Project for Master student

Measurement of the internal energy variation on metals under cyclic loading in tension and torsion in the macroscopic elastic domain.

Application to a quick fatigue strength determination method in the high cycle fatigue regime (10^6 - 10^7 cycles).

Many papers in literature are devoted to fast experimental techniques to determine the fatigue strength of metallic alloys in the high cycle fatigue regime, 10^6 – 10^7 cycles (for instance: Luong [LUO98], Larosa [LAR00], Meneghetti [MEN07], Munier [MUN14]). These methods are based on material self-heating measurements. However, there is no method allowing us to do an energy balance between the mechanical energy given to the material, the energy stored in the material and the thermal energy dissipated in heat.

The aim of this project is to quantify the internal strain energy variation in a metallic alloy depending on both the level of the cyclic loading and the material parametric state (surface roughness, heat treatment, residual stresses, fatigue damage, etc.) The final aim is to propose a mechanical method for a fast determination of the high cycle fatigue strength of metals.

According to the first thermodynamic principle, the internal strain energy variation in a material is the difference between the stored energy per cycle, ΔW, (directly measurable on a resonant testing machine) and the thermal energy dissipated in heat, ΔQ. This last energy can be deduced from the temperature field measured at the surface of a specimen under mechanical loading (sinusoidal in our case).

For calculating energy balances needed to determine this variation of the internal energy, mechanical and thermal measurements will be carried out on two resonant testing devices (one in fully reversed torsion, one in tension compression). These original testing devices, available at I2M, are operating at the mechanical resonance of the whole experimental set up (80 to 300 Hz) [NOU 84].

About the mechanical energy: the design of these experimental devices allow us to determine with a high accuracy (better than 10^{-4}) the volumetric density of the absorbed strain energy per cycle, ΔW, by using a differential method. Furthermore, temperature measurements (by infrared thermography or thermistances in a few points) will be used to compute the strain energy dissipated in heat, Q. Then the quantification of these energies will be used to compute the variation of the internal strain energy, ΔU, during cyclic tests. It will be necessary to identify all the causes of energy absorption in a material under cyclic loading (cyclic strain hardening, damage, etc.). After an exhaustive review of these causes, a hierarchy will be proposed for each load level, based on the magnitude order of the corresponding energy.

The aim of this project is to propose a model and an experimental methodology for determining the variation of the internal strain energy stored in a material loaded in HCF regime (10^6 à 10^7 cycles), i.e. when the material is loaded in its macroscopic elastic domain. Consequently, it will be possible, with a fast experimental technique, to determine the HCF strength of a metallic alloy having a low structural damping and a high thermal conductivity. Preliminary results are very interesting on aluminium alloys (2000 series) whereas thermal methods do not give good results for these alloys because of their high thermal conductivity and their low internal damping.

References

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[LAR00] G. La Rosa and A. Risitano (2000) Thermographic methodology for rapid determination of the fatigue limit of materials and mechanical components. Int. J. Fatigue 22, pp. 65–73.

[FAR02] G. Fargione, A. Geraci, G. La Rosa and A. Risitano (2002) Rapid determination of the fatigue curve by the thermographic method. Int. J. Fatigue 24, pp. 11–19.

[MUN14] R. Munier, C. Doudard, S. Calloch, B. Weber (2014) Determination of high cycle fatigue properties of a wide range of steel sheet grades from self-heating measurements, International Journal of Fatigue, 63, pp. 46-61.

[MEN07] G. Meneghetti (2007) Analysis of the fatigue strength of a stainless steel based on the energy dissipation, International Journal of Fatigue, 29, pp. 81–94

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Date / duration: 5 to 6 months from April 2018 (or next month)

Location: Institute of Mechanics and Mechanical Engineering (I2M), UMR CNRS, Bordeaux France.

Language for working: French or English

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