

# Experimental Study on the Filling Characteristics During Micro-Injection Molding

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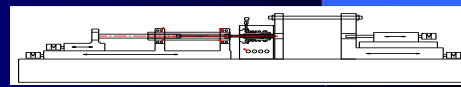
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# Outline

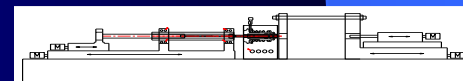
- Introduction
- The impact type micro injection machine
- Spiral flow experiment, Taguchi method
- Flow visualization
- Conclusions



# The Define 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  $\mu\text{m}$  scale
2. injection molded parts with micro-structured regions
  - characterized by the  $\mu\text{m}$  order such as the micro-hole and - slot
3. micro-precision parts
  - parts could have any dimensions, but has tolerances in the  $\mu\text{m}$  range

Kukla et al (1998)



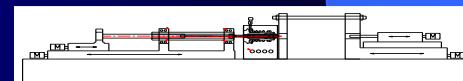
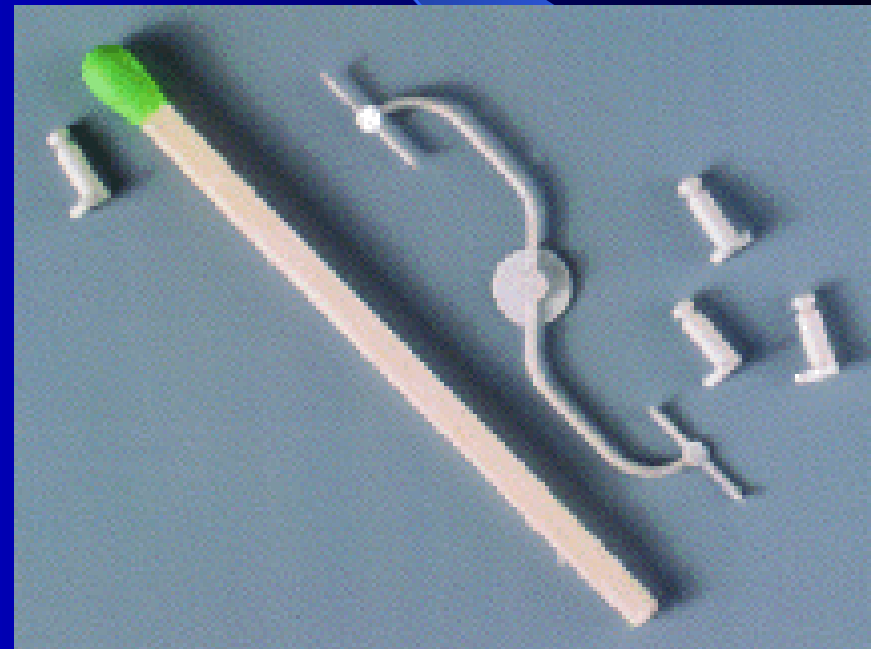
# The Application of Micro-Injection Molding (1/3)

## ➤ Precision Micro-parts

Micro-gears

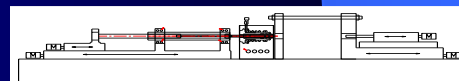
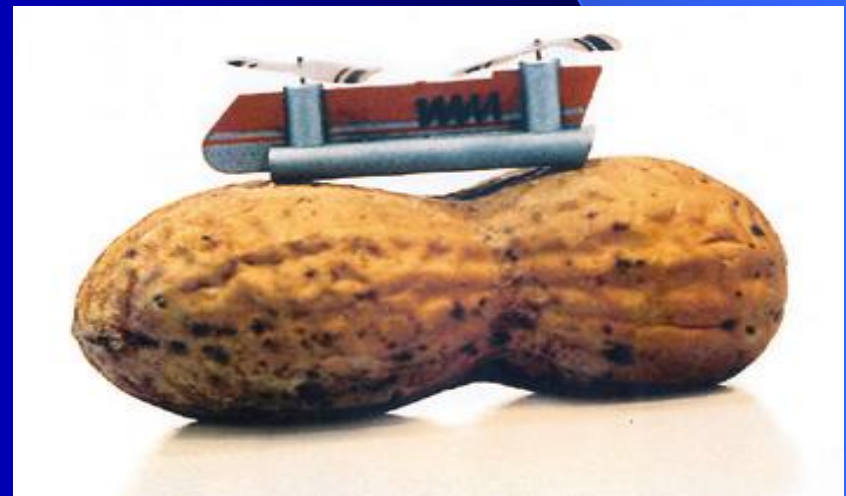
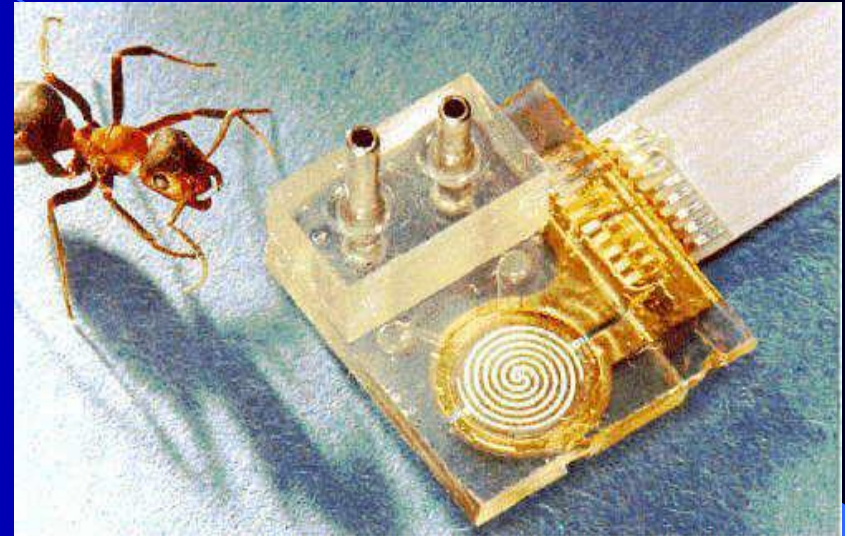
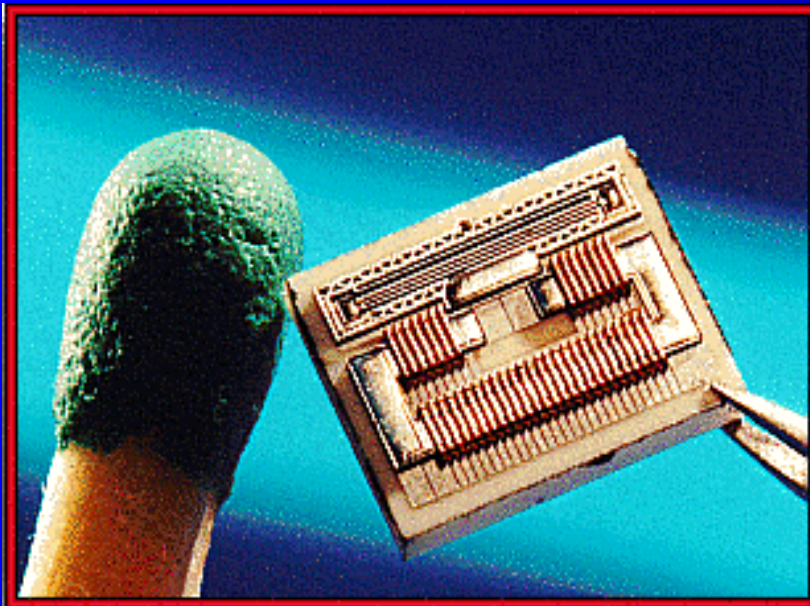


Micro-parts



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

## ➤ Micro-Electro-Mechanical System (MEMS)

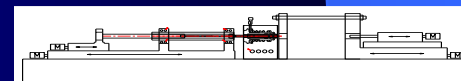
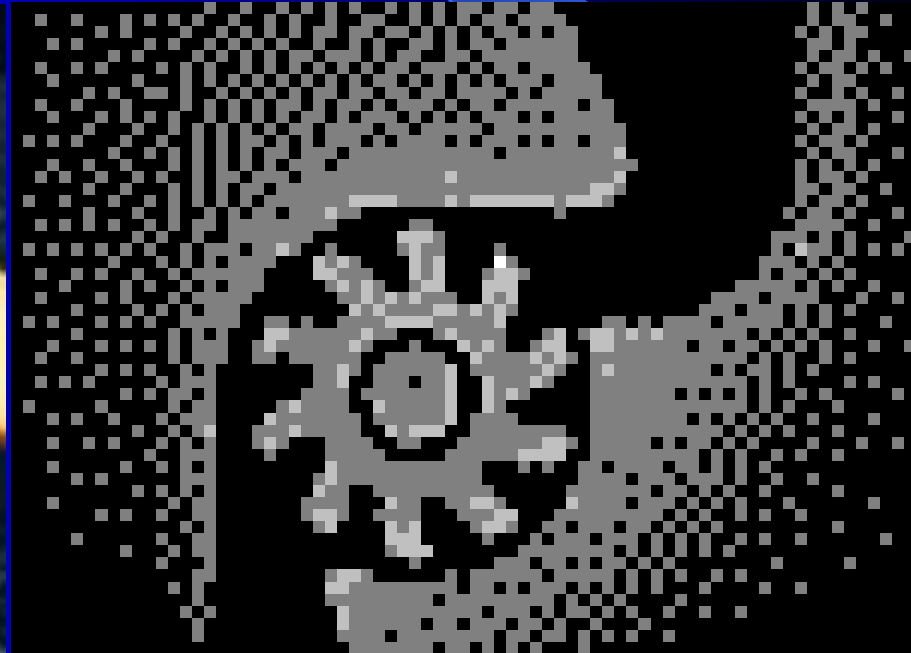


# The Application of Micro-Injection Molding (3/3)

## ➤ Biotechnology

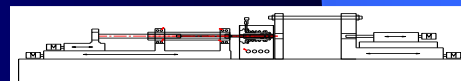
Component of audiphones  
( $\varnothing 0.8\text{mm}$  0.0028g)

Micro-pump

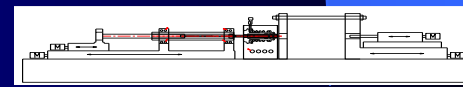
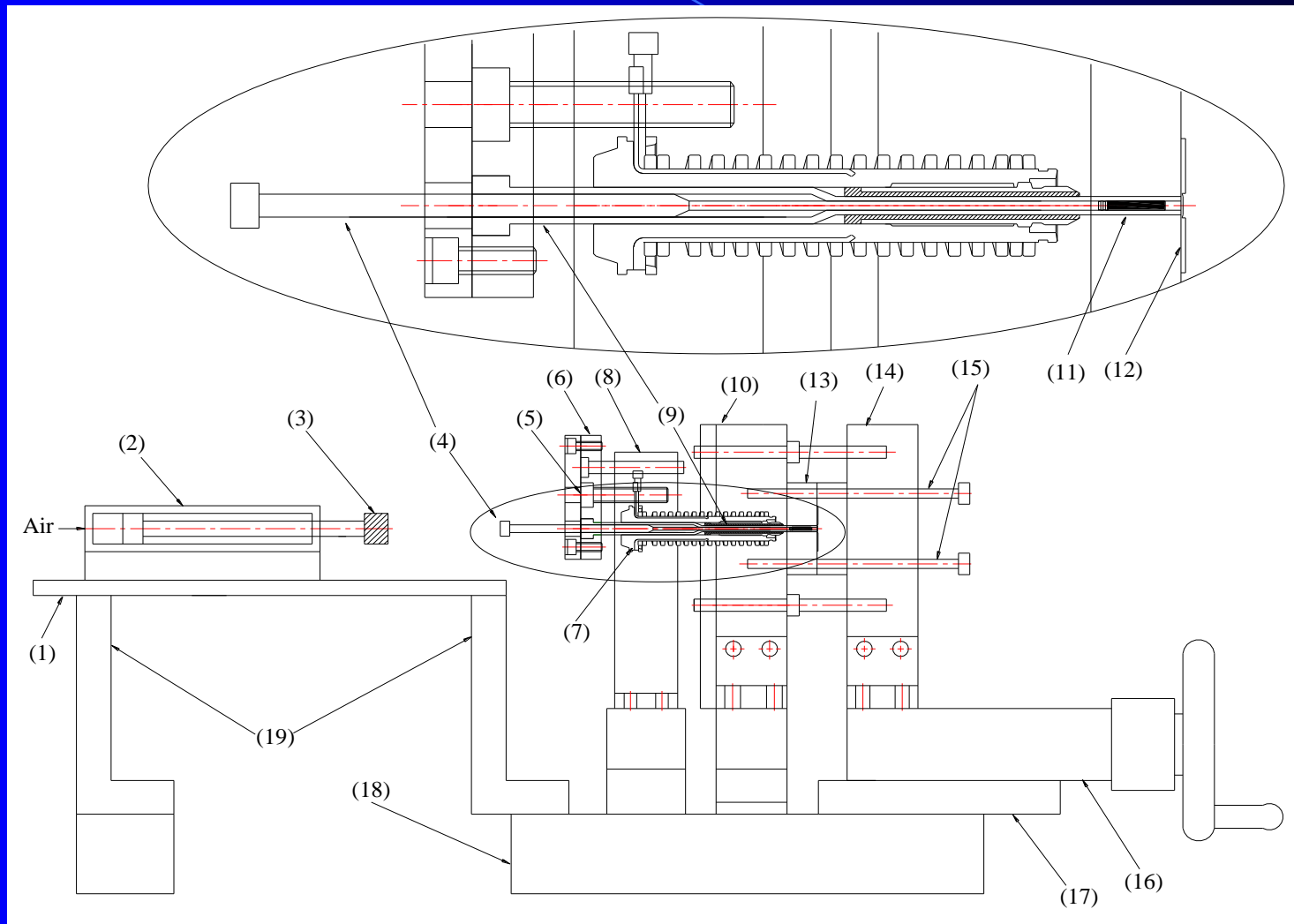


# Requirements of Micro-Injection Molding Machine

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

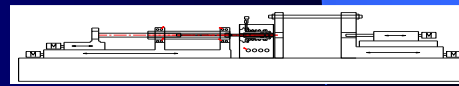
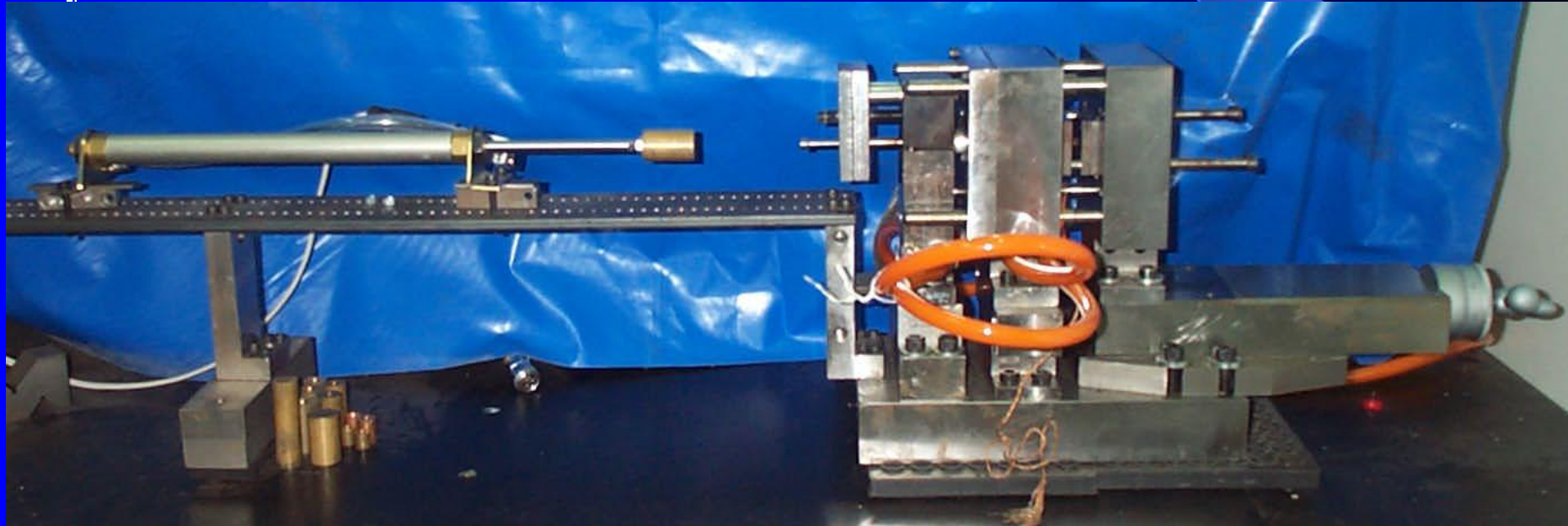


# Impact Type Micro-Injection Machine <sup>1/2</sup>

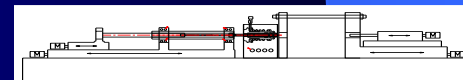
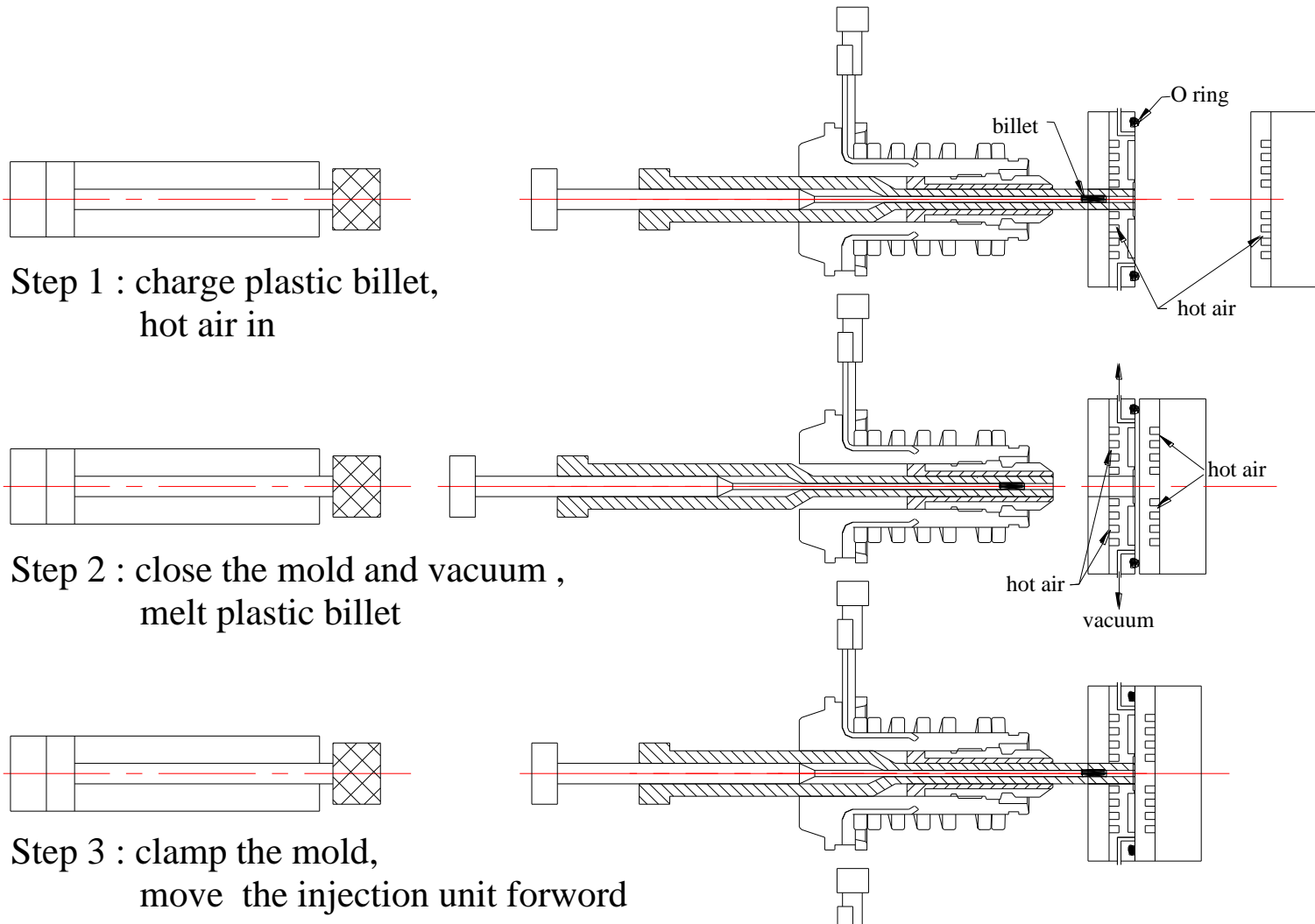


# Impact Type Micro-Injection Machine <sup>2/2</sup>

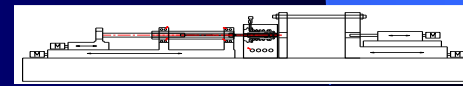
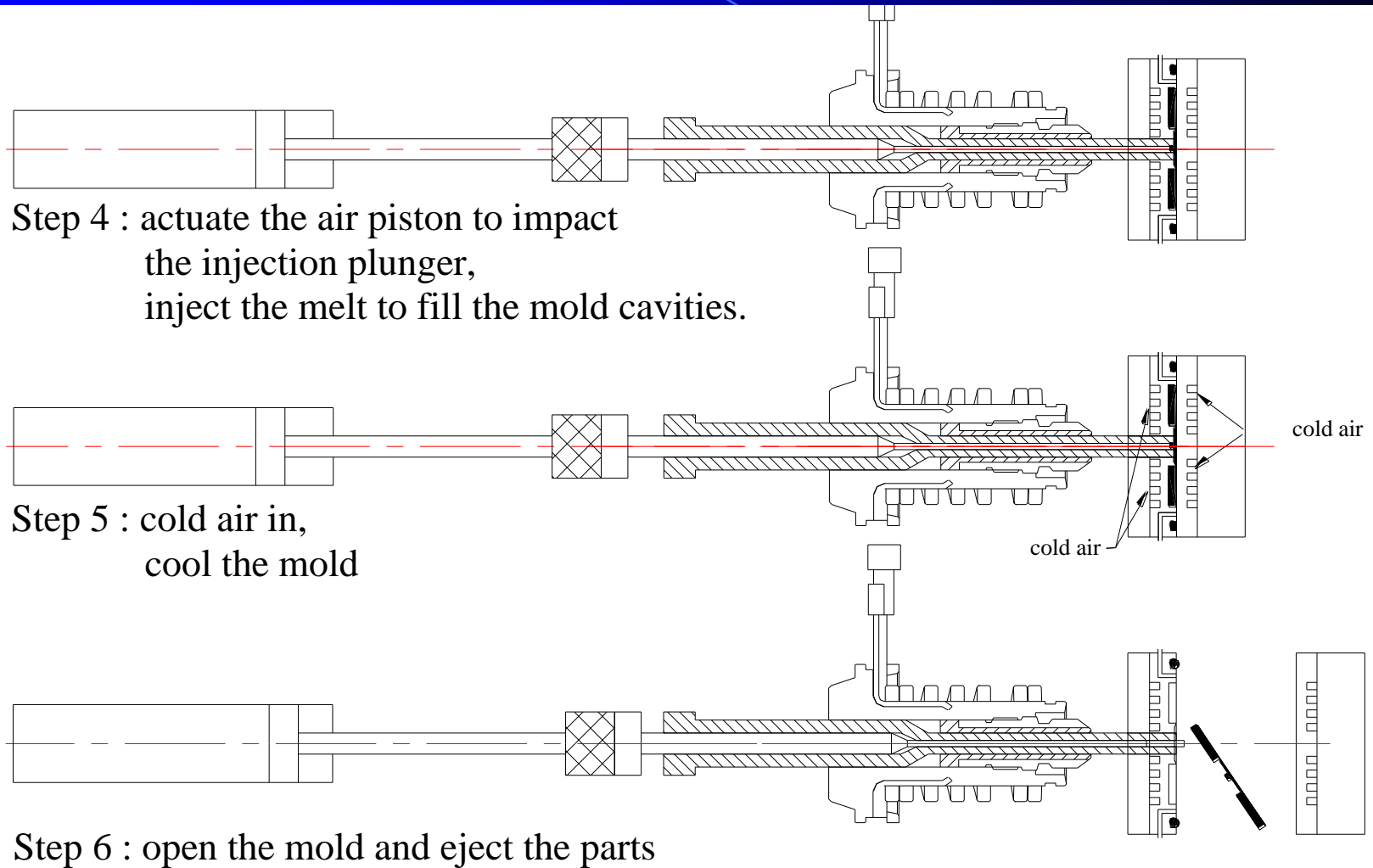
L: 950mm H: 300mm W: 140mm



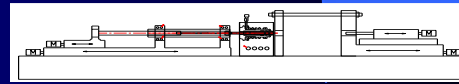
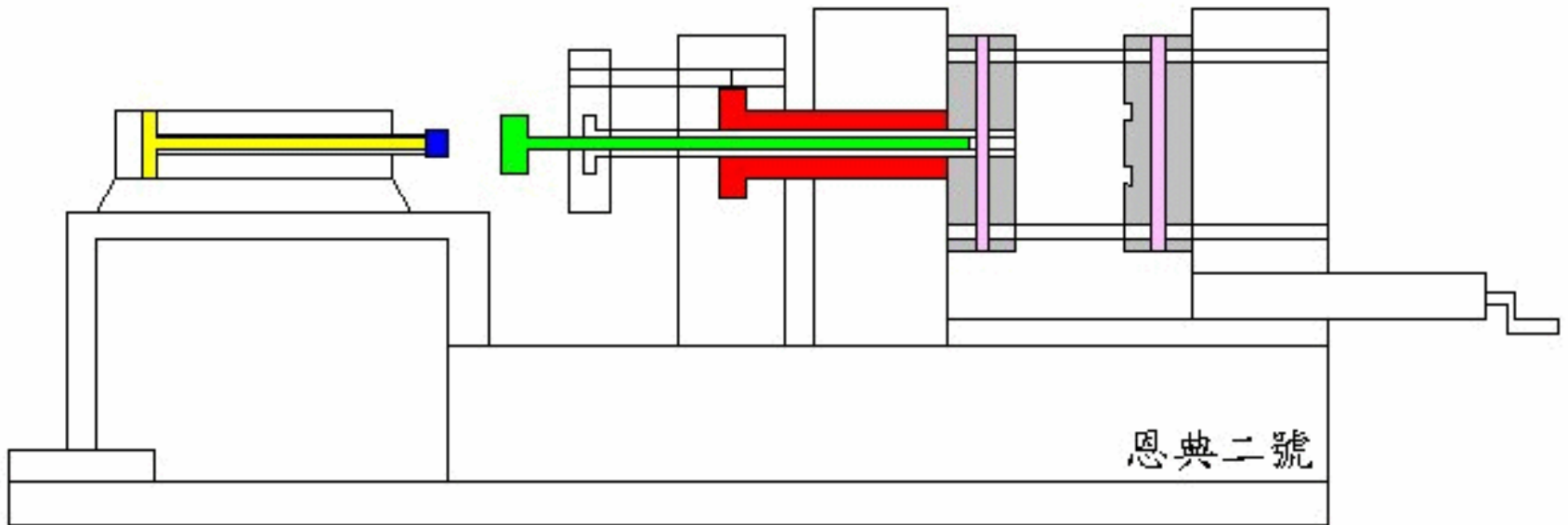
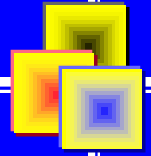
# The Procedures of Impact Type Micro-Injection Molding <sup>1/3</sup>



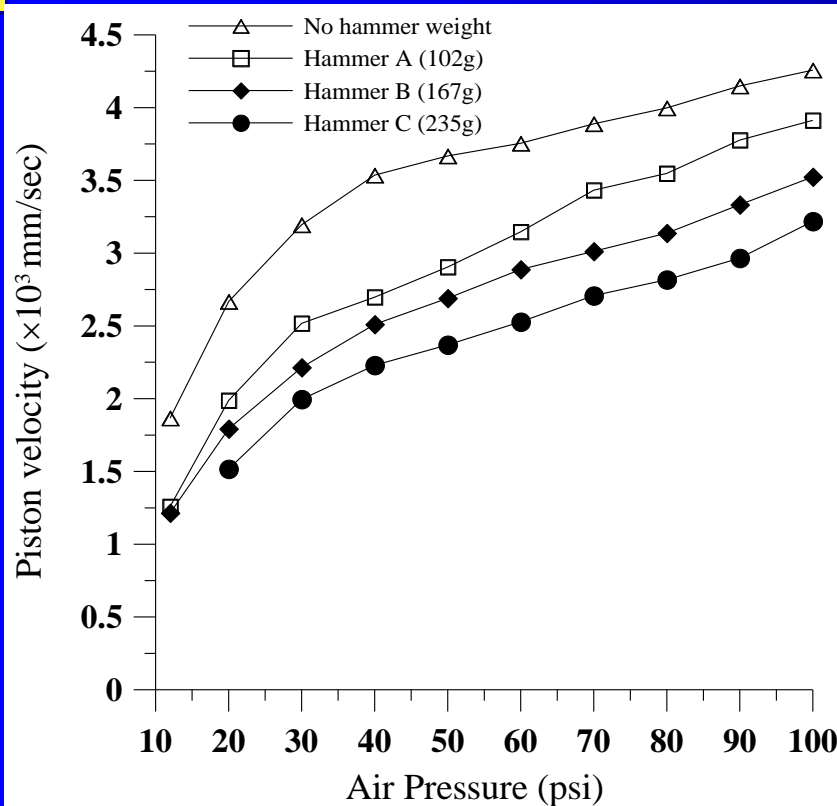
# The Procedures of Impact Type Micro-Injection Molding <sup>2/3</sup>



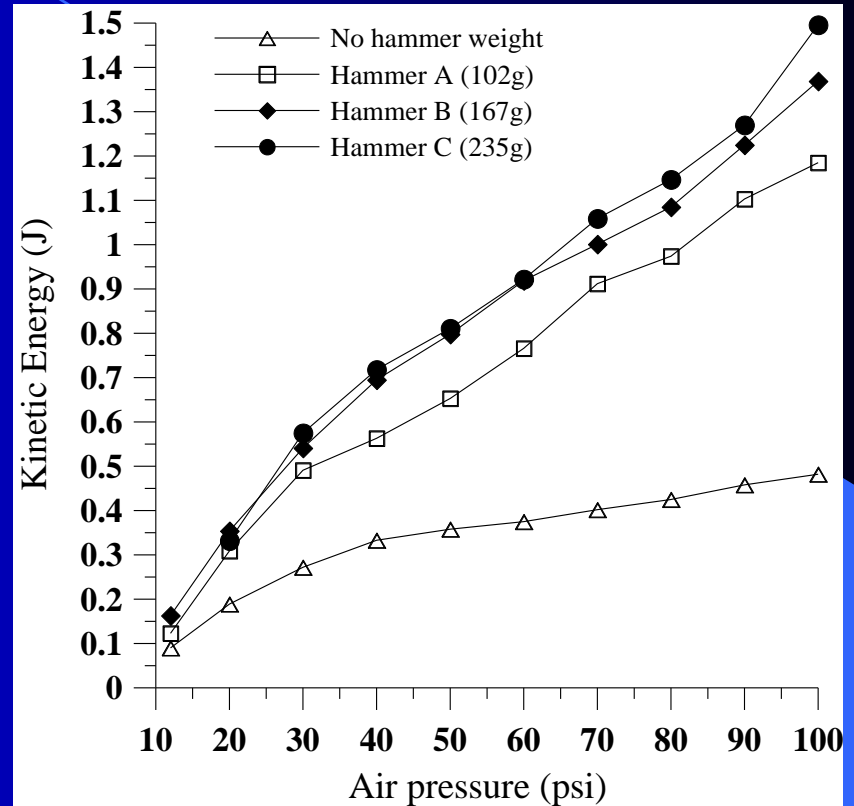
# The Procedures of Impact Type Micro-Injection Molding <sup>3/3</sup>



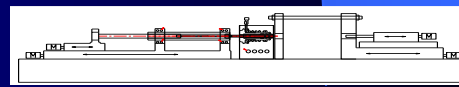
# The Characterization of Driving Capacity



The velocities of air piston before impacting injection plunger



The kinetic energies for impacting injection plunger



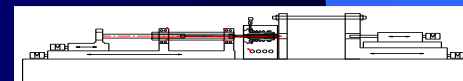
# EXP - 1

## Spiral Flow Experiment

The filling capacity is expressed in terms of the flow length in the spiral cavities.

### Objectives :

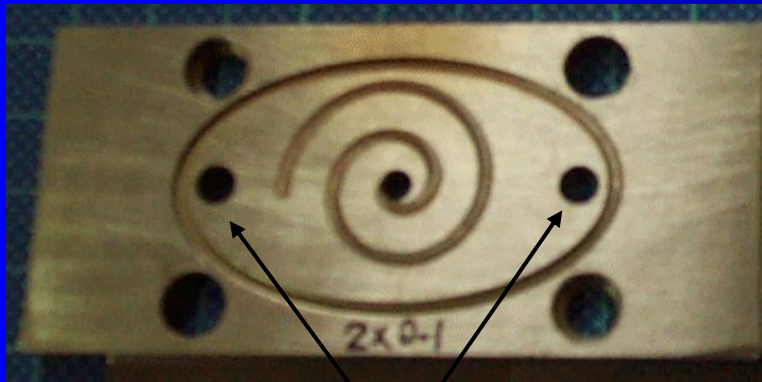
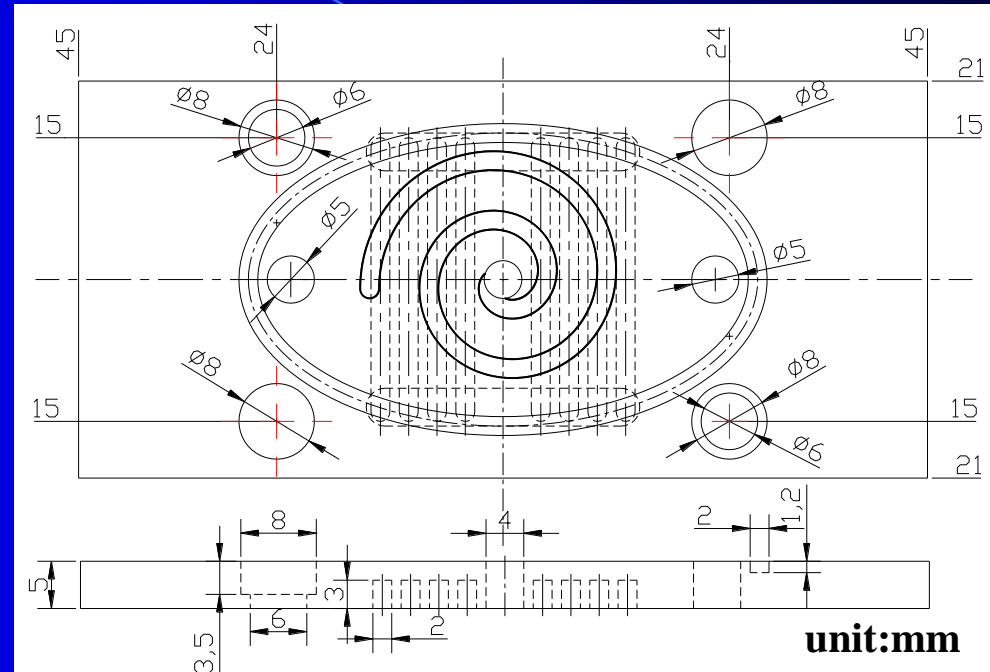
1. To evaluate the micro molding system with spiral molds
  - Variotherm and vacuuming system
2. To investigate the effects of impact injection processing parameters
  - Parameters include driving power, inertia, mold temperature, and melt temperature.



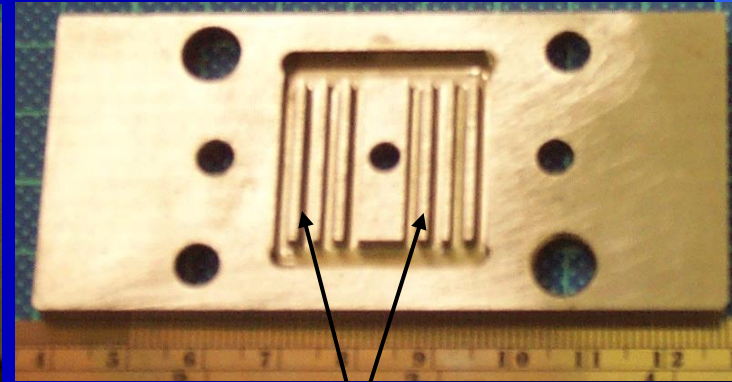
# The Effects of Processing Conditions

## - Spiral Mold

Cavity plate of the spiral mold

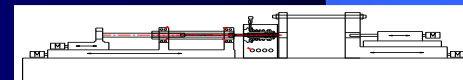


Vacuum holes

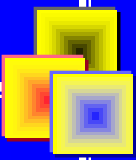


15

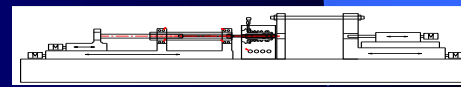
Fin



# Experiment Parameters of Taguchi Method and Their Levels

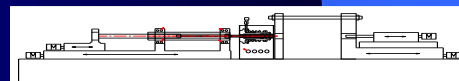


Parameters	Impact-hammer weight (g)	Melt temperature (°C)	Air pressure (psi)	Mold temperature (°C)
Levels	A	B	C	D
1	None	200	60	60
2	102	230	80	105
3	235	260	100	150



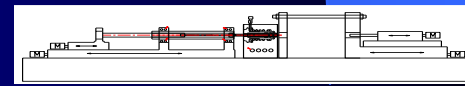
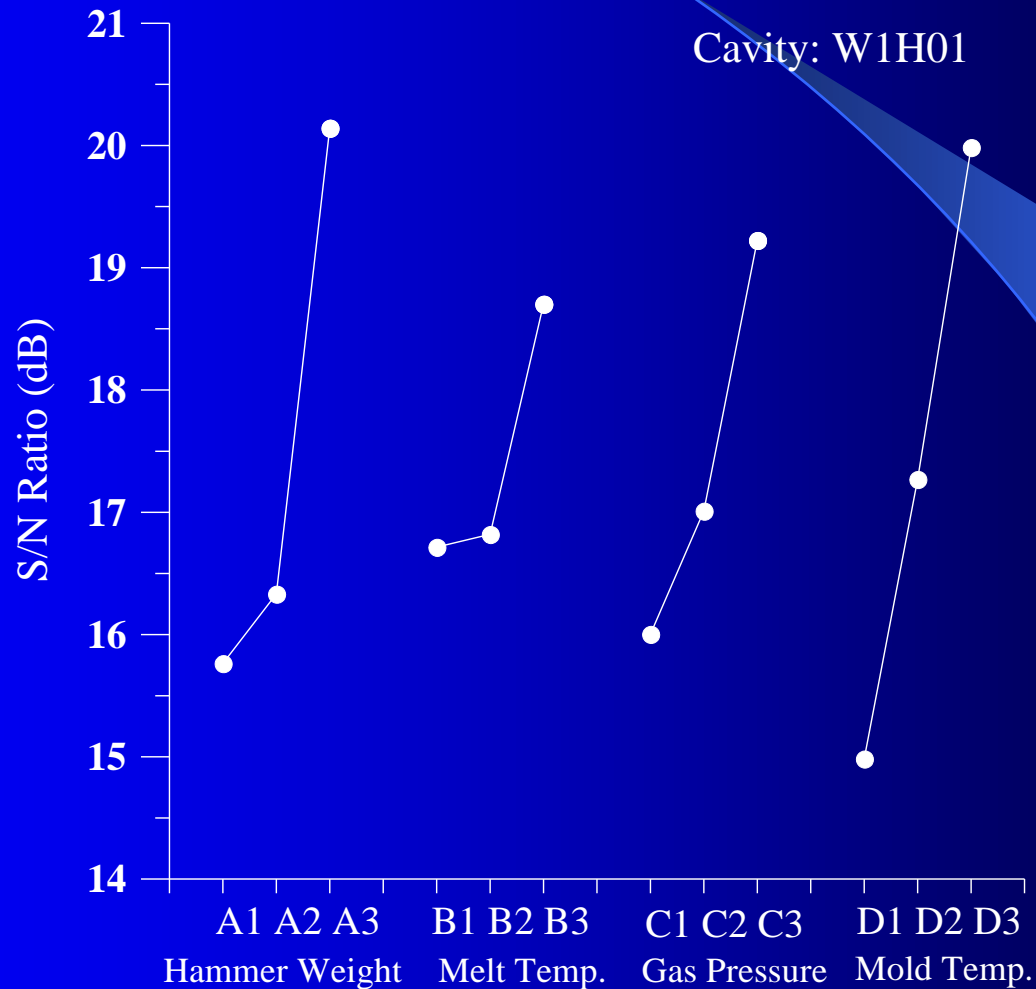
# The Experimental Array of Taguchi L9 Table

Parameters Run	Hammer Weight(g)	Melt Temp. (°C)	Air pressure (psi)	Mold Temp. (°C)
	A	B	C	D
L1	1	1	1	1
L2	1	2	2	2
L3	1	3	3	3
L4	2	1	2	3
L5	2	2	3	1
L6	2	3	1	2
L7	3	1	3	2
L8	3	2	1	3
L9	3	3	2	1



# The S/N ratio showing the processing effects of parameters on flow length in spiral cavity

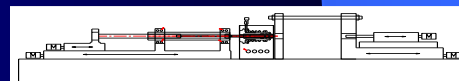
spiral cavity : width: 1mm depth: 0.1mm



# Conclusions - 1

## Spiral Flow Experiments

- An impact type micro-injection machine is developed for this study
  - Melt of micro size can be injected at high speed
- Impact energy can be increased with additional impact-hammer mass.
- Filling capacity increases with air pressure, impact energy, melt temperature and mold temperature.
- Mold temperature and impact-hammer mass are found to be the most critical parameters.



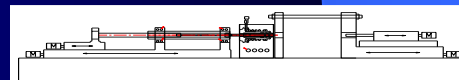
# EXP - 2

## Flow Visualization

Flow visualization is an effective method to observe and understand the flow-related phenomena.

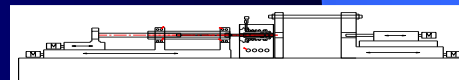
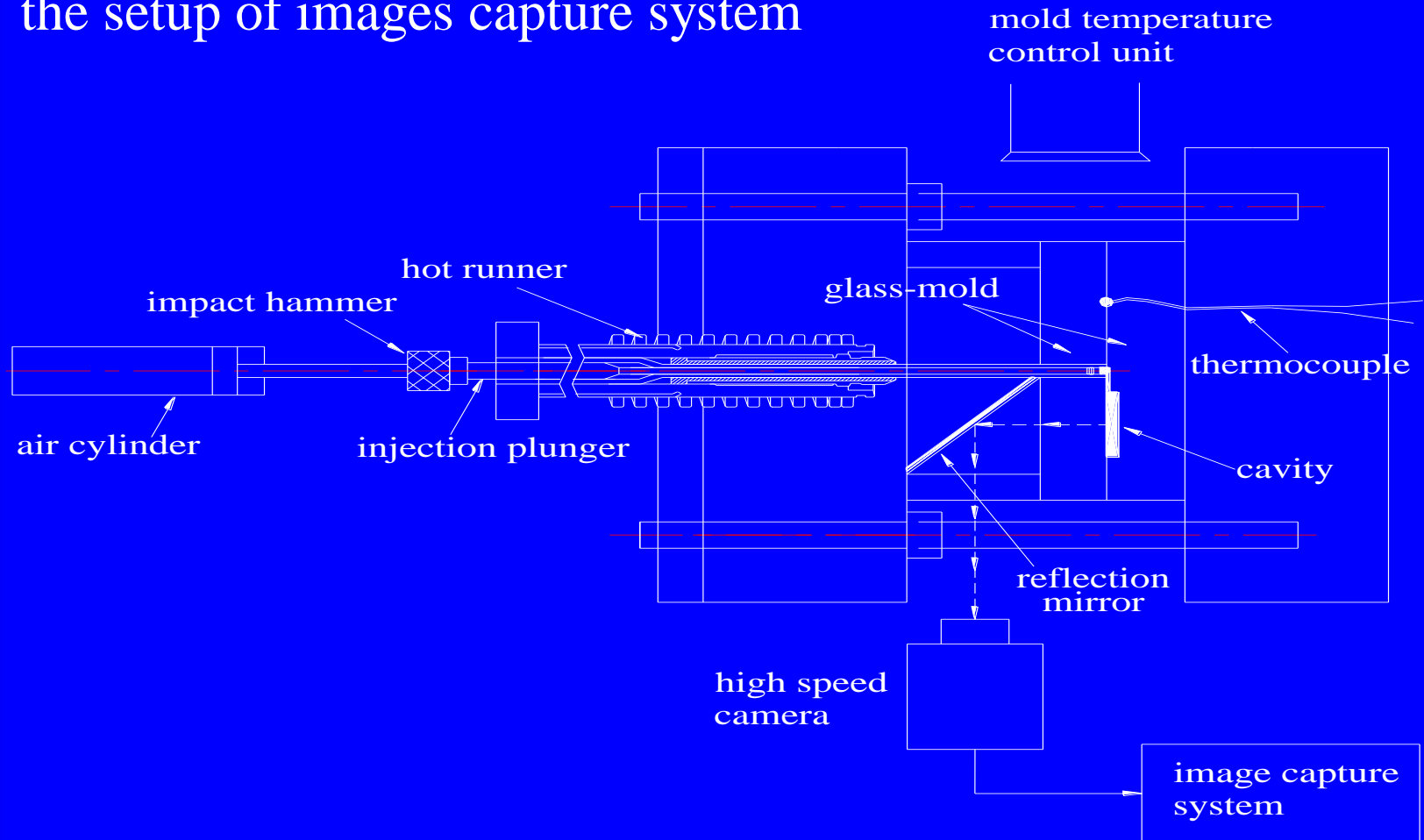
### Objectives :

- To understand the situation of melt flow under tiny cavity during impact injection molding process.
- To investigate the effects of processing parameter on impact injection molding.
  - The processing parameters include air pressure, mold temperature, and melt temperature.

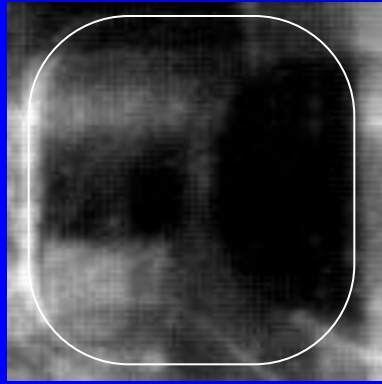
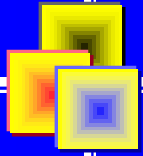


# The effects of processing conditions – flow visualization

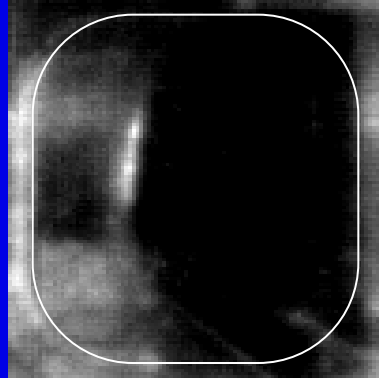
the setup of images capture system



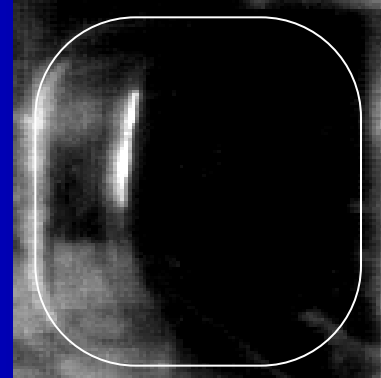
# The images of melt flow in glass mold with 4x4x0.2mm<sup>3</sup> cavity



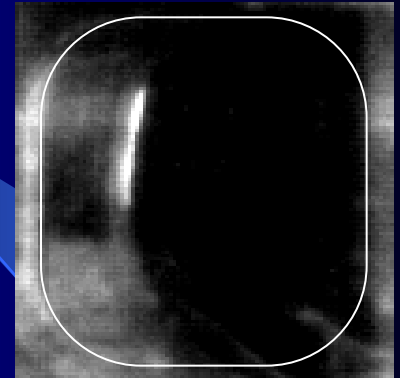
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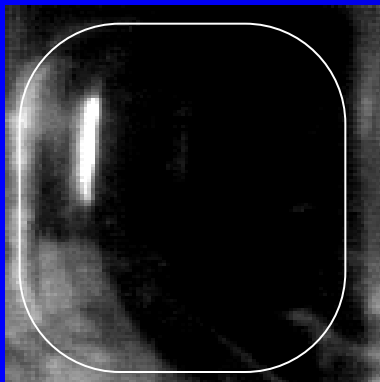
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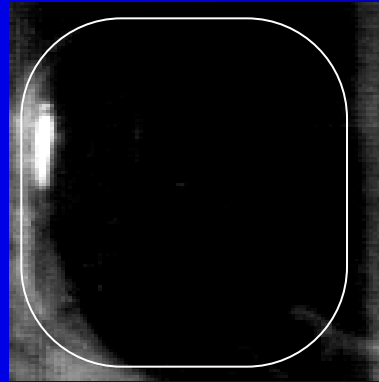
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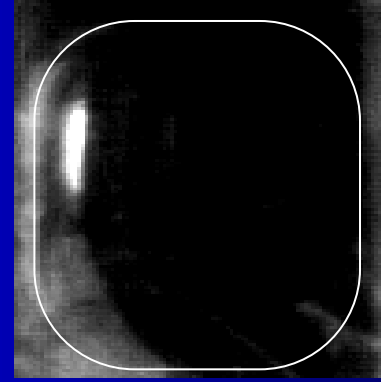
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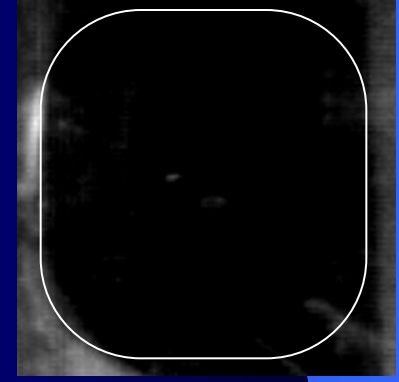
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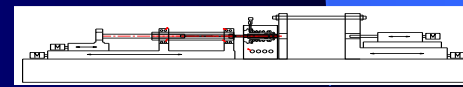
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0.017sec

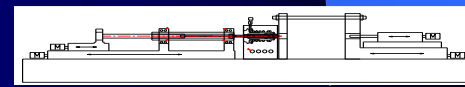
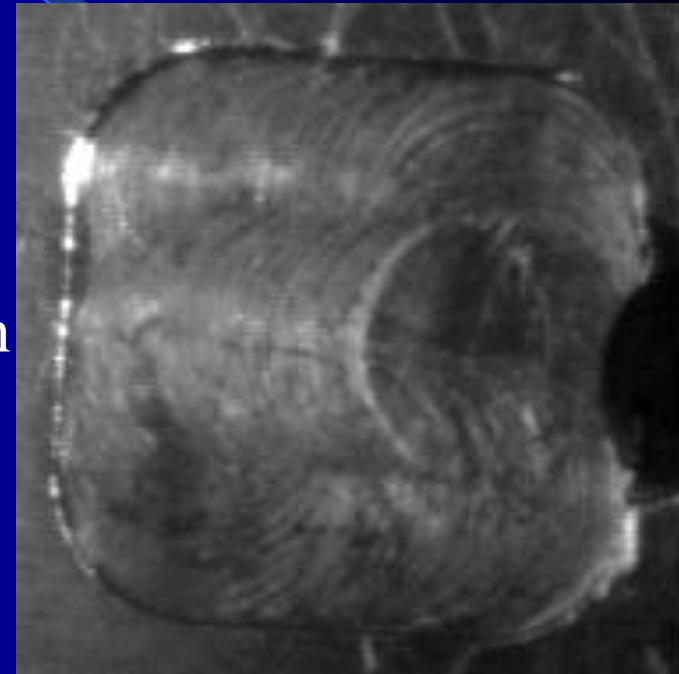


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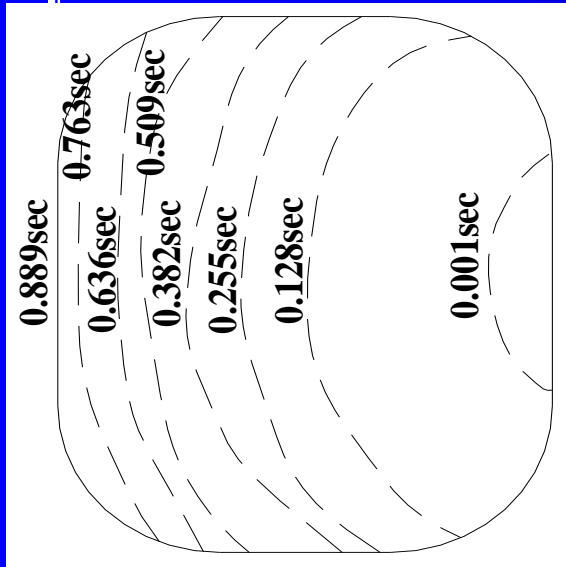


# The three stage of impact injection molding

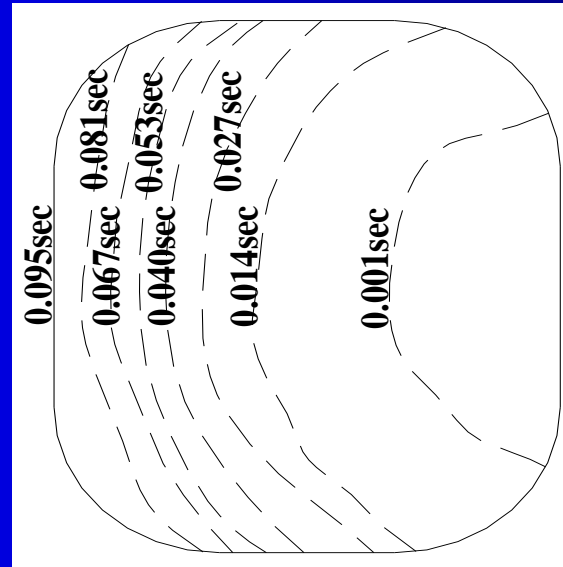
- Impact-filling stage
  - occurs at the impact twinkle
  - driving force : impact energy
- Pressure-filling stage
  - after the impact energy dissipation
  - driving force : plunger thrust
- Pressure-holding stage
  - after the cavity be filled
  - driving force : plunger thrust



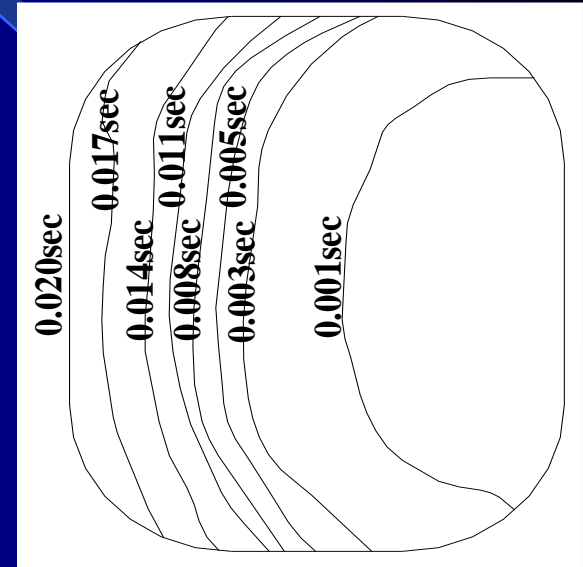
# Effects of air pressure



Pair 30Psi

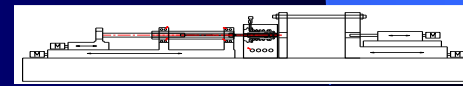


Pair 50Psi

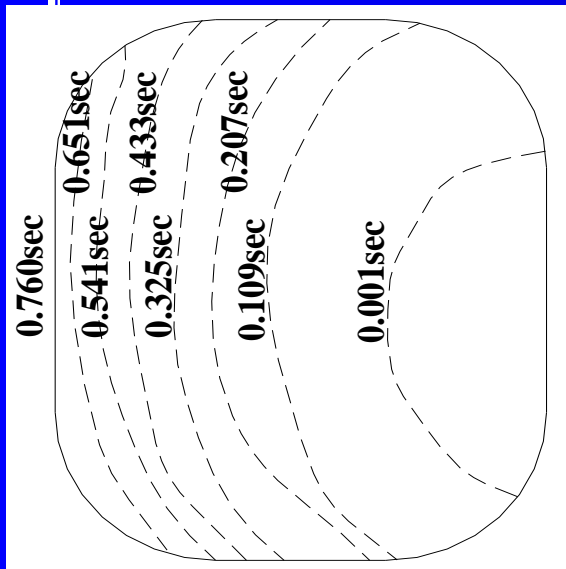


Pair 70Psi

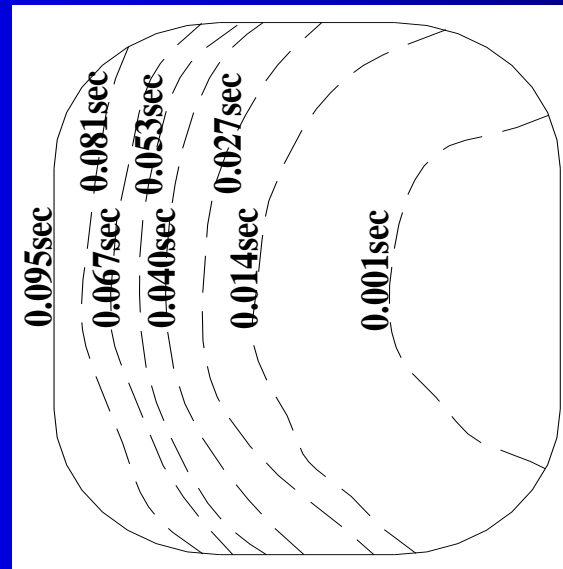
$T_{\text{mold}} 150^{\circ}\text{C}$   $T_{\text{melt}} 240^{\circ}\text{C}$



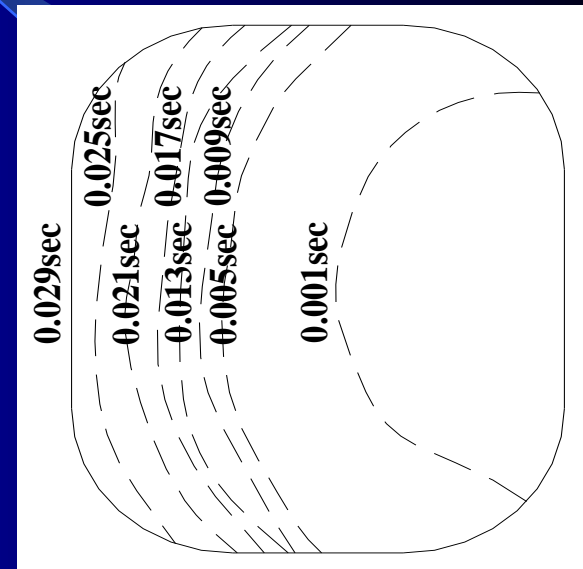
# Effects of mold temperature



$T_{\text{mold}} 130^{\circ}\text{C}$

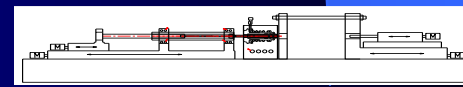


$T_{\text{mold}} 150^{\circ}\text{C}$

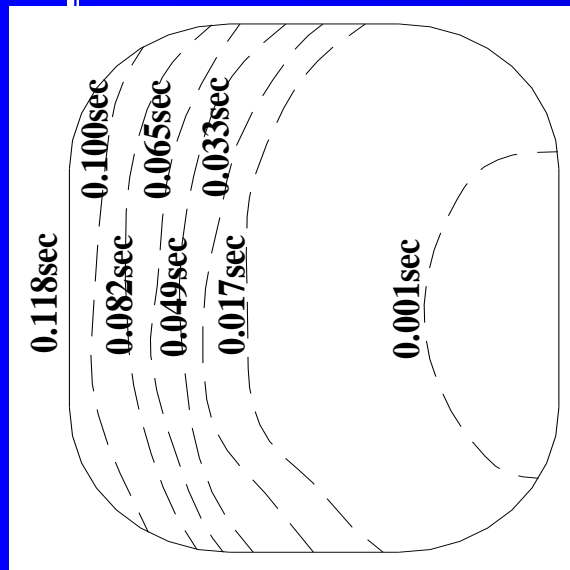


$T_{\text{mold}} 170^{\circ}\text{C}$

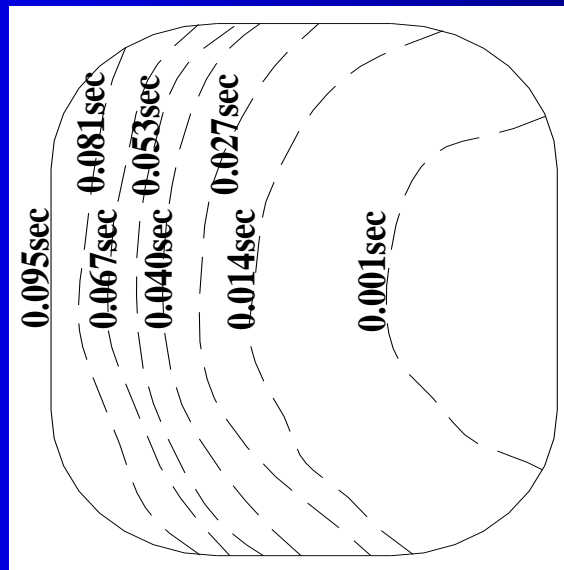
Pair 50 Psi  $T_{\text{melt}} 240^{\circ}\text{C}$



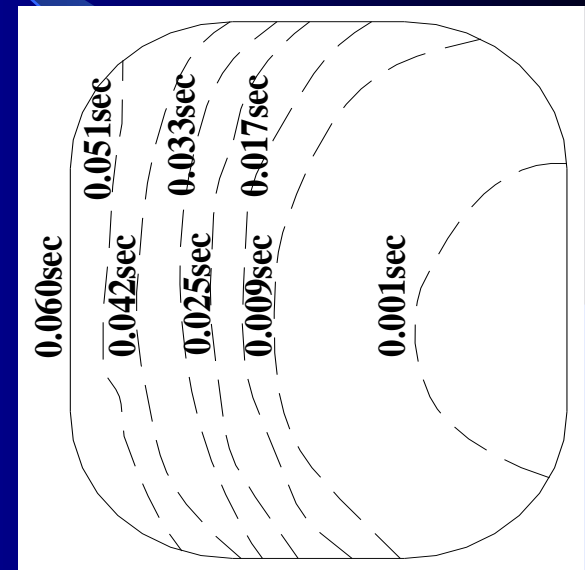
# Effects of melt temperature



$T_{\text{melt}} 220^{\circ}\text{C}$

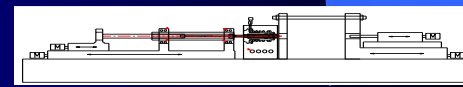


$T_{\text{melt}} 240^{\circ}\text{C}$



$T_{\text{melt}} 260^{\circ}\text{C}$

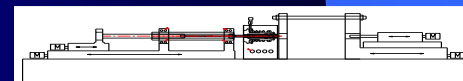
Pair 50Psi  $T_{\text{mold}} 150^{\circ}\text{C}$



# Conclusions - 2

## Flow Visualization

- The quartz glass mold could suffer the impact and thermal shock during impact injection molding and variotherm process.
- The Filling processing of impact injection molding divided into three stages
  - Impact-filling, Pressure-filling, and Pressure-holding stages
- Higher air pressure would largely reduce the total filling-time, and increase the proportion of impact-filling region.
- Mold temperature is a dominant parameter for micro-injection molding.



# SUMMARY

- An impact type micro-injection machine was developed for this study.
- Spiral flow Exp. and flow visualization are used to detect filling behavior.
- The Filling processing of impact injection molding could be divided into three stages
  - Impact-filling, Pressure-filling, and Pressure-holding stages
- Impact energy and mold temperature are most critical processing parameter.

