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Adaptive multiple scale meshless simulation on springback analysis in sheet metal forming

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ABSTRACT

Springback is one of the major considerations in the design of part shape, die geometry and processing parameters of sheet metal forming. In this study, an adaptive multiple scale meshless method is developed to predict the amount of springback, which occurs after unloading in sheet metal forming. A two-dimensional meshless continuum approach is applied to the bending deformation of plate/shell structures. The meshless method called reproducing kernel particle method (RKPM) is modified to develop the springback analysis algorithm using two scales. The effective strain is decomposed into two scales, high and low. The two scale decomposition is incorporated into non-linear elasto-plastic formulation to obtain high and low components of effective stresses. The high scale component of effective stress indicates the high stress gradient regions without posterior estimation. Enrichment nodes with a proper refinement scheme are inserted/deleted in those high stress regions to exactly calculate the stress distribution and thus accurately predict the amount of springback. The simulation results show that the algorithm can effectively locate the high stress gradient regions and can be utilized as an efficient indicator for the adaptive refinement technique for non-linear elasto-plastic deformation. The comparison of the amount of springback via the processing parameters between experiment, FEM (ABAQUS), meshless method and adaptive meshless method shows that the adaptive meshless solutions are the closest to experiment results.

1. Introduction

Springback is one of the critical issues not only in sheet metal forming itself but also in the numerical simulation of this process. Springback prevents the applicability and use of springback prediction and compensation techniques. Hence, it leads to amplified variations and problems during assembly of components, and in turn, results in quality issues. Thus, understanding, accurate characterization, prediction, control and reduction of springback and its variation have become very crucial in terms of decreasing development times and reducing scrap rate in mass production.

With the rapid development of computer technologies and the ever-increasing demand of high-quality products at a minimum cost, modeling and simulation of sheet metal forming has become a crucial tool to assist in the design of products and improve manufacturing processes. How to accurately predict the springback is indispensable capability for a useful simulation tool.

Numerous studies during the last 40 years have attempted to determine the controlling factors in springback and find ways to reduce it. The prediction methods for the springback can be broadly divided into two categories: an experimental approach and a numerical simulation approach. The experimental approaches are to examine mainly the effects of processing parameters and material property on springback. An early study by Baba and Tozawa [1] focused on the effect of stretching a sheet by a tensile force, during or after bending, in minimizing springback. Other studies investigated the role of process variables on springback. Zhang and Lee [2] showed the influence of blank holder force, elastic modulus, strain hardening exponent, blank thickness and yield strength on the magnitude of the final springback strain in a part. Geng and Wagoner [3] studied the effects of plastic anisotropy and its evolution in springback. They developed a constitutive equation for 6022-T4 aluminum alloy using a new anisotropic hardening model and proved that Barlat's yield function is more accurate than other yield functions in their case. A certain number of bending experiments [4] were carried out. They included die corner radius, punch-die clearance, punch nose radius, pad force and material type as the main variables. The experimental investigations presented on the effect of process variables on springback in straight flanging process. Beside the experimental approach, numerical simulations have been conducted to predict the amount of springback in sheet metal forming. Mattiasson et al. [5],

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