Blistering Problems of Strain Induced Melt Activated Aluminium Alloys

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Abstract— High temperature oxidation (HTO) of aluminium alloys has been a major problem feature of heat treatment processes. The theory suggests that degradation as a result of long time exposure to high temperatures in the presence of water vapour results in oxidation process which releases hydrogen that diffuses into metal to form hydrogen pores; thus leading to subsurface porosity or blisters. Although some of these defects could be removed during machining, higher population of these subsurface pores may lead to high number of scraps. Therefore, in this study, a thorough examination of the blister formation during heat treatment of aluminium alloys was investigated. The effect of metal quality and presence of bifilms on the size and morphology of blisters were examined.

Keywords—aluminium, heat treatment, blister, metal quality

I. INTRODUCTION

A series of heating and cooling operations are carried out with metals and alloys in order to enhance mechanical properties what is also known as ‘heat treatment’. When this term is applied to aluminium alloys it involves a precipitation hardening where hardness and strength is increased [1]. This process involves heating of the alloy to a single phase zone in the phase diagram and dissolving secondary phases followed by quenching to form a supersaturated matrix. At the final stage, homogeneous precipitation of phases throughout the matrix takes place at room or elevated temperatures.

During these operations, a commonly known defect formation takes place which is erroneously known as ‘high temperature oxidation’ (HTO). HTO leads to deterioration of properties. However, this misnamed condition of HTO is actually hydrogen diffusion into surface layers which is majorly affected from the furnace atmosphere [1]. And this is known as blistering. Blisters can easily be detected by visual inspection as well as ultrasonic and metallographic techniques.

In this study, a different approach has been taken in an attempt to re-evaluate blister formation in aluminium alloys.

The formation of hydrogen-assisted pores in aluminium has been attracting many researchers. Since a defect-free part is the ultimate goal. Many studies have been done on nucleation and growth of pores during casting process. Campbell [2] and Dışpinar [3] proposed that all porosity is initiated by folded oxide skins in aluminium castings. A detailed investigation was carried out by Dışpinar [3-8]. It was concluded that the opening of oxide bifilms involves negligible force, thus it can be assumed that this process will be an initiation source for porosity in aluminium casting where there was no nucleation barrier. Consequently, it was the growth stage.

Bifilms are the entrained defects which is the surface oxide that is introduced by several mechanisms such as turbulence. In such an action as shown in Fig 1, there is no bonding between the dry oxide surfaces. In addition, a little quantity of air is also entrapped. This is the most important characteristics of a bifilm since it is responsible for reduced properties and pore growth.

Figure 1: Surface turbulence; probably the most common mechanism of introducing bifilms into the melt [2]

In this work, wrought aluminium alloys were subjected to heat treatment and blister formation was investigated by means of the bifilm content.

II. EXPERIMENTAL WORK

Commercially available extruded 2024 and 7075 aluminium alloys were used to investigate the blister formation during a series of heat treatment processes. The composition of the alloys is given in Table 1.

Samples were placed into the furnace and subjected to heat treatment at elevated temperatures. The temperatures were selected to be 525°C, 550°C, 575°C, 600°C, 610°C and 620°C. The reason for the selection of these temperatures was mainly due to the fact that these are the temperatures ranges for Strain Induced Melt Activated (SIMA) process. Therefore, the samples were held at these temperatures up to 30 minutes. At
every fifth minute, a sample was taken out and quenched in water.

Table 1: Composition of the alloys used (%)

<table>
<thead>
<tr>
<th></th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024</td>
<td>0.5</td>
<td>0.5</td>
<td>5.0</td>
<td>0.9</td>
<td>1.8</td>
<td>0.1</td>
<td>0.2</td>
<td>rem</td>
</tr>
<tr>
<td>7075</td>
<td>0.4</td>
<td>0.5</td>
<td>2.0</td>
<td>0.3</td>
<td>2.9</td>
<td>0.3</td>
<td>6.1</td>
<td>rem</td>
</tr>
</tbody>
</table>

The samples were first visually inspected for blister formation and later subjected to metallographic and SEM analysis.

III. RESULTS

The surface images of heat treated 2024 samples are given in Figures 2 to 4. As seen in the figures, at 550°C, there is only the discoloration of the surfaces. However, the blisters start to appear around 20 minutes of holding at 550°C (Fig 3). At 600°C (Fig 4) the most significant blister formation is observed.

Figure 5: Sample photographs of 7075 heat treated at 550°C a) for 25 min. and b) for 30 min. holding time,

Figure 6: Sample photographs of 7075 heat treated at 575°C a) for 35 min. and b) for 40 min. holding time,

Figure 7: Sample photographs of 7075 heat treated at 600°C a) for 35 min. and b) for 40 min. holding time,

Microstructures that show the spherical grains of the heat treated 2024 are given in Figures 8 to 10. As seen in the figures, spherical grain formation is completed at 575°C at 20 minutes of holding time. At 600°C, there appears to be more secondary phases at the grain boundaries which were melted during the heat treatment at semisolid region.

Figure 8: Spherical grains of 2024 (treated at 575°C for 25 minutes)
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Figure 9: Spherical grains of 2024 (treated at 600°C for 20 minutes)

Figure 10 shows the SEM image of the spherical grains of 2024. Note the secondary phases (Cu-rich) at the grain boundary with different contrast.

Figure 10: SEM image of 2024 sample that has the spherical grains

Figures 11 and 12 show the spherical grains of 7075 obtained at 575°C and 600°C.

Figure 11: Spherical grains of 7075 (treated at 575°C for 30 minutes)

Figure 12: Spherical grains of 7075 (treated at 600°C for 20 minutes)

Figure 13 and 14 are the SEM images taken from inside the blisters that are formed during the heat treatment of 2024 and 7075.

Figure 13: SEM image inside a blister of 2024 sample that was heat treated at 600°C for 45 minutes

Figure 14: SEM image inside a blister of 7075 sample that was heat treated at 600°C for 45 minutes.
The experimental work showed that for alloy 2024, blisters began to appear at 550°C and for 20 minutes of holding times (Figs 2-4). These values are similar for 7075 (Figs 5-7). It is important to note that the furnace atmosphere was not controlled with inert gas.

The actual example of the schematic drawing in Fig 15 can be clearly seen in Figures 13 and 14. The wrinkled oxide skin on the surface of the dendrites is the clear demonstration of the bifilms.

V. CONCLUSION

During the SIMA process of 2024 and 7075, blisters start to form within an average of 15 minutes of holding time at temperatures above 550°C in an uncontrolled furnace.

SEM investigations revealed the existence of bilfim which initiated the formation of bifilms.

The presence of bifilms in aluminium alloys can require negligible force to open to form any defects that deteriorate the properties.

ACKNOWLEDGMENT

This work was supported by Pamukkale University Scientific Research Projects Fund (PAUBAP) with No. 2008FBE004. Authors would like to acknowledge the help and support of Taner Aktan from Suleyman Demirel University (Isparta/Turkey) for the SEM studies.

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