ABSTRACT OF THE DISSERTATION

Title: A study on electro-magnetic measurements of mechanically-induced martensite in Fe-based alloy during deformation at various strain rate

(変形中の鉄基合金を対象とした様々なひずみ速度における力学場誘起マルテンサイト相電気磁気測定法の研究)

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Recently, according to stress-induced martensitic transformation (SeIMT), shape memory alloys (SMAs) exhibit the unique and superior properties such as shape memory effect (SME) and superelasticity that have the ability to achieve huge deformation and recover a predefined shape after just unloading or upon unloading and heating. On the other hand, transformation-induced plasticity (TRIP) steel has attracted the interest of the scientific community because it has promising mechanical properties such as high strength, excellent formability, and toughness because of strain-induced martensitic transformation (SaIMT). Meanwhile, some researchers pointed out that the SeIMT and SaIMT properties of material strongly depended on the strain rate. However, up to now, it can be considered that experimental methods to evaluate the amount of martensite in Fe-based alloys including SMAs and TRIP steels, during deformation at various strain rates, particularly in the case of higher strain rate, becomes quite complicated and are not still well-established. Therefore, this study is mainly focused on electro-magnetic measurements of mechanically-induced martensite in Fe-based alloy during deformation at various strain rates.

In this study, firstly, the strain rate dependency of thermomechanical and SeIMT behavior in Fe-SMA is investigated. Before that, the plate specimens made of Fe-SMA with different grain size is prepared. Then, to investigate the strain rate sensitivity of SaIMT behavior, tensile tests are conducted on a metastable austenitic stainless steel, SUS304, at various strain rates. Furthermore, the changes in both volume resistivity and relative magnetic permeability of mechanically-induced martensite in Fe-based alloys during deformation at various strain rates will be estimated. On the other hand, the effect of a combination of grain size and strain rate on SME and thermomechanical properties of Fe-SMA will be examined. The dissertation includes the following chapters:

Chapter 1 introduces the research background, literature review, problem description, objective and structure of the dissertation.

In Chapter 2, the strain rate dependency and tension-compression asymmetry of thermomechanical and SeIMT behavior in Fe-SMA are investigated. During deformation at various rates, the SeIMT in Fe-SMA is estimated by using the developed measurement method of volume resistivity, and the temperature change is measured by using the extremely-thin thermocouple. After quasi-static deformation, the SME is evaluated by heating up the specimens to A_{f}. Not only that, microstructural investigations will be performed by the use of SEM at different stages. Based on these results, the difference in thermomechanical and SeIMT behavior in Fe-SMA for different strain rate and loading modes is clarified.

In Chapter 3, the strain rate dependency of thermomechanical and SaIMT behavior in SUS304 metastable austenitic stainless steels is studied. To evaluate the SaIMT of SUS304 under quasi-static tension, the real-time measurement method by measuring the relative magnetic permeability using an AC voltage supply is established. Besides, to determine martensite quantitatively and obtained the calibration curve with this magnetic measurement method, the suitable method for the quantitative determination of martensite such as XRD and SEM are used. In addition, due to the eddy current effects, the novel magnetic measurement with DC voltage is attempted to estimate the SaIMT at relatively high quasi-static strain rates particularly the impact strain rates.

In Chapter 4, the SaIMT behavior in SUS304 is estimated by using the electric measurement method used in Chapter 2, and then, based on the obtained experimental results of relative magnetic permeability with AC voltage in Chapter 3, the relationship between electric and magnetic properties of martensite will be discussed.

In Chapter 5, through the surface mechanical attrition treatment (SMAT) with different duration, the plate specimens made of Fe-SMA with different grain sizes are prepared. On the one hand, the effect of grain size on thermomechanical behavior is clarified. During deformation, the temperature change is measured by using thermography. On the other hand, the effect of a combination of grain size and the strain rate on SME is investigated by heating the treated specimens after the quasi-static tensile tests.

In Chapter 6, the main findings and conclusions derived from the results of the dissertation are described. In addition, the recommendations in the future works are proposed.