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Influence of Chemical Composition Variation and Heat Treatment on Microstructure and Mechanical Properties of 6xxx Alloys.

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***ABSTRACT**: The main aim of this work was to study the effect of the precipitation hardening on the microstructure and mechanical properties of 6022, 6061, 6063, and 6066 aluminium alloys.*
In this study differential scanning calorimetry (DSC) and hardness measurements have been utilized to study the effect of a precipitation hardening on the mechanical properties in 6xxx aluminium alloys. The mechanical properties (σ_u and σ_y) and plastic (A, Z) properties of the examined alloys were evaluated by uniaxial tensile test at room temperature. The microstructure was observed using optical microscope. The results show that the microstructure and mechanical properties changes during artificial aging due to the precipitation strengthening process. Therefore, the parameters (aging time and aging temperature) of precipitation strengthening process that may lead to the most favourable mechanical properties of 6022, 6061, 6063, and 6066 alloys were determined. The paper has provided essential data about the influence of chemical composition and aging parameters on the microstructure and mechanical properties of 6022, 6061, 6063, and 6066 alloys.

***Key word:** precipitation hardening, microstructure, mechanical properties, heat treatment,*

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I. INTRODUCTION:

Aluminium alloys are commonly used in the automotive, aerospace and construction industry because of an interesting combination of properties (low density, good thermal conductivity, relatively better mechanical properties and relatively good corrosion resistance [1]. There are two types of aluminium alloys: heat treatable and non-heat treatable alloys. Heat-treatable alloys employed to increase the strength and hardness by precipitation hardening. Commercial alloys whose strength and hardness can be significantly increased by heat treatment include 2xxx, 6xxx, and 7xxx series wrought alloys and 2xx.0, 3xx.0 and 7xx.0 series casting alloys. The heat treatable Al-Mg-Si alloys of the 6xxx series are often chosen for these applications, since they show a good combination of formability, corrosion resistance and weldability. The 6xxx-group contains magnesium and silicon as major addition elements. These multiphase alloys belong to the group of commercial aluminium alloys, in which relative volume, chemical composition and morphology of structural constituents exert significant influence on their useful properties [1, 20]. In the technical 6xxx aluminium alloys contents of Si and Mg are in the range of 0.5-1.2 wt%, usually with a Si/Mg ratio larger than one. Besides the intentional additions, transition metals such as Fe and Mn are always present. If Si content in Al alloys exceed the amount that is necessary to form Mg_2Si phase, the remaining Si is present in other phases, such as Al-Fe-Si and Al-Fe-Si-Mn particles [2,4,6-13].

The aluminium alloys of 6xxx group have been studied extensively because of their technological importance and exceptional increase in strength obtained by precipitation hardening. The 6xxx aluminium alloys are mostly used as extruded products, as well as for construction and automotive application. The ease with which these alloys can be shaped, their low density, their very good corrosion and surface properties and good weldability are factors that together with a low price these make them commercially very attractive. The precipitation of metastable precursors of the equilibrium β(Mg_2Si) phase occurs in one or more sequences which are quite complex. The precipitation sequence for 6xxx alloys, which is generally accepted in the literature [11-13], is:

α (SSS) →atomic clusters→ GP zones →β''→β'→β (stable).

Where α is the supersaturated solid solution; GP zones are considered as spherical clusters with unknown structures while the β'' is called fined needle-shaped zone (GP2 zone), β' is the rod-shaped precipitates. The most effective hardening phase for this type of materials is β''. The medium strength AlMgSi aluminium alloys are commonly processed by extrusion. Their extradubility depends to a large extent on chemical composition, casting condition and heat treatment parameters (e.g. homogenization treatment) which determine the microstructure of the billet before extrusion.

Although the precipitation process in Al-Mg-Si alloys has been extensively studied, the understanding of the hardening process is still incomplete, since any change in composition, processing and aging practices etc. could affect the precipitation hardening behaviour. In this study, hardness measurements, differential scanning calorimetry (DSC), universal tensile testing machine and scanning electron microscopy have been utilized to study the precipitation hardening behaviour in set of aluminium alloys 6022, 6061, 6063 and 6066.

II. METHODOLOGY

The investigation has been carried out on the following commercial aluminium alloys (6022, 6061, 6063, and 6066). Chemical composition of the alloys is indicated in Table 1.

Table 1. Chemical composition of the investigated alloys, (%wt)

Alloy	Si	Mg	Cu	Mn	Zn	Fe	Ni	Ti	Cr
6061	0.75	1.03	0.37	0.12	0.025	0.20	0.006	0.028	0.037
6063	0.46	0.56	0. 39	0.07	0.02	0.25	0.005	0.018	0.02
6066	1.17	0.95	0.85	0. 75	0.02	0.25	0.003	0.012	-
6022	0.68	1.02	0.20	0.6	0.014	0.10	0.002	0.-004	0.1

Thermal processing of the investigated alloys included a homogenization treatment and T6 heat treatment (artificially ageing after solution treatment). The temperatures of homogenization treatment of 6xxx alloys were determined on the basis of literature data and calorimetric investigations. The samples in as-cast state were preheated in an induction furnace to temperature 575°C held for 60 hours and subsequently cooled to room temperature. Additionally all alloys were heated in a resistance furnace for 12 hrs at 565°C and then quenched into a water. Subsequently the specimens were subjected to artificial aging at temperature 175^0C up to 96 hrs (4 days). In order to determine an influence of time on the kinetics of ageing the Brinell hardness was measured. DSC samples of the supersaturated 6022, 6061, 6063, and 6066 alloys were investigated in SETARAM Setsys thermal analyzer. The heat effects associated with precipitation of GP zones and intermediate metastable and stable strengthening phase (Mg2Si) were obtained by subtracting a super purity Al baseline run. After artificial aging, a set of specimens were prepared for tensile testing to study the effect of T6 heat treatments on mechanical properties of the examined alloys. The specimens were strained by tensile deformation on Instron TTF-1115 servohydraulic universal tester at constant rates at room temperature in according to standard PN-EN 10002-1:2004 (23). Tensile properties (tensile and yield strength; elongation) were evaluated using round test specimens of 8 mm diameter and 65 mm gauge length (according to ASTM E602-78T (24) standard). Metallographic investigations were performed on the samples at as-cast state after homogenization treatment and extrusion forging process. The microstructure of the alloys was observed using optical microscope - Nikon 300 on polished sections etched in Keller solution containing 0.5 % HF in 50 ml H_2O. The surfaces of fracture of the damaged samples were prepared to microscopic examination by scanning electron microscopy (SEM).

III. RESULTS AND DISCUSSION

The microstructure of the 6061 alloy in as-cast state and after homogenization is given in Fig. 1 - as an example of as-cast state of the investigated alloy.

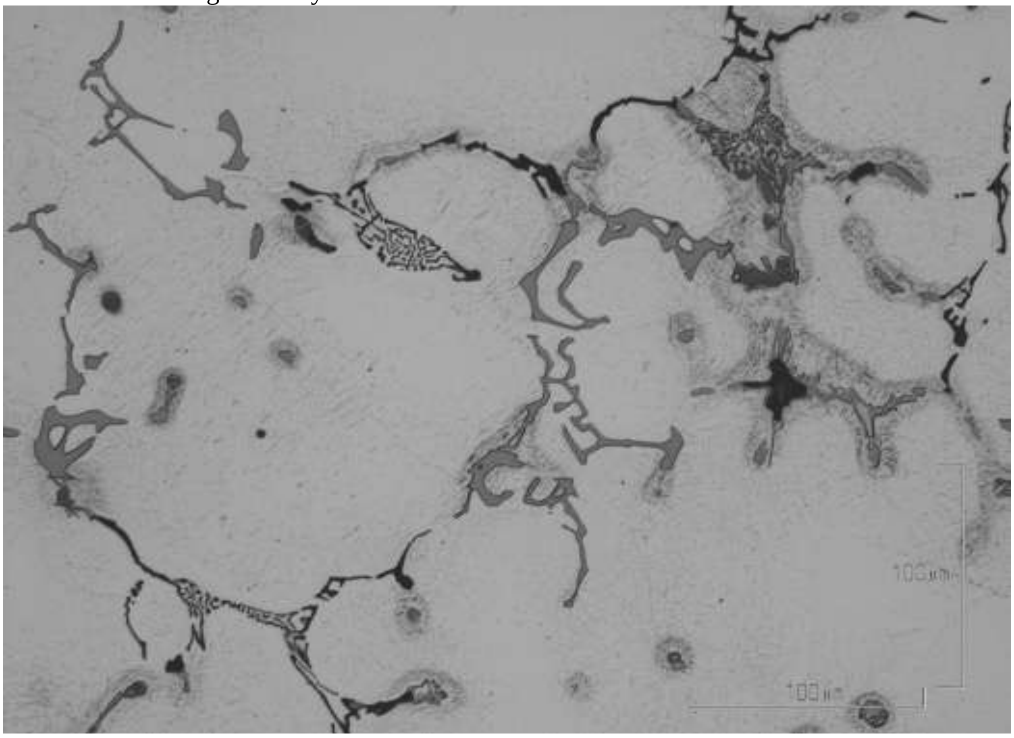
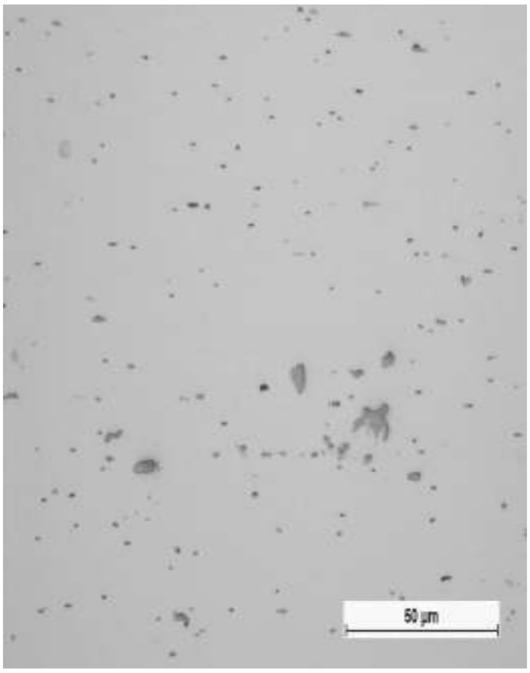
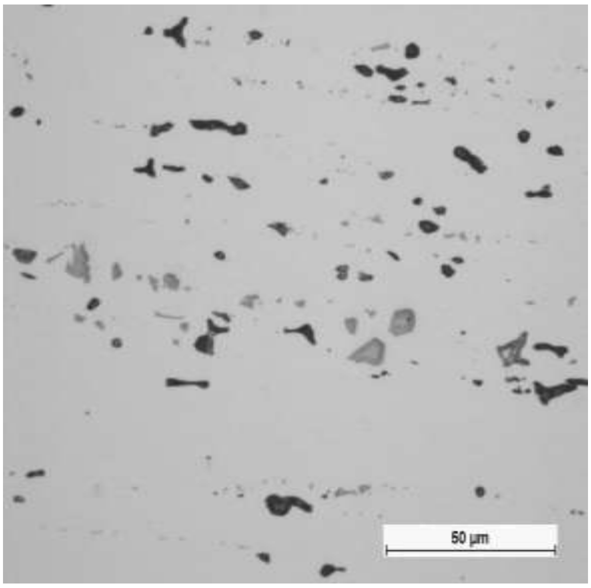


Figure 1. Microstructure of As-cast 6061 aluminium alloy.



a

b 

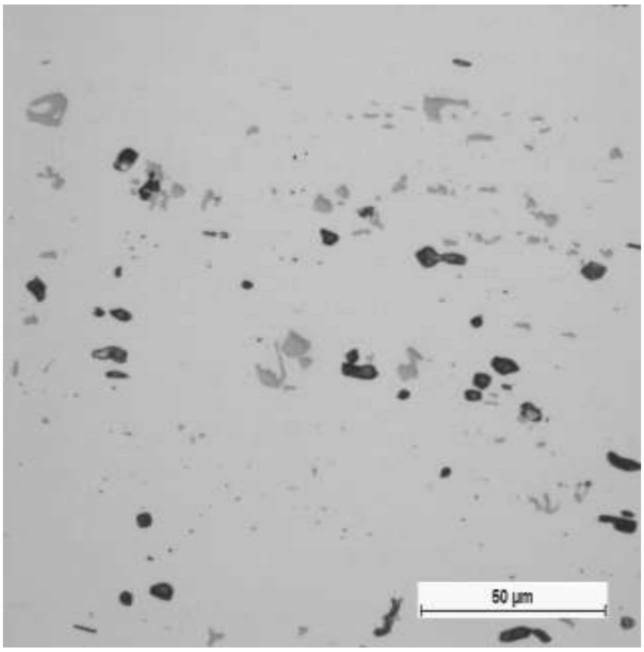
c 

Figure 2. Microstructure of extruded alloys a) 6063; b) 6070; c) 6061 alloys

During hot working of ingots, particles of intermetallic phases are arranged in positions parallel to direction of plastic deformation (along plastic flow direction of processed material) which allows for the formation of the band structure (Fig. 2). As a result, the reduction of size of larger particles may takes place. The accumulation of lattice defects in the material during hot extrusion forging process exerts a considerable influence on a structure formation. As a result, the strain hardening of the alloy takes place and, in consequence, an increase in mechanical properties occurred.

IV. CONCLUSIONS

1. It was found that the mechanical properties of the 6xxx series aluminium alloys in the T6 tempers are strongly depend on the chemical composition and an aging time at 175°C. The degree of strengthening

depends on the extent of β" precipitation which increases with increasing Mg and Si content in the chemical composition of the alloys.

2. The highest mechanical properties connected with a good plastic properties was achieved for 6061 alloy with the highest concentration of alloying elements Mg, Si, Cu, Mn and Fe. In 6061 aluminium alloy besides of β-Mg2Si strengthening phase the precipitation of θ-Al2Cu and Q(Al5Cu2Mg8Si6) phases can be present.
3. Observation fracture surface (SEM) specimens after static tensile test showed that cracking of the examined alloys begin by nucleation and growth of voids. The sites of heterogenic nucleation of voids are the precipitates of intermetallic phases. Subsequent decohesion process initially proceeded at the interface between matrix and particle.

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