Fatigue Properties of Materials Designed in Harmonic Structure: Summary of Reported Results and Remaining Challenges

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A large spectrum of manufacturing processes has been implemented to improve various properties of materials. This is particularly critical in the case of metallic materials, since their mechanical strengths are intrinsically related to their microstructures. Recently, structures possessing an heterogenous grain size structure are reported to enhance the tensile properties of metallic materials[1]. Based on this concept, Prof. Ameyama has proposed a bimodal grain size microstructure, so-called the "harmonic structure", which presents a grain size gradient in three dimensions. Materials designed in harmonic structure are reported to show higher tensile strength and / or longer elongation at failure[2]. Nevertheless, mechanical responses to complex loading conditions, such as fatigue ones, have to be investigated in order to assure the reliability of this type of materials.

In this context, the investigation of the fatigue behavior of various metallic materials designed in harmonic structure started approximately a decade ago. Among the numerous academic reports published in the literature, numerous experimental conditions related to the material fabrication processing or to the fatigue experimental protocols have been studied. For instance, Guennec et al.[3)] have underlined an effect of the specimen size on the fatigue strength of Ti-6Al-4V alloy designed in harmonic structure, as represented by the model in Fig. 1. Furthermore, discussions dealing with the investigations on the fatigue crack propagation mechanism has naturally been carried out. As a result, the fatigue properties of such materials are, to some extent, relatively well-understood. Nevertheless, some critical aspects still need to be clarified.

In the present presentation, the major advancement in the overall comprehension of the fatigue behavior of metallic materials designed in harmonic structure will be analyzed from the viewpoints of the fatigue strength and the fatigue crack propagation mechanism. Then, a focus on the remaining challenges related to the comprehension of the fatigue behavior will be introduced.

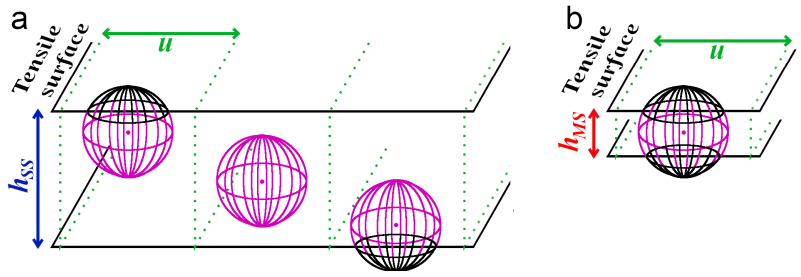

Fig. 1 Analysis of the specimen size effect on the fatigue strength of Ti-6Al-4V alloy designed in harmonic structure. (a) Large-size specimen; and (b) Small size specimen. Spheres represent the interface between coarse and fine grain regions.

1) X. Wu et al., PNAS, **2014**, 111, 7197.
2) M. Ota et al., *Mater. Trans*., **2015**, 56, 154.
3) B. Guennec at al., *Metals*, 2020, 10, 636.