

The artificial microstructure model and its applications on plasticity and damage of the dual phase steel

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“If you don’t believe you can do it then you have no chance at all”

Arsene Wenger

For the people who got the hard copy and would like to have the coloured pictures, please contact me via nvajragupta@gmail.com. I will be happy to provide you the further information.

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Abstract

In the recent decades, notable development on the computing power improves the human understanding about the microstructure-properties relationship. This results in the development of the new materials with enhanced properties. Micromechanical modelling approach is also another example of the computational materials discipline that has been heavily involved in this evolution of materials science and engineering. In the field of micromechanical modelling, the representative volume element (RVE) or the microstructure model is considered as one of the crucial issues as it must carry all the necessary information about the microstructure morphology into the practical numerical simulation. Furthermore, some of the RVE properties such as the periodicity, grain's geometry etc. are also required. Nonetheless, most of the available platforms to generate the RVE still cannot fulfil all of these demands. It is then the responsibility of the micromechanical modelling community to come up with the platform to generate the RVE in which these needs can be met.

Therefore, the objective of this study is to develop a universal platform for the generation of the RVE and it is called "The artificial microstructure model". This platform makes use of the necessary statistical information about the microstructure morphology as the input parameters for the weighted Voronoi tessellation based algorithm. Furthermore, the applications of this artificial microstructure model on plasticity and damage modelling of the dual phase steels are also discussed. As these applications require the plasticity descriptions of the constituents, the sound plasticity models along with the parameters calibration techniques are applied. For ferrite, phenomenological crystal plasticity framework is implemented whereas the nanoindentation test is used for the parameters calibration. Meanwhile, martensite deploys the empirical approach based on the measured local chemical composition to approximate the flow curve. Concerning the damage modelling, the hybrid approach combining the in-situ bending test in the large chamber scanning electron microscope (LC-SEM) with the micromechanical-based simulation discipline is conducted to characterize the microcrack initiation criterion. By integrating these work packages together, the application of the artificial microstructure model on plasticity and damage modelling of the dual phase steels can then be completed.

Kurzfassung

Die in den letzten Jahrzehnten bemerkenswert gesteigerten Rechenleistungen haben zu einem besseren Verständnis des Mikrostruktur-Eigenschaften Verhältnisses geführt. Dies kann einen wesentlichen Beitrag zur Entwicklung neuer Werkstoffe mit verbesserten Eigenschaften leisten. Als Anwendungsbeispiel in der Werkstoffmechanik ist der Ansatz der mikromechanischen Modellierung ein zentraler Bestandteil der Entwicklung innerhalb der Werkstoffwissenschaften. Im Bereich der mikro-mechanischen Modellierung stellt der Aufbau eines repräsentativen Volumenelements (RVE; auch Mikrostrukturmodell benannt) eine der Kernfragen dar, da es die wichtigsten Kennwerte der Gefüge-morphologie für eine zuverlässige numerische Simulation enthalten muss. Ferner ist die Berücksichtigung weiterer RVE Eigenschaften wie die Periodizität, die Korngeometrie usw. erforderlich. Nicht-destotrotz kann die große Mehrheit der aktuell vorliegenden RVE Erstellungs-algorithmen diese Anforderungen nicht vollständig erfüllen. Es ist daher eine wichtige Aufgabe der mikromechanischen Modellierungs-Gemeinschaft, umfang-reichere RVE Erstellungsalgorithmen bereitzustellen, so dass den Anforderungen Rechnung getragen wird.

Dementsprechend ist das Ziel dieser Arbeit, eine Universalplattform zur Erstellung von RVEs zu entwickeln. Dieser wird die Bezeichnung „Das künstliche Mikrostrukturmodell“ verliehen. Diese Plattform benutzt relevante statistische Daten über die Gefügemorphologie als Eingabeparameter für den gewichteten Voronoi-Tessellierungs-Algorithmus. Außerdem werden praktische Anwendungen des künstlichen Mikrostrukturmodells zur Modellierung der plastischen Verformung und der Schädigung von Dualphasenstählen vorgestellt und diskutiert. Da für diese Anwendungen die Beschreibung des Plastizitätsverhaltens der Gefügebestandteile notwendig ist, werden die Plastizitätsmodelle sowie die Kalibriertechniken zur Bestimmung deren Parameter im Rahmen der Arbeit entwickelt und umgesetzt. Für Ferrit wird ein phänomeno-logisches Kristallplastizitätsmodell implementiert, wobei die Parameter mit Hilfe des Verfahrens der Nanoindentation kalibriert werden. Die lokale Fließkurve der martensitischen Bereiche wird anhand eines empirischen Ansatz beschrieben, der auf der lokalen chemischen Zusammensetzung basiert. Für die Schädigungs-modellierung wird ein Hybridansatz aus einem in-situ-Biegeversuch

im Grosskammer Rasterelektronenmikroskop und entsprechender mikro-mechanischer Simulation zur Charakterisierung eines Kriteriums für Mikrorissinitierung entwickelt. Durch Zusammenführung der entwickelten Arbeitspakete können verschiedene Anwendungen des künstlichen Mikrostrukturmodells zur Modellierung des Plastizitäts- und Schädigungsverhaltens von Dualphasenstählen durchgeführt werden.

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