14th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2010, Mediterranean Cruise, 11-18 September 2010

INFLUENCE OF PROCESSING TECHNOLOGY ON MECHANICAL PROPERTIES AND STRUCTURE OF SELECTED NON-FERROUS METALS

Lubomír Čížek S. Rusz, D. Ostroushko, R. Puchký, O. Blahož
VŠB-Technical University of Ostrava
17.listopadu 15, 708 33 Ostrava
Czech Republic

M. Praźmowski,
Opole University of Technology,
S.Mikolajczyka St. 5, 45-271 Opole,
Poland

T. Tański
Silesian University of Technology,
Konarskiego St. 18a, 44-100 Gliwice,
Poland

ABSTRACT
Contemporary materials should possess high mechanical properties, physical and chemical, as well as technological ones, to ensure long and reliable use. The above mentioned requirements and expectations regarding the contemporary materials are met by the non-ferrous metals alloys used nowadays, including namely the aluminium and magnesium alloys.
Presented experimental work focused on the study and comparison of microstructure and mechanical properties selected non-ferrous metals after application different methods of forming and heat treatment respectively. Tensile test for mechanical properties determination were used. The study of microstructures has been used methods of light microscopy.
Keywords: processing technology, structure and mechanical properties, non-ferrous metals

1. INTRODUCTION

Non-ferrous metals find at present still more applications in many industry branches [1-5]. Aluminium and magnesium deal to a lightest of all structural metals. Magnesium and aluminium alloys are primarily used in aeronautical and automobile industry in wide variety of structural characteristics because of their favourable combination of tensile strength, elastic modulus and low density (magnesium is two-thirds that of aluminium and namely magnesium alloys have high strength-to-weight ratios (tensile strength/density), comparable to those of other structural metals. The development of engineering namely new methods of treatment aims at designs optimizing, reducing dimensions, weight, and extending the life of devices as well as improving their reliability.
Presented experimental work focused on the study of microstructure and mechanical properties selected non-ferrous metals after application of forming and heat treatment respectively. Tensile test and measurement of hardness for mechanical properties determination were used. The study of microstructures has been used methods of light microscopy.

2. MATERIALS, EXPERIMENTAL PROCEDURES

Materials of non-ferrous metals and alloys were supplied by VÚHŽ a.s. Dobrá. Experimental materials of aluminium (signed A), copper (signed B) and alloys AlFe1,5Mn (signed C), AlMn1Cu (signed D) and were chosen within structural condition corresponding with commercial expedition of producer (molten with slight reduction caused by rolling – up to 10%, thickness of sheet 15 mm). Magnesium alloy AZ91 was manufactured by the company ČKD Motory a.s. Hradec Králové.

Chemical composition used materials can be found in the Table 1.

Table 1. Chemical composition of used non-ferrous materials (in wt %)

Used materials	Al	Cu	Mn	Fe	Si	Zn	Mg	Ni	Cr
Al – A	99,5	0,05	-	0,40	-	-		-	-
Cu – B	0,05	99,5	-	0,05	-	-		-	-
AlFe1,5Mn – C	98,6	0,055	0,453	1,29	0,085	0,0065	0,0005	0,0044	0,0035
AlMn1Cu – D	98,1	0,005	1,26	0,287	0,168	0,0080	-	0,0005	0,0087
AZ91 – E	8,95	0,003	0,21	0,008	0,041	0,76	89,9	0,002	-

Materials A and B were further forging on thickness 2 mm. Than were cut on size 58 x 1000 mm for DRECE machining [6,7]. Flat samples were produced on milling cutter and samples notation for the implementation of a tensile test will be formed by the letter of alloy and number of pass value. Materials C and D were then cold rolled on rolling mill Q110. The alloy C was classical rolled by gradual reductions up to the amount of deformation 33, 50 and 80%, the alloy D then to 33 and 50%. Flat samples were produced on milling cutter to the thickness of 2mm. Samples for tensile test had a flat form with length l =120 mm. The other sizes of samples are mentioned in tables of test results. Henceforth, samples notation for the implementation of a tensile test will be formed by the letter of alloy and value of deformation (%). Part of the alloys E was also used for manufacturing of samples for determination of mechanical properties as cast state. Another part of the alloy was after heat treatment T4 [6] formed by hot pressing. Optimum conditions of pressing have been found. Samples for tensile test had a rod form with diameter 6 mm.
Tensile test was performed on tensile machine INOVA TSM 50 (See Figure 1).

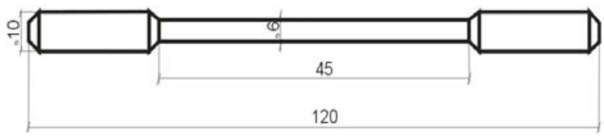

Figure 1. Size of sample for tensile test.

3. RESULTS AND DISCUSSION

Test results are mentioned in Tables 2 - 5.

Table 2. Results of tensile test – Aluminium - A

Aluminium	a_0 [mm]	b_0 [mm]	L_0 [mm]	$R_p0,2$ [MPa]	R_m [MPa]	A [%]
A0	2	12,5	25	64	91	20
A4	2	12,5	25	90	103	21
A6	2	12,5	25	86	99	28
A8	2	12,5	25	79	92	24

Table 3. Results of tensile test – Copper - B

Copper	a_0 [mm]	b_0 [mm]	L_0 [mm]	$R_p0,2$ [MPa]	R_m [MPa]	A [%]
B0	2	12,5	25	198	264	40
B2	2	12,5	25	252	284	10
B4	2	12,5	25	255	311	9
B6	2	12,5	25	247	324	7
B8	2	12,5	25	231	315	7

As it is seen from Tables 2 and 3 there is difference between DRECE processing of aluminium and copper. In the case of aluminium mechanical properties change very little while in the case of copper this change is significant namely for tensile strength R_m and elongation A. This fact can be explained by the possibility of pure Al recrystalization.

Table 4. Results of tensile test – aluminium alloy AlFe1,5Mn - C

AlFe1,5Mn	a_0 [mm]	b_0 [mm]	L_0 [mm]	$R_p0,2$ [MPa]	R_m [MPa]	A [%]
C0	2	12,5	50	199	217	8
C33	2	12,5	50	201	215	8
C50	2	12,5	50	185	199	11
C80	2	12,5	50	202	216	6

Table5. Results of tensile test – aluminium alloy AlMn1Cu - D

AlFe1,5Mn	a_0 [mm]	b_0 [mm]	L_0 [mm]	$R_p0,2$ [MPa]	R_m [MPa]	A [%]
D0	2	12,5	50	76	110	25
D33	2	12,5	50	139	148	14
D50	2	12,5	50	152	161	13

The similar results were observed in the case of alloys C and D. In this case we can presume that Cu has higher influence on mechanical properties than Fe.

Table6. Results of tensile test – magnesium alloy AZ91 - E

State	Diametr [mm]	$R_p0,2$ [MPa]	Rm [MPa]	A [%]
As cast	6	118	180	4
HT - T4	6	125	280	20
Hot pressed	6	225	340	22

As we can see from Table 6 the mechanical properties of alloy AZ91 (E) after HT T4 and namely in the case after hot pressing gain very favourable values. In this case the high tensile strength R_m and elongation A values were reached.

Above mentioned mechanical properties of materials studied were completed by metallographic analysis. Metallographic analysis was made on optical microscope NEOPHOT 2. After usual metallographic preparation Figures 2 - 16 show the obtained results of analysis of selected samples. In the case Al and Al alloys etching of deformed grain is difficult and for better view of Al and its alloys a polarized light was used (see Figures 2, 3 and 6- 12). As it is seen from Figures 2 and 3 for Al structure after 8 pass by DRECE shows more fine bands. Similar results showed Al alloy (see Figure 6- 12). From Figures 6-9 is seeing that structure this alloy show lower step of deformation bands in agreement with mechanical properties reached (see Table 4).

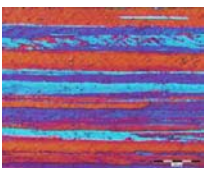

Figure 2. Structure of the sample A0

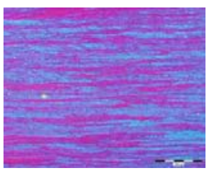

Figure 3. Structure of the sampleAM8

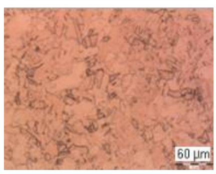

Figure 4. Structure of the sample B0

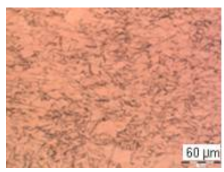

Figure 5. Structure of the sample B8

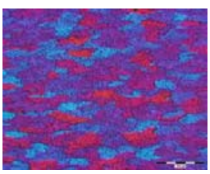

Figure 6. Structure of the sample C0

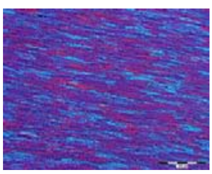

Figure 7. Structure of the sample C33

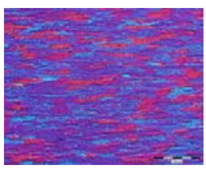

Figure 8. Structure of the sample C50

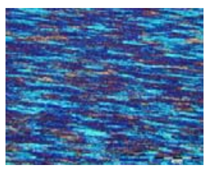

Figure 9. Structure of the sample C80

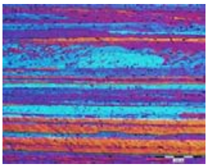

Figure 10. Structure of the sample D0

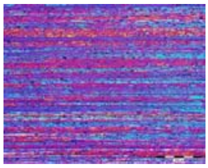

Figure 11. Structure of the sample D33

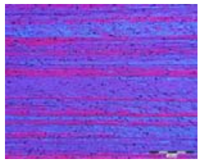

Figure 12. Structure of the sample D50

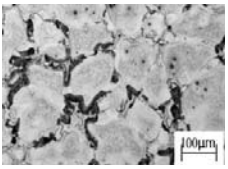

Figure 13. Structure of the sample E- as cast

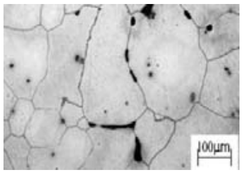

Figure 14. Structure of the sample E- after T4

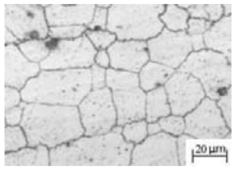

Figure 15. Structure of the sample E- after hot pressing

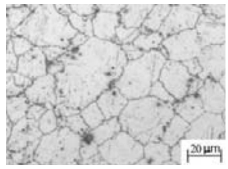

Figure 16. Structure of the sample E- after tensile test

Figure 13 shows structure of the sample G before heat treatment and Figure 14 after heat treatment T4. Figure 15 shows structure of alloy after hot forming. Forming resulted in significant refining of grain in comparison to previous states of the alloy. Details of magnesium alloys microstructure in reference [8]. Figure 16 shows change of structure after completion of tensile test. Original grains are deformed, grain boundaries are characterised by increased zigzag shape.

4. SUMARY

In this work were examined selected non-ferrous metals having the possibility of exploitation at development new methods of treatment in aeronautical and automobile industry. These examinations carried out after different processing technology show the influence used forming methods on results of mechanical properties and structure.

The alloy AlMn1Cu present significant higher increasing of mechanical properties with increasing deformation level against alloy AlFe1,5Mn.

The mechanical properties of alloy AZ91 after HT T4 and namely after hot pressing gain very favourable values.

ACKNOWLEDGEMENTS

The work was financed by aim of project MSM 6198910015 and sponsored of projects MPO No. 2A-1TP1/124, GAČR of the Czech Republic GA-101/08/1110 and INTERREG IIIA.

5. REFERENCES

[1] ASM Handbook No.2, Properties and Selection: Nonferrous Alloys and special –Purpose Materials, ASM International, Metals park Ohio, 1990, pp. 29,

[2] Davis, J.R.: Metals Handbook, Desk Edition, Second Edition, ASM International, The Materials Information Society , USA, 1998, pp.560- 564,

[3] Schedule of materials 3.0 [computer programme], august 2003,

[4] Michna, Š. a kol.: Encyklopedie hliníku (Aluminium Handbook), Adin Prešov, 2005, pp.14-24, 119, 131-137, 143-149, , 256-270, 293-297, 379, 382 – 386,

[5] Baker, H.: ASM Specialty Handbook. Magnesium and Magnesium Alloys, ed. Avedesian, ASM International, The Materials Information Society, USA, 1999,

[6] Tatsuya, T., Kazuhiko, O., Saburov, T.: Precise Extrusion Technology by Conform Process for Irregular Sectional Copper**,** Hitachi Cable Review, No. 21, 2002,

[7] Niewielski, G., Kuc, D.: Structure of the copper under controlled deformation path conditions, Archives of Materials Science and Engineering 36 (2009) 20-27,

[8] Čížek, L., Greger, M., Pawlica, L.,.Dobrzański, L.A., Tański, T.: Study of selected properties of magnesium alloy AZ91 after heat treatment and forming, Journal of Materials Processing Technology, 157-158 (2004), pp. 466-471.