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THEORY AND PRACTICE ON NUMERICAL APROACH OF GASOSTATIC FORMING

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ABSTRACT

In materials science, superplasticity is a state in which solid crystalline material is deformed well beyond its usual breaking point, usually over about 200% during tensile deformation. Such a state is usually achieved at high homologous temperature, typically half the absolute melting point. Examples of superplastic materials are some fine-grained metals and ceramics. Other non-crystalline materials (amorphous) such as silica glass ("molten glass") and polymers also deform similarly, but are not called superplastic, because they are not crystalline; rather, their deformation is often described as Newtonian flow. Superplastically deformed material gets thinner in a very uniform manner, rather than forming a 'neck' (a local narrowing) which leads to fracture. Also, the formation of internal cavities, which is another cause of early fracture, is inhibited. In metals and ceramics, requirements for it being superplastic include a fine grain size (~<20 micrometres) and a fine dispersion of thermally stable particles which act to pin the grain boundaries and maintain the fine grain structure at the high temperatures required for superplastic deformation. Those materials which meet these parameters must still have a strain rate sensitivity (a measurement of the way the stress on a material reacts to changes in strain rate) of >0.3 to be considered superplastic, [4,6,7].

KEYWORDS: gasostatic forming, superplasticity, strain rate, strain stress, superplastic forming

1. INTRODUCTION

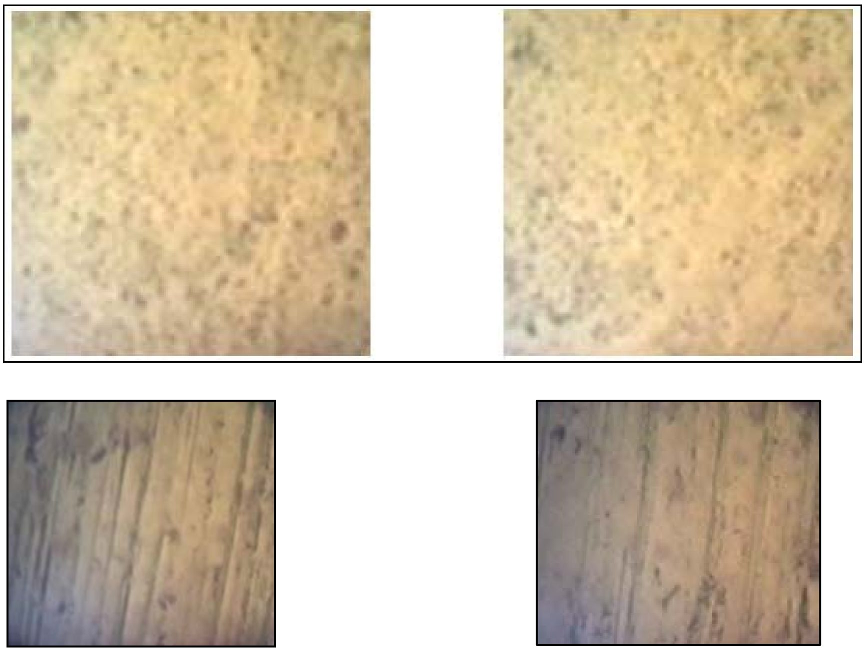
"Superplasticity is the name given to the ability of a material to sustain extremely large deformations at low flow stresses at a temperature around half the melting point expressed in Kelvin"(defined by *"Smithells Metals Reference Book", Seventh Edition, Edited by E.A. Brandes & G.B. Brook, Butterworth- Heineman, Oxford, 1998, page 36-1*).

Superplasticity is used to form complex objects, by the application of gas pressure or with a tool, and often with the help of dies. Aluminum and titanium parts are often superplastically formed for aerospace applications. More recently, superplasticity has been used to form parts for automotive applications. For application in the automotive industry, aluminum alloys are formed at a faster rate (compared to aerospace applications) to support high volume production, [6].

Recently researches of Mamoru Mabuchi, Japan, have emphasized superplastic behavior of some alloys with matrix of Al, Zn and even at few number of austenitic steels with strain rates by two even three orders of magnitude, hgher than the "classic" value that is about 10^{-3}- 10^{-5} sec^{-1}. Thereby was superplastic deformed Aluminium matrix alloys with strain rate $\dot{\varepsilon}=10^{-1}$ sec^{-1}. This increase of strain rate was possible beforehand by realization of a ultrafine microstructure grain.

Because the theoretical observations have to be verified and certified, or not, by experiments, I've realised, also at The Technical University of Cluj Napoca, Material Science and Engineering Faculty, Plastic Deformation Department, researches on superplastic aluminum comercial alloys: SUPRAL 100 (Aluminum 2004) and FORMALL (AL-7475)). This alloys are used to produce parts of plains wings and cockpit.

Grain size of alloys are determining to develop the superplastic deformation of this materials. In order to verify this I've realised the microstructure analysis and the results are presented in the images below:



a)- **SUPRAL 100** *b)- FORMALL*

Fig. 1 Metalografic sample of* SUPRAL 100 *and FORMALL, respectively

The grain size, measured on both axial and transverse directions, are $\mathbf{2[\mu m]}$. Technological parameters of superplastic forming are determined on theoretical basis above described, and are:

The pressure:

$$p = \frac{4s_o \cdot h \cdot \sigma \cdot K_s}{r_o^2\left(1 + \frac{h^2}{r_o^2}\right)^2} \qquad \textbf{(16)}$$

unde

- **s_o**-sample tthickness (**s_o=1,2 [mm]**);
- **h**-hemispherical shell height (**h=24[mm]**);
- σ-flow stress, at deforming temperature ($\sigma_{FORMALL} = 32[N/mm^2]$);
- **K_s**-transversal variations of thickness coeficient, coresponding at **m=0,5** (**K_s=0,7**);
- **r_o**- hemispherical shell radius (**r_o=16[mm]**)

Given this data, the air pressure is calculated at:**p=0.69585[N/mm^2]= 6,82404 [bar]**, so I used into my experiments **p=$7 \pm 1\%$[bar]**, considering the variations of pressure in the instalation.

<u>Strain rate</u>, as determining element of the pressure adjustment procedure, realised by one proportional regulator it is analytical determined by relation:

$$\dot{\varepsilon}_e = \left(\frac{2}{3}\dot{\varepsilon}_{ij}\dot{\varepsilon}_{ij}\right)^{\frac{1}{2}} \quad (17)$$

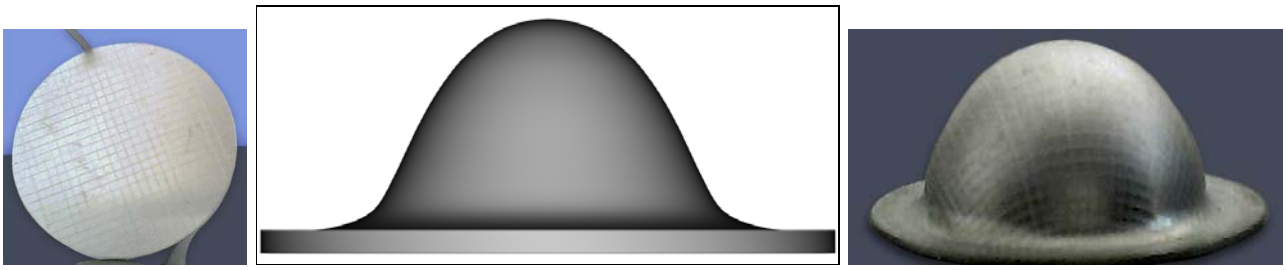
Although, from experiments I adopted the strain rate value of $\dot{\varepsilon} = 0{,}0001[s^{-1}]$ for FORMALL alloy and using this, I found the true strain rate as **v_{12}=0,0012[mm/s]**.

THE METHOD

There was realised experiments on a number of 11 sampels of FORMALL alloy, with 51[mm], in diameter, thickness 1,2[mm], at forming temperature T_{def}=510[^oC] and strain rate value $\dot{\varepsilon} = 0{,}1x10^{-3}[s^{-1}]$:

Fig. 2 – Gasostatic deep drawing samples

Samples was prepared by ddrawing a rectangular grid spaced at one milimeter distance:



a)-the sample *b)-deformed part*

Fig. 3 – A sample and the formed part

Using the Coordinates Measuring Machine of type MC 1200, with radius of the tool of **0,2332 [mm]**, was realised measurments and the results was stocked into a Delphi data file. Using this data the actual profile was realised also helped on Autocad facilities. On each section was realised grafical representation of the variation of transversal section;

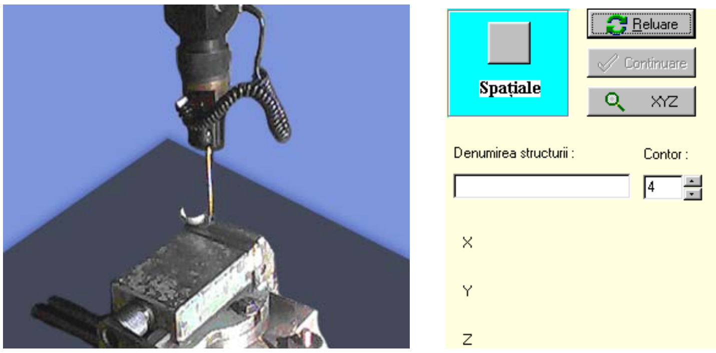


Fig. 4 – Thickness measurements into points series

OBTAINED RESULTS

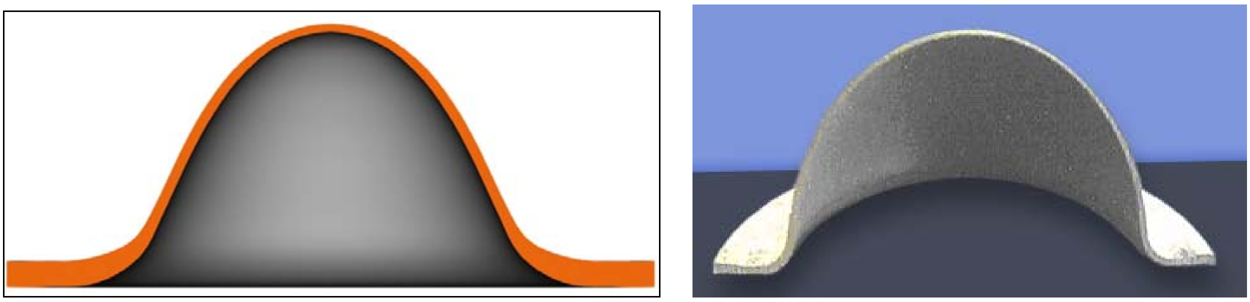


Fig. 5 – Deformed hemispherical shell

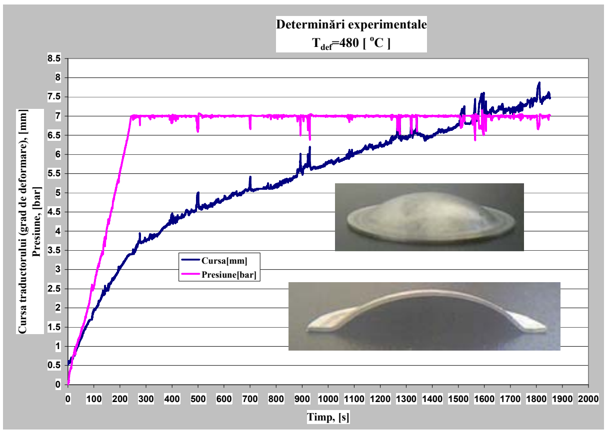


Fig. 6 – The pressure and strain variation, against the time
~starting thickness of 2.1 mm~

Fig. 7 – Dispertion of measurments points on the corner radius

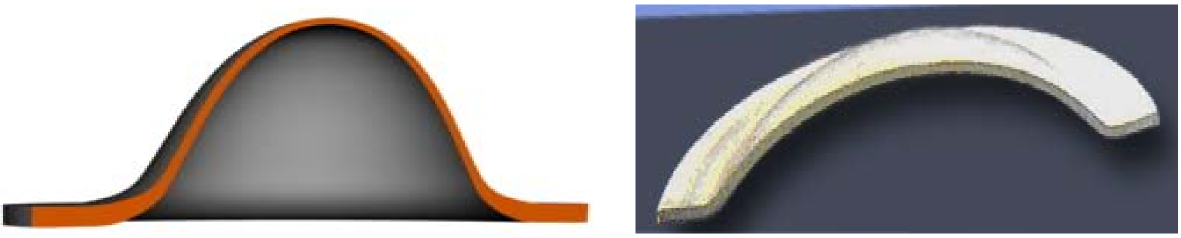


Fig. 8 Deformed part profile, sectioned on axial plan

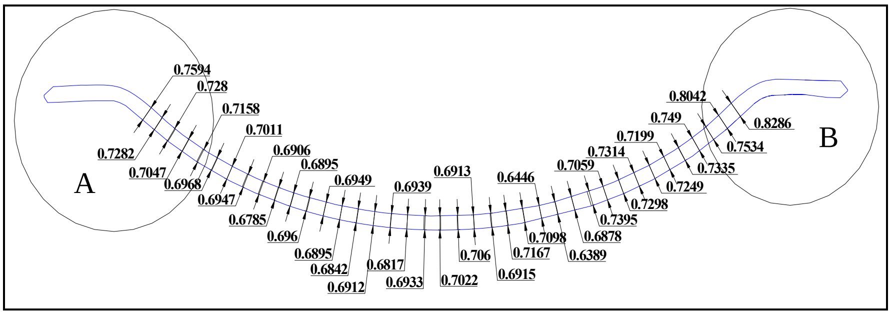


Fig. 9 – Dispertion of measurments points on section

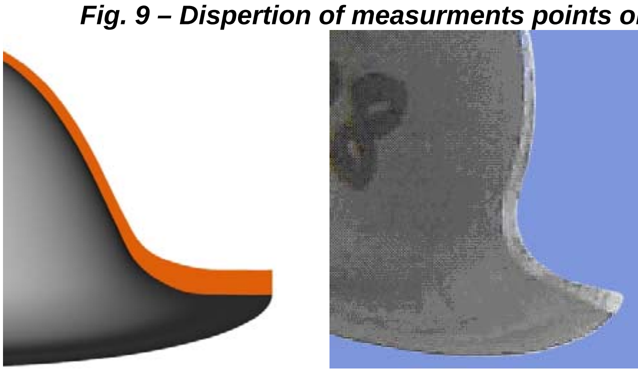


Fig. 10 – Deformed part in section (images optical magnified)

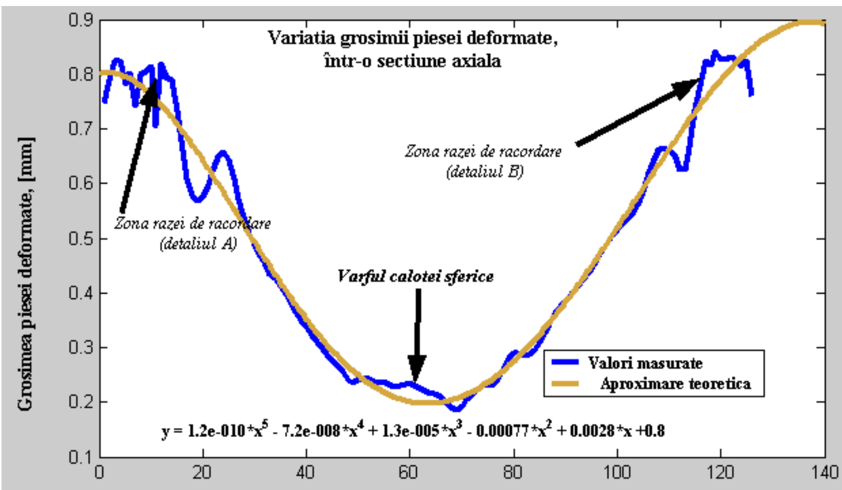


Fig. 11 – Thickness variation curve, actual end interpolated by a fifth degree polinom on the axial section

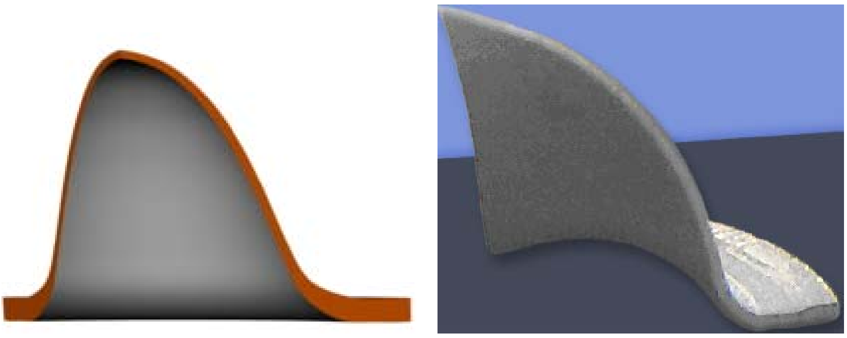


Fig. 12– Deformed part in section

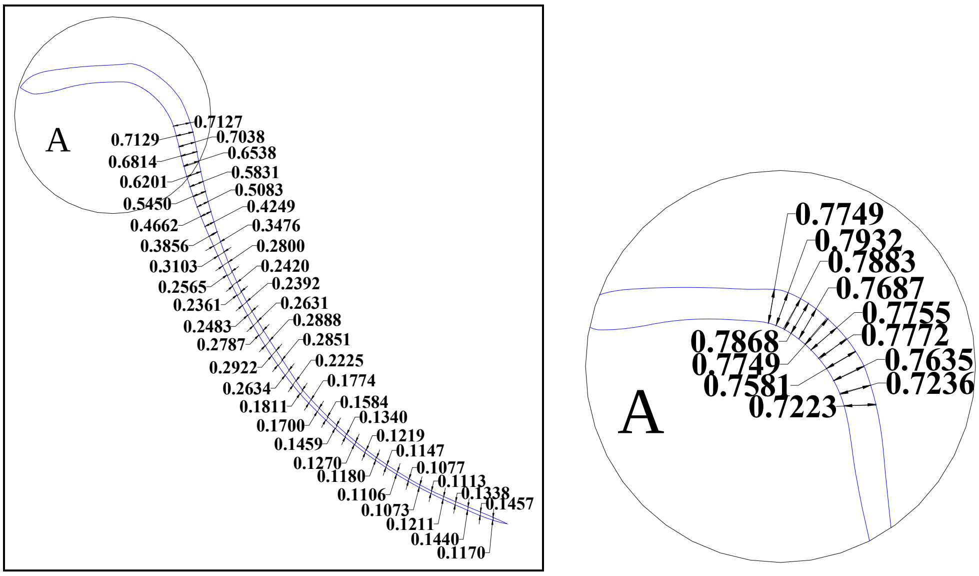


Fig. 13 – Dispertion of measurments points on section

REFERENCES

[1]. BEER, G.,ş.a.- Introduction to finite and boundary element methods for engineering, John Wiley & Sons, 1975

[2]. BONET, J. - Numerical Simulation of the Superplastic Forming ofThin Sheet Components Using the Finite Element method, " International Journal for Numerical Methods in Engineering", vol. 30,pag. 1719- 1737, 1990.

[3]. CHANDRA, N.- Membrane element analyssis of axisymetric and non-axisymetric superplastic metal forming processes, "Superplasticity and Superplastic Forming " ,ed. C.H.Hamilton & N. E. Paton , Warendale, 1989 .

[4]. GREBENIŞAN, G.- Analiza prin metoda elementului finit la deformarea superplastică, Referat II-doctorat, Cluj- Napoca, 1997.

[5]. KOBAYASHI, S.- Metal Forming and the Finite Element Method, Oxford University Press, New York, 1989.

[6]. PILLING, J. - Superplasticity in crystalline solids, The Institute of Metals, London, 1989.

[7]. YANG, T.Y. - Experimental and Finite Element Simulation Methods for Rate-Dependent Metal Forming Processes, " International Journal for Numerical Methods in Engineering " , vol. 31, pag. 345- 367, 1991.