HITCHINER
Since 1946

THE LEADING PROVIDER OF INNOVATIVE TECHNOLOGY SOLUTIONS FOR INVESTMENT CASTINGS

Hitchiner Mfg.// Cast GDI Components

October 25, 2012

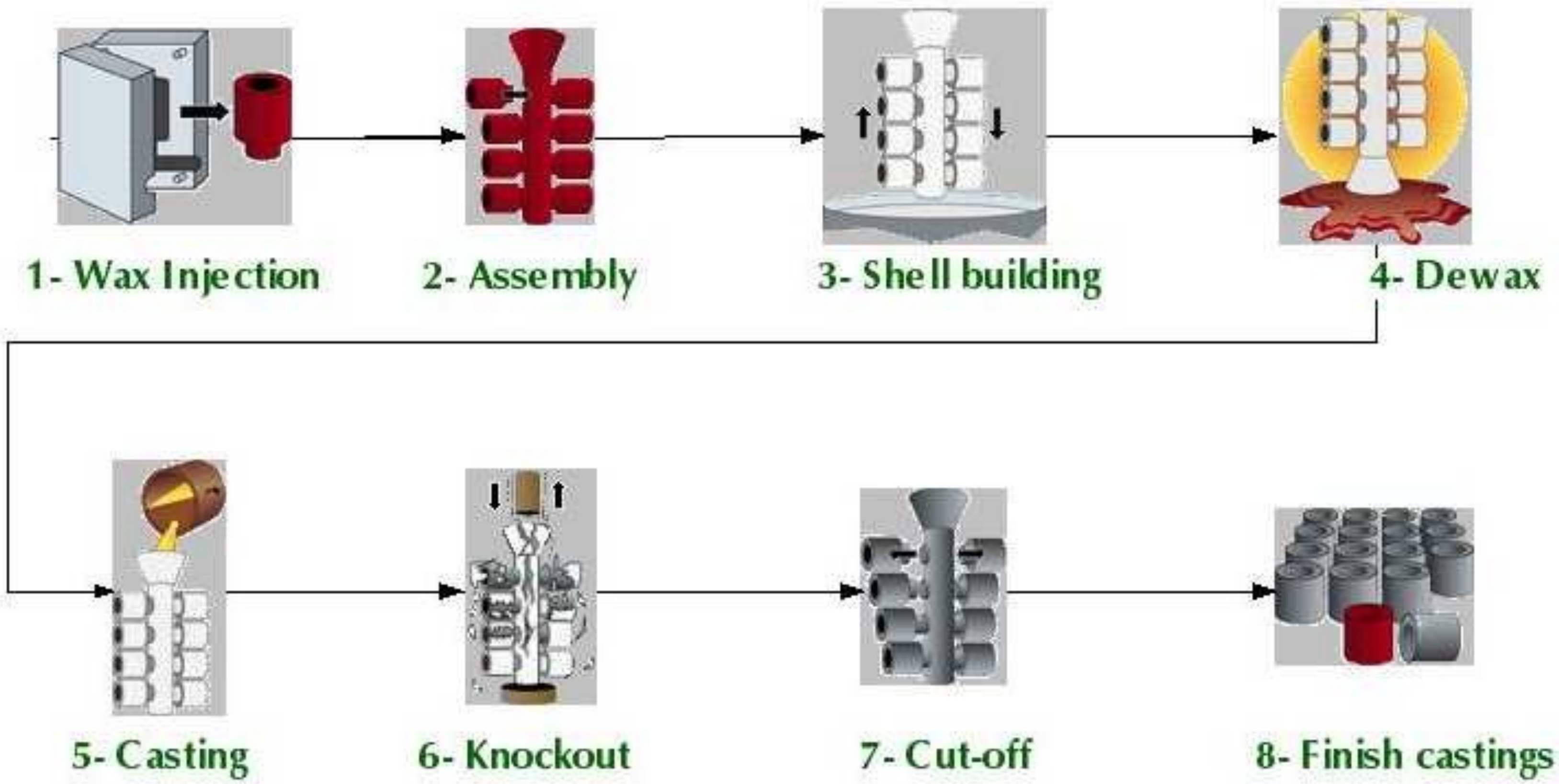
HITCHINER Manufacturing Co., Inc. 117 Old Wilton Road Milford, NH 03055 - USA

Summary- Hitchiner Milestones

- Hitchiner remains a privately owned corporation, with 62 years of consistent ownership
- Established in 1946 with over 64 years of manufacturing in New Hampshire
- $195M Sales (2011)
- 1,800 employees worldwide
- Operations in US and Mexico serving markets of North America, Europe and Asia
  - 5 primary manufacturing plants
  - Combined 1 million square feet of manufacturing space

Investment Casting Process

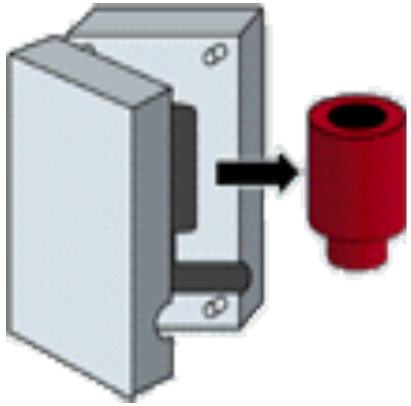
engineexpo2012
Novi, Michigan

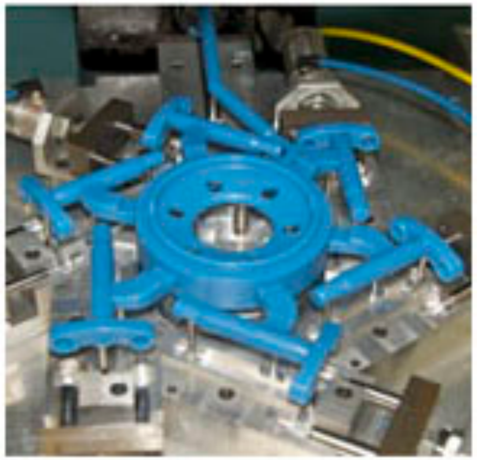


Wax injection

Wax patterns are produced by injection molding into aluminum or steel dies.

At Hitchiner (right), complex multi-cavity dies are used to form ring segments of patterns. Individual patterns can also be placed in a die and the center ring injected onto the patterns.

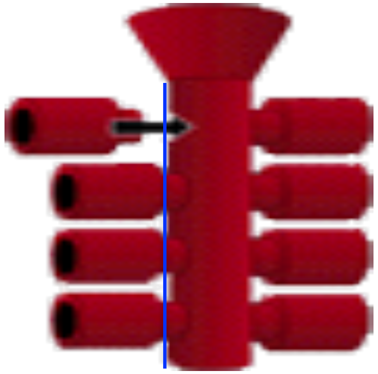




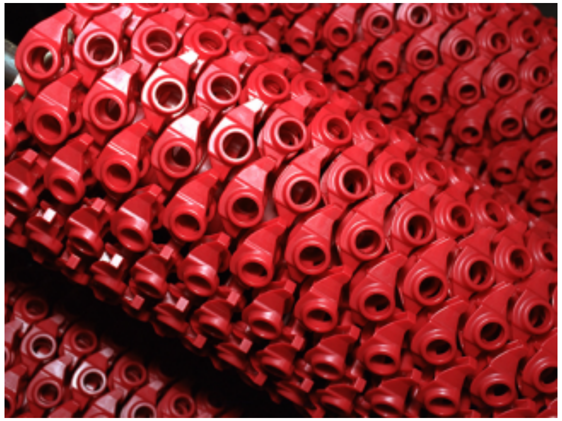
Wax assembly

The patterns are attached to a central wax stick, called a sprue, to form an assembly. With gravity casting, the parts have to allow for bandsaw cutoff after casting.

Hitchiner's ring segment waxes are simply stacked to form the assembly. The rings have alignment tabs so that the optimum pattern spacing is automatically and precisely achieved. No need for a cutoff plane results in high part loading.

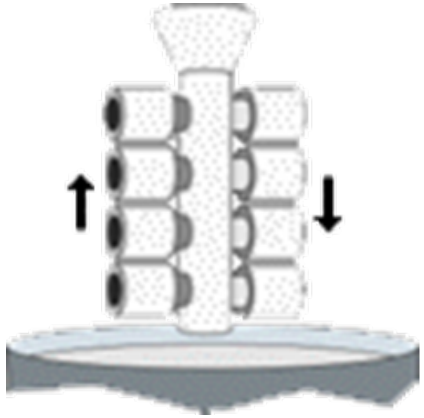


Cutoff plane



Shell building

The shell is built by immersing the assembly in a liquid ceramic slurry and then into a bed of refractory sand. Up to eight layers may be applied in this manner.



At Hitchiner, specialized shell building robots are used to build the shell. This automation provides for a consistent build and allows for larger molds than could be built by manual methods.
The symmetrical Hitchiner molds result in more uniform shell building.

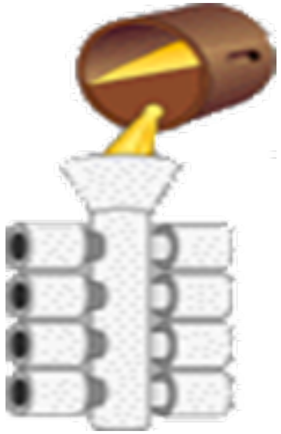
Dewax

Once the ceramic is dry, the wax is melted out, leaving a negative impression of the wax assembly within the shell

Steam autoclaves are used for this purpose. At Hitchiner, the wax is reclaimed, purified and recycled.

Casting

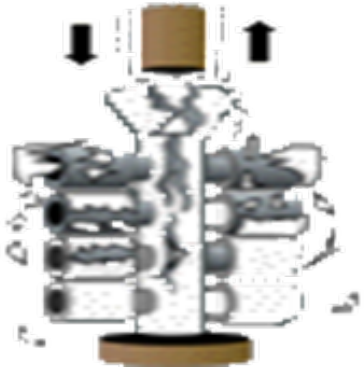
In the conventional pour process, used by most foundries, the shell is filled with molten metal by gravity pouring. As the metal cools, the parts, gates, sprue and pouring cup become one solid casting.



Hitchiner uses its exclusive counter-gravity processes to cast the mold. In these processes, molten metal is moved into the mold cavity by the application of a controlled vacuum to the mold. The vacuum is released when the parts and a portion of the gates have solidified, allowing the molten metal in the central sprue to return to the melt.

Ceramic removal

With a conventionally cast mold, the ceramic shell is broken off by vibration or water blasting and the entire sprue is abrasively blasted.

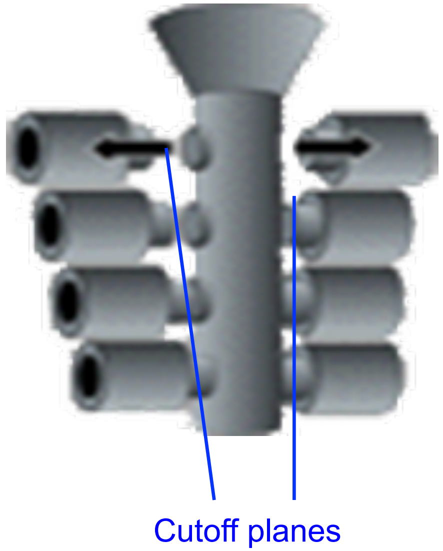


After countergravity casting, the individual castings are abrasively cleaned of the shell material.

Cutoff

Traditionally, the parts are cut away from the central sprue using a high speed friction saw.

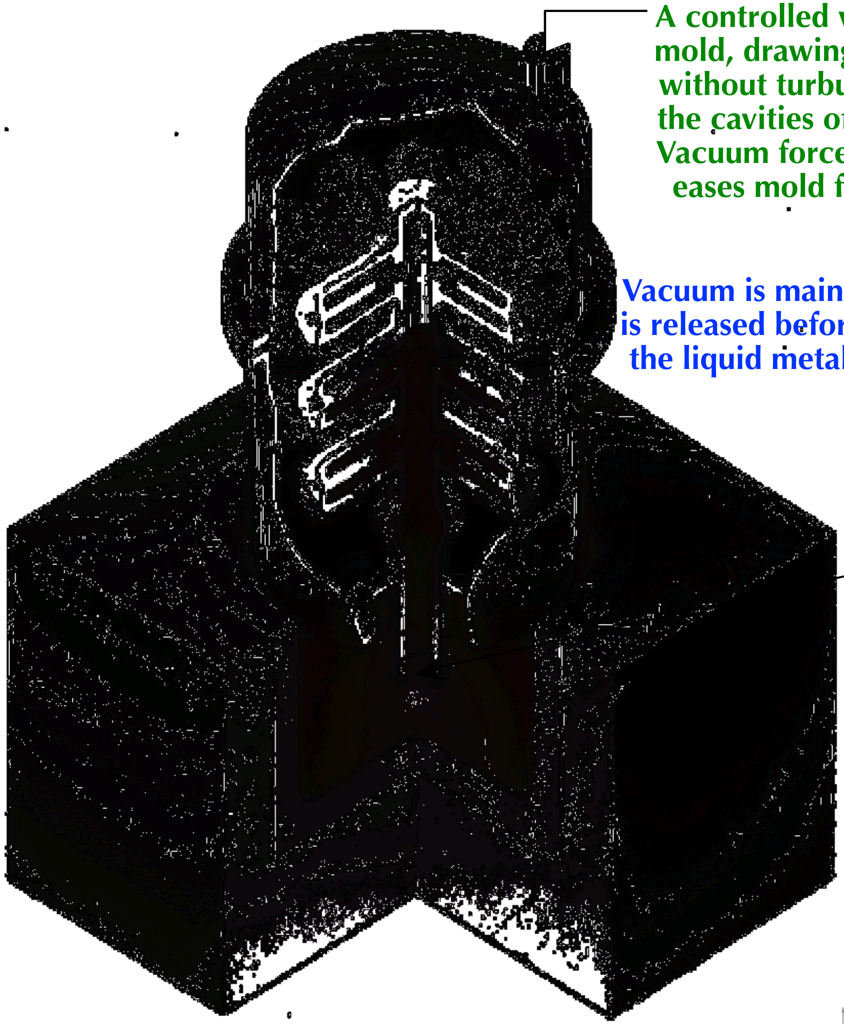
Hitchiner's countergravity-cast parts do not have a solidified central sprue and therefore do not require this operation. Only a small gate stub remains on the individual castings which is easily removed by an automated precision cutoff / grind operation



Finishing

Hitchiner has the capacity and experience to offer complete-to-print machining and subassembly operations, delivering a finished component ready for installation in the finished product.

Counter Gravity Casting



A controlled vacuum is created inside the mold, drawing up the metal that climbs without turbulences nor splattering, filling the cavities of the mold properly.
Vacuum forces the extraction of gas, which eases mold filling.

Vacuum is maintained while the parts solidify, and is released before the central stick becomes solid: all the liquid metal falls back to the melt.

Clean metal is drawn under the surface of the melt, directly from the melting crucible, under permanent temperature control.

Countergravity Casting Video

Technical advantages of Counter-gravity Casting

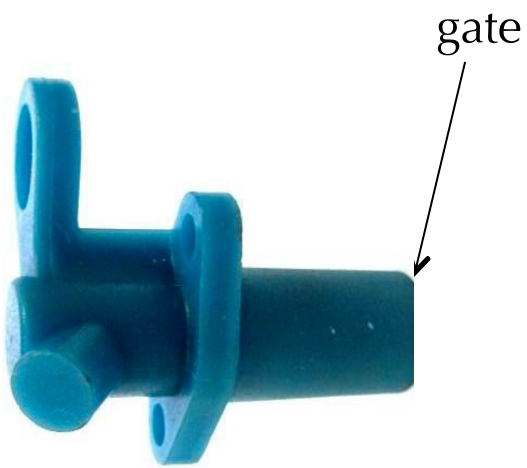
- **Uniform thermal gradients**
  - Symmetrical part arrangement
  - Consistent feeding of solidification shrinkage from part-to-part
  - Consistent grain structure
- **High density sprue loading**
  - Improved shell and foundry throughput
- **Excellent metal cleanliness**
  - The molten metal is cast into the mold directly from the melting furnace
  - Maintaining furnace power on during casting keeps any slag at the side of the furnace wall.
  - In gravity pouring, the slag floats on the melt surface and often becomes entrained in the castings.
- **Constant metal temperature from mold to mold**
  - Furnace power can be adjusted to maintain melt temperature.
  - In gravity pouring from a ladle, the metal temperature is rapidly dropping. The metal temperature of the first mold cast from the ladle will be a different than the second.
- **Optimized mold filling**
  - Mold filling is controlled by the vacuum system and can be adjusted for a particular mold configuration
  - In gravity pour, ability to control mold filling is very limited.
  - Allows casting of very fine features without non-fill.
- **A thinner shell can be used without mold failure by using support sand**
  - Improved shell and casting cleaning throughput
- **High melt utilization possible since sprue and head do not solidify.**

GDI Fuel Rail injector Cups

GDI Fuel Rail

Example of GDI fuel rail complete assy with injector

Injector Cup

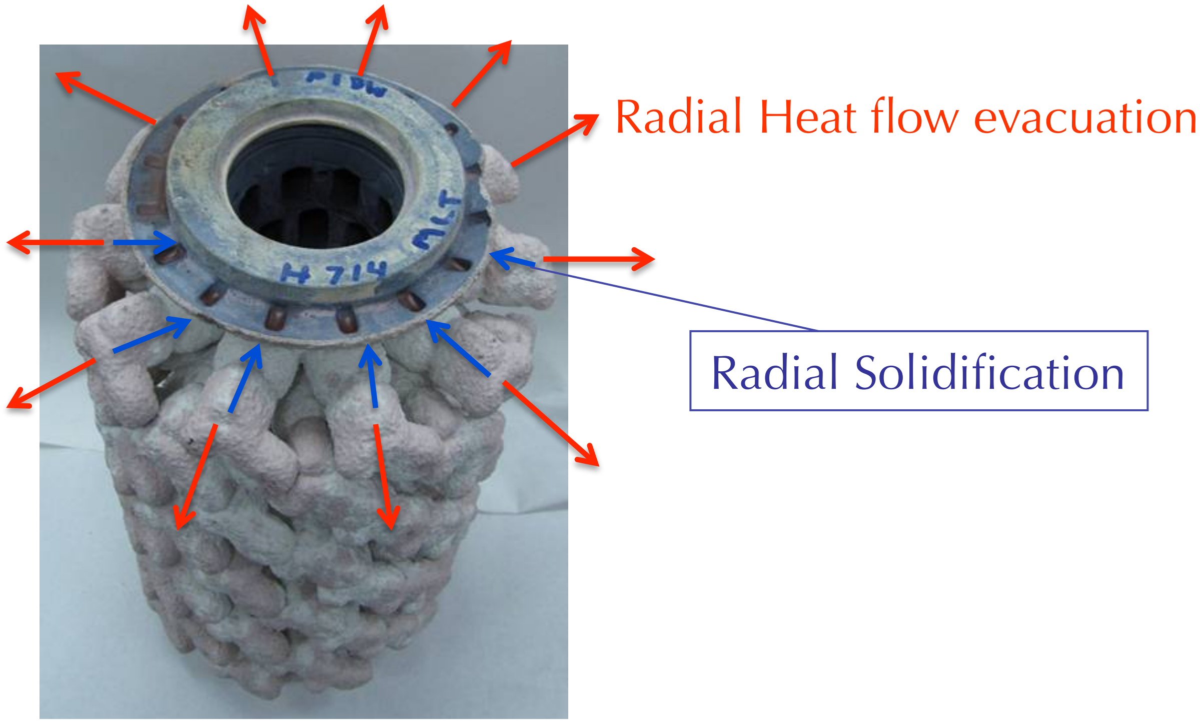


Wax pattern with gate/riser

Ceramic Shell after dewax

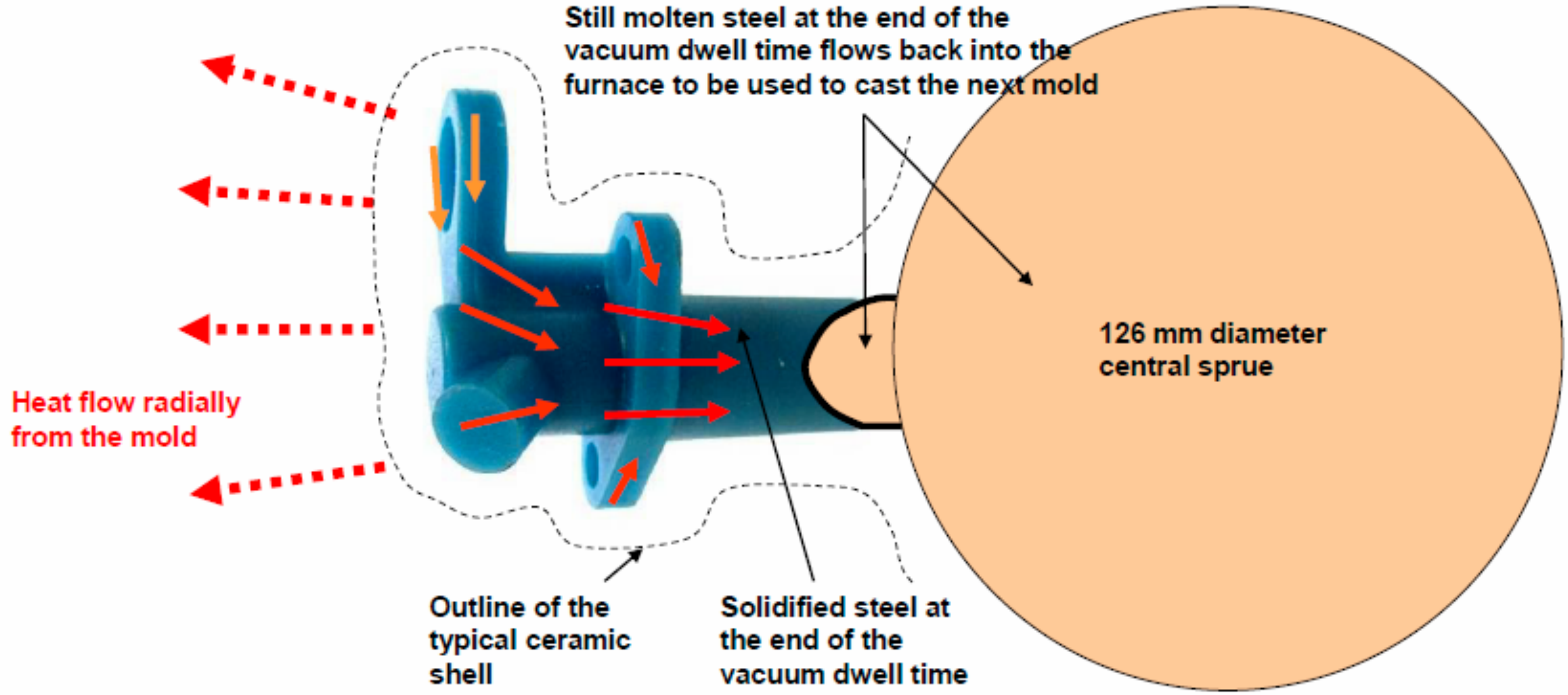
Counter gravity casting

Directional solidification



SSCLA sprue with a cylindrical symmetry arrangement allowing radial heat flow and solidification.

Schematic showing the directional solidification of the part.

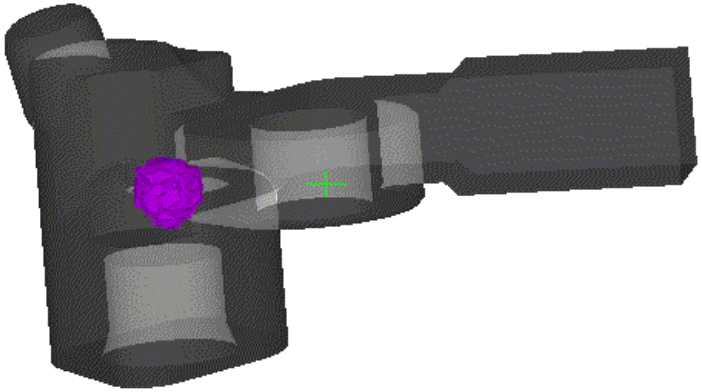


The part design as well as the gating position and size are important for directional solidification to occur properly

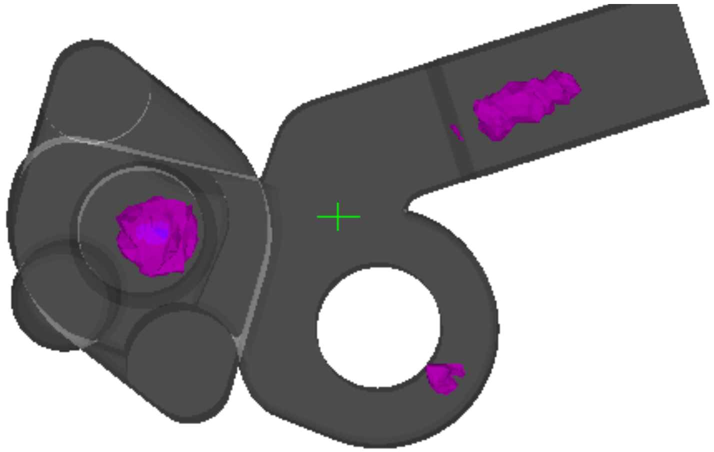
The gating size is optimized and verified during the prototype process. Production would use the verified gate geometry

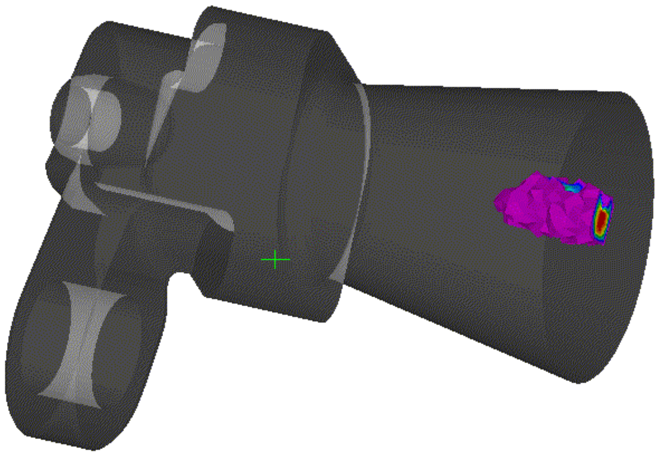
Solidification Modeling

Gate #1



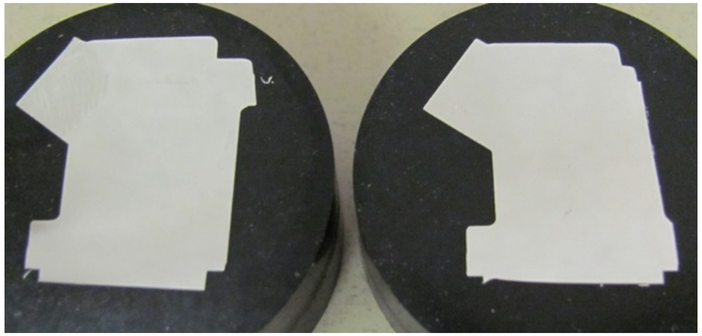
Gate #2



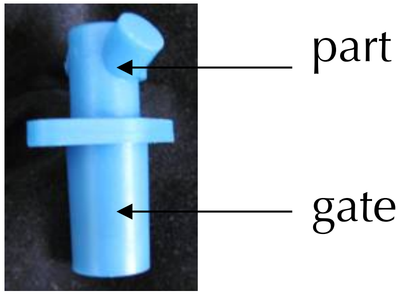


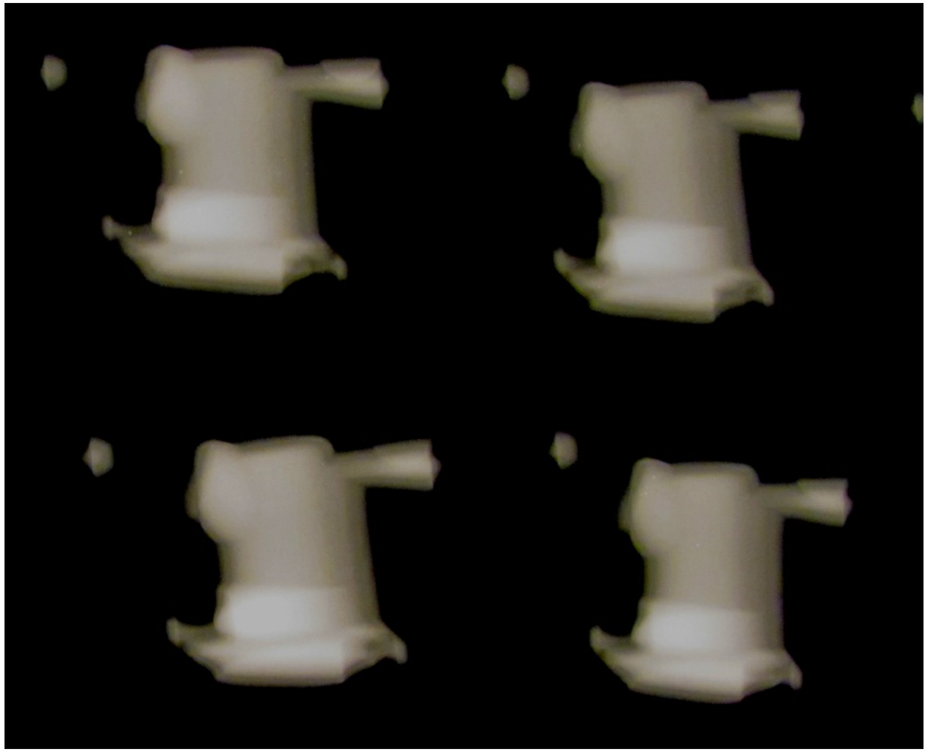
Final gate design

Example of Fuel System Component Soundness



Micrography :
0.003% porosity in any 1 x 1.25 mm field of view





Typical X-ray image

Factors controlling casting soundness

- Metal chemistry
  - Checked 3 times per crucible (adjusted if required) and once on castings per crucible
- Metal temperature
  - Controlled with immersion thermocouples in the melt
- Mold temperature
  - Controlled by burnout oven temperature controls and limits on the time from when the mold is removed from the oven until it is cast
- Rate of mold filling with metal
  - Counter gravity mold filling is controlled by a computer vacuum control system.
- Metallurgical cleanliness
  - Metal is drawn from the melt core under the surface and at controlled temperature
- Controlled solidification:
  - Amount of ceramic shell applied to the mold controlled by robot programming and shell recipe
  - Part spacing on the sprue controlled by ring die injection.
  - Gate size and placement on the casting, optimized during development

Process development for fuel system components

- **Gate optimization:**
  - Computer modeling, casting trials, Xray, and polished sections.

- **Process robustness by variation of process factors** :
    - metal temperature,
    - mold temperature
    - gate size.
  - The robustness study is done to maximize the size of the green zone and to center the production operating range within the green zone.

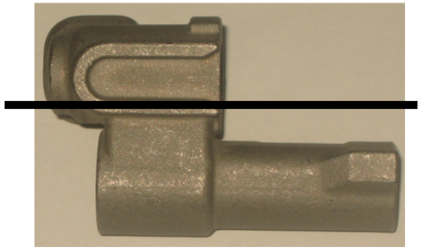
Fuel System Component Production

Production key control items:

- Control of the process variables that control soundness
- Foundry control X-ray
  - X-ray acceptance levels are typically divided into two areas
    - Dry area (bolt area)
    - Fluid (fuel passageway) area
  - X-ray levels follow ASTM E192

Example of X-Ray Inspection

1.- Part mapped in 2 areas



Fluid area

Dry area

2.- **Acceptance criteria** used for the Fluid area is tighten than the Dry area.
Standard used:
ASTM E-192 , “INVESTMENT STEEL CASTINGS FOR AEROSPACE APPLICATIONS

Example of X-Ray Inspection

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3- Acceptance Criteria for X-Ray Inspection

ASTM E -192 Reference Plates for ¾ inch thickness:
Fluid Area:

Defect: Shrinkage

* Acceptance level : Dendritic Level 4 Grade “C”, it is not accepted, Filamentary or Cavity

Defect : Gas

* Acceptance level: Level 3 Grade “B”

Dry Area:

Defect : Shrinkage

* Acceptance Level: Dendritic Level 6 Grade “D” , it is not accepted, Filamentary or Cavity

Defect: Gas

* Acceptance level : 5 Grade “C”

Example of X-Ray Inspection

4.- Xray in 4 views :

a) 5% of the Batch is evaluated in the Views 2 & 3
b) 100% Views 1 & 4
c) If it is found a defective piece in the 5% of the views 2& 3 the batch is 100% X-rayed in those views.

View # 1

View # 2

View # 3

View # 4

Conclusion

Hitchiner has been producing millions of castings for GDI applications, and has achieved 2ppm leakage so far.

Countergravity process combined Hitchiner expertise and experience provides the robust capability to produce reliable castings for critical applications such as fuel pressurized components, rocker arms, aerospace turbine blades.

Visit our stand in Hall 3, N° 3130,

www.hitchiner.com