The 3rd International Conference on
″Computational Mechanics
and Virtual Engineering″
COMEC 2009
29 – 30 OCTOBER 2009, Brasov, Romania

EXPERIMENTAL VALIDATION OF A NUMERICAL STUDY OF GASOSTATIC FORMING, USING WAVELET TRANSFORMS

Gavril GREBENIŞAN[1], **Sorin MUREŞAN**[1]
[1, 2] University of Oradea, Romania, grebe@uoradea.ro

Abstract: *Based on recently authors' works, [1], this paper, consists on an extension of volumes generation mathematical model, and are focused on a step by step procedure of volume generation. Main part of the paper are focussed on mathematical model of the evolution process, in a deformation process, and additional procedure it is used in order to open new means of appropriate procedure of signal processing. In this work, signal processing is used as another clearly and soft way of evolution process study. The file used by MATLAB wavelet transform it is the matrix results of experimental work, in order to obtain the blow-up parts.*
Keywords: *mathematical model, MATLAB, wavelet transform, superplasticity*

1. INTRODUCTION OF THE METHOD

This work describes, detailed, the theoretical study of the mathematical application $F : C \rightarrow C'$, $F(u,v,w) = (x,y,z)$, which is the evolution application, given by:

$$\begin{aligned} x(u,v,w) &= (R \quad \Delta l + w) \quad \frac{u}{R} \\ y(u,v,w) &= (R \quad \Delta l + w) \quad \frac{v}{R} \\ z(u,v,w) &= \quad R \quad \Delta l + \Delta s + \quad 1 \quad \frac{\Delta s}{\Delta l} \quad w \quad \frac{1}{R} \quad \sqrt{R \quad u^2 \quad v^2} \end{aligned} \qquad \mathbf{(1')}$$

where $u^2 + v^2 \le R^2$ and $w \in [\,0,\ \Delta l\,]$, are the parametric equations of volume **C**, [1].

First of all, if exists (u_1, v_1, w_1) and (u_2, v_2, w_2) in C such that $F(u_1, v_1, w_1) = F(u_2, v_2, w_2)$ then, it's obviously from definition of F, that $(u_1 = u_2\ , v_1 = v_2\ , w_1 = w_2)$ which verify injectivity of F.

Now we consider $P(X,Y,Z)$ a point in C', which means that will exist an unique $W_0 \in [0, \Delta l]$ with

$$\frac{X^2}{(R \quad \Delta l + W_0)^2} + \frac{Y^2}{(R \quad \Delta l + W_0)^2} + \frac{Z^2}{R \quad \Delta l + \Delta s + \quad 1 \quad \frac{\Delta s}{\Delta l} \quad W_0 \qquad ^2} = 1 \qquad \mathbf{(1)}$$

Choosing $U_0 = \frac{RX}{(R \quad \Delta l + W_0)}, V_0 = \frac{RY}{(R \quad \Delta l + W_0)}$ we verify that $F(U_0, V_0, W_0) \equiv P$.

1.1. Conditions on parameters U_0, V_0, W_0

We know that $W_0 \in [0, \Delta l]$ and using (1) we'll obtain $U_0^2 + V_0^2 = \frac{R^2 (X^2 + Y^2)}{(R \quad \Delta l + W_0)^2} = R^2 \quad 1 \quad \frac{Z^2}{[...]^2} \quad \le R^2$

1.2. Equation which define the application F

For U_0, V_0 *and* W_0 considered bove we obtain by (1') and (1)

$$x = \left(R \quad \Delta l + W_0\right) * \frac{U_0}{R} = X,$$

$$y = \left(R \quad \Delta l + W_0\right) * \frac{V_0}{R} = Y,$$

$$z = \quad R \quad \Delta l + \Delta s + \quad 1 \quad \frac{\Delta s}{\Delta l} \quad W_0 \qquad \frac{1}{R}\sqrt{R^2 \quad U_0^2 \quad V_0^2} =$$

$$\frac{R \quad \Delta l + \Delta s + \quad 1 \quad \frac{\Delta s}{\Delta l} \quad W_0}{R \quad \Delta l + W_0} \qquad \sqrt{1 \quad X^2 \quad Y^2} = Z$$

wich consists on a verification rule.

The application F is a bijection, should be demonstrate. Considering the cylindrical coordinates we have $\begin{array}{l}\Phi : K \to C \\ (\rho, \quad , h) \to \Phi(\rho, \quad , h) = (u, v, w)\end{array}$ given by $\begin{array}{l} u(\rho, \quad , h) = \rho \cos \\ v(\rho, \quad , h) = \rho \sin \\ w(\rho, \quad , h) = h \end{array}$ for $(\rho, \quad , h) \in K = [0, R] x [0, 2\pi] x [0, \Delta l]$.

It's easy to see that **Φ** is also bijective. We will have finally $\begin{array}{l} F_0 \ \Phi : K \to C' \\ (\rho, o, h) \mapsto F_0 \Phi(\rho, o, h) = (x, y, z) \end{array}$ defined by the following equations

$$\begin{array}{ll} x = (R \quad \Delta l + h) \quad \dfrac{\rho \cos}{R} & \\ y = (R \quad \Delta l + h) \quad \dfrac{\rho \sin}{R} & \begin{array}{l} \rho \in [0, R] \\ \quad \in [0, 2\pi] \\ h \in [0, \Delta l] \end{array} \\ z = \quad R \quad \Delta l + \Delta s + \quad 1 \quad \dfrac{\Delta l}{\Delta s} \quad h \qquad \dfrac{1}{R}\sqrt{R^2 \quad \rho^2} & \end{array} \tag{2}$$

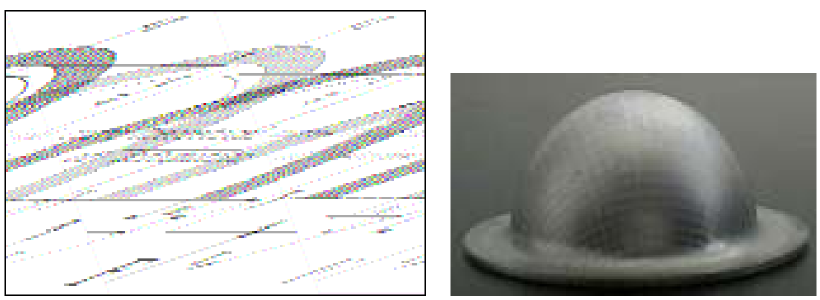

Figure 1 – The target first of all imposed

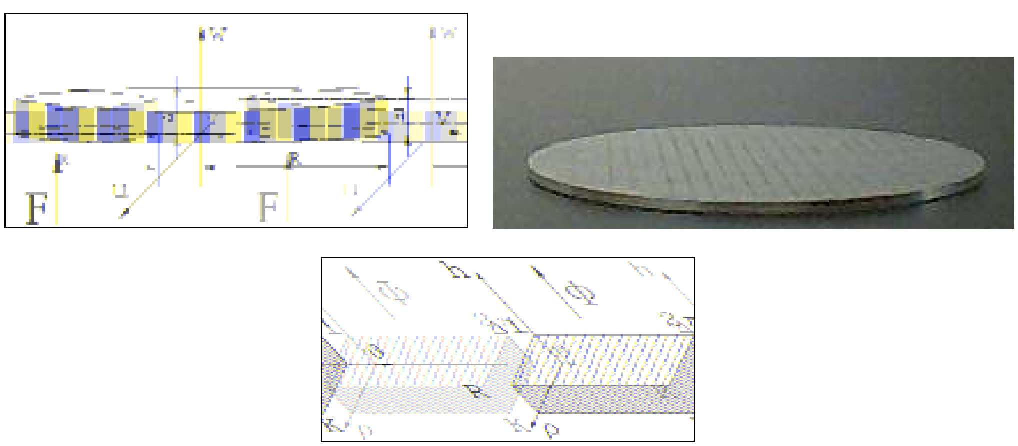

Figure 2 – Validation of the geometrical model

We will study now the description of C' obtained from some particulars decompositions of C and K under the action F and $\Phi_0 F$, respectively.

Let be Δ_1 a decomposition of C into 3-dimensional closed intervals (cubes ?, parallepipedes ?) which have the facettess parallel with the coordinates planes:

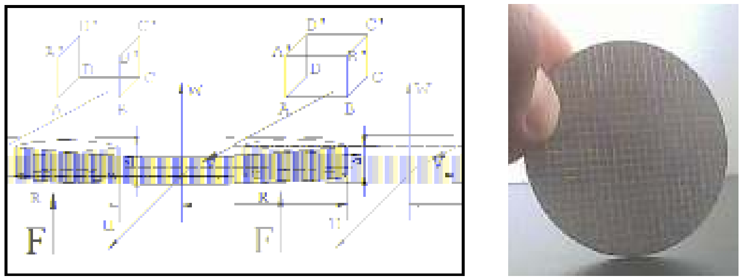

Figure 3- Decompozition on 3D elements

- The frontal faces $\left(A'ABB'\right)$ and the back face $\left(D'DCC'\right)$ are parallels with the coordinates plane u=0, hence we have the equations
  of $\left(A'ABB'\right): u = U_0$
  of $\left(D'DCC'\right): u = U_1$
- The left face $\left(A'ADD'\right)$ and the right face $\left(B'BCC'\right)$ are parallels with the coordinates plane v=0, hence we have the equations
  of $\left(A'ADD'\right): v = V_0$
  of $\left(B'BCC'\right): v = V_1$
- The bottom face $(ABCD)$ and the top face $\left(A'B'C'D'\right)$ are parallels with the coordinates plane w=0, hence we have the equations
  of $(ABCD): w = W_0$
  of $\left(A'B'C'D'\right): w = W_1$

From the above considerations we have the coordinates of vertices

$A(U_0, V_0, W_0)$ $\quad B(U_0, V_1, W_0)$ $\quad C(U_1, V_1, W_0)$ $\quad D(U_1, V_0, W_0)$

$A'(U_0, V_0, W_1)$ $\quad B'(U_0, V_1, W_1)$ $\quad C'(U_0, V_0, W_0)$ $\quad D'(U_1, V_0, W_1)$

The image of the line $\left[AA'\right]$: $\begin{matrix} u = U_0 \\ v = V_0 \\ w \in [W_0, W_1] \end{matrix}$ under F action:

$$\begin{aligned} x &= (R \quad \Delta l + w) \quad \frac{U_0}{R} \\ y &= (R \quad \Delta l + w) \quad \frac{V_0}{R} \\ z &= \quad R \quad \Delta l + \Delta s + \quad 1 \quad \frac{\Delta s}{\Delta l} \quad w \quad \frac{1}{R}\sqrt{R^2 \quad U_0^2 \quad V_0^2} \end{aligned} \tag{3}$$

$$\frac{x \quad (R \quad \Delta l) \quad \frac{U_0}{R}}{\frac{U_0}{R}} = \frac{y \quad (R \quad \Delta l) \quad \frac{V_0}{R}}{\frac{V_0}{R}} = \frac{z \quad (R \quad \Delta l + \Delta s) \quad \frac{1}{R}\sqrt{R^2 \quad U_0^2 \quad V_0^2}}{1 \quad \frac{\Delta s}{\Delta l} \quad \frac{1}{R}\sqrt{R^2 \quad U_0^2 \quad V_0^2}}$$

which is a line passing throught the point on coordinates:

$$(R \quad \Delta l)\frac{U_0}{R}, (R \quad \Delta l)\frac{V_0}{R}, (R \quad \Delta l + \Delta s)\frac{\sqrt{R^2 \quad U_0^2 \quad V_0^2}}{R} \tag{4}$$

and have the directions $\frac{U_0}{R}, \frac{V_0}{R}, \quad 1 \quad \frac{\Delta s}{\Delta l} \quad \frac{1}{R}\sqrt{R^2 \quad U_0^2 \quad V_0^2}$.

Similary, for the line $\left[BB'\right]: \begin{array}{c} u=U_0 \\ v=V_1 \\ w\in\left[W_0,W_1\right] \end{array}$ the image under F is the line which passing through the point $(R \quad \Delta l)\dfrac{U_0}{R},(R \quad \Delta l)\dfrac{V_1}{R},(R \quad \Delta l+\Delta s)\dfrac{\sqrt{R^2 \quad U_0^2 \quad V_1^2}}{R}$ and have the directions $\dfrac{U_0}{R},\dfrac{V_1}{R}, \quad 1 \quad \dfrac{\Delta s}{\Delta l} \quad \dfrac{1}{R}\sqrt{R^2 \quad U_0^2 \quad V_1^2}$.

- For the line $\left[CC'\right]: \begin{array}{c} u=U_1 \\ v=V_1 \\ w\in\left[W_0,W_1\right] \end{array}$ the image under F is the line which passing through the point $(R \quad \Delta l)\dfrac{U_1}{R},(R \quad \Delta l)\dfrac{V_1}{R},(R \quad \Delta l+\Delta s)\dfrac{\sqrt{R^2 \quad U_1^2 \quad V_1^2}}{R}$ and have the directions $\dfrac{U_1}{R},\dfrac{V_1}{R}, \quad 1 \quad \dfrac{\Delta s}{\Delta l} \quad *\dfrac{1}{R}\sqrt{R^2 \quad U_1^2 \quad V_1^2}$.

- For the line $\left[DD'\right]: \begin{array}{c} u=U_1 \\ v=V_0 \\ w\in\left[W_0,W_1\right] \end{array}$ the image is the line

$$\frac{x \quad (R \quad \Delta l)\dfrac{U_1}{R}}{\dfrac{U_1}{R}}=\frac{y \quad (R \quad \Delta l)\dfrac{V_0}{R}}{\dfrac{V_0}{R}}=\frac{z \quad (R \quad \Delta l+\Delta s)\sqrt{\dfrac{R^2 \quad U_1^2 \quad V_0^2}{R}}}{1 \quad \dfrac{\Delta s}{\Delta l} \quad *\dfrac{1}{R}\sqrt{R^2 \quad U_1^2 \quad V_0^2}} \qquad \textbf{(5)}$$

The image of the line $[AB]: \begin{array}{c} u=U_0 \\ w=W_0 \\ v\in\left[V_0,V_1\right] \end{array}$ under F is

$$\begin{aligned} x&=\left(R \quad \Delta l+W_0\right) \ \frac{U_0}{R} \\ y&=\left(R \quad \Delta l+W_0\right) \ \frac{v}{R} \\ z&= \quad R \quad \Delta l+\Delta s+ \quad 1 \quad \frac{\Delta s}{\Delta l} \quad W_0 \qquad \frac{1}{R}\sqrt{R^2 \quad U_0^2 \quad v^2} \end{aligned} \qquad \textbf{(6)}$$

$$\begin{aligned} & x = X_0 \ (const \quad) \\ & \frac{Ry}{(R \quad \Delta l+\Delta s)}=v \\ & \frac{Rz}{R \quad \Delta l+\Delta s+ \quad 1 \quad \dfrac{\Delta s}{\Delta l} \quad W_0}^{\ 2}=\sqrt{R^2 \quad U_0^2 \quad v^2} \end{aligned} \qquad \textbf{(7)}$$

$$\begin{aligned} & x=X_0 \ (const) \\ & \frac{R^2y^2}{\left(R \quad \Delta l+W_0\right)^2}+\frac{R^2z^2}{R \quad \Delta l+\Delta s+ \quad 1 \quad \dfrac{\Delta s}{\Delta l} \quad W_0}^{\ 2}=R^2 \quad U_0^2 \end{aligned} \qquad \textbf{(8)}$$

$$x = X_0$$

$$\frac{y^2}{\frac{\left(R^2 \quad U_0^2\right)\left(R \quad \Delta l + W_0\right)^2}{R^2}} + \frac{z^2}{\frac{R \quad \Delta l + \Delta s + \quad 1 \quad \frac{\Delta s}{\Delta l} \; W_0 \quad ^2 \left(R^2 \quad U_0^2\right)}{R^2}} = 1 \qquad \textbf{(9)}$$

which is an elipsis in plane $x = \left(R \quad \Delta l + W_0\right)\frac{U_0}{R}$ parallel with the coordinate plane x=0.

The image of the line $\left[A'B'\right]$: $\begin{array}{l} u = U_0 \\ w = W_1 \\ v \in \left[V_0, V_1\right] \end{array}$ under F is an ellipsis in the plane $x = \left(R \quad \Delta l + W_1\right)\frac{U_0}{R}$ (which is parallel with the previous one):

$$\frac{y^2}{\frac{\left(R^2 \quad U_0^2\right)\left(R \quad \Delta l + W_1\right)^2}{R^2}} + \frac{z^2}{\frac{R \quad \Delta l + \Delta s + \quad 1 \quad \frac{\Delta s}{\Delta l} \; W_1 \quad ^2 \left(R^2 \quad U_0^2\right)}{R^2}} = 1 \qquad \textbf{(10)}$$

- For the line $[CD]$: $\begin{array}{l} u = U_1 \\ w = W_0 \\ v \in \left[V_0, V_1\right] \end{array}$ the image under F is an elipse in the plane $x = \left(R \quad \Delta l + W_0\right)\frac{U_1}{R}$:

$$\frac{y^2}{\frac{\left(R^2 \quad U_1^2\right)\left(R \quad \Delta l + W_0\right)^2}{R^2}} + \frac{z^2}{\frac{R \quad \Delta l + \Delta s + \quad 1 \quad \frac{\Delta s}{\Delta l} \; W_0 \quad ^2 \left(R^2 \quad U_1^2\right)}{R^2}} = 1 \qquad \textbf{(11)}$$

and the image of the line $\left[C'D'\right]$: $\begin{cases} u = U_1 \\ w = W_1 \\ v \in \left[V_0, V_1\right] \end{cases}$ under F is an ellipsis in the plane $x = \left(R \quad \Delta l + W_1\right)\frac{U_1}{R}$:

$$\frac{y^2}{\frac{\left(R^2 \quad U_1^2\right)\left(R \quad \Delta l + W_1\right)^2}{R^2}} + \frac{z^2}{\frac{R \quad \Delta l + \Delta s + \quad 1 \quad \frac{\Delta s}{\Delta l} \; W_1 \quad ^2 \left(R^2 \quad U_1^2\right)}{R^2}} = 1 \qquad \textbf{(12)}$$

The image under *F* of the lines which are parallels with O_V coordinate axe are four ellipsises each of them in some different plane parallel with coordinate plane x=0.

2. ANALYSIS OF THE EXPERIMENTS AND RESULTS

Using data colected during earlier researches referring to the deformation process of aluminium alloys parts, under superplastic condition, this theoretical aproaches has been experienced on toolboxes offerred by MATLAB environment.

The analysis by MATLAB Programming Environment has carried out a numerical image of material behavior during superplastic deep gasostatic forming. The interpolation and fitting procedure with an interactive numerical method were used here to study the cross-section varied scene. All observation are made on pole zone and on corner radius zone, i.e. the most exposed zones of the test pieces.

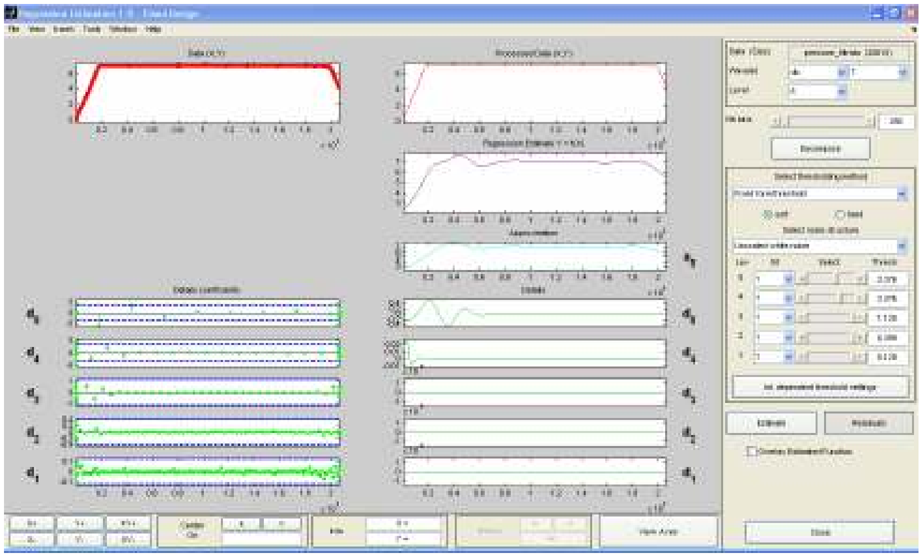

Figure 4 – Using Wavelet Transforms for process analysis

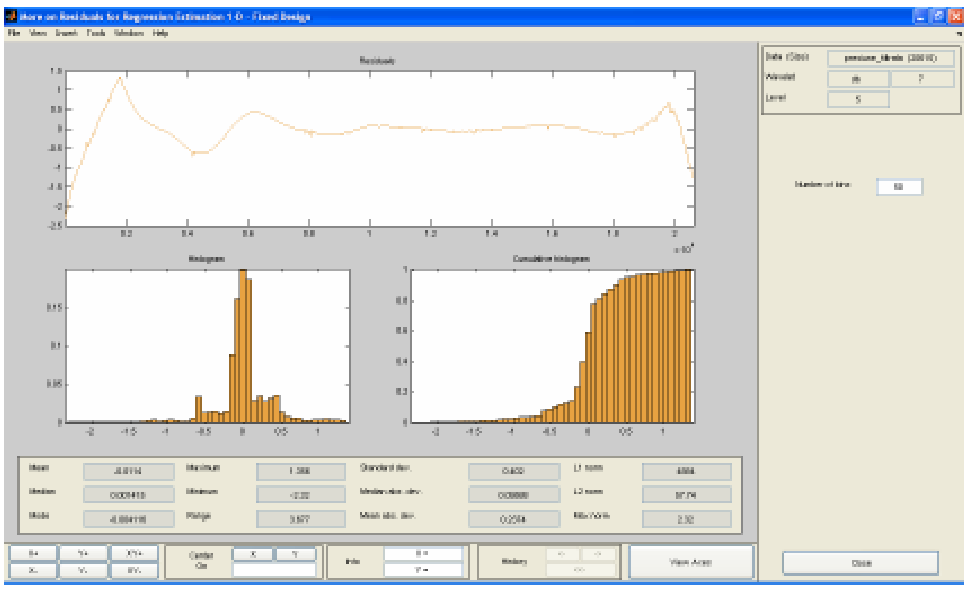

Figure 5 – Statistics of the signal (presure of the air-gasostatic parameter)

3. CONCLUSION

This experiments are done on two main parts: first of all this consists on an unconventional process, that is the gasostatic forming by air pressure blowing of a circular sheet material, and the second one, the experienced of the very unusual signal processing procedure the wavelets transform. The statistics results of the signal processing confirm the behaviour of the technical process parameters. In this ideea, the residuals (see figure no. 5) are on limits imposed by the process, and the decomposition of the signal by Daubechies wavelet transform (db 7 of level 5) depicted on figure 4, shows the behaviour of the parameter- air presurre into the limits of theoretical study.

REFERENCES

[1] Grebenişan, G., Mureşan, S.-Volumic generation mathematical model and experimental observation, International Conference on Materials Science & Engineering - BRAMAT 2005, Braşov, 2005.
[2] Grebenişan, G- Metoda deformaţiilor mici în analiza cu elemente finite a deformării volumice, Sesiunea anuală de comunicări ştiinţifice, cu participare internaţională, pp. 107-120, Oradea, 2001.
[3] Grebenişan, G. –Researches of superplastic deformation by the application on gaso-static deep drawing, PhD thesis, Cluj Napoca, 2003.
[4] Pilling, J. -Superplasticity in crystalline solids, The Institute of Metals, London, 1989.