Technical University of Cluj-Napoca
Faculty of Science and Materials Engineering

Eng. Ana-Luciana Rus

Abstract of PhD Thesis

RESEARCHES CONCERNING SUPERPLASTIC BEHAVIOUR OF METALLIC MATERIALS

PhD Supervisor
Prof.Dr.Eng. Traian CANTA

COMMITTEE FOR PUBLIC UPHOLDING

President:	Prof.Dr.Eng. Valer MICLE	Deputy dean, Faculty of Science and Materials Engineering Technical University of Cluj-Napoca
Members:	Prof.Dr.Eng. Traian CANTA	PhD Supervisor, Technical University of Cluj-Napoca
	Prof.DR.Eng. Virgil GEAMĂN	Reviewer, "Transilvania" University of Braşov
	Prof.DR.Eng. Octavian BOLOGA	Reviewer, "Lucian Blaga" University of Sibiu
	Prof.Dr.Eng. Dorel BANABIC	Reviewer, Technical University of Cluj-Napoca

2006

I CONTENT

CHAPTER 7
EXPERIMENTAL RESEARCHES CONCERNING SUPERPLASTIC BEHAVIOUR OF ALUMINIUM ALLOYS

CHAPTER 8
FINAL CONCLUSIONS. ORIGINAL CONTRIBUTION AND FURTHER DIRECTIONS OF DEVELOPMENT

REFERENCE
APPENDIX

II Keywords: superplasticity, strain rate, strain rate sensitivity, flow stress, grain refinement, cavitation, grain boundary sliding, thermomechanical processing, aluminium alloys.

III Short presentation of the thesis

The thesis is structured in eight chapters that show the information as follows: (1) The current stage of researches concerning superplatic behaviour of metallic materials; (2) Researches concerning superplastic behaviour of some metallic materials; (3) Researches concerning cavitation and fracture of superplastic materials; (4) Materials, test-samples, equipments and experimental methodology; (5) Finite element method simulation of superplastic deformation process using gasostatic deep drawing of an hemisphere; (6) Consideration concerning superplastic forming of one hemisphere through gasostatic deep drawing; (7) Experimental researches concerning superplastic behaviour of aluminium alloys; (8) Final conclusions.

Chapter 1 presents definitions, requirements and characteristics of superplastic behaviour of metallic materials, development of research in the area of materials' superplastic behaviour, types of superplastic behaviour, methods for grain refinement and grain growth control, the physical mechanisms that occur during superplastic deformation.

Superplastic materials are polycrystalline solids that have the ability to undergo large uniform strains prior to failure. For deformation in uniaxial tension, elongations to failure in excess of 200% are usually indicative of superplasticity, although several materials could display extensions greater than 1000%. The highest elongation reported is 8000% in a commercial aluminium bronze (Cu-10wt %Al-based alloy).

The types of superplastic behaviour (micrograin or microstructural superplasticity, internal-stress superplasticity, high-strain-rate superplasticity) the best known and studied is the micrograin superplasticity. The structural prerequisites for developing micrograin superplasticity are: size of grains, nature, mobility and shape of grain boundaries, strength, size and second phase distribution in the matrix.

Micrograin superplasticity is displayed by materials with a fine grain size, usually less than 10 µm, when they are deformed within the strain rate range 10^{-5} s^{-1} to 10^{-1} s^{-1}, at temperatures higher than $0{,}5T_m$, where T_m is the melting point in Kelvin degrees.

Superplastic deformation is characterised by low flow stresses and uniformity of plastic flow.

It is well established that a fine grain size is an essential prerequisite for superplasticity. Several methods are available for grain refinement including phase separation, phase transformation and mechanical working with recrystallization. It should be possible to develop fine grain microstructures using thermal treatments alone.

The most commonly considerend mechanism for superplastic flow involve grain boundary sliding, and it is necessary for an accomodation process to accompany grain-boundary sliding. Grain boundary sliding and grain rotation are accomodated by diffusive mass transfer and dislocation glide/climb over extremely short path lengths.

Chapter 2 presents the reseach focused on the determination of the method for grain refinement, for induced the superplastic behaviour in some metallic materials and their superplastic properties. Superplastic behaviour has been demonstrated for some alloys: aluminium alloys, iron based alloys, the titanimu alloys, the nickel-base alloys.

The research have been devoted to development of two different alloys:one designed for superplasticity and second, the commercial alloys that have been thermomechanical processed to be superplastic.

Chapter 3 tackles cavitation and fracture subject of superplastic materials, due to the fact that in thesis are studied the alloys which are liable to appearance of cavitation, than can diminish characteristics of deformation. Theoretical fundaments are presented here and the analysis of cavitation development, nucleation, coalescence and void growth stage that leads to premature fracture of materials, and determination of some parameters in order to estabish the fracture mode of metallic materials. The end of chapter presents the methods for diminish cavities.

In Chapter 4 is showed experimental materials, test-samples and equipments used and experimental methodology.

The materials used for experimental study of superplastic behaviour are: aluminium alloy 7075-T651, extrudate bar with 20 mm diameter, aluminium alloy 2024/1-T3 extrudate bar with 22 mm diameter and aluminium alloy 2024/2-T3 rectangular bar with 40 mm width and 20 mm thickness, furnishing of S.C. ALPROM S.A. Slatina.

For achievement a hot tensile tests of Al-7075 and Al-2024/1 as delivered are processig round test-samples with 5 mm diameter and initial lengh of 25 mm, and for aluminium alloys thermomechanical processed are used flat test-samples with 6,6 mm width and 3 mm thickness.

For gasostatic deep drawing tests are used round disc with 49 mm diameter and 0,67-0,7 mm thickness.

The tensile and gasostatic deep drawing tests are performed on the experimental setup existing in Department of Materials Processing Engineering.

In Chapter 5 is presented the theoretical fundaments of element finite method used to simulate the gasostatic deep drawing of hemisphere. A short introduction follows presenting ABAQUS software, special developed for simulation of deep drawing and considerations on gasostatic deep drawing of hemisphere.

In chapter 5.3 is presented the behaviour of 2024 alloy in deep drawing process, the laboratory tests, and also the deduction of equations used to calculate the "m" and "K" parameters based on tensile tests method.

Chapte 6 presents the deep drawing methods, the selection of most suitable methods of deep drawing, based an the semifinished material characteristics.

Chapter 7 presents the methods, the experimental results of the superplastic behaviour of tested alloys, the laboratory devices as well as the analysis of results.

The results obtained from the tensile tests show that the aluminium alloys as semifinished material have moderate elongations (<75% for Al-7075 and <110% for Al-2024) and a structure with grains of 56 μm to Al-7075 and 36-40 μm to Al-2024.

After thermomechanical processing the deformability increased.

Elongations grater than 200% are obtained only for 2024 aluminium alloys at temperatures of 460^0C (218%, 245,5% and 220,5% at strain rate of $8x10^{-4}$ s^{-1} , $1x10^{-3}$ s^{-1} and $1,5x10^{-3}$ s^{-1}) and at 480^0C (269%) at strain rate of $5x10^{-3}$ s^{-1}.

The maximum elongation of 269% was obtained to 480^0C at strain rate of $5x10^{-3}$ s^{-1}.

The value of strain rate sensitivity exponent at a strain of 0,1 at Al-2024 is the highest at 460^0C temperature (m = 0,3454), where the aluminium alloys displaying superplastic behaviour for the strain rate range $8x10^{-4} – 1,5x10^{-3}$ s^{-1}.

At 7075 aluminium alloy the elongations are smaller than 170%, and the strain rate sensitivity exponent for a strain of 0,1 is small, of 0,2482 at 520^0C temperature.

After the thermomechanical processing a fine grained structure was obtained with average size of 17 µm at Al-7075 and 5-8 µm at Al-2024.

In *Chapter 8* is presenting the general assessment regarding the subject of the thesis emphasizing the posibilities of future developing. The personal contribution regarding the approaching of subject and implantation of new aspects are presented, leaving open the direction for the future developments.

The appendix that is presented in the final of thesis shows the results obtained during the experimental processes.