COMPARING MECHANICAL PROPERTIES OF A356 TO 206

206 is a seldom-used aluminum alloy that offers significant jumps in mechanical properties, indicating it may be worth the effort for metalcasters to adjust foundry practices and process control to routinely cast them.

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The bulk of structural aluminum castings are produced in Al-Si-Mg alloys such as A356 or 357, poured in either sand or permanent molds. Despite their outstanding mechanical properties, aluminum-copper alloys such as 206 are seldom used because of their susceptibility to hot tearing and sensitivity to stress corrosion cracking. However, with good foundry practices and the use of available present process control tools, exceptionally strong, sound aluminum-copper alloys can be cast routinely.

In structural castings where weight gains are important, aluminum 206 can substitute for ductile iron (Fig. 1). Alloy 206 is always used in a heat-treated condition. The T4 condition is preferred when ductility and endurance are sought instead of yield strength. Using a T7 temper increases yield strength

Table 1. Composition of the A356 and 206 Alloys Melts Poured in the Present Study

Weight %	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Sr
A356	7.14	0.12	0.03	0.02	0.34	0.04	0.01	0.10	<0.01
206	0.16	0.12	4.42	0.26	0.20	0.04	<0.01	0.16	<0.01

Table 2a. Alloy Composition at 6 Locations inside the A356 Casting

	%Si	%Fe	%Cu	%Mn	%Mg	%Zn	%Ti	%Sr
Melt	7.14	0.12	0.03	0.02	0.34	0.04	0.10	<0.01
Location A	7.50	0.13	0.02	0.02	0.35	0.02	0.10	<0.01
Location B	7.43	0.12	0.02	0.02	0.34	0.02	0.10	<0.01
Location C	7.43	0.13	0.02	0.02	0.32	0.02	0.10	<0.01
Location D	7.38	0.13	0.02	0.02	0.34	0.02	0.10	<0.01
Location E	7.25	0.12	0.02	0.02	0.32	0.02	0.10	<0.01
Location F	7.24	0.13	0.02	0.02	0.35	0.02	0.10	<0.01

Table 2b. Alloy Composition at 6 Locations inside the 206 Casting

	%Si	%Fe	%Cu	%Mn	%Mg	%Zn	%Ti
Melt	0.16	0.12	4.42	0.26	0.20	0.04	0.16
Location A	0.18	0.13	4.78	0.26	0.20	0.04	0.16
Location B	0.16	0.11	4.11	0.25	0.18	0.04	0.16
Location C	0.17	0.11	4.39	0.27	0.19	0.04	0.16
Location D	0.17	0.12	4.63	0.25	0.20	0.04	0.16
Location E	0.16	0.11	4.26	0.25	0.18	0.04	0.16
Location F	0.15	0.11	4.02	0.25	0.18	0.04	0.14

by 40% while dividing elongation by about 3. The T7 treatment provides tensile properties which far exceed those of gray iron, approaching those of ferritic ductile iron.

In a recent study, the mechanical properties of 206 and A356 alloys were compared, with the effect of solidification conditions on local tensile properties assessed for both. An industrial casting weighting 31 lbs. (14 kg) and measuring 23 x 17 x 10 in. (560 x 410 x 250 mm) was studied.

A complete metallurgical study of the casting poured in the two alloys included metallographic analyses and measurement of tensile properties at six locations. The level of microvoids in both castings were compared, along with the grain size in the 206 casting and the secondary dendrite arm spacing in alloy A356.

The six locations investigated were named A, B, C, D, E, and F in sequential order of solidification. The local solidification times in the A356 casting—as determined by solidification modeling—were 3.1, 3.6, 4.5, 6.4, 8.2, and 13.8 minutes. Despite the difference in thermal properties, the alloy 206 casting had similar solidification times. Tensile specimens were cut from each of the locations for testing.

Metallurgical Quality

In the study, alloy A356 was grain refined by adding boron via an Al5Ti1B master alloy. The 206 melt was not grain refined. Both melts were degassed for 15 minutes with argon and poured with identical riggings at 720C for A356 and 740C for 206. The time needed to fill the mold cavity and the risers was 25 seconds.

Photo courtesy Eck Industries.

Fig. 1. This 33 lb. aluminum 206-T4 housing substitutes for ferritic ductile iron.

Table 1 shows the compositions of the alloys measured at the beginning of the pour. In such a relatively big casting, segregation might be an issue so a spectrographic analysis was performed at locations A through F in both castings (Table 2a and 2b).

Figures 2 and 3 show mosaics of the 0.35-in. diameter tensile specimens at locations C, D, E, and F. The measured percent surface area of microvoids at the six locations investigated, along with the predicted values based on solidification time and solidus velocity are in Table 3. The microvoid surface area is greater in aluminum 206, probably because of its wider solidification interval. It varies from 0.84-1.77% compared to 0.55-1.26% in A356.

On the other hand, the microvoids are longer in the A356 casting with a higher aspect ration because of the larger grain size in aluminum A356. For similar solidification conditions, the grain size is greater in A356 and somewhat independent of the solidification time while increasing from 128-248 micrometers from location A to Location F in the 206 casting.

Depending on the location in the

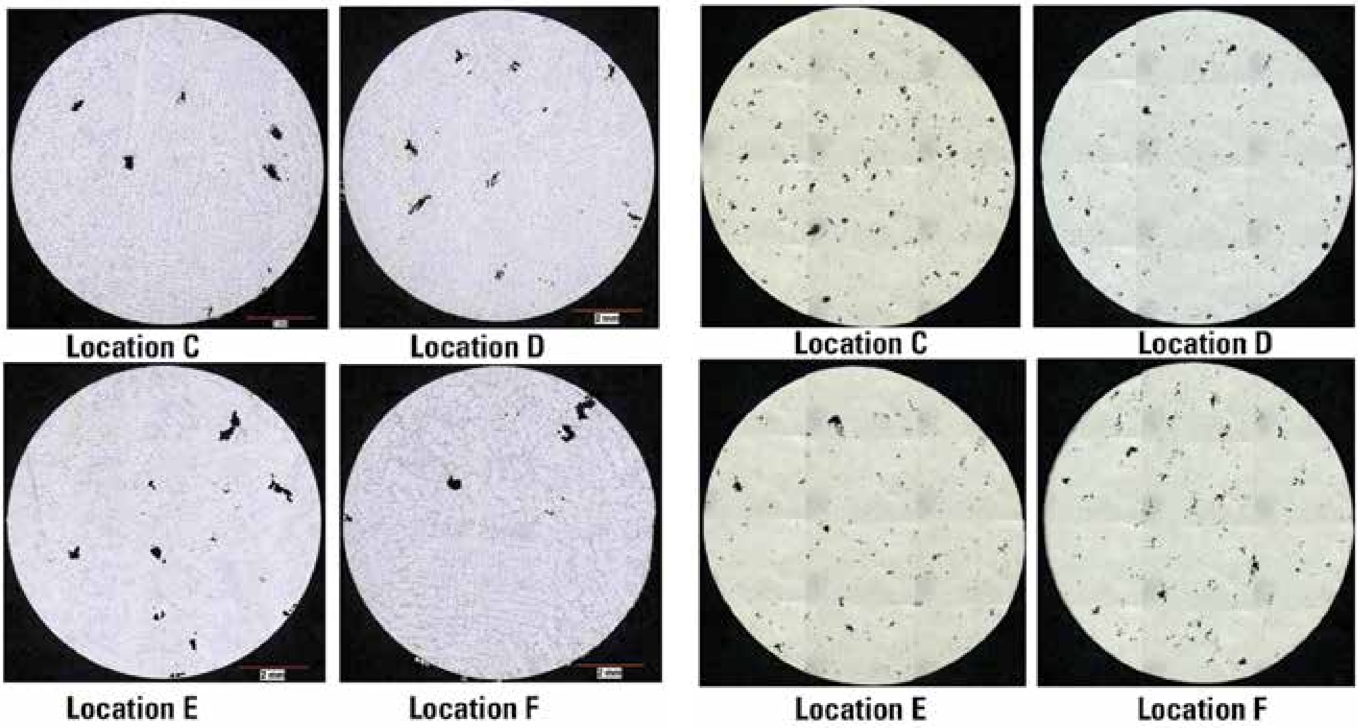

Fig. 2-3. These mosaics show the voids distribution at locations C, D, E and F in the A 356 casting (left) and 206 casting (right).

casting, the maximum length of the voids vary from 240 to 450 micrometers in the 206 alloy compared to 280 to 780 micrometers in alloy A356.

Figure 4 shows the typical dendritic structure of alloy A356 vs. the granular appearance of alloy 206 at locations A and F inside the castings. Alloy A356 dendrite arm spacing and 206 grain size increase with solidification time (Table 3). The 206 casting shows a slightly higher percent void content than its A356 counterpart; however, the maximum lengths of the void are smaller in 206, which should result in better fatigue resistance. The predicted

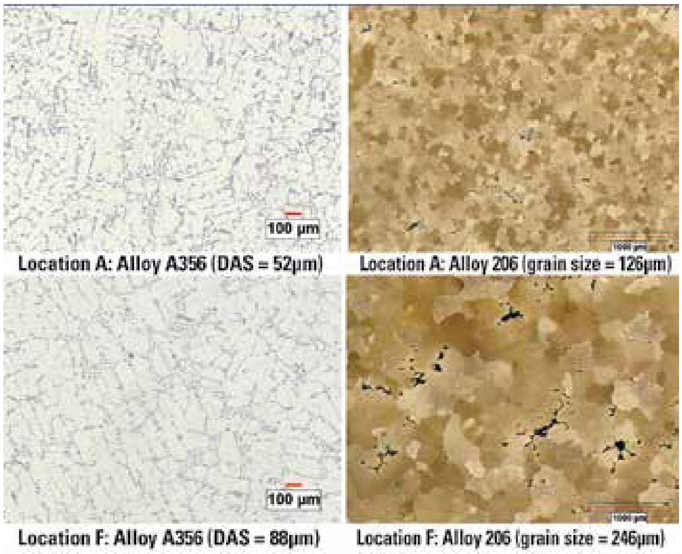

Fig. 4. The dendritic structure of alloy A356 is compred to the granular structure of alloy 206 at locations A and F.

Table 3. Alloy Composition at 6 Locations inside the 206 Casting

	Solidification time min A356/206	Microvoid in A356 (%) (predicted)	Microvoid in A356 Length µm (max)	DAS A356 µm	Grain size 206 µm	Microvoid in 206 (%) (predicted)	Microvoid in 206 Length, µm (max)
Location A	3.1/2.8	0.89 (0.98)	70 (540)	52	126	1.22 (1.29)	58 (315)
Location B	3.6/3.3	0.55 (0.79)	39 (280)	59	148	0.84 (1.00)	56 (240)
Location C	4.5/3.8	1.08 (1.03)	63 (440)	56	176	1.77 (1.49)	56 (250)
Location D	6.4/5.7	1.19 (1.06)	70 (670)	63	169	1.38 (1.34)	52 (320)
Location E	8.2/7.7	1.26 (1.52)	73 (780)	75	186	1.38 (1.48)	55 (450)
Location F	13.8/12.3	0.98 (1.41)	30 (670)	88	246	1.66 (1.80)	60 (450)

Table 4. Tensile Properties in the Standard ASTM B26 Test Bars and at Locations A, B, C, D, E, F for A356-T6 and 206-T4

Location (Nb of tests)	Solidification time, min	Yield Strength MPa (standard deviation)		Ultimate Strength MPa (std)		Elongation % (std)	
	A356 / 206	A356-T6	206-T4	A356-T6	206-T4	A356-T6	206-T4
ASTM B26(2)	1.1 / 1.0	201	228	258	353	3.4	13.6
A(3)	3.1 / 2.8	206 (2)	237 (5)	244 (5)	321 (13)	2.0 (.2)	6.3 (0.6)
B(3)	3.6 / 3.3	206 (5)	228 (4)	235 (2)	330 (8)	1.9 (.4)	8.7 (0.6)
C(6)	4.5 / 3.8	211 (5)	223 (3)	243 (2)	340 (13)	2.3 (.3)	10.2 (2.3)
D(2)	6.4 / 5.7	214	233	238	328	1.75	8.0
E(3)	8.2 / 7.7	205 (9)	227 (2)	227 (10)	328 (13)	1.5 (.4)	7.3 (1.4)
F(4,2)	13.8 / 12.3	201 (4)	210	215 (6)	299	1.6 (.3)	7.8

values of the percent surface area of microvoids agree reasonably well with the actual measured results except in the A356 casting at location F near the riser, where some amount of natural degassing might have taken place before the beginning of solidification.

Mechanical Property Results

Tensile test results for both castings are shown in Table 4 and on the graph Figure 5.

Yield strength inside the 206-T4 casting is always slightly higher (about 15%) than in the A356-T6 casting, while the elongation and ultimate tensile strength are far superior (+400% and +40%).

A previous study defined a tensile potential for 206 alloy based on metallurgical quality. This allows metallurgists to predict the tensile properties in the T7 condition when they are known in the T4 metallurgical state (T7=T4 + 5 hours at 190C). Figures 6 and 7 compare the expected tensile properties inside the casting in alloy 206-T7 to those inside the A356-T6 casting. The charts show the considerable increase in strength brought about by the T7 aging treatment. In the T7 metallurgical condition, the yield strength of alloy 206 is 50% greater than that in alloy A356-T6, along with substantially higher elongation. ■

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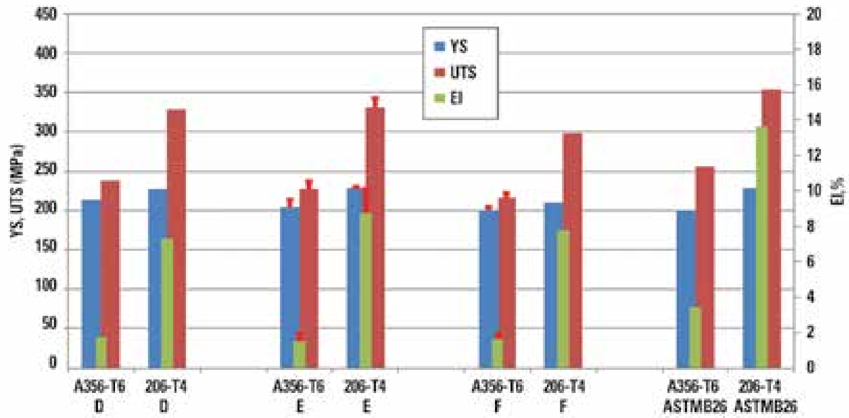

Fig. 5. Shown are the tensile properties inside the A356-T6 and 206-T4 castings at locations D, E, and F and in the separately cast ASTM B26 test bars.

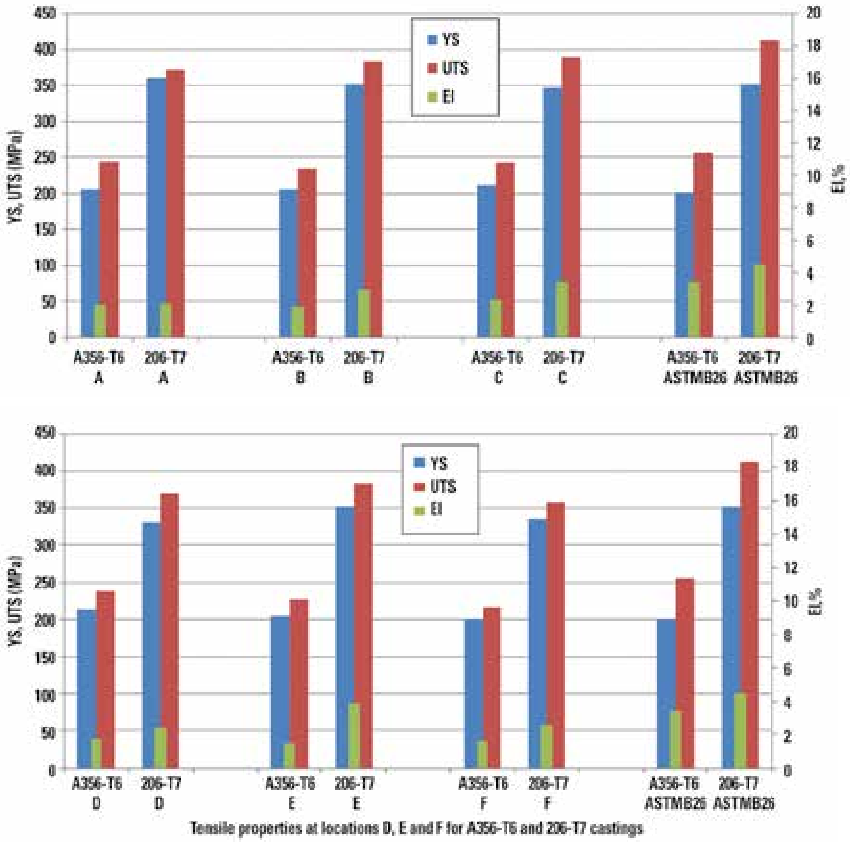

Fig. 6-7. These charts shows the predicted tensile properties of a 207-T7 casting versus A356-T6 at locations A, D, C, D, E and F and in the separately cast ASTM B26 test bars.