reasonable magnetic assembly requirements.

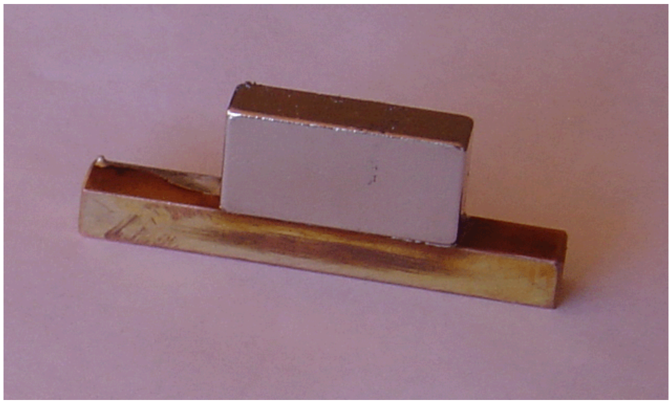

Figure 4. NdFeB 40SH permanent magnet blocks soldered to copper base.

Conclusion

The simple method for temporarily increasing the demagnetization temperature of permanent magnets was proposed and tested. The method can be applied to reduce risk of demagnetization during soldering as well as during other processes involving a temporary temperature rise of permanent magnets.

Acknowledge

I would like to thank Richard Rice and other people working in Annex for their generous help in the setting up of the described above experiments as well as my son Ivan Temnykh for editing this paper.