Hitchiner's CLA Process

Quality and process control benefits flow from lower-cost method

Hitchiner's countergravity low-pressure air melt process is a method for filling ceramic molds directly from metal melts. As shown in Figure 1, a vacuum chamber holds a ceramic mold configured with an open fill pipe facing down. The chamber lowers so that the fill pipe enters the melt. Applied vacuum siphons the metal into the mold, filling every section completely. After a brief hold time to allow the parts to solidify, the vacuum releases and the residual central sprue metal, including part of the gates, flows back into the melt.

Since Hitchiner introduced the CLA process in 1971, the company and its licensees have made more than a half billion castings. Variations of the basic process include methods to further reduce cost while enhancing quality and productivity, enable the casting of vacuum-melt nickel superalloys and other reactive alloys and enable the casting of heavyweight configurations.

Hitchiner initially invented the process to cut the cost of investment casting by reducing cutoff operations, significantly reducing mold weight per part while expanding parts per mold and enabling immediate recycling of sprue and gating metal. The process has also led to many quality and process control advantages over conventional gravity pouring (Figure 2).

These advantages include the ability to control the rate of metal flow; exclusion of surface slag and reoxidation macroinclusions formed by the turbulence of pouring; and uniform fillout of all sections, including superior flow into sections as thin as 0.015 inch (0.381mm).

Fill Control

Speed

Unlike conventional gravity pouring in which gravity determines the fill rate, the CLA process enables the foundry to control the fill rate. The vacuum (pulling the metal into the mold) vs. time can be programmed into a control computer to yield whatever velocity is suitable. Depending on the alloy, Hitchiner has used fill rates from 0.3 inches per second (7.6mm / second) to 20 inches per second (508mm / second) in production.

More viscous metals like metal matrix aluminum composites require slow rates. Drossy alloys such as aluminum bronze and aluminum also require slower filling speeds. Depending on the part shape, many common clean melting alloys can be filled at the higher speeds. Controlled rates eliminate the splatter and other effects caused by the turbulence inherent in gravity pouring.

Eliminating Turbulence and Its Effects

Nonmetallic inclusions. A graph from a Steel Founder's Society paper [Malcom Blair, etc. (Figure 3)] shows that 83% of the macroinclusions

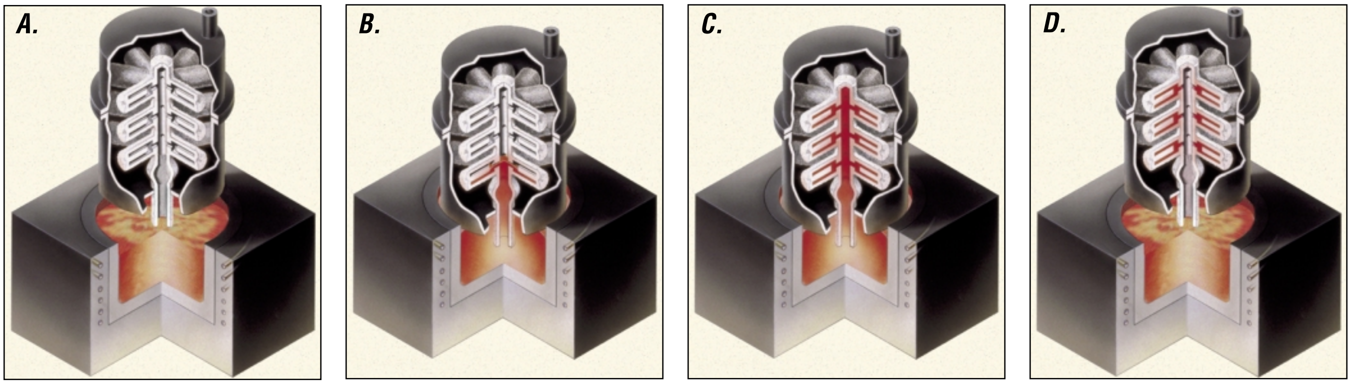


Figure 1. The CLA process: A chamber that can be closed and sealed holds a permeable mold; an open, impermeable fill pipe extends out of the chamber, (a). The fill pipe lowers into the melt and an applied vacuum draws molten metal, (b), up into the mold in a highly controlled fashion. Castings solidify while the passage stays molten, (c). When the vacuum releases, most of the gating metal returns to the melt for reuse and the castings are all separate in the mold, (d).

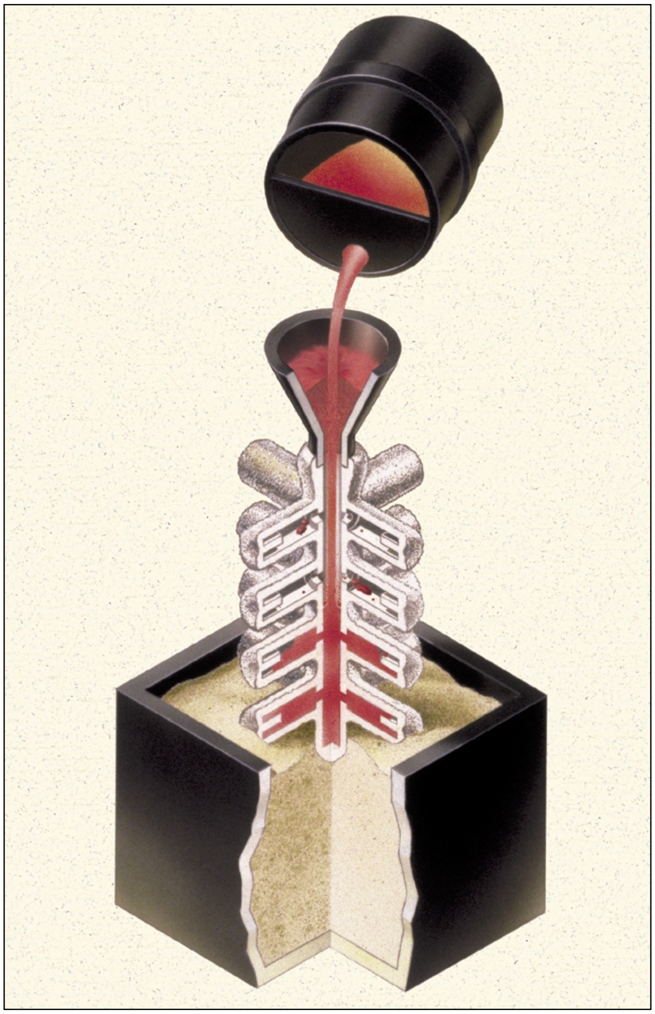


Figure 2. Conventional gravity pouring: The metal swirls in the pour cup, splashing sideways to splatter metal into upper cavities, and falls to the bottom, splashing metal into many cavities at once. The bottom cavities do not fill until the central passage builds up enough height (pressure) to force the air out of the lower cavities. Variation in filling from part to part in a mold is great.

(slag or metal oxide particles) are artifacts of the turbulence caused by gravity pouring. The use of vacuum to draw the metal into the mold ("countergravity") stops the metal from splashing and splattering as it does during a gravity pour.

Machinability. Eliminating the turbulence greatly reduces the cause of many nonmetallic inclusions and the incidence of cold shots and laps. Studies done at Hitchiner show about an 85% reduction in such inclusions. This greatly improves machinability. In one comparative test of 120 pieces of 316 stainless steel dairy processing parts, a competitor's gravity cast parts required 24 tool changes and had 18 pits after machining, while Hitchiner's CLA parts required only five tool changes and had only three pits after machining. Other comparative tests have found increases in tool cutting lives from 100% to 500%, depending on the alloy. Comparing CLA to ladle cast 17-4PH stainless steel microstructures shows the reason—far fewer particles of hard inclusions in the structure (Figure 4).

Fatigue endurance. Nonmetallic inclusions also affect the fatigue endurance limits of 17-4PH stainless steel (Figure 5). Of the 100% increase in endurance limit, the reduction in inclusions due to vacuum casting accounted for 25%. A similar test in high-strength, low-alloy steel increased the endurance limit to make it fully equal to wrought steel of the same analysis.

Splatter defects. Controlled metal flow also reduces splatter defects. Although these can be small they still influence the performance of parts under stress. Figure 6 shows seat belt sliders that were tension stressed to failure by pulling on a pin in the hole while holding the base in a fixture. CLA parts are clearly superior to ladle-cast parts in process reliability due to the better metal quality (Figure 7).

Mold fillout. CLA enables thin section fillout that could not be achieved by gravity pouring. The filling capability of CLA is such that it is possible to cast sections as thin as 0.015 inch (0.38mm) in areas as large as would normally be mechanically useful. Sharp edges such as those found on the wire cutters in handtool plier jaws can be cast sharp enough to cut paper. The fine knurls of the jaws are sharp and grip well.

CLA also enables fillout of thicker sections at much lower temperatures, which can greatly improve the mechanical properties of some alloys (Table: Mechanical Property Improvements for Alloys Cast by CLA).

Surface finish. Lower metal and mold temperatures improve the surface finish of many alloys as well, reducing metal-to-mold reactions.

Mold Design

The ability to fill almost any number of parts on a sprue and have the parts unattached to the gating after casting means that the parts can be packed tightly around a central sprue, giving more parts per mold. This higher yield reduces ceramic and metal use, energy costs and labor. This enables Hitchiner to provide metallurgically superior parts at competitive prices, even for the highly competitive automotive parts industry.

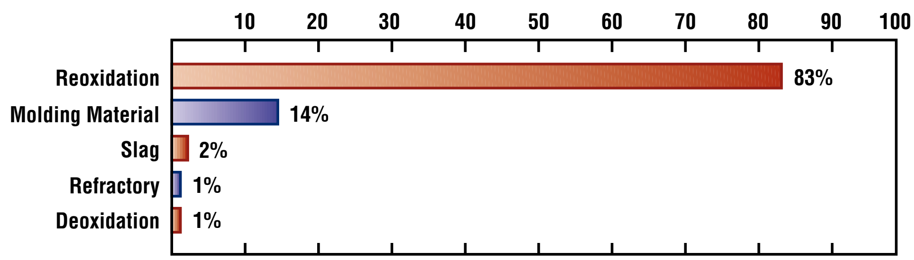
Mechanical Property Improvements for Alloys Cast by CLA						
		Yield Strength		Tensile Strength		Elongation
Alloy	**Casting Method**	**ksi**	**(MPa)**	**ksi**	**(MPa)**	**%**
C356	Ladle pour	33.3	(229)	44.3	(305)	8.0
	CLA	36.1	(249)	49	(338)	14.0
17-4PH	Ladle pour	170.6	(1175)	177.2	(1221)	11.0
	CLA	179.6	(1237)	181.4	(1250)	13.5
Cobalt 21	Ladle (air melt)	79.0	(544)	120	(827)	9.0
	Ladle (vacuum)	82	(565)	112	(772)	11.0
	CLA (air melt)	86	(593)	136	(937)	14.0
165 BeCu[1]	Req'd. min.	80	(551)	125	(861)	—
	CLA	127	(875)	163	(1123)	9[2]

[1] All bars were cast to size except for the BeCu, which was taken from a casting.
[2] This is reduction in area.

Table 1

Reoxidation Macroinclusions in Steel Castings

Percentage of carbon and low alloy macroinclusions. 396 total.



Distribution of macroinclusion sources in carbon and low-alloy steel castings

Figure 3. Sources of inclusions in low-alloy steel castings, reported by the Steel Founder's Society. "Reoxidation" is the term applied to inclusions caused by pouring turbulence.

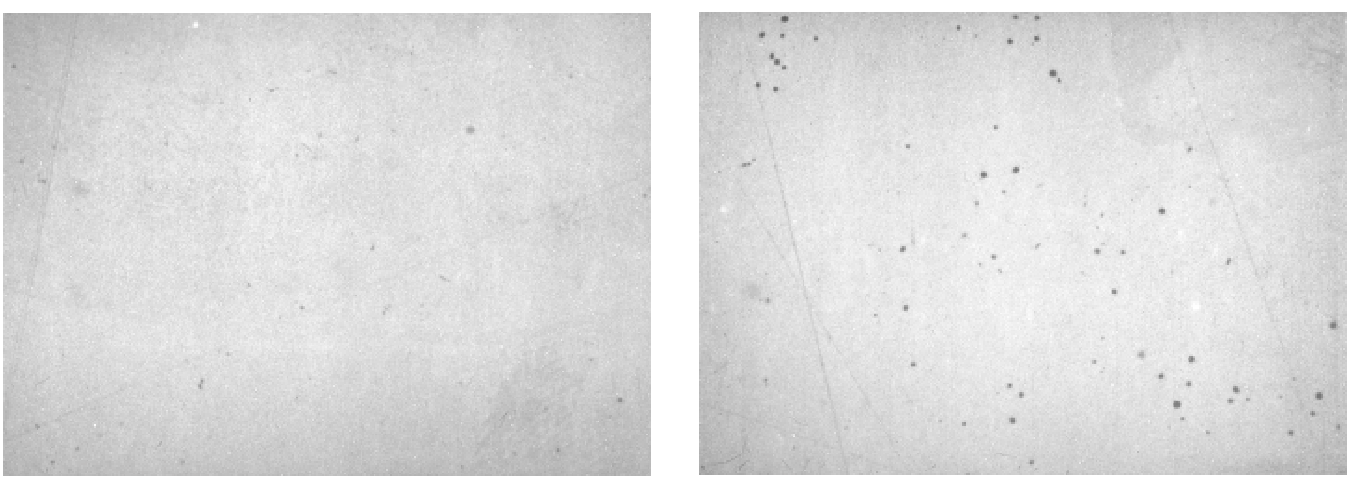


Figure 4. CLA cast cleanliness, left, vs. gravity cast, right, for 17-4PH stainless steel. Other alloys also show CLA metal cleanliness to be superior.

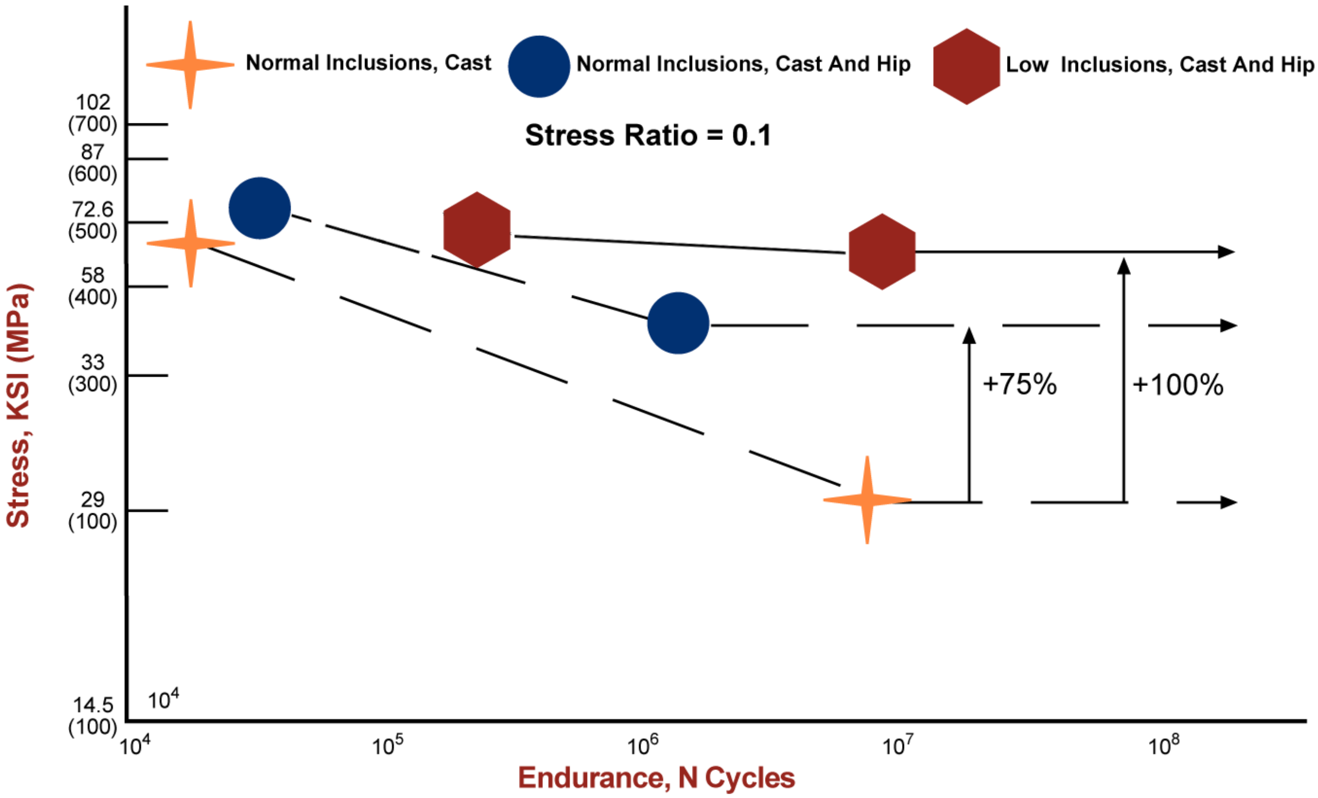


Figure 5. These stress/number of cycle curves for 17-4PH stainless steel show the great importance of microporosity closed by hot isostatic pressing and the presence of inclusions eliminated by vacuum casting.

Reference: Nagan, R. M. and Cunningham, R., "Optimizing Fatigue Properties of a Cast Precipition-Hardening Steel," Investment Casting Institute Annual Meeting (1980)

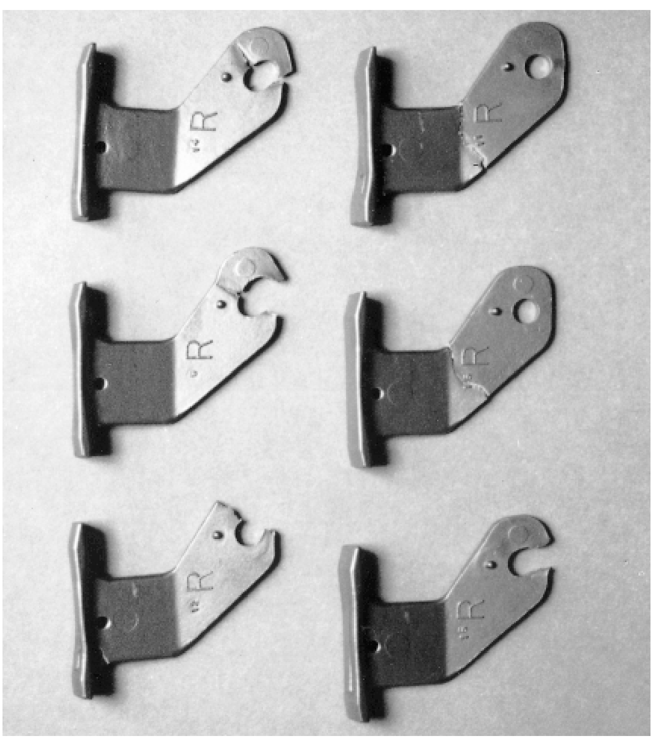
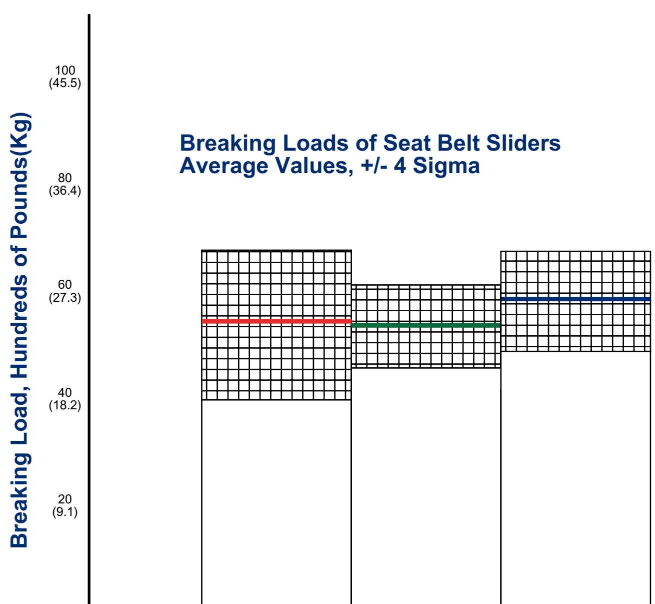


Figure 6. Seat belt slider parts in alloy 8630 that were tested to failure.



	Ladle Pour 8630 Rockwell 35-40	Cla Cast 8630 Rockwell C 35-40	Cla Cast 8620 Rockwell C 38-42
$\bar{X}$ lbs(Kg)	5422(2465)	5397(2453)	5923(2692)
Normal Population	No	Yes	Yes
Cpk	2.01	3.74	5.98

Figure 7. Comparison breaking loads of ladle-poured and CLA-cast seat belt sliders.