Abstract

The present Ph.D. thesis addresses the development of effective strategies for identifying hardening behavior of ductile metals by exploiting the post-necking phase of tensile tests. The availability of methods capable of calibrating elasto-plastic constitutive models appropriately and efficiently is of utmost importance for the reliability of Finite Element Analyses (FEA), increasingly employed in many engineering fields (e.g., metal-forming processes, dynamic impact events, energy-absorption systems, etc.). From a practical standpoint, elasto-plastic constitutive models are usually calibrated using experimental data and appropriate identification strategies within a phenomenological framework.

Among the wide variety of experimental techniques that can be employed, tensile tests on dog-bone specimens are still widely used for characterizing hardening of massive components. Indeed, these tests are both simple to execute and able to induce large plastic strains in ductile metals, thus broadening the calibration range of material laws. In addition, tensile tests can be readily adapted, through proper experimental setups, to study the effect of strain rate, temperature, and other environmental conditions. This makes such tests particularly attractive for both academic and industrial applications. Nevertheless, the largest strains are achieved during necking, because of a progressive strain localization. The non-uniform strain and stress fields, as well as the loss of stress uniaxiality, cause tensile test data to no longer be interpreted based on uniform deformation assumptions. This has motivated, over the past decades, the development of several analytical, experimental, and numerical approaches. Their final objective has been to exploit tensile tests fully, taking advantage of their well-known benefits, while enabling the reliable calibration of constitutive models for large-strain applications.

Based on the advances of previous research and supported by modern experimental and computational tools, further progress can be made towards methods that effectively combine efficiency and accuracy. This represents the main scope of the present thesis. Necking is regarded as an intrinsic feature of tensile loading that can be modeled and systematically used for material identification. The proposed approaches explicitly use the necking deformed configuration of the specimen as primary source of information. Specifically, FE simulations are used to establish quantitative links between observable quantities, primarily the evolution of necking silhouettes, and the underlying material behavior. On this basis, inverse and shape-based identification strategies are developed to extract material information over an extended deformation range. Additional effects such as strain rate sensitivity, thermal coupling, and material anisotropy are properly addressed whenever they significantly influence necking behavior and material parameter identification. Comparison with well-established methods on some experimental case studies highlights the advantages that the proposed approach offers in terms of combining accuracy and efficiency. Furthermore, experimental investigation proved the overall practical applicability, potentiality, and flexibility of the proposed framework of analysis.