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GOOD PRACTICE FOR GRAIN SIZE MEASUREMENT AND POST PROCESSING

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After completing a PhD in Materials Science, I joined the CNRS in 1991. I carry out my work as a CNRS research director at the Pprime Institute on the ENSMA site. My research focusses on the microstructure/mechanical property relationships of metallic materials, specifically on deformation and damage mechanisms to address durability issues under near in service conditions. This research aims to understand the mechanisms governing the transition between plasticity localisation and crack initiation under fatigue/creep/dwell conditions, often at high temperatures and in interaction with environmental processes such as oxidation. The alloy classes considered are primarily nickel-based superalloys, titanium alloys, and stainless steels. Studies focus on optimising microstructures and/or predicting service life. Beyond mechanical testing, scanning electron microscopy (SEM) is a central tool in these studies, particularly with the contributions of EBSD, a technique I introduced to the laboratory in 1994. This work is conducted within the framework of strong industrial partnerships in the aerospace sector (SAFRAN (SAE, SHE, Safran-Tech, SLS, etc.), Airbus, Aubert & Duval, Timet, etc.) as well as the energy sector (EDF, AREVA). Key elements: numerous collaborative programmes such as ANR, chairs, lab.com; 60 supervised theses; more than 150 articles – H-index 40.

1. ABSTRACT

It has been known since the beginning of the last century that the mechanical properties of metals and metallic alloys are often closely linked to grain size. This quantity has been introduced into numerous phenomenological models, allowing us to predict, for example, the yield strength or fatigue life.

Grain size characterisation for these models most often comes from the analysis of images obtained by optical microscopy or scanning electron microscopy. Various geometric-mathematical methods have been developed to extract a quantitative value associated with grain size. However, these methods can be questioned in terms of their representativeness and accuracy. For example, the ASTM grain size often used in the quality departments of metallurgical companies, can obscure key elements regarding the relationship between granular microstructure and properties.

The advent of EBSD has allowed for a re-examination of these concepts. This presentation will begin by revisiting the definition of what is considered as a metallurgical grain. Aspects related to EBSD data acquisition will be addressed, emphasising the definition of the need: Are we seeking to best describe a statistical distribution of grain size or to precisely describe grain contours, for example? Data processing will be discussed, including the exclusion of pixels that cannot be representative of grains. The representation of data in numbers or areas, and the inclusion or exclusion of twins in the grain definition, will be discussed. Examples will illustrate different grain size distributions, raising questions about the use of mean or maximum values to describe distribution and distribution tails. Texture aspects will be addressed through the crystal orientation distribution as well as through the morphological factors of the grains. Since the grains of a polycrystal are not always in an equivalent metallurgical state, orientation dispersion and/or orientation gradients within the grains will be discussed, as well as the presence of sub-grains. Tools for local measurement of disorientations (kernel and other quantities) to describe perfectly recrystallised or deformed grains will also be presented.

The aim of this presentation is to illustrate how EBSD enables a very rich, precise, and quantitative analysis for describing microstructures around the granular scale. Its advantages, as well as some limitations and even artifacts, will be discussed. The examples considered will concern metallic alloys, but the concepts discussed could very well be applied to other classes of materials.