Influence of Impurities and Gassing on the Tensile Properties of 2xx Sand Cast Al - Cu Alloys

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Abstract

Alloys A2xx (AlCu4) are the strongest aluminum casting alloys with tensile properties approaching those of ferritic ductile iron. These alloys are normally degassed before pouring but regassing of the melt might take place during handling. Also, returns used in the charge will cause an increase in impurity content (Fe, Si) and a consequent downgrading of alloy A206 to the 204 grade. In order to assess the effect of gassing on the tensile properties, well fed step castings, 6 mm, 13 mm and 25 mm in thickness were poured with degassed high purity A206 alloy and degassed and gassed alloy 204; the tensile properties for the three conditions were measured in the T4 and T7 tempers. The subsequent metallurgical study included metallographic analyses, grain size and microporosity measurements. The detrimental effect of tramp elements and gassing could be quantified by comparing the tensile properties of the alloys investigated. The drop in tensile strength observed was found to be more pronounced in the T7 tempers than in the T4 condition.

Keywords: Aluminium-copper alloys; sand casting; heat treatment; tensile properties.

1. Introduction

Since the take-off of the aluminum castings usage in the ‘70ies, the bulk of structural castings have been produced in Al-Si-Mg alloys (A356, 357) whether poured in sand or permanent mold. On the other hand, in spite of their “textbook” outstanding mechanical properties, aluminium-copper alloys of the 2xx series are still seldom used; the reason invoked is their susceptibility to hot tearing [1], the segregation of copper [2], and their sensitivity to stress corrosion cracking [3] as related to grain refining [4, 5]. However, the following question arises: Is the prevalence of Al-Si-Mg alloys due to a tradition established over the years rather than to a rational balance between the expected difficulties in pouring Al-Cu alloys and the far superior mechanical properties they provide? The foundry practices pertaining to these alloys have been outlined in an AFS webinar [6]; it attests to the fact that, in sand casting, exceptionally strong, sound Al-Cu castings can be routinely obtained through current “good foundry practices”, by implementing process control tools readily available. For structural castings where weight gains are important, aluminium A206 can even substitute ductile iron as is the case for the casting shown in Figure 1. In the T4 condition, important internal stresses generated in the quenching will make machining problematic as distortion is bound to occur at each machining pass. This can be alleviated by practicing a stress relief treatment (T43 per ASTM B917) consisting in heating the T4 casting for one hour at 160 °C. Caution should be exercised in not overdoing it so as to avoid making the casting vulnerable to stress corrosion [3].

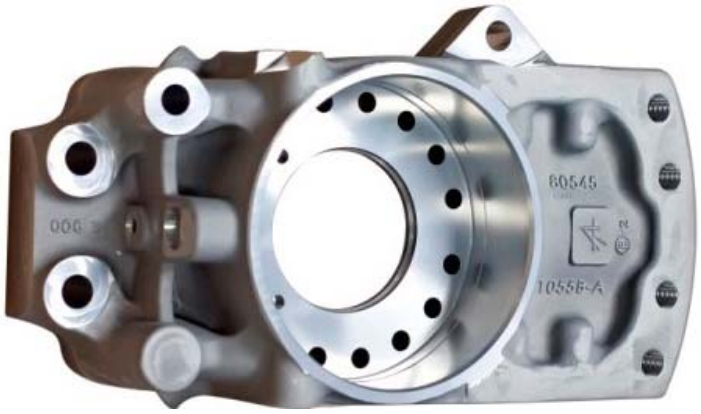

Figure 1. Aluminum A206 -T4 knuckle substituting ferritic ductile iron.
(*Courtesy of Eck Industries)*

In alloy A206, the chemical requirement on Fe and Si is very stringent: 0.10 % Fe and 0.05 % Si maximum. Alloy A206 is always used in a heat treated condition, the T4 (solutionized, quenched and naturally aged) being preferred when ductility and endurance are sought, rather than strength. The T7 condition is obtained by aging the T4 casting for 5 h at 190 °C, resulting in an increased tensile strength to the detriment of elongation. Typically, aging a T4 treated A206 casting to a T7 temper increases its yield strength by 40 % while dividing its elongation by 2 to 3 [8]. This T7 treatment provides tensile properties which exceed those of grey iron, comparing to those of ferritic ductile iron.

Peak aging (T6) is not practical as it lead to a condition prone to stress corrosion cracking [3].
In the course of casting runs, as the charge contains typically 50 % of returns, the melt content in Fe and Si tends to rise and stabilize to values above the very stringent specifications of A206; The alloy can thus be downgraded to 206 and 204. The effect of these elements on tensile properties has been previously studied under laboratory conditions, first on a wedge casting with extremely long solidification time [7], and in permanent mold, on ASTM B108 tensile test bars where the solidification time is of the order of 30 s [9,10]. The present work will involve conditions much closer to foundry practices: sand casting with solidification times ranging between 0.67 to 4.8 minutes.

2. Experimental Procedure

High Si and Fe content Al-Cu aluminium 204 alloy melts (gassed and degassed) were direct-poured at 740 °C into step molds cavity via a Kalpur filter cup, as illustrated in Figure 2. A 10 p.p.i. filter at the bottom of the cup prevented the excessive turbulence which a top poured casting would entail. Figure 3 shows the casting after shake-out on the left; on the right, a section of the step casting and attached direct-pour cup is sketched with the successive plate thickness of 25mm, 13mm, 6mm and a 2mm flow-off. The composition is given in Table 1.

Table 1. Chemical composition of the Al-Cu aluminum 204 melts (gassed and degassed).

	%Si	%Fe	%Cu	%Mn	%Mg	%Zn	%Ti
Weight %	0.23	0.12	4.23	0.33	0.14	0.06	0.25

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7. References

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