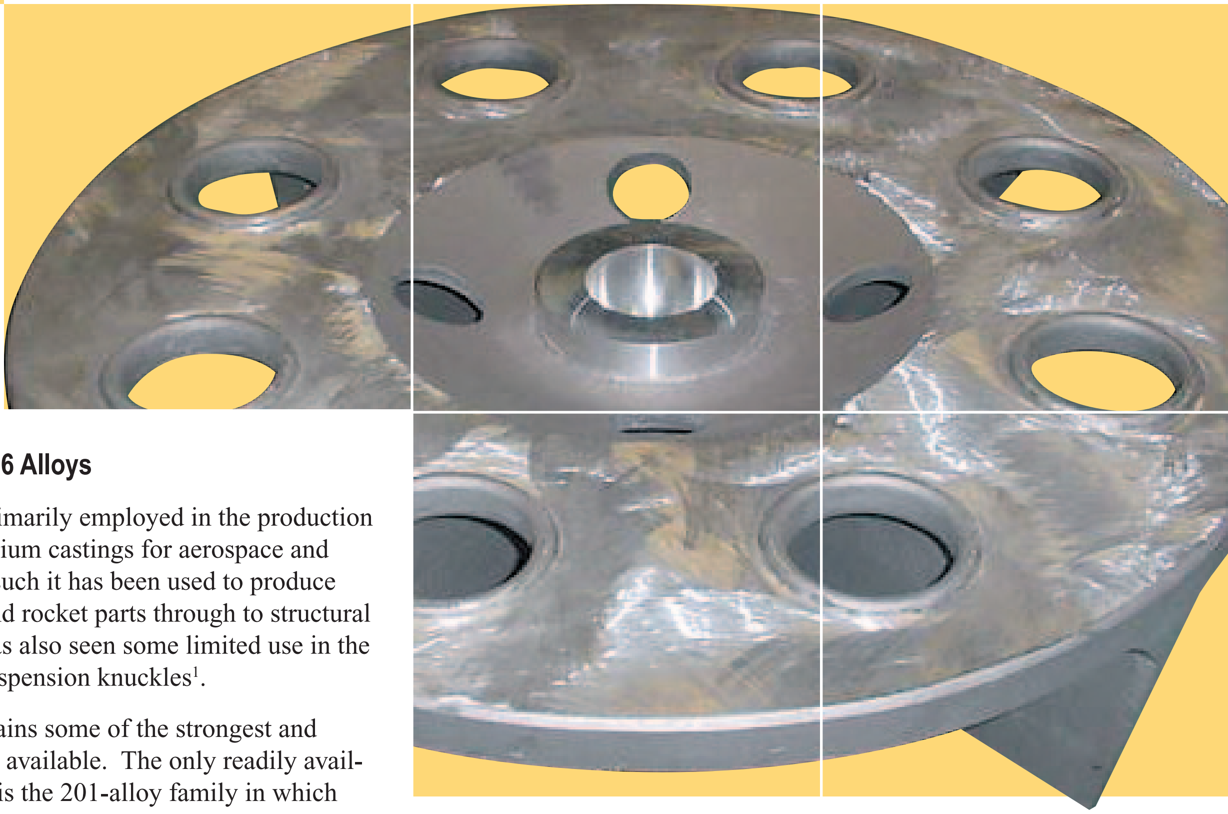
Alcan AA206 Primary Foundry Alloys

206.2, A206.2 and B206.2



General Background - 206 Alloys

The 206-alloy family is primarily employed in the production of very high strength premium castings for aerospace and military applications. As such it has been used to produce everything from missile and rocket parts through to structural castings for airliners. It has also seen some limited use in the automotive industry for suspension knuckles[1].

The 206-alloy family contains some of the strongest and toughest Al foundry alloys available. The only readily available alloy that beats these is the 201-alloy family in which silver is added as an additional precipitation-hardening element to the base 206 compositions. Heat treatable, the 206-alloy family can be T4 tempered to give medium high strength with high fracture toughness and very high ductility. For applications where more strength is required, the alloy can be T7 heat-treated to give very high strength at some sacrifice of ductility. The T6 temper can be employed for even higher properties but the alloy becomes prone to stress corrosion cracking and this temper is not recommended for general use for that reason.

The 206-alloy family consists of three members that vary in impurity limits and grain refinement strategy.

The main precipitation hardening reactions involve Al, Cu, and Mg. 206 is the commercial primary casting alloy and is serviceable for many applications. A206 is the very high purity variant used in aerospace and critical military applications where the highest possible mechanical performance is desired. Both of these alloys are covered by specifications that were developed many years ago and both alloys include a Ti specification of 0.15% to 0.30% in the final cast part. The basis for this was work such as that shown in Figure 1 in which elemental Ti was used as the grain-refining agent.

As modern Ti-B based grain refiners were developed, the tendency was to simply add them on top of the existing elemental Ti content. This did improve the grain refinement quite a bit but no effort to determine whether the actions of these two parts of the overall grain refinement strategy were actually cumulative or not has been made until quite recently.

Composition

The 206 alloy variants currently registered with the Aluminum Association are shown in Table 1. These consist of the original alloy, 206, together with the higher purity A206 variant and the new B206 variant that takes advantage of recent R&D efforts to improve the grain refinement and reduce the tendency towards hot tearing of the alloy family[2 3].

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Alloy	Si	Fe	Cu	Mn	Mg	Ti	Zn	Others Each	Others Total
206.0	0.10	0.15	4.2-5.0	0.20-0.50	0.15-0.35	0.15-0.30	0.10	0.05	0.15
206.2	0.10	0.10	4.2-5.0	0.20-0.50	0.20-0.35	0.15-0.25	0.05	0.05	0.15
A206.0	0.05	0.10	4.2-5.0	0.20-0.50	0.15-0.35	0.15-0.30	0.10	0.05	0.15
A206.2	0.05	0.07	4.2-5.0	0.20-0.50	0.20-0.35	0.15-0.25	0.05	0.05	0.15
B206.0	0.05	0.10	4.2-5.0	0.20-0.50	0.15-0.35	0.10	0.10	0.05	0.15
B206.2	0.05	0.07	4.2-5.0	0.20-0.50	0.20-0.35	0.05	0.05	0.05	0.15

Table 1 - Registered AA206 alloy compositions

The main differences amongst these include the purity, i.e. the Fe level, as well as the Ti limits, which vary according to the grain refinement strategy employed.

The B206 variant of the alloy is based on recent work by GKS Engineering and a USCAR[5] funded project that has shown that modern Ti-B grain refiners appear to actually be more effective at lower overall Ti contents. In fact, with the same Ti-B grain refiner addition, the grain size of an experimental alloy with an overall Ti level of less than 0.05% was roughly half that of the conventional A206 alloy at the much higher Ti level.

Mechanical Properties of 206 Alloys

The list of known mechanical properties for 206 and A206 are fairly extensive and have been tabulated elsewhere[6]. AMS specifications also exist covering 206 and A206[7]. B206 is more recent but, as it's chemistry is in all respects other than the Ti level identical to A206, its properties can be expected to be virtually identical to that of A206.

The mechanical properties of 206 alloy variants are a function of several factors, as per most foundry alloys. These included metal cleanliness, hydrogen level, chemistry, heat treatment, and the local solidification time as evidenced by the secondary dendrite arm spacing. As a result, customer or AMS specifications on the alloy may need to be interpreted differently for different castings or casting processes. The chemistry and temper that meets these in one process may be wholly inappropriate for another. Figures 2 and 3 show examples of the post-heat treat properties attainable for low Ti 206.0-T4 variants cast in the form of separately cast PM tensile bars[8]. These plots were generated from a statistically designed experiment in which the major alloy elements, as well as the main impurities of Fe and Si, were varied between minimum and maximum values. Figure 2 demonstrates particularly well the impact of chemistry on the yield strength. Figures 3a and 3b are similar plots for

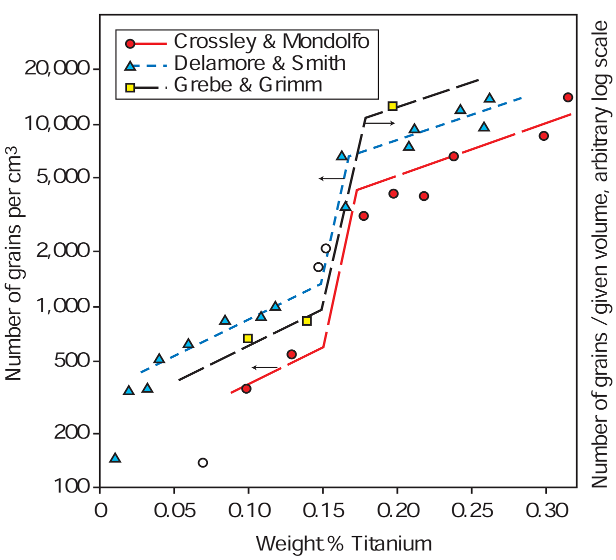

Figure 1. A sharp transition can be seen at approximately 0.15% Ti. Above this level the number of grains per unit area rises quite sharply; i.e. the grain size drops. As a fine grain size is important to combat the tendency towards hot-tearing characteristic of this alloy system. One can easily see the origin of the minimum Ti content that appears in many of the 200 and 700 series alloy specifications[4].

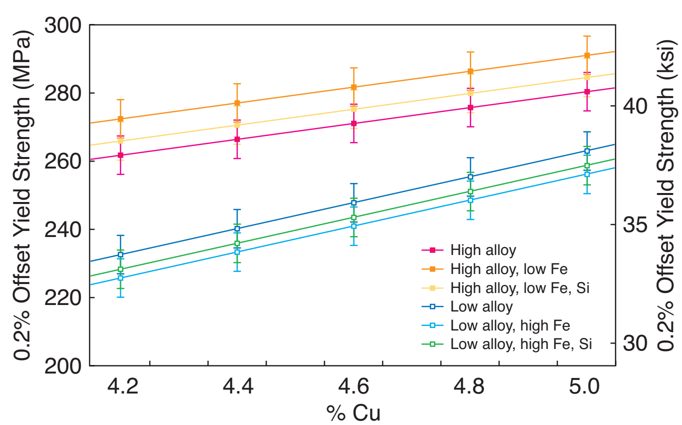

Figure 2. The difference in yield as a function of chemistry in a 206.0-T4. The yield strength increases with Cu content. The "High Alloy" curve runs at the top end of the experimental range for all elements. The impurity levels are tightened to the low end of the 206 range sequentially in the next two curves. Similarly, the "Low Alloy" has all elements set to the low end of the experimental range. The two curves below it show the effect of increasing the impurities. The error bars are 95% confidence intervals calculated for the predicted curves.

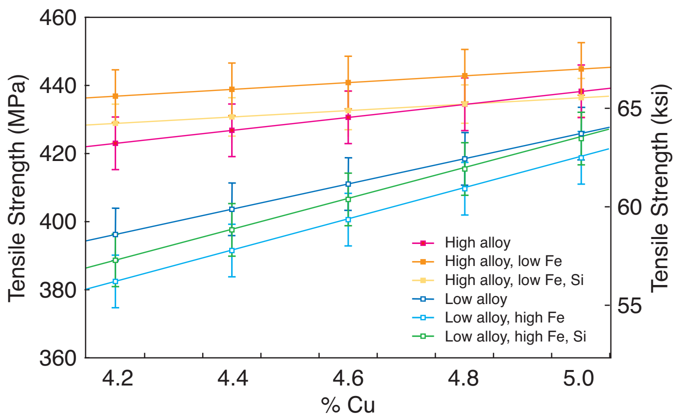

Figure 3a. Tensile strength of 206-T4.

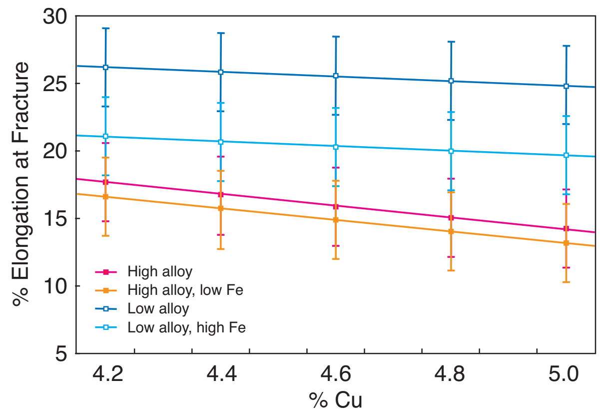

Figure 3b. % elongation of 206-T4.

the tensile strength and the %elongation. In all cases the major alloy elements can be adjusted to impact the tradeoff between strength and ductility. Fe can be seen to be detrimental to the properties while, in this temper, the Si content had little impact over the range covered by the 206 specification.

Figures 4, 5, and 6 are similar plots for the T7 temper. In the T7 temper high ductilities are harder to achieve as the tradeoff between strength and ductility skews in favor of strength. Compositionally, the more dilute alloys should be chosen when trying to maximize ductility in the T7 temper.

Heat Treatment of 206 Alloys

Heat treatment of 206 alloys requires more thought than some of the conventional foundry alloys in so far as the solutionizing operation must be carried out in stages so as to avoid incipient melting of some of the phases which form during solidification. For lighter and/or more rapidly solidified castings a two stage solution heat treatment may well suffice: Hold at 480-515°C (900-960°F) for 2 hours and then at 525-530°C (980-990°F) for as long as required.

For thicker and/or very slowly cooled parts a three stage operation may be required.

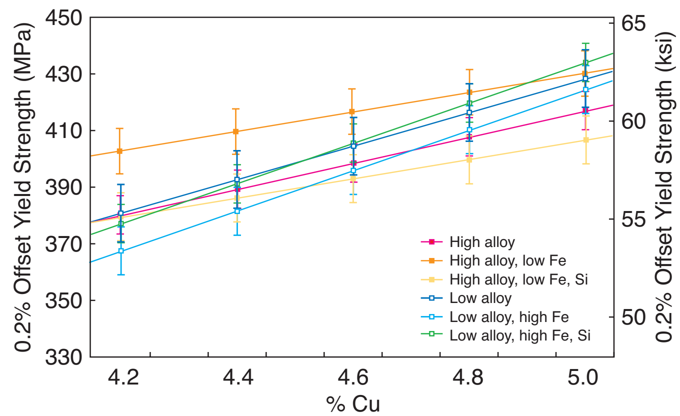

Figure 4. The above is a plot showing the yield strength of 206-T7 as a function of composition. As was the case for the previous curves, the curve labeled "High Alloy" runs at the top end of the experimental range for all elements. The impurity levels are tightened to the low end of the range sequentially in the next two curves. Similarly, the "Low Alloy" has all elements set to the low end of the experimental range. The two curves below it show the effect of increasing the impurities.

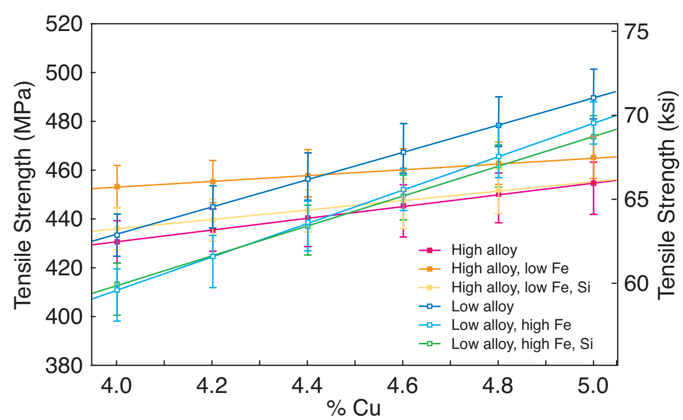

Figure 5. Tensile strength of 206-T7.

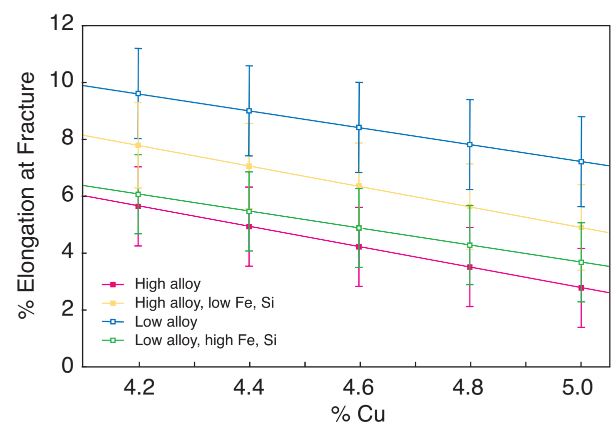

Figure 6. % elongation of 206-T7.

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To achieve the following tempers age as follows:

T4: Quench into 65 to 100°C (150 to 212°F) and then naturally age for at least 5 days.

T6: Starting from the freshly quenched T4 temper, naturally age at room temperature for 12-24 hours and then artificially age at 150-155°C (305-315°F) for 20 hours and cool back to room temperature (method not critical).

T7: Starting from the freshly quenched T4 temper, naturally age at room temperature for 12-24 hours and then artificially age at 185-190°C (365-375°F) for 5 hours and cool back to room temperature (method not critical).

Note that the T6 temper is stress corrosion crack prone and should not be used under any conditions in which this condition might arise. The T4 and T7 tempers, on the other hand, do meet all requirements for stress corrosion cracking resistance.

In addition to the chemistry, the mechanical properties of 206 Aluminum alloys are also significantly impacted by the solidification rate. Figure 8 demonstrates this effect by plotting two different compositions of 206, a ductile alloy and a strong alloy, against the cell size. Note that cell size is generally easier to measure than secondary dendrite arm spacing for alloys like those of the 206 family since very little interdendritic eutectic remains after heat treatment.

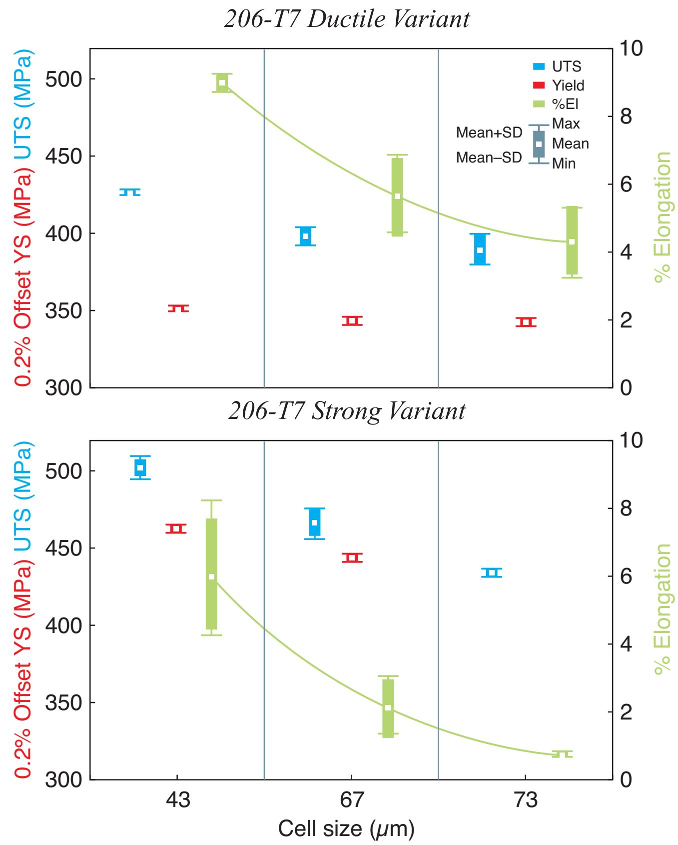

Figure 8. These two graphs demonstrate the variability in mechanical properties that may be expected with solidification rate in the 206 alloy family. The two alloys differ in chemistry so as to give different balances between strength and ductility as already shown in Figures 1 to 6. In addition, each is plotted against the cell size. Both effects impact the mechanical properties quite significantly.

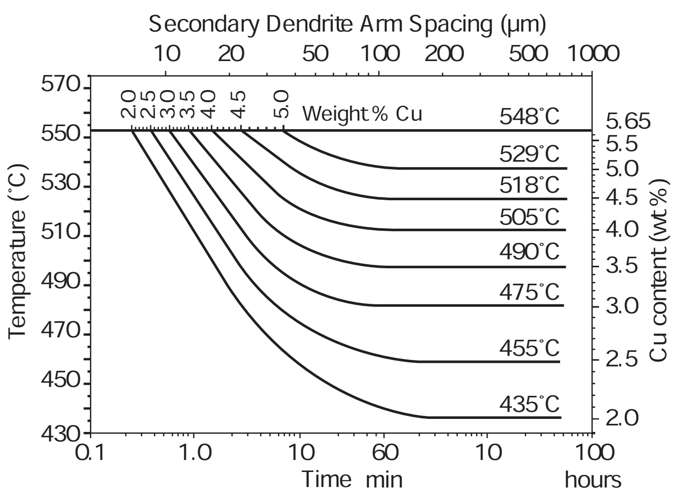

Figure 7. A nomogram for solutionizing of Al-Cu alloys[9]. Depending on the level of Cu and the initial coarseness of the microstructure, solutionizing of 206 alloys may take as little as a few hours to as long as 30 hours. Therefore the choice of alloy composition will influence the economics of the operation.

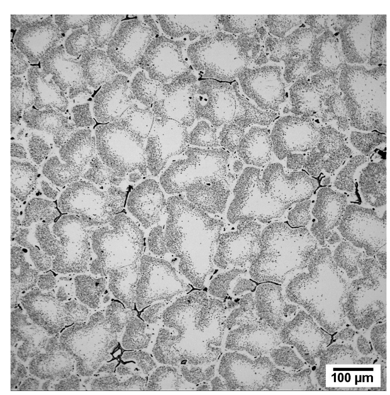

Figure 9. 206 Sample etched for cell size analysis. Cell size is 73 µm.

[1]Gangalore Keshavaram, David Seiler, & Dave DeWitt, "Aluminum Alloys for Automotive Knuckle Castings", SAE Technical Paper No. SP-1504.
[2]Sigworth, G., "Method for grain refinement of high strength aluminum casting alloys" United States Patent No. 6,368,427.
[3]Geoffrey K. Sigworth, Frank DeHart, & Scott Milhollen, "Use of high strength aluminum casting alloys in automotive applications", in Light Metals 2001 *Métaux Léger,* M. Sahoo & T. Lewis, ed., pp. 313-322.
[4]After Cole, et.al., 1972
[5]United States Council for Automotive Research
[6]Society of Manufacturing Engineers, "Properties of Cast Aluminum, A206.0 Premium Grade, 206.0 Commercial Grade 4.5Cu-0.30Mn-0.25Mg-0.22Ti", Sept. 1981.
[7]AMS Specifications 4235, 4236, and 4237.
[8]ASTM B108 style bars (Stahl Mould).
[9]After E.G. Fuchs and A Roósz: "TTD-Diagrams for the Homogenization of As-Cast Structures," *Z. Metallkunde*, Vol. 63, pp. 211-214 (1972).

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