WE-P3-112

SQUID NDE for In-situ Inspection of Copper Heat Exchanger Tubes

Y. Hatsukade[1], A. Kosugi[1], N. Ishizaka[1], K. Mori[2], S. Tanaka[1]

1. *Toyohashi University of Technology*, 2. *Sumitomo Light Metal Industries, Ltd. Copper Works*

Recently, the copper heat exchanger tubes for air conditionings have a thickness of less than 1 mm to extract better performance. During the process of thinning tubes, defects such as micro flaws have accidentally occurred on the tube surfaces. In the case of thin tubes, even if a flaw reaches only a few tens micrometer in depth, it will cause a tube breakage due to bending or flaring processes. At the present time, commercial in-situ eddy current testing system cannot detect such shallow flaws less than 50 micrometer in depth. In this study, a nondestructive evaluation (NDE) system has been developed for in-situ inspection of micro flaws on the copper heat exchanger tubes using a HTS SQUID. The goals of this study are following: to establish a SQUID NDE technique that can detect a micro flaw of less than 50 micrometer in depth on the tubes, and to construct an in-situ SQUID NDE system for the tubes that can be employed in potentially noisy tube factories, in which the tubes in thinning process are moving at a velocity of 60 m/min at least. An eddy-current-based SQUID NDE system was constructed using an HTS SQUID gradiometer and Helmholtz-coil inducer. Thin copper tubes of 6.35 mm in diameter and 0.8 mm in thickness were prepared. They had artificial flaws of 100 micrometer in width, 15 mm in length and 10 to 100 micrometer in depth on the surfaces of the tubes, individually. In the preliminary research, the tubes were moved stepwise by a stepper-motor through the inducer, which generated an excitation field of 1.6 micro T at 5 kHz to induce eddy currents in the tubes. The gradiometer, which was set above the tubes with a lift-off 1.5 mm, could detect an anomalous magnetic response due to the flaw of 30 micrometer in depth with a signal to noise ratio of 20. After the improvement of the system, in which the tubes could be moved continuously by a motor, a flaw of 10 micrometer in depth was clearly detected by the system with a velocity of tube motion at 24 m/min.

WE-P3-113

Scanning SQUID Microscope for Magnetic Flux Detection

C.H. Wu[1], J.C. Chen[1], K.L. Chen[1], H.E. Horng[2], H.C. Yang[1], M.S. Syu[3]

1. *Department of Physics, National Taiwan University, Taipei 106, Taiwan*, 2. *Institute of Electro-optical science and technology, NTNU*, 3. *Department of Physics, Chung Yuan Christian University, Chung Li, Taiwan*

We have set up a scanning SQUID probe to study the circuit boards in unshielded environment. In order to improve its spatial resolution a permalloy needle was used as a flux guide. The flux guide makes it possible to measure sample in air room temperature. In order to reduce the distortion of magnetic field, the SQUID was designed with a superconducting flux transformer to focus flux into the pickup loop of SQUID magnetometer of SSM. The scanning SQUID probe detects the magnetic fields of circuits using the lock-in detection technique or directly measuring the magnetic field. Furthermore, we scanned the magnetic dots and plant magnetic field.

WE-P3-115

Multi-channel SQUID-based NMR and MRI at micro-Tesla Fields

R. Kraus, M. Espy, P. Volegov, A. Matlachov, J. Mosher, C. Carr

Los Alamos National Laboratory

We have built a prototype system for Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI) that employs a SQUID array (number of channels >10) and operates in measurement fields of the order of 10 microT. The system uses a pre-polarizing field of approximately 10 mT generated by simple room temperature wire wound coils that are turned off during the measurement period. The instrument has an open geometry with samples located outside of the cryostat at room temperature. We have obtained NMR spectra from a variety of samples including living tissue, and simple multi-channel MRI images have been recorded for a water-plastic phantom. Advantages to ultra-low field (ULF) NMR/MRI measurements include lower susceptibility artifacts caused by high strength polarizing and measurement fields, and negligible line width broadening due to measurement field inhomogeneity, reducing the burden of

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