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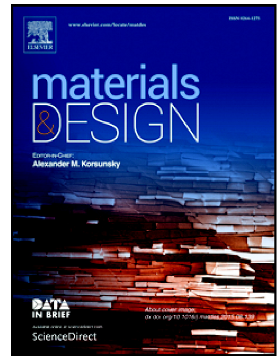

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New Methods for Automatic Quantification of Microstructural Features Using Digital Image Processing

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ABSTRACT

Thermal and mechanical processes alter the microstructure of materials, which determines their mechanical properties. This makes reliable microstructural analysis important to the design and manufacture of components. However, the analysis of complex microstructures, such as Ti6Al4V, is difficult and typically requires expert materials scientists to manually identify and measure microstructural features. This process is often slow, labour intensive and suffers from poor repeatability. This paper overcomes these challenges by proposing a new set of automated techniques for 2D microstructural analysis. Digital image processing algorithms are developed to isolate individual microstructural features, such as grains and alpha lath colonies. A segmentation of the image is produced, where regions represent grains and colonies, from which morphological features such as; grain size, volume fraction of globular alpha grains and alpha colony size can be measured. The proposed measurement techniques are shown to obtain similar results to existing manual methods while drastically improving speed and repeatability. The benefits of the proposed approach when measuring complex microstructures are demonstrated by comparing it with existing analysis software. Using a few parameter changes, the proposed techniques are effective on a variety of microstructure types and both SEM and Optical microscopy images.

1. Introduction

The microstructure of a metal often reveals important information about its mechanical properties, such as strength, ductility, yield stress, tensile strength, hardness and surface roughness among others [1], [2]. In fact, the ability to control the microstructure of a manufactured part has now become a key aspect of many manufacturing techniques [1]. Differences in thermal and mechanical processing can produce different microstructures and therefore components with different properties. Carefully controlling these factors allow material properties to be refined to best suit a specific application [3]. Development of new manufacturing processes or models, and the existing design and manufacturing of high value components, must consider the effect of the microstructure of the material. This makes microstructural analysis essential for many academic and industrial projects.

Microstructures can contain a variety of different features, each often requiring different analysis procedures to measure them. Several techniques have already been proposed to measure a range of microstructural features, however, all have limitations that still need to be addressed.

The American Society for Testing and Materials (ASTM) produce industrially recognised standards for the analysis of material microstructure. The ASTM E112 standard describes streamlined methods for manually measuring average grain size based on linear intercepts of line segments [4]. A set of lines are overlaid on an image and marked at locations where they cross a boundary between grains. The mean displacement between these marks gives an approximation of the mean grain size of that microstructure. Typically, only a subset of grains is measured, with 300 measurements required for statistically valid results. If the set of lines is placed randomly, then the result would be free from bias but the aspect ratio of grains could not be calculated. Manually selecting lines, so that they run the length and width of each grain, allows for more detailed measurement but at the cost of exposing the result to bias, as users can select which grains to measure. The ASTM E562 standard describes techniques to measure volume fraction based on point counting [5]. A set of points are distributed throughout