On a General Concept of Isotropic and Anisotropic Hardening

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Summary

The aim of this work is to develop a unified and rational formulation of isotropic and anisotropic hardening within the framework of the tensor functions representation theory. The classical concepts of isotropic and kinematic hardening are analyzed in detail and it is shown that they cannot describe some important mechanical phenomena. A general concept of isotropic and anisotropic hardening is proposed, which involves as special cases the classical isotropic and kinematic hardening, as well as existing laws of anisotropic hardening. Within the presented scheme, special emphasis is laid on the description of the different features of anisotropic hardening and some specific examples of hardening rules are developed and compared with available experimental results.

It is first shown that kinematic hardening can be split into specific isotropic and anisotropic hardening. This splitting is analyzed in detail. Attention is stressed on the anisotropic contribution in the general and different special cases of kinematic hardening. The obtained anisotropy is of a restrictive type, which cannot describe observed anisotropic hardening phenomena, in particular for metals. Secondly, it is shown that certain materials, when subjected to specific mechanical processes, undergo an isotropic evolution of their internal structure, which results in a modification of the shape of the initial isotropic yield condition, without appearance of anisotropic properties. Examples are given for this phenomenon, which, obviously cannot be taken into account by the classical isotropic hardening. Finally, the classical concepts of isotropic and kinematic hardening are not disjointed and do not cover the range of observed mechanical phenomena. Consequently, there appears a need for a more general concept and a rational formulation of isotropic and anisotropic hardening.

Such a formulation can be based on the assumption that the evolution of mechanical properties, due to the modifications of the materials internal structure, can be taken into account by specific transformations of the stress tensor involved in the constitutive law. The same procedure, in a very restrictive application, is usually employed for the description of damage growth. Within the proposed scheme, the generalyzed concepts of isotropic and anisotropic hardening are defined by, respectively, isotropic and anisotropic transformations of the stress tensor. By application of the theorems of representations for tensor functions, it is shown that under generally accepted mechanical hypotheses, the proposed procedure permits to transform an arbitrary initial yield condition into an arbitrary isotropic or anisotropic subsequent criterion. The full range of observed mechanical phenomena are thus taken into

account and the classical concepts of isotropic and kinematic hardening appear as special cases of the developed theory.

Special attention is stressed on anisotropic hardening. The problem of the evolution of the type and the "degree" of the initial or induced anisotropy is analyzed in detail. Existing laws of anisotropic hardening are reviewed as special cases of the proposed scheme. Finally, in order to show the versality of the presented theory, some examples of specific formulations are developed and compared with experimental results.

The significant results concern a detailed analysis of kinematic hardening, as well as the development of a general and unified concept of isotropic and anisotropic hardening, which enables to describe in a rational manner the complex mechanical phenomena associated with work-hardening processes of materials.