

Flow Visualization of Filling with Aid of Colored Billets During Impact Micro-Injection Molding

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Outline

- Introduction
- The impact type micro injection machine
- Experiment setup
- Results and discussion
- Conclusions

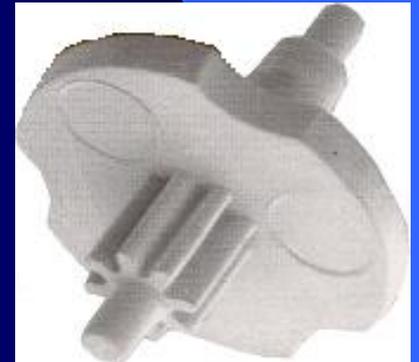
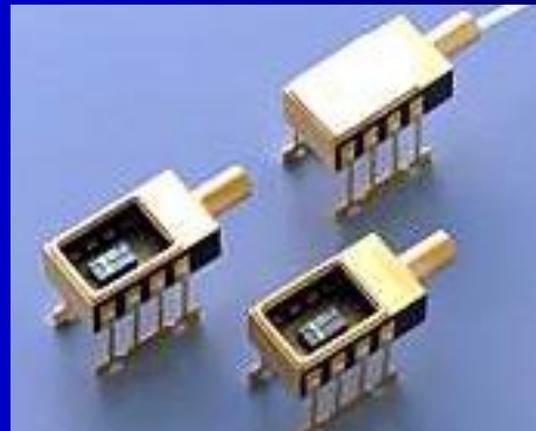
The Definition of Micro-Injection Molding

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

Kukla et al (1998)

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

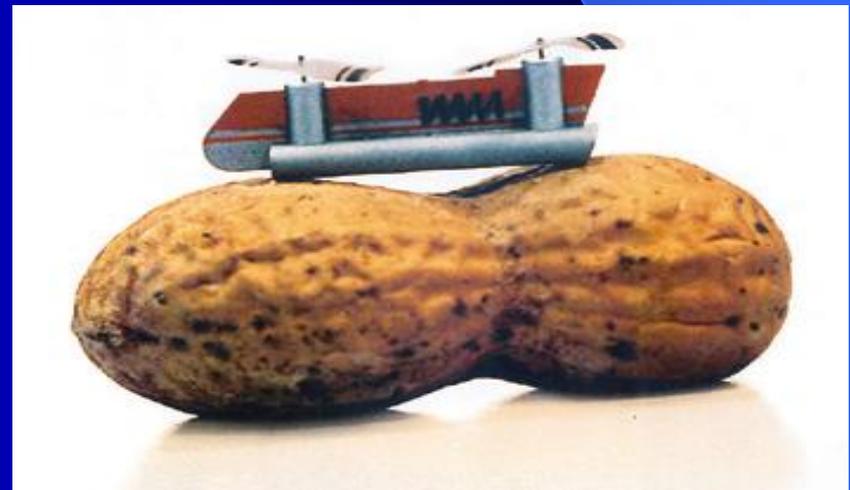
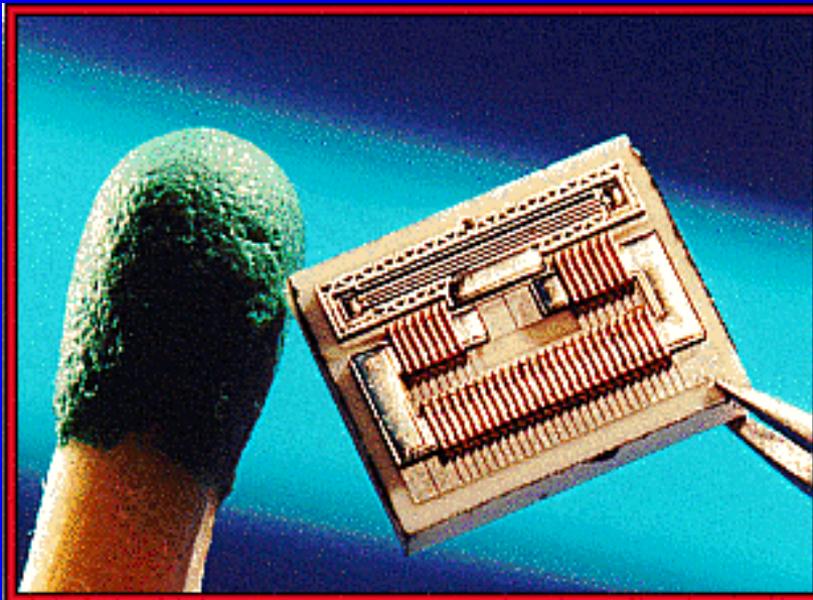
➤ Precision Micro-parts



(Battenfeld Kunststoffmaschinen Ges.m.b.H.)

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

➤ Micro-Electro-Mechanical System (MEMS)

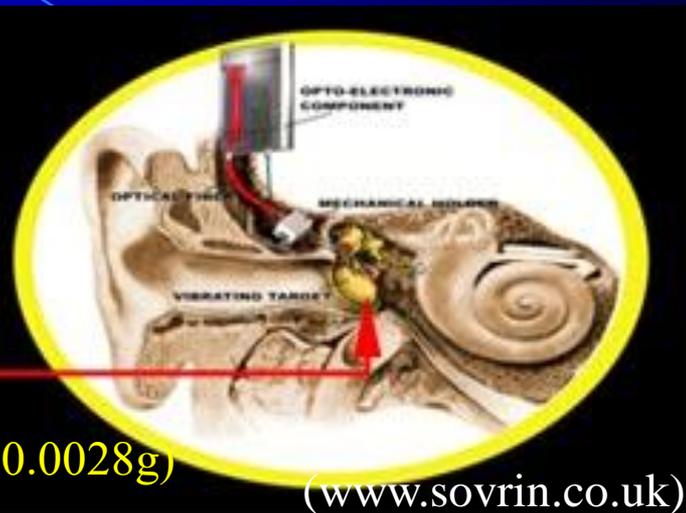


The Application of Micro-Injection Molding (3/3)

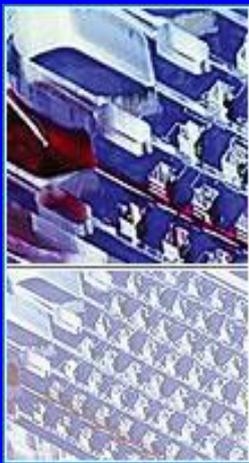
➤ Biotechnology



Component of audiphones ($\psi 0.8\text{mm}$ 0.0028g)



(www.sovrin.co.uk)



Cell Chip



(LILLIPUT)



Micro-pump

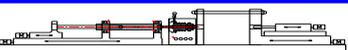
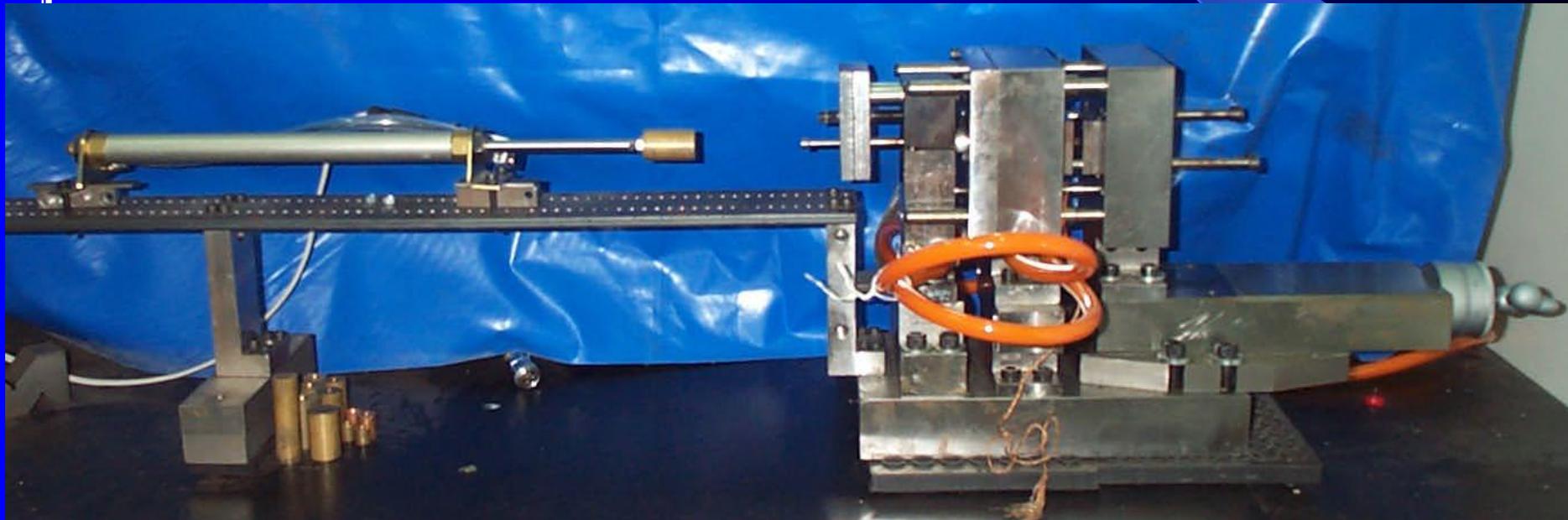
(IKV)

Requirements of Micro-Injection Molding Machine

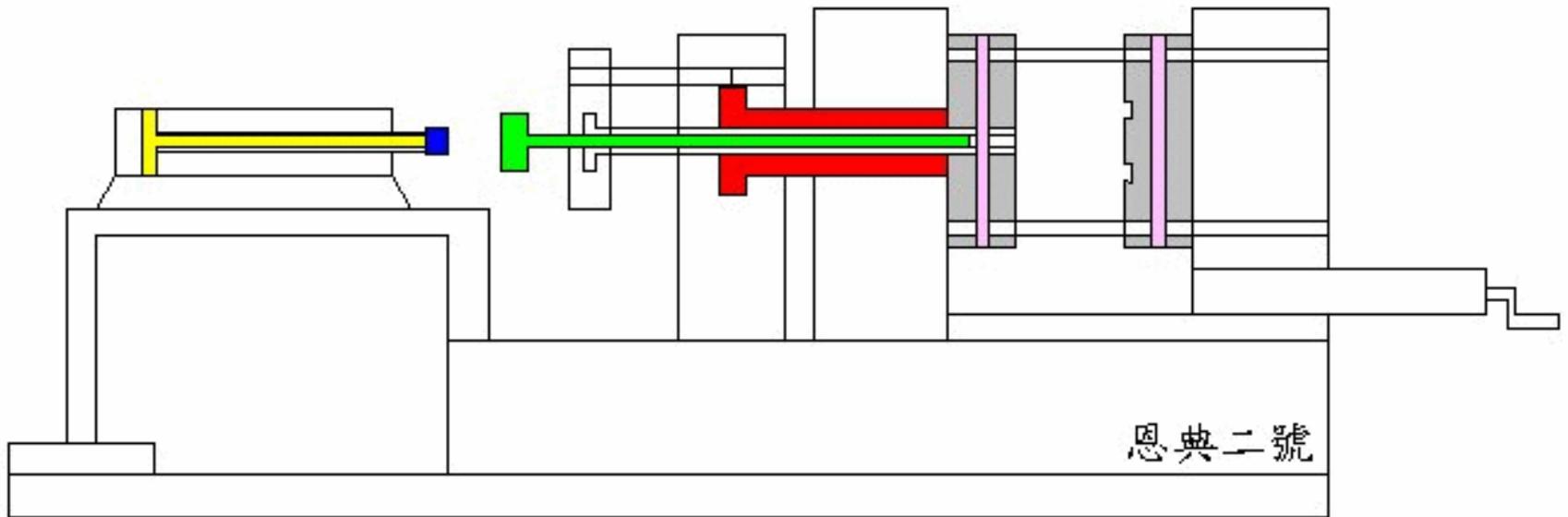
1. small amount of melt
 - to reduce the melt residence time in the plastication unit
2. small diameter of injection unit
 - to increase the accuracy of shot weights and the plunger traveling distance
3. high injection rate
 - to avoid the occurrence of short shoot

Impact Type Micro-Injection Machine ^{1/2}

L: 950mm H: 300mm W: 140mm



The Procedures of Impact Type Micro-Injection Molding ^{1/2}



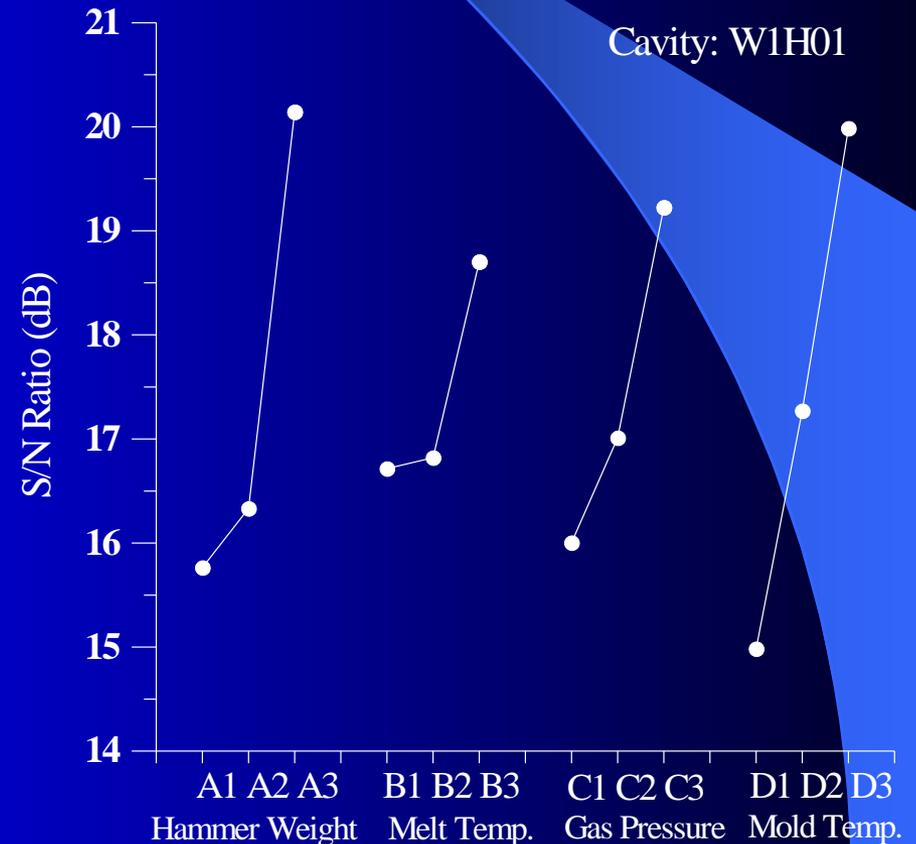
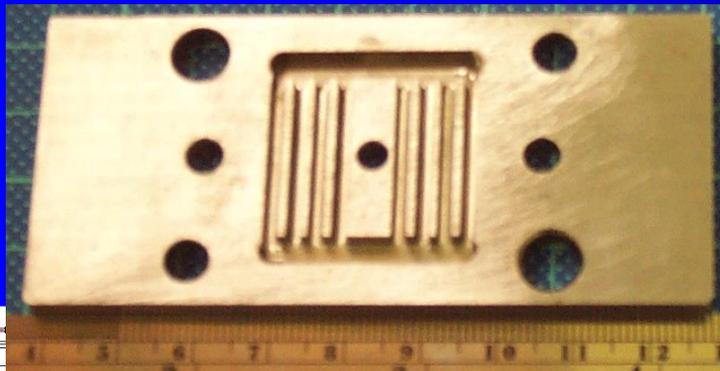
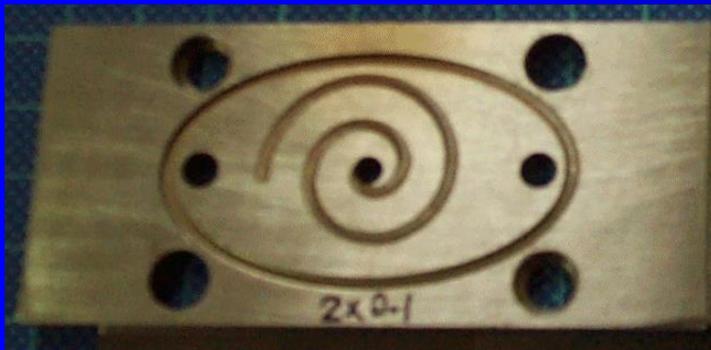
恩典二號

The previous experiments of Impact Type Micro-Injecting Molding

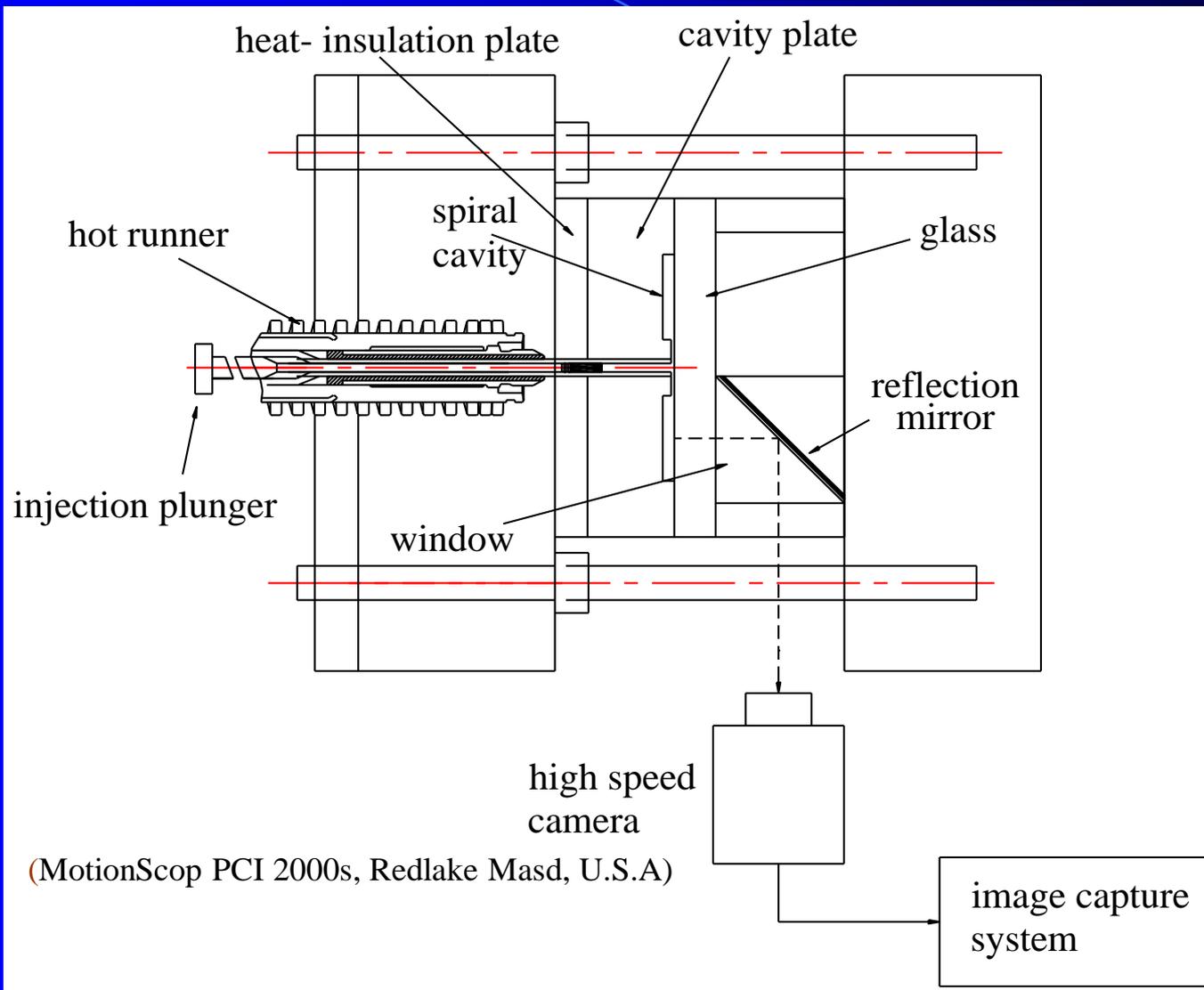
The effect of operation parameters - Taguchi method of spiral mold

- The filling capacity is expressed in terms of the flow length
- The S/N ratio showing the processing effects of parameters

spiral cavity : width: 1mm
depth: 0.1mm

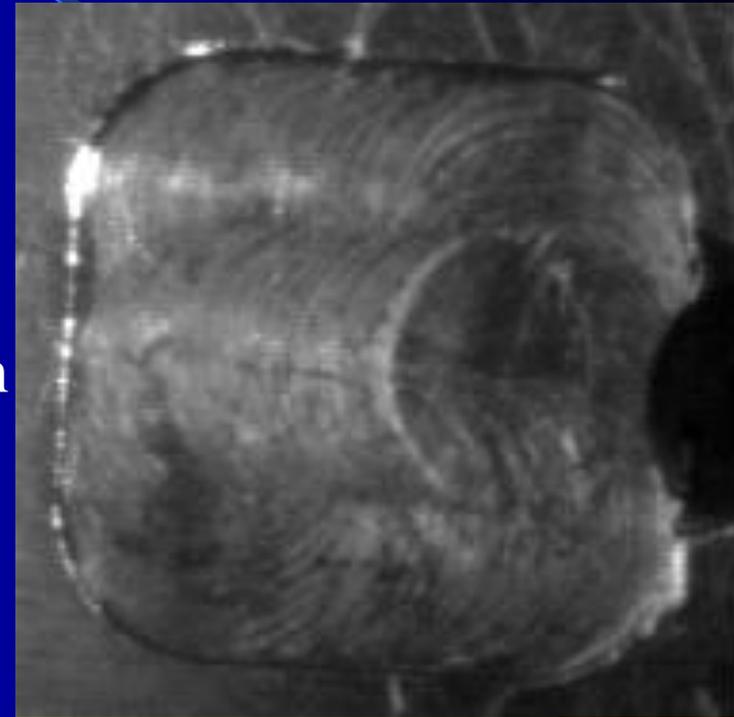


The Setup of Images Capture System



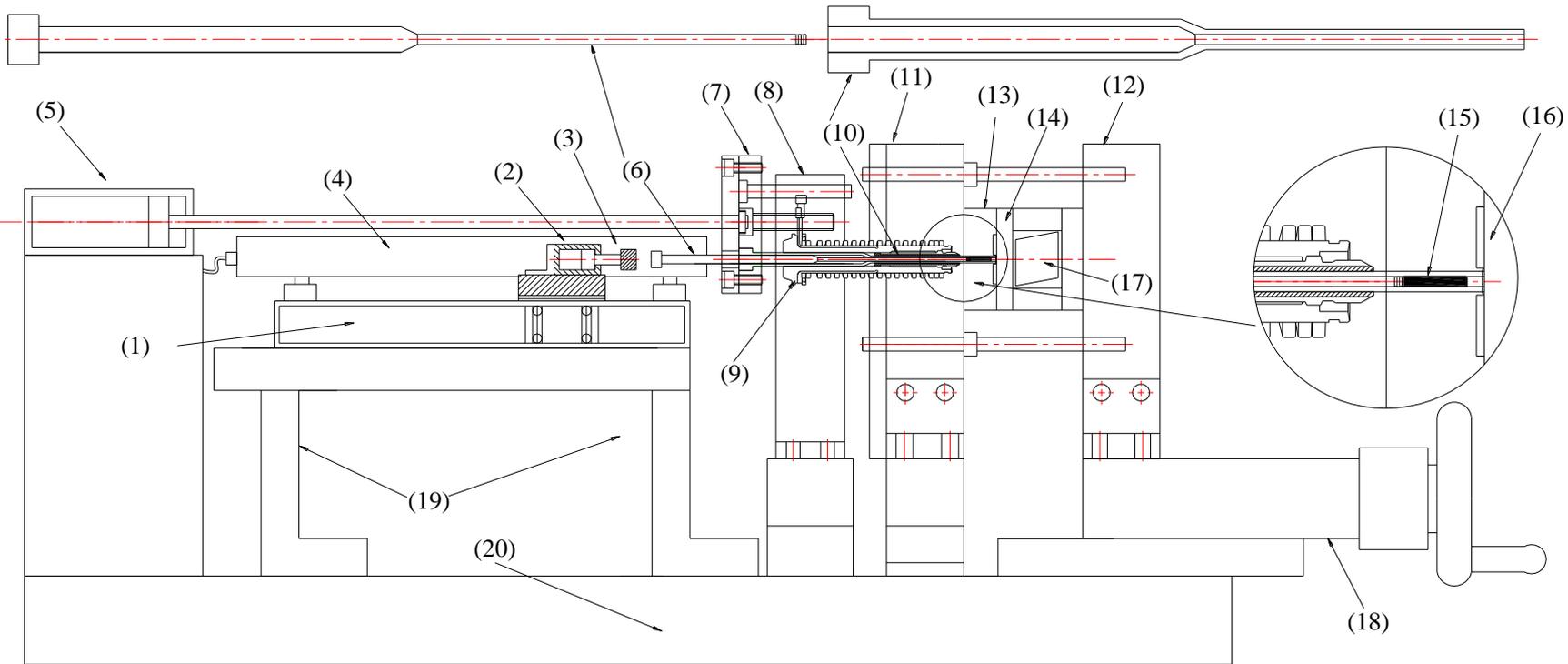
The Three Stage of Impact Injection Molding

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



Impact Type Micro-Injection Machine ^{1/2} (New Version)

➤ L 1400mm、W 200mm、H 300mm

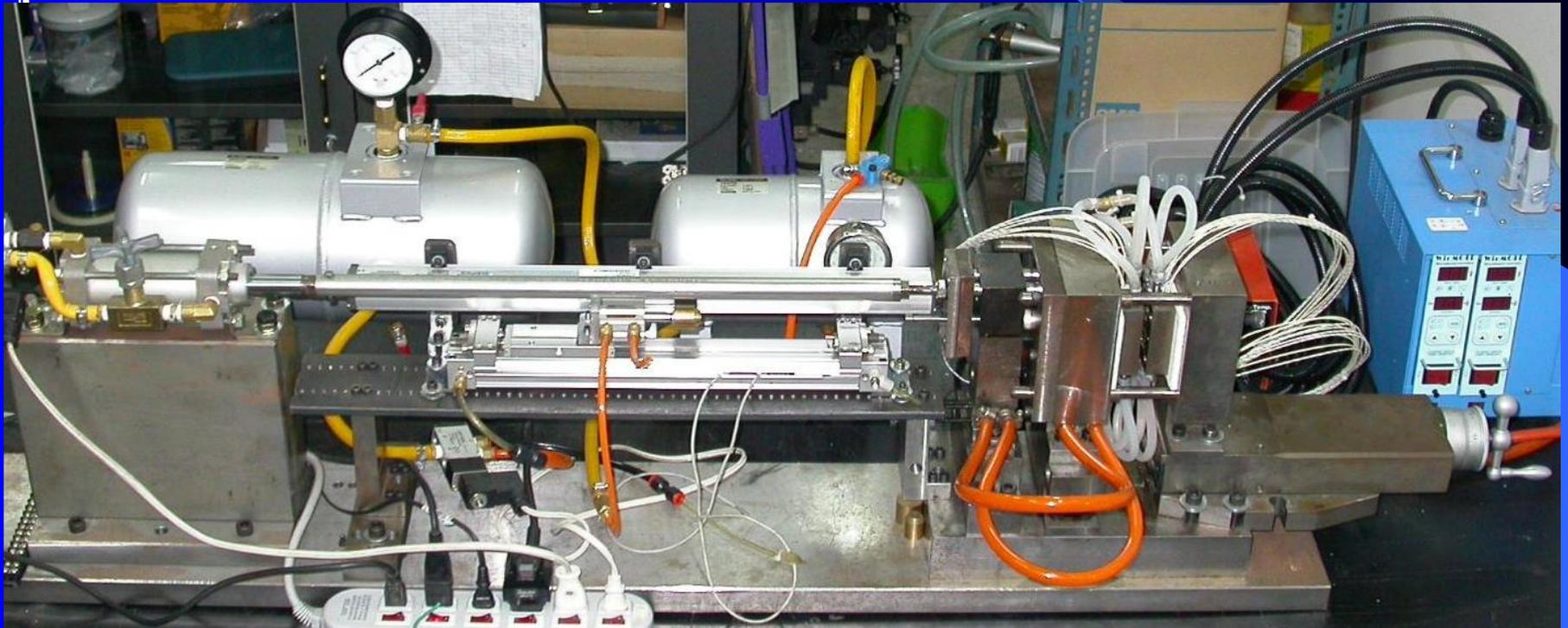


(1)air cylinder of impact accelerating (2)air cylinder of packing pressure (3)impact hammer (4)linear variable differential transfer
 (5)air cylinder of sleeve moving (6)injection plunger (7)injection sleeve stationary base (8)melt unit stationary base (9)melt unit (hot runner)
 (10)injection sleeve (11)stationary-side mold base plate (12)movable-side mold base plate (13) injection mold (14)tempered glass
 (15)plastic billet (16)mold cavities (17)reflection mirror (18)clamping device (19)supporting frames (20)stationary base of the machine

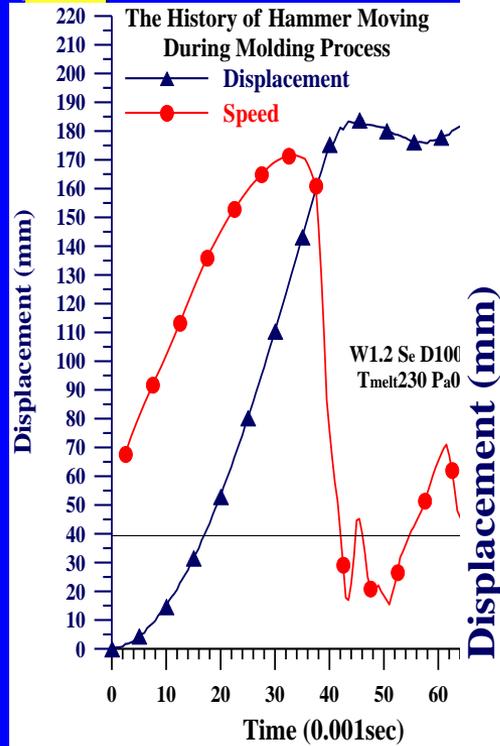
Impact Type Micro-Injection Machine ^{2/2} (New Version)

air pressure of
accelerating cylinder

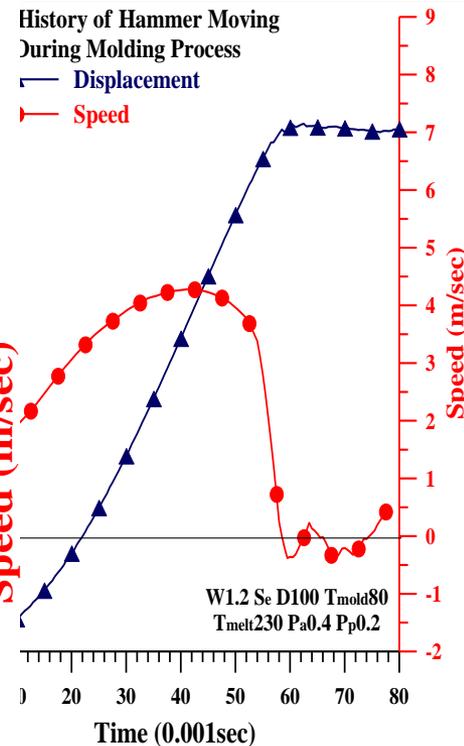
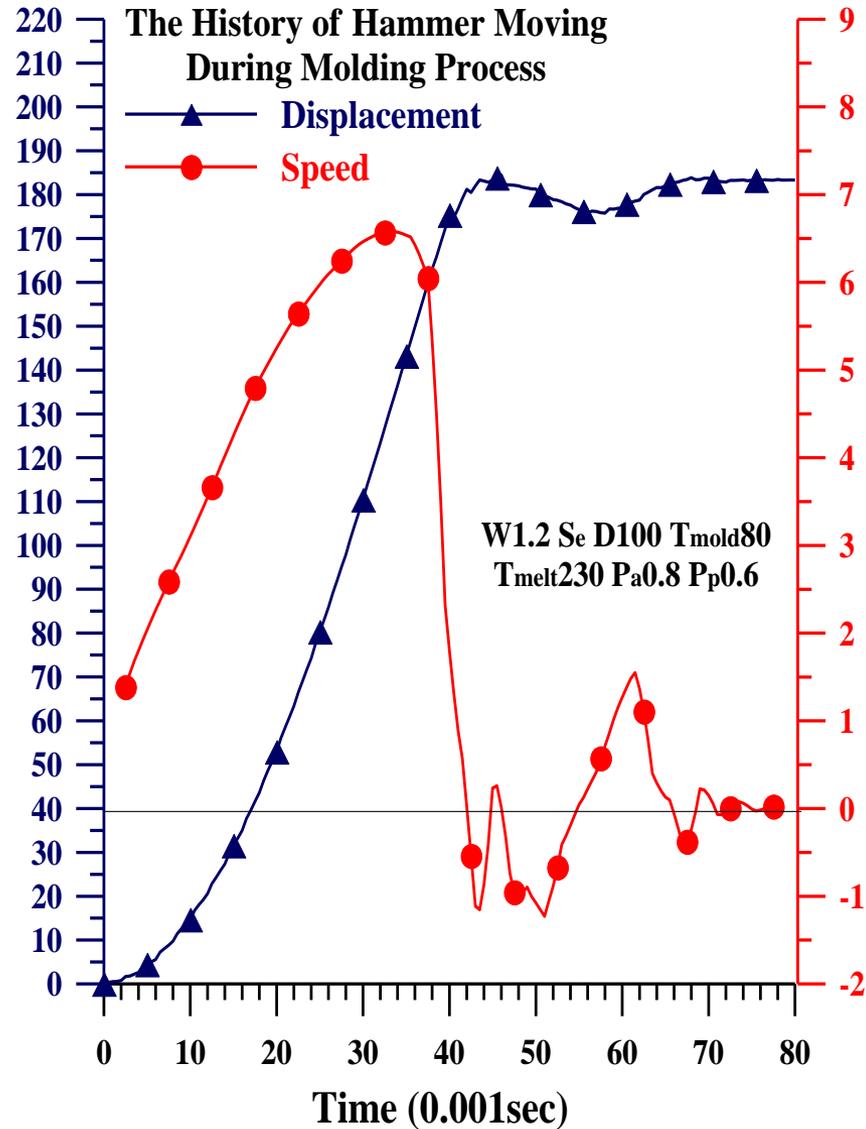
air pressure of
packing cylinder



The Displacements and Speeds of Impact Hammer Moving under Various Air Pressure



$P_a = 0.8\text{Mpa}$
 $P_p = 0.6\text{Mpa}$



$P_a = 0.4\text{Mpa}$
 $P_p = 0.2\text{Mpa}$

Capacity of Impact Injection Molding

Air Pressure	0.2Mpa	0.4Mpa	0.6Mpa	0.8Mpa
Packing Pressure	20Mpa	40Mpa	60Mpa	80Mpa
Piston Force	6.3kgf	12.6kgf	18.8kgf	25.1kgf
Impact Speed	2580mm/s	4300mm/s	5620mm/s	6580mm/s

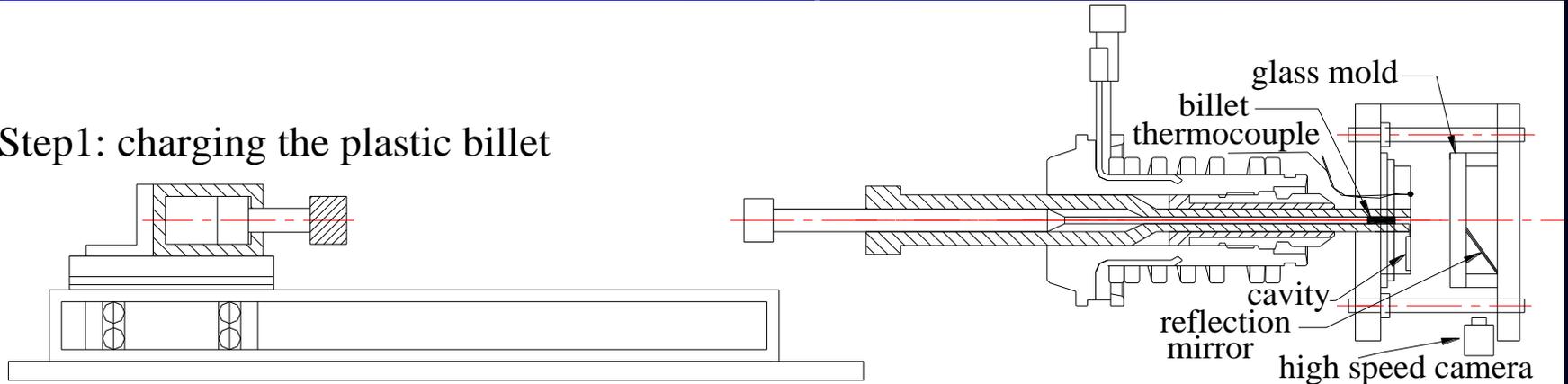
Diameter of impact accelerating piston = 20mm

Diameter of impact accelerating piston = 20mm

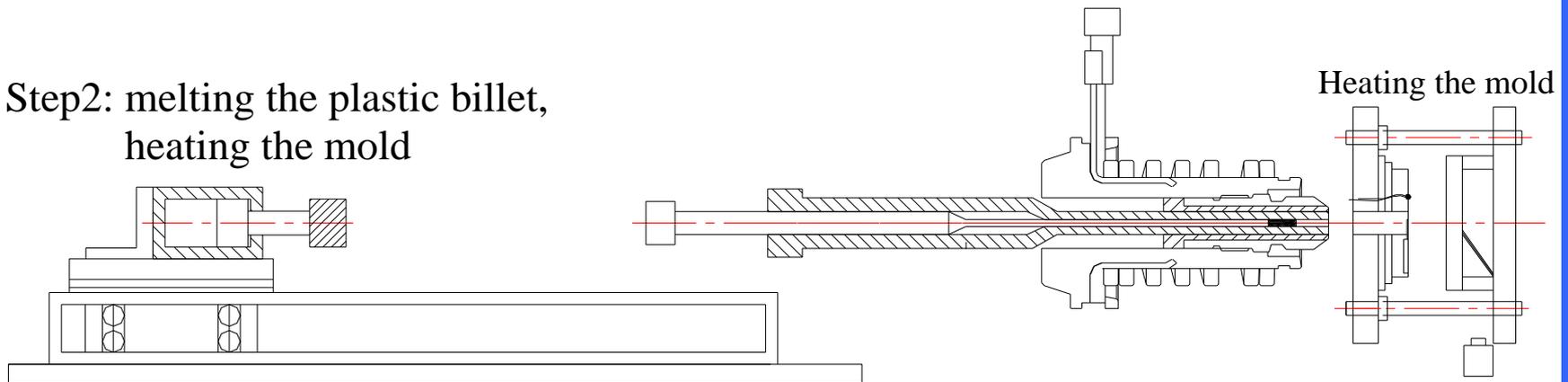
Diameter of injection plunger = 2mm.

The Procedures of Impact Type Micro-Injection Molding ^{1/2}

Step1: charging the plastic billet

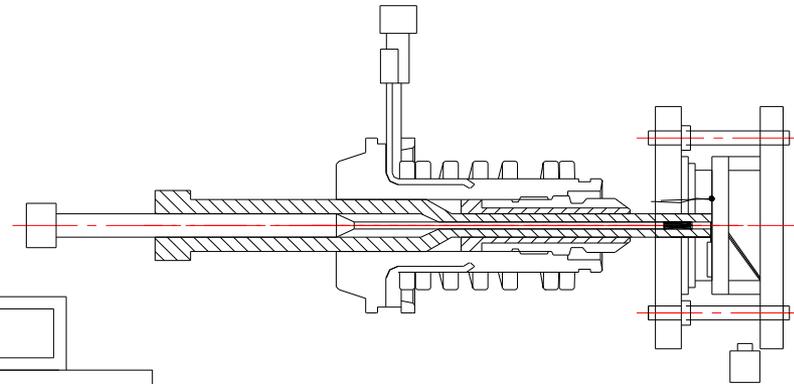
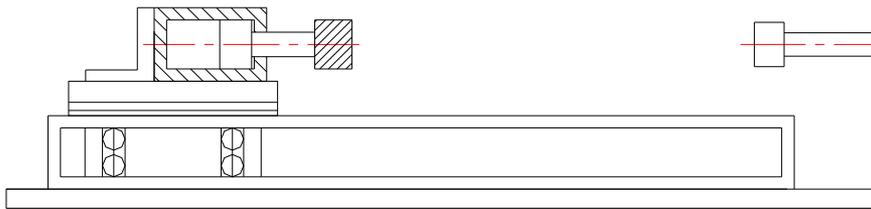


Step2: melting the plastic billet, heating the mold

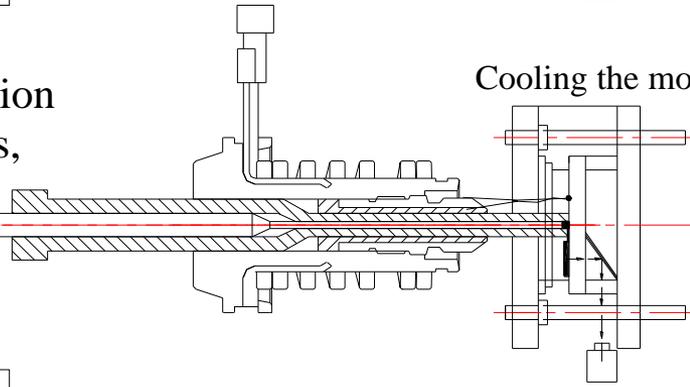
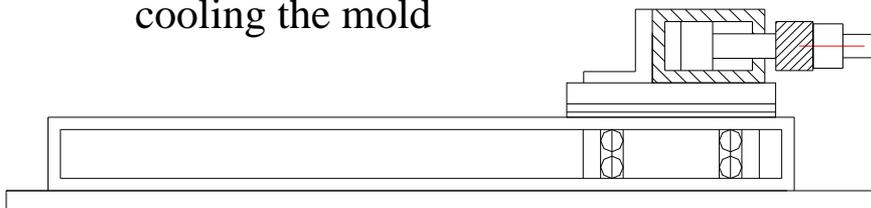


The Procedures of Impact Type Micro-Injection Molding ^{2/2}

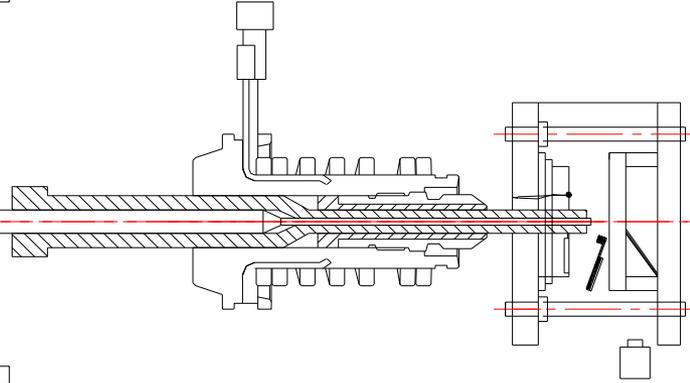
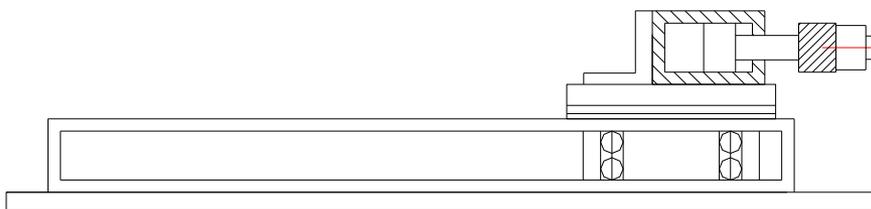
Step3: closing the mold,
moving forward the injection unit



Step4: actuating the air piston to impact the injection
plunger causing the melt to fill the cavities,
cooling the mold

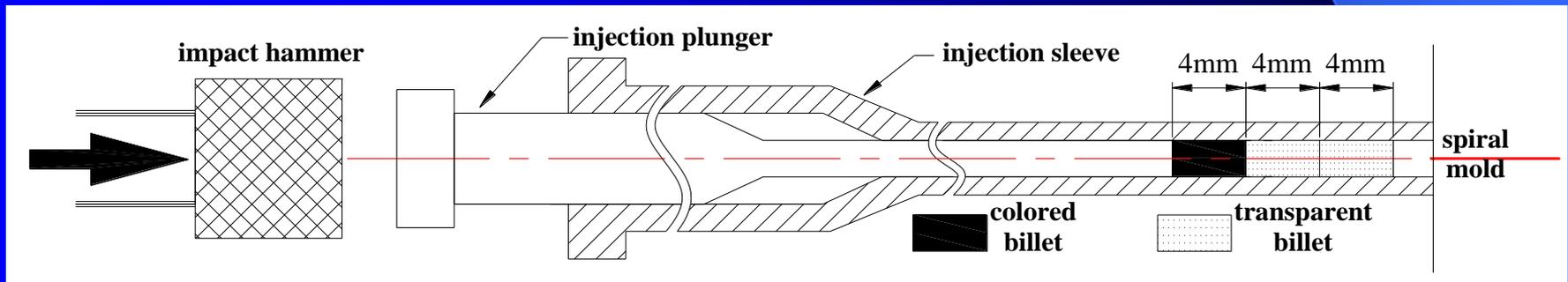


Step5: opening the mold and ejecting the parts



Objectives of Study

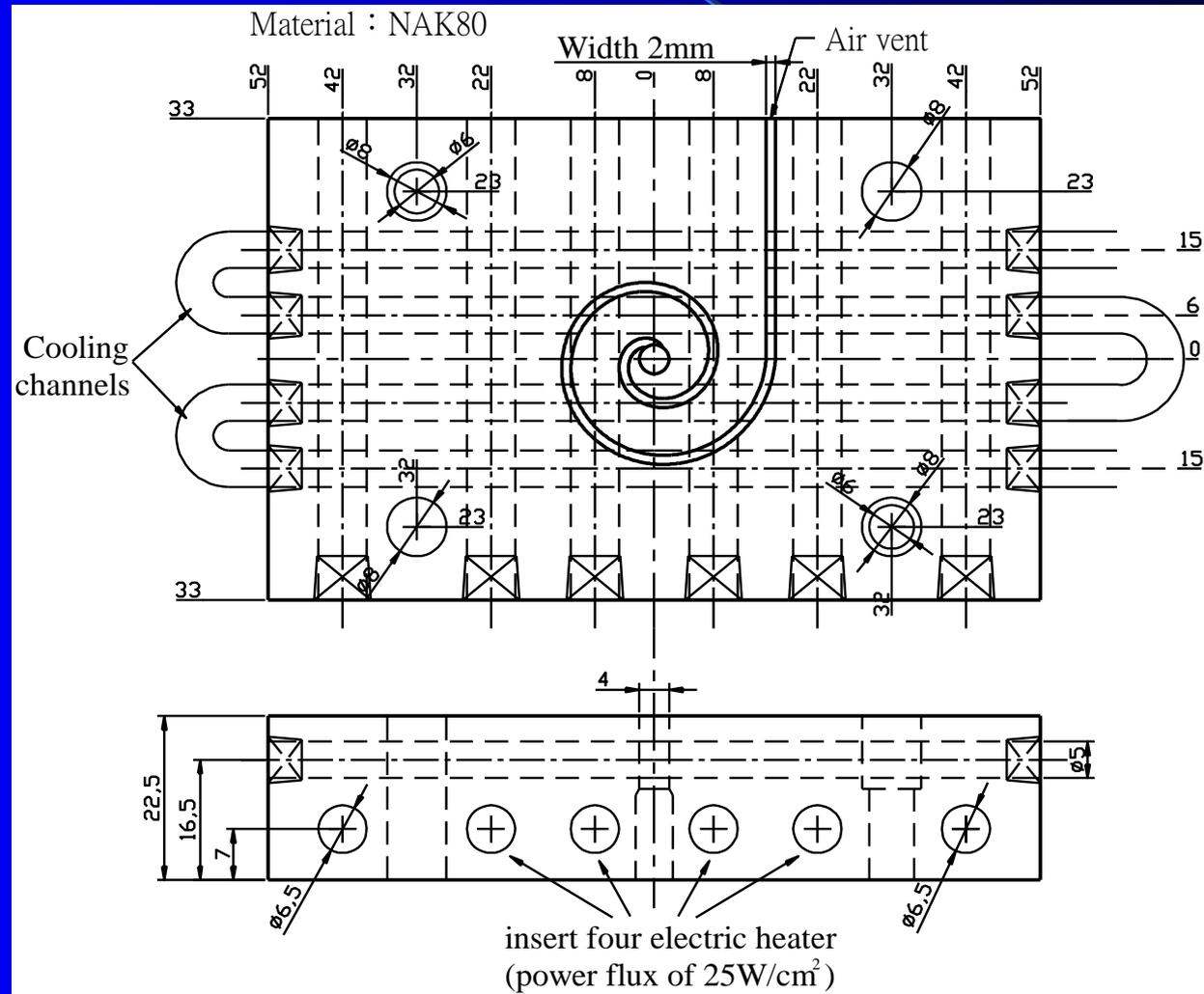
Objective : To observe flow behaviors of melt during filling the spiral cavity with aids of **colored billets** and **high-speed video camera**



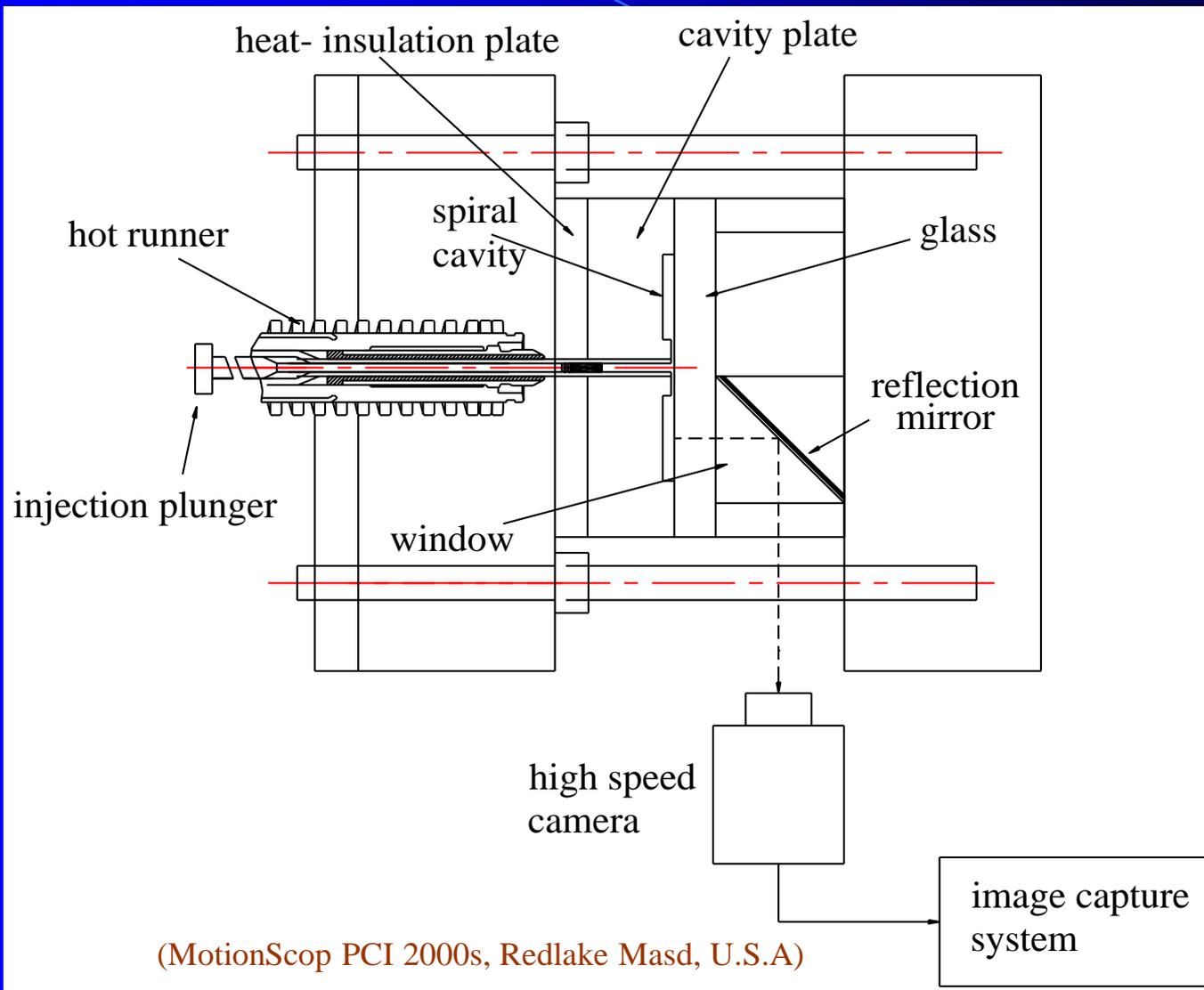
The Dimensions of Spiral Mold

Spiral Cavities: Width = 2 mm

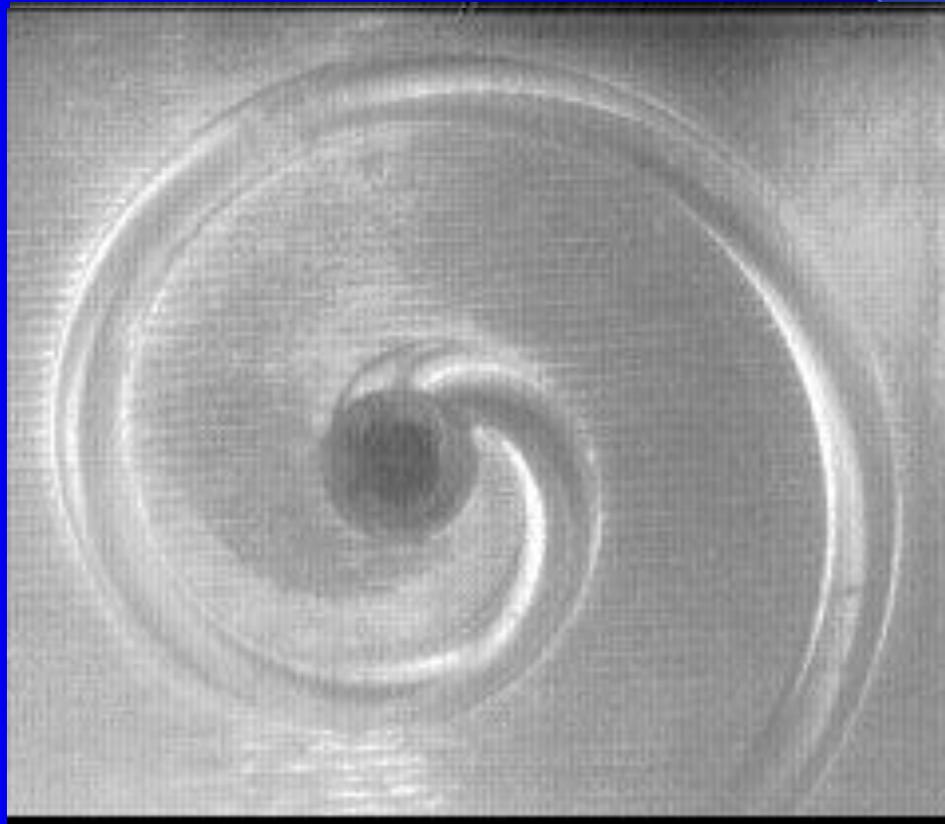
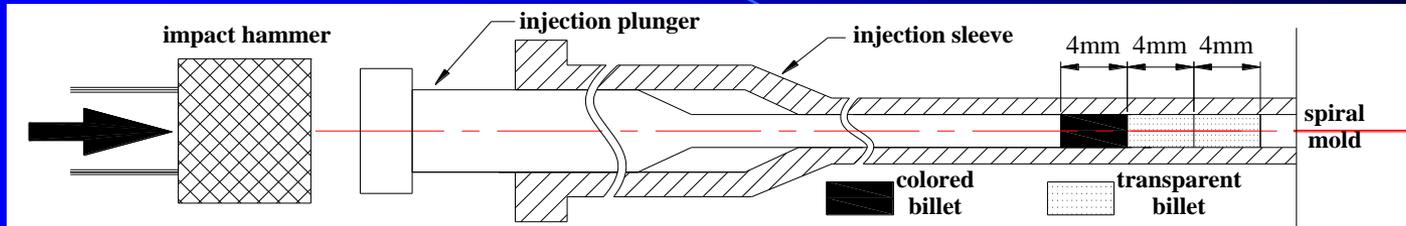
Depth = 50 μ m, 100 μ m, 200 μ m, 300 μ m



The Setup of Images Capture System



Images of Melt Flow in Spiral Mold With 200 μm Depth Cavity



$$T_{\text{melt}} = 230^{\circ}\text{C}$$

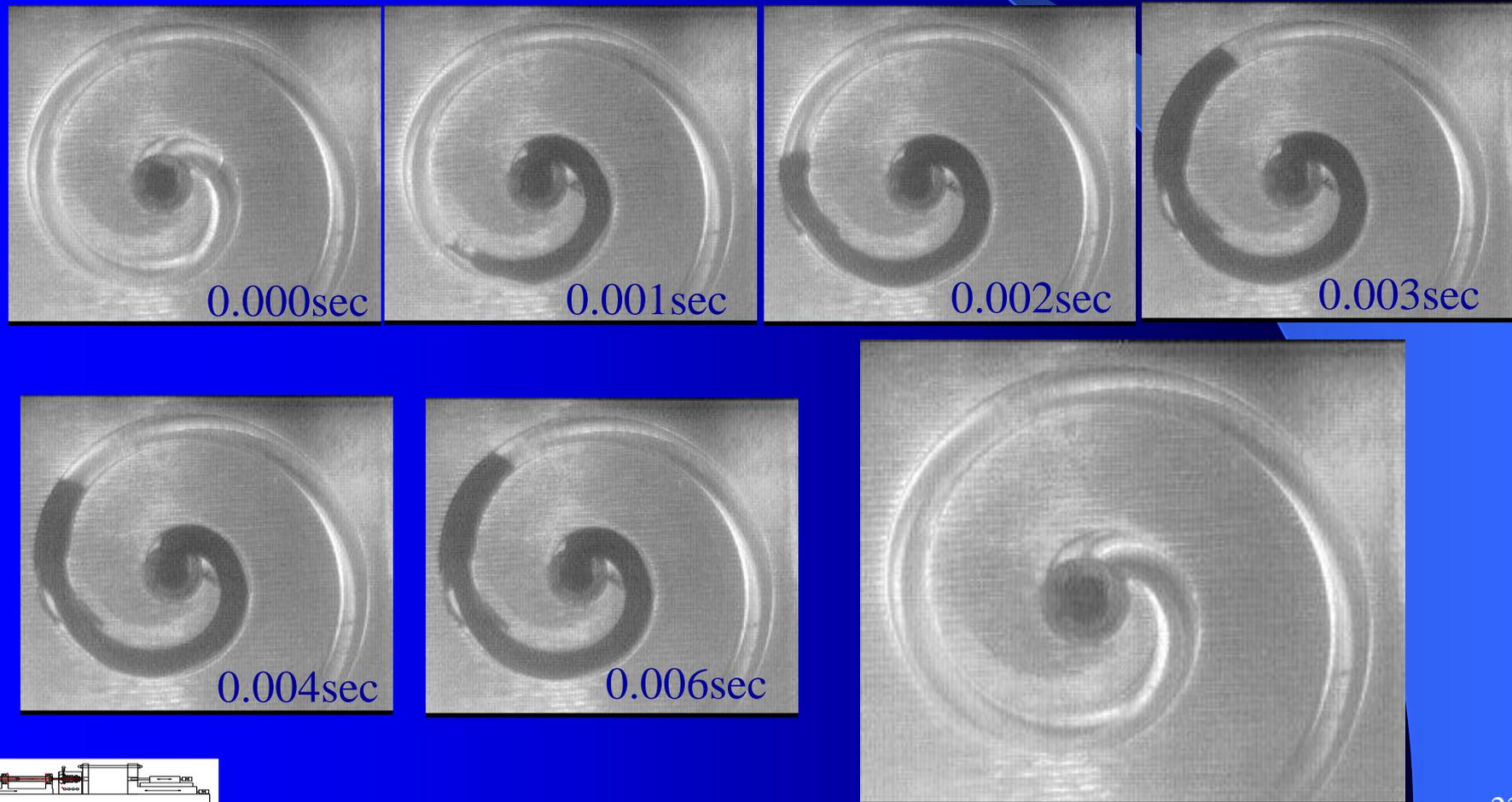
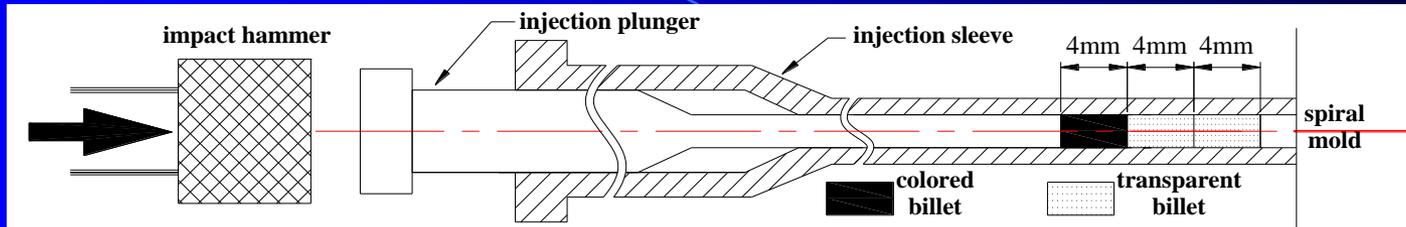
$$T_{\text{mold}} = 80^{\circ}\text{C}$$

$$P_a = 0.8\text{Mpa}$$

$$P_p = 0.6\text{Mpa}$$

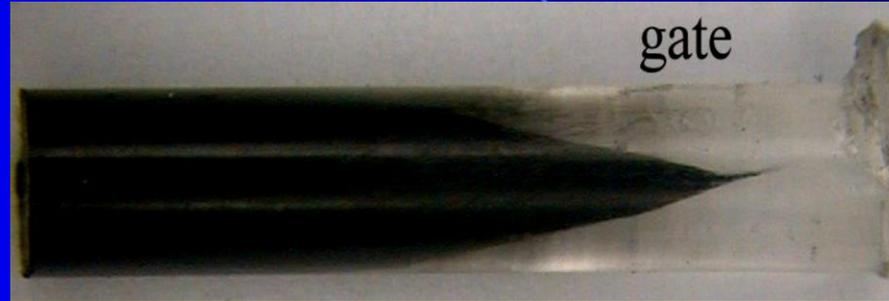
1000 Frames/sec All Frames Delay 350 : 1

Images of Melt Flow in Spiral Mold With 200 μ m Depth Cavity



The Residual Melt Inside the Injection Sleeve

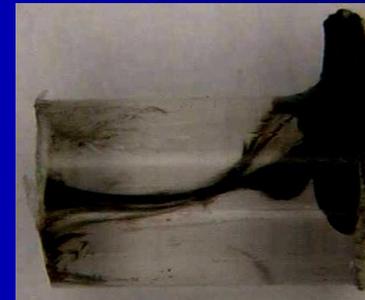
Plunger



Plunger



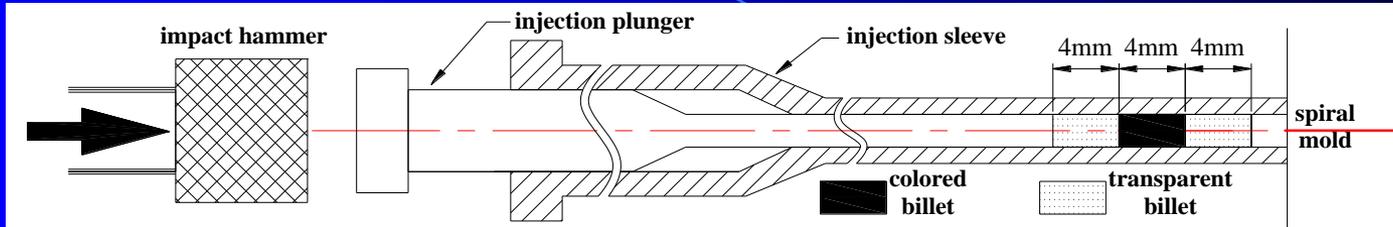
Plunger



Melt Flow Behavior During Filling a Cavity of 200 μm Depth

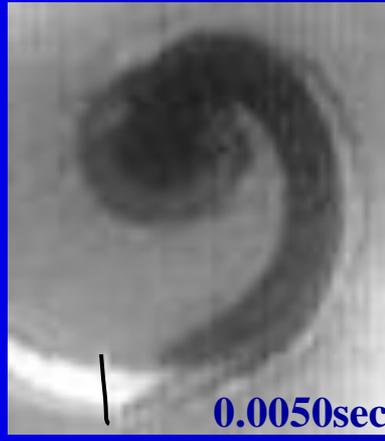
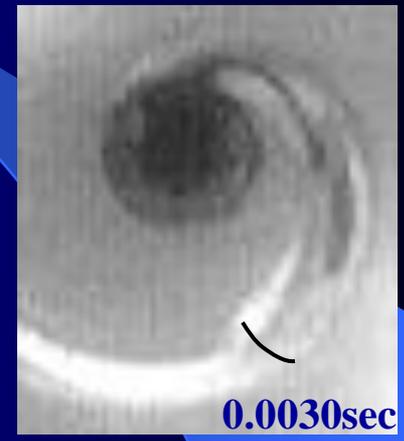
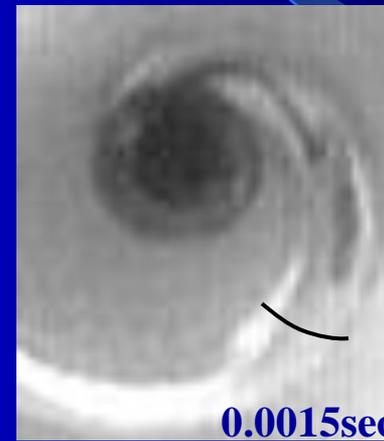
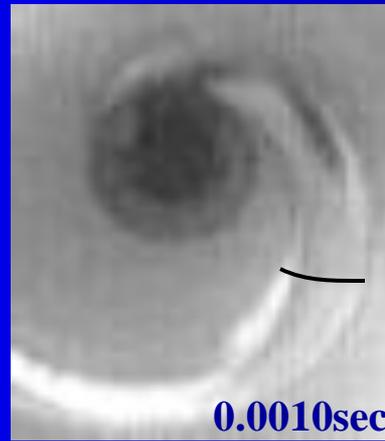
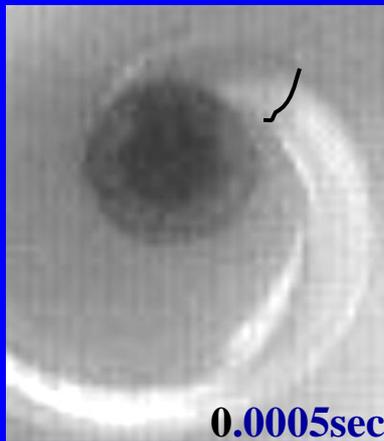
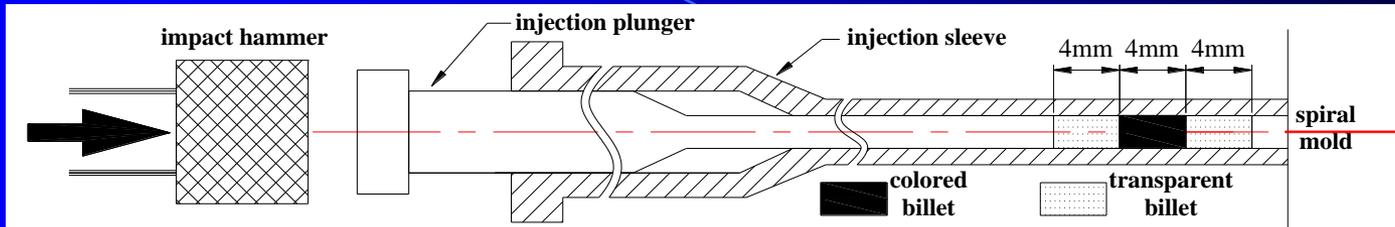
- The colored melt that is in the back of the sleeve will penetrate through the core of melt ahead and leads the melt front.
- The patterns of colored melt flow in the sleeve is like a funnel with its outlet leading to the gate.
- The colored melt appears soon after the transparent melt is injected into the spiral cavity.
- The flow type during impact filling is fountain flow.

The Images of Melt Flow in Spiral Mold With $100\mu\text{m}$ Depth Cavity

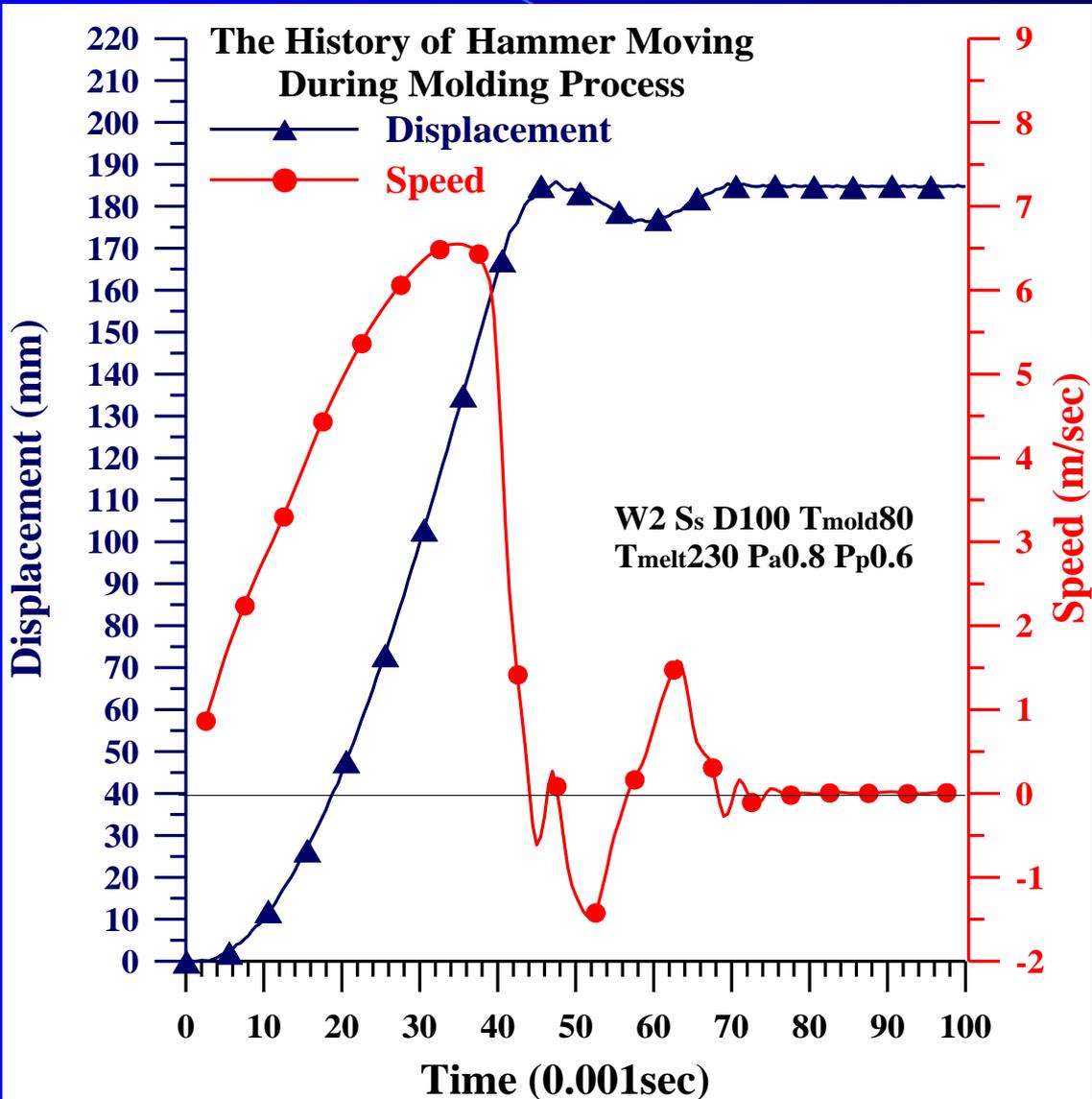


2000 Frames/sec All Frames Delay 500 : 1

The Images of Melt Flow in Spiral Mold With 100 μ m Depth Cavity



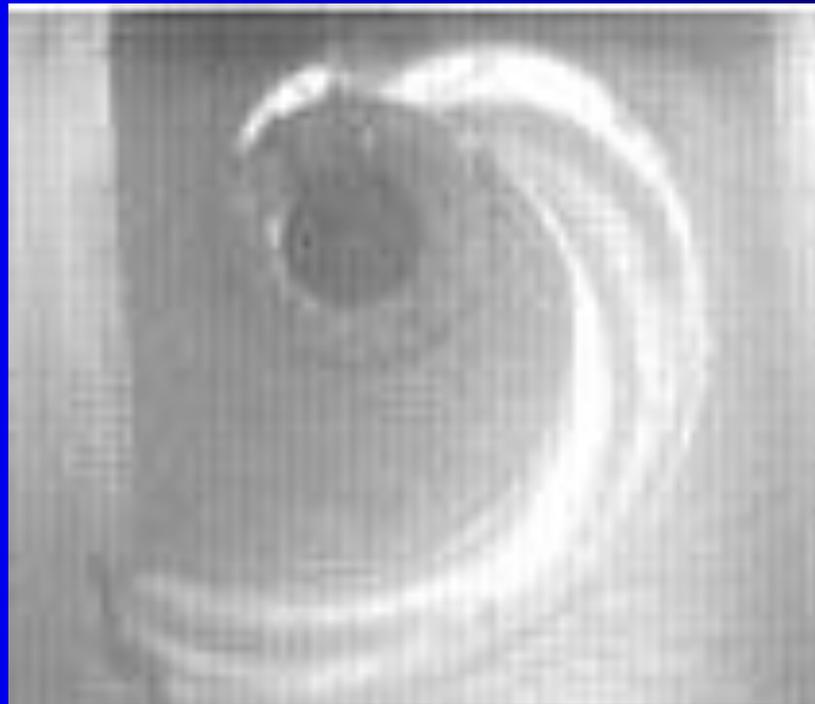
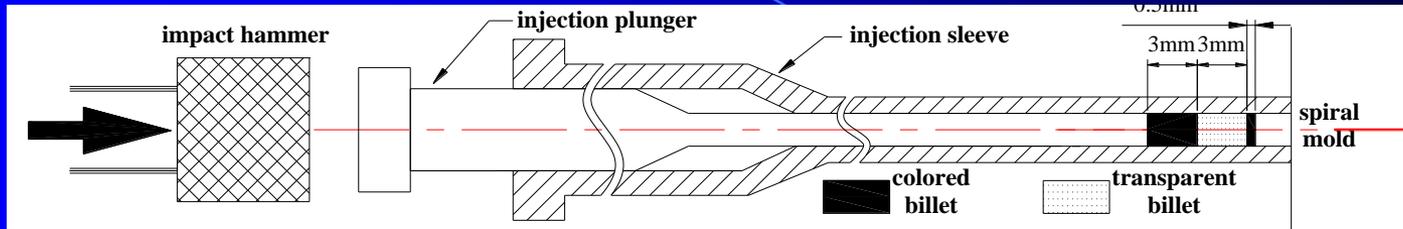
The Displacements and Speeds of Impact Hammer Moving



Melt Flow Behavior During Filling a Cavity of 100 μm Depth

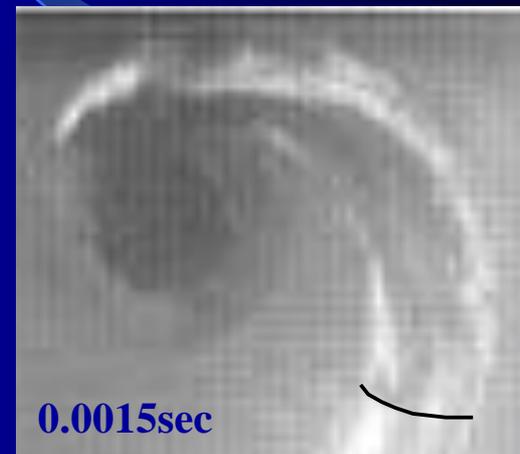
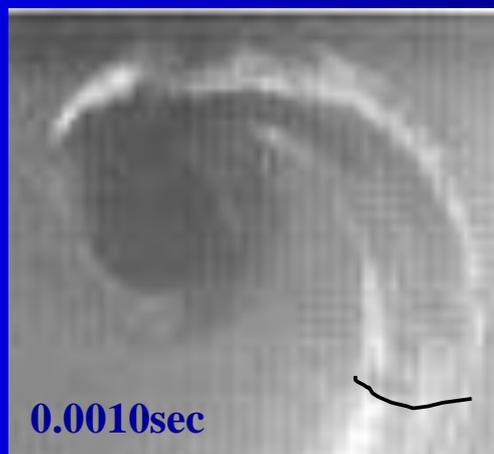
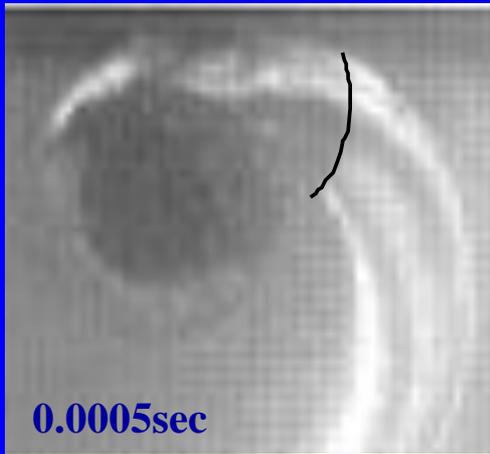
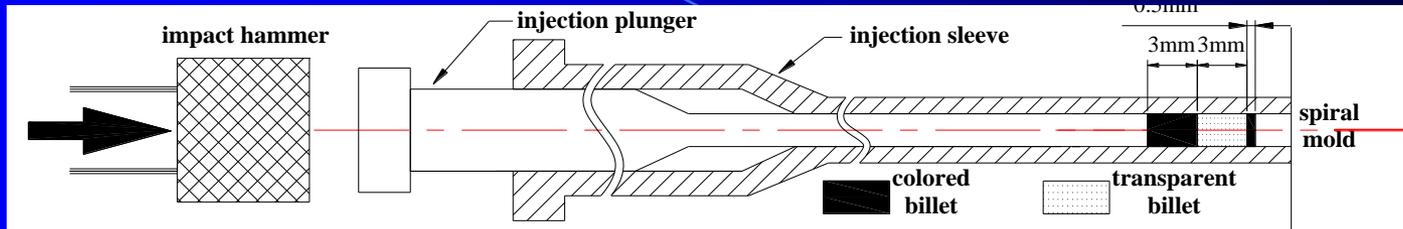
- The flow length decreases significantly when the cavity thickness reduces.
- During filling the cavity of 100 μm depth, a hesitation phenomenon was observed. The second impact caused the melt to further advance.

The Images of Melt Flow in Spiral Mold With $50\mu\text{m}$ Depth Cavity



2000 Frames/sec All Frames Delay 300 : 1

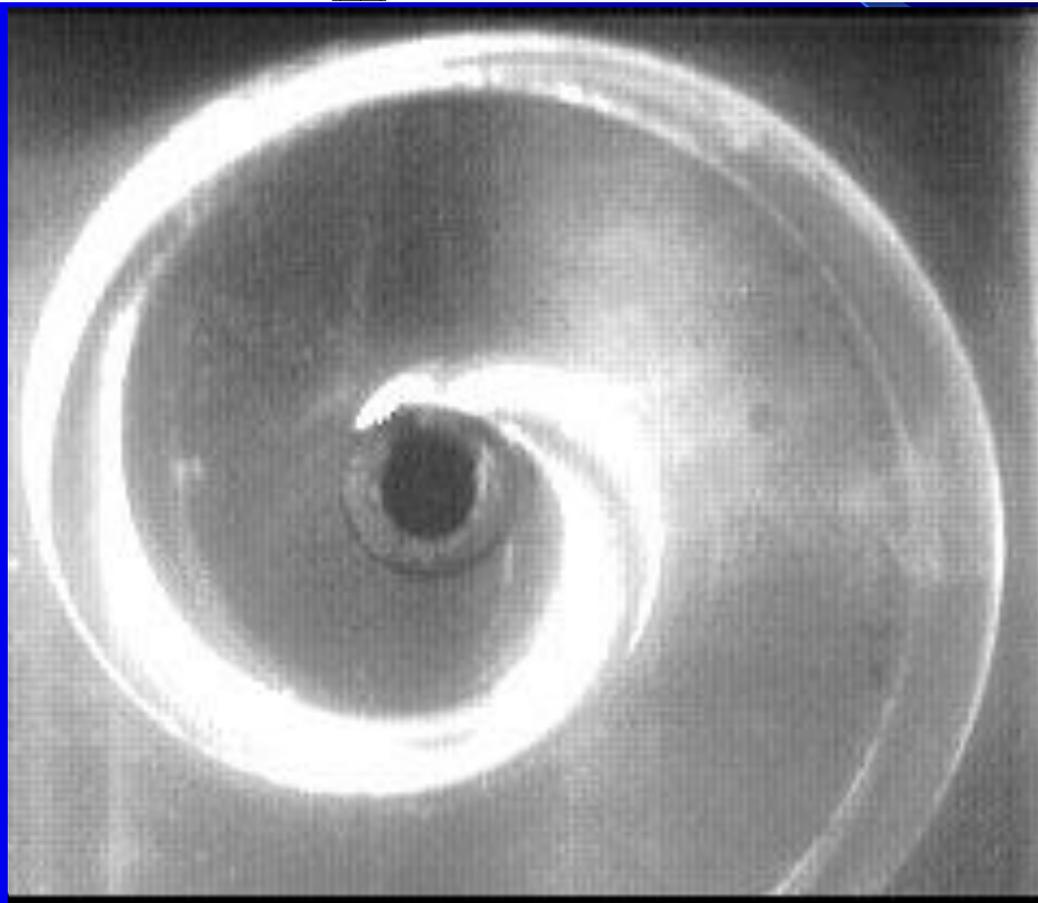
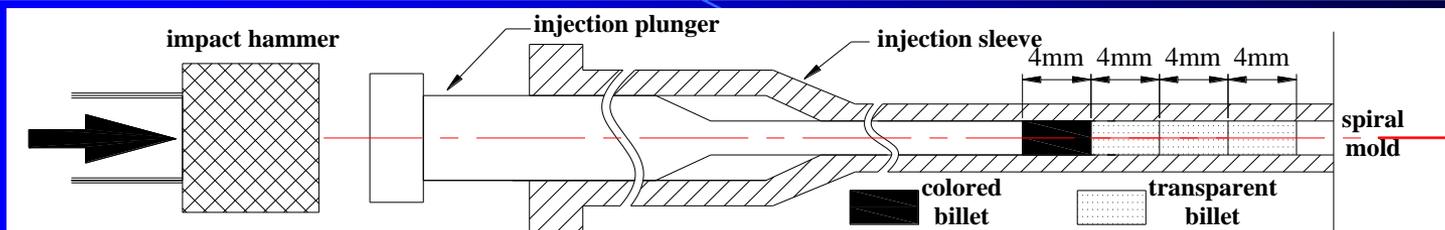
The Images of Melt Flow in Spiral Mold With $50\mu\text{m}$ Depth Cavity



Melt Flow Behavior During Filling a Cavity of $50\mu\text{m}$ Depth

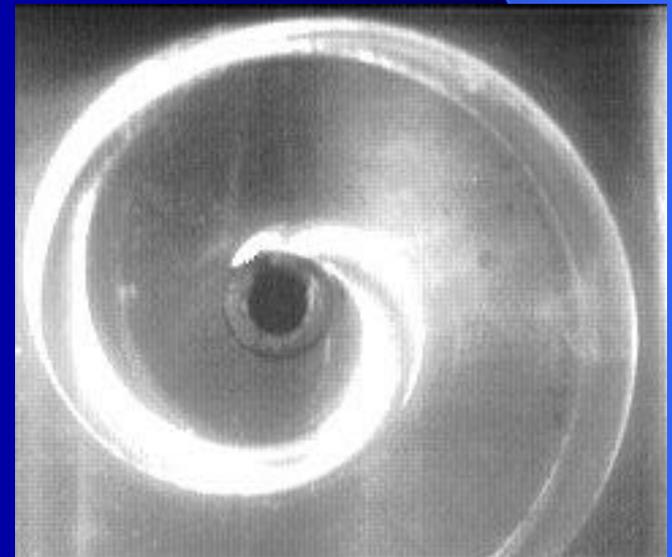
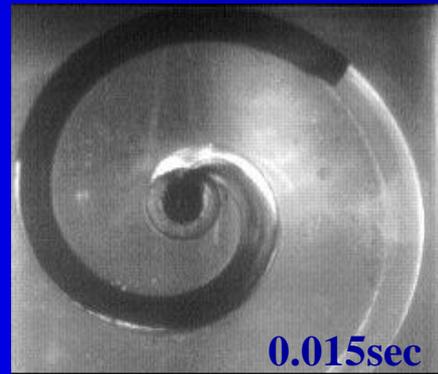
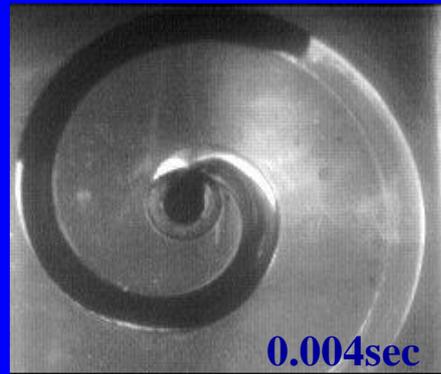
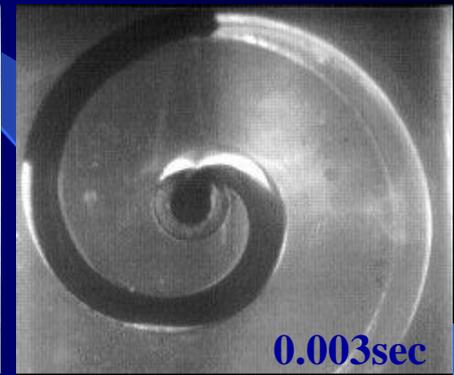
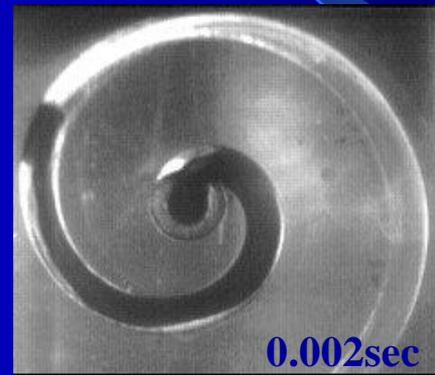
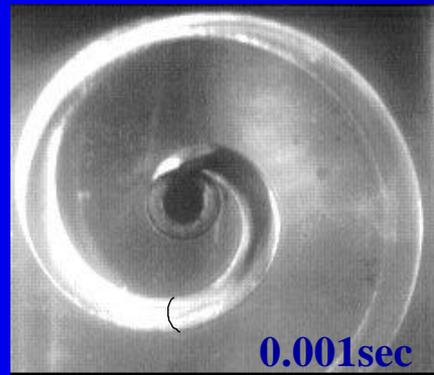
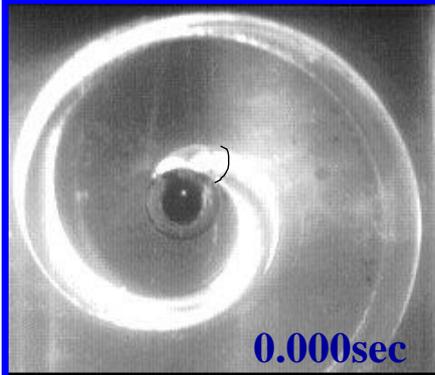
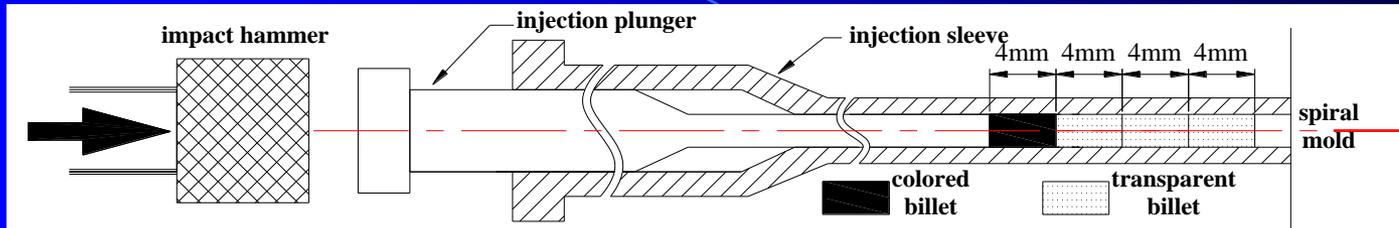
- The melt advanced in this ultra thin cavity only at the instant of impact; It quickly stopped in less than 0.001 second.
- The colored melt flowed along a path close to the inner side of spiral cavity that has shorter distance and higher pressure gradient.
- The second impact failed to drive the melt to advance further. But more melt was packed into the spiral cavity.

The Images of Melt Flow in Spiral Mold With 300 μm Depth Cavity



2000 Frames/sec All Frames Delay 300 : 1

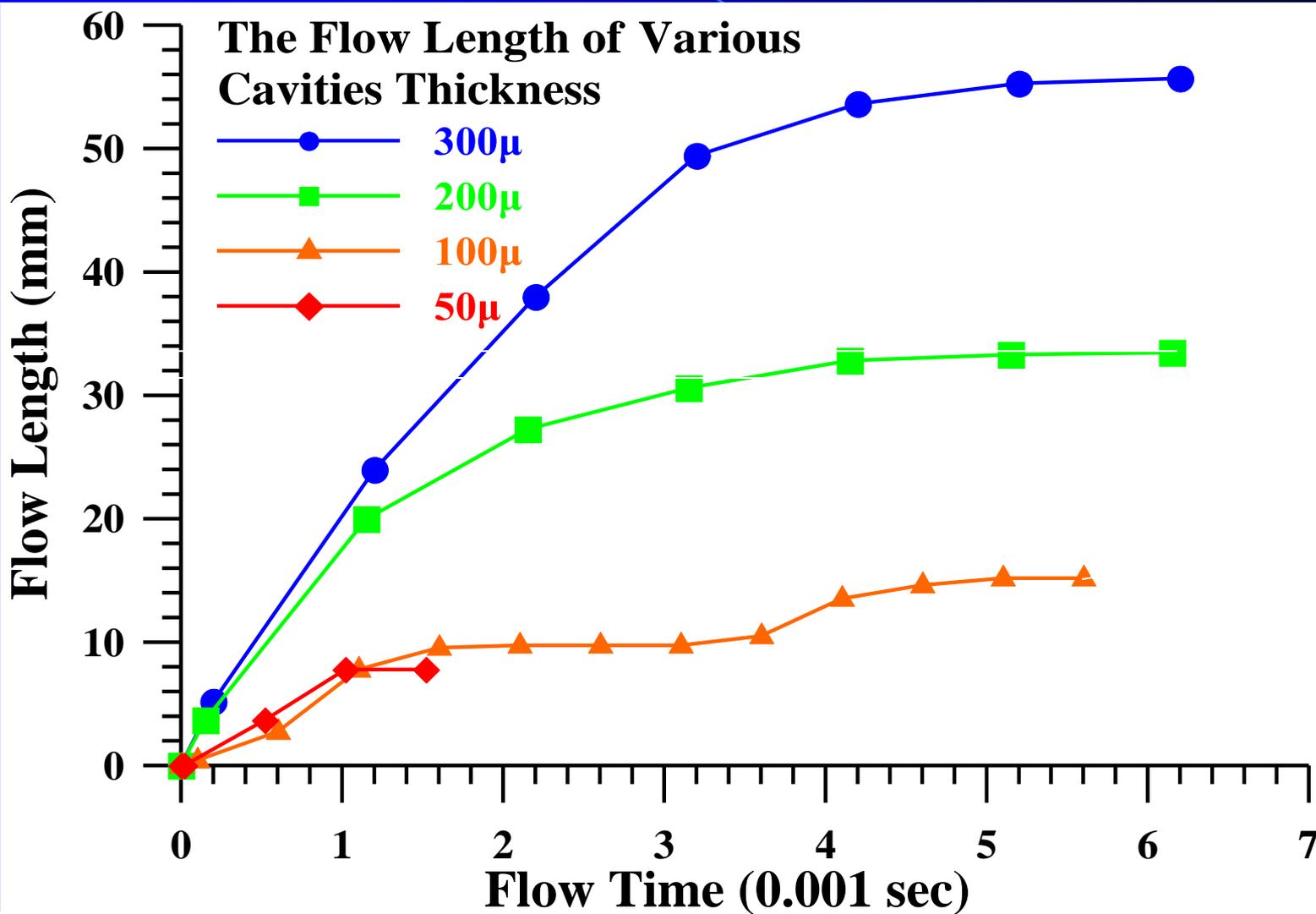
The Images of Melt Flow in Spiral Mold With 300 μ m Depth Cavity



Melt Flow Behavior During Filling a Cavity of 300 μm Depth

- The melt flow has longest flow length in cavity of 300 μm depth.
- In the end, near the gate, the transparent melt will flow into the cavity again.
- Packing phenomenon can be observed clearly near the gate.

The Flow Length in Cavities of Various Thickness



Conclusions

1. The melt in the back penetrates through the core of melt ahead and leads the melt front.
2. The melt flow during filling spiral cavities is fountain flow.
3. The filling of deeper cavities (300, 200 μm) clearly shows impact-filling and pressure-filling stages.
4. During filling the cavity of 100 μm depth, the flow paused for a short while and advanced again.
5. During filling the cavity of 50 μm depth, the melt flows only upon impact.

Thank You !

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