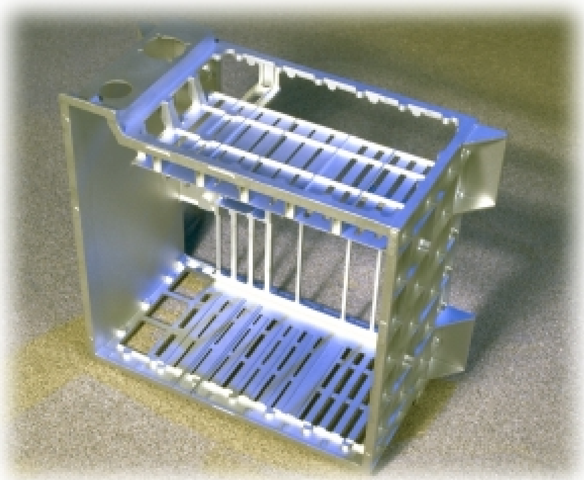
T E C H N I C A L   U P D A T E

Premium Quality Aluminum Castings

For many years, achieving all classes of the mechanical properties of premium-quality aluminum called for by casting specifications such as SAE AMS A 21180 has required metal chills (heat sinks) to solidify the casting sections more quickly, reducing dendritic arm spacing and refining the structure so that it would respond to heat treatment. While these operations are not too difficult when casting in sand molds, they are difficult and expensive when casting in the ceramic molds used for investment castings. Table 1 lists the minimum requirements of SAE AMS A 21180 for the most popular casting alloy, A356.

Class 1, 2 and 3 property requirements must be achieved in designated areas. Class 10, 11 and 12 property requirements must be met in any randomly selected area of the casting; the basic casting process must yield a good structure without chilling or the properties will not meet the specification.



Lowering metal casting temperatures and mold temperatures as much as possible while still filling the castings are the main things an investment casting manufacturer can do to achieve premium-quality structures. While thick castings can be filled at lower temperatures than thin ones, their slower rate of solidification yields a poorer structure and lowers properties, other things being equal. Using higher temperatures to fill thin sections correspondingly lowers their properties. These practical influences may cause thick and thin sections to yield almost the same properties.

Normal Casting Process Capabilities

To show Hitchiner's normal process capability for meeting SAE AMS A 21180, we cast five different part configurations in A356. The part wall thicknesses varied from 0.09 inch (2.2mm) to 0.320 inch (8.1mm). We cast all five parts using the normal gravity pour / vacuum assist method as well as Hitchiner's countergravity low-pressure air melt (CLA) process (Hitchiner Technical Update 2D5).

The CLA process filled the castings at significantly lower metal and mold temperatures, thus providing more rapid solidification and better metallurgical structures than conventional gravity pouring. After heat treatment, we machined 42 tensile test bars from the various thicknesses and tested them for mechanical properties (Table 2. CLA- vs. Gravity / Vacuum Assist-Cast Part Properties at Different Thicknesses).

The CLA process yielded significant improvements in properties. On the average of all thicknesses, CLA improved tensile strength 11.7%, yield strength 8.1% and elongation 81.7%. The CLA process can produce castings meeting the highest requirements (Class 10) in sections up to 0.25 inch (6mm), while ladle casting cannot meet Class 10 requirements in any thickness and Class 11 safely only up to 0.150 inch (3.8mm).

Post-Cast HIPping

One must either chill the part to refine its structure and / or use hot isostatic pressing to close porosity and achieve property requirements higher than those yielded by the CLA process alone or to achieve those requirements in thicker sections.

Both chilling and HIPping add a lot of cost to investment castings. However, a new process using high pressure liquids instead of gas—liquid hot isostatic pressing—can reduce the cost of HIPping dramatically (Technical Update 3D4). Not only is the process itself low-cost, but using CLA enables gating reduction.

When making large castings at low casting temperatures in sections of up to 0.75 inch

(19mm) thickness, gating efficiencies of up to 99% of the casting weight can be achieved. Hydrogen is added to prevent surface-connected porosity in isolated heavy sections, assuring complete closure of internal voids. This process cannot correct the coarse segregated structure of such thick unchilled parts, but the porosity closure doubles the fatigue endurance limit and greatly improves ductility. For example, using this procedure on some sand cast, unchilled, 356 parts 0.75 inch (19mm) thick, quenching directly from the LHIP operation and then aging gave the properties listed in Table 3.

While these are excellent properties, they do not meet all classes of SAE AMS A 21180. Apparently the standard can only be met by solidifying the part rapidly to make the alloy more responsive to heat treatment, thereby generating the higher yield and tensile strengths. Where the designer can use Classes 1, 10, 11 or 12, the use of LHIP offers a much lower-cost part with high ductility and, of course, a higher fatigue endurance limit.

Future of Premium-Quality Aluminum Castings

While Hitchiner is ready to use all of these techniques in production to meet customer needs for premium castings, Metal Casting Technology is continuing work to see if there is a more economic way to achieve all classes of SAE AMS A 21180.

Minimum SAE AMS A 21180 Requirements for Alloy A356			
Property Class	Tensile Strength ksi (MPa)	Yield Strength ksi (MPa)	% Elongation
1	38 (262)	28 (193)	5.0
2	40 (276)	30 (207)	3.0
3	45 (310)	34 (234)	3.0
10	38 (262)	28 (193)	5.0
11	33 (227)	27 (186)	3.0
12	32 (220)	22 (152)	2.0

Table 1

CLA- vs Gravity Pour-Cast Part Properties at Different Thicknesses								
			CLA (Hitchiner Process) Cast			Conventional Gravity Pour		
No. of tests	Thickness Inches	(mm)	Tensile ksi (MPa)	Yield ksi (MPa)	%Elong.	Tensile ksi (MPA)	Yield ksi (MPa)	%Elong.
6	0.09	(2.2)	41 (282)	30 (207)	7.8	37 (255)	29 (200)	3.8
3	0.12	(3)	41 (282)	37 (255)	6.0	38 (262)	31 (214)	3.0
9	0.15	(3.8)	42 (289)	33 (227)	6.6	38 (262)	32 (220)	3.5
1	0.25	(6)	40 (276)	31 (214)	5.0	35 (241)	29 (200)	3.0
2	0.32	(8.1)	40 (276)	29 (200)	6.5	36 (248)	27 (186)	4.8

Table 2

Sand Cast, Unchilled, 356 Parts Quenched Directly from LHIP and Aged			
Thickness Inches (mm)	Average of Five Tensile Strength ksi Range (ksi) [MPa]	Average of Five Yield Strength ksi Range (ksi) [MPa]	Average of Five %Elongation [Range]
0.75 (19)	39.4 (39.1-39.9) [269-275]	29.1 (27.2-30.5) [187-210]	7.7 (6.2-9.1)

Table 3