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Institut für Eisenhüttenkunde

Xiaoxiao Li

Microstructure-property relationship in cold rolled complex phase steel

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Abstract

In complex phase (CP) steels, partially bainitic microstructure smooths the property gradient between soft ferrite and hard martensite phases, meaning that CP steels exhibit better local formability and hole expansion tolerance. In this study, in order to investigate the influence of microstructure constituents (ferrite, bainite, and martensite) on local plasticity behavior, microstructure characterization and micromechanical characterization were performed and coupled on a cold rolled steel CP800. First, different microscopic techniques (light optical microscopy (LOM), scanning electron microscopy (SEM), electron probe microanalysis (EPMA), and transmission electron microscopy (TEM)) were used to identify the microstructure constituents. A criterion for segmenting microstructure components, based on electron backscatter diffraction (EBSD) and EPMA measurements, was next proposed. Second, we implemented a novel method employing SEM-based microscopic digital image correlation (µDIC), together with ex-situ mechanical testing. This method enables the joint high-resolution mapping of deformation-induced micro-strain evolution. Furthermore, the prior austenite grain (PAG) was reconstructed from CP800, in order to achieve understanding of slip-based deformation mechanisms within bainite phase. The final digitized microstructure constituent map was correlated with a micro-strain analysis. The strain partitioning behavior between microstructure constituents, as well as between different interfaces, in complex phase CP800 during deformation was intensively examined and precisely quantified.

Zusammenfassung

In Complexphasen-Stählen (CP) glättet die teilweise bainitische Struktur den Eigenschaftsgradienten zwischen der weichen Ferrit- und der harten Martensitphase, was den CP-Stählen eine verbesserte lokale Umformbarkeit und Lochaufweitung verleiht. Um den Einfluss der Mikrostrukturbestandteile (Ferrit, Bainit und Martensit) auf das lokale plastische Verhalten zu untersuchen, wurden in dieser Studie Mikrostruktur- und mikromechanische Charakterisierungen zusammen an einem kaltgewalzten Stahl CP800 durchgeführt. Zuerst wurden verschiedene mikroskopische Verfahren (Lichtmikroskop (LOM), Rasterelektronenmikroskop (REM), Elektronenstrahl-Mikroanalyse (EPMA) und Transmissionselektronenmikroskopie (TEM)) zur Identifizierung der Mikrostrukturbestandteile benutzt. Ein Kriterium, basierend auf Elektronenrückstreubeugung (EBSD) und EPMA-Messungen, wurde zur Aufteilung der Mikrostrukturkomponenten vorgeschlagen. Als nächstes wurde eine neue Methode durch die Verwendung von SEM-basierte mikroskopischer digitaler Bildkorrelation (μDIC) verbunden mit ex-situ mechanische Prüfung durchgeführt, wodurch eine hochauflösende Abbildung der verformungsinduzierten Mikrodehnung möglich wurde. Für ein verbessertes Verständnis des Verformungsverhaltens der Bainitphase wurden die ursprünglichen Austenitkorngrenzen des CP800 rekonstruiert. Die finale digitalisierte Abbildung der Mikrostrukturbestandteile wurde mit der Mikrodehnungsanalyse korreliert. Das Verhalten der Dehnungsaufteilung zwischen den Mikrostrukturbestandteilen sowie unterschiedlichen Grenzflächen im Complexphasen-Stahl CP800 während der Verformung wurde umfassend besprochen und präzise quantifiziert.