Casting Design Fundamentals

How casting design affects foundry process

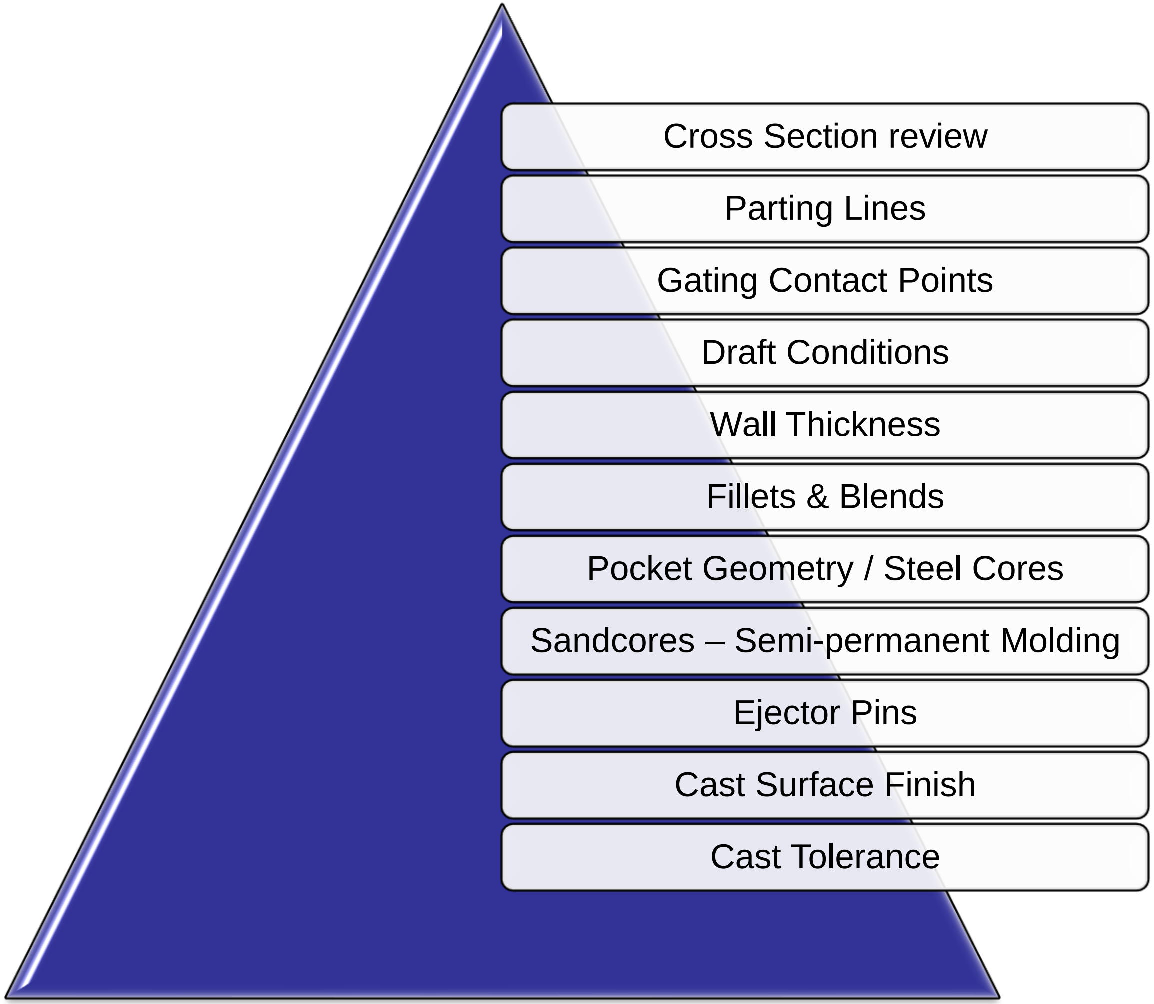
August 14, 2024

Casting quality starts with casting design

Geometry and shape choices affect a foundry's ability to maximize both the casting quality and output

- Process parameter ranges (temperatures; pouring rates)
- Soundness / x-ray
- Tool complexity
- Resulting surface finish
- Internal scrap rates for non-fills / cold shuts, weld repair
- Post processing complexity

The higher the expected quality level, the more paramount it is to follow optimal casting design guidelines


Cross Section review
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Cross Section Review

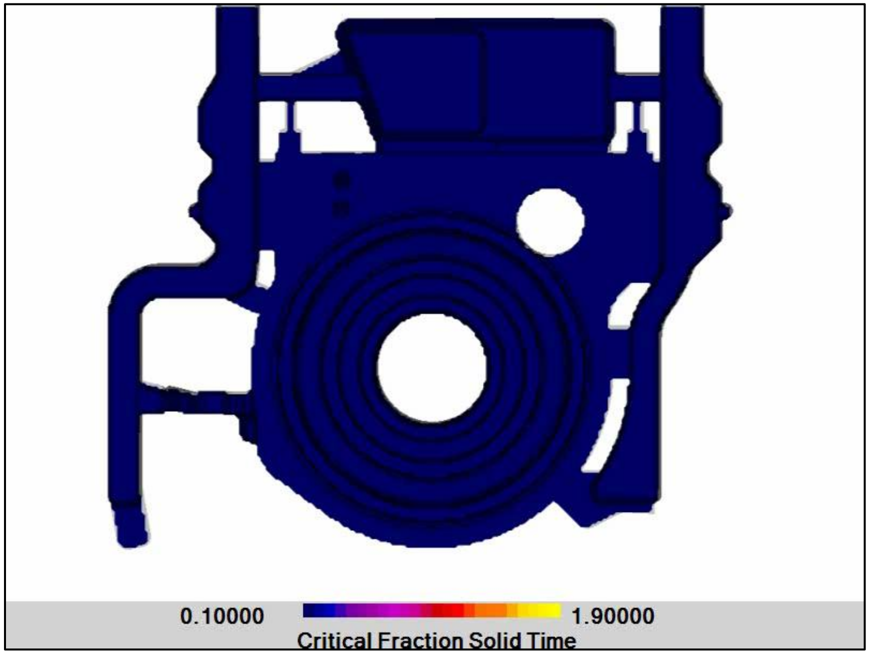
Most fundamental aspect of making a sound casting of high quality is directional solidification

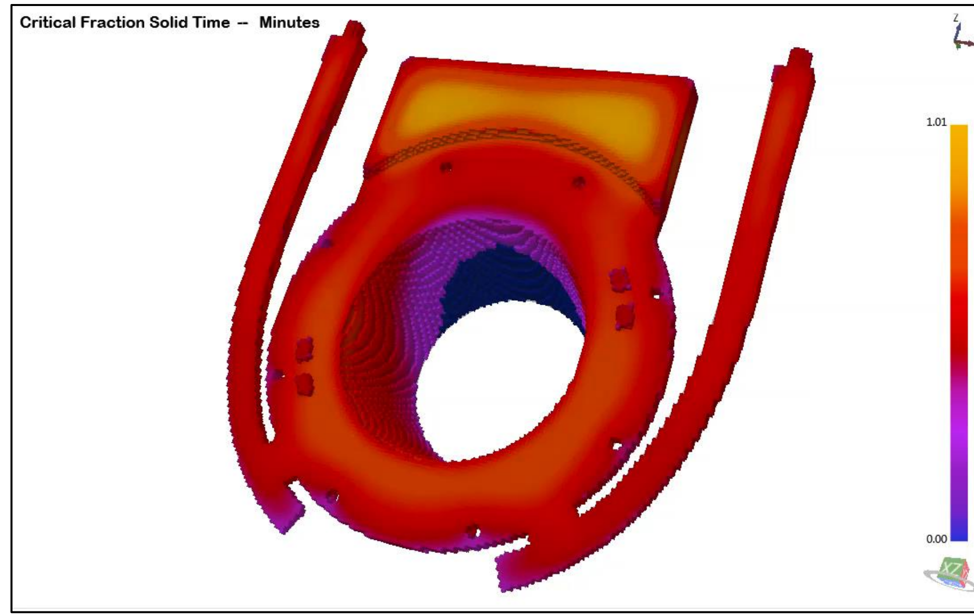
Heavy or thick cross sections are not always “bad”

Design goal should be to minimize the size of any isolated heavy sections that can not be connected directly to feed metal

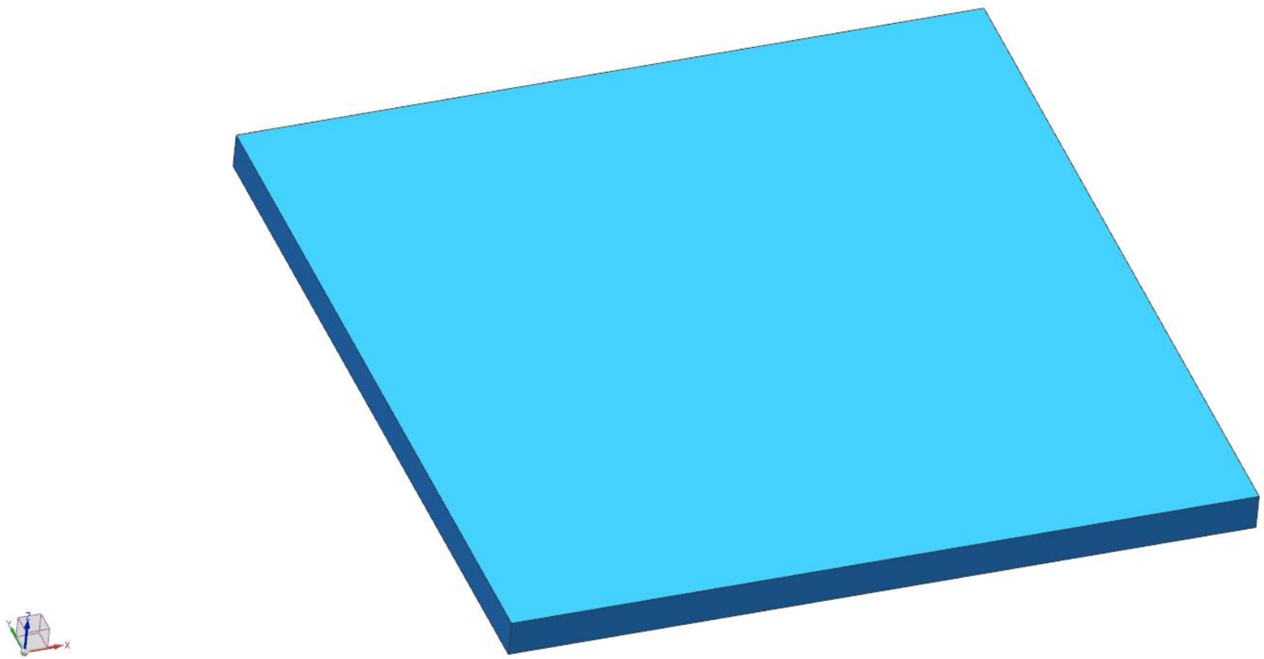
Optimal casting design allows the natural thermal response of the casting shape to establish proper directional solidification patterns

Non-directional Solidification Examples



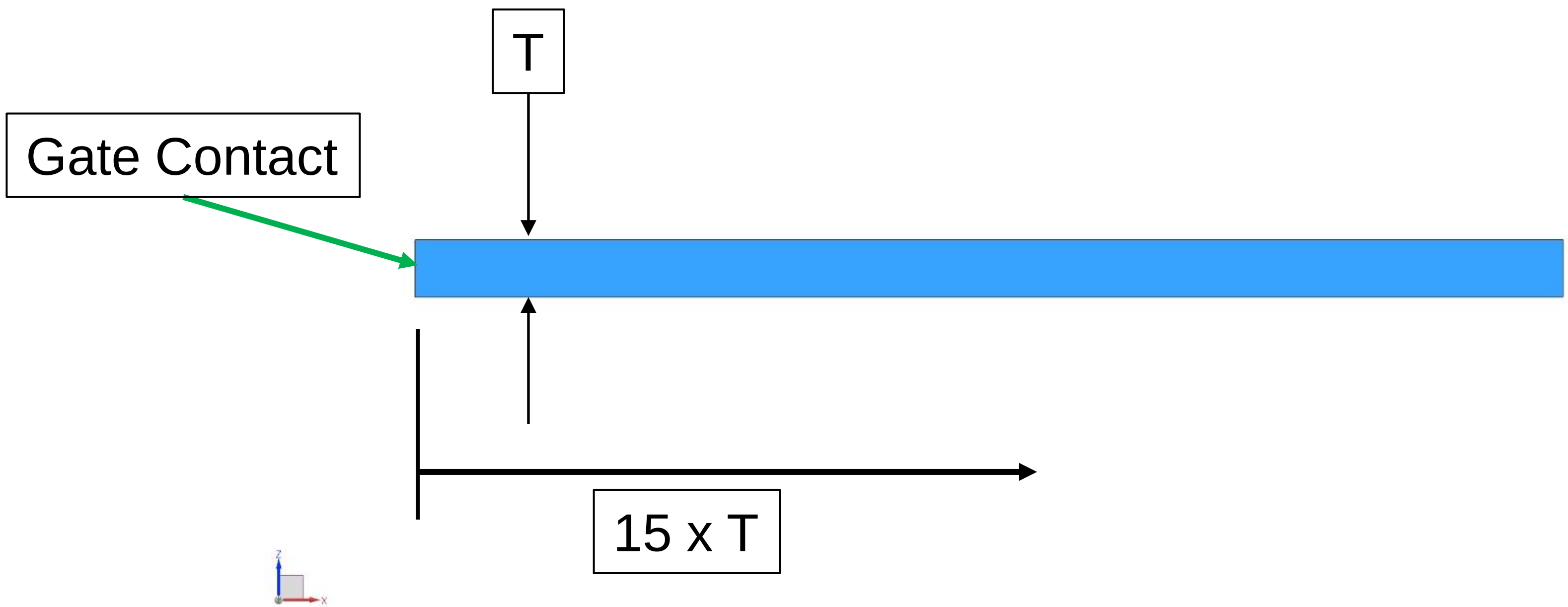


Feeding distance

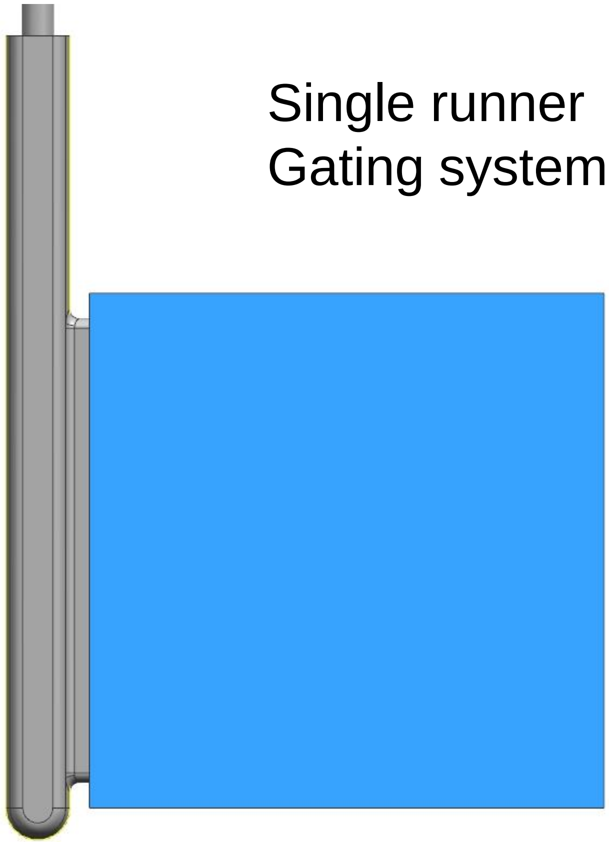


Simple plate
Casting

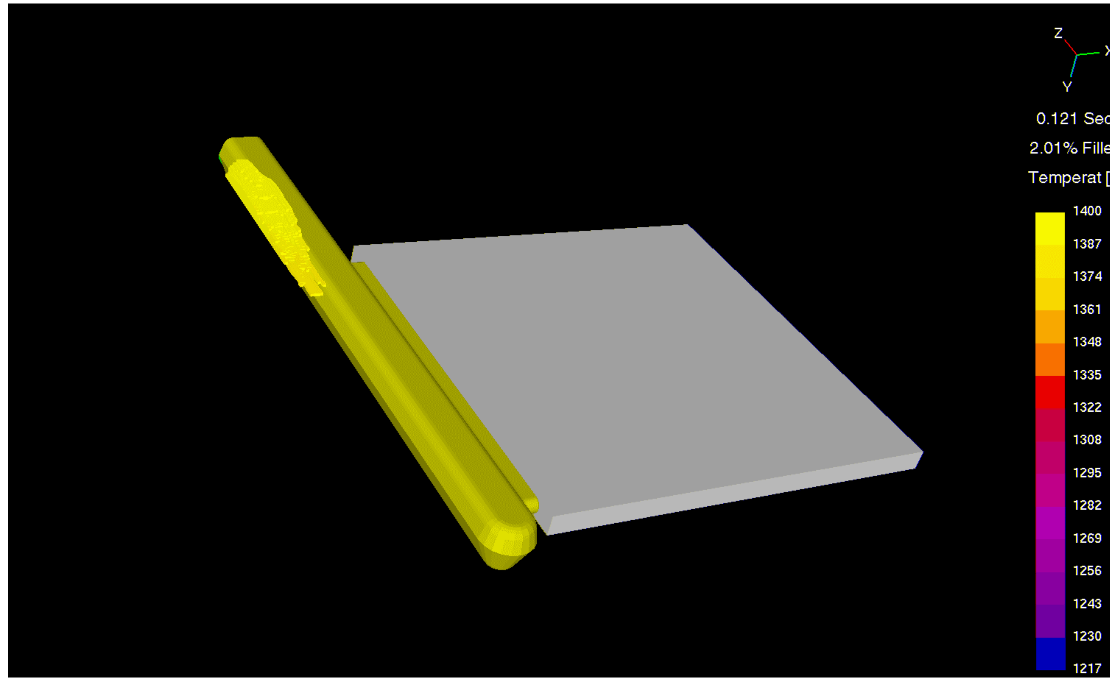
Feeding distance



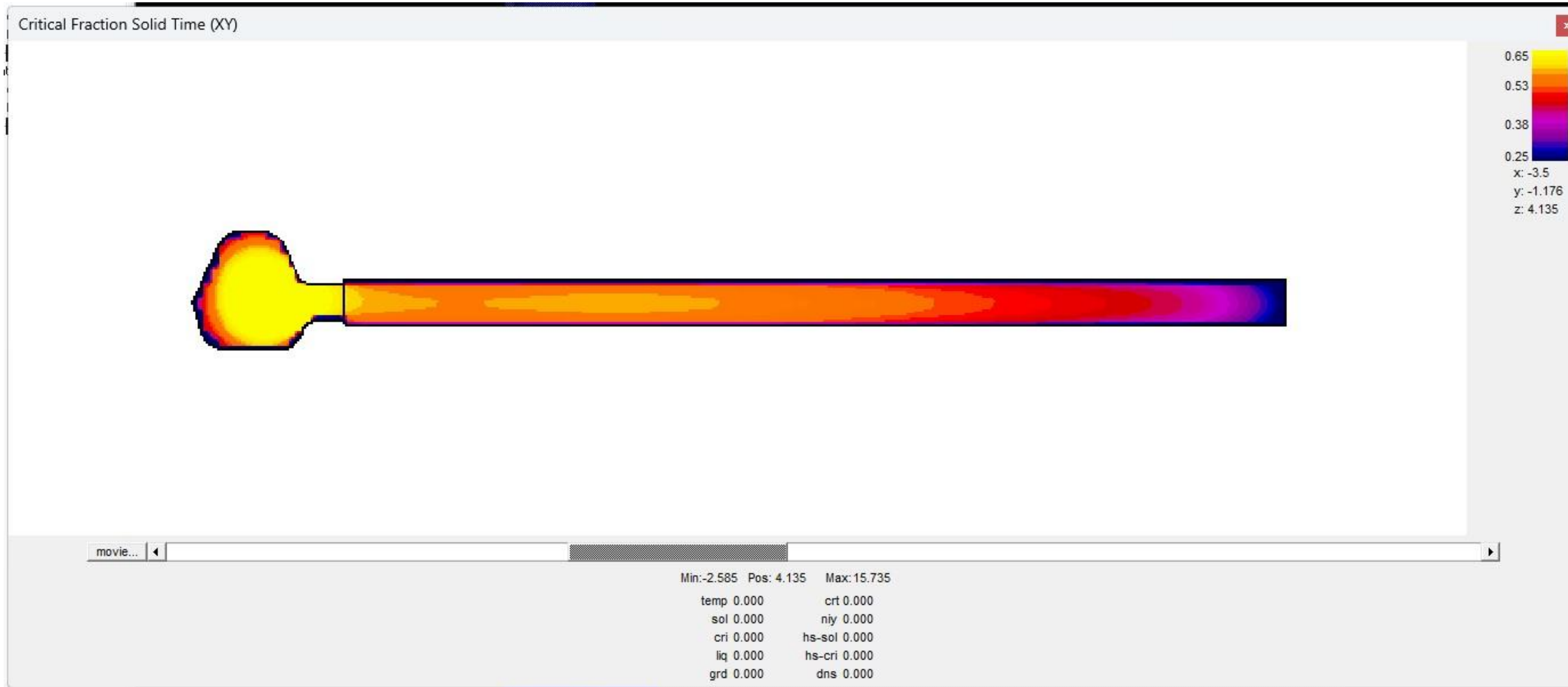
Feeding distance



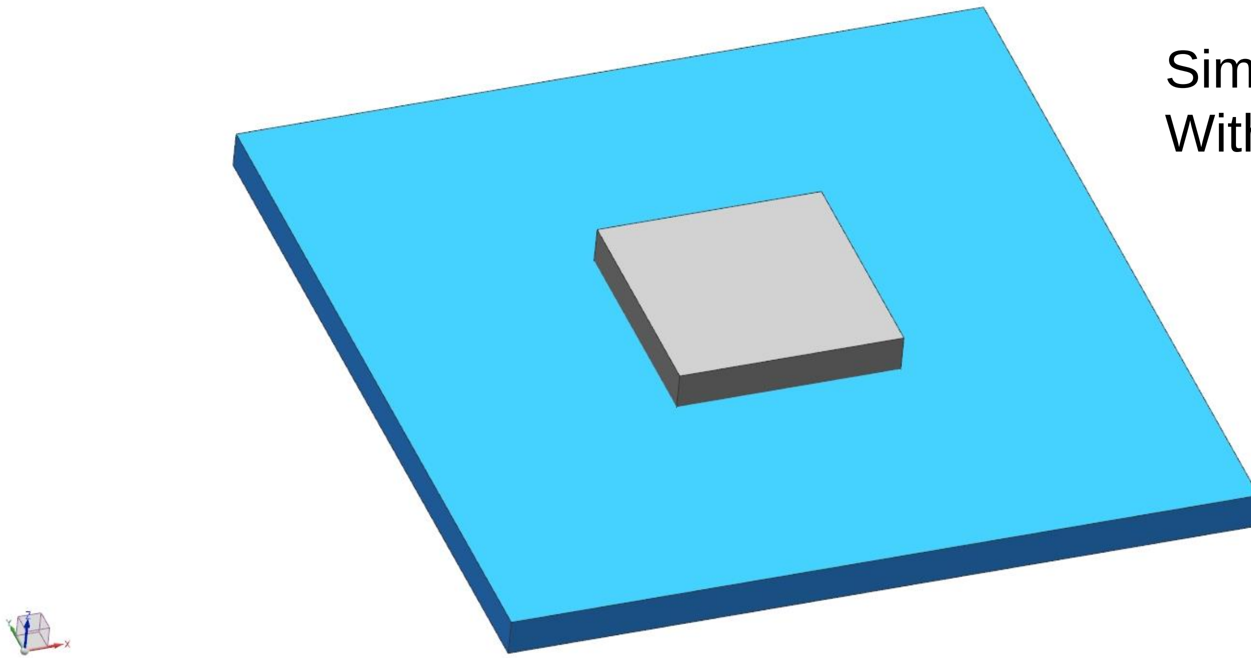
Single runner
Gating system



Feeding distance

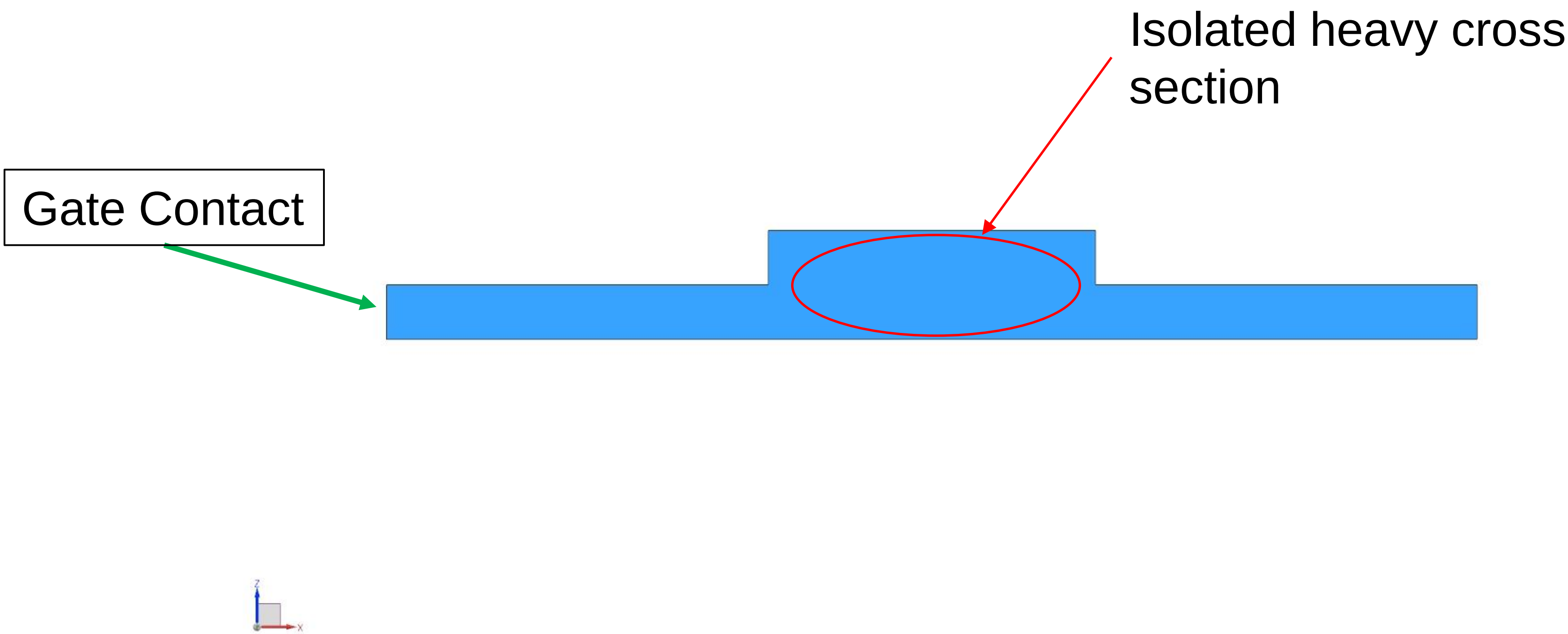


Isolated heavy cross section

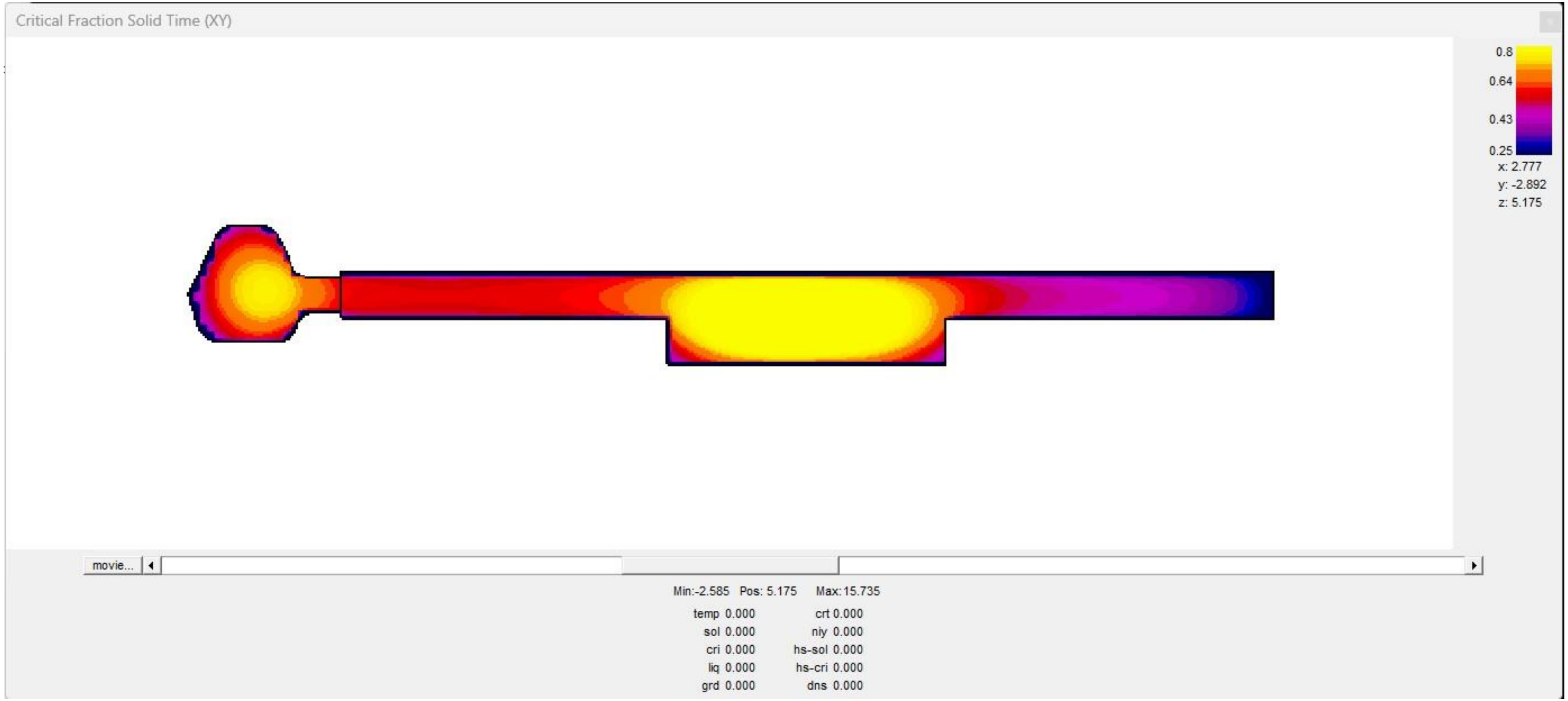


Simple plate
With isolated boss

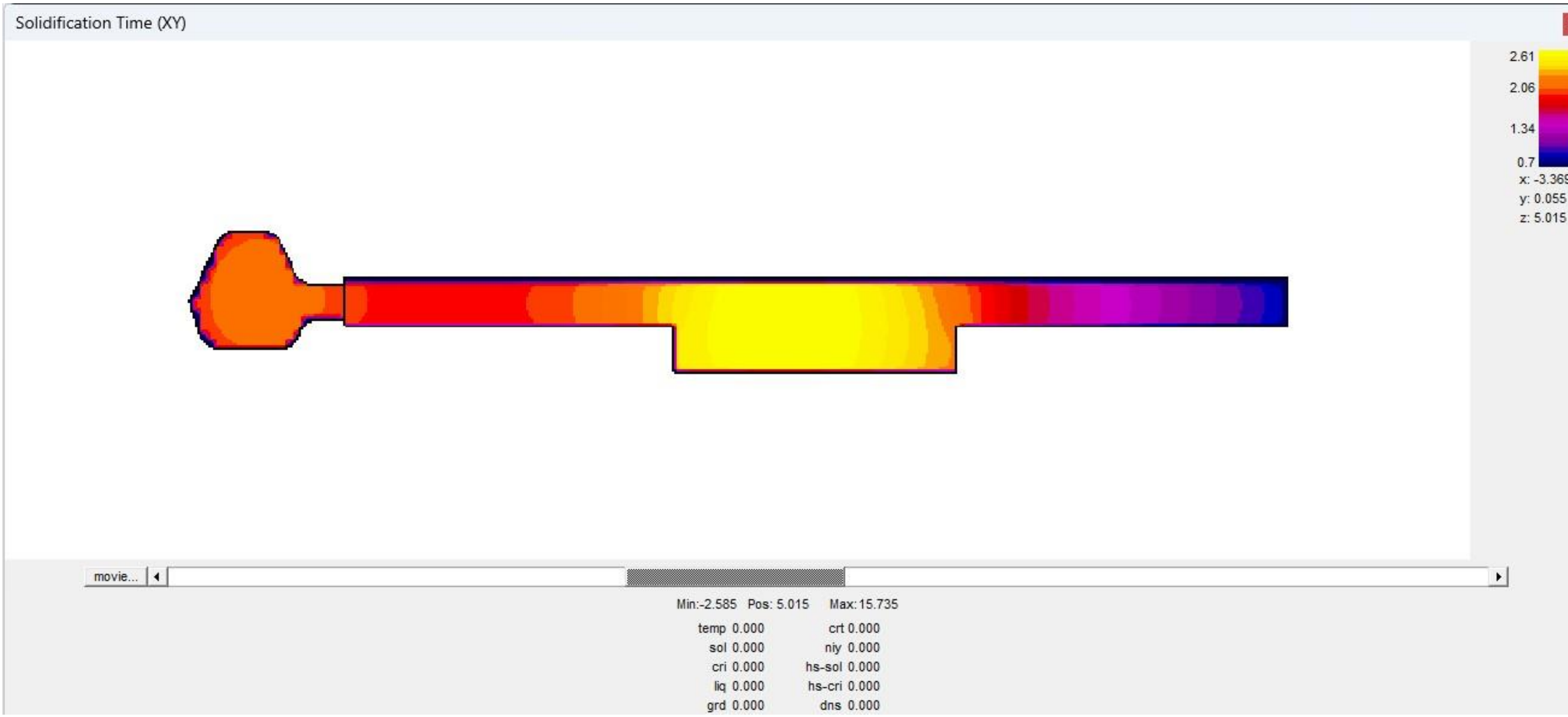
Isolated heavy cross section



Isolated heavy cross section



Additional concern with Cross sectional disparity – Hot Tears



Parting Lines

Parting line is the tooling split line defined by the casting geometry.

The most basic parting line is either a flat or contoured shape for a 2 piece mold

Parting shape must be “toolable” and provide a shape that supports the needed gating system for metal delivery

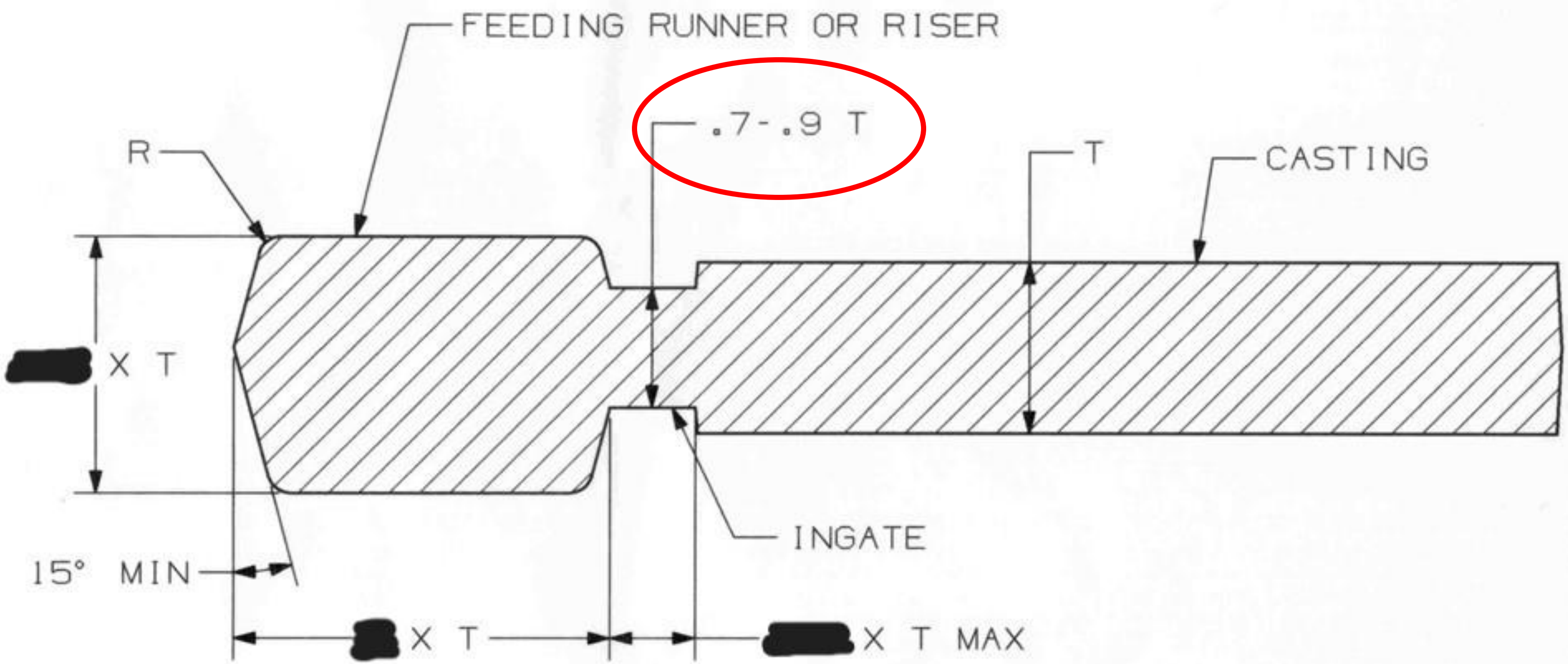
Complex parting line can have negative process effects

- Reduces number of cavities possible
- Can create turbulence in metal flow - transitions
- Can hold mold open at process temp
- Can reduce possible gate contact points
- Can increase tooling cost and casting cost (slides; sandcores)
- Post processing increases with complexity

Gating Contact Points

- Gating contacts serve to provide filling entry points for molten metal delivery
- Gating contacts also serve to provide liquid metal supply during solidification (feeding)
- Feeding contacts are sized according to the largest cross section that is being fed
- Filling contacts can be as thin as ~5mm as long as high velocities are not produced during filling
- Most gate contacts serve both functions

General Gating Contact Rule



Draft Conditions

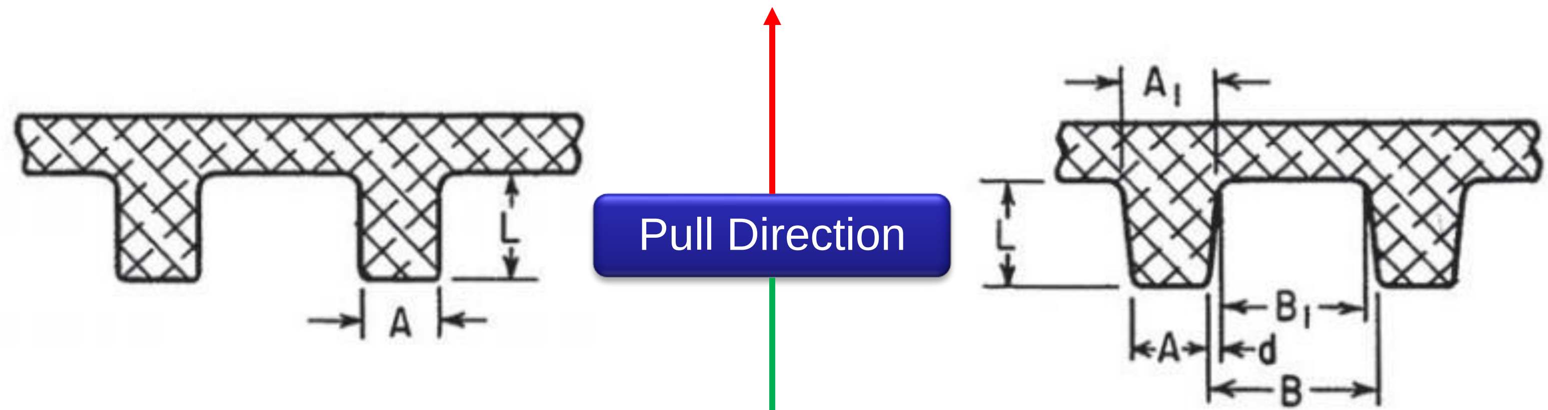


Figure 1 Figure 2

*Images extracted from Aluminum Association Standards

- 3 degrees of draft is the typical standard for die casting
- Draft is always measured in the tooling pull direction
- High pressure and sand casting processes can tolerate smaller drafts in many cases
- Surfaces with less than 3 degrees of draft should be minimized in size or ideally eliminated
- Reduced draft conditions will cause more difficult ejection and sticking which can lead to mechanical distortion
- Reduced draft conditions also erode cavity coatings prematurely, leading to surface drags and pop-off defects
- Generally, more draft is better unless it creates a local heavy section

Wall Thickness

Wall thickness is limited by fluidity (heat extraction rate) during filling

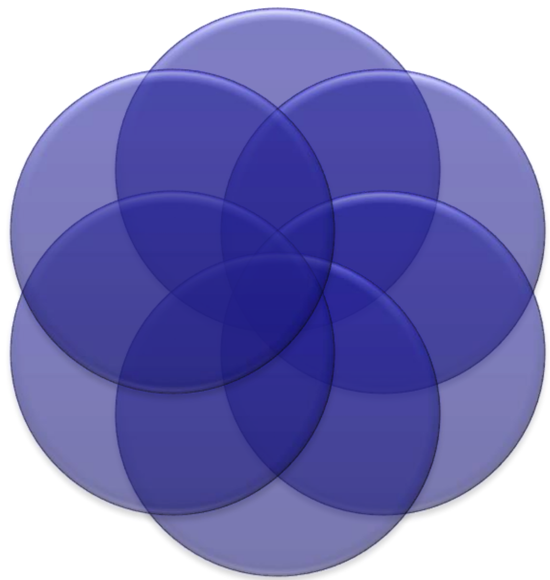
Thin walls require higher temps and faster filling times, both of which in most cases lead to reduced quality of castings, especially in moderate to heavy sections of the casting

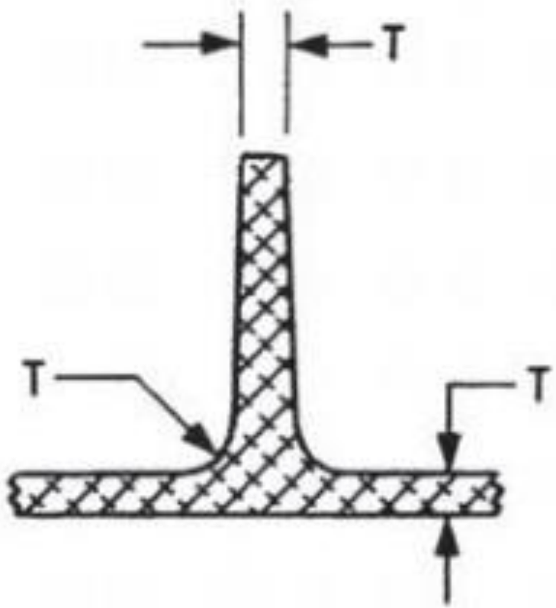
Permanent mold minimum wall – 4.5mm

Semi-permanent minimum wall – 5mm

Thinner walls than this can be achieved in limited / small regions, but not as a general overall wall thickness

Cross hatching can be utilized in many cases to promote / extend fluidity of thin regions





Wall thickness applies to ribs as well

Aspect ratios of ribs beyond 5xT can cause:

Difficulty in properly applying and maintaining mold coatings

Difficulty in cleaning and dressing mold during toolroom maintenance

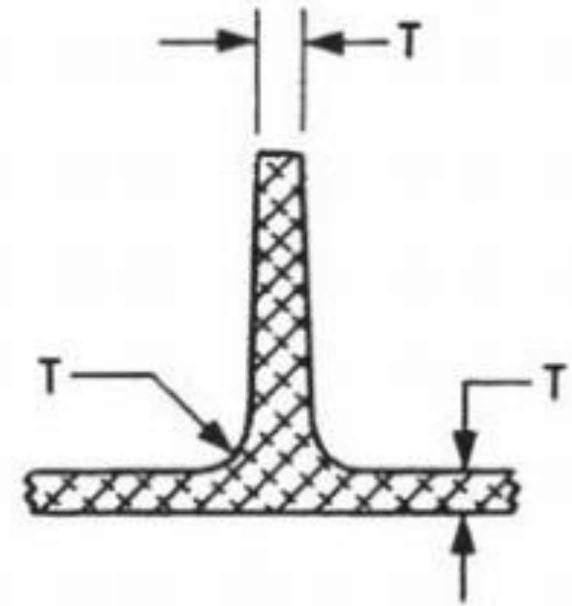
Increased tooling costs to cut the geometry (small end mills; EDM burn, Etc.)

*Images extracted from Aluminum Association Standards

Fillets & Blends

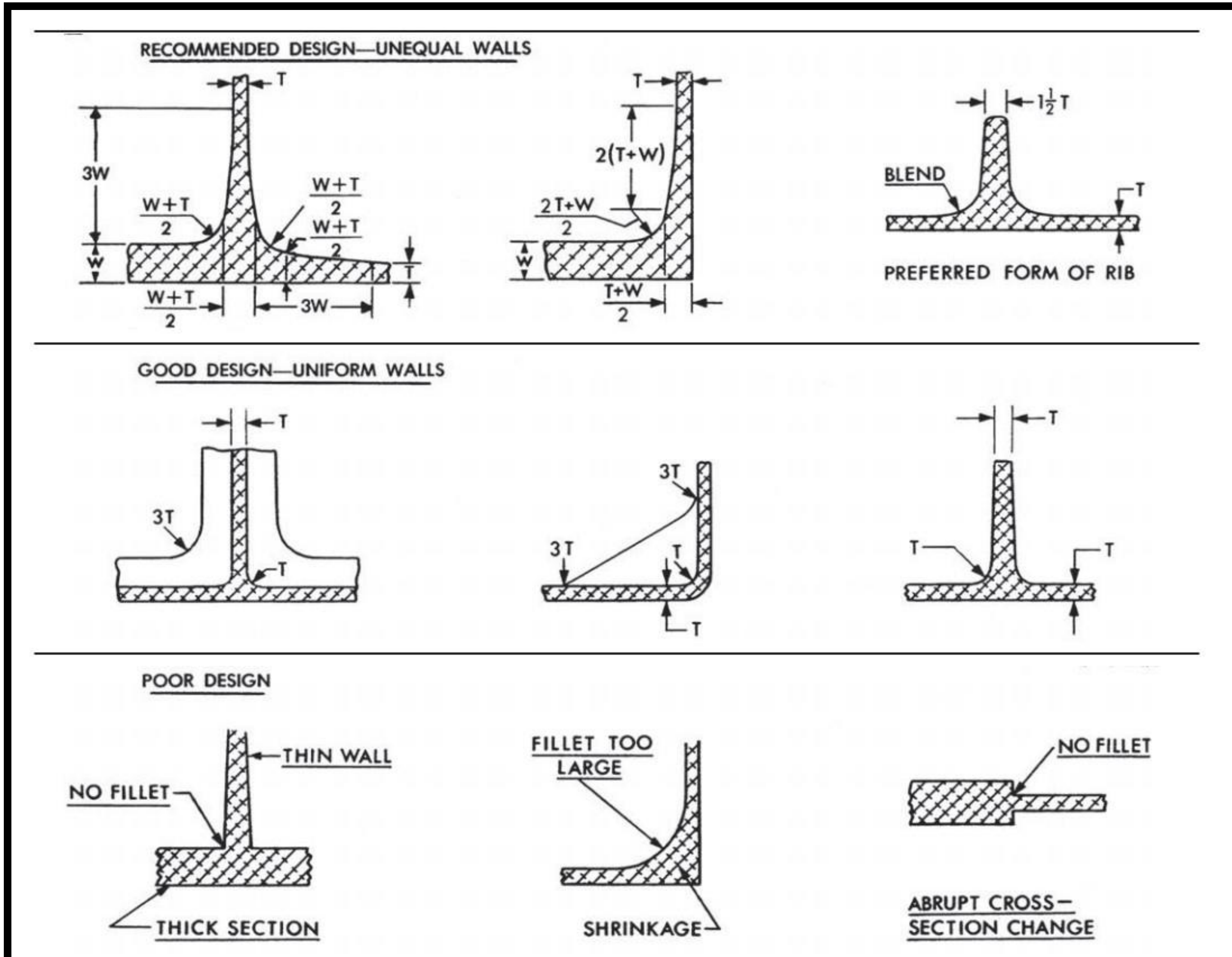
Most general rule for fillets is for the radius to match the wall thickness being blended

Similar to Draft, larger radii are typically better, unless it creates a local heavy section



Small radii in tooling create the following concerns:

- Vertical blends (in the direction of pull) require very small cutter diameters during tool manufacture
- Small fillet blends superheat due to converging heat flows which can cause local shrinkage defects and mold coating erosion and subsequent build up
- Small corner blends become premature crack initiation sites within the tooling



*Images extracted from Aluminum Association Standards

Pocket Geometry / Steel Cores

- Weight savers or pocket geometry can easily create poor tooling shapes that do not manage heat well
- This can result in hot spots in the tooling that is equivalent to an isolated heavy cross section
- Typical recommendation is a ratio of depth to width of 3:1
- Widths of 2” of greater can have larger ratios, but will still operate at a higher bulk temperature due to converging heat flow

Sandcores

Many geometries require the use of a sandcore to make undercuts in pull direction or passages and chambers

This process is called Semi-permanent Molding

Sandcore shapes must follow the same guidelines for draft and parting line development as previously discussed for castings

Design Considerations when using a sandcore

- Core prints (openings in the casting) that are at least as large as the internal sand cross section
- Small core openings can restrict sand removal or trap sand within the casting during cleaning
- Core openings need to touch off on both mold halves for stability in the closed mold condition
- Cored openings need to create a stable pattern in the drag half of the mold for dimensional stability (c.g. of core within the touch off pattern)

Ejector Pins

Ejector pins are a crucial part of die casting processes

Pins transfer force from the casting machine into the molded casting to effectively “push” the casting off the mold shapes

If pin sizes are too small, or the number of pins is too few, it can cause distorted parts

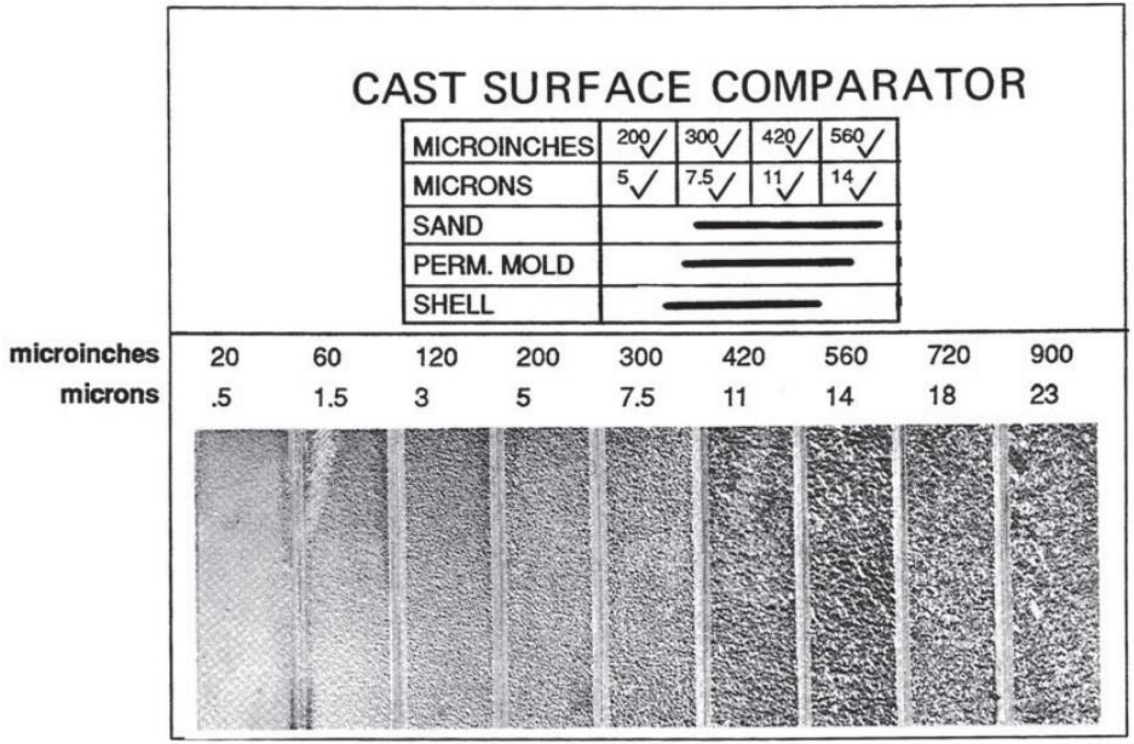
Pins serve a secondary role as a vent, and in many cases are added to rib like features to help evacuate air that is being displaced by the incoming metal

In the case of ribs or small features, it may require a boss feature to be added to the shape to support a sufficiently sized diameter ejector pin

Cast Surface Finish

Many of the factors discussed today can affect the resulting surface finish

- Castings with feeding problems (isolated heavy sections) will end up having rougher or varying surface finish because of required changes to the coatings to help promote the missing directional solidification
- Castings with reduced draft will have rougher surface finish due to frequent additional release coatings and repeated repair of eroded coatings
- Castings with thin walls or thin regions will have rougher surface finish based on repeated addition of coating to fight non-fills and cold shuts



Permanent mold process produces a cast surface finish between 200-500rms

Superior surface finishes can be achieved in hie pressure die casting, investment casting, and in some sand processes

Cast Tolerance

Recommend the Aluminum Association Standard as a design reference for tolerance expectations

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Understanding the predicted profile tolerance will help the designer determine:

- Assembly clearance conditions
- Machine stock requirements
- Minimum wall conditions between cast content and machined content