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C3Po1D-02: Performance improvement of a hydrogen condensation heat exchanger applying intermittent reciprocating flow

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In a decarbonized society, hydrogen is attracting attention as an energy carrier. There are several forms of hydrogen transportation and storage, including liquefied hydrogen, ammonia, methylcyclohexane, and compressed hydrogen, each of which has its advantages and disadvantages, so it is expected that hydrogen will be used in a form appropriate to the method of use. Of these, attention is focused on liquefied hydrogen, which can be reduced to about 1/800 the volume of normal hydrogen at normal temperature and pressure, has high purity, and does not require purification. The disadvantages of liquefied hydrogen are its liquefaction temperature of 20 K and the large amount of energy required for liquefaction. Highly efficient hydrogen liquefaction is expected to help reduce the cost of hydrogen supply. In this study, we expect to improve the liquefaction efficiency by magnetic refrigeration, which can realize an ideal refrigeration cycle that does not use Joule-Thomson expansion in the refrigeration cycle. Magnetic refrigeration is a refrigeration cycle that utilizes the magnetocaloric effect of magnetic materials. The magnetocaloric effect is a phenomenon in which magnetic entropy is manipulated by applying a magnetic field change to a magnetic material, causing a temperature change in the magnetic material. With this temperature change, the refrigeration cycle is constructed by repeated heat absorption and heat exhaustion with the external system. Ideally, a Carnot cycle with adiabatic and isothermal processes is shown. However, this cycle has the disadvantage that the cooling temperature range cannot be extended because the temperature of the magnetic materials changes uniformly during the adiabatic process. To solve this problem, magnetic materials with high specific heat and magnetic calorimetric effect are processed into particles, and helium, a heat exchange fluid, flows between the particles during the adiabatic process to create a temperature gradient in the magnetic materials. This method draws a small Carnot cycle at each temperature, which occurs continuously with respect to temperature, thus drawing an Erickson cycle as a whole and increasing the cooling temperature range. This is called Active Magnetic Regenerative Refrigeration (AMR). The flow of the heat exchange fluid in AMR is an intermittent reciprocating flow, in which the flow is stopped at the timing of the excitation and demagnetization of the magnetic material due to its operating principle. The heat transfer rate during the flow stoppage time is expected to be lower than that of continuous reciprocating flow. By reducing this reduction in heat transfer, the cold heat generated by the magnetic caloric effect of the magnetic material can be transferred to hydrogen with less loss. As a result, it can help improve the liquefaction rate of the whole liquefaction system. The heat transfer rate was measured by using the fabricated heat exchanger with different flow stop time. The results and discussion are reported.

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