

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

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"Transilvania" University of Braşov

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"Lucian Blaga" University of Sibiu

Prof.Dr.Eng. Dorel BANABIC

Reviewer,
Technical University of Cluj-Napoca

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I CONTENT

INTRODUCTION

CHAPTER 1

CURRENT STAGE OF RESEARCHES CONCERNING SUPERPLASTIC BEHAVIOUR OF METALLIC MATERIALS

- 1.1 Definitions. Requirements and characteristics of superplastic behaviour of metallic materials
- 1.2 The advance of researches concerning superplastic behaviour of metallic materials
- 1.3 Types of superplastic behaviour
 - 1.3.1 Micrograin superplasticity
 - 1.3.2 Internal-stress superplasticity
- 1.4. Grain refinement methods in order to induce superplastic properties
 - 1.4.1 Processing methods for grain refinement
 - 1.4.1.1 Grain refinement by mechanical working
 - 1.4.1.2 Grain refinement by phase separation
 - 1.4.1.3 Grain refinement by phase transformation
 - 1.4.2 Grains growth restriction during superplastic deformation
- 1.5 Mechanisms of high temperature deformation and phenomenological relations for micrograin superplasticity
 - 1.5.1 Superplastic and non-superplastic flow
 - 1.5.2 Creep mechanisms
 - 1.5.3 Grain-boundary sliding using processes that facilitates the sliding
 - 1.5.3.1 Grain-boundary sliding facilitated by diffusion
 - 1.5.3.2. Grain-boundary sliding facilitated by dislocation slip
- 1.6 Conclusions

CHAPTER 2

RESEARCHES CONCERNING SUPERPLASTIC BEHAVIOUR OF SOME METALLIC MATERIALS

- 2.1 Aluminium - based alloys
- 2.2 Iron-based alloys
 - 2.2.3 Titanium-based alloys
- 2.4 Conclusions

CHAPTER 3

RESEARCHES CONCERNING CAVITATION AND FRACTURE OF SUPERPLASTIC MATERIALS

- 3.1 General considerations
- 3.2 Fracture with unstable plastic flow
- 3.3 General characteristics of cavitation
- 3.4 Cavities nucleation
- 3.5 Cavities growth
- 3.6 Growth of voids through coalescence
- 3.7 Methods for reduction of cavities
- 3.8 Conclusions

CHAPTER 4

MATERIALS, TEST-SAMPLES, EQUIPMENTS AND EXPERIMENTAL METHODOLOGY

- 4.1 Materials used
- 4.2 Test -samples used
- 4.3 Experimental equipments
 - 4.3.1 Experimental equipment for tensile tests
 - 4.3.2 Experimental equipment for gasostatic deep drawing
- 4.4 Experimental methodology
 - 4.4.1 Hot tensile test for 7075 and 2024 aluminium alloys as delivered
 - 4.4.2 Thermomechanical processing for grain refinement of 7075 and 2024 aluminium alloys
 - 4.4.2.1 Thermomechanical processing by grain refinement of 7075 aluminium alloy
 - 4.4.2.2 Thermomechanical processing by grain refinement of 2024/1 aluminium alloy designed for tensile tests.
 - 4.4.2.3 Thermomechanical processing by grain refinement of 2024/2 aluminium alloys for gasostatic deep drawing tests
- 4.5 Conclusions

CHAPTER 5

FINITE ELEMENT METHODS SIMULATION OF SUPERPLASTIC DEFORMATION PROCESS USING GASOSTATIC DEEP DRAWING OF AN HEMISPHERE

- 5.1 The aim of simulation
- 5.2 Considerations concerning the finite element method
- 5.3 Commercial software ABAQUS for simulation of superplastic forming of an hemisphere using gasostatic deep drawing
 - 5.3.1 General presentation of ABAQUS commercial software for gasostatic deep drawing of one hemisphere
 - 5.3.2 Conception of gasostatic deep drawing simulation software
 - 5.3.2.1 Description of operation
 - 5.3.2.2 Pre-processing.
 - 5.3.2.3 Calculation with finite element (Analysis)
 - 5.3.2.4 Post-processing.
 - 5.3.3 Results' simulation
- 5.4 Calculation of "m" and "K" materials' parameters from tensile test for gasostatic deep drawing simulation
- 5.5 Conclusions

CHAPTER 6

CONSIDERATIONS CONCERNING SUPERPLASTIC DEFORMATION OF AN HEMISPHERE USING GASOSTATIC DEEP DRAWING

- 6.1 General considerations
- 6.2 Gasostatic deep drawing processes
 - 6.2.1. Simple gasostatic deep drawing

- 6.2.2 Gasostatic deep drawing with positive die
- 6.2.3 Reversibil gasostatic deep drawing
- 6.3. Conclusions

CHAPTER 7

EXPERIMENTAL RESEARCHES CONCERNING SUPERPLASTIC BEHAVIOUR OF ALUMINIUM ALLOYS

- 7.1 Analysis of results obtained using X-ray diffraction of 2024/1 aluminium alloy
- 7.2 Microstructural and microhardness characteristics before the tensile test of 7075 and 2024 aluminium alloys
 - 7.2.1 Microstructural and microhardness characteristics before the tensile test of 7075 aluminium alloy
 - 7.2.2 Microstructural and microhardness characteristics before the tensile test of 2024 aluminium alloy
- 7.3 Analysis of experimental results obtained from hot tensile tests of 7075 and 2024 aluminium alloys
 - 7.3.1 Analysis of superplastic behaviour using hot tensile tests of 7075 and 2024 aluminium alloys as delivered
 - 7.3.2 Analysis of superplastic behaviour at hot tensile tests of 7075 and 2024 aluminium alloys thermomechanical processed
 - 7.3.2.1 Analysis of superplastic behaviour at hot tensile tests of 7075 aluminium alloy thermomechanical processed.
 - 7.3.2.1.1 Stress-strain curves (plastic flow) for 7075 aluminium alloy thermomechanical processed
 - 7.3.2.1.2 Influence of strain rate on flow properties of 7075 aluminium alloy
 - 7.3.2.1.3 Influence of temperature on flow properties of 7075 aluminium alloy
 - 7.3.2.2 Analysis of superplastic behaviour at hot tensile tests of 7075 aluminium alloy thermomechanical processed
 - 7.3.2.2.1 Determination of thermal regime parameters homogenization and deformation parameters for 2024 aluminium alloy
 - 7.3.2.2.2 Stress-strain curves (plastic flow) for 2024 aluminium alloy termomecanical processed
 - 7.3.2.2.3 Influence of strain rate on flow properties of 2024 aluminium alloy
 - 7.3.2.2.4 Influence of temperature on flow properties of 2024 aluminium alloy
- 7.4 Analysis of microstructural characteristics and of test-samples fracture mode of 7075 and 2024 aluminium alloys after hot tensile tests
 - 7.4.1 Analysis of microstructural characteristics and of round test-samples as delivered fracture mode, made of 7075 and 2024 aluminium alloy after hot tensile tests
 - 7.4.2 Analysis of microstructural characteristics and of test-samples fracture mode after hot tensile tests for 7075 aluminium alloy thermomecanical processed
 - 7.4.3 Analysis of microstructural characteristics and of test-samples fracture mode after hot tensile tests for 2024 aluminium alloy thermomecanical processed
- 7.5 Analysis of experimental results obtaining from gasostatic deep drawing tests
 - 7.5.1 Measurement of the deep drawing depth and representation of depth vs. time variation
 - 7.5.2 Thickness measurement and hemispheres walls thickness distribution
 - 7.5.3 Comparison from results obtained using gasostatic deep drawing simulation with experimental research results
- 7.6 Conclusions

CHAPTER 8

FINAL CONCLUSIONS. ORIGINAL CONTRIBUTION AND FURTHER DIRECTIONS OF DEVELOPMENT

8.1 Finale conclusions

8.2 Original contributions 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 superplastic 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 considered mechanism for superplastic flow involve grain boundary sliding, and it is necessary for an accommodation process to accompany grain-

boundary sliding. Grain boundary sliding and grain rotation are accommodated by diffusive mass transfer and dislocation glide/climb over extremely short path lengths.

Chapter 2 presents the research 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 titanium 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 fundamentals 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 establish 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 processed round test-samples with 5 mm diameter and initial length 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 fundamentals 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 on 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 greater than 200% are obtained only for 2024 aluminium alloys at temperatures of 460°C (218%, 245,5% and 220,5% at strain rate of $8 \times 10^{-4} \text{ s}^{-1}$, $1 \times 10^{-3} \text{ s}^{-1}$ and $1,5 \times 10^{-3} \text{ s}^{-1}$) and at 480°C (269%) at strain rate of $5 \times 10^{-3} \text{ s}^{-1}$.

The maximum elongation of 269% was obtained to 480°C at strain rate of $5 \times 10^{-3} \text{ s}^{-1}$.

The value of strain rate sensitivity exponent at a strain of 0,1 at Al-2024 is the highest at 460⁰C temperature ($m = 0,3454$), where the aluminium alloys displaying superplastic behaviour for the strain rate range $8 \times 10^{-4} - 1,5 \times 10^{-3} \text{ s}^{-1}$.

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 520⁰C 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 possibilities 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.