

【Grant-in-Aid for Scientific Research (S)】
Science and Engineering (Engineering)



**Title of Project : Research on supreme fatigue property in steel:
importance of microstructurally-small fatigue crack**

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Research Project Number : 16H06365 Researcher Number : 40179990

Research Area : Structural and functional materials

Keyword : fatigue; fatigue crack arresting; strain aging; martensitic transformation; steel

【Purpose and Background of the Research】

Fatigue is one of most prevalent and historical causes of failure that affects all metals and alloys. Developing materials with strong resistance to fatigue is a critical challenge for our society, since fatigue failure severely restricts the long-term and safe application of advanced structural materials in various fields such as energy conversion, fusion power, light weight mobility, fuel cells and hydrogen-based industry cycles.

Recently, we have proposed two high strength materials with supreme fatigue properties: (1) precipitation-hardened aluminum alloy with distinct fatigue limit; (2) austenitic steel with superior low-cycle fatigue life.

It is well known that the fatigue limit of carbon steels is not the critical stress for crack nucleation but for crack propagation. It means that when a fatigue crack is nucleated, it can be stopped during further fatigue stress cycling at a relatively low stress level. In these circumstances, it is found in the case of material (1) that matrix strengthening near the crack tip is a key of appearance of the fatigue limit and atomic diffusion of a particular element affects the strengthening.

Low-cycle fatigue is a type of fatigue phenomenon where a large stress/strain is applied so that the number of cycles to failure (fatigue life) becomes less than 10,000 cycles. Typically, the fatigue life is reported to be around 2,000 cycles at a total strain range of 2 %. In contrast, we have achieved fatigue life of more than 10,000 cycles for material (2) where martensitic transformation from FCC to HCP occurs around a crack tip.

These new findings strongly encourage us to research and find a new design concept for material development with strong resistance to fatigue. In this research project, we make challenge to build up a new concept to develop advanced steels with supreme fatigue properties based on our new findings.

【Research Methods】

In the first half term of the project, FY2016 and 2017, the mechanisms contributing to the supreme fatigue properties of the materials (1) and (2) will

be investigated in details. Atomic diffusion causing matrix hardening called dynamic strain aging and shear type transformation allowing reversible deformation to take place dynamically around a crack tip during fatigue would be essential for the mechanisms.

In the second half term, FY2018 to FY2020, we will attempt to apply our obtained knowledge of mechanisms to the development of new steels: (a) austenitic stainless steels with high fatigue limit; (b) austenitic steel without deterioration of fatigue life even under hydrogen circumstance. Additionally, a new but fundamental research field called 'microstructurally-small fatigue crack' will be established.

【Expected Research Achievements and Scientific Significance】

Fatigue-resistant steel as well as hydrogen-resistant steel is a new type of steel which will be appreciated by society, i.e., hydrogen-based industry cycles. The fatigue crack propagation mechanism, especially for so-called microstructurally-small crack, with dynamic phenomenon of diffusion and transformation will give us a new fundamental research field of mechanical engineering and materials science.

【Publications Relevant to the Project】

Yun-Byum Ju, Motomichi Koyama, Takahiro Sawaguchi, Kaneaki Tsuzaki, Hiroshi Noguchi : "In situ microscopic observations of low-cycle fatigue-crack propagation in high-Mn austenitic alloys with deformation-induced ϵ -martensitic transformation", *Acta Materialia*, **112** (2016), 326-336.

【Term of Project】 FY2016-2020

【Budget Allocation】 151,000 Thousand Yen

【Homepage Address and Other Contact Information】

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