HITCHINER
Since 1946

THE LEADING PROVIDER OF INNOVATIVE TECHNOLOGY SOLUTIONS FOR INVESTMENT CASTINGS

Counter gravity investment casting for fuel pressurized GDI applications

14 June 2012- 10:50AM



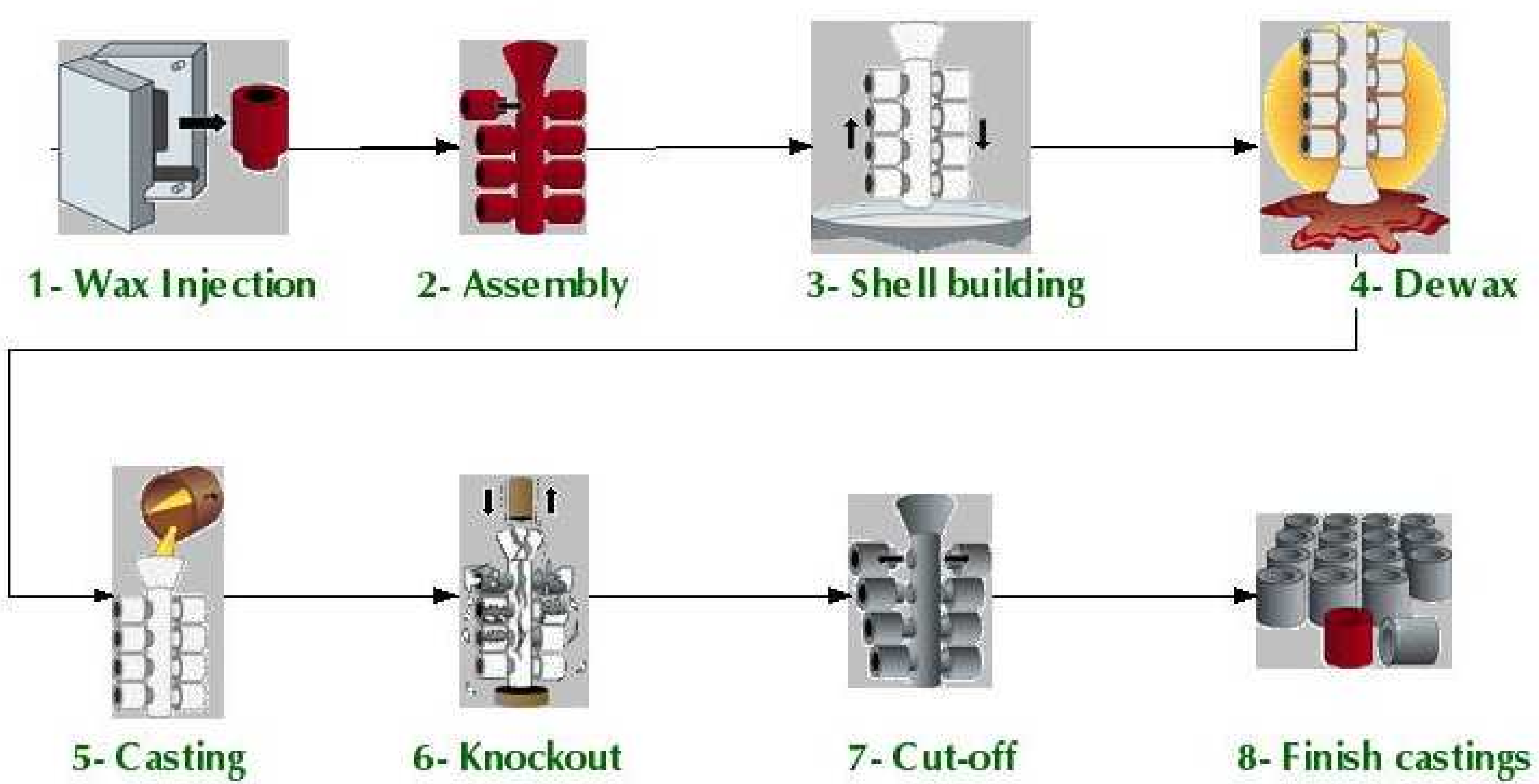



HITCHINER Manufacturing Co., Inc. 117 Old Wilton Road Milford, NH 03055 - USA

Hitchiner profile

- Established in 1946 , core business investment casting
- 1975 first patent for counter gravity Investment casting technology.
- $190M Sales (2011), 50% automotive, 50% aerospace
- 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

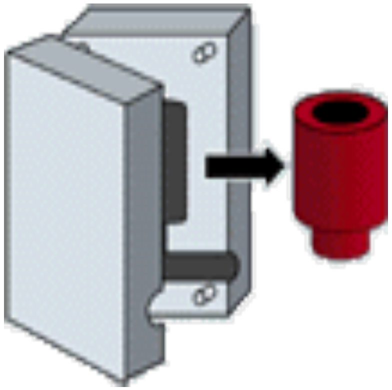
Investment Casting Process



Process stage 1: Wax

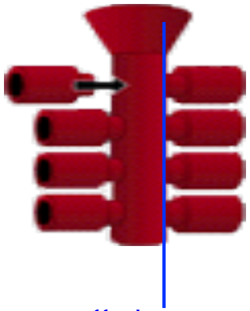
Conventional

Hitchiner



<u>Wax injection</u>

Multiple patterns injected in a ring



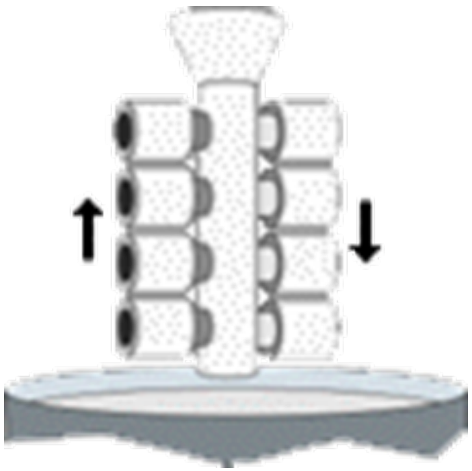
<u>Wax assembly</u>

Stacking of rings

Process stage 2: shell

Conventional

Hitchiner



Shell building

Robot processes multiple molds

Dewax

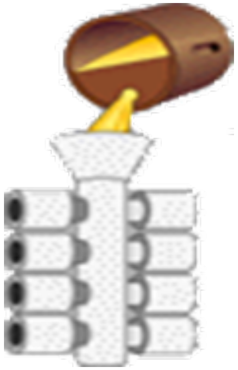
Autoclave with Wax recycle

Process stage 3: metal casting

Conventional

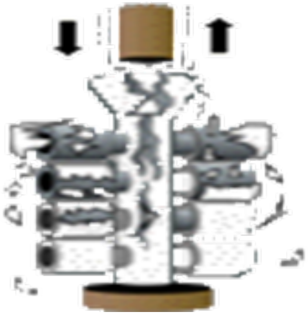
Hitchiner

Casting



Countergravity

Ceramic removal



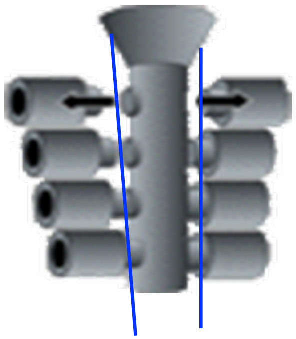
Automated blasting
On separated castings

Process stage 4: finishing

Conventional

Hitchiner

Cutoff from mold

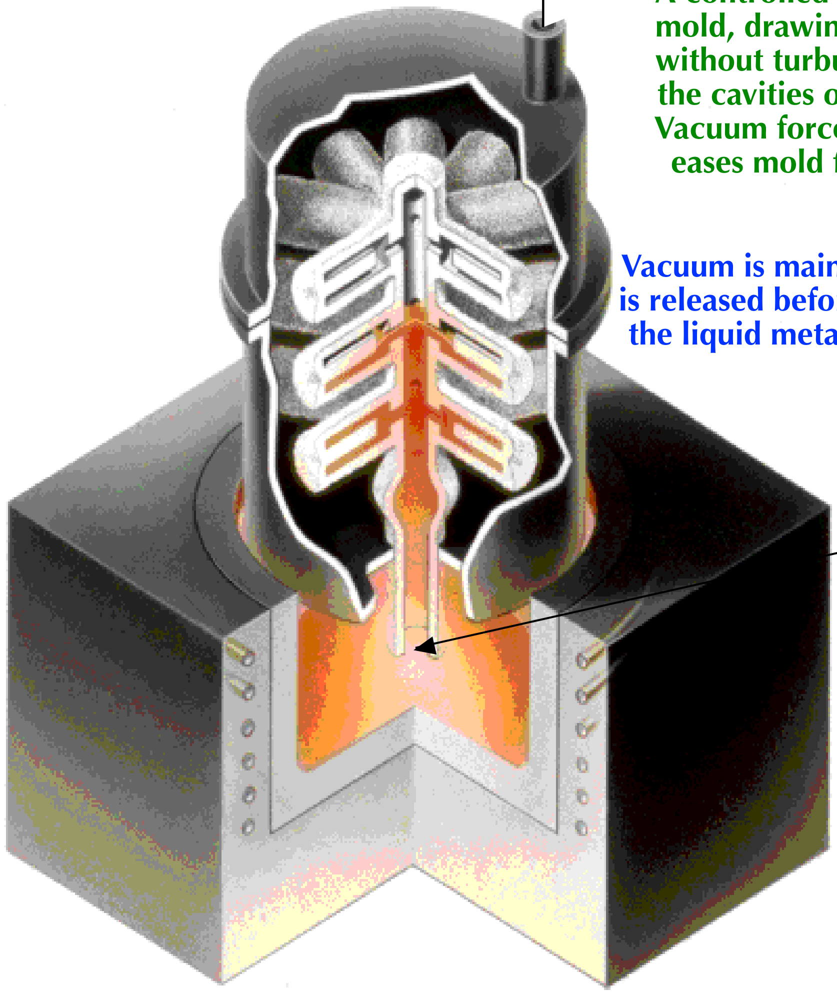


Cutoff planes

Not required, parts are
Not attached to each other

Finishing/machining

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.

Supported Shell Counter-gravity Low pressure Air melt casting

Quality Advantages by a Controlled Process

- **Cylindrical Symmetry arrangement of parts around a center sprue**
  - **Solidification control**
    - Uniform thermal gradients lead to good feeding and directional solidification

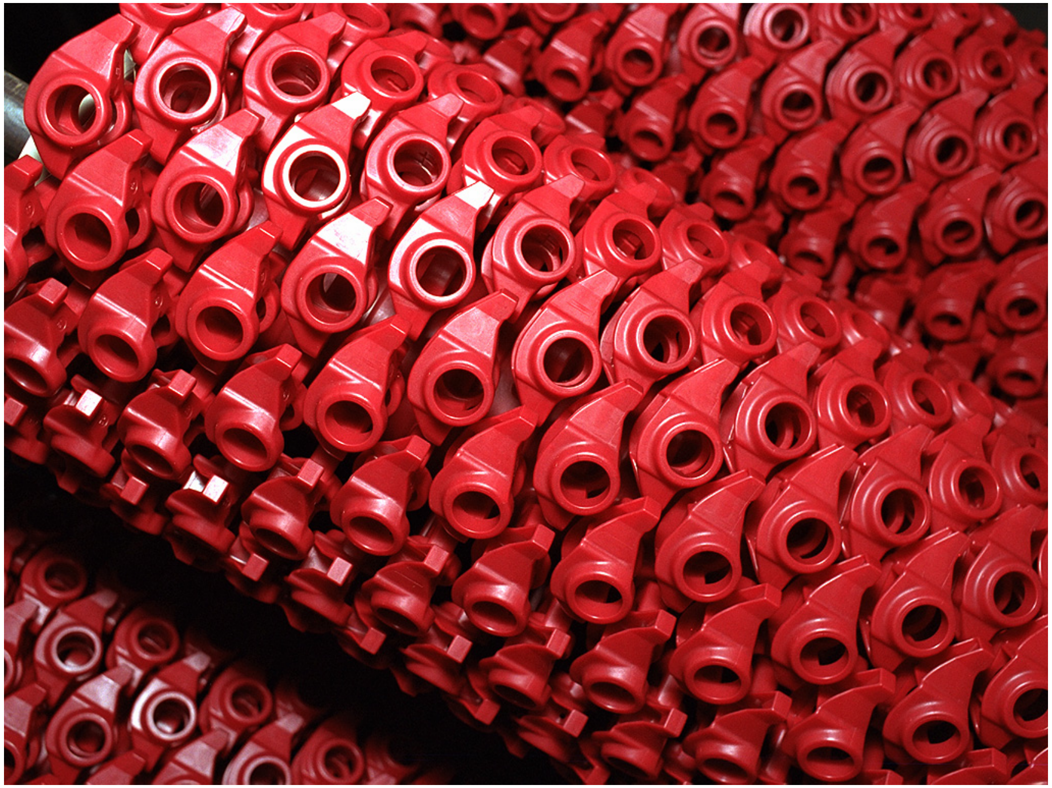
- **The molten metal is cast into the mold directly from the melting furnace**
  - **Excellent metal cleanliness**
    - Metal is drawn through a snout that enters the melt through clean metal.
    - In gravity pouring, the slag on the metal floats across the surface of the melt and can be poured into the mold creating inclusions
  - **Precise temperature control**
    - Furnace power can be adjusted to maintain constant metal temperature from mold to mold
    - 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
  - **Metal filling is controlled by the vacuum system compared to gravity pouring.**
    - Controlled rate of vacuum application for consistent and controlled mold filling
    - Thin walls and very fine details can be cast

- **High density sprue loading**
  - Central column not solidified returns to melt: castings are not attached when solid
  - High shell and foundry throughput for high volume part applications

High sprue loading

Central feeding
column not solidified

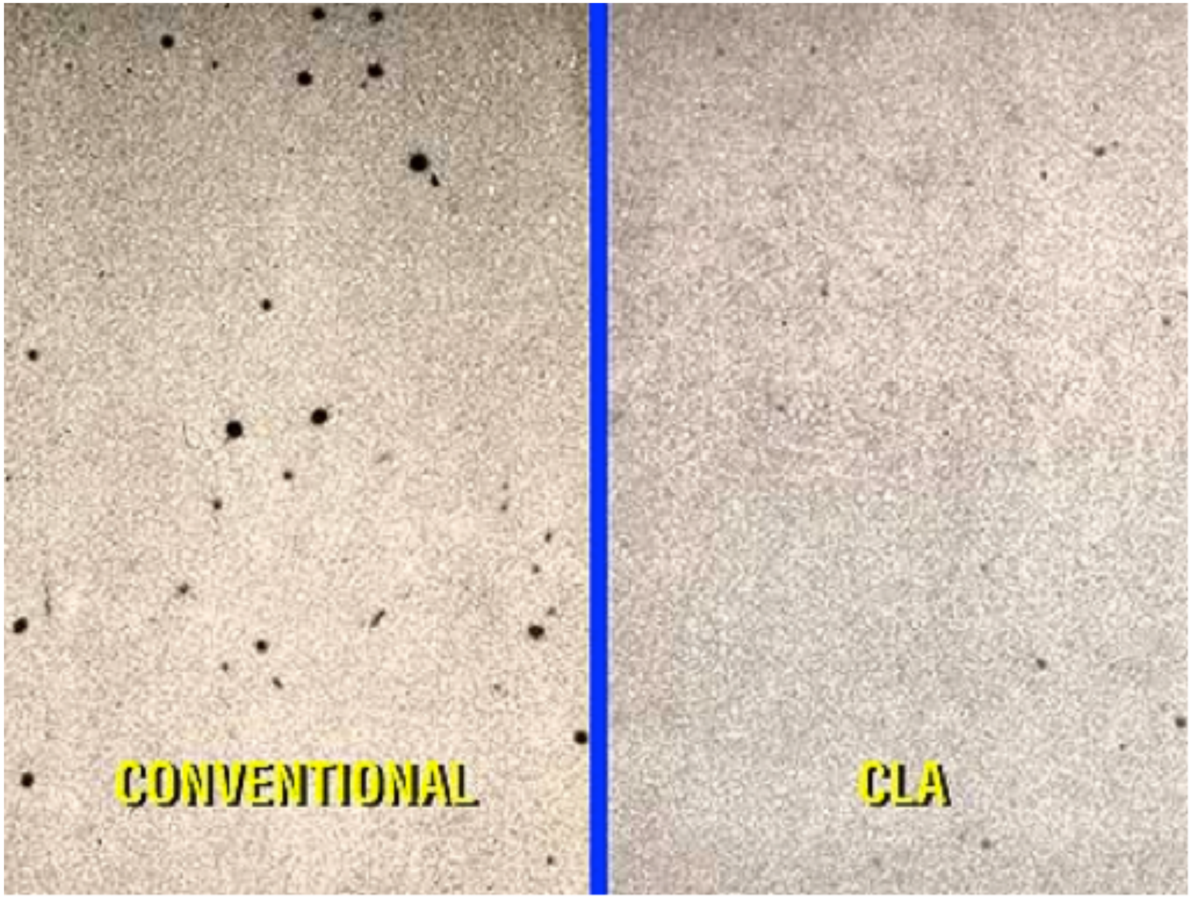
No need to space
Parts for gate cut off



Higher metal utilization

Feeding column not solidified (50% of total molten alloy)

Metallurgical cleanliness



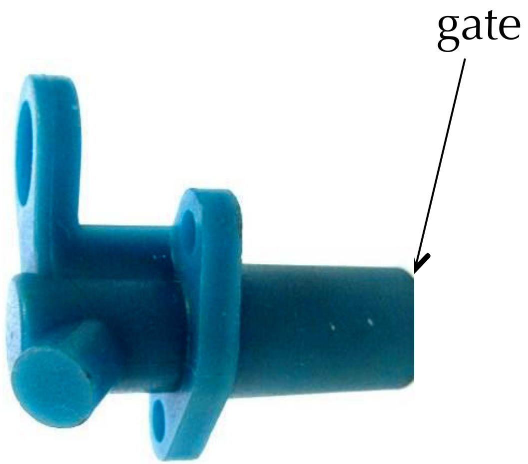
85% less inclusions in a CLA casting

GDI Fuel Rail injector Cups

GDI Fuel Rail

Example of GDI fuel rail complete assy with injector

Injector Cup

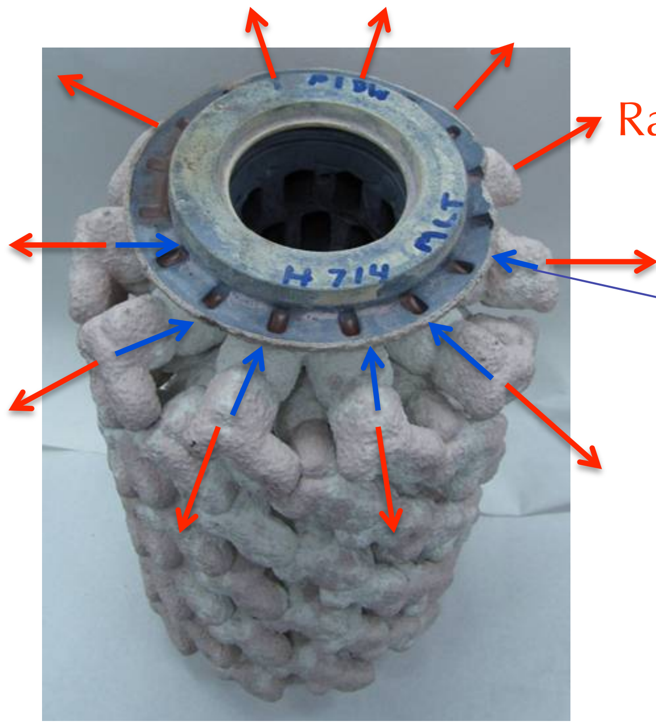


Wax pattern with gate/riser

Ceramic Shell after dewax

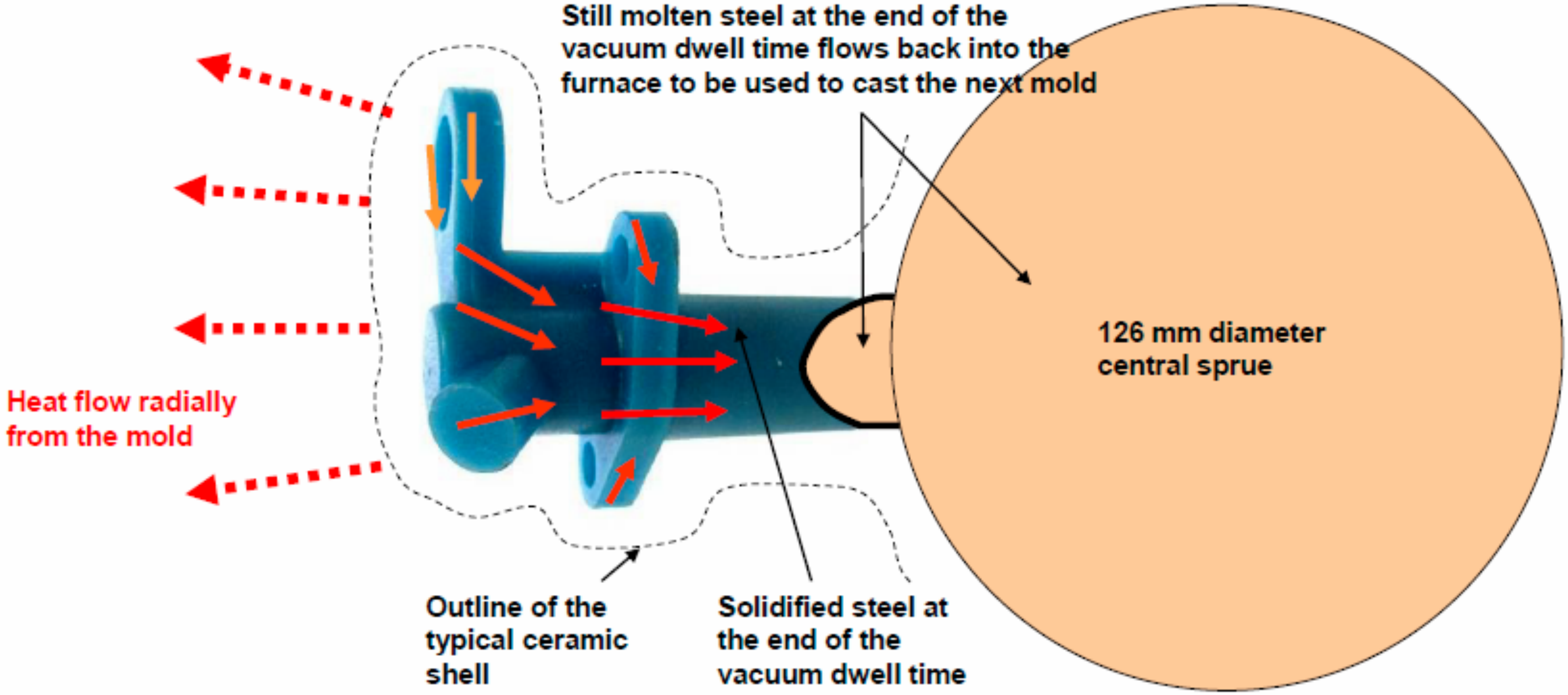
Counter gravity casting

Directional solidification



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

Schematic showing the directional solidification of the part.

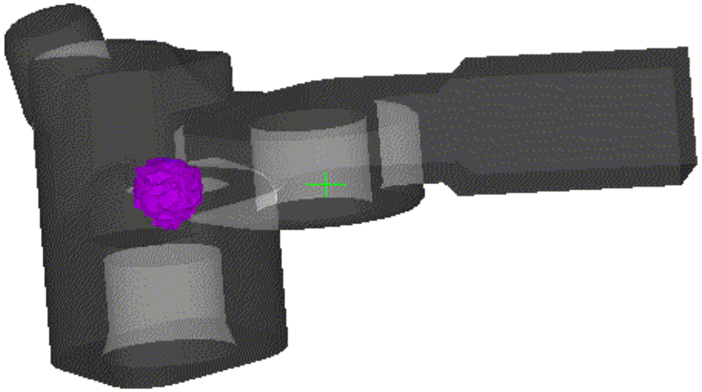


The part design as well as the gating position and size are important for directional solidification to occur properly

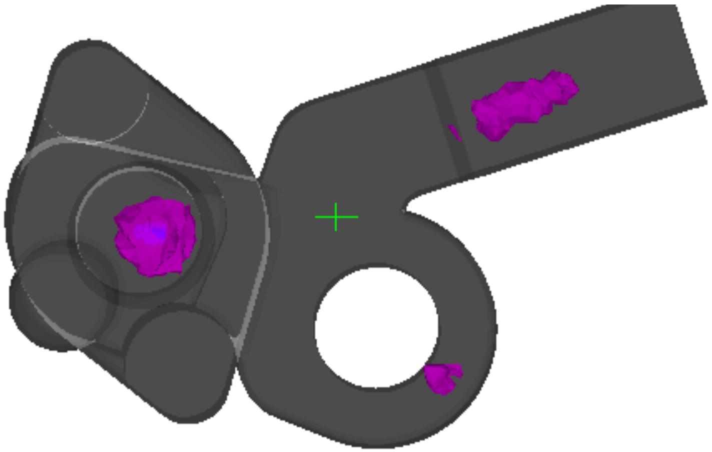
The gating size is optimized and verified during the prototype process. Production would use the verified gate geometry

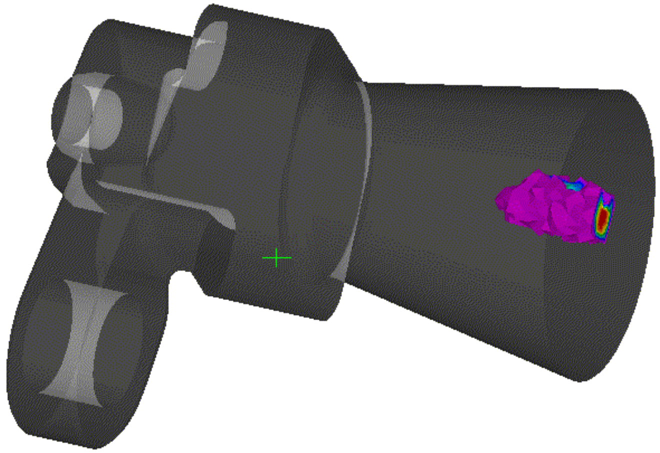
Solidification Modeling

Gate #1



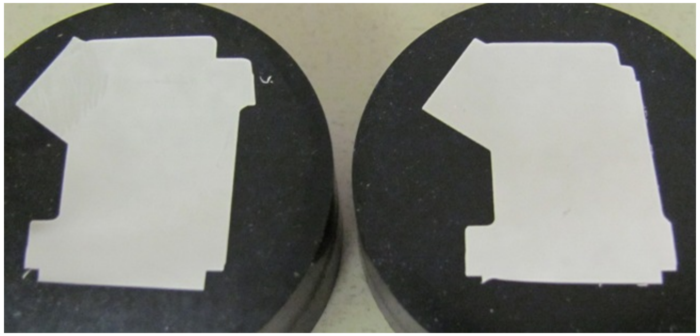
Gate #2



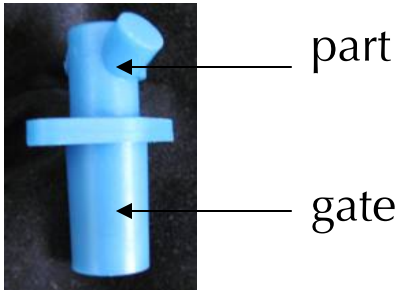


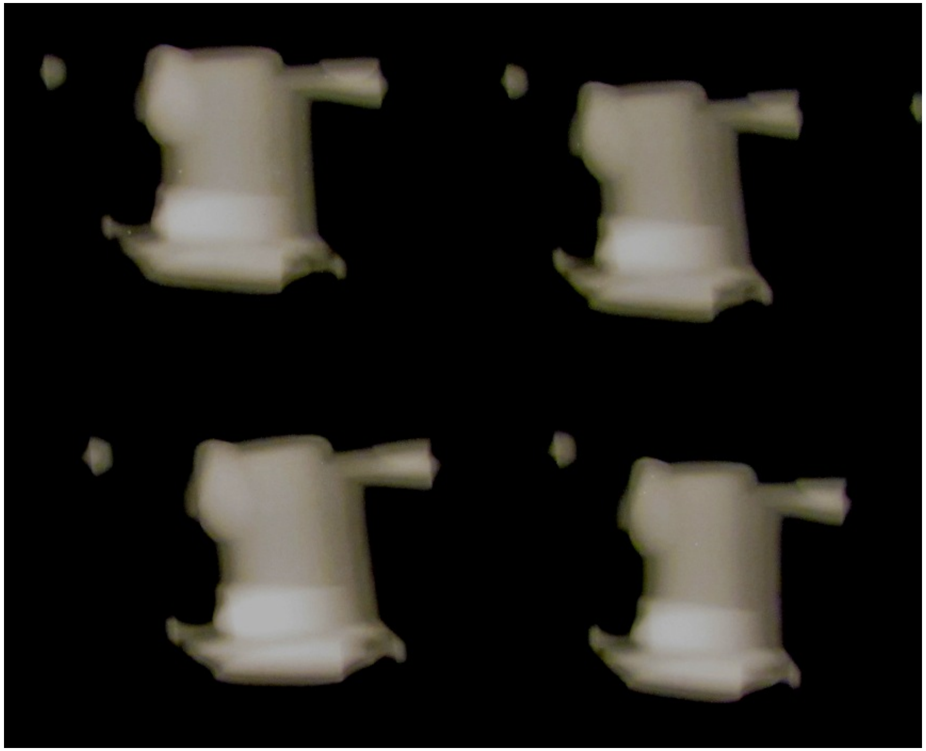
Final gate design

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.

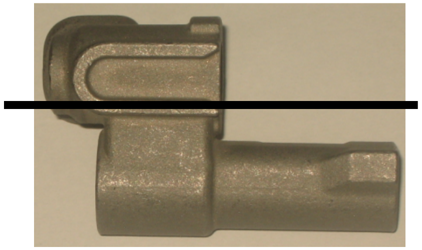
Fuel System Component Production

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

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"

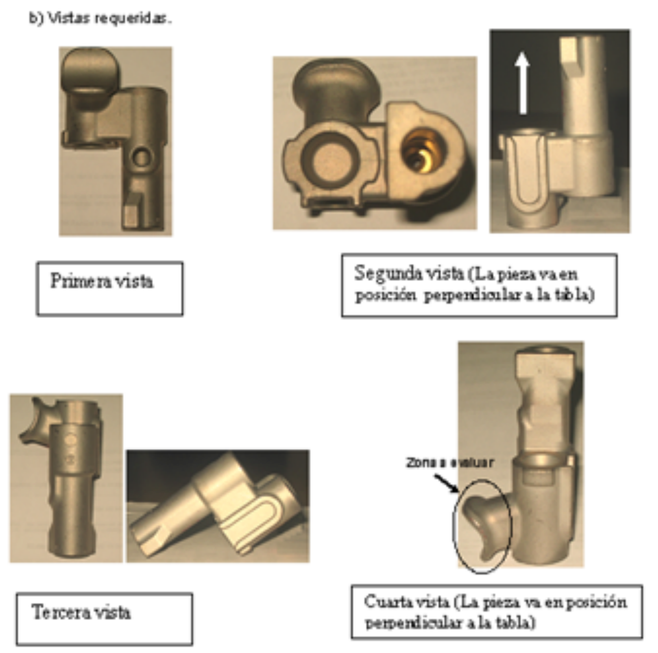
Example of X-Ray Inspection

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.

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Counter gravity beer: fast and clean

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