MLF Experimental Report

提出日 Date of Report
June 19, 2017

課題番号 Project No.2016B0087

実験課題名 Title of experiment
In situ Neutron Diffraction during Low-Cycle Fatigue Testing on Fe-Mn-Si-Based Alloys.

実験責任者名 Name of principal investigator
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装置責任者 Name of responsible person
S. Harjo

装置名 Name of Instrument/（BL No.）
TAKUMI (BL19)

実施日 Date of Experiment
Feb. 24-28, 2017 (5 days)
Mar. 2, 2017 (1 day)

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

- Fe-15Mn-10Cr-8Ni-4Si (mass%) alloy, Solid
- Fe-15Mn-10Cr-8Ni-3Si (mass%) alloy, Solid
- Fe-30Mn-4Si-2Al (mass %) alloy, Solid
- Fe-30Mn-3Si-3Al (mass %) alloy, Solid
- Fe-28Mn-6Si-5Cr (mass %) alloy, Solid

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）

Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

Three kinds of measurements were performed at BL19 of MLF J-PARC. The obtained results are still under analyses and discussion in order to make presentation and then submission as full papers.

(1) An evidence for reversible martensitic transformation under cyclic loading

We have proposed that low-cycle fatigue lives of Fe-high Mn alloys can be drastically improved when a reversible two-way martensitic transformations between γ-austenite and ε-martensite occurs. Up to now, however, the microstructural evidence for the latter phenomenon is limited. In the present experiment, we tried to prove the reversible martensitic transformation under cyclic loading in a Fe-30Mn-4Si-2Al steel that exhibits an extraordinarily long LCF life. A dog-bone type specimens was subjected to cyclic tension-compression loadings at room temperature, at the total strain range of 0.04, and at the strain rate range of 0.0004 - 0.004 s^{-1}.

During the cyclic deformation, neutron diffraction profiles were obtained by the two detector banks set at 90 degrees with respect to the incident beam. Fig. 1 exhibits the applied load history and the corresponding diffraction intensities of 10-11 ε in the two directions, which clearly shows the reversible martensitic transformation.

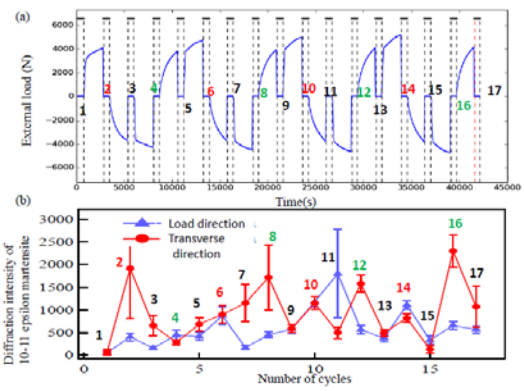

Fig. 1 Applied load history (a) and diffraction intensities of 10-11 epsilon in the two directions (b) for 4Si-2Al

2. 実験方法及び結果（つづき） Experimental method and results (continued)

(2) Effect of phase stability on the reversible martensitic transformation

The effect of phase stability between the γ- and ε-phases on the reversible martensitic transformation was examined by the LCF in-situ neutron diffraction at room temperature in different Fe-30Mn-(6-x)Si-xAl alloys, and by the LCF in-situ neutron diffraction at different temperatures in a Fe-28Mn-6Si-5Cr shape memory alloy.

In the both cases, the reversible martensitic transformation is obvious at a certain thermodynamic condition, i.e. at room temperature in the Fe-30Mn-4Si-2Al alloy and at 423 K in a Fe-28Mn-6Si-5Cr shape memory alloy. As compared to these, decrease in Al content in the Fe-Mn-Si-Al system or decrease in deformation temperature in the shape memory alloy resulted in rapid increase in the ε fraction under cyclic loading. For example, Fig. 2 exhibits the changes in diffraction profiles and load with time for Fe-30Mn-5Si-1Al alloy in the transverse direction. The diffraction intensities rather monotonically increase under cyclic loading, and the reversible transformation is less obvious. On the other hand, increase in Al content in the Fe-Mn-Si-Al system or increase in deformation temperature in the shape memory alloy diminished the ε-martensite.

The results clearly indicate that the phase stability between the γ- and ε-phases is one of the most important controlling factors affecting the reversible martensitic transformation. An optimum condition is considered to be $\Delta G^{\gamma\rightarrow\varepsilon} \approx 0$, where both of the forward and reverse martensitic transformations can occur with an equal possibility.

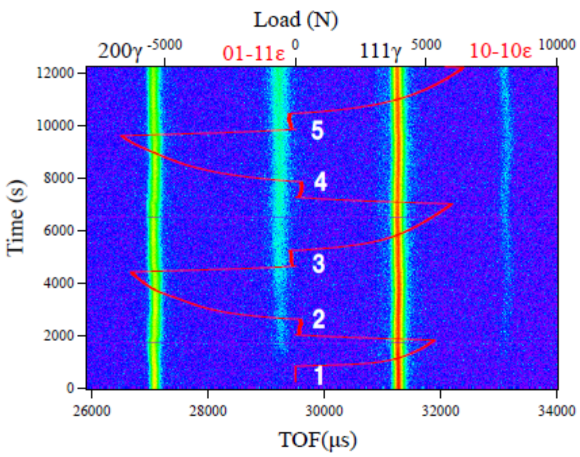

Fig. 2 Changes in diffraction profiles and load with time for 5Si-1Al in the transverse direction (led

(3) Comparison between tensile and cyclic deformations in Fe-15Mn-10Cr-8Ni-4Si alloy

Using a Fe-15Mn-10Cr-8Ni-4Si alloy, which is used as fatigue-resistant seismic dampers in a real construction, a comparative study was made on dynamic change in tensile and cyclically deformed microstructure by means of neutron diffraction. A special attention was paid to the evolution of martensite fractions of two types of martensites, namely ε-martensite and α’ -martensite.

It is well known that the α’ -martensite is formed at the intersections of the crossing ε-martensite variant plates on different {111} habit planes. In the studied alloy, this was more obviously observed in the tensile deformed microstructure, whereas the cyclic deformation exhibited less α’ -martensite. The increase in the ε-martensite versus accumulated plastic strain under cyclic deformation is also much slower than the increase in the ε-martensite versus monotonic increase in the tensile plastic strain.

The result suggests suppressed growth of both types of martensite under the cyclic deformation. Further analysis on this topic is still underway. Additional microstructural observations by ex-situ methods, such as EBSD and TEM is also ongoing.