Publishing House
AKAPIT

COMPUTER METHODS IN MATERIALS SCIENCE
Informatyka w Technologii Materiałów

Vol. 13, 2013, No. 2

AN EXPERIMENTAL AND NUMERICAL STUDY OF MATERIAL DEFORMATION OF A BLANKING PROCESS

SŁAWOMIR ŚWIŁŁO*, PIOTR CZYŻEWSKI

Faculty of Production Engineering, Warsaw University of Technology,
ul. Narbutta 85, 02-524 Warszawa, Poland
**Corresponding author: s.swillo@wip.pw.edu.pl*

Abstract

An experimental and numerical investigation is carried out in order to determine a material deformation of a blanking process. A highly localized, large strain distribution during the process at the last stage of a complete martial separation, has influence on the final surface quality product. Commonly using method in simulation of the blanking process is based on numerical approach. However, due to the large plastic element deformation is highly recommended to use remeshing procedure and other estimation solutions to simulate the last stage. To verify the final results and theoretical model other method are required. The paper present some implementation of experimental investigation in the field of displacement and strain measurement using a digital image correlation technique (DIC). The authors presents an experimental results of 1 mm thick specimen at the planar blanking process, where different clearances were used in the designed, fully automated apparatus. Finally, the experimental results were compared to the FEM simulation model with a good agreement.

Key words: vision system, blanking process, correlation method, strain measurement, FEM

1. INTRODUCTION

Currently, the technology of making numerous electronic components and equipment, such as engine rotors or transformer cores, is based on the use of a punching process. The above mentioned components are assembled by packeting a group of cut out elements. Hence, very important for the overall quality of the electrical assembly operation is the quality of single components in a packet. The limiting factor is too large burr on the cutting edge, which causes inaccurate adhesion of the sheet metal in a packet and serious deterioration of the quality of electrical assemblies. Finding a solution to this problem is one of the key issues in this technology of making components, and one of the methods currently applied is an experimental analysis of the cutting process.

Experimental analysis of the blanking process is a very complex issue and for a long time it lacked a solution due to the occurrence of large and irregular deformations near the die edge and punch. For a long period of time, the method used for the analysis of displacements was that of visioplasticity (Sutton et al. 1986), unfortunately giving less accurate results and requiring time-consuming calculations. Difficult to identify patterns of the grids, the blurred images of which were subjected to image processing, did not allow obtaining satisfactory results. Hence the need has emerged to search for new solutions in the field of numerical analysis. An outcome of this search was the development of a method based on Fourier transform, applied in the analysis of displacement increase between the individual stages of a cutting process (Leung et al. 2004). By

 ISSN 1641-8581

comparing the image of a certain stage of deformation with the image following immediately this stage, a distribution of displacement was obtained, which enabled the deformation size to be determined. However, certain conditions had to be satisfied to make such calculations possible. The goal was achieved by designing a special unit to carry out the punching process. With the punching process performed under static conditions, the authors were able to gain control of the image recording at a resolution relevant to the size of material displacement, since the proposed method required visualisation of even the smallest displacements of the material, possible to achieve only with a sufficiently large image resolution. This was due to the fact that, instead of the typical markers applied to the surface in the form of mesh, material texture was examined. Since that time, mainly due to the rapid development of various vision techniques and gaining access to solutions offering rapid cameras of high-resolution, many authors (Stegeman et al. 1999) have tried to solve this problem, getting results even when operating on millimetre samples. However, the results obtained in this way were mainly based on tests carried out with the aid of specially designed instruments, taking into account the conditions adequate to vision measurements, but irrelevant to the real conditions under which processes of this type are performed. Hence, the submitted studies lacked any conclusions regarding the tool wear behaviour and analysis of the crack formation tendency, both these issues being quite fundamental in control of the tool performance and monitoring of the process run.

The authors' proposal for the study of the cutting process relates to vision measurements taken under the real conditions of the punching operation. These conditions demand taking into account the external factors such as vibration, adequate lighting and vision access to the area of material deformation. All these factors make the analysis of the deformation process of the die-cut materials a great experimental challenge in the field of measurement techniques for both experimental and numerical methods (Makich et al. 2008, Brokken et al. 1998, and Hambli 2001).

2. EXPERIMENTAL SET-UP

The schematic representation of a measurement stand is shown in the attached figure 1. Specially designed illumination system allowing for the small measurement area and diversity of material structures enables taking a sequence of images captured by the vision system with specially chosen lens and a digital camera recording in the memory hundreds of photos per second. Thus gathered information is transformed to the computer memory and subjected to further numerical analysis, taking into consideration two stages of the process shown in figure 1a, i.e. plastic flow in the initial phase and crack formation next. For tests an albumin plate was used. From the sheet with overall dimensions of 100x80 millimetres and 1.5 millimetres thick, strips of 1.5x7x35 mm dimensions were cut out. Tests were carried out using a specially designed blanking apparatus, with several elements such as: base, side walls and upper connecting element and bearing shell as well as sliding element with clamping of the upper cutting surface, where the sheet metal is pressed between plate and die. Initially, the blanking process was performed using only a hand holder. Currently, the process is carrying out using a stepper motor, with precise punch location for each step of deformation (figure1b). A final configuration of the experimental set-up is demonstrated in figure 1c, where all the systems such as: optical, illumination and vision systems are presented.

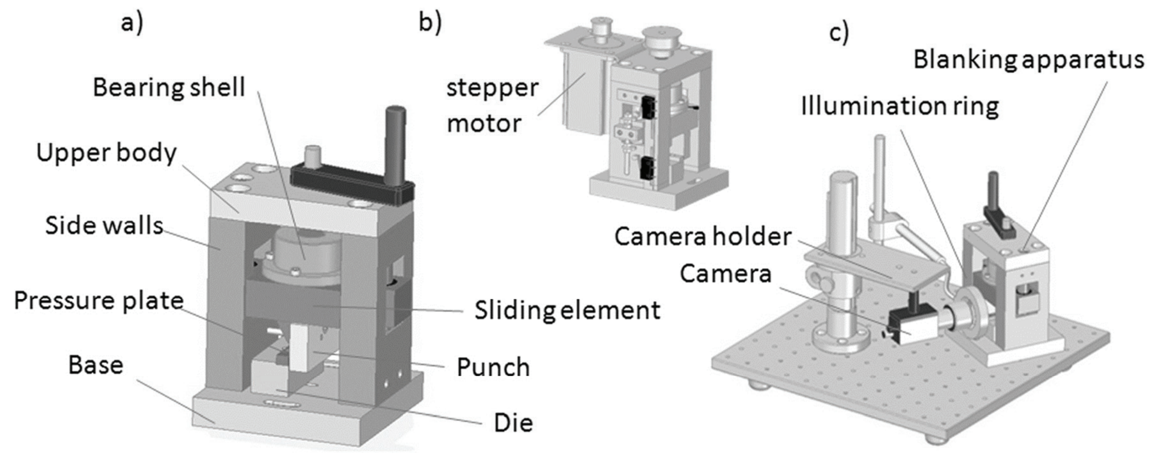

Fig. 1. *Schematic of the experimental set-up: a) blanking apparatus, b) vision system configuration.*

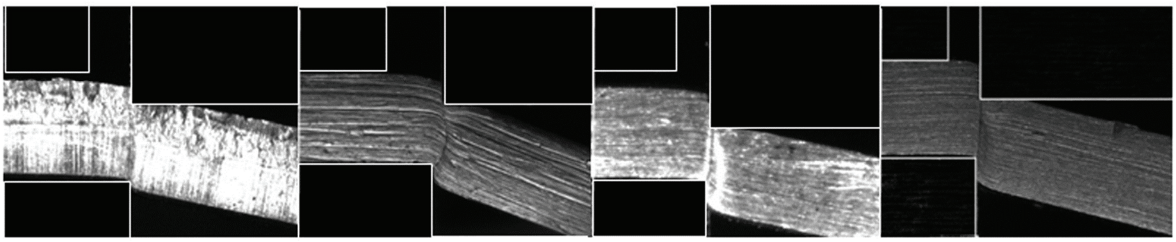

Fig. 2. Specimen surface quality under different illumination and after surface machining.

To perform an analysis of the recorded images of the surface of the cut out material, advanced numerical solutions of the image processing based on digital image correlation have been used. However, a high surface specimen quality is required, where material texture combine with their illumination are the major parameters as shown in figure 2. Next the optical magnification is an important parameter, since the DIC method is sensitive for the texture marks. To accurately measure the material flow on the surface of an object, a texture patterns need to be related to small group areas. To meet this requirement, several solutions are applied, such as: dividing the examined area into small sub-groups or using high resolutions. In the tests carried out, although a low-resolution camera has been used (640x480 pixels), any possible inaccuracies in calculations were compensated by optical zoom and limiting the analysis to a small area with the highest strain concentration (figure 3).

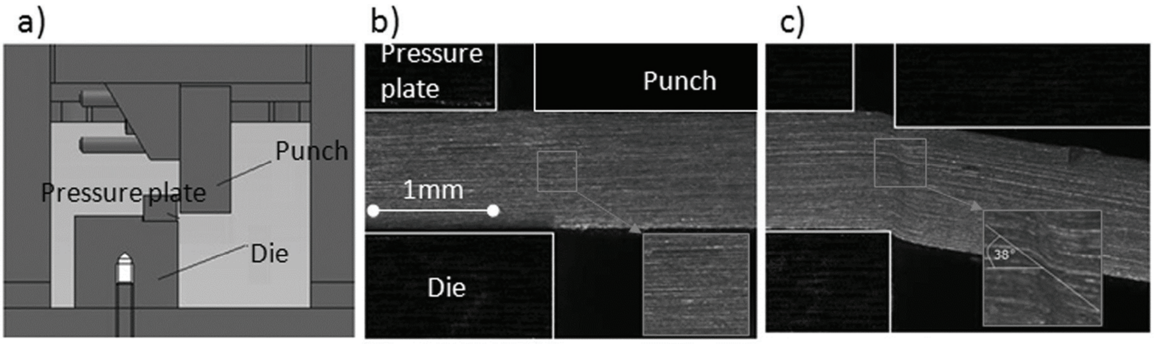

Fig. 3. Methodology of the planar blanking process: a) blanking apparatus, b) initial step, b) final step (just before cracking).

3. STRAIN MEASUREMENT

The measurement of deformation in a punched sample is a serious problem due to high localisation of the non-linear strain distribution. Assuming that the die-cut sheet has a thickness of 1 mm, the maximum strain will be concentrated in an area not larger than tens of micrometers. Therefore, the strain measurement method should be characterised by high resolution and high accuracy. For this reason, a method for the strain measurement has been proposed that demands the use of combined advanced solutions in the field of machine vision based on the correlation of two images. The numerical process of comparing two images is performed for each pixel in the examined area, which enables high-accuracy determination of the measured parameters. Due to this, the process of the measurement discretisation is imposed solely because of the image resolution. The measurement conditions, however, require that the test area was adequately illuminated and the process of numerical calculations referred to small displacements of the material. Figure 4 shows results of the surface discretization for the sample before and after process using virtual grid pattern. An advantage of this method over the traditional techniques using different mesh geometry is the process of measurement discretisation, which in the case of the proposed solution is not restricted by the geometry of the pattern used. An additional advantage of the proposed solution is its simplicity, involving the use of a simple natural pattern resulting directly from the texture of the material.

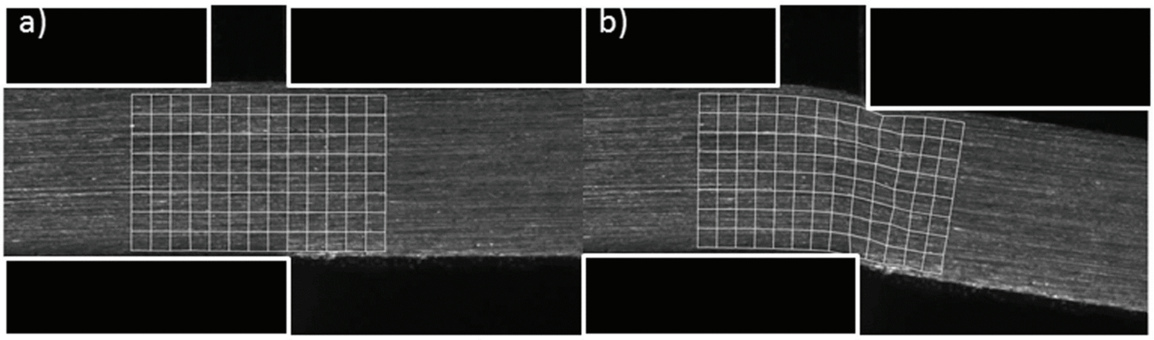

Fig. 4. Surface discretization using digital image correlation method (virtual grid pattern applied to the real surface: a) initial stage, b) final stage.

As for the kinematics calculation a method of analysis of grid has been applied, and by taking into consideration the impact of the near-by surrounding (Swillo 2001). In a mathematical formulation it means the use of a directional derivative of the gradient of an increment of displacement. The next surrounding in relation to the grid is conceived as neighboring points, the assessed quantity of which depends upon the position of the analyzed node. Let us choose some point $x_i^{(n)}$ from the neighborhood of the point x_i. On the basis of directional derivative of the displacement increment vector we get:

$$v_j^{(n)}\Delta u_{i,j} = \frac{\Delta^2 u_i^{(n)}}{\Delta s^{(n)}} \qquad \text{for } i,j = 1,2,3 \qquad (1)$$

where: $\Delta^2 u_i^{(n)}$ is the second order increment of the displacement vector, $\Delta s^{(n)}$ is a distance between the points $x_i^{(n)}$ and x_i in the ν direction, $v_j^{(n)}$ expresses vector directional cosines of the *n* direction. The upper braced index denotes the chosen direction. The displacement increments Δu_{ij} are unknown in this equation. The solution of the equations is available when at least two directions are investigated and the least square method is used.

Finally, the total logarithmic strain was calculated as presented in figure 5, showing a good agreement to the FEM results. In the numerical simulation a large grid pattern was used intentionally (similar to the virtual grid – figure 4) in order to verify the image processing procedure that has been performed based on the correlation method.

4. DISCUSSION OF THE RESULTS

Next, additional experimental investigation was conducted for a planar blanking process to determine an influence of the clearance for the material fracture. Ten sets of experiments were conducted in the range of 0.035mm to 0.485mm of clearance (figure 6). During these experiments the clearance between the material and the punch was measure and the blanking process was recorded in computer memory. The punch penetration for each case were obtained every time up to fracture. Figure 7 shows that the relation between the punch penetration and clearance is most likely linear. That prediction could be successfully implemented in numerical calculation.

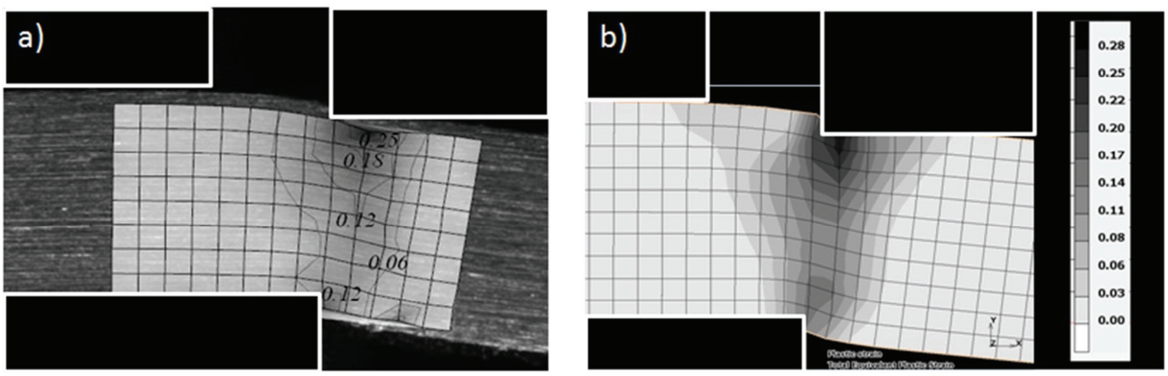

Fig. 5. Results of the True Strain for the planar blanking process: a) experiment, b) FEM.

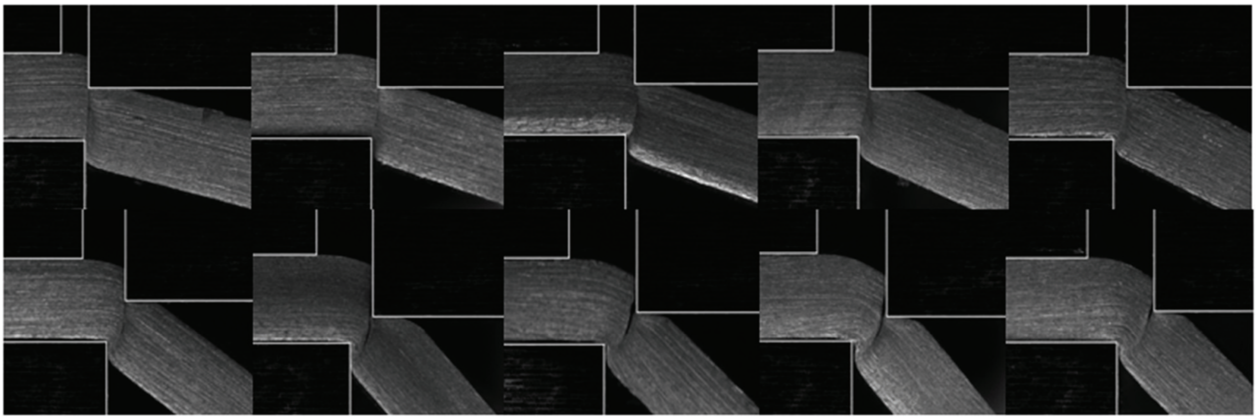

Fig. 6. Set of experimental results for different clearance (0.035-0.485 mm), monitored up to fracture.

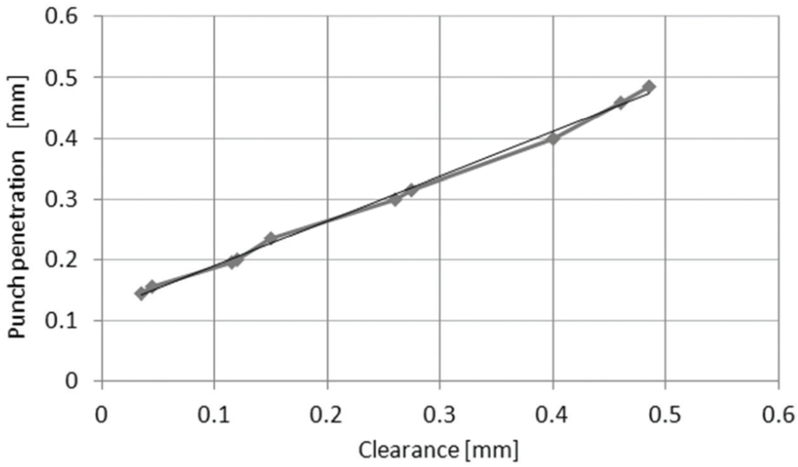

Fig. 7. Influence of clearance on the material punch penetration.

5. SUMMARY

In the currently ongoing project, the deformation in a planar blanking process was monitored up to fracture. The DIC method was used to numerically control the defamation and the FE method was compare to experimental results. The proposed automatic vision system enabling the realization of measurements and calculations in a quick and precise manner for the blanking process even for the small (less than 1 mm) thick. The experimental examples presented in this paper referring to the two dimensional displacement analyses (according to the function (1)) and strain measurements using grid method. The results indicate that there are ample possibilities in the field of experimental analysis of the material flow, and are a valuable tool for verifying numerical methods.

Acknowledgements. Scientific work financed as a research project from funds for science in the years 2011-2013 (Project no. N N508 628140).

REFERENCES

Brokken, D., Brekelmans, W.A.M., Baaijens, F.P.T., 1998, Numerical modeling of the metal blanking process, *Journal of Materials Processing Technology*, 83, 192–199.

Hambli, R., 2001, Comparison between Lemaitre and Gurson damage models in crack growth simulation during blanking process, *International Journal of Mechanical Sciences*, 43, 2769–2790.

Leung, Y.C., Chan, L.C., Tang, C.Y., Lee, T.C., 2004, An effective process of strain measurement for severe and localized plastic deformation, *International Journal of Machine Tools and Manufacture*, 7-8, 669-676.

Makich, H., Carpentier, L., Monteil, G., Roizard, X., Chambert, J., 2008, Metrology of the burr amount - correlation with blanking operation parameters (blanked material – wear of the punch), *Int. J. Mater. Form.*, 1, 1243-1246.

Stegeman Y.W., Goijaerts A.M., Brokken D., Brekelmans, W.A.M., Govaert, L.E., Baaijens F.P.T., 1999, An experimental and numerical study of a planar blanking process, *J. Mat. Proc. Techn.*, 87, 266-276.

Sutton, M.A., Mingqi, Ch., Peters, W.H., Chao Y.J., McNeill, S.R., 1986, Application of an optimized digital correlation method to planar deformation analysis, *Image and Vision Computing*, 3, 143-150.

Swillo, S., 2001., Automatic of strain measurement by using image processing. *Proc. Conf. Engineering Design and Automation 2001,* eds, Parsaei, H.R., Gen, M., Leep, H.R., Wong J.P., Las Vegas, Nevada, 272-277.

DOŚWIADCZALNA I NUMERYCZNA ANALIZA PROCESU CIĘCIA W POMIARACH DEFORMACJI

Streszczenie

Doświadczalne i numeryczne badania zostały przeprowadzone, w celu określenia wielkości deformacji w procesie cięcia. Duże wartości odkształcenia połączone z ich koncentracją na niewielkich obszarach prowadzące do procesu rozdzielenia materiału mają duży wpływa na końcową jakość wyrobu. Tradycyjne metody analizy tych zjawisk opierają się wykorzystaniu metod numerycznych. Z uwagi jednak na dużą koncentrację odkształceń zalecane jest weryfikowanie tych wyników innymi metodami doświadczalnymi. W artykule przedstawiono możliwość zastosowania numerycznej obróbki obrazu z zastosowaniem korelacji w pomiarach pól przemieszczeń i odkształceń. Zaprezentowano wyniki obliczeń doświadczalnych dla procesu cięcia dla różnych wielkości luzów. Wyniki pomiarów doświadczalnych zostały zestawione z symulacja komputerową MES.

Received: October 17, 2012
Received in a revised form: October 22, 2012
Accepted: November 5, 2012