Role of Sintering, Co-particles on Properties of Milled Al-Zn-Mg-Cu Matrix Produced via PM

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Abstract

In the current study, mechanically alloying has done to synthesizing Aluminum-Zinc-Magnesium-Copper-Cobalt powders via high-energy ball milling. The green compacts milled Al-Zn-Mg-Cu-Co powders were compacting using hydraulic press uniaxial at 300 MPa. The milled mixtures Al-compacts were conducted by the sintering treatments at various temperatures of 400-600 °C for 1-1.5 hours. Over all ball-milling route turn on: a ratio weight of ball-to-powder about 10:1, the speed of rotation 350 rpm; and the milling time of 8 hours. The assessment of the precipitates particles and intercom pounds of the milled Al-matrixes PM undergone conditions of sintering process were examined using the X-ray diffraction (XRD) and scanning ‘electron microscopy-(SEM) with energy-dispersive X-ray spectroscopy (EDS). Outcomes of micro structural the sintered Al-PM alloys investigated having a precipitations and cobalt-compounds in the matrix during several treatments. The highest Vickers hardness recorded of Al-Zn-Mg-Cu-Co PM alloy under sintering at 600 °C.

Keywords: Aluminium-Cobalt Alloys; Sintering; Hardness.

Introduction

Press-sinter, powder metallurgy (P/M) and mechanical alloying (MA) are synthesis techniques of considerable interest in the scientific field organizations. They are widely considered in the fabrication of likable Aluminium alloys for the automotive, aeronautics, aerospace, military and transportation industries, where weight reducing result as using of lighter materials with promote mechanical performances [1-2].

Aluminium (7xxx series) alloys synthesized using mechanical alloying exhibe enhances mechanical properties, if what they resembled with their ingot metallurgy Al-alloys[3]. The dispersal of nonequilibrium phases, and the extension in the solid solubility limits are appealing characteristics achieved in heat treated aluminium alloys. Refine grain and hardening of precipitation that two key approaches to enhance properties of heat treated Aluminium alloys. Recently, many attempts have accomplished on precipitation-hardenning with additives of particular elements led to improve the mechanical properties of an AlZnMgCu alloys P/M processed. MacAskill et al. [4] noticed that the silicon additions in Al-Mg-Ni PM alloy promoted the formation liquid phase and highly diffused into the α-Al grains and enhanced in thief strength and ultimte tensile property of alloys. On the other words, Schaffier et al. [5] detected the role of microalloying-(Pb, Sn and In) within the sintering of the AlZnMgCu alloys afterther they have identifying an improve of the sintering finding. Senderski et al [6] found that adding Zr element within the AlZnMgCu PM alloy led to improving in the mechanchal properties.

However, influence of addition of iron and silicon in the Al-Zn-Mg-Cu P/M-alloy had been inspected by Milman [7] detected that improved the mechanical properties. The interest of this work to evaluate role cobalt additives and sintering temperatures on the microstructural and hardness property of an AlZnMgCu alloy. Thus effects of sintering coupled with the additives were studied for
the mechanical alloyed AlZnMgCu alloy in this research.

Experimental Procedure

Synthesis of Alloy Powders

Elemental powder precursors of Al, Zn, Mg, Cu and Co have used as start material to produce Al based Alloys; (Al–6.5%Zn–2.5%

Mg–1.7%Cu–2%Co) compositions. All composition are expressing in the weight percentages (wt. %). Table 1 list of the purity levels and the particle size of the raw materials. Malvern Master Size 2000 powder size analyzer measured particle size distributions.

<table>
<thead>
<tr>
<th>Powder</th>
<th>Description</th>
<th>Particle sizes (µm)</th>
<th>Purity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Flake</td>
<td>D50 of 51</td>
<td>98.00</td>
</tr>
<tr>
<td>Zinc</td>
<td>Rounded</td>
<td>D50 of 18</td>
<td>96.00</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Rounded</td>
<td>D50 of 115</td>
<td>98.00</td>
</tr>
<tr>
<td>Copper</td>
<td>Irregular</td>
<td>D50 of 39</td>
<td>99.50</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Rounded</td>
<td>D50 of 11</td>
<td>99.50</td>
</tr>
</tbody>
</table>

Table 1: Specification of materials

Milling Alloying, Compaction, and Sintering Treatments

The ball milling alloying process of the Al-Zn-Mg-Cu-Co alloy powders were applying in planetary high-energy ball mill-Fritsch-underwent the argon atmosphere sby the stainless steel balls of 10-20 mm diameter. The balls/to powder weighted ratio has of 10:1 and the rotation speed was 350rpm. Milling alloying (Mechanical Alloying), processes was completed at milling time of about 8 hours. The powder metallurgy processing route included powder milling, uniaxial-die compaction and sintering process. Compacts-bulk products, which prepared by cold press the milled Al mixtures at 300 MPa under uniaxial-load in using a hand-operated hydraulic press. The milled powders were briquette into cylindrical samples of 10 mm in dia., and weighing 3.5 grams were compacted. Green compacts were sintered at range of 1-1.5 hour under different temperatures as showed in Table2; with the constant heat-rate of 20 °C/min., green compacts-bulk were sintered in the electric furnace.

<table>
<thead>
<tr>
<th>ID Sample</th>
<th>Sintering Temps (°C)</th>
<th>The soaking Duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>400</td>
<td>90</td>
</tr>
<tr>
<td>II</td>
<td>450</td>
<td>90</td>
</tr>
<tr>
<td>III</td>
<td>500</td>
<td>90</td>
</tr>
<tr>
<td>IV</td>
<td>550</td>
<td>60</td>
</tr>
<tr>
<td>V</td>
<td>600</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 2: Presentation of the sintering temperatures and duration of soaking of Al-Zn-Mg-Cu-Co alloy compaction

Characterization of the sintered products included the measurement average hardness in Vickers Hardness, according to ASTM E92-82, “Mitutoya-DX.256 series”. Indentation force was set at 20 N, and 10 second dwelled time.

To assess microstructures, they detected by the scanning-electron-microscopy (JEOL scanning election microscopes) coupled energy dispersive’ X-ray spectrocope and X-ray diffraction analysis was (SHIMADZU), used under the following conditions; scan range: 20°-80°, step size: 0.03, scan rate: 5°/min.

Results and Discussions

Figure 1 show the effects of milling alloying route on the morphology of alloy powders. The original particles were semi-spherical; some small-rounded particles also existed (Fig. 1a). Plastic deformations lead to cold welding, changes the particle shape, and fractures were the almost factors during ball milling [2].

In this research, Al-Zn-Mg-Cu-Co powders particles undergone the ball milling operation commenced with by repetitive collision and the impaction of the particles with the milling media (balls of stainless steel). The Al, Mg, and Zn are considered soft thus that a plastically deformed easily.
Then their shapes were change from nearly spherical to flake-like large aggregates because of their high ductility (Fig. 1b). Other relatively harder particles of Cu and Co mainly fractured to smaller sizes. The outcome of the 8 hours ball milling operation that was Zn–Mg–Cu–Co alloyed composite particles of polygonal grains dispersed and embedded in Al matrix as shown in Fig.1b.

The scanning electron micrograph (SEM) in Figure 2 (a) depicts the dark areas of microstructure Al-alloy compact the as sintered (at 500 °C). The alpha aluminum (primary solid solution) grains surrounded by a light phases (bright dispersions represent the inter compounds of additives with precipitates of alloying elements) which is a remnant of the zinc-enriched sintering liquid that decomposes on solidification to the α-aluminum, (η)-Mg Zn, T and S phases were shown in the EDS. The more details about the precipitations phase (T, S, η) for this research are also mentioned by Naeem [9-10]. Fig. 2 (b) detects the proposing stoichiometry similar to the T-(AlMgZn) phase and the S-(Al Cu Mg) phase with Mg Zn components as well as scattered Cobalt-particles.

The mean of sintered density for the Al-compacted sample (II) was 2.759 g/cm³ or 93% of the theoretical value (2.967 g/cm³). During the sintering process; the target was to develop the strong inter-particles bonds and homogeneously distributed of alloying elements within the matrix. The ball milled Al-alloy compacts under multi-temperatures of the sintering (400, 450, 500, 550, 600 °C) exhibited improved the homogeneity of the alloying elements and dissolved some inter metallic compounds.

Figure 1: Changes in morphology of the mixture Al Zn Mg Cu Co powders during mechanical alloying process: after 8 hrs of milling time

Figure 2: The (a) SEM micrograph and (b) EDS micro analysis of the ball milled Al-Zn-Mg-Cu-Co PM-(III – alloy after applying sintering process at 500 °C)
Figure 3 shows compare X-ray diffraction (XRD) patterns of the Al-Zn-Mg-Cu-Co PM alloy as compacted, after applying sintering treatments.

It can be observed that the Al-PM alloy under sintering (at 400-450 °C (I, II)) in Fig. 3 (a-b); it is chiefly composed of major peaks (1-AlZn), (2-Al₅Mg₁₁Zn₄), (3-Al₃CuMg) and other secondary peaks are (4-MgZn₂) with (5-Al₃Co). In general, the acceptance that the metastable (MgZn) phase and its compounds play the main roles in the strengthening of precipitations hardening for Al-Zn-Mg-Cu alloys. Main precipitations in the sintered compacts are AlZn and (η-MgZn) phase. The XRD results (Fig. 3c) the milled Al-Zn-Mg-Cu-Co compact PM alloy detects an newly existence of (8-Mg₂Zn₁₁) as a main phase which happen more dissolved for alloying elements (Zn and Mg) during increasing sintering temperature into 500 °C, additionally presence inter compound phase (6-Al₃Co). The XRD analysis (Fig. 3e) of the ball milled Al-Zn-Mg-Cu-Co alloy compact after the sintering at 600 °C indicates high-intensity diffraction of (8-Mg₂Zn₁₁) peak.

In addition to, the having a new creation of inter metallic (7-Al₅Co) peak generally, it had been suggested that during the highest temperature, of the sintering (600 °C for 60 min, during this study), undisclosed (Mg Zn) transformed into the (η’-Mg₂Zn₁₁) phase and then formed into numerous MgZn₂ and the η’ phases.
Vickers hardness for the milled PMAl-alloy compacts under the different sintering conditions (Fig. 4). Generally, the milled Al-alloy undergoing the condition of sintering at 600°C have significantly increment hardness more than what was observed in the sample as sintered temperatures at 400-550°C. Predominately, values of mica hardness for the Al-Zn-Mg-Cu alloy depends on strength mechanisms such the precipitation hardening results as the alloying elements, which assumed that the influences of the (η-Mg Zn) cohesive with η’-(Mg:Zn11) phase are precipitates within the Al-matrix as stated by [8].

These precipitate acts as pin-points, which impeded the dislocation movement thus improve the hardness. Another strengthening, it was determined by growing densities of dislocation, and with the grain refinement because of the mechanically alloying (milling alloying) process. Thus, ball milled Al-PM alloy under conditions of sintering led to up more value of hardness [12-13]. Additionally effects of cobalt-inter compounds were disturbed uniformly dispersion within Aluminium-Zin-Magnesium-Copper matrix. These inter metallic’s cause to rise of hardness through Orowan mechanism [3, 10].

Conclusions

Through the experiments of this research that accomplished, it has understood that:

- High-energy ball milling route has conducted to synthesize Al-Zn-Mg-Cu-Co powder particles. The cobalt additives semi-completely dissolved with alloying elements (Zn, Mg, and Cu) within Aluminum matrix as well as the solid solutions for alloying elements were formed undergone eight hrs time of ball milling.
- The milled Al-Zn-Mg-Cu-Co matrix PM alloy were much responding to condition of sintering and it reaches density sintering of about 93% of theoretical.
- Micro structural observations mentioned that the milled Al-Zn-Mg-Cu-Co matrix after sintering treatments, to having more precipitations particles with Cobalt-inter metallics in the sintered Al-matrix. Meanwhile the matrix of Al-PM was defects free.
- The compacted alloy after doing the sintering at 600°C have the highest Vickers hardness because of the precipitation particles (MgZn2 and Mg:Zn11) and compounds of cobalt (Al:Co, Al:Co1 and Al:Co2) in addition to roles of mechanical alloying on particle-powders of alloying.

Acknowledgment

This study done in Muthanna University-Iraq. The authors gratefully acknowledge the outstanding support provided by the technicians of the workshop in Colleges of Science and Engineering.

References


