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Sensitivity analysis of stamping processes using various friction models appropriate for non-stationary contact problems

Mfanafikile Don Mhlongo*

Department of Mathematics, Mangosuthu Technikon, Durban, KwaZulu-Natal, South Africa

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Abstract

This paper looks at the sensitivity of thickness to variation of friction. The models of friction used are: the classic Amontons–Coulomb; a nonlinear pressure-dependent model proposed by Wriggers, vu Van and Stein; and a velocity-dependent model proposed by Molinari, Estrin and Mercier. They are coded in FORTRAN for use with finite element program ABAQUS. The contact problem is then formulated in the total Lagrangian formulation for contact between an elastic–plastic body and rigid tools. The variational (weak) form of the formulation is given and this is discretized by finite element method. To test and compare the models, one common metal forming processes is simulated: deep drawing of a square-cup. The sensitivity graphs showing each of the three friction models together is given at the end. One other conclusion although not major part of this work is that Amonton–Coulomb is not the best model suited for contact conditions in metal forming processes, because Wriggers et al. model and Molinari et al. model provide better results for modelling bends and corners.

Keywords: Sensitivity; Stamping process; Contact problem; Friction models; Thickness

1. Introduction

Stamping is a sheet metal forming process. Sheet metal forming is the process of converting a flat sheet of metal into a part of desired shape without fracture or excessive

*Tel.: +27 31 9077436; fax: +27 31 9077284.
E-mail address: don@julian.mantec.ac.za

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localized thinning. In stamping, a sheet metal called blank, is held on its edges by a blankholder and is deformed by a motion of a punch or die. The movement of the blank into the die cavity is controlled by a programmed pressure between the blankholder and the die, Davies [1].

The major problems encountered in sheet metal forming are fracturing, thinning, buckling and wrinkling, shape distortion, loose metal, and undesirable textures, Davies [1]. The success of these have been studied by a number of researchers. This depends largely on the input i.e., process parameters.

The process parameter, that is considered in this paper, is friction i.e., friction models and a model variable. The mathematical problem solved in sensitivity analysis of stamping is the calculation of the change in thickness of a blank due to the friction variations of blanking for various friction models. The formula is

$$Sensitivity = \frac{\partial output\ variable}{\partial friction}, \tag{1}$$

where the output variable is thickness.

2. Basic models of friction

The phenomenal model of friction proposed by Michalowski and Mroz [2] and Curnier [3] has proved to be most successful for modern sheet-metal technique proposed for coated surfaces. For two bodies Ω_1 and Ω_2 in contact, the outward normal vector N at the point of contact is defined on one body Ω_1. The relative displacement u between the two bodies is separated into the tangential and normal parts

$$u = u_T + \mathbf{u}_N \cdot \mathbf{N}, \tag{2}$$

where $u_N = u \cdot N$ and $u_T = (I - N \otimes N)u$. Similarly, the surface stress p

$$F = F_T + \mathbf{F}_N \cdot \mathbf{N}, \tag{3}$$

where F_N is just the contact pressure.

Following the ideas by Michalowski and Mroz [2], the tangential relative velocity is decomposed into adherence and slipping parts

$$\dot{u}_T = \dot{u}_T^{ad} + \dot{u}_T^{sl}. \tag{4}$$

Experiments have shown that the adherence stage is elastic—this is from deformation of microwelds or asperities—and for simplicity we assume a linear elasticity law

$$p_T = -ku_T, \tag{5}$$

where k is the elastic contact stiffness. For the slipping part we define, as in plasticity, a simple evolution rule i.e., constitutive equation is expressed by

$$\dot{u}_T = -\dot{\gamma}\frac{\partial \psi}{\partial p_T}, \tag{6}$$