Available online at www.sciencedirect.com

ScienceDirect

ELSEVIER

Procedia Engineering 63 (2013) 616 – 622

Procedia Engineering

www.elsevier.com/locate/procedia

The Manufacturing Engineering Society International Conference, MESIC 2013

Study of the Indentation Process under Specific Technological Parameters

M.M. Marín[a,]*, A. M. Camacho[a], M.A. Sebastián[a]

[a]*Department of Manufacturing Engineering. National Distance University of Spain (UNED), C/ Juan del Rosal 12, 28040 Madrid, Spain*

Abstract

There is a large variety of Compressive Forming Processes with different typologies and characteristics. In this paper, the indentation process is studied from the point of view of manufacturing. The influence of technological parameters such as friction and shape factor on the process has been studied. The aluminum alloy AA 6082 has been employed in this study due to its good mechanical properties, light weight and its capacity of being recycled. The Finite Element Method (FEM) has been used for the analysis. The indentation process has been studied under axisymmetric conditions. The forces to carry out the indentation process and the contact pressures have been obtained. Finally, it is shown that the forces and the contact pressures do not have a high dependency on the friction between the surfaces of the punch and the workpiece. The shape factor has a greater influence on the process, especially the width of the workpiece.

Selection and peer-review under responsibility of Universidad de Zaragoza, Dpto Ing Diseño y Fabricacion

Keywords: friction; shape factor; axial symmetry; FEM; indentation process

1. Introduction

The technological advances and the recent researches provide new alternatives for manufacturing processes based on conventional processes (Groche, et al., 2007). This paper studies the indentation process from the point of view of manufacturing. There are a variety of studies on the indentation process. However in most of them, indentation is used to obtain mechanical properties of the material such as hardness (Rebouca, et al., 2010),

* Corresponding author. Tel.: +34 913 988 733; fax: +34 913 986 046.
E-mail address: mmarin@ind.uned.es

Selection and peer-review under responsibility of Universidad de Zaragoza, Dpto Ing Diseño y Fabricacion
doi:10.1016/j.proeng.2013.08.273

(Camacho, et al., 2011a), (Camacho, et al., 2011b). In the present study, the indentation process is analyzed as a unitary compression process (Grosman, et al., 2012). This unitary operation studies the influence of technological parameters such as the friction and the workpiece geometry (Marín, 2011).

In this study, it has been employed a ductile material. The aluminum alloy AA 6082 has been chosen due to its good mechanical properties, its light weight and its capacity of being recycled (Martchek, 2006).The indentation process has been studied under axial symmetric conditions.

The Finite Element Method (FEM) is used to analyze the indentation process. All cases have been analyzed by the Finite Element Method (FEM) using a general purpose code of implicit methodology (ABAQUS/Standard) (Hibbitt, et al., 2011).

The forces to carry out the process and contact pressures are evaluated. For this purpose, different workpiece geometries have been considered under different friction conditions (Joun, et al., 2009).

Nomenclature

B	diameter of the punch
p	stroke of the punch
d	diameter of the workpiece
h	height of the workpiece
μ	Coulomb friction coefficient

2. Methodology

The indentation process is studied under axisymmetric conditions. Both geometries of the punch and the workpiece have got circular section and the application of load through the punch is axial kind. Initially, the punch is in contact with the top-surface of the workpiece. In this situation, the punch does not apply forces on the workpiece. Below, the punch compresses the workpiece until the punch displaces 2 mm in all cases. Figure 1 has represented the axisimmetric model where the stroke of the punch is named with the variable p.

A cylindrical geometry of the punch is considered, where *B* is the diameter. The workpiece dimensions, diameter and height, have been defined by the variables *d* and *h,* respectively.

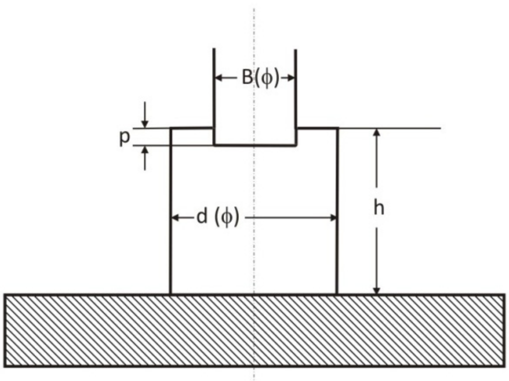

Fig. 1. Geometry of the axisimmetry model

2.1. Parameters

Many parameters can influence the compression process. One of the most important variables in metal forming is the friction. In this study the friction coefficient has been studied in the shown models of the Table 1. To do this, it has been carried out an analysis with different Coulomb friction coefficients, changed from μ=0 to μ=0,5 in increments of 0,1.

Table 1. Geometry of the models

			h = B			
d	2B	3B	5B	7B	9B	11B
			h = 2B			
d	2B	3B	5B	7B	9B	11B
			h = 2B			
d	2B	3B	5B	7B	9B	11B
			h = 4B			
d	2B	3B	5B	7B	9B	11B
			h = 5B			
d	2B	3B	5B	7B	9B	11B

In this study the friction has been considered combined with the workpiece geometry. The different workpiece geometries have been defined based on the geometry of the punch. The obtained geometries keep an aspect ratio between the dimension of the punch and the dimensions of the workpiece called shape factor. Throughout the study, the height and diameter of the piece have been changed. The different geometric models analyzed are shown in Table 1.

3. Analysis

The study of the different models has been carried out by means of the finite element method. This case has been done using ABAQUS/Standard (Hibbitt, et al., 2011) finite element code. It is a general purpose software of implicit methodology. Continuous, first order, reduced integration elements and Lagrangian formulation has been chosen. The elements CAX4R belongs to Abaqus/Standard element library. The models analyzed have been solved through the Newton-Rhapson method.

For the analysis, a ductile material has been chosen. The aluminum alloy AA 6082 has been selected among the wide variety of ductile materials. This is due to their good mechanical properties in this kind of processes and their wide use in industrial environments. Before the analysis, a study of the mesh has been done.

3.1. Study of the mesh

For this analysis has been chosen the models shown in Table 1. The force to carry out the process and the contact pressures have been obtained under different element sizes of the mesh (Camacho, et al., 2011b).

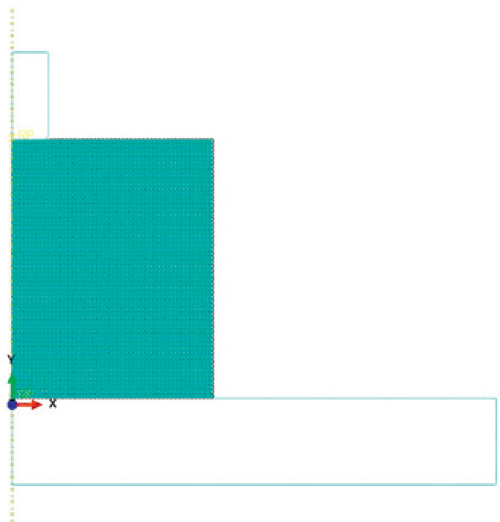

Fig. 2. *The employed mesh in the workpiece*

In this study three models have been selected with different height each one. The chosen heights have been *h*=*B*, *h*=3*B* and *h*=5*B* with different shape factor. This manner the studied models had the following diameters: *d*=2*B*, *d*=5*B* and *d*=9*B*.

Each analysis has been made with different element sizes of the mesh. The different element sizes have been 0,5 mm, 0,7 mm, 0,9 mm and 1 mm. The obtained forces and contact pressures have been studied. With the obtained results it has been deduced that the mesh most suitable is an homogenous mesh for the entire workpiece with an element size of 0,5 mm. The model employed has been validated through a comparison with classical studies (Marín, 2011). The employed mesh is shown in Figure 2.

4. Results

4.1. Influence of friction

In Figure 3 it is shown the force to carry out the process in models with different shape factor. The friction coefficient changes from 0 until 0,5, with increments of 0,1.

In the graphics it has been represented the obtained forces considering different friction coefficients and shape factors. Due to the large amount of models studied, only the most representative of them are shown in this paper.

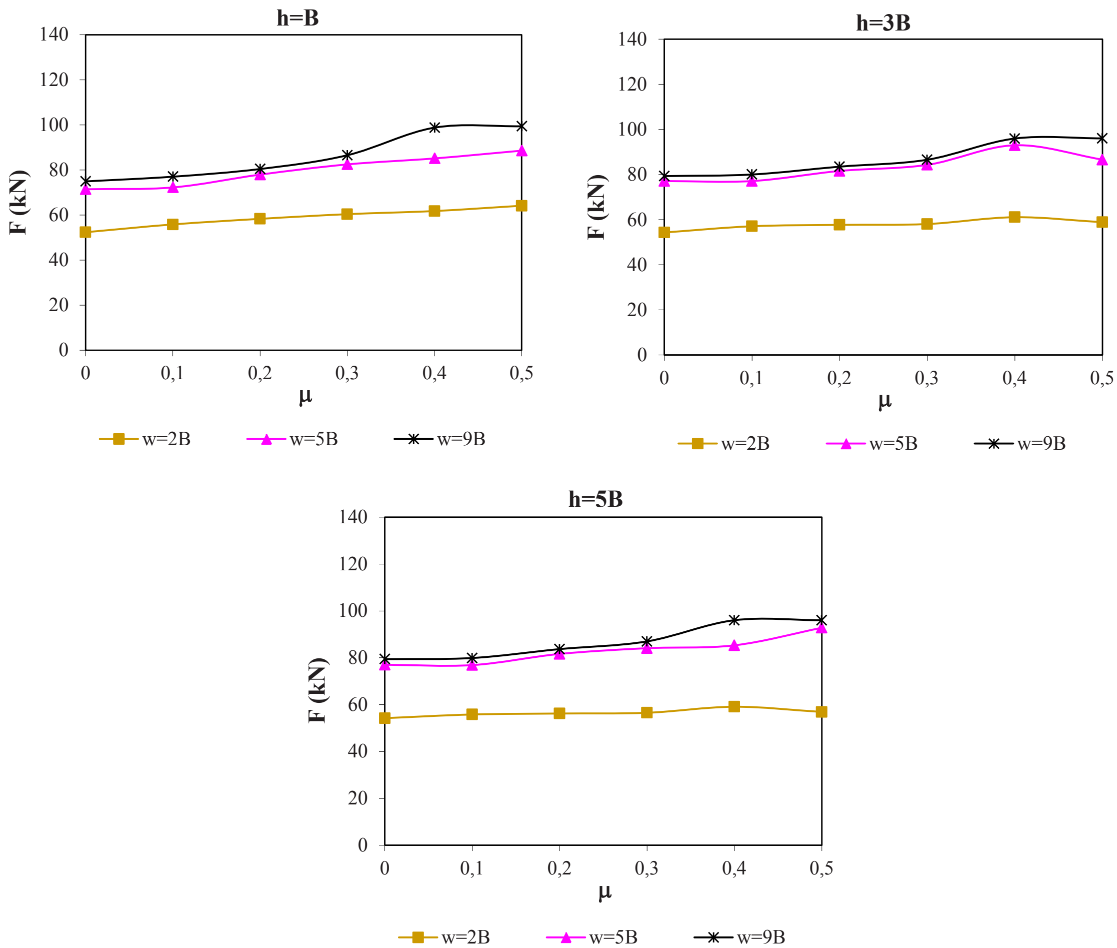

Fig 3. Forces versus friction in some models

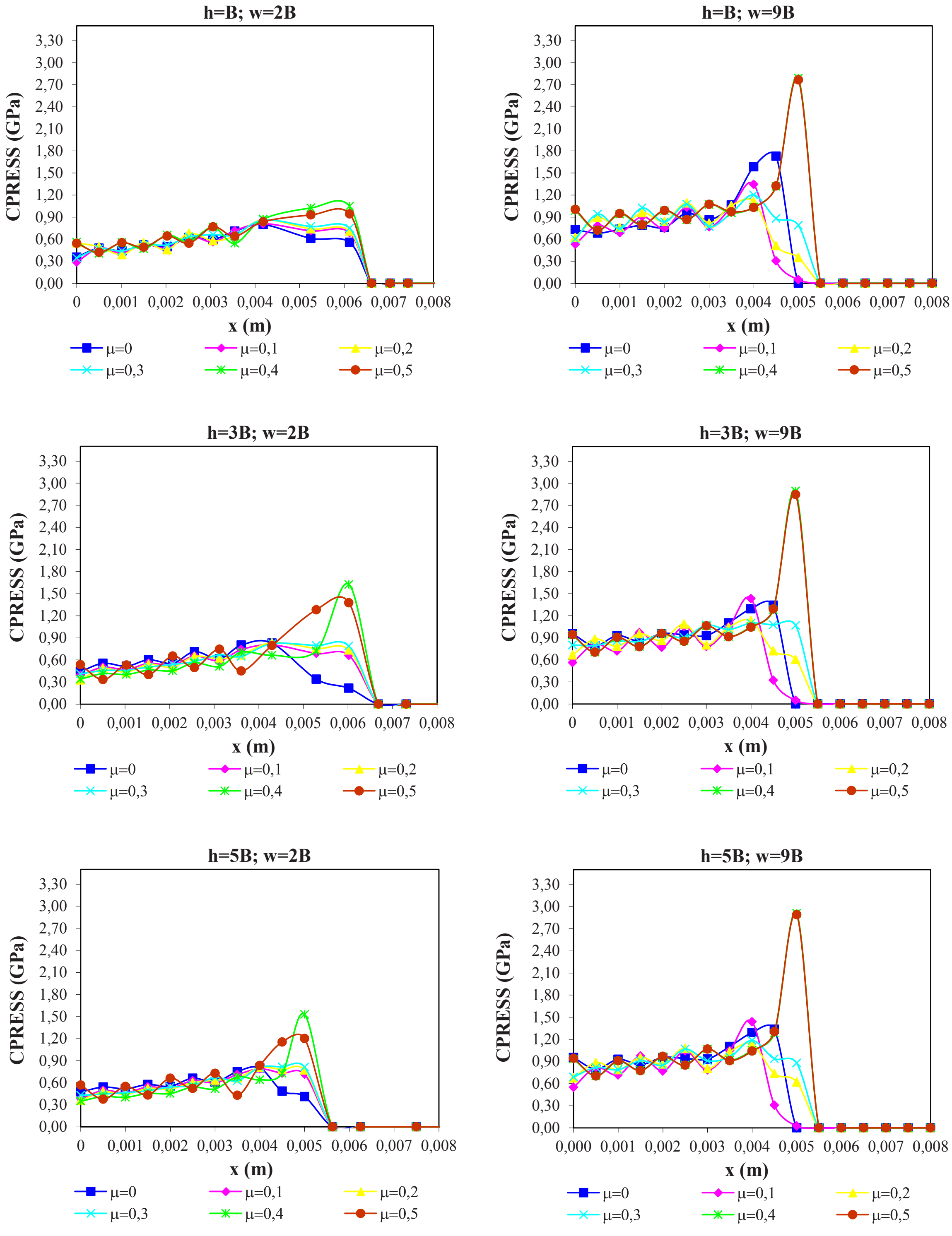

Fig. 4. Contact pressure versus friction in some models

In general terms, the higher the friction coefficient, the higher the forces required. However, this increase is not significant compared to the change of the friction coefficient. Due to this, the forces to carry out indentation process under axisymmetric conditions does not seem to depend on the friction coefficient.

Also, the contact pressures have been analyzed considering the friction coefficient. In Figure 4 the contact pressure graphics are represented for some studied models. As in the case of forces, the models represented in Table 1 have been analyzed. It has been represented the pressures on contact surface of the workpiece, considering the different friction coefficients and the shape factors.

In the figure it is observed that the difference between the contact pressures at the top and the bottom are more pronounced when there is higher friction between contact surfaces. In general, it seems that the average contact pressures do not depend on the friction coefficient.

4.2. Influence of shape factor

In Figure 5 the obtained forces versus the shape factor are represented. In the figure it is observed that with a constant height of the workpiece, the higher the width, the higher the forces to carry out the indentation process.

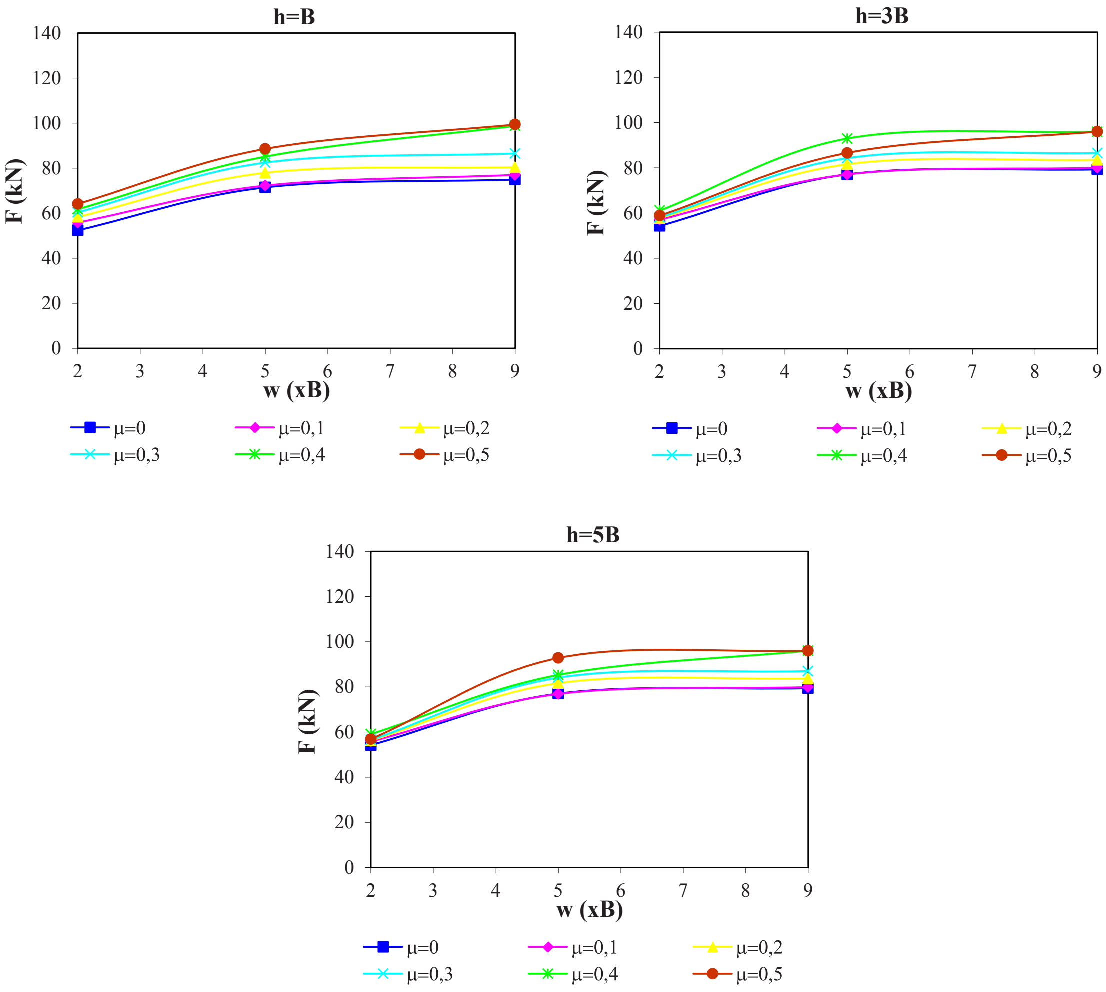

Fig. 5. Forces versus shape factor

Nevertheless, if the width of the workpiece remains constant and the height increases, the obtained forces are almost the same. Therefore, in the indentation process under axisymmetric conditions it has more influence a variation of width that a change of the workpiece height.

As it is observed in Figure 4, it can also be analyzed from the point of view of the shape factor. If the same workpiece height is kept, the higher the width, the higher the contact pressures. However, if the width is constant, with a higher height, the result contact pressures will be the same.

5. Conclusions

In this work technological parameters such as the Coulomb friction and the geometry of the workpiece (shape factor) in indentation processes have been studied. To analyze the influence of them, it has been obtained the forces to carry out the indentation process and the contact pressures between the punch and workpiece.

The indentation process has been analyzed by the finite element method. It has been used the implicit methodology. The studied models have been analyzed under axisymmetric conditions. It has been demonstrated that apparently the forces do not depend on the friction between the contact surfaces of the punch and workpiece. The forces in axisymmetric models are influenced by the width of the workpiece while the height is not so relevant.

The average contact pressures reached between the surfaces of the punch and the workpiece do not depend on the friction. On the other hand, the higher the width of the workpiece, the higher the contact pressures. Whereas the higher the height, the contact pressures are almost the same. Therefore, the contact pressures depend on the width of the workpiece while the height seems to have a lower relevance.

Acknowledgements

This work has been financially supported by the Ministry of Economy and Competitiveness of Spain (Project DPI2009-07300) and the funds provided through the Annual Grant Call of the E.T.S. Ingenieros Industriales (ICF04).

References

Camacho, A., Marín, M., Bernal, C., Sebastián, M., 2011a. Simulation and experimental techniques for the analysis of localised-incremental forging operations. Guimares, Portugal, pp. 161-167.

Camacho, A., Marín, M., Rubio, E., Sebastian, M., 2011b. Modeling strategies for efficient FE simulation of LIF processes. Cadiz, España, pp. 725-732.

Groche, P., Fritsche, D., Tekkaya, E.A., Allwood, J.M., Hirt, G., Neugebauer, R., 2007. Incremental bulk metal forming. CIRP Annals – Manufacturing Technology, p. 635 – 656.

Grosman, F., L., M., Ziółkiewicz, S., Nowak, J., 2012. Experimental and numerical investigation on development of new incremental forming process. Journal of Materials Processing Technology, 212(11), pp. 2200-2209.

Hibbitt, D., Karlsson, B., Sorensen, P., 2011. ABAQUS v6.10, User´s Manuals. Providence, USA.

Joun, M.S., Moon, H.G., Choi, I.S., Lee, M.C., Jun, B.Y., 2009. Effects of friction laws on metal forming processes. Tribology International, pp. 311-319.

Marín, M., 2011. Estudio de factores tecnológicos en procesos de compresión por deformación plástica de materiales metálicos dúctiles por el método de los elementos finitos. PhD Thesis. Madrid, España.

Martchek, K., 2006. Modeling more sustainable aluminum: case study. The International Journal of Life Cycle Assessment, 11, pp. 34-37.

Rebouca, P., Cavalcante, T., Alburquerque, V.,Tavares, J., 2010. Brinell and Vickers hardness measurement using image processing and analysis techniques. Journal of Testing and Evaluation, 38(1), pp. 88-94.