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A numerical method for the optimal blank shape design

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ABSTRACT

This paper describes a numerical procedure for the blank shape design of thin metallic parts obtained by stamping. The objective is to determine the initial blank shape knowing the geometry of the desired 3D CAD part. The numerical procedure consists of two stages: At first, an estimation of the initial blank shape is given using the one step inverse approach (IA). Then, update of the blank shape is continued by iterations combining optimization algorithms and finite element analysis (FEA). The numerical procedure for the blank shape design is tested in the case of an industrial stamping process where the part is formed using a manual press without blank-holder. The proposed numerical procedure can provide very quickly the optimal blank shape in a few iterations.

1. Introduction

To avoid trial and error design procedures, numerical simulation of sheet metal forming processes is extensively being used in the stamping industry to optimize the process parameters and to evaluate the forming defects such as: fracture, springback, wrinkling, shape errors and residual stresses. One of the main parameters that should be optimized at the beginning of any sheet metal forming process is the initial blank shape. The optimal blank not only improves formability and product quality but also reduces material cost and product development period. Since the optimal blank design is an attractive subject to the sheet metal forming, several methods have been developed and there are lots of different approaches. These methods can be categorized in deformation path iteration method [1], backward tracing [2], ideal forming [3], inverse approach (IA) [4], slip line field method [5], geometrical mapping [6], sensitivity analysis method [7,8], trial and error method based on FEA [9–11].

In sheet metal forming the initial blank shape is often calculated from the known 3D CAD shape using the IA [4]. The discrepancies between the specified shape and the shape obtained after sheet metal forming may be eliminated by a post-processing step. In some applications, this operation is economically not viable, and the end shape after forming has to conform to the specified end shape within a given production tolerance. In that case, the initial shape definition has to be modified accordingly, either in a purely experimental way or by using a finite element (FE) simulation of the processing step. This article focuses on the latter approach. The difference between the modelled end shape and the specified end shape has to be quantified and the difference has to be applied to the initial blank shape, with an opposite sign. The quantification of this difference is repeated until the modelled end shape conforms to the design shape within a given tolerance.

In this paper, the authors propose a pragmatic method for the blank shape design based on inverse and incremental approach. In Section 2, the principle of the numerical procedure is presented. Section 3 provides a description of the IA used for the preliminary design of the blank shape, followed by a presentation of the iterative optimization algorithm used in combination with FEA. An industrial case has been considered in Section 4 to test the proposed procedure where some numerical results are finally presented and discussed.

2. Principle of the numerical procedure

The numerical procedure for the blank shape design is performed using Abaqus® scripting interface [12] which is based on Python® object-oriented programming language [13]. The role of the Python script is to perform automatically the different steps of the numerical procedure: accessing the functionality of Abaqus/CAE (Computer-Aided Engineering), loading the Output Data Base (ODB), launching the optimization algorithm, modifying the Model Data Base (MDB) and submitting the FEA. The numerical procedure has to operate without operator intervention once it has started. Fig. 1 illustrates the numerical procedure based on inverse and incremental approach in conjunction with the optimization algorithm. When the shape errors between the desired 3D CAD part and stamped part become less than the specified tolerance, 0.05 mm, the optimal blank mesh can be converted to a CAD file for machining and then to be formed by a manual press.

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