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50. Internationales Wissenschaftliches Kolloquium
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Effect of the grain anisotropy on the dimensioning of micro components

ABSTRACT

To ensure the reliable dimensioning of micro components the three-dimensional modelling of the microstructure of micro components is presented. The influence of the material anisotropy of the grains on stresses has been analysed.

Introduction

To reduce development times and costs, modern product development processes employ numerical methods. However, sine new effects e.g. caused by material anisotropy occur in the dimensions of micro technology, the question arises how these can be considered within numerical simulations.

Modelling

Generally microstructures are described with voronoi-mosaics [1] based on a random poisson point process [2]. These computed microstructures than can be meshed with finite elements [3] and analysed by means of a finite element analysis after the material modelling and the application of boundary conditions. This approach is adequate for two-dimensional secnarios [4], but not for three-dimensional examinations due to the complex meshing process of the grains as well as the micro component. In order to modell a three-dimensional microstructure of a micro component, the micro component is meshed as a whole in a first step and the geometrical element centroids are derived. In a second step the micro component is imported into a software tool and filled with a point field by a random poisson point process. In a next step the finite elements are associated with a point of the field by means of an evaluation of their centroids' distance to the nearest point. Each finite element is then clearly associated with one random point. Therefore all finite elements of a random point describe one grain. This procedure leads to a meshed micro component with its microstructure.

The grains are considered as single crystals with anisotropic behaviour and a random orientation of the crystallographic axes. The orientation is described by Euler angels which are used as random variables. For the analysis material property files with random material orientations based on single crystal values for an arbitrary amount of grains were generated.

Results

The influence of the grain anisotropy in the case of complex geometries has been studied at the tooth root of a micro planetary wheel tooth of 17-4PH. The tooth width was 156 µm and the grains size has been varied between 80 µm to 20 µm, which means 30 to 1.000 grains in the whole model. Each model has been analysed with 50 different anisotropic material files.

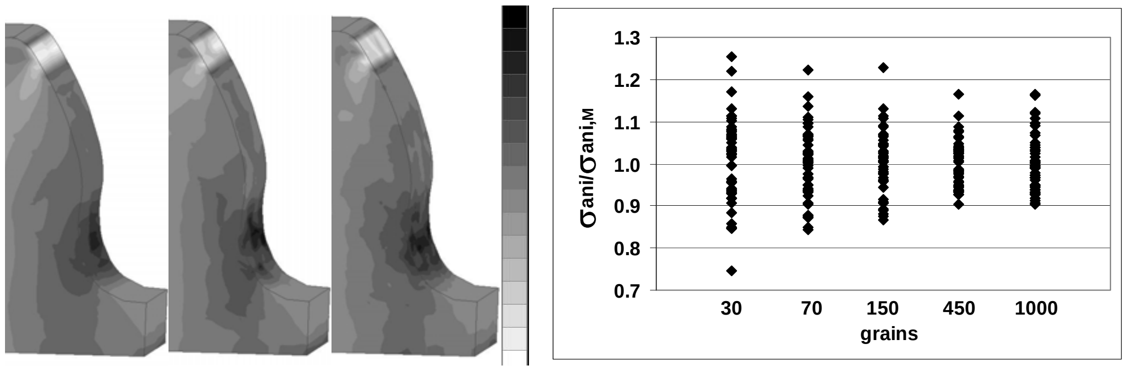

Fig. 1: tensile stress distribution at the tooth root (30 grains on the left, 150 grains in the middle and 1.000 grains on the right) and scatter of the maximum von Mises stresses of the different models.

The stress maxima always occur at the tooth root but are varying by means of their amplitude and location within the critical area depending on the anisotropic material file (see figure 1). It can be observed that the scatter decreases with an increasing number of grains in the tooth root. For a given grain size it is therefore possible to derive safety factors for the dimensioning.

Conclusion

A method for the modelling of the microstructure of three-dimensional micro components has been presented. For a reliable dimensioning of micro components with only few grains in critical areas it is now possible to obtain information about the scatter of the stresses which allows an improvement of the dimensioning of those micro components.

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