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Simulation of beam plastic forming with variable bending moments

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A versatile generic elastic/plastic moment/curvature equation is used to simulate beam deflections. Solutions are obtained numerically and used to investigate whether forming equations based on the assumption of pure bending can be extended in a rational way to more complicated loadings. It is concluded that the answer is affirmative, with only knowledge of the elastic/plastic behavior associated with pure bending and the elastic behavior associated with the actual loading being needed to make the extension.

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1. Introduction

The plastic (cold) forming of metal parts is accomplished by deforming blanks beyond the elastic limit to produce permanent deformation. In traditional plastic forming, forming loads are used to press the blank against a tool (mold). In the newer process of free-plastic forming the tool is dispensed with and the forming loads are predetermined to produce a given shape. For simplicity, henceforth the shape produced by the forming loads will be referred to as the tool shape for both the types of plastic-forming processes. In either case, because of the nonlinearity inherent in plastic deformation, release of the forming loads produces elastic springback of the deformed blank so that the shape of the formed part is not identical to that produced by the forming loads. If time-consuming and costly trial and error is to be minimized, an estimate of the relation between the tool shape and the part shape must be available. The development of such estimates by mathematical modeling for the plastic forming of beam-like blanks by bending about a principal axis is the subject of this paper.

Simulation of plastic forming can be carried out using models having levels of sophistication ranging from those based on empirical formulas determined from test results to those based on finite element methodology which account for all the details of the process. Examples of the latter are provided by the paper of Karafillis and Boyce [1] on traditional plastic forming and the paper on free-plastic forming by Thalmain and Lippman [2] (see also the refs. in [1,2]). These comprehensive finite element approaches are computationally intensive. For this reason less sophisticated models, which idealize certain aspects of the forming process and employ a mechanics of materials based approach are attractive both for obtaining quick design estimates and for use in forming control algorithms. For forming of beams (or long plates) by one way bending, such models have a long history. Some representative earlier publications are those by Gardiner [3], Johnson and Yu [4], and Yu and Johnson [5]. Two more recent examples are the paper by Zhang and Hu [6] and the paper of Asnafi [7] (which gives an overview of the application of such models in the automotive industry).

One of the simplifying assumptions often employed in the mechanics of materials approach is that the blank is subjected to pure bending (see, for instance, [3–5]). It is of interest to know the applicability of the associated results to situations in which more general loading states are involved in the forming process. The present work addresses this question.

An important element of a plastic-forming model is the beam moment/curvature relation. This depends on both the beam cross-section and the material elastic/plastic stress/strain equation. Such relations are discussed in Section 2 and that proposed by Goldberg and Richard [8] and Richard and Abbot [9] is selected for use herein. In Section 3 the moment/curvature model of [8,9] is used as a basis for forming simulations involving pure bending, a central concentrated load, and a uniformly distributed load. Numerical solutions of the appropriate equations are required which are accomplished by finite difference methodology. Appropriate comparisons of the results associated with each of the three loadings are made. Section 4 contains a summary of the work reported in the present paper. In addition, important conclusions are reviewed.

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