NEW RESEARCH ON COMPOSITE MATERIALS AT THE METAL FORMING RESEARCH CENTRE

Claudia GÎRJOB[2], Octavian BOLOGA[1,2], Gabriel RACZ[2], Cristina BIRIS[2]

[1]Full Member of the Academy of Technical Sciences of Romania,
[2] "Lucian Blaga" University of Sibiu

Abstract : The Metal Forming Research Centre functions as separate research unit within "Lucian Blaga" University of Sibiu, Romania. This is one of the first centres of its kind in Romanian higher education system and emerged under the aegis of the European inter-university TEMPUS (JEP 2766-91), by Ministry of Education and Science no. 8541/1991. One of the central concerns in this moment is related to the requirements of the automotive and aeronautics industry regarding the introduction of new light alloys processed by pressing to lightweight construction thus achieving weight reduction, low fuel consumption and low gas emissions. From this point of view, light metal materials such as aluminum or magnesium alloys and composites gains, in recent years, more and more attention, successfully replacing traditional materials. Starting from these premises this work aims to present a study regarding the plastic deformation behavior of materials lighter than traditional materials. For this purpose the following materials were chosen: from lightweight class of metallic materials with low plasticity processing at ambient temperature was studied alloy AZ31B magnesium alloy, magnesium alloy system representative - zinc – aluminum, from composite material group were studied metallic materials with the following configuration: aluminum-plastic-aluminum, tin-coated plastic film and steel-plastic-steel and from traditional materials was chosen DC03 steel. The main objectives of the research program is the determination of mechanical properties and intrinsic properties by tensile test, the values expected results: the modulus of elasticity, yield strength, tensile strength, elongation at break, strain hardening coefficient, resistance coefficient, and the coefficients of the plastic anisotropy necessary subsequent numerical simulations by FEM plastic deformation processes.
Keywords: AZ31B, FEM, lightweight material

1. INTRODUCTION

The Centre for Studies and Research for Metal Forming functions as a distinct research entity, inside the structure of the "Lucian Blaga" University of Sibiu, Romania, subordinated to the university senate. It is one of the first such centres in the Romanian higher education system and appeared under the care of the European Inter-university Cooperation TEMPUS (JEP 2766-91), through the Order of the Romanian Minister of Education and Science no. 8541/1991. The centre's structure and activities were set up to be similar to those of the metal forming institutes of the universities of Stuttgart and Hannover (Germany): Institut für Umformtechnik Stuttgart and Institut für Umformtechnik und Umformmaschinen Hannover, respectively.

For the determination of the centre's research activities, we have started from the remark that the current world-wide industrial development is generated by an "explosion" based on the implementation of metal forming technologies. The obtained results have materialised, from a scientific point of view, in the theoretical and experimental substantiation of new procedures for the processing by metal forming, in the usage and development of modern techniques regarding the computer-aided design of products and tools used in deformation processes and in the development of techniques and methods for the simulation of deformation by means of the finite elements method.

The implementation of modern metal forming technologies requires also the usage of performing equipment and/or the modernising of existing equipment. Therefore, another research direction tackled by the Centre for Studies and Research on Metal Forming is referring to the improvement of the performances of equipment used in flexible cells for processing by deformation: the pressing machines and the inter-operational transfer systems (industrial robots and manipulators).

The scientific research of the research centre's members in this direction has tackled the structural optimisation of equipment, the study of methods and methodologies for the increase of the flexibility and automation of equipment, the studying of the possibility to implement computer control, the elaboration of techniques and methods for the on-line monitoring and diagnosis.

In the context of a world-wide spread of the new metal forming technologies, the centre's scientific activity was oriented towards studying the possibilities for applying modern procedures, and the adequate equipment, in the Romanian industry, and providing potential beneficiaries with the knowledge needed for their industrial implementation.

The researches with regard to the possibilities of implementing the modern deformation procedures in the flexible manufacturing variant, in flexible manufacturing cells, answers the new conditions in the Romanian economy, which require a very rapid response of the companies to changes in the production orders, according to the modifications on the market.

One of the central concerns in this moment is related to the requirements of the automotive and aeronautics regarding the introduction of new light alloys processed by pressing to obtain lightweight construction thus achieving weight reduction, fuel consumption and gas emissions. Thus, it seeks to improve the characteristics and properties of these new materials by low power consumption and cost as little. From this point of view light metal materials such as aluminum or magnesium alloys and composites gains, in recent years, more and more land successfully replacing traditional materials.
Starting from these premises present paper aims to study the processing of the plastic deformation behavior of materials lighter than traditional materials. For this purpose were chosen following materials: from lightweight class of metallic materials with low plasticity processing at ambient temperature was studied alloy AZ31B magnesium alloy, magnesium alloy system representative - zinc – aluminum, from composite material group were studied metallic materials with the following configuration: aluminum-plastic-aluminum, tin-coated plastic film and steel-plastic-steel and from traditional materials was chosen DC03 steel.

Research conducted aimed at:

- the determination of mechanical properties and intrinsic properties by tensile test, the values expected results: the modulus of elasticity, yield strength, tensile strength, elongation at break, strain hardening coefficient, resistance coefficient, and the coefficients of the plastic anisotropy necessary subsequent numerical simulations by FEM plastic deformation processes;

- the determination of the limit curves deformation by Nakajima method, subsequently used to evaluate the results obtained by numerical simulation by FEM, regarding the evaluation of cracking and fracture in plastically deformed material.

To achieve these activities were used the Centre for Studies and Researches for Metal Forming equipments: stand for tensile testing: consisting of a tensile testing machine Instron type 5587 and optical system for measurement of deformations - Aramis, respectively modular device for determining the limit of deformation curves.

2 MATERIALS USED IN THE RESEARCHES

The experimental researches were made in order to evaluate the forming capacity of low plasticity alloys. Among this category of materials, the AZ31B magnesium alloy has been chosen, alloy representative for magnesium-zinc-aluminum systems. The main advantage of this alloy is its very low density (1,74g/cm3), it is used for automotive industry and aeronautic industry parts, parts which have to have a reduced height.[4]

The chemical composition of the magnesium alloy AZ31B, in percent by mass, is shown in Table 1.

Table 1. **The chemical composition of the magnesium alloy AZ31B**

AL	CU	ZN	MN	SI	MG
3,0 [%]	0,05 [%]	1,0 [%]	0,2 [%]	0,1 [%]	Rest

The mechanical characteristics of the magnesium alloy AZ31B are presented in Table 2 [1].

Table 2. **The mechanical characteristics of the magnesium alloy AZ31B**

Mechanical characteristics	Values
Density [kg/mm^3]	1,74x10^{-6}
Young's modulus [GPa]	45
Yield strength [MPa]	150
Tensile strength [MPa]	255
Elongation [%]	10
Anisotropy [-]	1,91
Poisson coefficient [-]	0,35

3 EXPERIMENTAL RESEARCHES

The research directions are, consequently, the following:

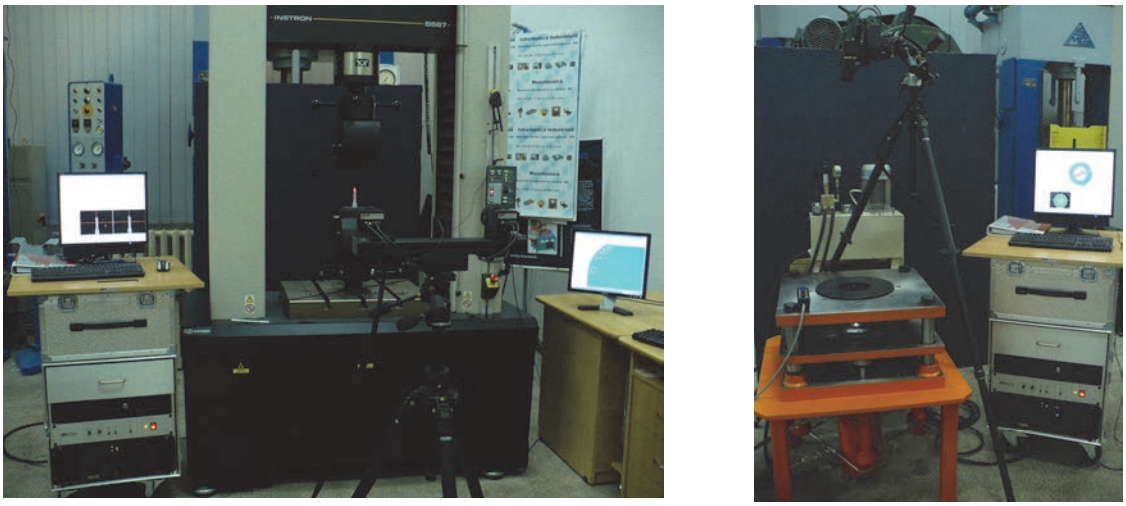
- the determination of the mechanical parameters and the characteristic properties using the tensile test;
- the plot of the forming limit curves using Nakajima test;

The tests were made for AZ31B magnesium alloy specimens in two different states, respectively:

- non treated state, corresponding to the material delivered without incurring any thermal or mechanical;
- treated state, corresponding to the heat-treated material prior to application of the plastic deformation process, at 250^{o}C temperature with one hour maintaining period.

The tests were carried out using test samples made of AZ31B magnesium alloy, 1mm thickness, using the following experimental layouts:

- the mono-axial tensile layout consisting from the tensile test machine Instron 5587 and the strains optical measurement system Aramis (Fig. 1.a);
- the forming limit curves and drawing layout consisting from the modular deep drawing device, with exchangeable active elements, and optical strain measurements systems –Aramis („on-line") respective Argus („off-line") (Fig. 1.b);
- furnace Nabertherm L15/11/P320: for heat treat of the magnesium alloy AZ31B.



a. b.

Fig. 1. The experimental layout used for the tensile test b. the forming limit curve test.

The tests were performed using equipment belonging to the specialty laboratory of the Research Centre for Metal Forming of the "Lucian Blaga" University of Sibiu.

In order to determine the forming limit curves, the authors used an experimental setup as presented in figure 1.b., consisting of a modular drawing device, a system for the acquisition and processing of the experimental data and the strains measurement system ARAMIS. The deep drawing device is composed of a modular deep drawing die, fastened on the device's table, having in the lower part the hydraulic actuation devices. The active elements of the system: punch, die and blankholder, are modular, and rapidly exchangeable, so that various types of tests can be carried out: Nakajima test, Marciniak test, deep drawing tests for cylindrical, conical, parallelipipedical parts etc.

3.1 Employed test samples

As test sample type for mono tensile test was chosen proportional specimen with the dimension of the calibrated zone 75*12,5 mm*mm. (Fig. 2), according to SR EN 10002-1:2002 standard.

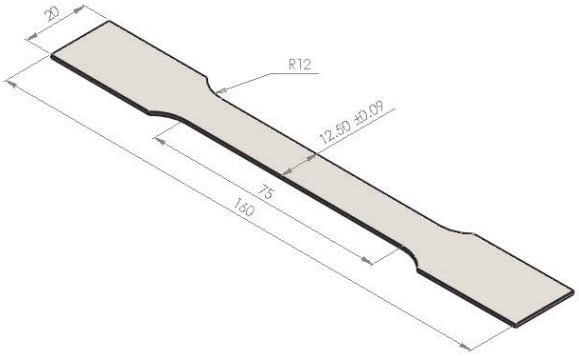


Fig. 2. Proportional test sample

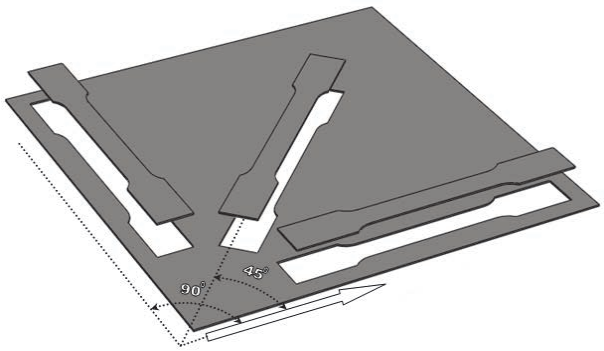


Fig. 3. Proportional test samples made at 0^0, 45^0 and 90^0 to the rolling sheet direction

To study the anisotropy of the material sets of specimens were made at angles of de 0^0, 45^0 90^0, respectively to the rolling sheet direction (Fig. 3).

As test sample type for forming limit curves there was chosen the type suggested by Haşek in 1978, namely circular-shaped test samples with a diameter of 200 mm, with lateral cutouts symmetrical to the rolling direction (Fig. 4), with various radii as presented in Table 3. By using these types of test samples, there can be obtained forming paths comprised between the uniaxial stretching and the equibiaxial stretching. This means that the whole variation domain of the forming states encountered in metal sheet forming processes is covered. [3].

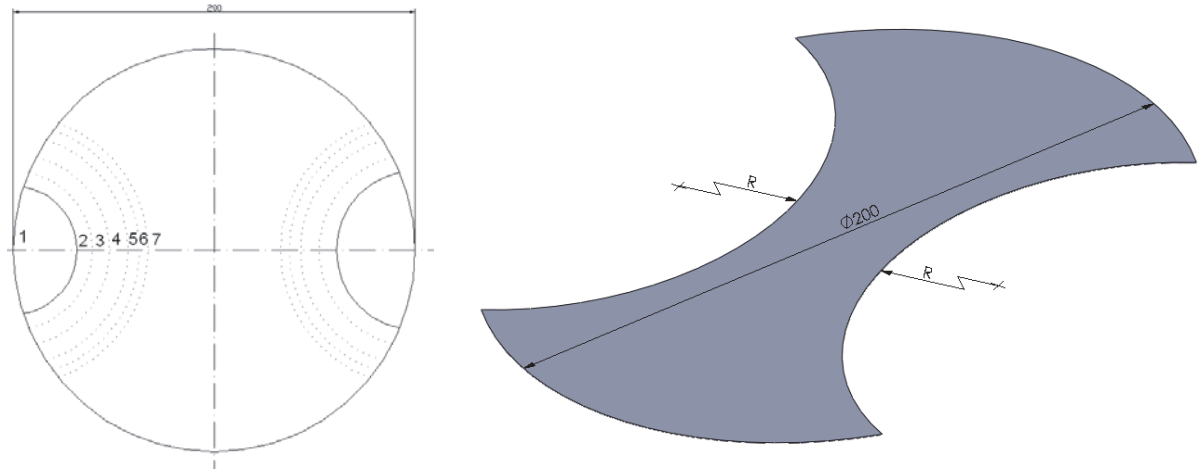


Fig. 4. The shape of the test samples used for determining the forming limit curves.

Table 3. **Cut out radii at the test samples used for determining the forming limit curves**

Specimen	1	2	3	4	5	6	7
r [mm]	0	40	50	57,5	65	72,5	80

3.2 The uniaxial tensile tests

The uniaxial tensile tests performed have targeted the determination of the mechanical characteristics and the properties of the AZ31B magnesium alloy. In order to evaluate the tensile behaviour of both non-treated and heat treated AZ31B magnesium well as the specific elongation at breaking were compared (Table 4).

Table 4 Mechanical characteristics of the AZ31B magnesium alloy

Mechanical characteristics	AZ31B	
	Non treated (20°C)	Heat treated (250°C-1h)
Tensile stress at yield, Rp0.2 [N/mm2]	161.94	156.67
Tensile stress at failure, Rm [N/mm2]	261.06	265.42
(Rm-Rp0.2) [N/mm2]	99.12	108.74
Tensile strain at yield Ar [%]	12.37	25.03

Figure 5 presents the strain hardening curves for the AZ31B magnesium alloy in heat treated and non treated state, determined by means of the uniaxial tensile test, as well as the values of the strain hardening coefficient and of the strength coefficient in the two states of the material.

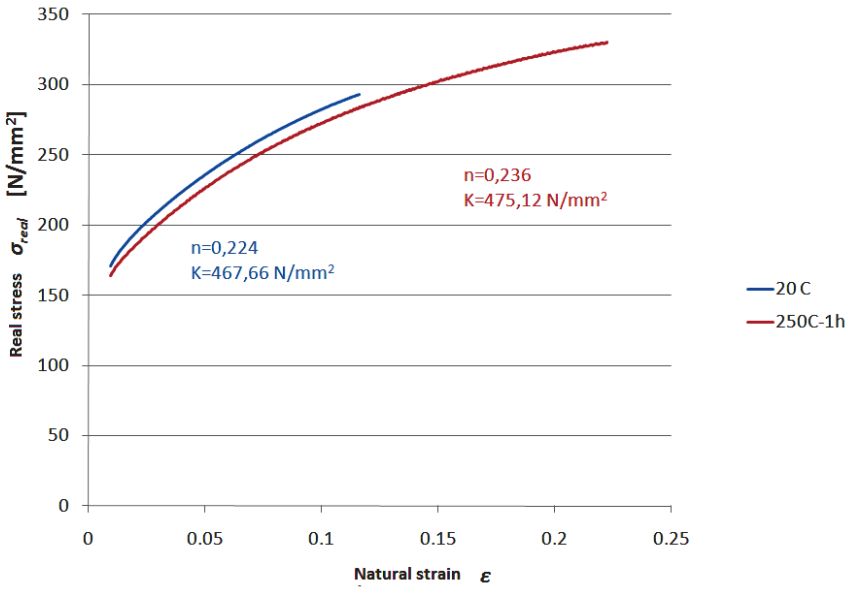


Fig. 5. Strain hardening curves for the AZ31B magnesium alloy in heat treated and non treated state.

3.3. Determining the forming limit curves

In order to determine the forming limit curves the Nakajima test was chosen, which uses a hemispherical punch and a circular die for the analysis. The main advantages of the Nakajima test consist, on the one hand, in the fact that the forming tool is very simple, and on the other hand, it

allows the determining of the forming limits curves on the whole usual domain of the strains. Also, the shape of the test samples is a very simple one [3].

The forming limit curves for the AZ31B magnesium alloy heat treated at the temperature of 250°C for a period of one hour are shown in Figure 6.

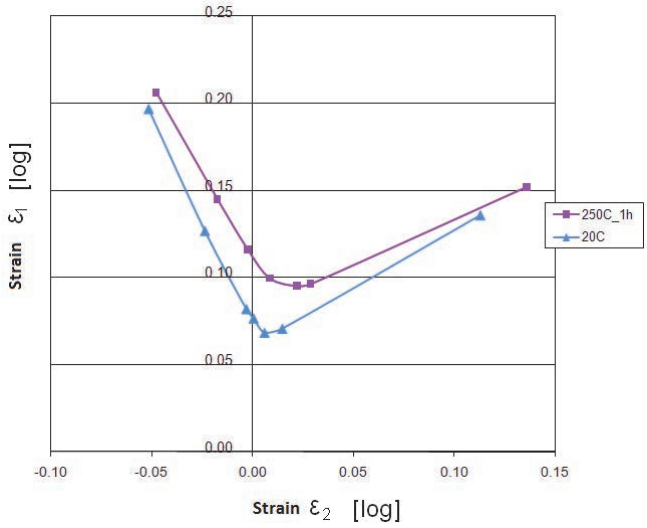


Fig. 4. Forming limit curves for the AZ31B alloy sheet metal in non treated and heat treated state.

It can be noticed that the forming limit curve for the heat treated AZ31B magnesium alloy is located above the curve corresponding to the non treated state, which indicates a better plastic deformation behavior after heat treatment.

4. CONCLUSIONS

Based on the comparative analysis, it may be concluded that the mechanical characteristics and the properties of the researched materials were determined with good accuracy and the parameterized finite elements model offers similar results to those obtained experimentally.

The general conclusion of the researches is that the AZ31B magnesium alloy heat treated at 250°C temperature with a maintaining period of one hour may be used for forming processes with small deformation degrees, its behavior being better than in the non treated state.

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NOI CERCETĂRI PRIVIND MATERIALELE COMPOZITE LA CENTRUL DE STUDII SI CERCETĂRI PENTRU DEFORMĂRI PLASTICE – UNIVERSITATEA "LUCIAN BLAGA" DIN SIBIU

Claudia GÎRJOB[2], Octavian BOLOGA[1,2], Gabriel RACZ[2], Cristina BIRIS[2]

[1]Membru titular al Academiei de Ştiinţe Tehnice din România
[2] Universitatea "Lucian Blaga" din Sibiu

Rezumat: În structura Universităţii "Lucian Blaga" din Sibiu funcţionează, ca unitate de cercetare distinctă, Centrul de Studii şi Cercetări pentru Deformări Plastice. Acesta este unul dintre primele centre de acest fel din învăţământul superior românesc şi a apărut sub egida programului european TEMPUS. Una dintre preocupările centrului în acest moment este legată de cerinţele din industria de automobile şi din cea aeronautică in ceea ce priveşte introducerea de noi aliaje uşoare, prelucrabile prin presare obţinându-se astfel reducerea maselor, a consumului de combustibil şi implicit a emisiilor de gaze. Pornind de la aceste premize lucrarea urmăreşte studierea comportării la prelucrarea prin deformare plastică a materialelor uşoare comparativ cu materialele clasice. În acest scop au fost alese următoarele materiale: din clasa materialelor metalice uşoare şi cu plasticitate scăzută la prelucrări la temperatură ambiantă a fost studiat aliajul de magneziu AZ31B, aliaj reprezentativ pentru sistemul de aliaje magneziu – zinc – aluminiu, din grupa materialelor stratificate au fost studiate materiale metalice având următoarea configuraţie: aluminiu-material plastic-aluminiu, tablă acoperită cu film din material plastic respectiv oţel-material plastic-oţel respectiv dintre materialele clasice a fost ales oţelul DC03. Cercetările vizează determinarea caracteristicilor mecanice şi a proprietăţilor intrinseci, prin încercare la tracţiune, rezultatele vizate fiind valori pentru: modulul de elasticitate, limita de curgere, rezistenţa la rupere, alungirea la rupere, coeficientul de ecruisare, coeficientul de rezistenţă şi coeficienţii de anizotropie plastică, necesare ulterior simulărilor numerice prin MEF a proceselor de deformare plastică.
Confirmare: Această lucrare a fost finanţată din contractul POSDRU/159/1.5/S/133255, proiect strategic ID 133255 (2014), cofinanţat din Fondul Social European, prin Programul Operaţional Sectorial Dezvoltarea Resurselor Umane 2007 – 2013.