Investigation of Roller Burnishing on Zamac5 Alloyed by Copper

Dr. Safwan M.A. Al-Qawabah,
Mechanical Engineering Department, Tafila Technical University, Tafila, Jordan, 66110, P.O.Box:179, Mobil: 00962777499418

Abstract: In this paper the literature related to Zn-5 % Al (Zamak5) cast alloy was reviewed and discussed. This alloy has about 1 % Cu, and a few works have been published on the effect of Copper addition and roller burnishing process on the microstructure, hardness and surface roughness of the obtained alloys. This forms the objectives of the present work. The copper added at a rate from (2.5 to 10) % Cu to commercially Zamak5. Then the roller burnishing process done on the produced alloys. It was found that there is an enhancement on the hardness and the maximum is 18 % I Zamac5-10 % Cu alloy. The best surfaces result was 0.05 micrometer that obtained at 0.04 mm/rev burning feed rate in Zamac5-10 % Cu alloy

Key words: zamac5, Roller Burnishing, Copper, Surface Roughness, Microhardness.

INTRODUCTION

Zinc–aluminum alloys form the basis of a number of commercial alloys including ZA-8, ZA-12, ZA-27 and ILZRO-12[1-8]. Zinc and zinc alloys are use in the form of coating, casting rolled sheets drawn wire, forging, and extrusions. In its pure form, zinc is available as slabs, ingots, shot, powder and dust, combined with oxygen, it is available as: Zinc oxide powder. Impurity limits are very important when zinc is used for alloying purpose. Exceeding impurity limits can result in poor mechanical and corrosion properties. Pure zinc shot is used primarily for additions to electro galvanizing baths, and zinc powder and dust are used in batteries and in enhanced corrosion-resistant paints. Zinc oxide is used as pigment in primers and finish paint, as a reducing agent in chemical processes, and as a common additive in the production of rubber products. The research works [9,10-12] showed that the addition of alloying elements including copper, silicon, magnesium and nickel can improve the mechanical and tribological properties of zinc-aluminum alloys. In the present work, a new Zinc-aluminum alloy contains 4 % aluminum called commercially known as Zamac5 which forms the base material of investigation. The effect of copper addition to the base Zamac5 and the roller burnishing parameters on the microstructure, microhardness and surface finish is therefore the purpose of this work.

MATERIALS AND METHODS

Materials: In this work set of materials were used such as the commercial zinc-aluminum alloy No.5 die casting (Zn – %5 Al), and it will be reviewed as zamac 5 in this work, high purity copper to prepare the different alloys.

No.5 casting alloy (zamac 5): The base material used throughout this work is zamac 5 commercially available in the form of blocks, the chemical analysis of this base alloys is shown in Table 1.

Copper: Pure copper is used extensively for cable, wire and pure powder, the density of copper is 9.95 gm/cm3 and the melting point is 1080 °C. Coppers have many important advantages however, its corrosion resistance, Easy to fabrication, High electrical and thermal conductivity. The copper purity used in the work is 99.99 %.

Equipment

The following machines and equipment were used throughout the experimental work:

1. An electric resistance furnace (Carbolite) with 0-1100°C.
2. XRF Model 1800- shemadzu, Japan
3. Digital microhardness tester (model HWDM-3).
5. Microscope type NIKON 108.
7. CNC lathe machine (Boxford).
8. CNC milling machine (KM3000).
10. Roller burnishing tool as shown in Fig.2.
11. Surface roughness tester (kosaka surfcorder SE3500)
A special mould of brass alloy is manufactured in order to use in producing the needed specimens of different Zamac5-Cu alloys, as shown in Fig. 1.

**Experimental Procedure:**
- Cutting Zamac5 material to small pieces by saw.
- Get the weight for every sample by analytic balance.
- Get the weight for copper percentage according to the zamac 5 ratio.
- Raise the temperature of the furnace to 760 °C.
- Put the specimens in the crucible-graphite then put in furnace for 30 min until we get it in liquid state.
- Get the crucible out to add the require amount of copper.
- Mix both of it by glass rod to make it more homogeneous.
- Return the crucible to the furnace for 20 min.
- Mix both of it by glass rod to make it more homogeneous.
- Return the crucible to the furnace for 20 min.
- Get the specimen from the furnace then pour it in brass mould.
- After preparing the specimens grind it with rotary speed (350 rpm) and (0.08 mm/rev) feed rate.

Four alloys, in addition to commercially Zinc-aluminum, with different weight percentage of copper were prepared, i.e. 0, 2.5, 5, 7.5 and 10 wt. % Cu which shown in Table 2.

- By using the roller-burnishing tool shown in Fig.2 the outside cylindrical surfaces of the specimens were pressed by the bearing, which hold in roller burnishing tool. The variable burnishing force, feed is used to study the effect of such process on the specimens.
- Before applying roller burnishing process, calibration of the pressing force had been done accurately.

**Calibrations of the Pressing Force:** After performing calibration of the pressing force (N) the following measurements were recorded, Table 3 shows the load corresponding to the indicator reading, Fig. 3 shows a schematic diagram that how the calibration setup perform.

**RESULTS AND DISCUSSION**

In this section, the effect of copper addition and roller burnishing on the microstructure, microhardness, mechanical behavior and surface roughness on Zamac5 Zamac5-aluminum- alloys will be presented and discussed.

**Effect of Cu Addition on the Micro Hardness of Zamac5-Cu Cast Alloy:** It can be seen from Fig. 4 that there a direct relation between the micro hardness and the copper addition, that as the copper addition increased the microhardness increase. The maximum enhancement is 18 % at 10 % copper addition.

**Effect of Burnishing Parameters on Surface Roughness and Microhardness:** The effect of burnishing feed rate and force on micro hardness surface roughness was studied.

**Effect of Burnishing Feed Rate on the Microhardness and Surface Roughness:** It can be seen from Fig.5 that the microhardness was increased with increasing the burnishing feed rate up to specific point then it become to decrease, the best results was obtained at 0.06 mm/rev burnishing feed rate for all Zamac5-Cu alloys.

It can be seen from Fig. 6 that the surface roughness is increased with increasing the feed rate up to certain point (0.06 mm/rev) then it begins to decrease, it is also observed that higher reduction in surface roughness happened at very low burnishing feed rate. The best result was 0.05 micrometer that obtained at 0.04 mm/rev burnishing feed rate in Zamac5-10% Cu alloy.

**Effect of Burnishing Force on the Microhardness and Surface Roughness:** It can be seen that the micro hardness increase by increasing the burnishing force until certain value then it begins to decrease, the best results was 128 Hv which obtained at F = 159.5N in Zamac5-5% Cu alloy.

It can be also seen from Fig. 8 that the surfaces roughness decrease until force = 159.5N then it detoriated, the best enhancement is 0.04 micrometer at 159.5 N in Zamac5-2.5 % Cu alloy.

**Effect of Roller Burnishing Process on Microstructure:** It can be seen from Fig. 9 the effect of copper content after the burnishing process that we fixing the force and the feed rate, there is an inverse relation between the depth of hardening and the copper content however, this consistence with the results of microhardness that shown previously in Fig. 4, the maximum hardening depth equal to740 μm that made in Zamac5 pure, where the minimum hardening depth equal to 390 μm in Zamac5-10 % Cu alloy.

**Conclusions:** At 10 % Cu addition to Za-5 cast alloy we have the optimum addition on the micro hardness. Addition of Cu didn’t change the dendritic structure of pure Za-5 cast alloy.
Table 1: Chemical analysis of zamac 5 (Zn-% 5 Al) alloys, wt.

<table>
<thead>
<tr>
<th>Element</th>
<th>Al</th>
<th>Cu</th>
<th>Mg</th>
<th>Fe</th>
<th>Pb</th>
<th>Cd</th>
<th>Sn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>%, Wt</td>
<td>3.5-4.3</td>
<td>1</td>
<td>0.03-0.08</td>
<td>0.1</td>
<td>0.005</td>
<td>0.004</td>
<td>0.003</td>
<td>Bal</td>
</tr>
</tbody>
</table>

And the density for zamac 5 is (6.6) gm/cm³ and melting range is (380-386) °C.

Table 2: Different Zamac 5 – Cu% cast alloys

<table>
<thead>
<tr>
<th>Alloy</th>
<th>% Cu addition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zamac5 (pure)</td>
<td>0.0</td>
</tr>
<tr>
<td>Zamac5 (2.5 % Cu)</td>
<td>2.5</td>
</tr>
<tr>
<td>Zamac5 (5 % Cu)</td>
<td>5</td>
</tr>
<tr>
<td>Zamac5 (7.5 % Cu)</td>
<td>7.5</td>
</tr>
<tr>
<td>Zamac5 (10 % Cu)</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 3: Pressing force calibration

<table>
<thead>
<tr>
<th>Load (N)</th>
<th>Indicator reading X 0.01mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>40</td>
<td>3</td>
</tr>
<tr>
<td>92.5</td>
<td>8</td>
</tr>
<tr>
<td>159.5</td>
<td>14</td>
</tr>
<tr>
<td>212</td>
<td>19</td>
</tr>
<tr>
<td>279</td>
<td>25</td>
</tr>
</tbody>
</table>

![Fig. 1: Brass mould](image1)

![Fig. 2: Set up of the roller burnishing process](image2)

![Fig. 3: Calibration setup of the pressing force](image3)
Fig. 4: Effect of Cu addition on the micro hardness of Zamac5-Cu alloys

Fig. 5: Effect of burnishing feed on micro hardness (Force=159.5 N, V= 320 r.p.m )

Fig. 6: Effect of burnishing feed on Ra.(Force=159.5 N, V= 320 r.p.m )

Fig. 7: Effect of burnishing force on microhardness at ( feed rate = 0.04 mm/rev, V = 320 rpm)
Fig. 8: Effect of burnishing force on surface roughness (Ra) (Feed rate = 0.04 (mm/rev), V=320 r.p.m)

A (pure Zamac5) Feed Rate = 0.04(mm/rev) Depth of hardening = 740 µm

B (Zamac5 2.5 % Cu) Force = 212 N Feed Rate = 0.04 (mm/rev) Depth of hardening = 578 µm

C (Zamac5-5 % Cu) Force = 212 N Feed Rate = 0.04 (mm/rev) Depth of hardening = 659 µm

D (Zamac5-7.5 % Cu), Force = 212 N. Feed Rate = 0.04 (mm/rev). Depth of hardening = 610 µm
From the results of the microstructure, there is a direct relation between the depth of hardening (that is produced by burnishing process) and % Cu addition to Zn-5cast alloy, burnishing force, and burnishing feed. The maximum depth appeared in specimen A (0.0% Cu addition, F= 212N, Feed rate= 0.04 mm/rev) and it was (740 µm).

It was observed that higher reduction in surface roughness would happen at very low burnishing feeds (0.04 mm/rev).

It was also observed that the increase of burnishing force, the surface roughness decreased, the subsequent increase of burnishing force (more than 159.5 N) gets worst surfaces.

REFERENCES


