A method for identification of high-quality subsets within a domain of interest - estimation of microscale strain fields in pearlitic steel using DIC and in-situ SEM

E. Dartfeldt[1a], J. Ahlström[2], M. Hörnqvist[2] and R. Peng[3]

[1]SP Technical Research Institute of Sweden, Borås, Sweden, [2]Chalmers University of Technology, Gothenburg, Sweden, [3]Linköping University, Linköping, Sweden

[a]erik.dartfeldt@sp.se

Abstract. In this contribution a method for identification of high-quality subsets within a domain of interest is proposed. The method is based on the eigenvalues of the Hessian of the autocorrelation function and the initial standard deviation of the subset. The proposed method is evaluated using in-situ SEM images of a pearlitic microstructure. Rather than using a synthetic speckle the microstructure of the pearlite (cementite lamellae embedded in a ferrite matrix) is used as a natural speckle.

Introduction

The objective of the present contribution is to develop a method that can identify high quality subsets within a Domain Of Interest (DOI) of a specimen. The term “high quality” refers (in this context) to the ability to identify the motion of the subset with high accuracy. The method is particularly aimed at situations where it is difficult to apply a synthetic speckle. The proposed method is evaluated using in-situ SEM images of pearlitic steel where the microstructure of the material is used as a natural speckle.

Identification of high quality subsets

A subset needs to fulfil two criteria in order for its motion to identifiable with adequate precision. To begin with, the subset needs to contain enough information meaning that the Intensity Field (IF) within the subset needs to span over a sufficient range. This quantity can be measured by the standard deviation (of the IF) within the subset. However, this requirement is insufficient. Consider, for example, the situation where the IF only varies in one direction. In that case it will only be possible to identify the motion of the subset in that direction. This quality can be measured by the eigenvalues of the Hessian of the autocorrelation function. Examples of subset of varying quality are shown in Figure 1.

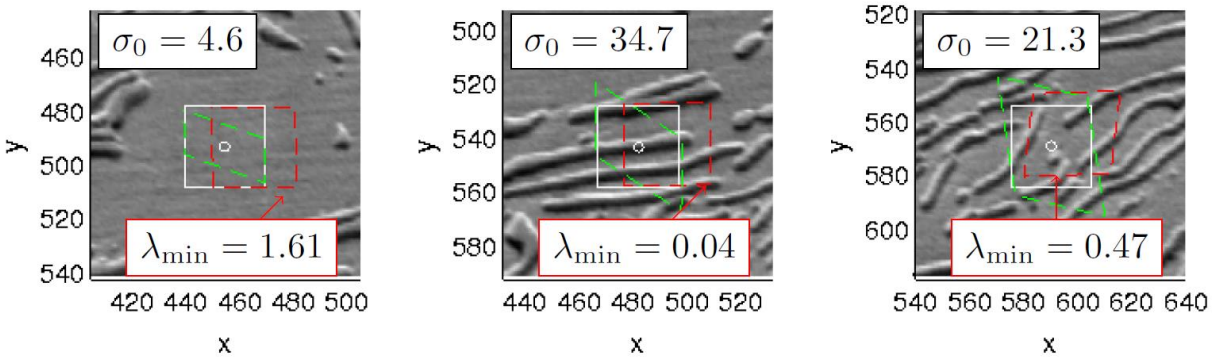

Figure 1: Subsets of varying quality. Left: low initial standard deviation. Mid: low eigenvalues. Right: Subset with both large standard deviation and large eigenvalues.

The proposed method used these two criteria to identify good subsets within the DOI. All subsets are required to have a standard deviation greater than a predetermined value. It is also required that all eigenvalues (as discussed above) are greater than some value. The result of applying the method to an SEM image of pearlite can be seen in Figure 2 where it can be noted that problematic areas are avoided.

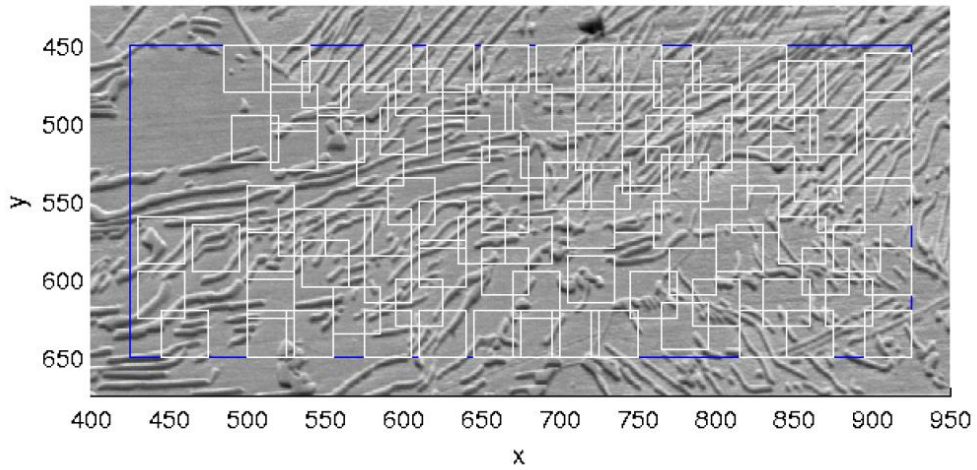

Figure 2: Identified subsets within the DOI.

Error estimation using synthetic deformations

In this contribution the DIC implementation was validated using a series of synthetically deformed (uniaxial elongation) images. Since the exact motion (in the image plane) is known the errors in the identified motion can be measured. This opens up the possibility to study the impact of the method parameters (subset size, grid spacing, order of the kinematic approximation, etc) on the errors to be studied. In Figure 3 the local displacement error is plotted against the loading (uniaxial straining) for different choices of method parameter values.

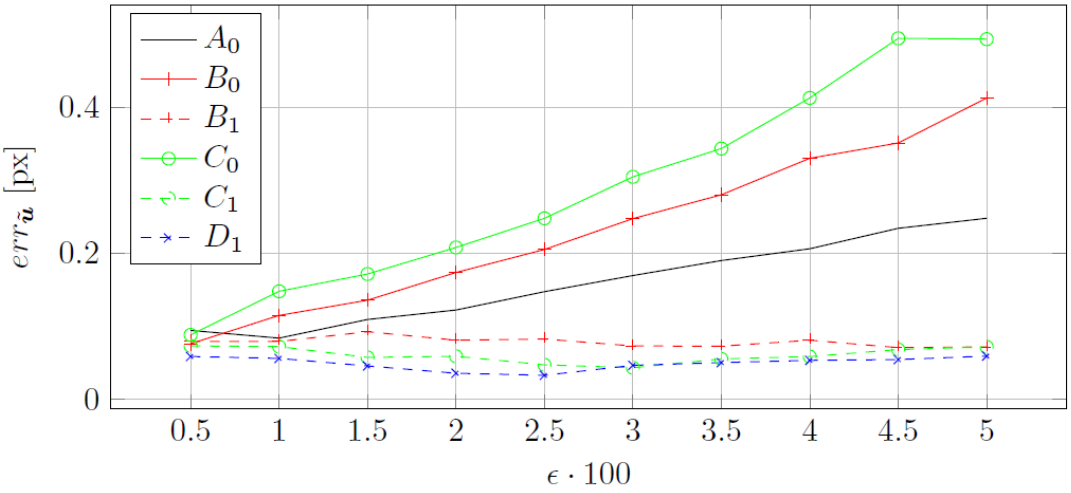

Figure 3: Maximum error of local subset displacemt plotted as function of the applied loading (uniaxial straining) evaluated for different method parameters (subset size and order of kinematical approximation).

Conclusion

The aim of this study is to develop a method that can be used to identify high quality subsets within a domain of interest. Such a method, based on the initial standard deviation of the subset and the eigenvalues of the Hessian of the autocorrelation function, is proposed. The results show that the method successfully avoids areas where the image contents is such that it is likely that it will be difficult to identify the motion of the specimen in the particular region with sufficient precision. The method has been applied to in-situ SEM images of pearlite where the microstructure of the specimen is used as a natural speckle. In such a situation is may be difficult to apply a synthetic speckle.

References

[1] To be provided