

Abstract [English]

Magnetic refrigeration is an innovative, promising and ecologic technology, which aims to substitute the conventional vapor-compression refrigeration by the employment of solid materials as refrigerants instead of the fluid-state ones, own of vapour compression refrigeration. This emerging technology bases its operation on the magnetocaloric effect (MCE), which is a physical phenomenon, related to solid-state materials with magnetic properties. The magnetic field causes an entropy change due to magnetic ordering. The maximum MCE occurs near the magnetic ordering temperature, which is recognized as the Curie temperature of a ferromagnetic material. For materials displaying simple magnetic ordering (i.e. paramagnetic to ferromagnetic phase transformations) a rapid increase in magnetic field causes a temperature rise in the material; likewise, a rapid reduction in the field causes cooling. This variation in temperature is called adiabatic temperature change which is a function of the magnetic field intensity and of the initial temperature. To reach a useful temperature span it is required employing a regenerative thermodynamic cycle. In 1982, the employment of a reciprocating thermal regenerator coupled with magnetocaloric cycle has been shown: it was introduced the Active Magnetic Regenerative refrigeration cycle, well known as AMR cycle. The innovative idea leads to a new magnetic cycle, different from the previous ones (Carnot, Ericsson, Brayton, or Stirling). It considers a magnetic Brayton cycle but the main innovation consists of introducing the AMR regenerator concept, i.e. the employment of the magnetic material itself both as refrigerant and as regenerator. A secondary fluid is used to transfer heat from the cold to the hot end of the regenerator. Substantially every section of the regenerator experiments its own AMR cycle, according to the proper working temperature. Through an AMR one can appreciate a larger temperature span among the ends of the regenerator.

Active Magnetic Regenerator is the core of a magnetic refrigerator system. The performance of an AMR system strongly depends on the magnetocaloric effect of the magnetic material used to build the regenerator, on the geometry of the regenerator and on the secondary fluid.

The present thesis aims to explore, report and explain all the aspects of the research, treated during the PhD period. The personal contribution in the research field of magnetic refrigeration has combined both the numerical and the experimental research that have been done hand in hand. At the Refrigeration Lab (LTF) of University of Salerno, the first Italian prototype of a Rotary Permanent Magnet Magnetic Refrigerator (RPMMR) has been projected and developed (Aprea et al., 2014), whose name is 8Mag and presents a rotating magnetic group whereas the magnetocaloric material (MCM) is stationary. Gadolinium has been selected as magnetic refrigerant and demineralized water has been employed as heat transfer fluid.

In the present thesis, the experimental tests conducted on the RPMMR have been presented, with the purpose to investigate the energy performances of the device, like temperature span, refrigerating power and Coefficient of Performance (COP), when the system was subjected to different operating conditions obtained by varying the cycle AMR frequency, the thermal load, the volumetric flow rate of the auxiliary fluid and the temperatures of the cold and hot heat exchangers. In particular, the results of three different campaigns of tests are presented: 1) a primary campaign based on zero load tests; then two other campaigns have been conducted in order to explore the energetic performances of 8Mag: 2) by changing the cycle frequencies, the cooling load and fluid flow rate, while the hot side temperature was fixed, in order to give an overview of the performances and to underline an optimal operating frequency, for each set of operating conditions. 3) Fixing flow rate and AMR cycle frequency to the optimal value, a further investigation has been conducted by varying cooling load.

A two-dimensional numerical model of a packed bed- AMR regenerator has been developed, as primary purpose, to operate according to the prototype, since the model replicates the thermo-fluid-dynamical behavior of one of the RPMMR's regenerators, including the magnetocaloric effect acting into the solid refrigerant. To this aim, the model has been experimentally validated with experimental results provided by the prototype. This model has been used to optimize the experimental device and to identify significant areas of device improvement. Thus, it has been used to explore the critical aspects of 8Mag and to outline the way to improve performances. Anyway, the model has been easily generalized to consider different device geometries, temperature spans, secondary fluids, and magnetic materials. As a matter of fact, in this thesis are shown the results obtained investigating, through the model, the effect of other different magnetocaloric materials when they act as refrigerant employed in one of the AMR regenerator of the prototype. Moreover, the environmental impact in terms of greenhouse effect has also been investigated, by comparing the performances of the RPMMR with the one of a vapor compression plant in terms of TEWI index (Total Equivalent Warming Impact).