Investigation on Hot Tearing Susceptibility of A201 Aluminum Alloy in Different Ingate Velocities and Molds

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Abstract

In this research, Hot tearing Behavior and susceptibility of the Al-Cu A201 aluminum alloy in different mold has been investigated. There are a lot of methods that used for hot tear tests but between all of these methods that proposed for this kind of the tests, The Ring model was employed for testing the hot tearing tendency. In order to increase the investigated parameters, wooden model designated to support different ingate velocities. Some samples that exposed to the Hot Tear were inspected by visual and NDT (None destructive) tests followed by Scanning Electron Microscopy (SEM) to study of the teared surface of the samples. The extracted results show that the number and severity of tears increased by changing the strength of mold from green sand to CO2 sand. The evaluation of the experimental results in this study showed that these results is in good agreement with the other obtained by another researchers.

Keywords: Aluminum-Copper Alloys, Hot Tearing, Mold Strength, Critical Velocity.

1. Introduction

It has been widely recognized that hot tearing, also referred to as hot cracking, is a major defect in alloy castings [1,2]. Hot tearing occurs due to obstructed contraction of the solidifying alloy, often at a location of stress concentration associated with a sudden change in the transverse cross section [2].Hot tearing refers to the tears that can occur within the mushy zone of some solidifying alloys and castings at high solid fractions [3].It is specially a serious defect in alloys with large mushy zones [4]. Number of studies carried out on the hot tearing susceptibility of Al–Cu alloys have demonstrated the influence of such variables as Cu concentration, superheat, and the volume fraction of eutectic and ingate velocity of melt. It has been shown that all variables play a significant role in the formation and development of hot tears.
D'Elia and et al [5,6]. Investigated the hot tearing mechanisms of B206 aluminum–copper alloy.
They found that higher mold temperatures were successful at reducing the severity of hot tears in unrefined B206 alloy, but it did not eliminate them. Higher mold temperatures could enhanced the time available for liquid metal feeding, and therefore helped to limit the severity of hot tearing. According to previous studies,[7] one of the important factors contributing to the tendency of alloys to hot tearing is the number of grain boundary films on which the contraction strain occurred in last stages of solidification [8,9]. In this case, if a crack nucleate on these films, a casting could be teared completely. A201 alloy is a heat treatable optimum engineered aluminum alloy commonly used in applications where superior mechanical properties as well as lightweight are required. A201 is a light alloy used in aircraft frames, cylinder heads, and pistons applications [10].
A number of experimental methods have been devised over the years for determining the hot tearing susceptibility but in this research, a previously developed [11] Ring mold which is designated to evaluate the hot tear susceptibility was used to determine the effect of the mold strength and ingate velocity of melt on hot tearing of A201 aluminum alloy.

2. Materials and Methods

In order to evaluate the hot tearing tendency of A201 aluminum alloy in green and CO_2 sand, Ring model test was used (Fig. 1.). As shown in Fig.1., the designation of the mold support different ingate velocities in order to investigate the effect of critical velocity along with other parameter.
A round mold with diameter of 108 mm was poured, while four chills are located in the center of mold. The diameter of the round steels was 90 mm.
Electrical furnace was used to perform the casting process, and pouring temperature was about 750 °C.

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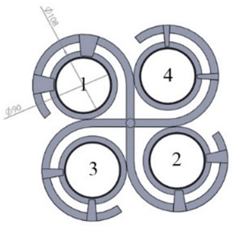
The chemical analysis was conducted using optical emission spectrophotometry. The chemical composition of A201 alloy are given in Table. 1.



Ring No.	Theoritical ingate velocity
1	0.5
2	0.75
3	1
4	1.5

Fig. 1. Ring mold designation for hot tearing susceptibility evaluation.

Table. 1. Chemical composition of used A201 alloy (wt.%).

Cu	Si	Mg	Fe	Mn	Ti
4.500	0.100	0.250	0.150	0.350	0.220

Tear surface were examined through Visual examination and NDT test according to SNT-TC-1A standard, and also using a SEM equipped with an energy dispersive X-ray spectrometer. The acceleration voltage was 25 kv, the filament current 23-30 µA, and the working distance were around 20-25 mm.

3. Results and Discussion

Visual observation test results of castings were demonstrated in Table. 2. In Table. 2., the length, width, and severity of formed cracks are shown. According to these results, most of the specimens teared. The data extracted form samples implicated that A201 aluminum alloy has a high tendency to hot tear. As indicated in Table. 2., only two rings showed tendency to hot tear in case of green sand mold (ring No. 3 and 4). After conducted the NDT test, no tears were found in ring no. 1 in both cases and ring no.2 in case of green sand. Therefore, tendency to hot tears increased with strength of mold (from green to CO_2 sand).The use of steel chills in case of CO_2 sand mold resulted in more severity of tears formed in castings.In Fig. 2. digital photographs of A201 specimens are shown.

Table. 2. Length and width of hot tears formed in castings.

Mold type	Ring No.	length of hot tear (mm)	Width of hot tear (mm)
A201 Green sand	3	15	1
	4	16	0.5
A201 CO_2 sand	2	18	Broken
	3	18	Broken
	4	18	Broken

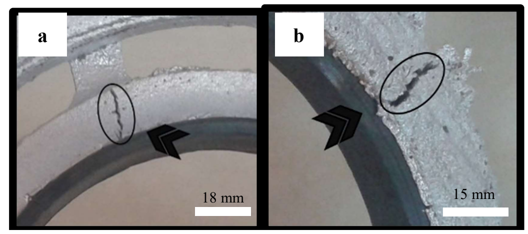


Fig. 2. Formation of hot tears in a) ring No. 2 of CO_2 sand mold, b) ring No. 3 of green sand mold.

Visual examination showed that when casting process performed in CO_2 mold, tears found in three rings. These tears led to complete rupture of rings. Also, two tears formed in ring No. 4 of CO_2 sand mold.

Correlate with the designation of the gates, the ingate velocities of melt in rings No. 1 and 2 were lower than the other rings. According to studies conducted earlier concerning the role of critical ingate velocity on the hot tearing susceptibility, it seems that ingate velocity of the melt into the mold is as important a factor as strength of the mold.

It can be seen in specimens with higher ingate speeds. Importance of working with turbulence-free filling systems for castings was always a special factor. This because the majority of all defects are directly related to turbulence. Studies demonstrated that when liquid metal enters into mold at higher speeds of 0.5 m/s, there is a danger that the surface of the liquid metal maybe folded over by surface turbulence and that could leads to bi-films which are the possible nucleation sites for hot tears. As it is presented in Table. 2., with increasing in ingate velocities (ring 1 to 4), the length and width of tears observed in samples were increased. It should be mention that in designated rings with ingate velocity close to 0.5 m/s, there is no conclusive evidence of cracks.

Figs. 3. shows scanning electron micrograph of the A201 casting. The dendritic structures of specimens are clearly visible. Because of the occurrence of tears in the last stages of solidification, the tears could not be filled with the melt. Based on EDS results, the existance of Al_2Cu intermetallic phase was proved (Fig. 4.). The tear surface of castings were shown in Fig. 3. Coarse dendritic morphology with Al_2Cu eutectic dispersed along these regions can be noticed. Base on previous studies, the nucleation of Al_2Cu did not commence until nearly 100 percent solid α-Al was formed. Therefore, a continuous network of solid Al dendrites was developed in the alloy. As a result, Al2Cu phase was limited to interdendritic regions [7].

Since the hot tears were seen to initiate prior to the formation of Al_2Cu, the presence of the eutectic on the hot tears surfaces suggests that eutectic-rich liquidattempted to fill and heal the developing tears. Since the eutectic liquid was not successful at completely healing the hot tears it can be concluded that if the available time for feeding of the eutectic liquid was long enough, the number and severity of hot tears would be lowered.

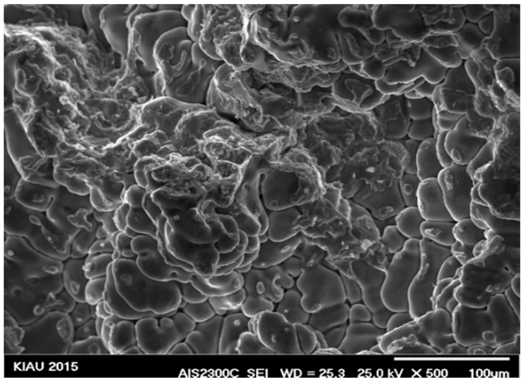


Fig. 3. SEM image of A201 teared surface casted in CO_2 sand mold.

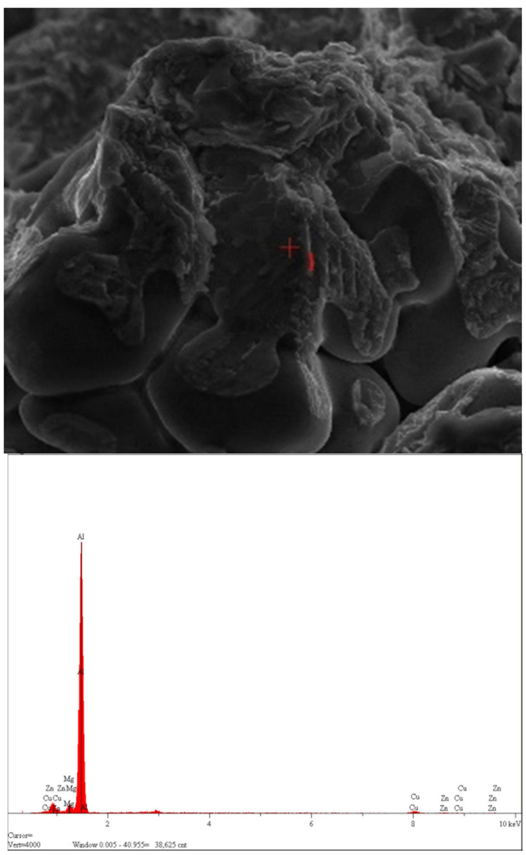


Fig. 4. EDAX analysis of A201 alloy sample.

4. Conclusions

1. by increasing the strength of the mold from green to CO_2 sand, hot tearing tendency of the castings enhanced. As it obtained in this study, the length and width of formed tears increased in CO_2 sand.
2. No cracks were formed in castings with standard ingate velocity of 0.5 m/s in both cases. As it is achieved by other researchers, ingate speed of 0.5 m/s is the most optimum speed for Al alloys.
3. The running system and consequently ingate velocity of melt could be a critical parameter in alloys susceptible to hot tearing.

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