Hessisches Kompetenzzentrum
für Hochleistungsrechnen

Modelling of the Deformation Behaviour of Metal-Matrix-Composite Material with Brittle Cores

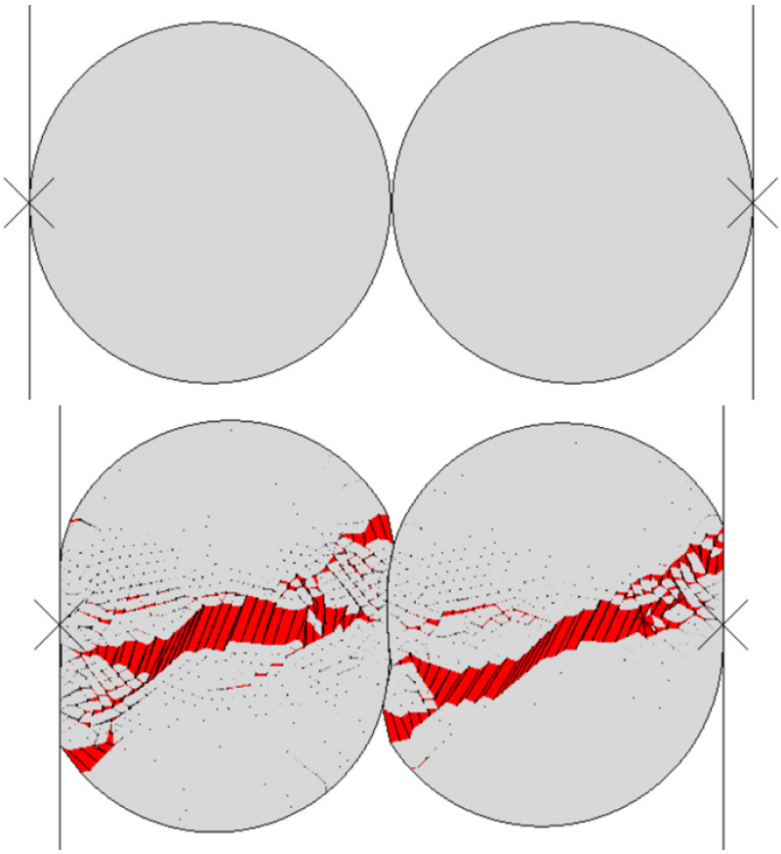


Figure 1: Simulation of brittle fraction behaviour of two Nd-Fe-B grains.

Introduction

Permanent magnets are the key component of electric motors and generators, which currently have a high demand in the renewable energy sector. Within this project, advanced manufacturing technologies, such as rotary swaging, are used for optimizing the nanostructure and magnetic hysteresis of permanent magnetic materials. Since it is not possible to observe the change of microstructure during the manufacturing processes, goal of this project is to simulate the microstructural evolution with the help of HPC to research the mechanical influences on the final products.

Methods

Finite-Elemet-Method (FEM) simulations combined with Discrete-Element-Method (DEM) and Cohesive-Interface-Element (CIE)

Project Manager
Fansun Chi

Principal Investigator
Prof. Dr.-Ing. Dipl.-Wirtsch.-Ing. Peter Groche

Project Term
2021 - 2022

Clusters
Lichtenberg Cluster Darmstadt

Software
Abaqus

Institute
Institut für Produktionstechnik und Umformmaschinen

University
Technische Universität Darmstadt

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
TECHNISCHE UNIVERSITÄT DARMSTADT
UNIKASSEL VERSITÄT
Philipps Universität Marburg

were applied for the research goal. Abaqus Version 2020 from Dassault Systemes was chosen as the solver. With this method, it is able to simulate the fragmentation process of the brittle Nd-Fe-B grains. In this model, separations of conventional material elements occur when the fraction energy of CIE is exceeded. Different mechanical boundary conditions were applied in the processes and as result, the distributions of fragmented grain size are compared, in order to find the optimal process parameters for a fine-grained permanent magnet microstructure by rotary swaging. The following parameters were varied in the FEM model: Grain size, velocity, grain shape and exposure to oscillation.

Results

A 2D FDEM model was successfully built for simulating the brittle fracture of Nd-Fe-B grains in micrometer level. Thereby, the geometry data, the material parameters, the mechanical conditions and other setups (mesh size, mesh type, mass scaling) are set and tested for correctness. In addition, the setups (number of cores, usage of CPU memories) for executing jobs were optimized. With the first comparison of simulation results, it can be found that the difference of grain sizes is a main factor for the homogeneous fragmentation. We can observe that the greater the difference of grain size between two grains is, the more fragmented is the smaller one of both grains. This means, the large differences of grain size should be avoided during the whole process. Furthermore, the differences of fragmentation results can be observed by varied grain geometry, collision speed and direction of mechanical stresses.

Discussion

The fact that in a collision between large and small grains the latter breaks more strongly can be attributed to the higher Hertzian contact stress present here. Current simulations suggest that a high collision speed can lead to an improvement of the homogeneity of the grain size distribution. In order to validate these simulation results, parallel forming tests are carried out via rotary swaging and the microstructure of samples were researched by Scanning electron microscope (SEM) after processing. In addition, further simulations are necessary to investigate more process parameters with regard to their influence on the grain crushing and thus to find optimal process and material parameters.

Last Update: 2023-01-06 12:27