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Phase Characterisation of Nickel-based Superalloys Using Ultrasound

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ABSTRACT

Nickel-based superalloys are a group of materials widely deployed across the engineering industry due to their excellent mechanical properties under harsh working conditions (especially in aerospace engines and power plants). However, there is a risk of undergoing microstructural phase changes at elevated temperatures, resulting in changes of mechanical properties which could compromise the safety of the components. Existing techniques to evaluate the phase changes of superalloys are typically destructive and costly, and this paper presents work towards developing a non-destructive, rapid and inexpensive evaluation method using ultrasound. After introducing the theoretical foundation of the technique, the experimental configurations including the ultrasonic scanning platform and sample preparations are described before presenting preliminary results from both ultrasonic and microscopic optical scans, on a range of samples that have undergone various heat treatment histories. Results from an initial set of Inconel 718 samples show that the ultrasonic responses have a clear correlation with the microstructure of the materials, a positive indication of the viability of the proposed method, and subsequent testing on a further set of samples having undergone different processing has allowed for initial phase composition estimates.

Keywords: Ultrasonics, Non-Destructive Evaluation, Materials Characterisation, Nickel-based Superalloys

INTRODUCTION

Nickel-based superalloys are widely across the engineering industry, due to their superior mechanical properties at elevated temperatures, and excellent resistance to creep and fatigue under harsh working conditions. The microstructure of the material, influenced by phase composition and grain size, greatly affects these characteristics. A notable superalloy is Inconel 718, where the amount of the gamma double prime phase precipitated within the main gamma phase matrix is most important for material performance – though other phases are also present, including the gamma prime and delta phases. Existing methods for material characterisation are destructive, expensive and time-consuming (such as SEM and EBSD), as are techniques for determination of fatigue life of components (which require surface preparation for hardness testing); hence it would be highly beneficial to develop a non-destructive, rapid and reliable method enabling quick inspections for characterising a material's microstructure to assess its suitability for a particular application, or indeed to tailor the properties to optimise a component's design.

PAPER SUMMARY

This project aims to develop a non-destructive inspection method using ultrasound for phase characterisation of nickel-based superalloys. The technique uses a spherical convolution theoretical basis, which has been successfully applied to extracting texture information of other crystalline materials (including titanium, zirconium and stainless steels [1]), but has not previously been utilised for nickel-based superalloys (which have a slightly different crystal structure). In contrast to existing characterisation techniques, this method requires minimal surface preparation, and gives a statistical average over a volume (as opposed to surface or near-surface measurements only), thus greatly reducing the overall time of inspection. Four samples of Inconel 718 were used for this investigation, two of which were retained in the as-received condition with the others undergoing a heat treatment simulating heat damage.

Experiments have shown conclusive evidence that this spherical convolution technique is capable of detecting phase changes within the material [2]; the uncertainty of the ultrasonic water tank system has also been quantified. This test setup has also been used to acquire attenuation measurements, with the aim of combining these two streams of information as a useful tool for fatigue life analysis. Subsequent tests on a further set of Inconel 718 samples which have undergone different heat treatment processes have been used to predict the amount of delta phase present [3], and thus laid the foundations for the development of this method for rapid phase characterisation of nickel-based superalloys; further investigations will include applying the method to other nickel-based superalloys, such as Udimet 720Li, to assess its effectiveness with differing material microstructures and precipitates.

REFERENCES

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