A Study on the Effect of Influence of Weld Heat Affected Zone on the Magnetic Domain Arrangement

Juhyeon Park[1], Hoyong Lee[2], and Jinyi Lee[1*]

[1]IT-based Real-time NDT Center, Chosun University, Korea
[2]Department of Defense Science & Technology, Gwangju University, Korea

[*]Corresponding author: jinyilee@chosun.ac.kr

1. Abstract

Recently, a method for analyzing the magnetic field distribution on the surface of a test specimen to determine defects has been actively studied. Attention should be given to determine flaws by the magnetic field measuring method, as the change in the magnetic field generated in the weld area occurs due to the defect and the influence of the heat-affected zone (HAZ). This study proposes an experimental method to identity any change in the magnetic field distribution caused by flaws only by measuring the influence of HAZ. The test specimens were fabricated using 304L cladded SA516 material and the magnetic field distribution vector was measured in two dimensions using a tunnel magneto resistance (TMR) sensor. The magnetic field vector was measured as the heat input to the specimen. The cause of the magnetic hysteresis was identified by measuring the magnetic domain change with the intensity of the external magnetic field.

2. Introduction

Welding is a semi-permanent jointing method used for assembling large structures such as automobiles, nuclear power plants, thermal power plants, oil refineries, space stations, aerospace vehicles, ships, marine structures and bridges. In fusion welding, the surfaces of two separate metallic parts are melted so as to make them join using heat and pressure; this may result in pitting, slag mixing, poor fusion, and lack of penetration during the welding process. Moreover, cracks and corrosion of welds that occur during the usage of a large structure can lead to fracture. If the welding defects on a structure are found early and repair measures are taken, it can last until its design life, and further damage tolerance analysis can be used to extend the service life.

Liquid penetrant testing (PT) and magnetic particle testing (MT) are mainly applied as non-destructive testing methods for surface detects of welding [1]. In PT, the surface to be tested is cleaned and sprayed using dye to penetrate into the surface defects via capillary action. In this process, various chemicals such as penetrant, developer, and cleaning agent are used, and the temperature is varied from 15 to 50 °C for the chemical process. In MT, the ferromagnetic test specimen is magnetized by applying alternating current (AC) or direct current (DC), and the defects are identified by the shape of the magnetic particles emerging from the magnetic flux leakage area. When MT and PT are applied to vertical welds, use of chemicals is not easy due to gravity, also spray chemicals—such as magnetic particles, penetrants, and developers—are difficult to use in the field when the wind is strong, the weather is cold, or the humidity is high. Thus, developing a novel non-destructive testing method that minimizes the chemical impact on the environment, is free from the effects of climate, and has simplified process to reduce inspection time is necessary.

To satisfy the above requirements, surface inspection systems have been actively studied for analyzing the magnetic field distribution of welded structures by using a magnetic sensor arranged in one-dimension or two-dimension to determine existence of defects [2–3]. The magnetization characteristics affecting the magnetic field distribution vary greatly depending on the size, direction, and distribution of the magnetic domain of the test specimen. Therefore, understanding the influence of the characteristics such as heat, residual stress, intermetallic compound, and bead on magnetic domains of the welded area is critical to developing electromagnetic non-destructive testing method. Herein, we propose an experimental method to investigate the influence of heat, which is an inherent characteristic of the welded area, on the magnetic domain and report the results using tensile test specimens.

3. Results and Discussion

Fig. 1 shows the test specimen, and Fig. 2 shows the experimental setup. The specimens were machined from 304L cladded SA506 plates used for nuclear power plant pressure vessels into round tensile bars. The thickness of the base material is 43 mm, and the thickness of the clad is 3 mm. The total length of the test specimen is 88 mm, and the observation area has 32-mm width and 5-mm thickness. The observation area was processed to a surface roughness R_{max} = 6.3S. As the region closer to the cladded surface is more heat affected, three types of test specimens were made depending on the distance from the cladded surface.

The magnetic field of the test specimen observation region was measured and imaged using a TMR sensor having a spatial resolution of 10 μm in the circumferential direction (*Φ*) and the axial direction (*z*). The specimens were rotated in the circumferential direction using a low-speed motor, the sensor was mounted on the motorized stage, and moved in the axial direction. The magnetic flux density distributions in the axial direction and the circumferential direction were measured to obtain a two-dimensional magnetic field vector. To understand the fundamental cause of the magnetic hysteresis, the magnetic domain change with the intensity of the external magnetic field was measured, for which the tensile test specimens under test were gradually polished and the change of magnetic field vector according to the intensity of the external magnetic field was measured. Further details will be presented at the International Conference on Materials and Reliability (ICMR) 2019.

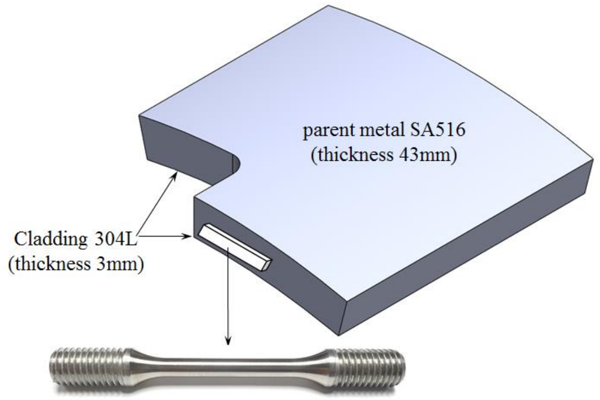

Fig. 1 Test specimen

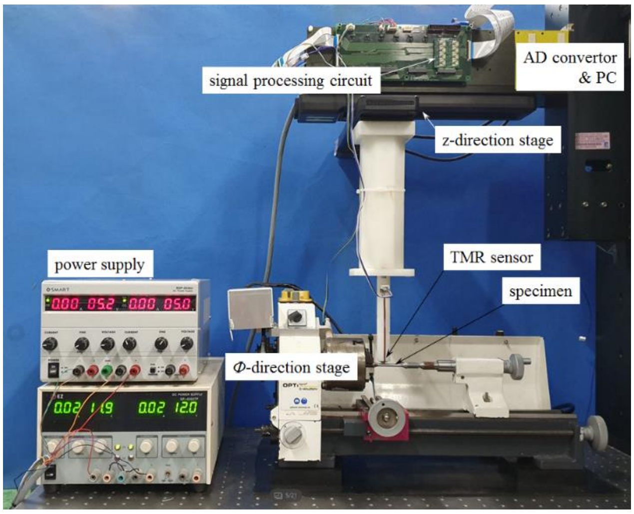

Fig. 2 Experimental setup

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