Part and tooling design

Eastman Tritan™ copolyester

Part and tooling design

- Process
- Part design
- Tooling design
- High cavitation considerations

Process

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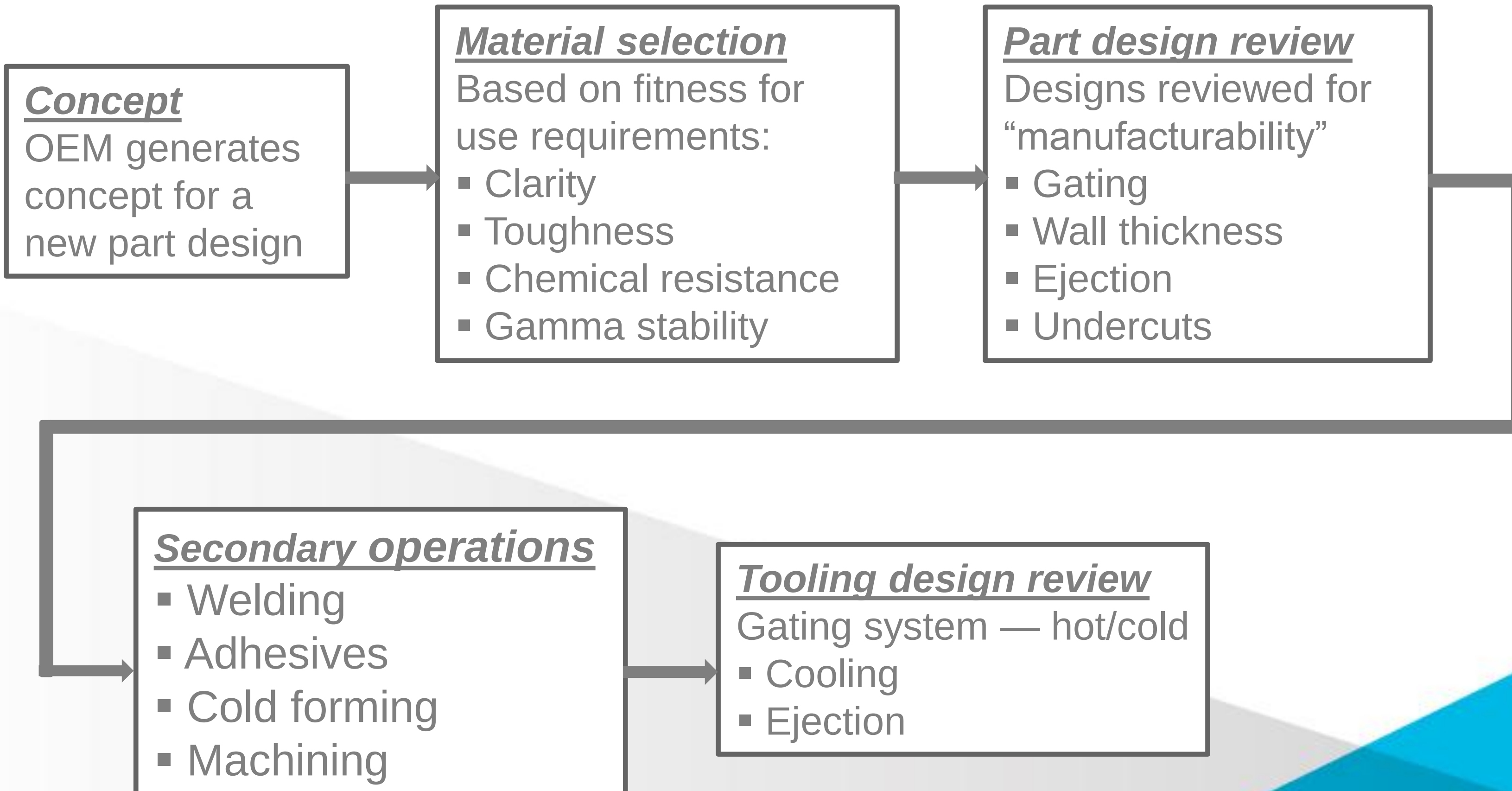
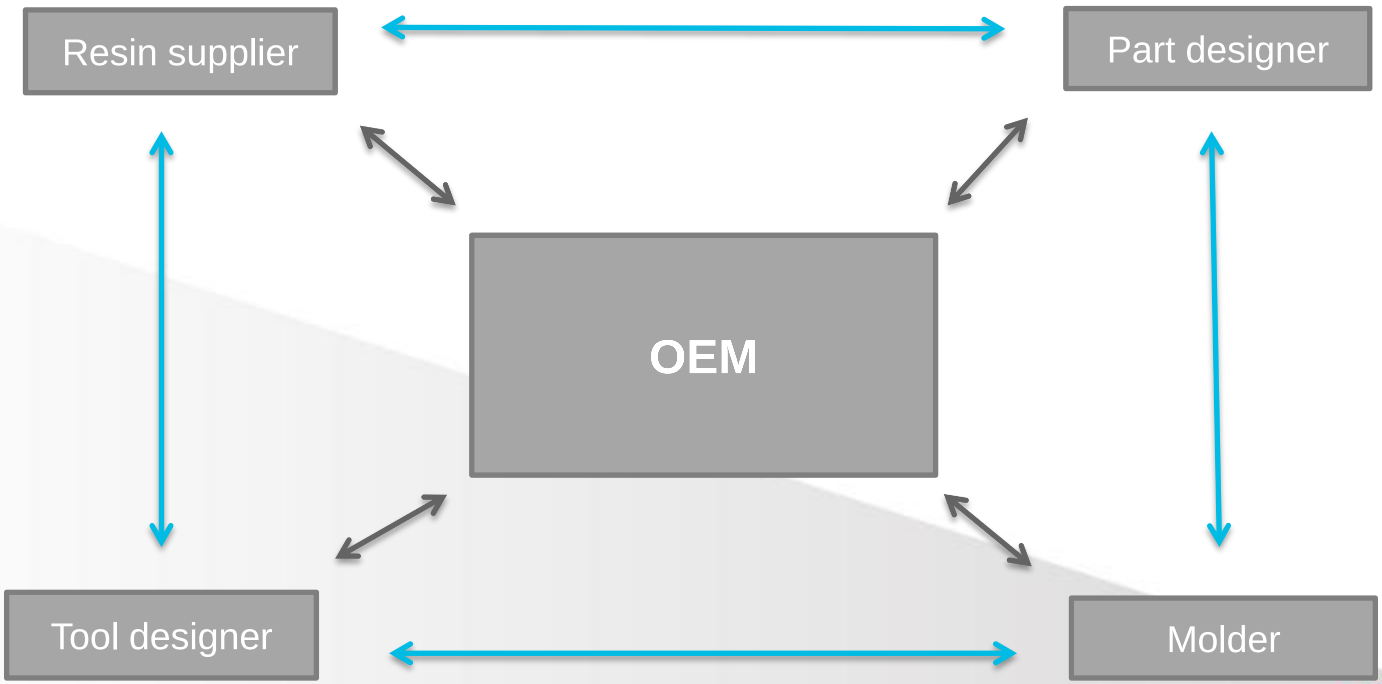
Process — Project development flow chart



Collaboration

Chances of success in injection molding application development projects are increased with ***early involvement of all major stakeholders.***



Benefits of collaboration

- Lower scrap rate
- Optimized cycle times
- Optimized part performance
- Reduced product development time

Greater return on investment for everyone

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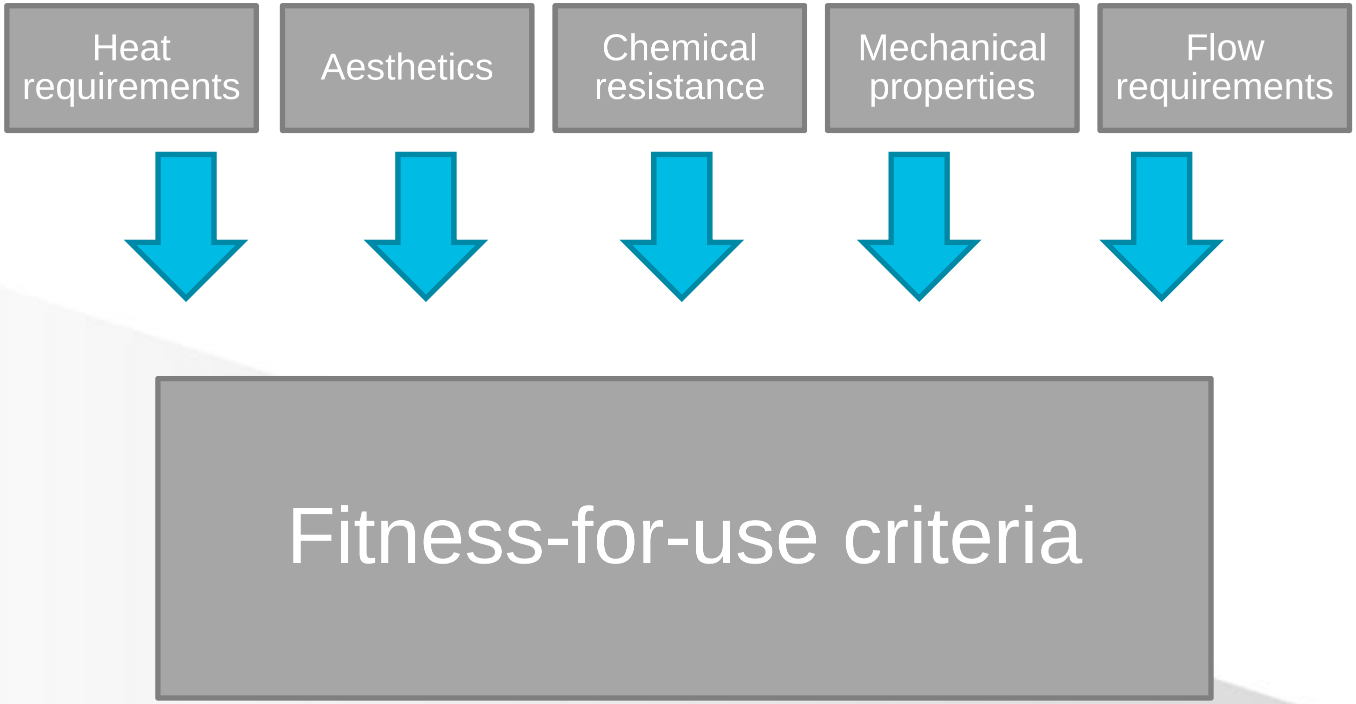
Part design

Part design – Proper resin requirements



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Part design — Reasonable fill pressure requirements

Improves the "moldability" of a design

- Excessive fill pressures can result in injection molding challenges.
  - High clamp tonnage requirements
  - Reduced life of mold components due to high stress loading
  - Higher ejection force requirements
  - Tendency for molders to run excessive melt temperatures to reduce fill pressures

Eastman uses mold filling simulation to estimate required fill pressure for a proposed part design. The target maximum fill pressure for a part design as determined is 15,000 psi or 20,000 psi if the simulation model includes runner and gate.

Resin	MFR (g/10 min, 280 C, 1.25 kg load)
Tritan MX711	7
Tritan MX811	8
Tritan MX731	18
Bayer Makrolon 2658	12
Bayer Makrolon 2458	20

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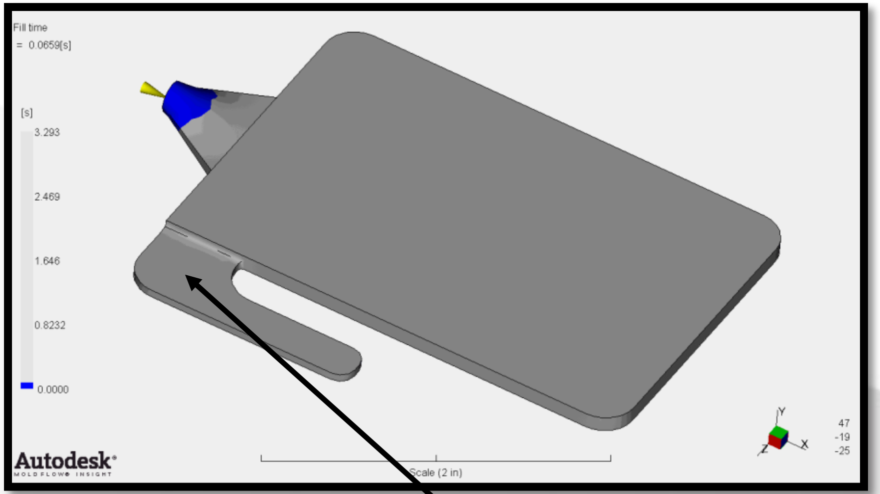
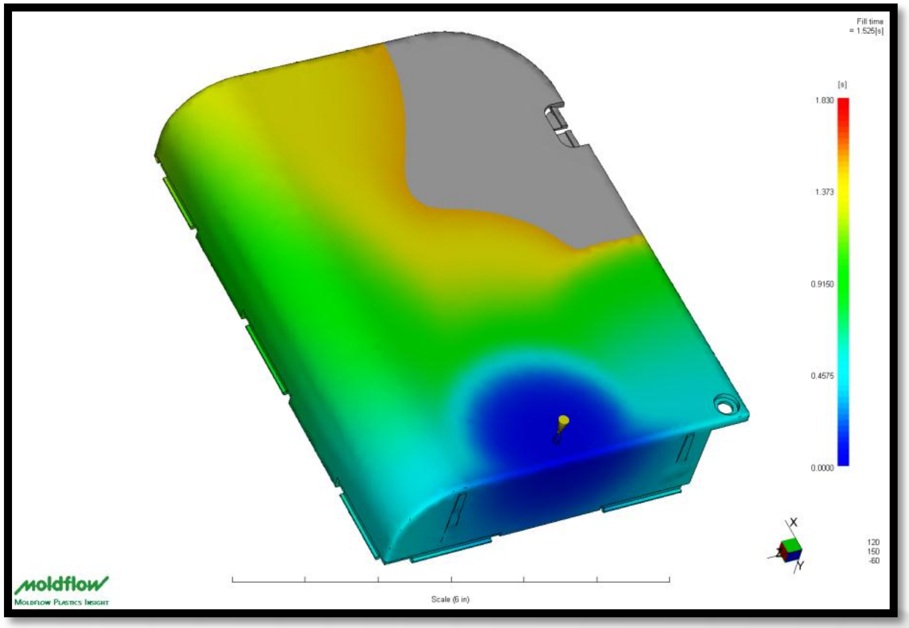
Part design — Reasonable fill pattern

- Eastman uses mold filling simulation to predict the fill pattern of a proposed part design and gate location which is effective in predicting potential fill pattern problems.
  - Weld lines
  - Air traps
  - Flow front hesitation
- These often require costly modifications to correct after tooling construction.



Flow front hesitation resulting in incomplete fill

Part design — Reasonable fill pattern



Predicted fill pattern

Actual fill pattern

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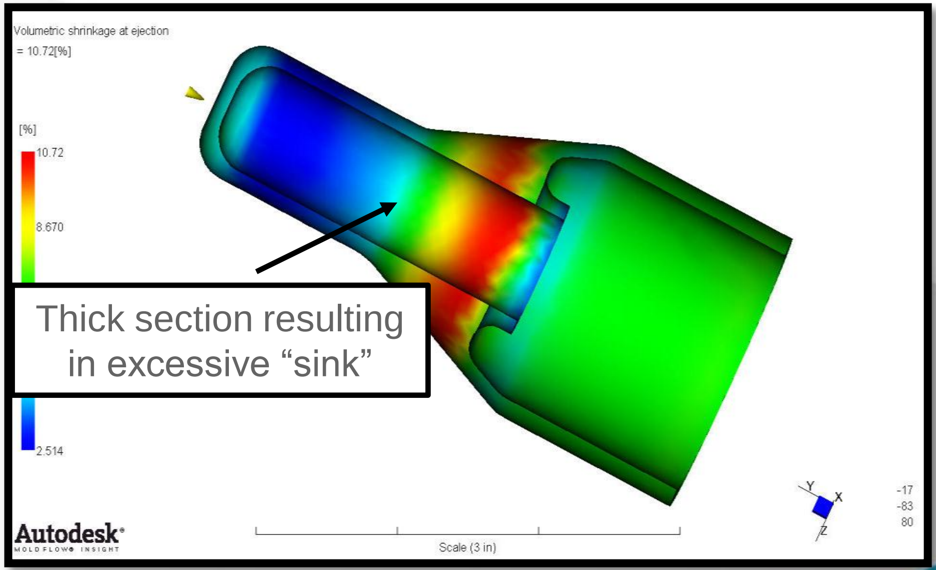
Part design — Eliminate areas of excessive "shrink"

- Excessive volumetric shrinkage during the injection molding process can result in part appearance defects.
  - Sinks on the part surface
  - Vacuum voids (appear as bubbles)
- Eastman uses mold filling simulation to predict "volumetric shrinkage" levels in proposed part designs, and the guideline is 6% maximum volumetric shrinkage for proposed part designs.



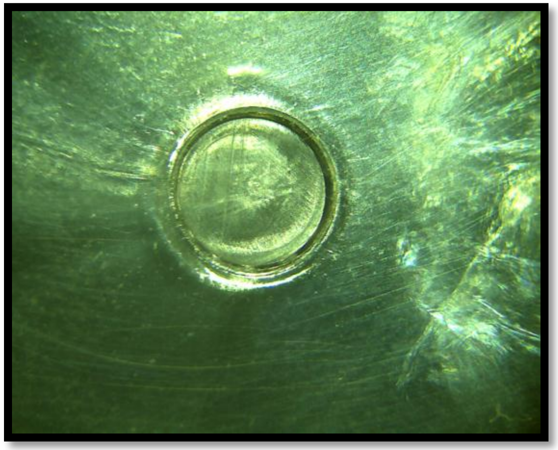
Part design — Gate location considerations

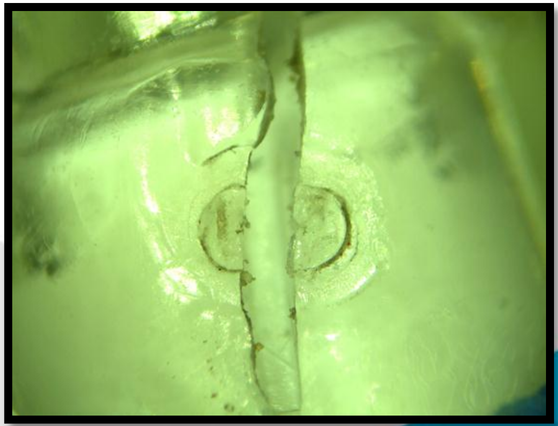
Aesthetics

- The gate location on an injection molded part leaves a “witness” where the part is separated from the runner system and is considered an appearance defect, typically hidden in an area of the part that is not obvious.

Mechanical properties

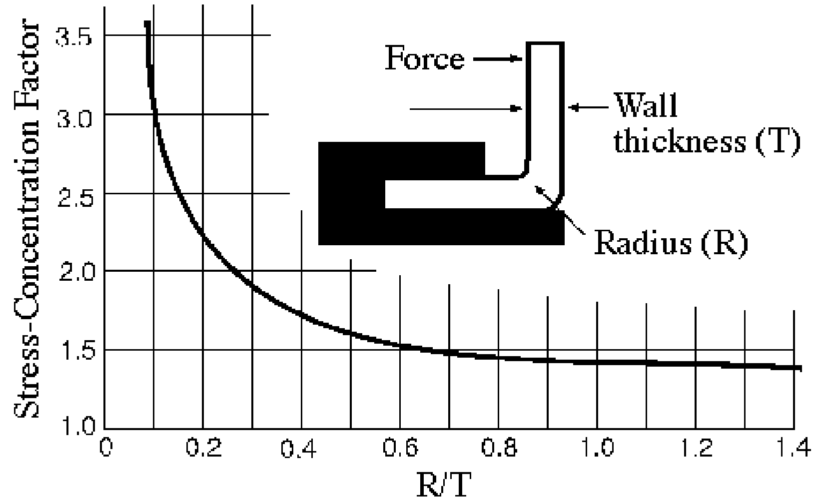
- Resin enters the molding cavity at high pressures and temperatures at the gate location.
- The part surface in the gate area typically includes defects that can behave as stress concentrations during tensile loading or drop testing.
- Gate locations exhibit inferior mechanical properties compared to the molded resin out in the cavity.
- Gate locations should be located in areas of the part which are not subjected to externally applied high tensile loading.





Part design — Eliminate notches

Impact failures in part designs are frequently initiated by a “stress concentration” created by a sharp notch. The performance of a part in a drop test can often be significantly improved with a small increase in radii of sharp features.



This curve gives an indication of the proper radius to be used for a given wall thickness.

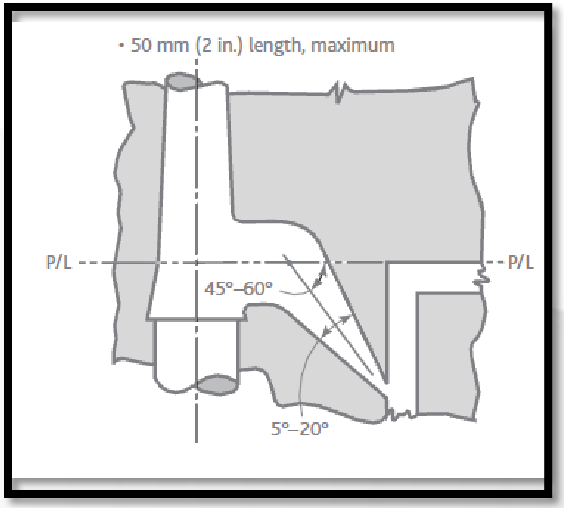
Courtesy of S.P.I. Plastics Engineering Handbook

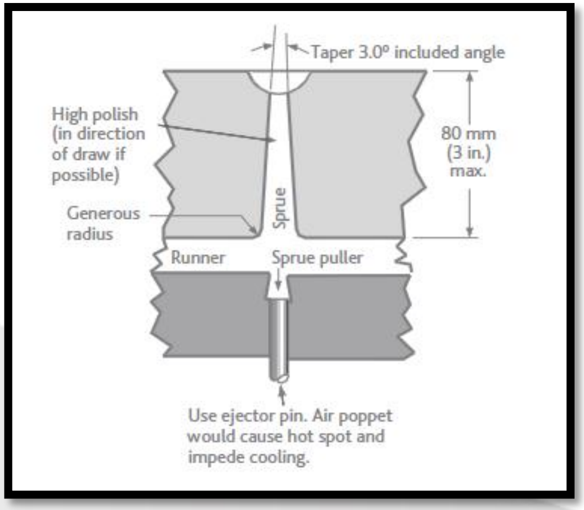
Tooling design

Tooling design — Cold gating systems

- Standard systems such as sub, pin, fan, edge, sprue, and diaphragm gates have been successfully used in Tritan injection molding applications.

- Design details for these gating styles are available in the Eastman copolyester Design Guide. (PP-7E).

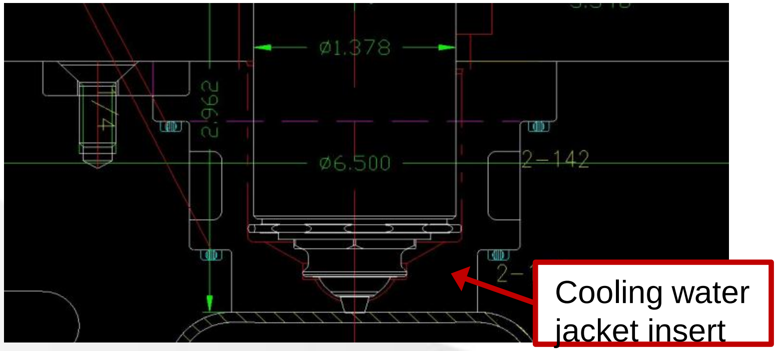




Tooling design — Hot gating systems

Valve gates are the recommended gating style. Critical design features of Tritan valve gate systems include:

- Thermal control
  - Provides excellent thermal control around the gate area. Many valve gate suppliers offer water-jacketed gate inserts which typically work well with Tritan resins. A cooling water circuit in close proximity is also typically sufficient.



- Independent water supply
  - It is beneficial to design the gate cooling water circuit so that it can be plumbed independent from cavity cooling circuits. Although this may not be necessary for satisfactory operation, it will allow the gate cooling water temperature to be controlled independent of the cavity cooling water.

Tooling design — Hot gating systems, valve gates

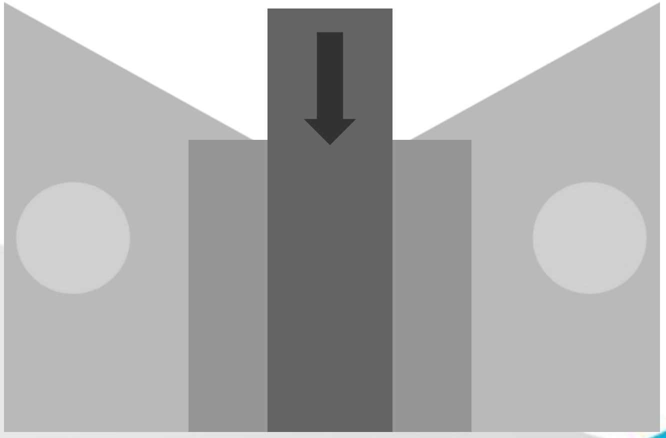
- Small parts
  - Valve gate diameter: 1 mm is the minimum that should be used.
    - Designing gates smaller than this can result in excessive pressure losses through the gate. Extremely small gates can also be difficult to avoid gate “blush” (hazy appearance around the gate) due to high shear rates.
- Large parts
  - Valve gate diameter should not exceed 5 mm in diameter.
    - Valve gate pins in excess of 5 mm become difficult to cool across the face of the pin. This can result in resin sticking to the face of the pin during ejection, creating a weak spot on the part, as well as an appearance defect.
- Design
  - No “holdup” areas
    - Valve gate designs supplied by hot runner system vendors should not have any areas in the flow path where resin can hold up and degrade, resulting in possible appearance defects such as brown streaks.

Tooling design — Hot gating systems

Straight vs. tapered pin valve gate design considerations

- Tapered
  - Provide a heat transfer surface to extract heat from the pin face when in the closed position
  - Can fatigue and break due to cyclic loading
- Straight
  - Through pin designs do not have a pin seat to break.
  - Cooling the pin face becomes less critical with smaller pin sizes (< 2 mm).

Tapered pin

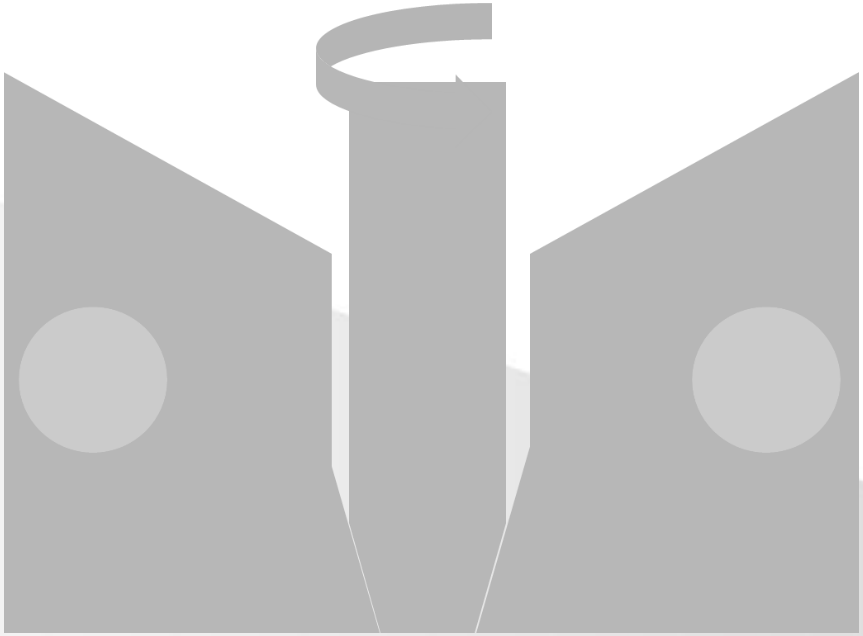


Straight pin

Tooling design — Hot gating systems

Tapered valve gate pin/seat

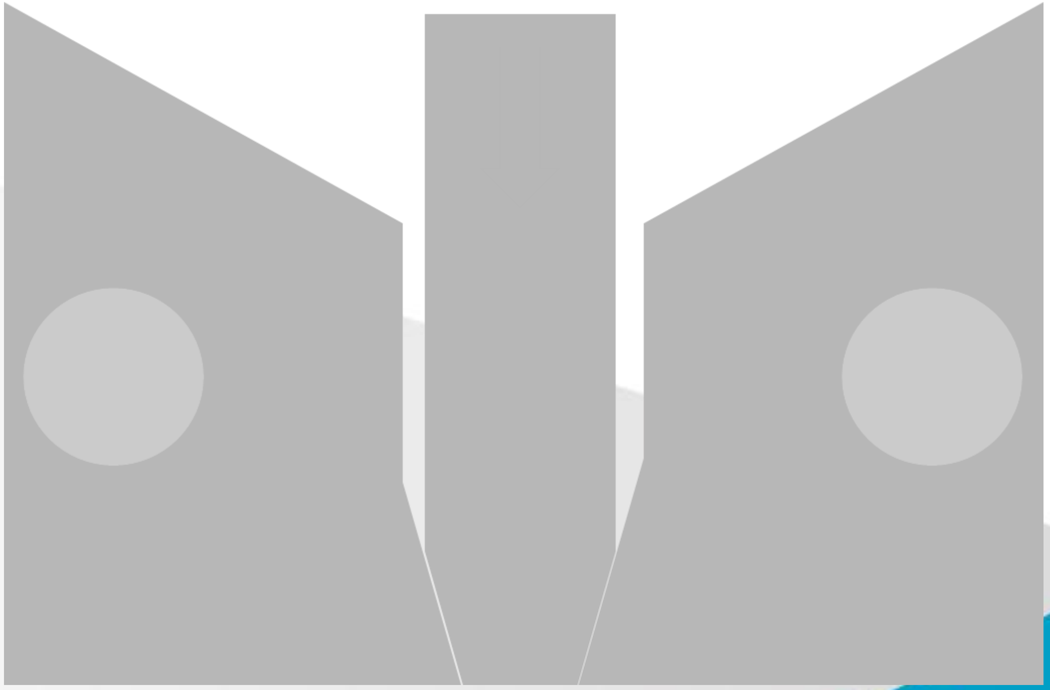
- Valve gate pins should be lapped to tapered seat to ensure optimum heat transfer in the closed position.



Tooling design — Hot gating systems

Valve gate actuator

- Should have adequate air/hydraulic pressure to ensure good thermal contact between valve gate pin and seat.



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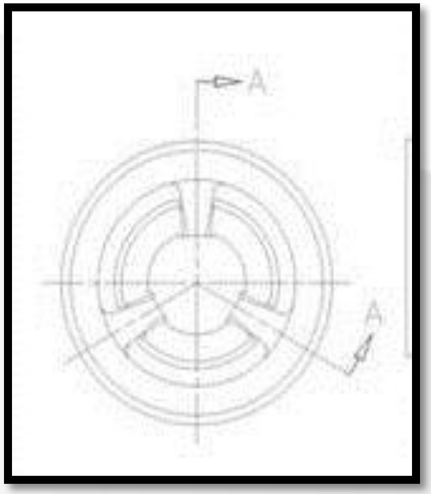
Tooling design — Hot gating systems

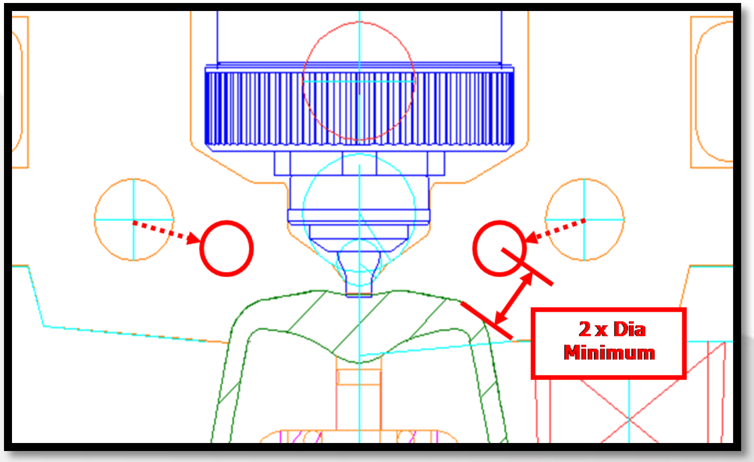
Valve gate flow interruptions

- Some valve gate systems with a straight pin design require a lower annular bearing to maintain alignment of the pin with the seat during operation and can result in small weld lines on the part face which can reduce mechanical properties in the gate area. Self aligning pin designs (such as a tapered pin) should be used in applications subjected to high external loading or drop testing.



Tooling design — Gate cooling

- Injection molding gates typically have the highest heat load in an injection mold.
  - If steel surface temperatures around the gate rise above the glass transition temperature of the resin (108˚ C for Tritan) during rapid cycling, the resin will remain sticky and difficult to eject.
- Submit tooling drawings to Eastman for a review of the plan for cooling in the area around the gate.



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Tooling design — Cooling mold materials

- Thermal conductivity should be a consideration when selecting materials for mold construction with Tritan copolyesters.
- Higher thermal conductivity steels allow greater heat transfer rates, potentially reducing cycle time and providing a more uniform cavity temperature.

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ENGINEERED MATERIALS

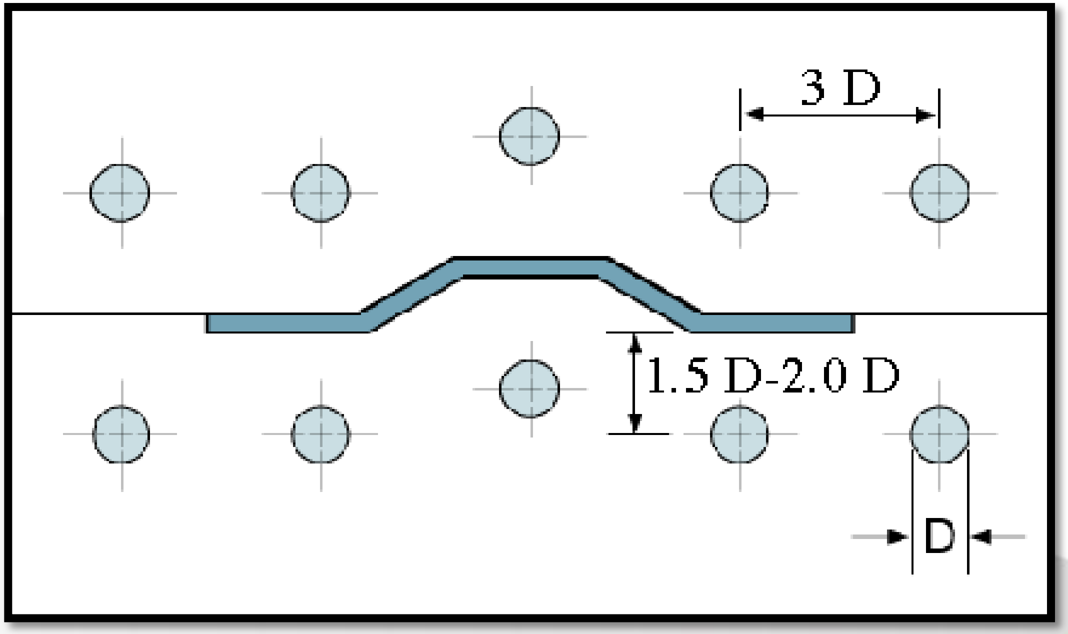
moldMAX® + PROtherm®

MATERIAL PROPERTIES

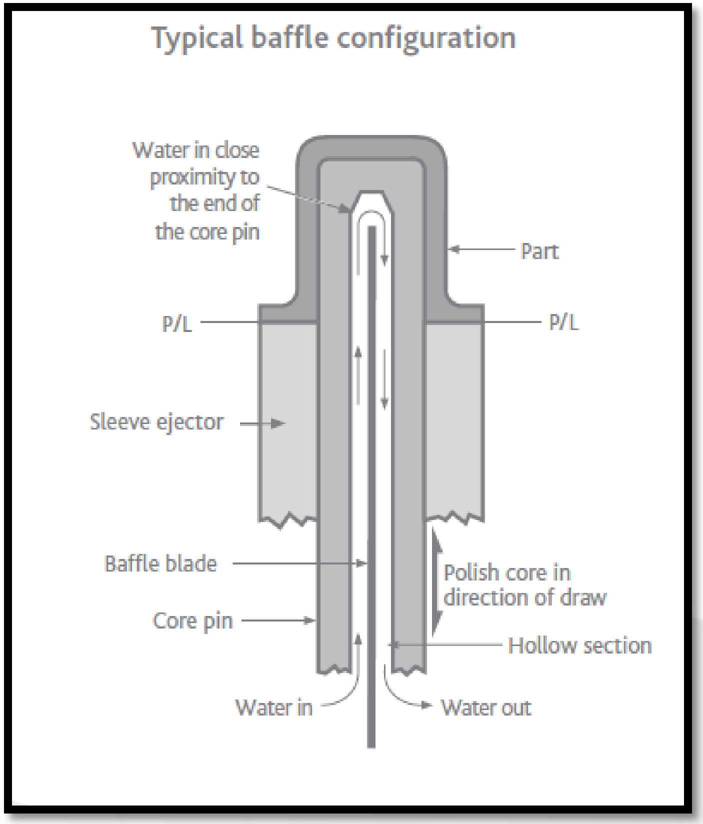
PRODUCT	THERMAL CONDUCTIVITY (BTU/ft hr F)	ROCKWELL HARDNESS	CHRAPY V-NOTCH IMPACT STRENGTH (ft-lb)	COMPRESSIVE YIELD STRENGTH (ksi)	TENSILE STRENGTH (ksi)	ELONGATION (%)	COEFFICIENT OF THERMAL EXPANSION (10^{-6}/F)
STAINLESS STEEL 420	13	HRC 50	12	215	255	10	6.1
TOOL STEEL H-13	15	HRC 45	14	185	210	15	7.1
*MOLDMAX High Hardness	60	HRC 40	4	155	185	6	9.7
*MOLDMAX Low Hardness	75	HRC 30	12	140	170	10	9.7
TOOL STEEL P-20	17	HRC 30	25	110	140	20	7.1
*PROTHERM	145	HRB 96	50	90	115	18	9.8
ALLOY 940	120	HRB 94	35	75	100	12	9.7
ALUMEC 89	95	HRB 88	30	75	80	7	12.9
ALUMINUM QC7	93	HRB 91	30	75	80	7	12.8

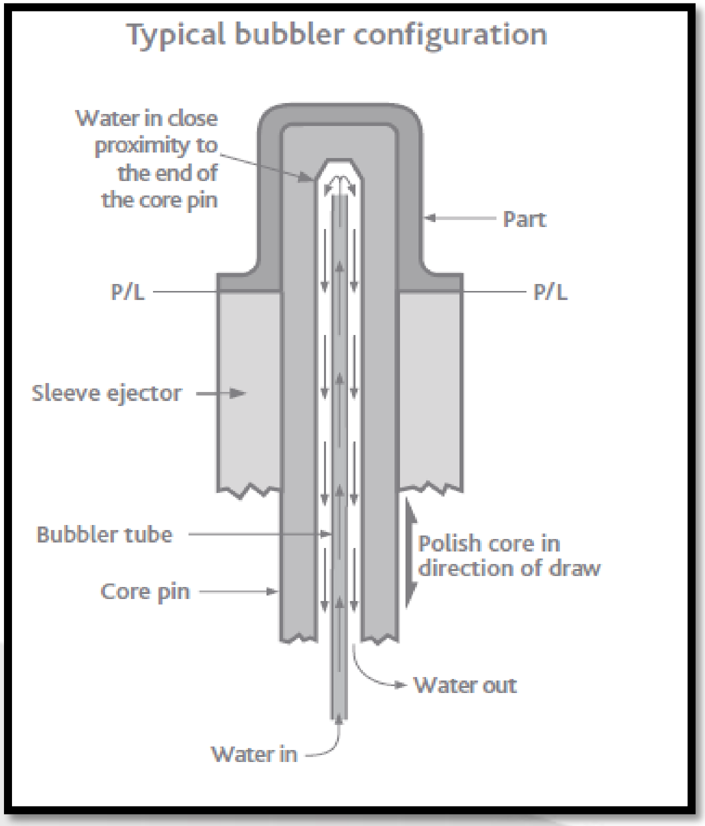
Tooling design — Cooling cavity

Design cooling line layout for uniform cavity steel temperature.



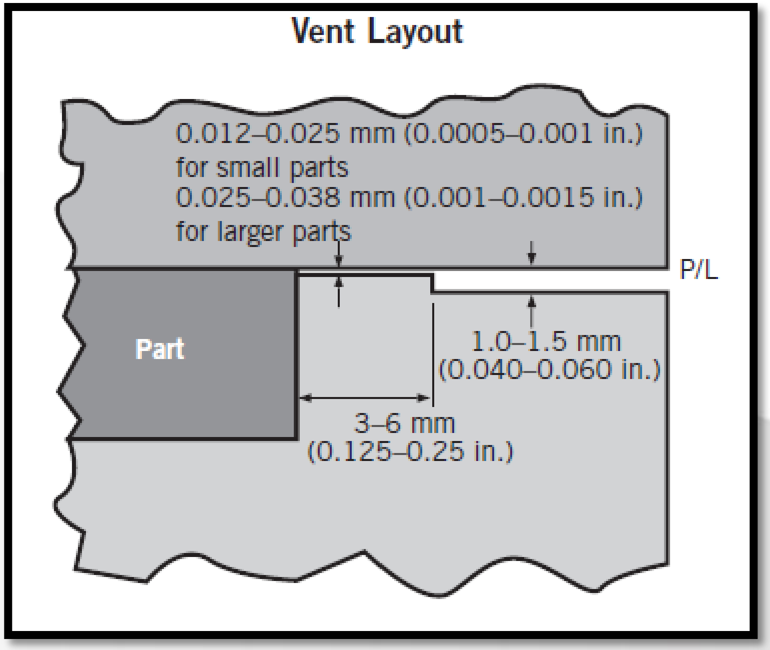
Tooling design — Cooling cores





Tooling design — Venting

- Air is displaced by resin in the cavity during the injection molding process, requiring a path for the air to be evacuated. The inability to remove air from the cavity can result in part appearance defects such as incomplete fill (short shots) and burn marks due to heat of compression.
- Suggested vent depths for Tritan resins are typically 0.0005″–0.0015″
- Eastman can assist with a review of proposed venting layouts



Tooling design — Ejection

- The part is pushed out of the moving half of the injection mold using a mechanical device such as an ejector pin or stripper ring.
- Part design features like long cores or deep ribs with minimal draft can result in high forces being placed on the molded part during this process.
- Tritan resins have a relatively low modulus (more flexible) and yield strength compared to some competitive transparent resins.
- Factors affecting the ability to eject a part successfully:
  - Draft
    - Eastman guidelines for minimum draft on wall surfaces in the direction of draw is 1 degree per side.
  - Mold Steel coatings to reduce the coefficient of friction vs. resin
    - There are several mold steel coatings that have been successfully used to reduce required ejection forces. Consult with Eastman for a description of these coatings.
  - Polish
    - Polishing mold cavity features in the direction of draw will reduce required ejection forces.

High cavitation tooling

High cavitation tooling

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- 32 cavities or greater is often considered for relatively small parts with hot runner/valve gate systems.

- Several design considerations when evaluating two 16-cavity molds vs one 32-cavity mold
  - Residence time
    - As cavitation is increased, the distance from the machine nozzle to the cavities increases. This results in a greater volume of resin in the hot runner manifold and subsequently longer residence times.
    - Eastman guidelines for design residence time is 5 minutes.
  - Pressure drop
    - The increased distance from the machine nozzle to the cavities results in longer flow length requirements for the resin. Higher pressure losses through the runner system are typical of higher cavitation tooling.
    - Eastman guidelines for maximum fill pressure for a runner/part/gate is 20,000 psi.
  - Balance
    - Higher cavitation tooling can be more difficult to achieve cavity-to-cavity balance during the filling process. This can affect part quality and increase scrap rate.

All of these factors should be considered when evaluating the high cavitation option.

Questions?
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