Journal for Technology of Plasticity, Vol. 34 (2009), Number 1-2

ANALYSIS OF THE HOLE FLANGING PROCESS

[1]*Milan Šljivić*, [1]*Ranko Radonjić*, [2]*Milentije Stefanović*
[1]*University of Banja Luka, Faculty of Mechanical Engineering, Republic of Srpska, B&H*
[2]*University of Kragujevac, Faculty of Mechanical Engineering, Serbia*

ABSTRACT

This paper presents analysis of the hole flanging process by virtual manufacturing tools. The dependency between initial hole diameter and hole diameter after hole flanging process of sheet metals was numerically analyzed. Hole flanging process formability is analyzed for three different hole diameter, and according to received results dependency between initial hole diameter and collar diameter after forming process is defined. Necessary mechanical properties data of formed material (St 14 according to DIN standard) for process modeling were determinated by experiment. Simulation results show very high coincidence with the empirical data. Also, dependency between maximum punch load and punch stroke for different hole diameters have been defined on basis of simulation outputs.

Key words: *sheet metal, hole flanging, hole diameter, numerical analysis.*

1. INTRODUCTION

Hole flanging is a one of the important sheet metal forming techniques where workpiece prepared from sheet metal with previously drilled or punched hole in the centre, is rigidly clamped around its periphery, and then punch is used to force blank into a die to form collar (hollow-flanged component). There are two types of hole flanging process: hole flanging with ironing and hole flanging without ironing (without intended thickness changing). Parts produced by the first way are usually used for thread cutting at collar, and parts obtained without ironing have adaptation as a support for pipe joining by welding with other assembly parts. Products which in forming steps have and hole flanging operation are very common in car bodies, at exhaust gases systems, etc.

2. HOLE FLANGING PROCESS

In hole flanging process the deformation of the sheet blank around the hole periphery is a combination of bending and stretching. The circumferential strain induced at the flange edges, and however, is often large enough to cause failure to neck or tear. Schematic drawing of the hole flanging process is shown on Fig. 1. Equilibrium equation in the forming zone has the form [6]:

$$\rho \frac{d\sigma_\rho}{d\rho} + \sigma_\rho - \sigma_\theta = 0 \tag{1}$$

Where σ_ρ is circumferential stress and σ_θ tangential strees.

Deformation work force (punch load) can be calculated by derived formula:

$$F = 2\pi \cdot R_\delta \cdot s \cdot \sigma_{\rho \max} \cdot \sin\alpha \tag{2}$$

α - inclined angle between workpiece and rounded die edge.

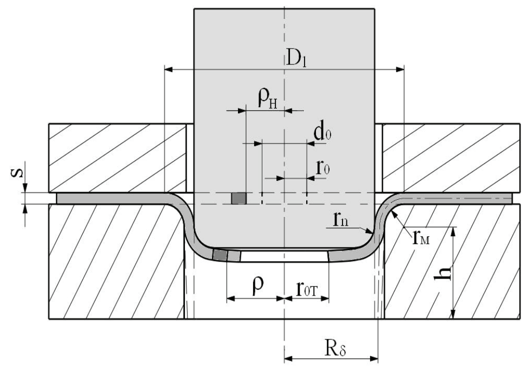


Fig. 1 - Shematic drawing of the hole flanging process

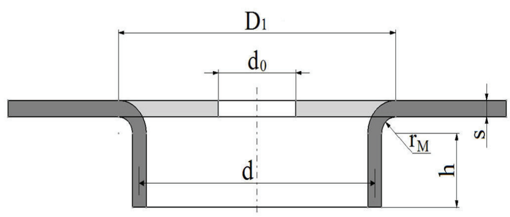


Fig. 2 – Workpiece with formed collar

The initial diameter of the hole needed for collar forming can be determined by using equality of lengths, Fig. 2.

$$\frac{D_1 - d_0}{2} = h + \left(r_M + \frac{s}{2} \right) \frac{\pi}{2}$$

$$d_0 \cong D_1 - 2h - 3.14 r_M - 1.57 s \tag{3}$$

But by using a formula (3) can not be determined the initial hole diameters that will ensure the forming process without the cracks emergence. Definition of the initial diameter that will ensure the process without cracks can be done experimentally or by the application of modern numerical simulation.

3. NUMERICAL SIMULATION

For numerical simulation of forming processes firstly it is necessary to prepare and define all geometrical data about tools and specimen and their material data. After that, it is possible sequentially simulate process and find optimal resolution.
Modeling is an activity for defining of all necessary parameters based on existing technical knowledge, ideas and innovations for creating of a product or process virtual model. Simulation is the illustration, imitation, or a dedicated created presentation for demonstration or analysis for previously pre-processed problem that performs computer – numerical simulation.
The process of solving tasks by finite element method (FEM) consists of the following basic steps:

- The problem identification,
- Discretization,
- Determination of boundary condition,
- Formulation of equations for element
- Connecting equations for element
- Numerical solving of formed equations
- Analysis of achieved results.

In FE analysis of the production process, the process must be viewed as a system of interconnected relevant parameters. The key technical problems that must be considered in the analysis of processes are related to:

- Workpiece: size and shape, material, chemical composition and microstructure, flow properties in forming terms (flow stress in the function of strain, strain rate and temperature), thermal and physical properties;
- Tools: geometry, surface condition, material and hardness, working temperatures, rigidity and accuracy;
- Conditions in forming zone: surface condition, lubrication, friction and heat transfer,
- Deformation zone: the mechanics of plastic forming, material flow, stress, speed and temperature;
- Production equipment: speed, productivity, capacity in terms of maximum force and energy, rigidity and precision.

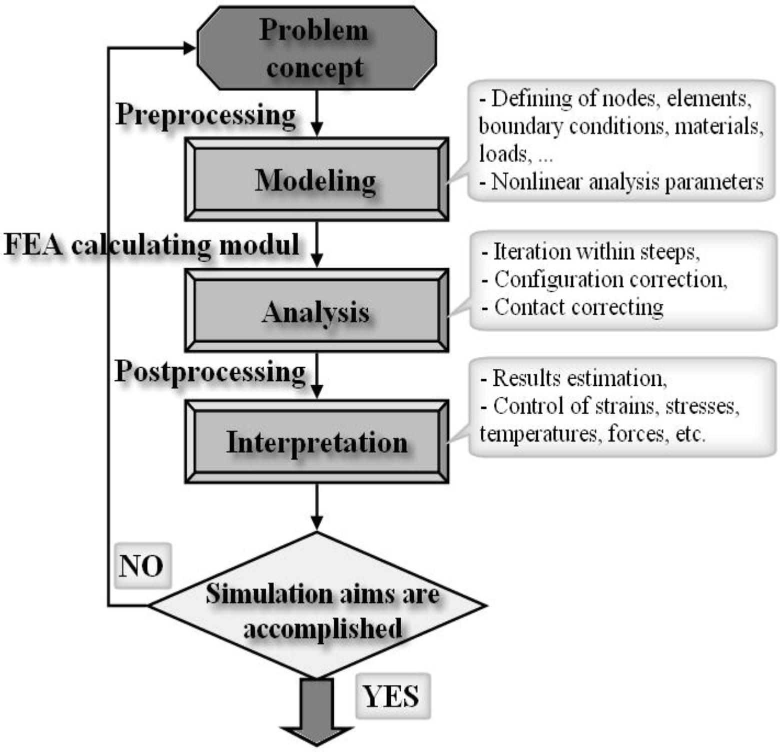
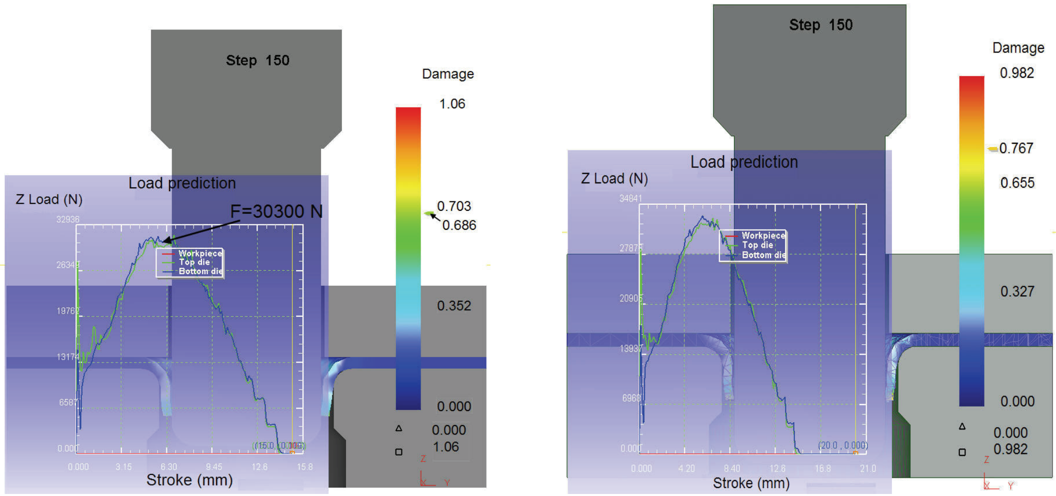


Fig. 3 - Procedure for problem solving by FEM

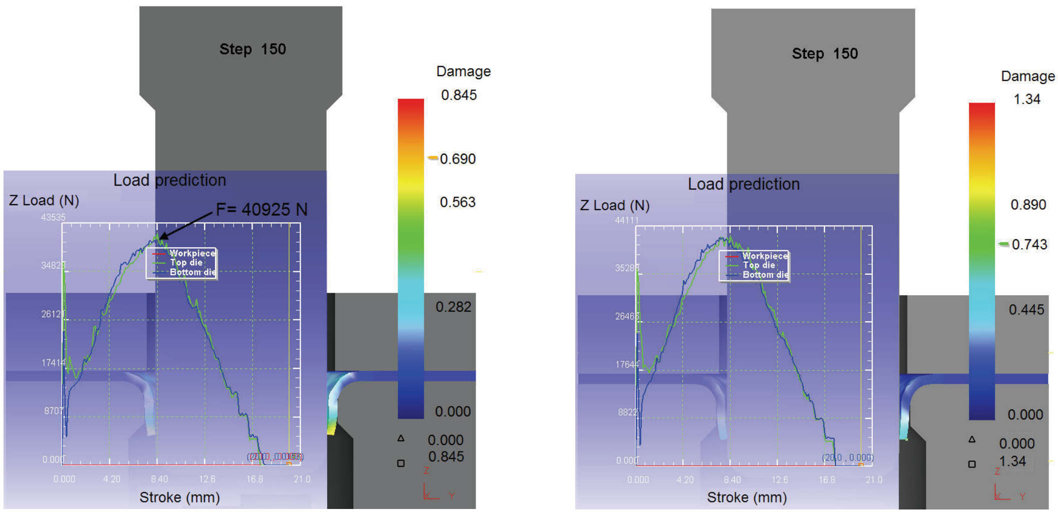
For determination of limiting relation values between hole diameters before and after hole flanging process a few numerical simulations have been made so far. In this work workpiece material was St 14 according to DIN standard. Simulations were done for sheet metal with thickness 2 millimetres, and in accordance with simulation results dependency between initial hole diameter in sheet metal (hole diameter before hole flanging process) and hole diameter after forming process was established. Successfulness of hole flanging process was evaluated by analysis of values for effective stress at formed workpiece part. Beside that, evaluation of the process is done in accordance with obtained results regarding damage. In DEFORM software package allowed value for damage at hole flanging process and similar sheet metal forming processes is 0,7, and with damage values lower than 0,7 cracks at drawn collar will not arise. For collar analysis forming with diameter of 27 mm initial hole, diameter which is necessary for successful forming process (without cracks) was determined (13,5 mm, Fig. 4). Simulation results shows that at sheet metal forming with initial diameter 13 mm cracks will arise.



(a) (b)

Fig. 4 - Hole flanging process for diameter d=27mm in sheet metal with 2 mm thickness; (a) with initial hole diameter d_o =13.5 mm, (b) with initial hole diameter d_o =13 mm

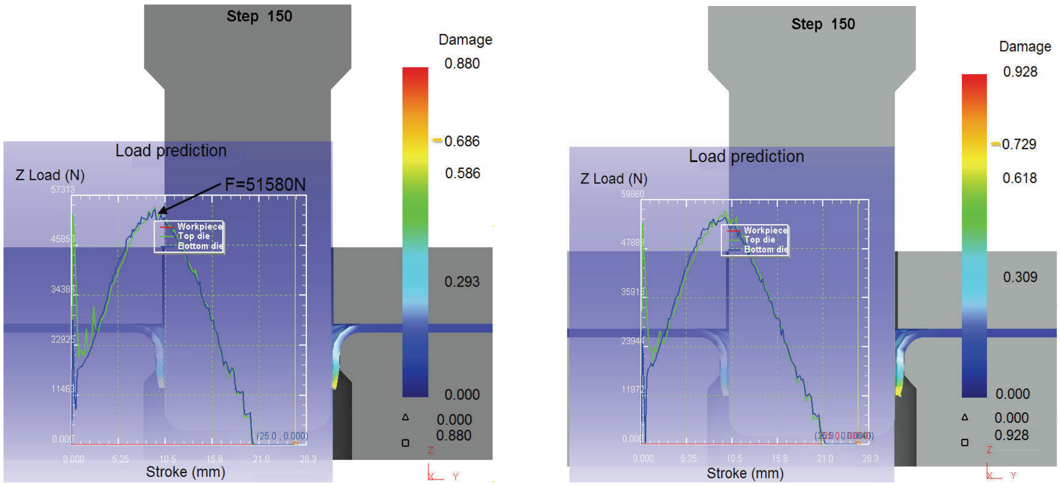
For the required hole diameter d = 35 mm *it* was found that the initial hole diameter should be d_o =17.5 mm (value for „damage“ is 0.69, while damage value for initial hole diameter d_o =17 mm is 0.743), Fig. 5. Also, effective stresses were analyzed, and their results at sycessfull hole flanging process are lower than stress that appears at the moment of localization. Data regarding stress localization were determined by experiment (tension test).



(a) (b)

Fig. 5 - *Hole flanging process for hole diameter d=35mm in sheet metal with 2mm thickness; (a) with initial hole diameter d_o =17.5 mm, (b) with initial hole diameter d_o =17 mm*

Optimal initial hole diameter for collar dimension d = 43 mm after forming process was determined by simulation, and its size is d_o *=21 mm* (value „damage" is 0.686, and for initial hole diameter d_o *=20 mm* damage value is 0.729), Fig. 6.



(a) (b)

Fig. 6 - *Hole flanging process for hole diameter d=43mm in sheet metal with 2 mm thickness; (a) with initial hole diameter* d_o *=21 mm, (b) with initial hole diameter* d_o *=20 mm*

Based upon data which are derived by numerical simulation for sheet metal with 2 mm thickness and three different hole diameters after forming process, diagram which shows dependency betwen initial hole diameter and collar diameter after hole flanging process is made (Fig.7). It can be seen from Fig.7.that the dependency between above mentioned diameters is almost linear.
In accordance with the results obtained by numerical simulation approximated relation between initial hole diameter and collar diameter, after hole flanging process can be derived. This relation is valid only for the domain d$\in$[27 , 43] and workpiece material St 14 according to DIN standard.

$$d_o = \frac{d}{2} \qquad (5)$$

Where is: d (mm) – hole diameter after forming process, d_o (mm) - initial hole diameter

Based upon values for hole flanging deformation forces for three different hole diameters (27 mm, 35 mm and 43 mm) which are obtained by a.) numerical simulation and forces which are b.) calculated by the derived formula (2), the relationship (diagram) is obtained (Fig.8). The diagram shows that deviations between force values obtained by two above defined ways are very good.

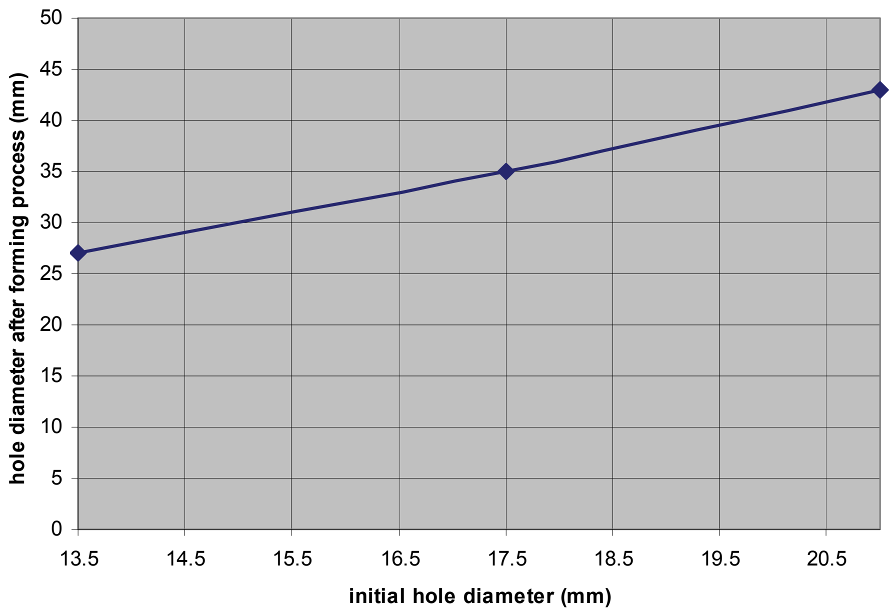


Fig. 7 –Dependency between initial hole diameter and collar diameter

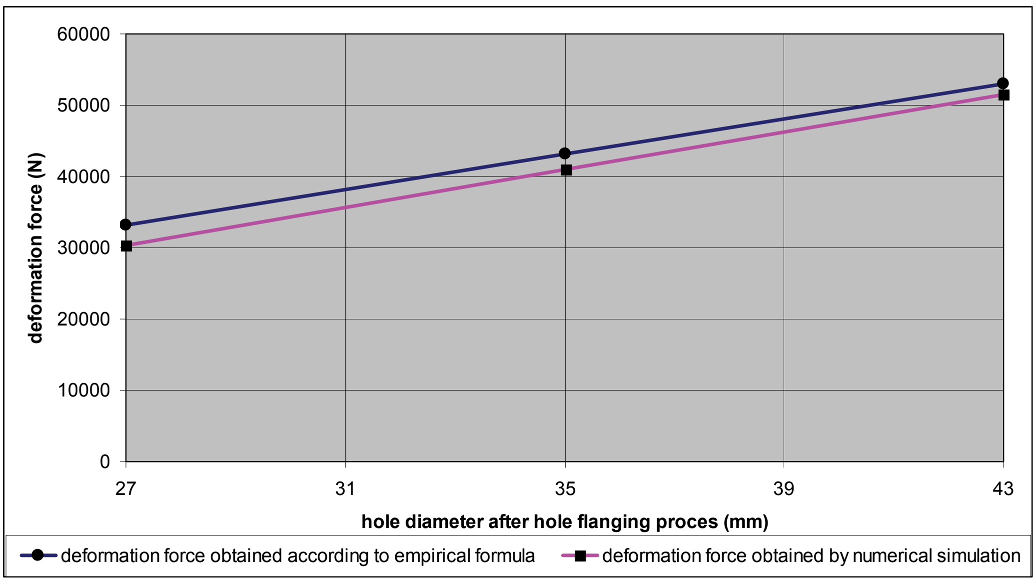


Fig. 8 – Diagram of dependency between deformation force (punch load) and hole diameter after forming process for domain d ∈ [27 , 43] and workpiece material St 14

4. CONCLUSION

In this paper process of hole flanging has been analysed. The comparison between the geometrical results obtained by numerical simulation for three different hole diameter shows satisfactory compliance with the results obtained by empirical derived data.
Deformation forces obtained by above mentioned methods are also in good accordance. Material applied in the investigations was St 14 according to DIN standard with the thickness of 2 mm.
Numerical simulation has proved to be a powerful method for solving problems in this field but still, in further work experimental investigations are needed in order to verify numerically obtained results.

REFERENCES

[1] Altan, T., Vasquez, V.: *Status of process simulation using 2D and 3D finite element method,* Journal of Materials Processing Technology 71, page 49-63, 1997.

[2] Banabic, D., Bunge, H.-J., Pohlandt, K., Tekkaya, A.,E.: *Formability of Metallic Materials*, Springer-Verlag, Berlin, 2000.

[3] Kobayashi, S., Oh, S., Altan, T.: *Metal Forming and the Finite-Element Method*, Oxford Universty press, 1989.

[4] Liewald, M.: *New Developments in Sheet Metal Forming*, Institute for Metal Forming Technology, University of Stuttgart, Stuttgart, 2008.

[5] Plancak, M., Vilotic, D.: *Metal forming technology*, University of Novi Sad, Novi Sad, 2003.

[6] Popov, E, A..: *Basic theory for sheet metal forming,* Masinostroenie, Moscow, 1968.

[7] Stefanovic, M.: *Tribology of deep drawing process*: Yugoslav association for tribology and the Faculty of Mechanical Engineering Kragujevac, Kragujevac, 1994.

[8] Sljivic, M., Radonjic, R.: *Sheet metal forming technology,* University of Banja Luka, Faculty of Mechanical Engineering, Banja Luka, 2009.

[9] Sljivic, M., Radonjic, R., Stanojevic, M.: *Modeling of the forward extrusion process by virtual* manufacturing, 10th International Conference on Flexible Technologies – MMA, Novi Sad, 2009.

[10] Huang, Y.M., Chien, K.H.: *The formability limitation of the hole-flanging process*, Journal of Materials Processing Technology 117, page 43-51, 2001.

.

ANALIZA PROCESA IZVLAČENJA OTVORA IZ LIMA

[1]**Milan Šljivić,** [1]**Ranko Radonjić,** [2]**Milentije Stefanović**
[1]*Univerzitet u Banjoj Luci, Mašinski fakultet, Republika Srpska, BiH*
[2]*Univerzitet u Kragujevcu, Mašinski fakultet, Srbija*

REZIME

U radu je izvršena analiza procesa izvlačenja otvora iz lima pomoću alata virtuelne proizvodnje. Zavisnost između početnog prečnika otvora (otvor prije izvlačenja) i prečnika otvora poslije procesa izvlačenja otvora u limu je analizirina numerički. Analiza je urađena za tri različita prečnika, i u skladu sa rezultatima dobijenim numeričkom simulacijom je određen model procesa (važi samo za dijapazon istraživanih prečnika).
Neophodni podaci o mehaničkim karakteristikama procesiranog materijala (St 14 prema DIN standardu) za modeliranje procesa su određene eksperimentalno. Poređenjem rezultata dobijenih pomoću numeričke analize sa rezultatima određenim na osnovu empirijskih podataka, može se vidjeti dobro slaganje. Rezultati numeričke analize uključuju i zavisnost između maksimalne sile na žigu i puta žiga za različite prečnike otvora.
***Ključne riječi**: lim, izvlačenje otvora, prečnik otvora, numerička analiza.*