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The influence of symmetry boundary conditions in the design of heterogeneous mechanical tests using topology optimization

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Abstract: Designing specimens for mechanical testing has gained wide popularity in the material behavior characterization field. Standard mechanical tests are usually performed to extract material properties, however, due to the lack of information provided by each test, mechanical tests with more complex geometries or boundary conditions are being proposed. These present richer mechanical fields and strain and stress states similar to the ones that occur in most common sheet metal forming processes. An efficient way of finding the richest specimen is designing using an optimization approach. In this work, the design by topology optimization is used to find the optimal geometry for the specimen. Given an initial design space with a set of boundary conditions, an adapted version of the theory of compliant mechanisms is employed to obtain the material distribution with the most heterogeneous displacement field. The use of different boundary conditions leads to different material configurations and, therefore, to specimens with different performances. Therefore, this work aims at analyzing the impact of using symmetry boundary conditions in the test design. Several specimen designs are obtained from different initial design domains with and without symmetry boundary conditions. Their influence on the heterogeneity of specimen mechanical fields is then evaluated.

Keywords: Heterogeneous mechanical tests, Material behavior, Topology Optimization, Compliant Mechanisms

1 Introduction

Material behavior characterization and constitutive model calibration are of upmost importance in the development of sheet metal forming parts. In that sense, mechanical tests play a key role in providing information about material behavior, being used to identify material properties. The design of new mechanical tests has been addressed over the years and several designs and methodologies have already been proposed to replace limited standard mechanical tests [1]. Several works have used the heterogeneity of the mechanical fields as a criterion to design a test that provides a high diversity and quality of information [2]. A mechanical test is considered more informative if a large number of mechanical states are covered. The use of an optimization approach is proved to be efficient in finding the specimen design that presents the best quality and quantity of data on the material behavior. The use of topology optimization in the design of tests has already been addressed [3], where the optimal layout of material for the specimen is found within a given design space. The use of different boundary conditions leads to different material configurations and, therefore, to specimens with different performances. This work aims at studying the influence of symmetry boundary conditions in the design of a heterogeneous mechanical test using topology optimization.

2 Heterogeneous test design

A topology-based optimization methodology is implemented with the aim of finding the material layout for the sheet specimen that corresponds to the test with the best performance. Since inducing heterogeneity directly in the strain field seems to be complex, this methodology proposes to induce heterogeneity through the displacement field. By using an adapted version of the theory of compliant mechanisms, it is possible to apply displacements in specific locations of the specimen and control the displacement field and, consequently, the strain states induced on the specimen [3]. Several specimen geometries with innovative shapes are obtained from different design domains with and without symmetry. Their mechanical fields are then evaluated taking into account the diversity of mechanical phenomena.

3 Disclaimer

The results reflect only the authors' view, and the European Commission is not responsible for any use that may be made of the information it contains.

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