STATISTICAL FRACTOGRAPHY: THE MISSING LINK BETWEEN FRACTURE MECHANICS AND FAILURE ANALYSIS

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Introduction

The in-service failure of critical components represents a unique opportunity to determine their real conditions of use and thus can, in principle, guide the (re)design of new components with enhanced reliability and durability. However, standard fractographic tools only provide qualitative information limited to the failure mode, rendering the practical implementation of such an approach extremely challenging.

Statistical fractography, a new engineering technique halfway between data science and failure analysis, fills this gap. Resulting from 30 years of research [1], it extracts mechanics data encrypted in the fracture surfaces from the statistical analysis of their roughness [2]. Statistical fractography provices the in-service mechanical load and material properties, thus paving the way to a fracture mechanics modelling of the in-service failure of critical components.

Results

An example of a rather simple failure analysis carried with statistical fractography is provided in Fig. 1. As a starting point of the approach, the fracture surface of the failed part is scanned with a profilometer to measure its topography. The resulting heigh map is then post-treated using statistical tools that determine different types of information. Like standard fractographic analysis, statistical fractography provides the failure history (crack propagation direction and initiation, crack propagation mode…) and thus may assist traditional expertise. More remarkably, it also measures previously inaccessible data if the elastoplastic properties of the material are known. In particular, statistical fractography provides the in-service mechanical properties of the failed material, like its toughness, its failure strength or its fatigue resistance. Using fracture mechanics, one can finally determine the applied mechanical load at failure, like e.g. the stress applied locally at the location of the crack initiation, but also the load applied gloabally on the part when failure took place. These information, complementary to the classical metallurgic analysis, are precious to determine the failure root causes. In particular, it informs whether the part has been over-loaded or the material resistance is as large as expected.

This technique has now been used for a few years in Europe for determining the root causes of critical in-service failure in the aeronautics, train, automotive and energy sector. In this presentation, I will show through several examples [3] how statistical fractography changes the scope of failure analysis by providing not only the root causes of failure events with unprecedented details but also key information that make failure analysis, more than ever, a keystone for corrective action, (re)design [4] and development of new and more reliable products.

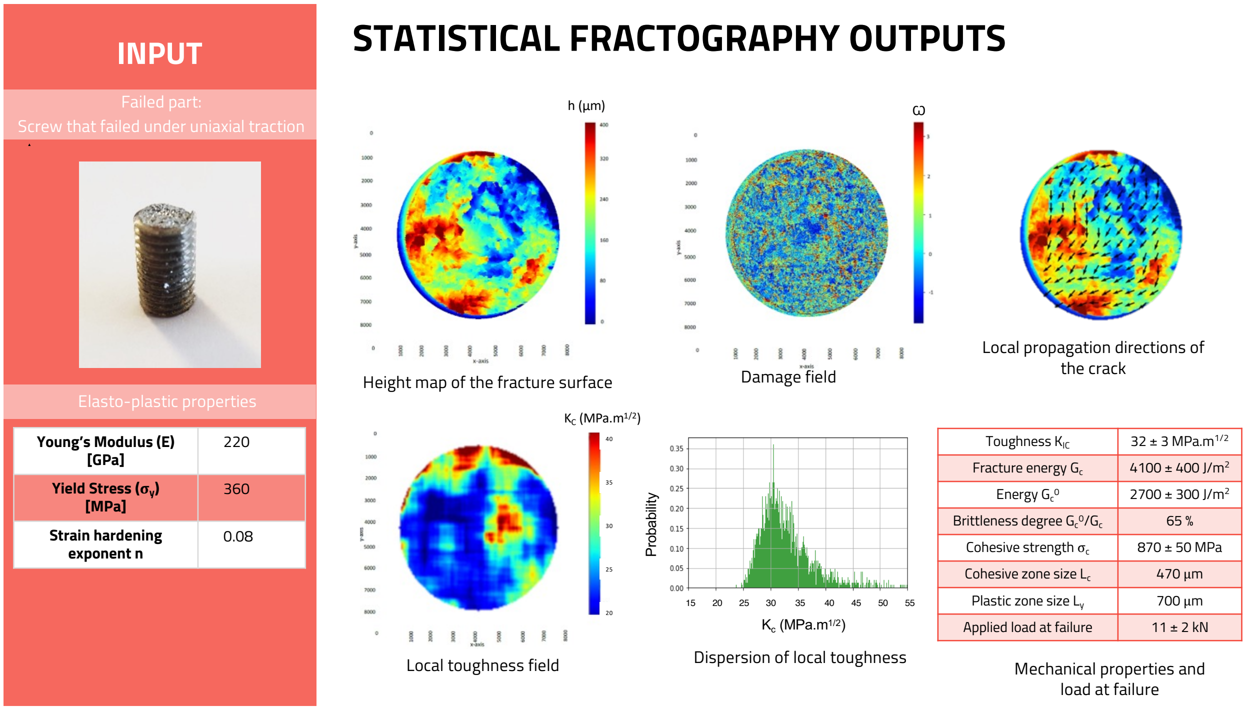

Fig. 1 – An example of simple failure analysis carried with statistical fractography. The topographic map of the fracture surface serves as input data together with the elastoplastic properties of the material. As output, the technique provides the failure mode and crack propagation history, like standard fractographic analysis. But more remarbly, it also provides mechanical data innaccesible before, like the fracture properties of the failed material. Ultimately, using fracture mechanics, one can determine the load amplitude applied in-service to the part when failure took place, a crucial information to discriminate different faiure scenarios and design new parts with enhanced reliability and durability.

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