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INTERNATIONAL CENTRE FOR MECHANICAL SCIENCES

COURSES AND LECTURES - No. 351

SHAPE MEMORY ALLOYS

M. FREMOND
LAB. DES MATERIAUX ET STRUCTURES DU GENIE CIVIL

S. MIYAZAKI
UNIVERSITY OF TSUKUBA

Springer-Verlag Wien GmbH

Le spese di stampa di questo volume sono in parte coperte da
contributi del Consiglio Nazionale delle Ricerche.

This volume contains 99 illustrations

Originally published by Springer-Verlag Wien New York in 1996

In order to make this volume available as economically and as
rapidly as possible the authors' typescripts have been
reproduced in their original forms. This method unfortunately
has its typographical limitations but it is hoped that they in no
way distract the reader.

ISBN 978-3-211-82804-5 ISBN 978-3-7091-4348-3 (eBook)
DOI 10.1007/978-3-7091-4348-3

PREFACE

The thermal and mechanical properties of shape memory alloys are puzzling: thermal actions induce large deformations. In some sense thermal actions are equivalent to mechanical actions. This equivalence is the basic tool for many practical applications. The complete description of the shape memory alloys involves physics, metallurgy, crystallography, mechanics and even mathematics to deal with the predictive theories describing their behaviour.

This book consisting of two chapters is devoted to the crystallographic and thermomechanical properties and to the macroscopic modelling of the shape memory alloys. It results from part of the lectures given by professors Fremond, James, Miyazaki and Müller during a session of the Centre International des Sciences Mécaniques from October 4 to October 8, 1993.

The first chapter describes the thermomechanical macroscopic theory. Shape memory alloys are mixtures of many phases: martensites and austenite. The composition of the mixtures vary: the martensites and the austenite which have different mechanical properties transform into one another. The phase changes can be produced either by thermal actions or by mechanical actions. The striking and well known properties of shape memory alloys results from these links between mechanical and thermal actions.
The macroscopic modelling is based on thermodynamics involving internal quantities. It gives a macroscopic theory which can be used for engineering purposes, for example to describe the evolution of structures made of shape memory alloys. Some of the internal quantities which are chosen, the phase volume fractions for instance, are submitted to constraints (for instance their actual value is between 0 and 1). It is shown that most of the macroscopic properties of shape memory alloys result from a careful treatment of these constraints. The thermomechanical modelling uses continuum thermodynamics and some elementary notions of convex analysis as basic tools.

The second chapter describes the experimental works on the crystallographic and thermomechanical properties. Recent development of shape memory alloys is reviewed, emphasis being placed on the Ti-Ni, Cu-based and ferrous alloys which are considered as practical materials for applications among many shape memory alloys. Crystal structures of the parent and martensitic phases *are described, and the crystallography of the martensitic transformations is also briefly explained. The origin of the shape memory effect and the shape memory mechanisms are discussed on the basis of the crystal structure and the crystallography of the martensitic transformations. Since an applied stress also induces the martensitic transformations, successive stages of the stress-induced martensitic transformations are reviewed briefly in Cu-based and Ti-Ni alloys, which show martensite-to-martensite transformations upon loading. Then, the transformation and mechanical characteristics of the shape memory alloys are reviewed in detail; i.e. phase diagrams, transformation temperatures, transformation process, stress-induced transformation, aging effects, cycling effects, fracture, fatigue, grain refinement, two-way shape memory effect, and so on. Recent development of sputter-deposited Ti-Ni thin films is also introduced.*

The authors wish that this book would be a good guide and introduction for the readers to the study of shape memory alloys.

M. Fremond
S. Miyazaki

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