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Fri-Mo-Po.09-08: Design of the evaluation system for materials testing using HTS coils at cryogenic temperature

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The International Maritime Organization has set a 'Net Zero' target for the maritime industry to reduce greenhouse gas emissions to zero by 2050 in response to climate change. To achieve this goal, the shipbuilding industry is focusing on the design and research of cryogenic equipment for the transportation of liquid hydrogen and carbon capture in cryogenic states. Liquid hydrogen must be stored and transported at cryogenic temperatures. Therefore, testing of specimens is crucial to accurately assess the performance and stability of materials used in such equipment. Currently, most specimen tests are conducted at relatively high temperatures, which do not reflect the actual operating environments, complicating the accurate prediction of material performance. In cryogenic conditions, the mechanical properties of materials can change significantly, and conventional specimen tests may not ensure material reliability at operational temperatures.

This paper deals with an evaluation system for materials testing at cryogenic temperatures using HTS coils. The evaluation system is configured to evaluate the mechanical properties of specimens by utilizing the repulsive force generated when current flows in the same direction through each HTS coil. A pair of HTS coils was designed to generate a high magnetic field and force. Within the evaluation system, the HTS coils are positioned at an appropriate distance considering the test specimen. A specimen was positioned between two HTS coils for the mechanical test. The evaluation system was designed for the capability to test the tensile strengths exceeding 520 N/mm², similar to those used in liquid hydrogen tanks like SUS316L.

The HTS coils were designed with YBCO wire and metal insulation to enhance cooling performance and ensure mechanical stability under significant electromagnetic forces. The operating temperature of the HTS coils was set at 20 K, the same as the test temperature of the specimen. A tensile testing fixture conforming to the standard of ISO 6892-3 was located on the side of the HTS coil bobbin, and the specimen was positioned between the fixtures. The HTS coils were cooled down by the conduction cooling method using a cryocooler, and the specimen positioned between the HTS coils was also cooled to 20 K through conduction cooling. The HTS coils are connected to the cryostat through G10 supports, and the G10 supports and cryostat are linked by a rod to allow for swinging like a pendulum when repulsive forces occur between the HTS coils. The margin of the HTS coils in the evaluation system was set at 75%, with the maximum operating current and central magnetic field measured at 462 A and 4.82 T, respectively.

As a result of ramping a pair of HTS coils at a rate of 0.1 A/s, the repulsive force increased by 22 N with each increment, culminating in a maximum repulsive force of 100 kN. The simulation results confirmed that tensile testing of materials using the electromagnetic force between the HTS coils is feasible in a cryogenic environment. The evaluation system for materials testing is expected to be widely utilized in the fields of cryogenic properties and material testing.

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