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EDITORIAL

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Forming-induced residual stresses: experiment, modeling, simulation

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1 Editorial

Residual stresses are considered mostly as a major cause of unexpected failure, but they also have the potential to improve the mechanical properties of components. The goal-oriented adjustment of beneficial residual stresses to improve properties through forming processes has not yet been widely realized in either sheet metal or solid forming.

An important reason for this is the lack of knowledge on the underlying process–property relationships. Established methods for determining residual stresses, e.g., borehole method or X-ray diffraction, can only be used to a limited extent in most processes with complex component geometries because accessibility is not given or the achievable penetration depths are too small. As a result, there are considerable inaccuracies in the numerical simulations of residual stresses. Furthermore, the large plastic deformation occurring in formed parts as well as effects related to texture and the multiphase nature of materials represent major challenges that are not satisfactorily taken into account during experimental characterization and simulation.

Since 2017, the Priority Program SPP 2013 funded by the German Research Foundation (DFG) aims at providing the scientific basis for the targeted use of forming-induced residual stresses in metallic components. In this priority program, 12 interdisciplinary projects involving experts from production technology, mechanics, materials science, measuring and testing technology as well as structural durability are being funded. In total, partners from 28 institutes and 15 locations across Germany participate.

In the first project phase from 2017 to 2019, it was shown that residual stress states can be reproducibly induced using forming manufacturing processes. Novel numerical and constitutive models for the qualitative prediction of residual stresses and the corresponding property improvements have been developed, and the production of representative components was demonstrated.

This special issue presents a selection of articles that document the progress achieved during the second project phase from 2020 to 2021 where the achievable property improvements for various manufacturing processes have been quantified and the associated simulation models and measurement methods have been validated. The first six articles in this collection are related to thin-walled structures. The content ranges from the analysis of fundamental mechanisms, specific applications to the numerical determination of residual stresses in duplex steels. The latter is accompanied by a cross-project contribution, which addresses the aspects of texture and multiphase materials using an experimental–numerical approach. A similar arrangement is chosen for the set of articles related to solid forming. Following an overview on strategies for the targeted adjustment of residual stresses, different processes are analyzed both numerically and experimentally. The collection is

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completed by the quantitative prediction of the influence of residual stresses on service life and fatigue crack propagation.

Based on the knowledge gained, the work in the third phase from 2021 to 2023 will focus on the layout, design and optimization of the necessary processes, equipment and tools to improve the properties of the produced components. This also includes demonstrating the residual stress stability under realistic load cases.

After completion of the projects, the transfer of the findings to real components and industrial manufacturing processes is aspired to enable a more sustainable production and longer-lasting products.

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