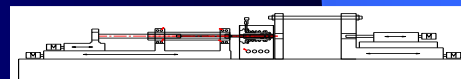


Study on the Performance of Rapid Mold Heating/Cooling System for Micro Injection Molding

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Taipei, Taiwan, R.O.C.*

Outline

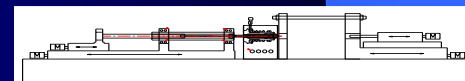
- Introduction
 - Micro-Injection Molding
 - Rapid Mold Heating/Cooling System
- The mold design and procedure for three rapid heating/cooling systems
 - Air heating and air cooling
 - Heat pipe heating and water cooling
 - Heat pipe heating / nitrogen cooling
- Results and conclusions



The Definition of Micro-Injection Molding

Kukla et al (1998)

1. parts with micro weight
 - parts with mass of a few milligram, not necessarily having dimension on the μm scale
2. parts with micro-structured regions
 - parts characterized by local micro feature of the μm order such as the micro-hole or -slot
3. parts with micro-precision
 - parts could have any dimensions, but has tolerances in the μm range



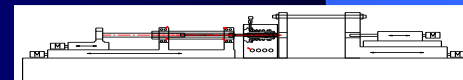
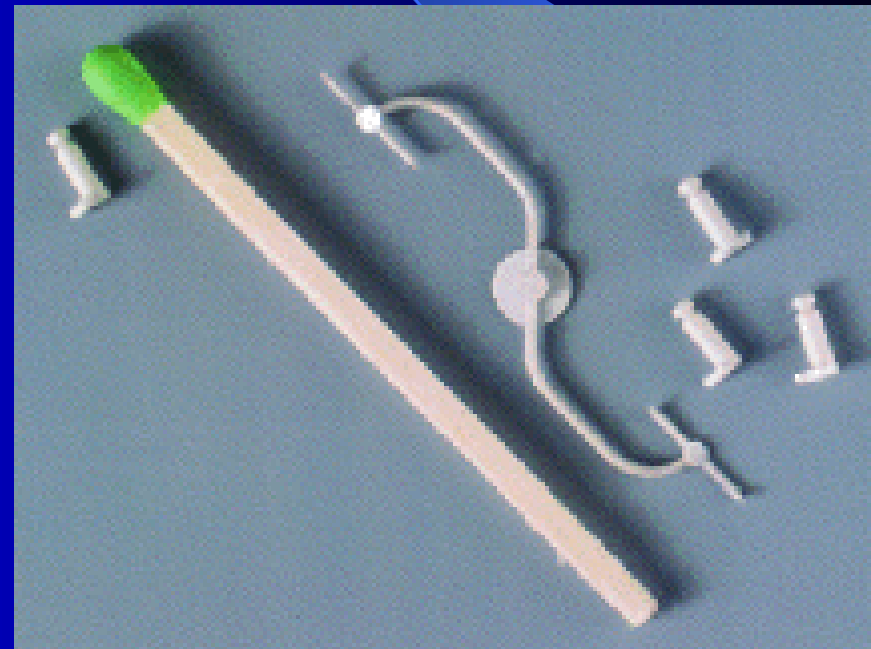
The Application of Micro-Injection Molding (1/3)

➤ Precision Micro-parts

Micro-gears

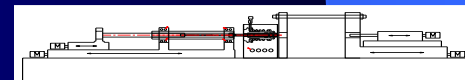
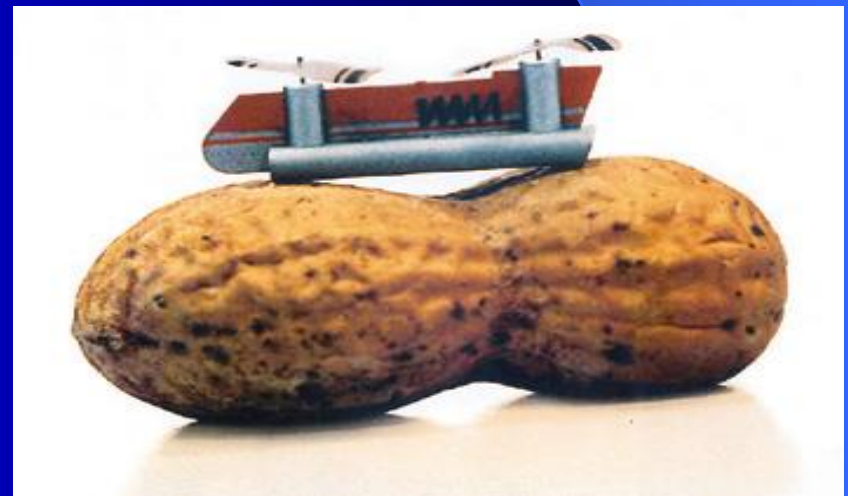
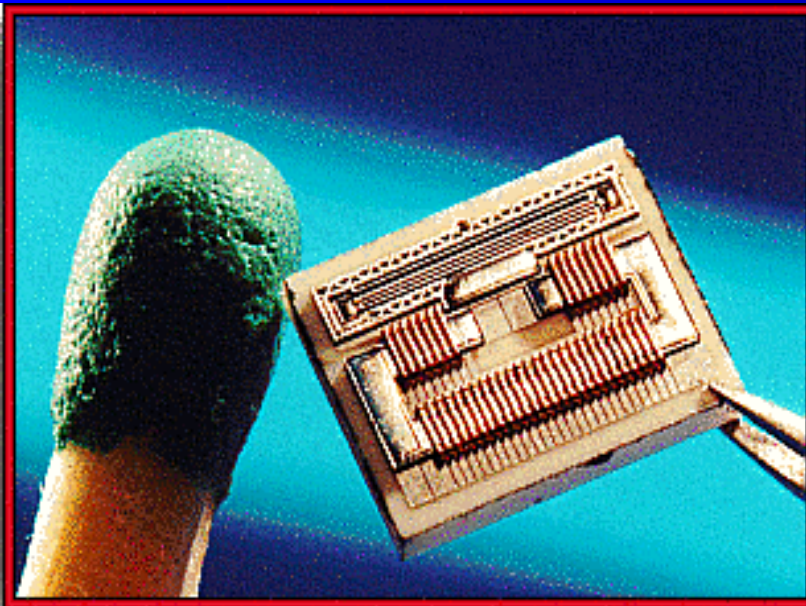
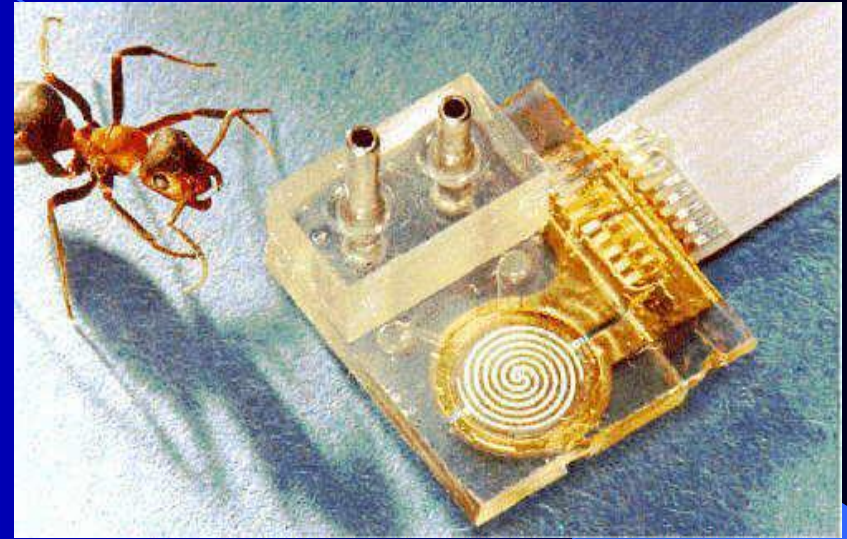


Micro-parts



The Application of Micro-Injection Molding (2/3)

➤ Micro-Electro-Mechanical System (MEMS)

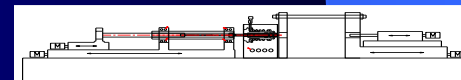
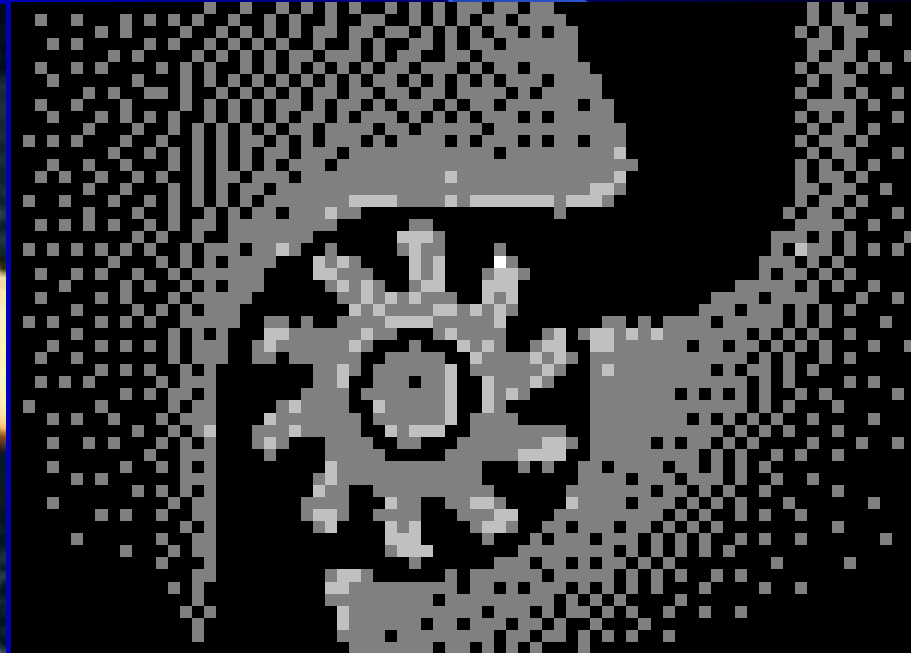


The Application of Micro-Injection Molding (3/3)

➤ Biotechnology

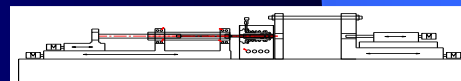
Component of audiphones
(ψ 0.8mm 0.0028g)

Micro-pump



Requirements of Micro-Injection Molding

1. Accuracy injection control
 - small shot weight, shot response time, and high injection speed
2. Higher injection speed
 - shorter heat transfer time, larger shear-thinning, and larger viscous dissipation effects
3. Higher mold temperature
 - higher mold temperature will significantly decrease the flow resistance and residual stress, and increase the replication ability



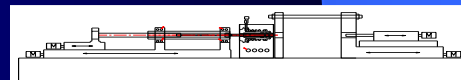
Rapid Mold Heating/Cooling System

(Dynamic temperature control system / Variotherm system)

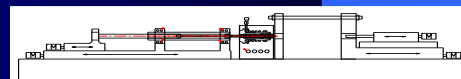
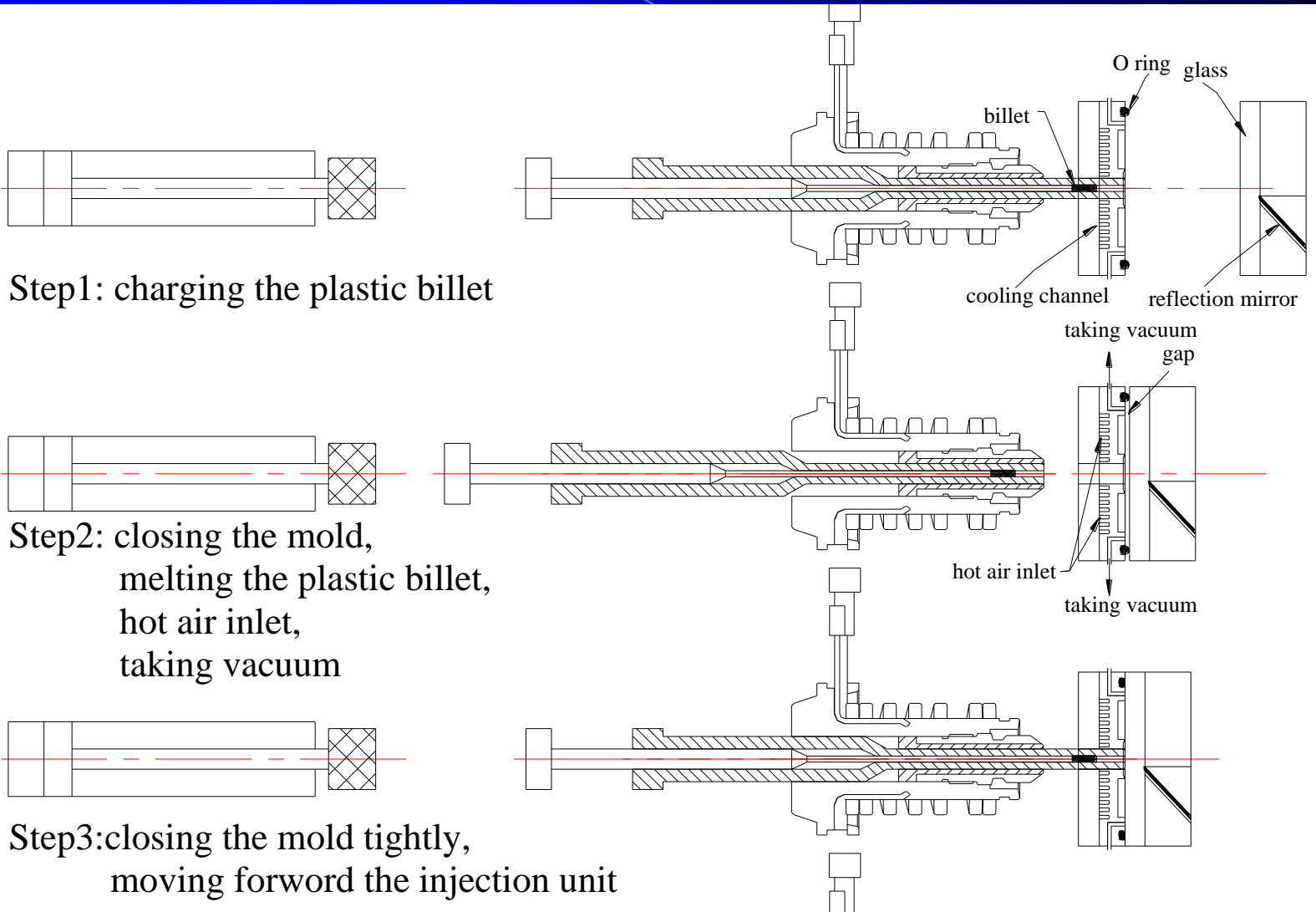
The variotherm process means the mold temperature is varied during a molding process.

- Higher mold temperature prolong the cooling time.
- Mold temperature larger than the parts rejection temperature

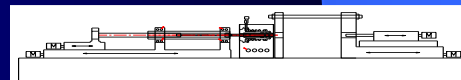
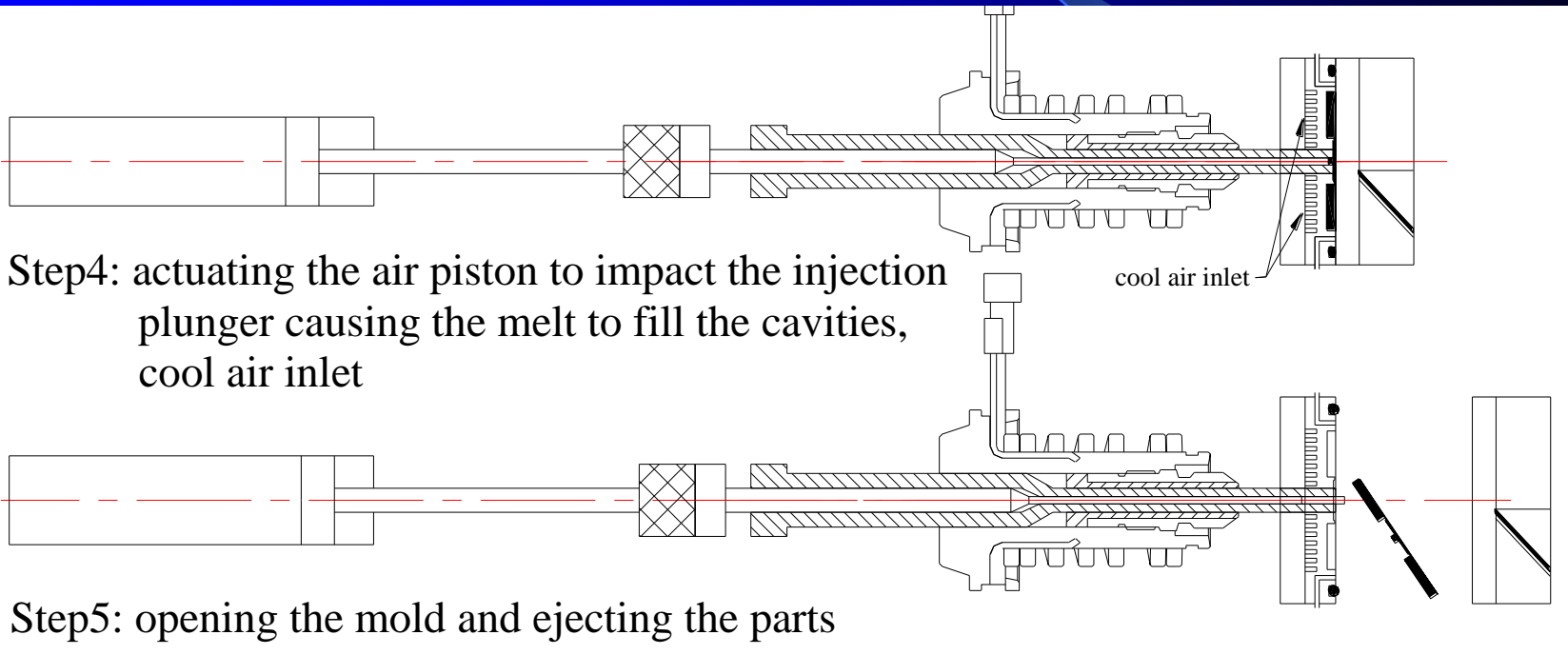
The main purpose of this study is to find an efficient and cost-effective variotherm system for the micro-injection molding



The Procedures of Impact Type Micro-Injection Molding ^{1/3}



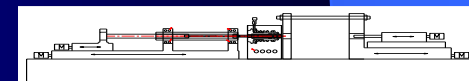
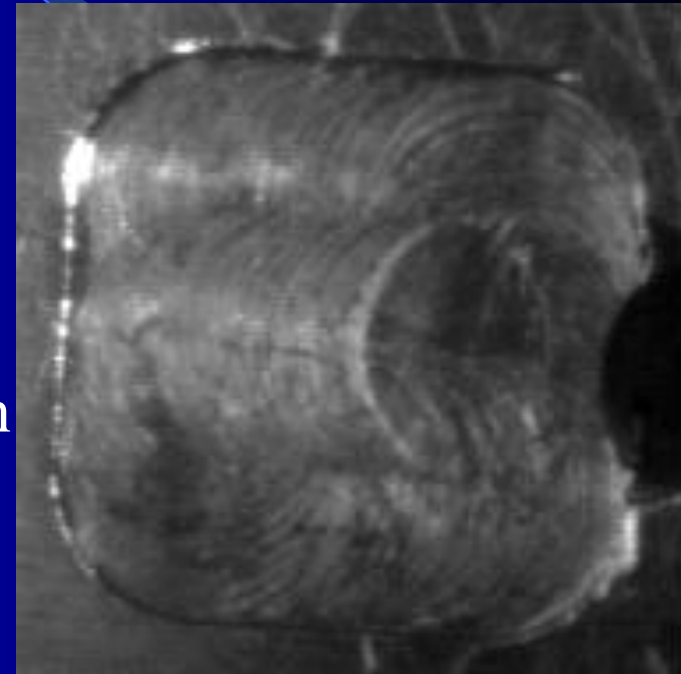
The Procedures of Impact Type Micro-Injection Molding ^{2/3}



The Characterization of Impact Type Micro Injection Molding

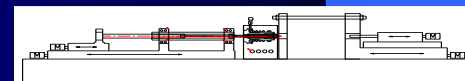
The three stage of impact injection molding

- Impact-filling stage
 - occurs at the impact twinkle
 - driving force : impact energy
- Pressure-filling stage
 - after the impact energy dissipation
 - driving force : piston thrust
- Pressure-holding stage
 - after the cavity be filled
 - driving force : piston thrust



Flow Visualization Experiment

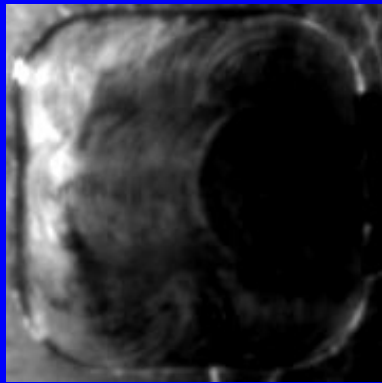
- The effects of vacuuming
- The effects of cylinder attach with hammer
- The effects of gate type
 - Fan gate, edge gate
- The effects of injection materials
 - PS (PS-951N, TAI-TA, Taiwan)
 - PMMA (Delpet 70-FH, ASAHI, Japan)



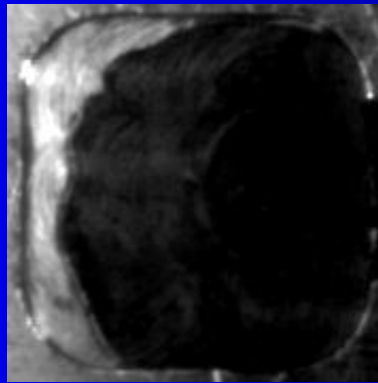
Effects of Vacuuming (1/3)

$P_{air} = 50\text{Psi}$,
 $T_{mold} = 150^{\circ}\text{C}$,
 $T_{melt} = 240^{\circ}\text{C}$

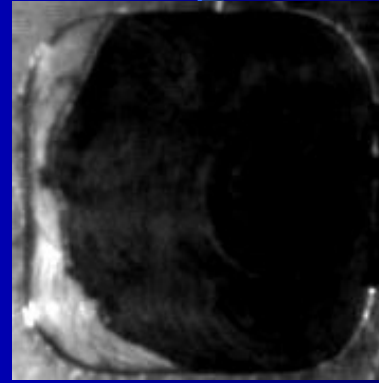
vacuuming condition, Fan gate, without attached with hammer,
polystyrene (PS-951N, TAI-TA, Taiwan)



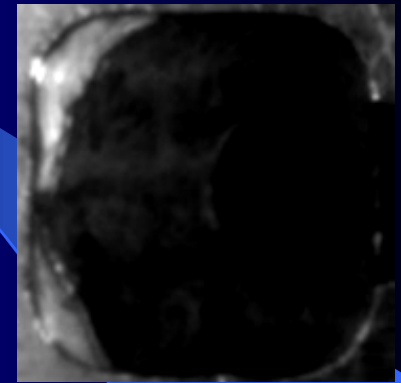
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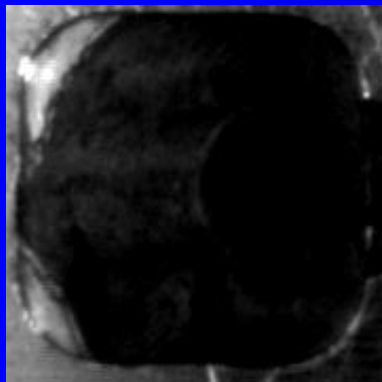
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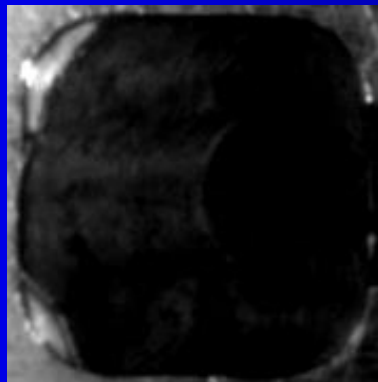
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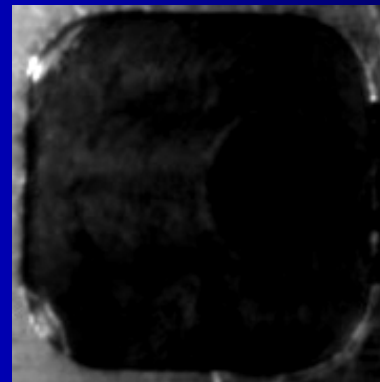
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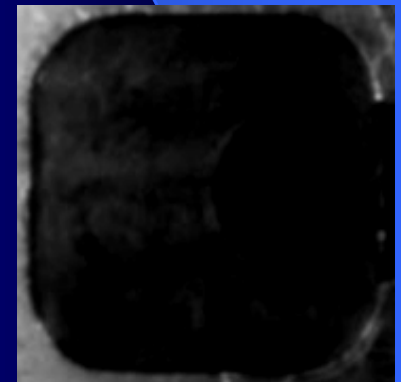
0.025sec



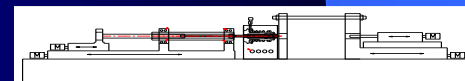
0.031sec



0.038sec



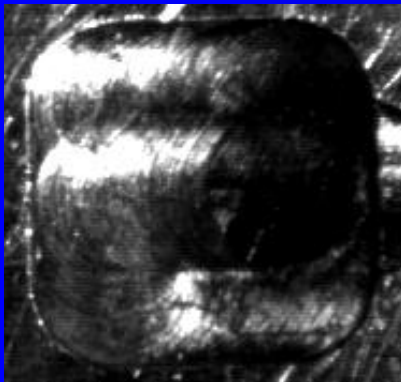
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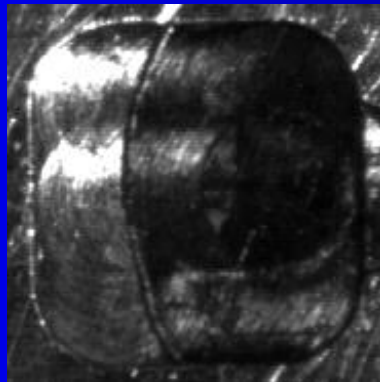
Effects of Vacuuming (2/3)

without vacuuming condition

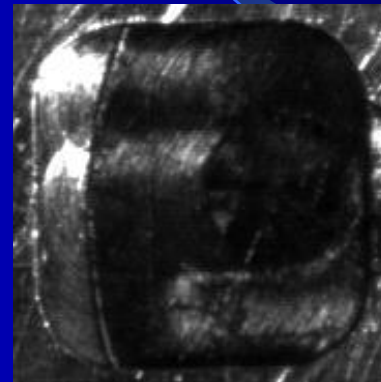
Fan gate, $P_{air} = 50\text{Psi}$, $T_{mold} = 150^\circ\text{C}$, $T_{melt} = 240^\circ\text{C}$



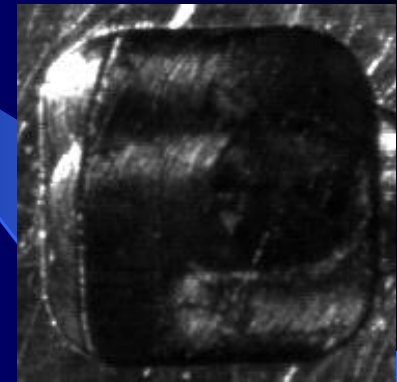
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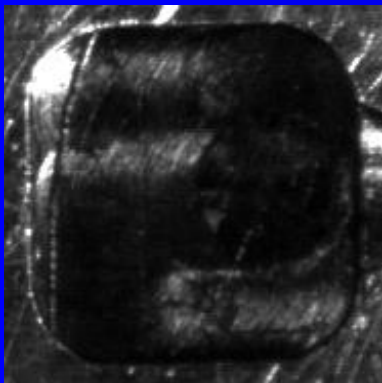
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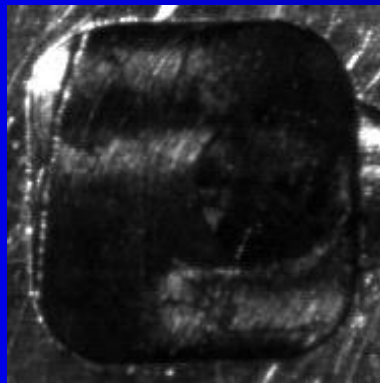
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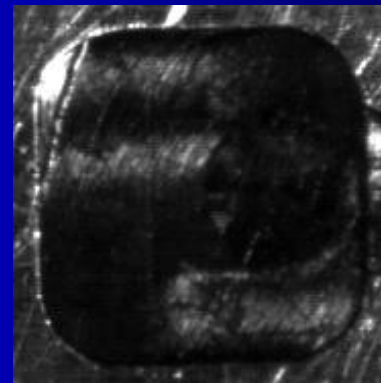
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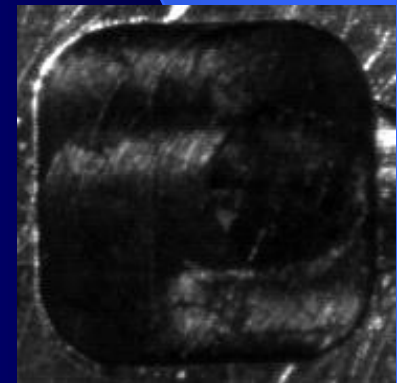
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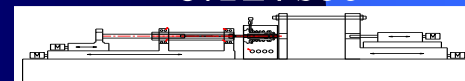
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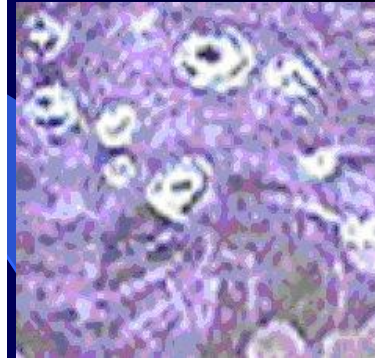
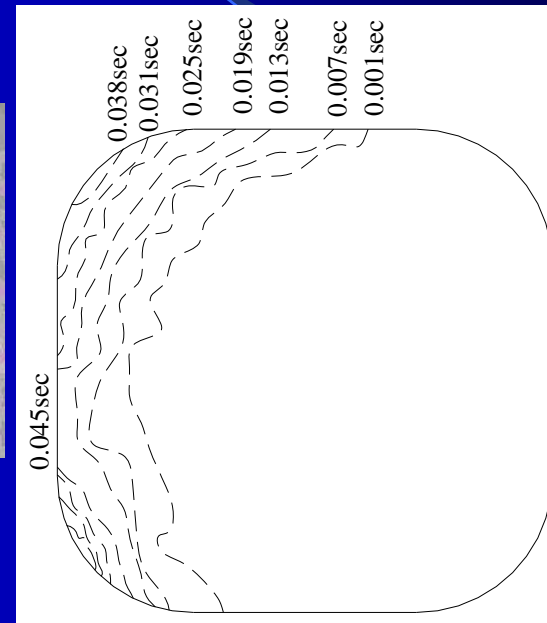
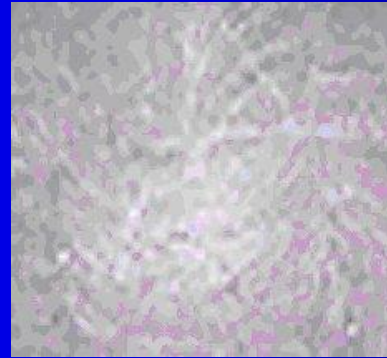
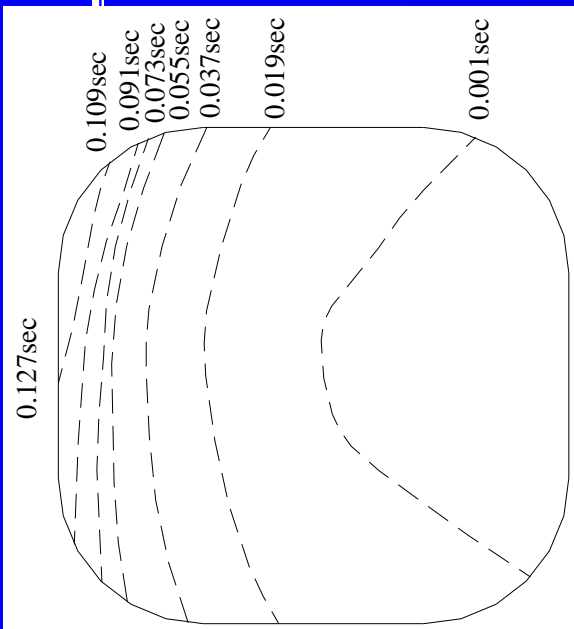


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Effects of Vacuuming (3/3)

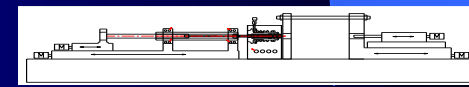
The melt front contours under various vacuuming conditions



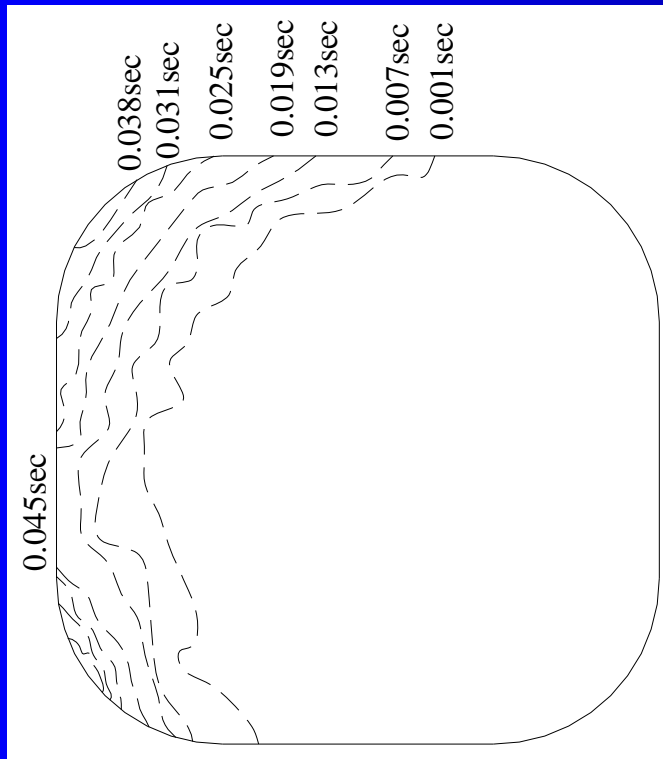
without vacuuming

vacuuming

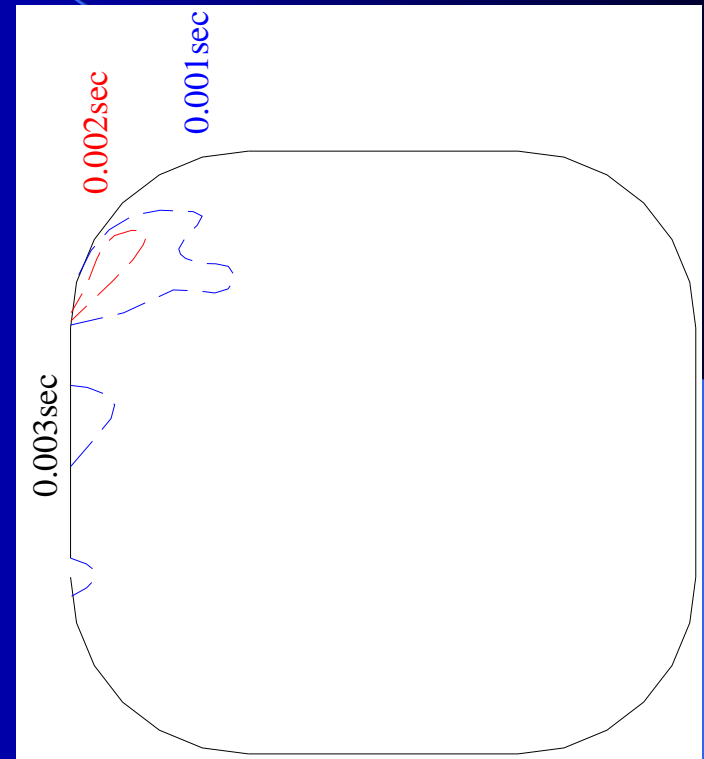
Fan gate, $P_{air} = 50\text{Psi}$, $T_{mold} = 150^{\circ}\text{C}$, $T_{melt} = 240^{\circ}\text{C}$



Effects of Cylinder Attach with Hammer

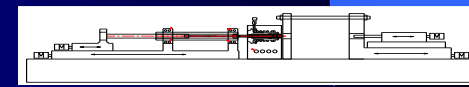


without hammer

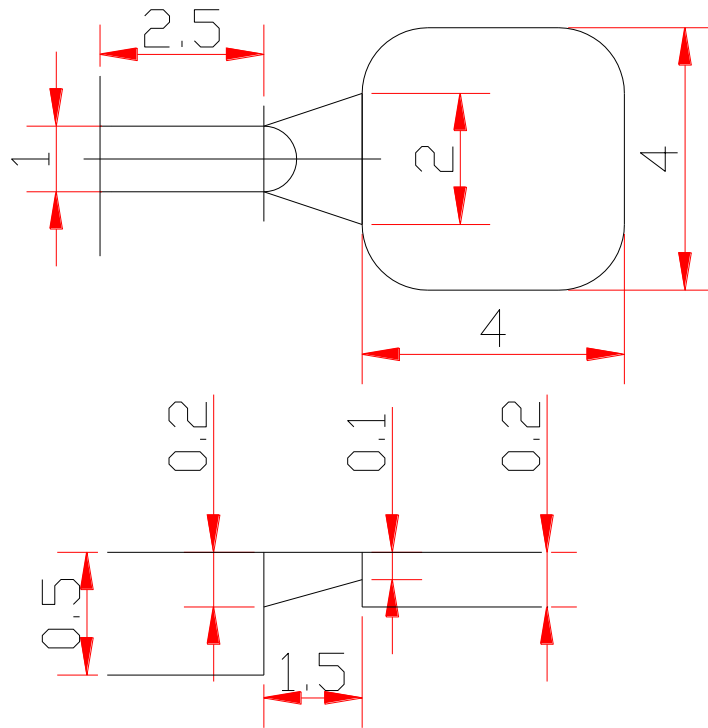


Attach with 101.5 g hammer

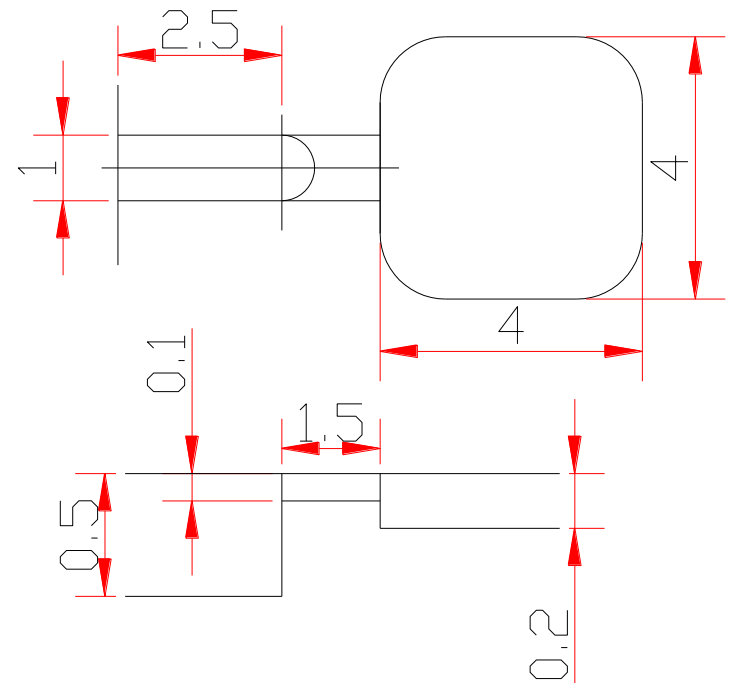
Fan gate, $P_{air} = 50\text{Psi}$, $T_{mold} = 150^\circ\text{C}$, $T_{melt} = 240^\circ\text{C}$



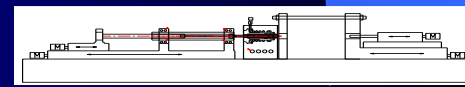
The Geometries of Fan Gate and Edge Gate



Fan gate dimensions

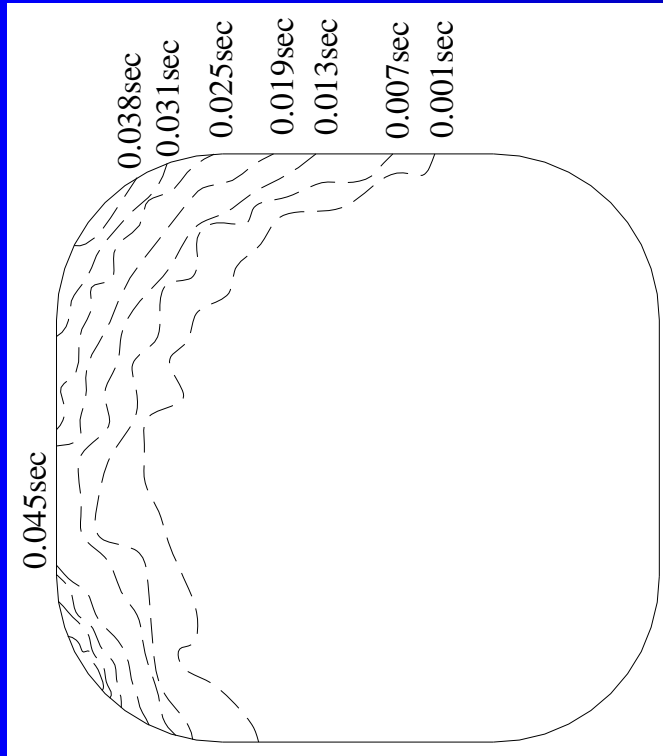


Edge gate dimensions

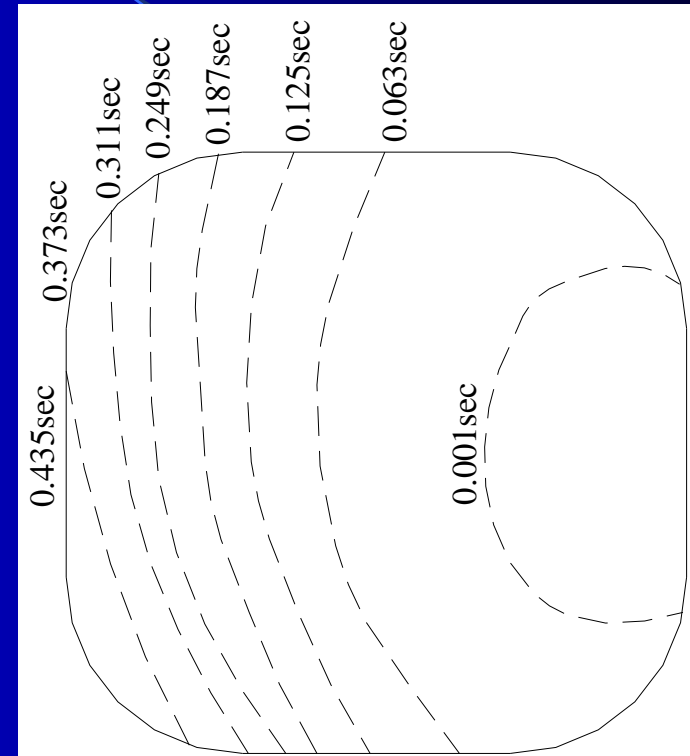


Effects of Gate Type

The melt front contours under different gate type

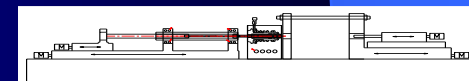


Fan gate



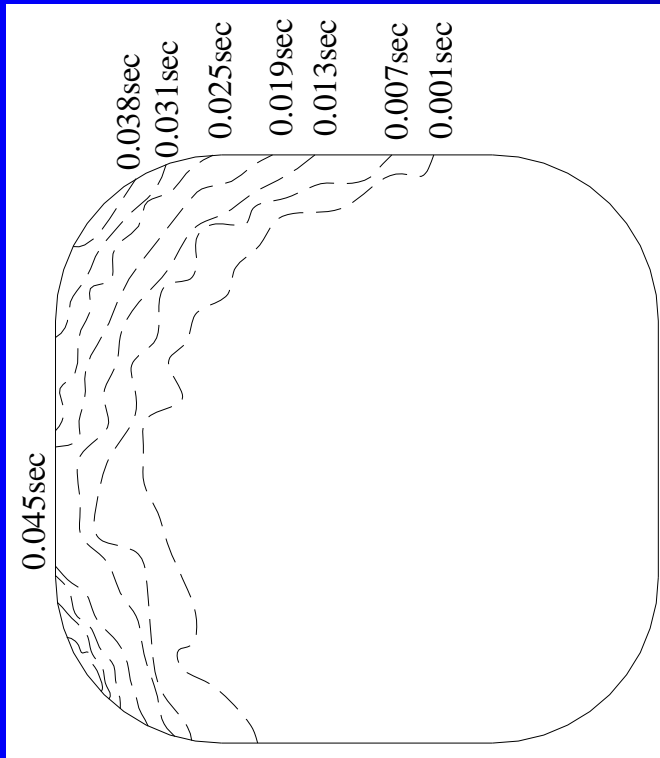
Edge gate

Fan gate, $P_{air} = 50\text{Psi}$, $T_{mold} = 150^{\circ}\text{C}$, $T_{melt} = 240^{\circ}\text{C}$

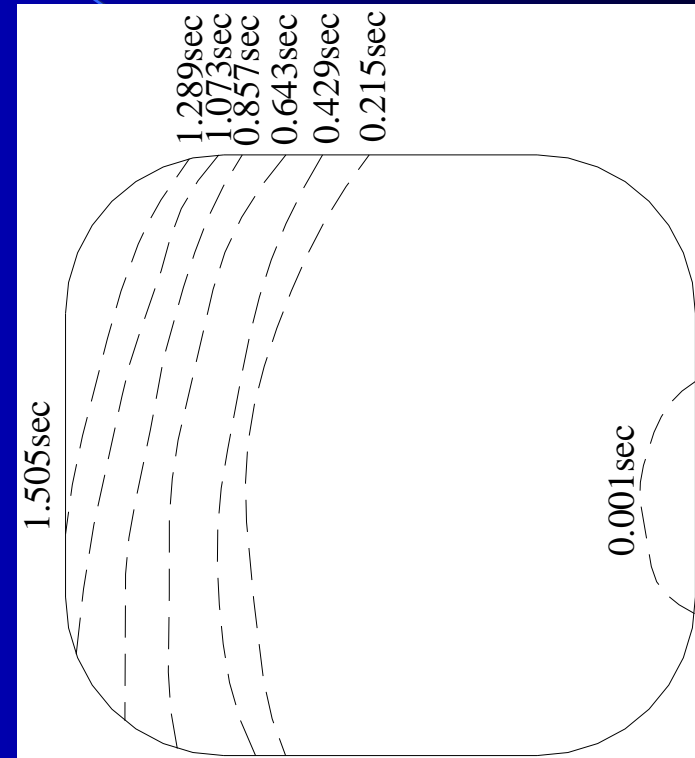


Effects of Injection Materials

The melt front contours under various injection materials

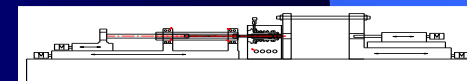


**PS (PS-951N, TAI-TA,
Taiwan)**



**PMMA (Delpet 70-FH,
ASAHI, Japan)**

Fan gate, $P_{air} = 50\text{Psi}$, $T_{mold} = 150^{\circ}\text{C}$, $T_{melt} = 240^{\circ}\text{C}$



Conclusions

- In vacuuming condition, the filling time is greatly reduced and the melt fronts easier be affected by noise.
- When the piston is attached with a hammer, almost whole cavity can be filled at the impact-filling stage.
- Longer filling time and smoother melt fronts are observed in edge gate cavity than in fan gate cavity.
- High melt viscosity will results in the filling time increase substantially.

