Preface

This textbook introduces into the theory of non-linear Finite Element Methods (FEM) in structural mechanics, divided into the main parts on geometric non-linearity, non-linear material behaviour and contact. While it is not possible to describe the total FEM of linear mechanics in one book, this is even more the case for the non-linear FEM, as "non-linear" is not a special property but means that the limiting assumptions, which for good reason dominate undergraduate studies in Technical Mechanics, are missing. This book should prepare the reader to work with advanced books and papers.

The formulae used are intentionally derived in detail in order to enable the reader to transfer the described relations into computer programs and to create equations for similar physical effects.

The book addresses first and foremost students who want to attain Master's level, but FEM users should get useful insights as well. In the linear FEM, provided the systems are sufficiently constrained, a result is always obtained (the correctness/accuracy is not to be discussed here); however, the user, especially the novice one, of non-linear analysis will end up in non-convergence and thus without equilibrium in a number of attempts. In this situation, it is good to know the potential causes. This will help to decide whether and how convergence can be achieved by changes to the settings. Here, the chapters on stability and on convergence in contact analysis are recommended. It should be noted that the success of a non-linear analysis depends on realistic input data, as a failure of the system will not only appear in the final results (when comparing them with strengths) but will influence convergence at an earlier stage.

For the user there is a further necessity—maybe even more important—of the theoretical background: the FEM programs on the market offer numerous options and settings to choose which usually are described for a user with knowledge on how Finite Elements are formulated. In this book, it is assumed that the reader knows how this is done for linear FEM. For that subject, there are numerous books and often lectures in engineering courses.

The sample results in this book, if not from table calculation, are mostly obtained with ANSYS, but other well-known FE codes use similar concepts such that the findings can be transferred.

This textbook describes the knowledge the author obtained over many years, the majority of them as a practical engineer. Most of it is common among experts. Therefore, the book does not list the origin of all these theories and algorithms but only gives advanced references. Since the book is derived from scripts of lectures, general solution methods are worked out in full when the related problem occurs for the first time.

This work is based on scripts of lectures being given by the author in the frame of Master's courses at Universities of Applied Sciences of Hanover (where the author is affiliated) and Lausitz as well as at the European School of Computer Aided Engineering Technology (ESoCAET). The roots, however, are teaching and development duties of the author during his long-lasting employment at CADFEM GmbH. The author would particularly like to thank its founder, Dr.-Ing. Günter Müller, for the opportunity to learn during everyday work as well as for his uncomplicated handling of possible copyright questions.

The author first earned his stripes in the field of Finite Elements—which already included a certain amount of non-linearity—at "Institut für Baumechanik und Numerische Mechanik" (Institute for Structural and Numerical Mechanics) of University of Hanover under the guidance of Prof. Dr.-Ing. Erwin Stein, who awakened the author's enthusiasm first for mechanics, then for Finite Elements and to whom the author gives his heartfelt thanks.

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