The use of SPS technique for the production of high coercivity recycled $SmCo_5$ magnet prepared by HD process

Anas Eldosouky[1,2], Awais Ikram[2,3], Farhan Mehmood[2,3], Spomenka Kobe[2,3], Saso Sturm[2,3], Kristina Zuzek Rozman[2,3], Irena Skulj[1]

[1] Magneti Ljubljana, d.d., Stegne 37, SI-1000 Ljubljana, Slovenia
[2] Jožef Stefan International Postgraduate School, Jamova Cesta 39, SI-1000 Ljubljana, Slovenia
[3] Department for Nanostructured Materials, Jožef Stefan Institute, Jamova 39, SI-1000 Ljubljana, Slovenia

Rare earth permanent magnets are considered to be a keystone in many industries and technology sectors as in electric motors, wind turbines and communications technology. SmCo and NdFeB magnets dominate the market of rare earth permanent magnets, with $SmCo_5$ providing better temperature resistance and coercivity values than NdFeB. As the magnets contain valuable elements of rare earths and cobalt, many organizations including the European Commission started to emphasize the recycling process for the magnets, mostly by the direct recycling routes as hydrogen decrepitation process (HD), Where, the magnets react with hydrogen gas to form a powder of smaller particles sizes. The powder produced by the HD procedure can be used in a number of ways, including sintering, plastic bonding or to extract the individual constituents' elements. Spark plasma sintering (SPS) is a promising technique for the consolidation of permanent magnets, as the process showed the possibility to achieve full dense magnets at very short time in the matter of minutes.

In This study, industrially produced $SmCo_5$ magnets were crushed by using the HD process to produce powder of particle size less than 200 µm. The decrepitated powder was milled in a nitrogen atmosphere jet mill to 4-20 µm. The milled powder was sintered by using SPS technique at a 10 mm inner diameter graphite die to produce isotropic recycled magnets. The SPS sintering parameters was 800-1000 ^oC sintering temperature, heating rate of 50 ^oC/min the sample was kept at the sintering temperature for 1 min. were the applied pressure was 80 MPa. Partial pressure of 200 mbar argon was kept during sintering to reduce the Sm evaporation during sintering. For comparison, isotropic $SmCo_5$ magnets prepared from fresh powder, using the conventional sintering route were prepared. The recycled SPS magnets prepared at sintering temperature of 900 ^oC showed to have better magnetic properties in comparison with the fresh conventional sintered magnets. The remanence (B_r), the extrinsic coercivity ($_bH_c$) and the maximum energy product (BH_{max}) for the 900 ^oC SPS-ed sample were 0.471 T, 366.8 kA/m* and 43.4 kJ/m^3, respectively, in comparison to 0.466 T, 324.16 kA/m* and 36.37 kJ/m^3 for the conventionally sintered magnets, respectively. The magnetic properties for the 900 ^oC SPS-ed sample at high temperature of 180 ^oC was measured, where the sample showed to have good magnetic properties of B_r of 0.436 T, intrinsic coercivity ($_jH_C$) of 1502 kA/m and BH_{max} of 36.4 kJ/m^3. The SEM, EDX, XRD, oxygen analyses and density measurements showed that, the microstructure and the mechanical properties for the 900 ^oC SPS-ed and the conventionally sintered magnets are similar, with refinement in the microstructure of the SPS-ed sample. The study shows the possibility to use SPS technique as an effective route for the consolidation of recycled $SmCo_5$ magnets, where the magnets showed to have promising magnetic and mechanical properties at room and high temperatures.

*Intrinsic coercivity where higher than 1500 kA/m, where the exact value could not be measured using the present instrument.