Nondestructive Evaluation for Small Plastic Deformation and Deformation Histories in Reduced-activation Ferritic/Martensitic Steels

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Abstract: Magnetic Barkhousen Noise, Magnetic Incremental Permeability and Magnetic Flux Leakage methods are non-destructive evaluation methods for ferromagnetic materials. Reduced Activation Ferritic/Martensitic (RAFM) steel is a new kind of ferromagnetic material considered to be an important candidate structural material for thermal nuclear fusion reactors. The feasibility to use magnetic non-destructive evaluation techniques of MBN, MIP and MFL methods to evaluate the plastic strains in RAFM steel is experimentally investigated in the previous work of authors. Results show that signals of these three method change dramatically in small plastic deformation. In order to enhance high detection precision for RAFM steel, the change of NDT signals in samples with small plastic deformation and plastic deformation history is studied experimentally in this study.

Keywords: RAFM, Small plastic deformation, Deformation history, NDE, Fusion reactors

１． INTERDUCTION

Reduced-activation Ferritic/Martensitic (RAFM) steel is considered to be an important candidate structural material for thermal nuclear fusion reactors because of its low activation, excellent mechanical property, and good microstructure stability[1]. The plastic deformation inevitably occurs during the operation of the reactor for reason of unexpected giant loading process, such as a large earthquake. Therefore, reliable Non-Destructive Evaluation(NDE) is needed. Magnetic Barkhausen Noise (MBN), Magnetic Incremental Permeability (MIP) and Magnetic Flux Leakage (MFL) as three typical electromagnetic NDE techniques for ferromagnetic materials were studied to evaluate the plastic deformation of RAFM steel in previous works[2]. The validity of these three methods is proved while the precision of small plastic deformation is still need to be improved. Therefore, the relationship between NDT signals and small plastic deformation in RAFM steel and the influence of plastic deformation history is studied experimentally in this work.

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２． EXPERIMENTS

2.1 Experiment systems

MBN, MIP and MFL methods describe the change of different magnetic properties during a magnetic procedure. An U shaped permalloy yoke, a group of excitation coils wounded on the yoke, a function generator and a power amplifier are used to generate integrated magnetization processes for the specimens. A high frequency sinusoidal excitation is also generated to get the signal of MIP in each time step by a lock-in amplifier. MBN and MIP signals are measured using a bottom coil of the ECT probe nearby the TP surface. MFL signals are collected by a Hall sensor which is set at the TP surface along the tensile direction. The functional block diagram of the experimental system is described in Fig.1.

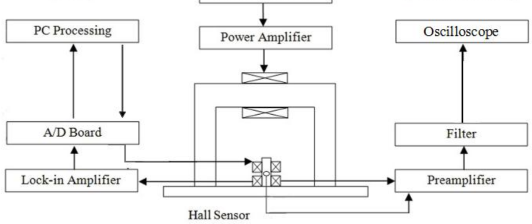


Fig.1 Integrate measurement system

2.2 Experiment procedures

Strain gages with the max value of 5% were used to control the deformation of specimens. Tensile machine INSTRON 5582 was used with displacement control in speed of 0.3mm/min. The specimens were divided into two groups to investigate the relationship between NDT signals and small plastic deformation in RAFM steel and the influence of plastic deformation history in small deformation. Different levels of residual plastic strains (0%, 0.1%, 0.3%, 0.5%, 1%) were applied to Group.1 (No.1- No.5 Specimens). For each specimen NDT signals of three points were acquired after unloading. Group.2 (No.6 Specimen) was stretched 4 times and NDT signals of three points were detected before each tensile test.

3． RESULTS

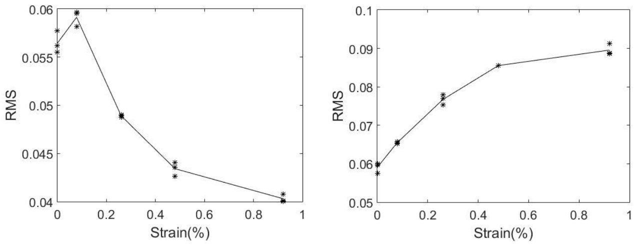
The correlation between the NDT signals and the residual strain is shown in Fig.2. *K* factor defined as formula (1) is taken as the feature parameter of MFL signals. Here A1， A3， A5， and A7 denote the amplitudes of high harmonics of the MFL signals.

$$K = \sqrt{\frac{A_3^2 + A_5^2 + A_7^2}{A_1^2}} \qquad (1)$$

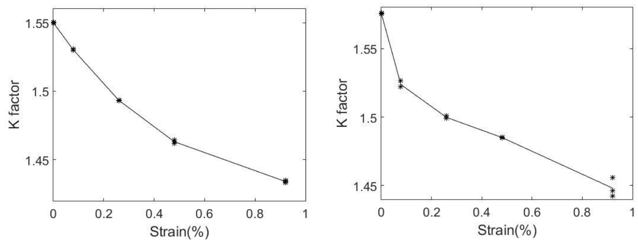
The results of MBN show different tendency to specimens with and without deformation history. The root mean square(RMS) of MBN signals specimens stretched only once are firstly increasing then decreasing with plastic deformation, the peak value is at around 0.1%. While the signals of specimens with deformation history show a rising trend. The K factor of MFL signals are not influenced by deformation history and decreasing monotonously with increasing plastic deformation. The Height of Imaginary Part (HIP) of MIP signals is not influenced by deformation history and have the same tendency with RMS signals.

4． SUMMARY

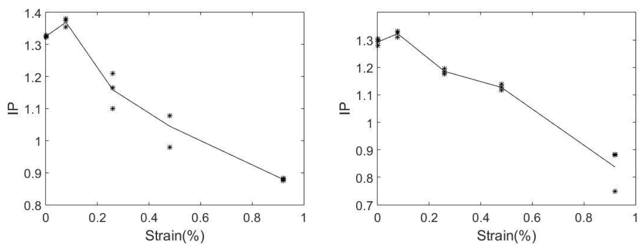
In this work, several NDE methods for small deformation were investigated experimentally. The relationship between NDT signals and strains was drawn. Plastic deformation history have influence on MBN signals in small plastic deformation while it does not affect MIP and MFL signals.



No.1-No.5 (a) MBN N.6



No.1-No.5 (a) MFL N.6



No.1-No.5 (a) MIP N.6

Fig.2 The relationship between NDT signals and strains a. Root mean square, b. *K* Factor, c. Height of imaginary part.

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