Methods for modelling of imperfections of additively manufactured metal components and prediction of the structural properties of imperfect components

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The application of additive manufacturing is increasing not only in prototyping but also in series production of aircraft structure elements. In particular, the production of highly optimized components makes the processes suitable for achieving further mass savings in aircraft structures. Compared to conventional manufacturing processes, additive manufacturing also raises the probability of occurrence for material imperfections (e.g. pores or material anisotropy) due to the characteristic layer-by-layer creation of components. Knowledge about the effects of imperfections is of high importance, since they can negatively influence component properties. Without knowing the influence of imperfections on the component properties, this fact requires many expensive post-treatment steps (e.g. hot isostatic pressing or surface etching) for the manufactured components that may reduce the beneficial effects of additive manufacturing. Therefore, these studies aim to understand and predict the influence of manufacturing-process-related imperfections on the structural component mechanical properties.

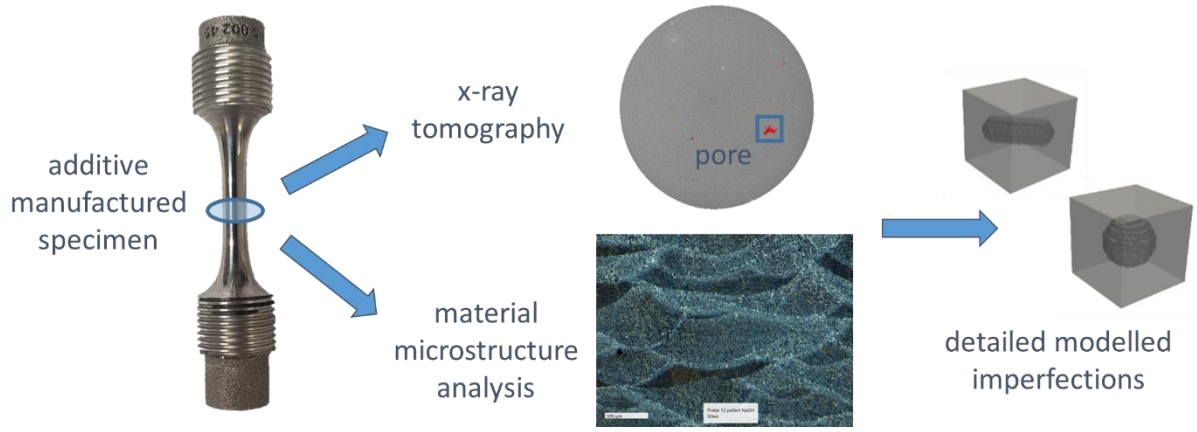

Figure 1: Creation of detailed simulation models from the analyzation results of seperate imperfections

The prediction of the influence can base on simulations using the finite element method. This means that simulation methods providing a detailed mapping of imperfections on a microscopic level are necessarily developed (see Figure *1*). In this way, the effects on the material properties are determined in dependence of the constitution of the imperfections. In order to bridge the significant scale differences to the component, methods for homogenising the imperfection models used on the microscopic scale are established (see Figure *2*). An in-house software supplies the foundation for the implementation of developed methods. This model generator has the functionality to create any possible combinations and characteristics of imperfections and introduce them and especially their properties into a finite-element model of a component. A series of experimental analyses (e.g. high-resolution CT scans) of components produced by selective laser melting (SLM) are used to determine exemplary

information about the real constitution and distribution of imperfections. Simulation models of the imperfect components are created based on these data and using the developed methods. The component properties are determined by using numerical simulations. Furthermore, the methods are validated through the results from mechanical load tests.

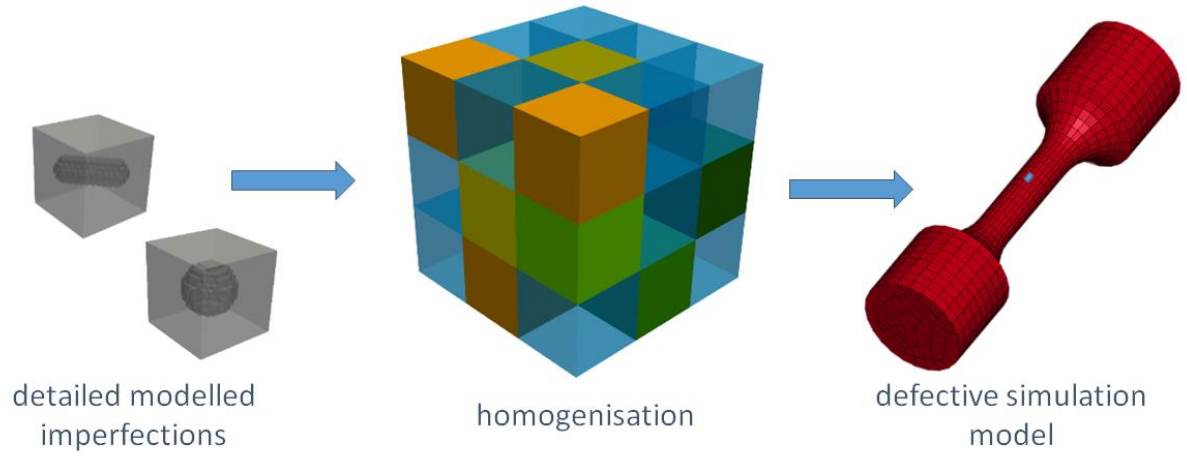

Figure 2: Bridging of scale differences from the imperfection to the defetive model by the use of homogenisation

Knowing about the imperfection contained in the component, predictions of the components structural behaviour are possible with the help of the developed simulation methods. In addition, the methods are suitable for the specific investigation of the effects of any other constitution of imperfections (type, distribution, number of defects) on the mechanical properties of additively manufactured components. A large-scale and expensive component production with parameter variations is not necessary to generate this database.