Materials and Design 32 (2011) 108–120

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Optimisation of process parameters in flanging operation in order to minimise stresses and Lemaitre's damage

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ARTICLE INFO

Article history:
Received 11 February 2010
Accepted 16 June 2010
Available online 20 June 2010

Keywords:
C. Sheet bending process
E. Mechanical damage
F. Plastic behaviour

ABSTRACT

The objective of this work is modelling and optimisation of sheet bending process by means of numerical simulation. One of the problems to be solved in the sheet metal forming processes of thin sheets is the taking into account of the effects of technological process parameters so that the part takes the desired mechanical characteristics. Accordingly, it has been a crucial research subject for designing bending tools guaranteeing an optimal performance of products in terms of mechanical properties and good rigidity. In this paper, we propose a numerical procedure allowing the definition of the optimal values of process parameters in flanging operation, which minimises the residual stresses and the material damage at the end of the bending phase. The concept of continuum damage mechanics fully coupled with elasto-plasticity has been retained to describe the progressive damage accumulation into the sheet metal. According to parametric investigation on the maximum stress and calculated damage values, it has been found that the punch-die clearance and the die radius have significant effects on mechanical behaviour of parts. An application of design of experiments was developed as a preliminary step for the optimisation of the process parameters by using response surface methodology. This model allows the identification of the influential parameters of an optimisation problem and the reduction of the number of evaluations of the objective function.

1. Introduction

Sheet metal flanging process is one of the most frequently used manufacturing operations in industry. The development and optimisation of design of bending processes is associated with time consuming and costly experiments. Therefore, the finite element simulation of the process could be a helpful tool for the designer to assure the highest possible quality of products. Numerical simulations of the problems associated with sheet metal forming such as stamping, bending and hydro-forming using the finite element method (FEM) are widely used and can help design the process by reducing the number of trial steps. Nevertheless, process modelling by FEM simulation is already used in industry in a wide variety of forming operations.

In order to determine the inevitable mechanical springback of bent plates designed for assembling spherical tanks made of steel StE500, Math et al. [1] have used an elastic–plastic incremental finite element calculation to analyse axisymmetric strain in sheet metal forming process. Sufficiently accurate stress distributions and deformed geometry of plates as parts of spherical tanks have been carried out through the whole bending process.

Esat et al. [2], used commercially available FEA software to analyse bending and springback of different aluminium materials with different thickness. The amount of springback, the total equivalent plastic strain and the equivalent von Mises stresses are presented and the FEA results are compared to empirical data.

Hambli et al. [3], studied a 3D finite element modelling of air-bending process allowing the prediction of damage evolution during the forming operation. The numerical simulation of the damage evolution has been modelled by means of continuum damage approach based on the Rice and Tracey ductile fracture criterion allowing the description of the exponential dependence on triaxiality which has been implemented in finite element code. The mechanical state of the workpiece is determined by the material properties variation of the bending arc such as the hardening and damage states. As results, we can note the increase in strain toward the inner and outer surfaces in the bending arc. In the same subject, numerical simulation of unbending operations of previously bent parts in press tools was presented by Bahloul et al. [4]. They studied the prediction and location of cracking during the unbending process. In this regard, a fully coupled constitutive model of elastic-plasticity and ductile damage has been developed and implemented in the implicit solver of ABAQUS [5]. Material tests have been performed to identify the constants in the constitutive model, and bending-unbending tests for validation of results of

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doi:10.1016/j.matdes.2010.06.028