metals

Editorial

Deformation, Fracture and Microstructure of Metallic Materials

Xiaowu Li * and Peng Chen *

Key Laboratory for Anisotropy and Texture of Materials, Ministry of Education, Department of Materials Physics and Chemistry, School of Materials Science and Engineering, Northeastern University, Shenyang 110819, China
* Correspondence: xwli@mail.neu.edu.cn (X.L.); chenpeng@mail.neu.edu.cn (P.C.)

1. Introduction

Metallic materials are mostly a combination of metallic elements, such as iron, aluminum, magnesium, titanium and manganese, which may also include small amounts of non-metallic elements, such as carbon, nitrogen and oxygen. As the first materials that humans discovered and applied, metallic materials not only play significant roles in human civilization but have also been widely and irreplaceably used in modern engineering. This is due to the fact that their great potential in terms of properties, quantities and qualities could evolve and renew with growing demand, and their remarkably complex properties are adaptable to the requirements of daily life and technology. Therefore, it is necessary to endlessly seek new metallic materials that have outstanding mechanical properties or modify existing materials to improve their mechanical properties; in this way, an in-depth understanding of the deformation, fracture and microstructure of various metallic materials is of particular significance.

As is well known, the deformation and fracture mechanisms of materials are strongly dependent on their initial microstructures (e.g., grain size, grain boundary character, inclusion, precipitate, phase composition, microstructural and chemical nonuniformity), which play a determining role in defining their mechanical properties. In addition, understanding the evolution of a microstructure during deformation is also extremely important for understanding the deformation and fracture mechanisms.

2. Contributions

Eleven papers, including two review papers and nine research papers, have been published focusing on the microstructure-related deformation and fracture behavior of steels, superalloys, titanium alloys and so on. Subsequently, an overview of the contributions is given as follows:

The two review papers summarize the technology and methods deployed in the exploration of fractured microstructures and improving the mechanical properties of metallic materials. Sánchez et al. [1] reviewed the adoption of mini-CT specimens for the fracture characterization of ferritic steels, particularly focusing on those used in the nuclear industry. The main existing results are displayed, and the main scientific and technical issues are thoroughly discussed. Li et al. [2] summarized the recent progress in the theoretical models and mechanisms of twin-related grain boundary engineering (GBE) optimization. An appropriate GBE treatment has been confirmed to be an effective pathway to improve some special mechanical properties (e.g., high-temperature tension, creep, low-cycle fatigue, etc.); thus, it is a feasible method for the development of high-performance metallic materials.

Steel materials are the most important metallic materials and have a wide range of applications, and the relevant investigations on the microstructure—property relationship are of the greatest importance. Qiu and Inoue [3] traced the evolution of Poisson's ratio during the tensile deformation process in a low-carbon hot-rolled steel. The results revealed that the average Poisson's ratio could not accurately express the local Poisson's ratio in the discontinuous-yielding regime, and the Poisson's ratio varied significantly within a plastic

check for updates

Citation: Li, X.; Chen, P. Deformation, Fracture and Microstructure of Metallic Materials. *Metals* **2023**, *13*, 1015. https://doi.org/10.3390/met13061015

Received: 25 April 2023
Accepted: 5 May 2023
Published: 25 May 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

band in this phase. Cao et al. [4] designed a special-shaped epoxy steel sleeve (SSESS) to repair low-strength tee pipes, and the reliability of the repairs was proven in repairing tests, hydraulic burst tests, and simulations. In Du et al. [5], the effect of strain rate on the tension deformation behavior of an Fe-30Mn-8Al-1.0C low-density austenitic steel was elucidated. Their results indicated that a good strength–ductility combination was achieved in the sample deformed at 10^{-3} s^{-1}; in this case, microbands and deformation twins were observed. Thus, the combination of microband-induced plasticity together with twinning-induced plasticity (TWIP) leads to a continuous strain hardening behavior and, consequently, to superior mechanical properties. Li et al. [6] investigated the quenching residual stress of hot-rolled seamless steel tubes with different cooling intensities by using ANSYS simulation software. Their results offered data support and theoretical reference for the heat treatment process design of seamless steel tubes. Yang et al. [7] have explored the microstructure, tensile properties, fatigue properties, and fatigue cracking mechanisms of 35CrMo steel processed by four heat-treatment procedures to obtain optimum fatigue performance. In addition, a suitable formula for fatigue strength prediction of the Cr–Mo steel was established on the basis of corresponding fracture mechanisms. Zhang et al. [8] conducted the axial loading fatigue tests on the G20Mn5QT steel applied in axle box bodies of high-speed trains and studied its size and shape effects on fatigue behavior. Their work is beneficial for the design of axle box bodies in high-speed trains.

There are also many other metals and alloys (e.g., superalloys, Ti alloys, and Mg alloys) used in different applications, and the corresponding relationship between microstructures and properties also needs to be comprehensively understood. In Yang et al. [9], high-resolution transmission electron microscopy (TEM) was used to study the recast layer formed by electrical discharge machining a single-crystal superalloy, considering the significant role of the microstructure of the recast layer for the performance of single-crystal blades. The results showed that the recast layer is in the condition of a supersaturated solution with a single-crystal structure epitaxially grown from the matrix. Fleishel et al. [10] intentionally induced the defects generated by the electron beam melting (EBM) of Ti-6Al-4V and investigated their influences on fatigue life. The reduced fatigue life caused by these defects and the relation of defect morphology to the material failure were investigated. Liu et al. [11] performed molecular dynamics (MD) simulations to study the interaction between Zn-Ca clusters and twin boundaries (TBs) to clarify the pronounced hardening effects, which is favorable to understanding the work hardening behavior of Mg-Zn-Ca alloys.

3. Conclusions and Outlook

This Special Issue aims to collect the latest scientific achievements in the microstructure-related deformation and fracture behavior of various metallic materials under monotonical or cyclic loads. According to the research findings arising from this collection of works, the initial microstructure and microstructural evolution have a significant effect on deformation and fracture mechanisms and, thus, mechanical properties. To this end, various microstructure characterizations, mechanical tests and numerical simulations have contributed to this Special Issue. These results are beneficial for promoting the potential applications of the involved materials and for the future development of novel high-performance materials. Finally, I would like to thank all of the authors for their contribution and the managing office of *Metals* (MDPI) for their support in the development of this Special Issue.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Sánchez, M.; Cicero, S.; Kirk, M.; Altstadt, E.; Server, W.; Yamamoto, M. Using Mini-CT Specimens for the Fracture Characterization of Ferritic Steels within the Ductile to Brittle Transition Range: A Review. *Metals* **2023**, *13*, 176. [CrossRef]
2. Li, X.; Guan, X.; Jia, Z.; Chen, P.; Fan, C.; Shi, F. Twin-Related Grain Boundary Engineering and Its Influence on Mechanical Properties of Face-Centered Cubic Metals: A Review. *Metals* **2023**, *13*, 155. [CrossRef]

3. Qiu, H.; Inoue, T. Evolution of Poisson's Ratio in the Tension Process of Low-Carbon Hot-Rolled Steel with Discontinuous Yielding. *Metals* **2023**, *13*, 562. [CrossRef]
4. Cao, J.; Jia, H.; Ma, W.; Wang, K.; Yao, T.; Ren, J.; Nie, H.; Liang, X.; Dang, W. Repair Reliability Analysis of a Special-Shaped Epoxy Steel Sleeve for Low-Strength Tee Pipes. *Metals* **2022**, *12*, 2149. [CrossRef]
5. Du, J.; Chen, P.; Guan, X.; Cai, J.; Peng, Q.; Lin, C.; Li, X. The Effect of Strain Rate on the Deformation Behavior of Fe-30Mn-8Al-1.0C Austenitic Low-Density Steel. *Metals* **2022**, *12*, 1374. [CrossRef]
6. Li, Z.; Zhang, R.; Chen, D.; Xie, Q.; Kang, J.; Yuan, G.; Wang, G. Quenching Stress of Hot-Rolled Seamless Steel Tubes under Different Cooling Intensities Based on Simulation. *Metals* **2022**, *12*, 1363. [CrossRef]
7. Yang, M.; Gao, C.; Pang, J.; Li, S.; Hu, D.; Li, X.; Zhang, Z. High-Cycle Fatigue Behavior and Fatigue Strength Prediction of Differently Heat-Treated 35CrMo Steels. *Metals* **2022**, *12*, 688. [CrossRef]
8. Zhang, Z.; Li, Z.; Wu, H.; Sun, C. Size and Shape Effects on Fatigue Behavior of G20Mn5QT Steel from Axle Box Bodies in High-Speed Trains. *Metals* **2022**, *12*, 652. [CrossRef]
9. Yang, Z.; Liu, L.; Wang, J.; Xu, J.; Zhao, W.; Zhou, L.; He, F.; Wang, Z. Revealing the Formation of Recast Layer around the Film Cooling Hole in Superalloys Fabricated Using Electrical Discharge Machining. *Metals* **2023**, *13*, 695. [CrossRef]
10. Fleishel, R.; Ferrell, W.; TerMaath, S. Fatigue-Damage Initiation at Process Introduced Internal Defects in Electron-Beam-Melted Ti-6Al-4V. *Metals* **2023**, *13*, 350. [CrossRef]
11. Liu, R.; Wang, J.; Wang, L.; Zeng, X.; Jin, Z. Cluster Hardening Effects on Twinning in Mg-Zn-Ca Alloys. *Metals* **2022**, *12*, 693. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.