Modelling of Guillotining Process of Grain Oriented Silicon Steel Using FEM

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Abstract. The aim of the present study is to generate and validate 3D FE model of the guillotining process of grain oriented silicon steel which can be used in practical industry to analyzing the influence of conditions of the process on physical phenomena which occur in the cutting process and quality of the workpiece. Developed model is validated with experimental research by using guillotining test stand and vision-based solutions. The use of an advanced vision systems to monitor of the cutting process of difficult to cut materials allows observing the phenomena of edge bending, slivers formation and the development of guidelines for the correct selection of processing parameters. The effect of selected process technological parameters on the mechanically affected zone and burr formation process on workpiece is analyzed.

INTRODUCTION

The guillotining process of sheet metals has been used often to prepare workpieces for subsequent forming operations. The primary challenge in designing a guillotining process is to increase the durability of the tools, efficiency of the process and the quality of the sheared edge, which are all affected by both the material properties and the process parameters [1, 2]. Grain oriented and non-oriented silicon steels are widely used to produce laminations for electrical machines and transformers. The main difficulty at production lines during forming this materials is the deteriorating effect of cutting on the magnetic properties of the material close to the cut edge. This is a result of deformations, which generate elastic stresses in zones adjacent to the area of plastically deformed and strongly affect the magnetic properties. The another problem of guillotining processes is deterioration of electrical steels cut surface quality by forming of burrs and slivers which may include increasing the metal core eddy current loss and prevents the preparing of sheet bundles.

Knowledge of the mechanical cutting process of grain oriented and non-oriented silicon steels is limited and based mainly on experimental methods, which are often unable to analysis of strongly nonlinear phenomena occurring in the tools - material contact zones. Computational models using the finite element method (FEM), are valuable in reducing the number of trial-and-error experiments required to predict the state of material displacement, residual stresses, strains, material fracture, sheet deformations and quality of the sheared edge after cutting [3, 4, 5].

FINITE ELEMENT MODELING AND EXPERIMENTAL RESULTS

The description of the nonlinearity of the material is conducted using an incremental model that takes into account the influence of the history of strains and strain velocities. For the purpose of constructing the material model, the following is used: Huber-Mises-Hencky's nonlinear plasticity condition, the associated flow law and combined strengthening (i.e., isotropic and kinematic). The incremental contact model covers the contact forces, the contact rigidity, the contact boundary conditions and the friction coefficients in this area. The mathematical model is supplemented with incremental equations of the object's motion and the uniqueness conditions. For the purposes of the solution to the present problem, the central difference method, which is also known as the explicit integration method, is used [6, 7].

A three-dimensional finite element model of guillotining is developed in the general purpose finite element software package LS-DYNA. ET 122-30 (0.3 mm thick) grain oriented silicon steel which is often employed for industry, is used to simulate typical production conditions. Example of results are given at Fig. 1. During the guillotining process four main phases can be observed: elastic, elastoplastic, elastoplastic in which damage occurs, initiation and propagation of cracks leading to final rapture [8]. During the first part of the process, the knives indent the sheet, pulling down some surface material. This causes the sheet to bend and creating the rollover and burnish zone at cut surface. As a result of the upper knive movement the sheet is progressively cut from one end to the other (Fig. 1a). The highest stresses can be observed at tool - sheet cutting zone.

Research with the use of an integrated image registration system enables analysis of the large displacement process and deformation taking into account the nonlinearity of the process. The use of vision techniques makes it possible to explain the physical phenomena accompanying the cutting process. Figure 1b presents final stage of guillotining process recorded by high speed camera. The deformation zone for this case is non-symmetric with respect to the top and bottom knives. The mechanically affected zone in this area is extended. In the cracking phase, it is possible to observe the extension of the plasticized area to the entire thickness of the sheet. The flow zone is visible in the form of a brighter area in the photo from the camera (Fig. 1b).

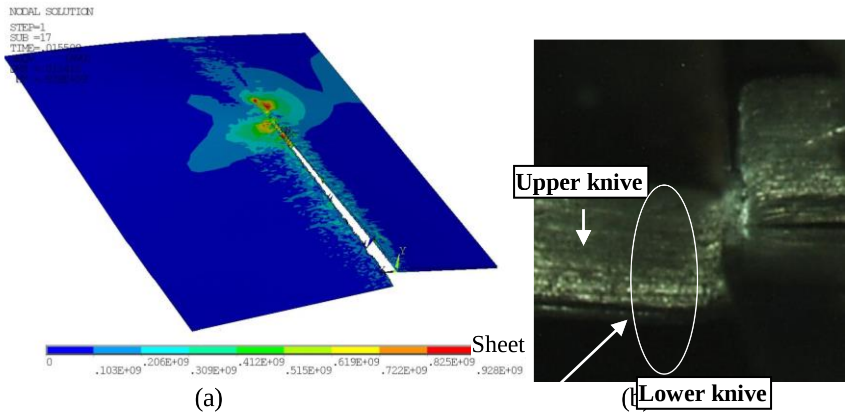

FIGURE 1. Equivalent stress distribution during guillotining [Pa] (a), image from high speed camera at cracking phase (b)

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