Molding of Thin Sheets Using Impact Micro-injection Molding

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Outline

- Introduction
- The Impact Micro-Injection Molding
- Experiment Setup
- Results and Discussion
- Conclusions

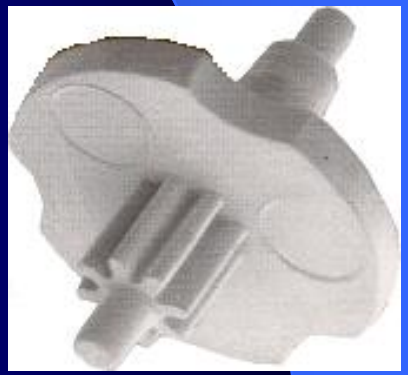
The Definition of Micro-Injection Molding

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)

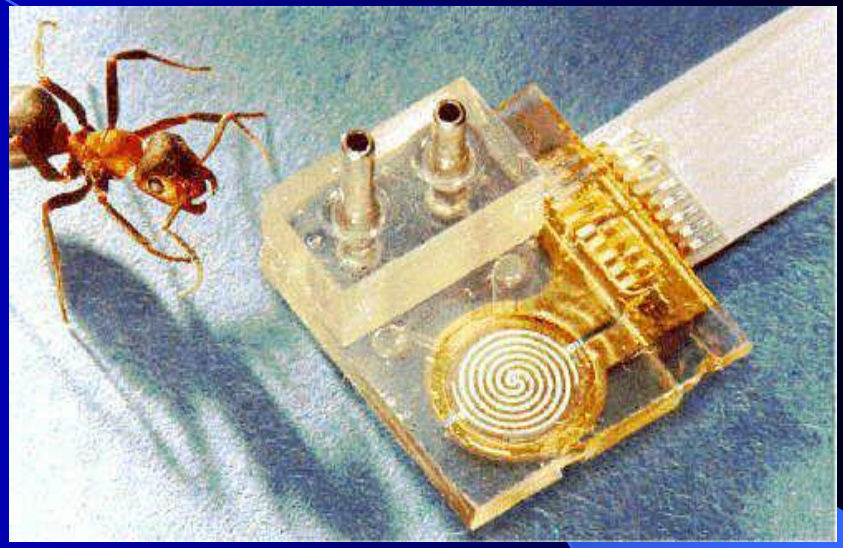
- Precision Micro-parts

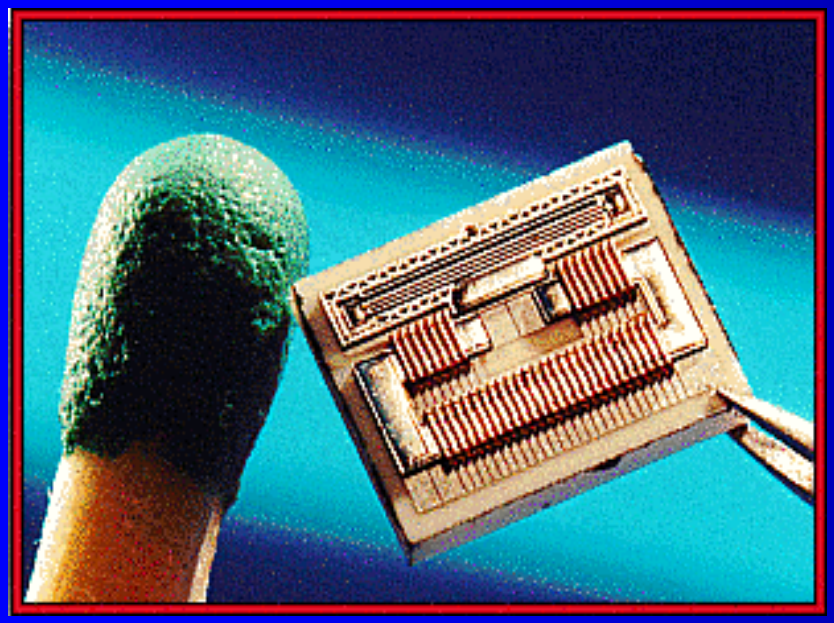


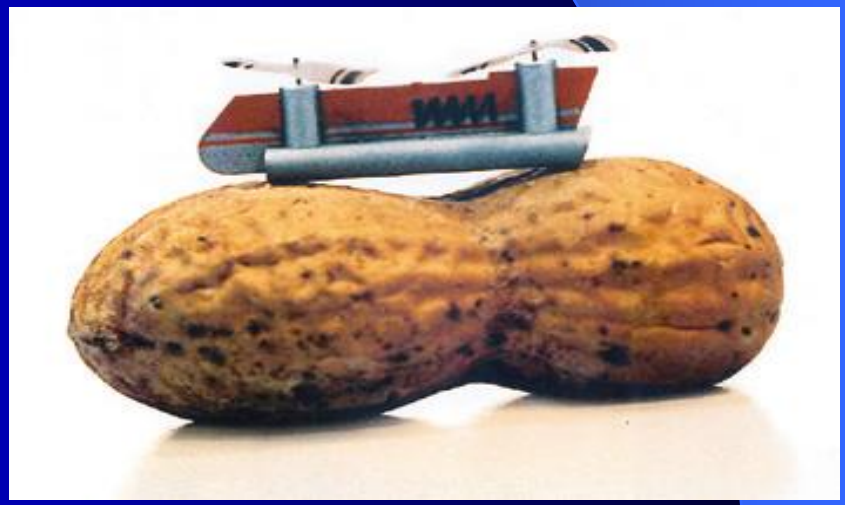
(Battenfeld Kunststoffmaschinen Ges.m.b.H.)

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

- Micro-Electro-Mechanical System (MEMS)

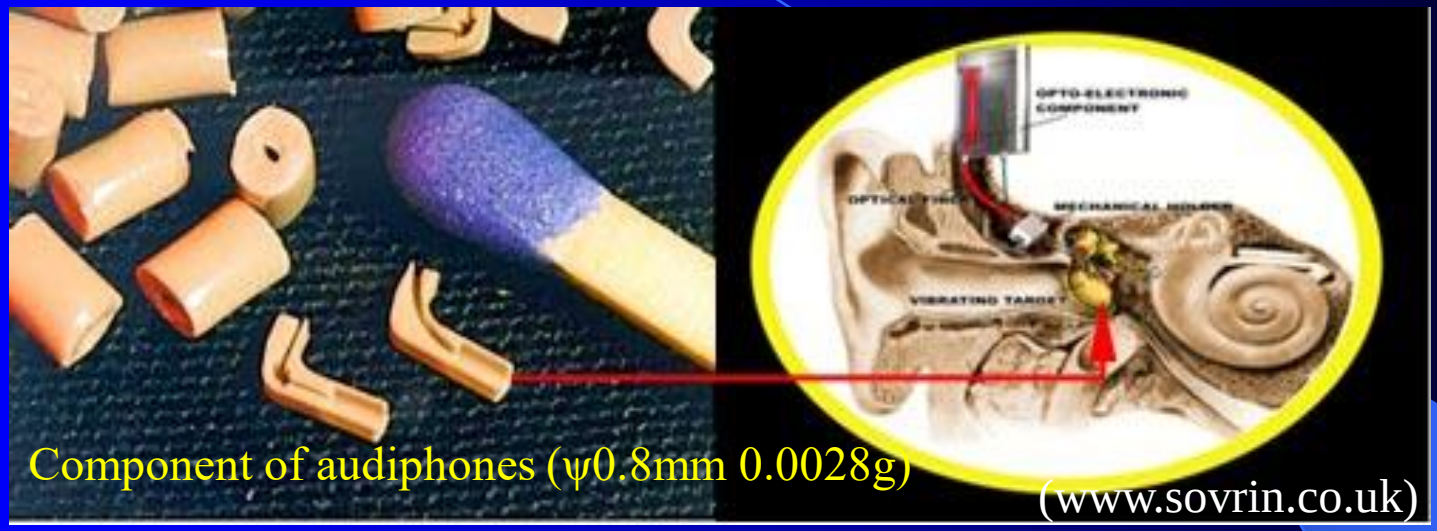






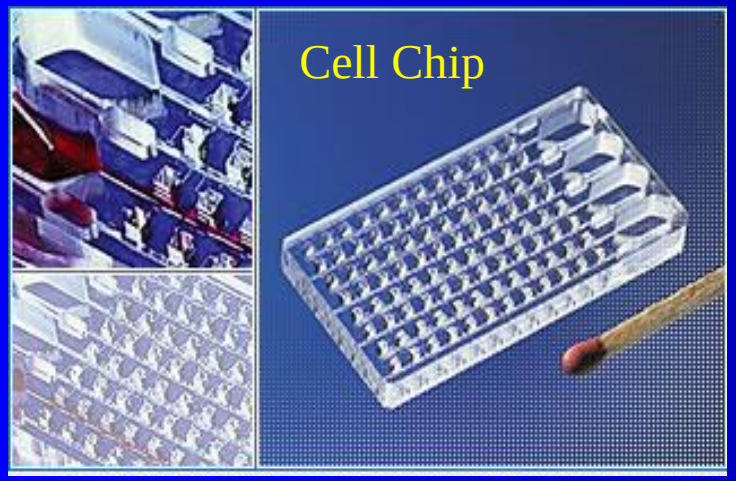
The Application of Micro-Injection Molding (3/3)

- Biotechnology

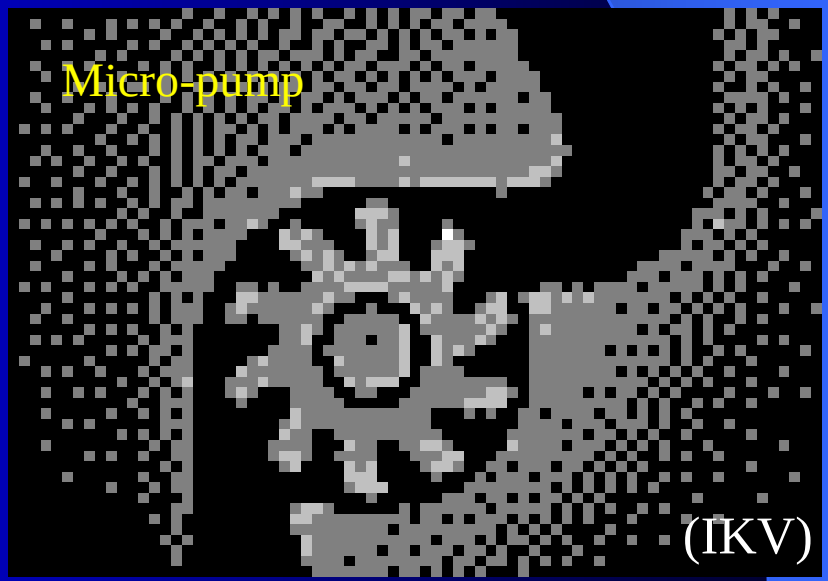


Component of audiphones (ψ0.8mm 0.0028g)

(www.sovrin.co.uk)



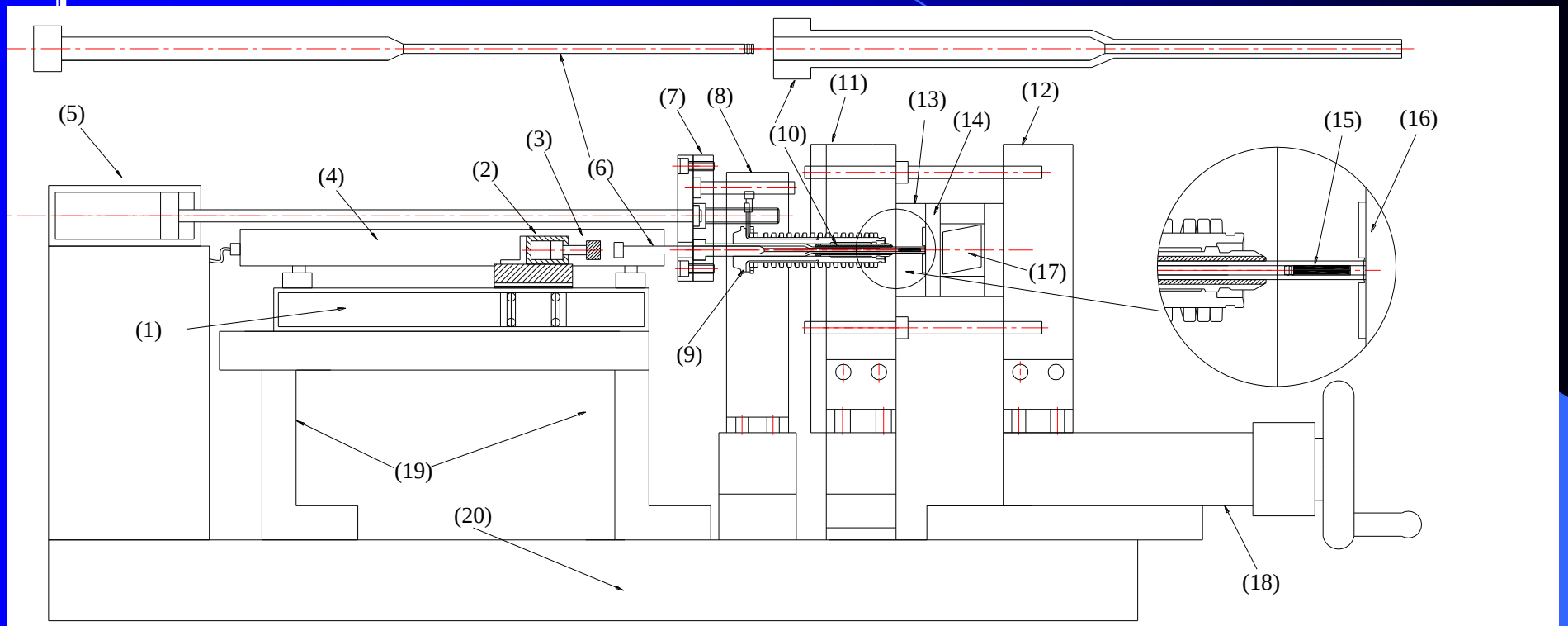
(LILLIPUT)



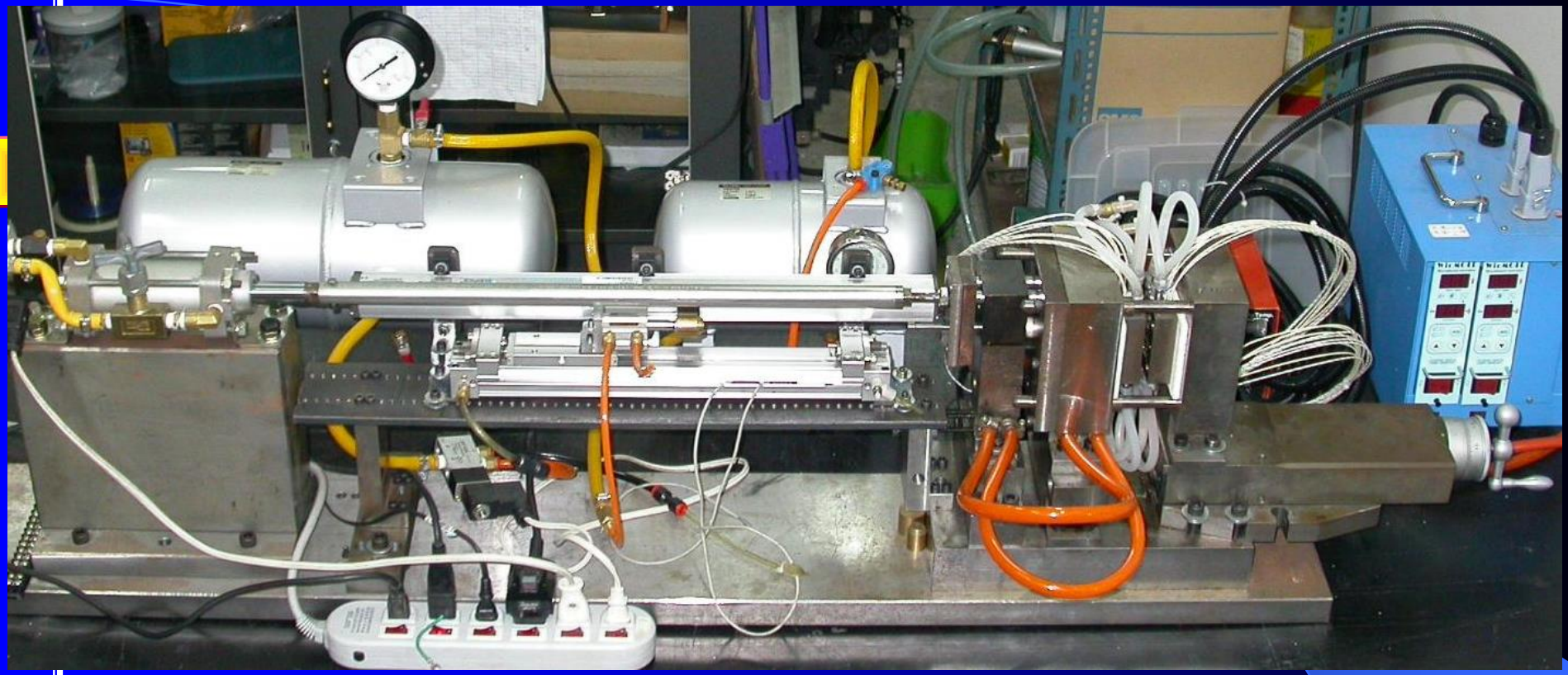
(IKV)

The Impact Type Micro-Injection Machine

- Length:1400mm, Width:200mm, and High:300mm



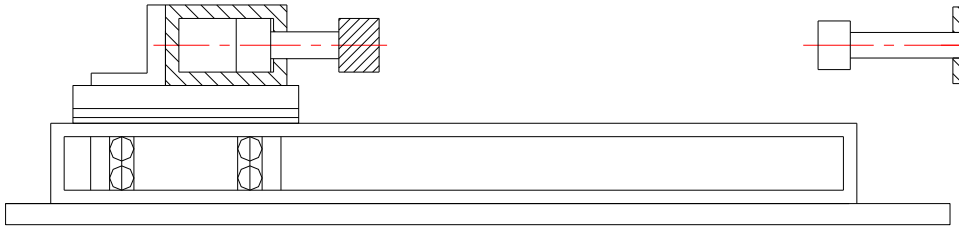
(1)air cylinder of impact accelerating (2)air cylinper of packing pressure (3)impact hammer (4)linear variable differential transfer (5)air cylinder of sleeve moving (6)injection plunger (7)injection sleeve stationary base (8)melt unit stationary base (9)melt unit (hot runner) (10)injection sleeve (11)stationary-side 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

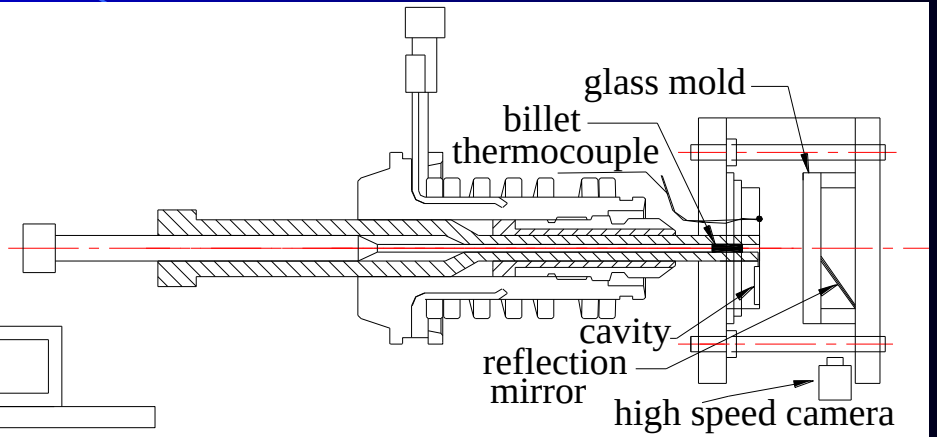


Air Pressure	0.2MPa	0.4MPa	0.6MPa	0.8MPa
Piston Thrust	6.3kgf	12.6kgf	18.8kgf	25.1kgf
Packing Pressure	20MPa	40MPa	60MPa	80MPa
Impact Speed	2580mm/s	4300mm/s	5620mm/s	6580mm/s
Notation	Diameter of Accelerating and Packing Cylinders : 20mm Diameter of Injection Plunger : 2mm			

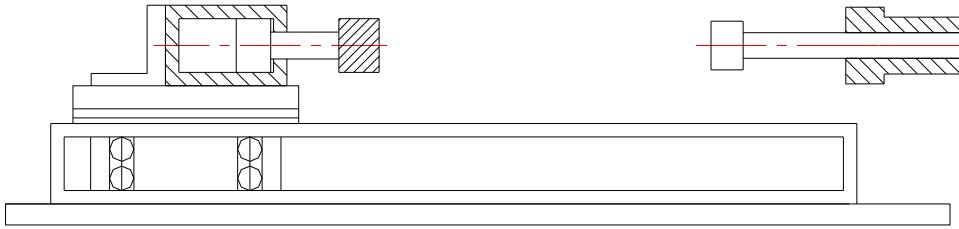
The Procedures of Impact Type Micro-Injection Molding 1/2

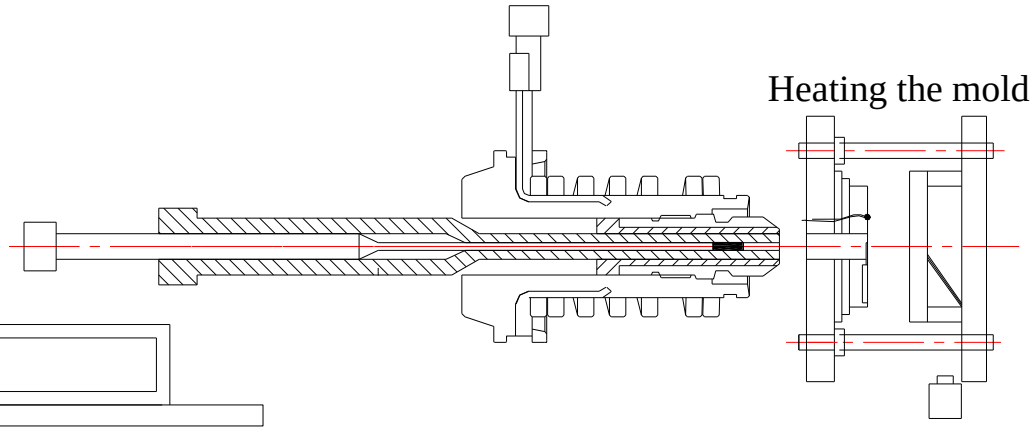
Step1: charging the plastic billet





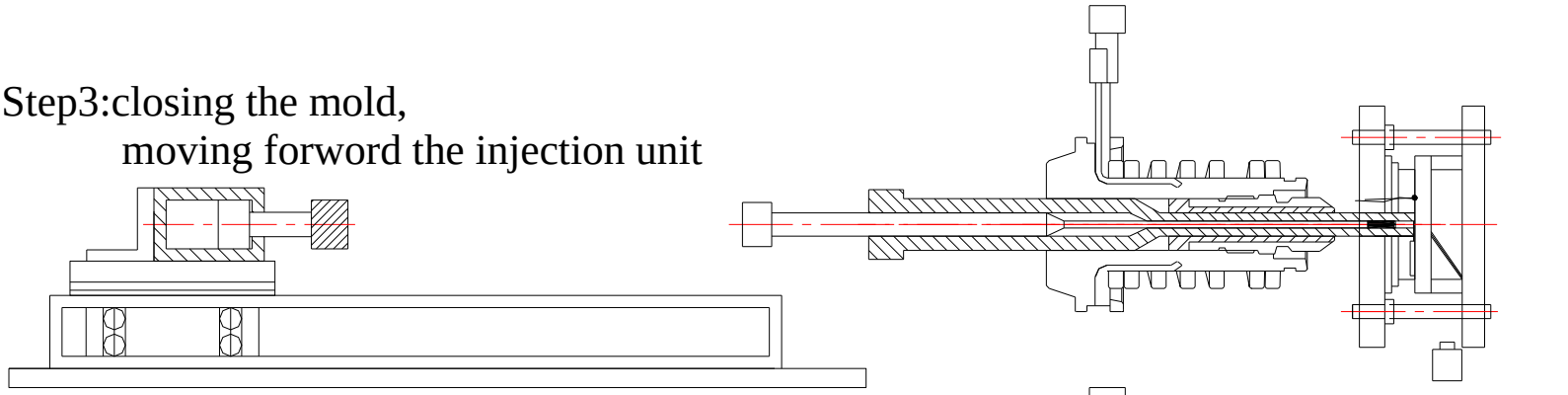
Step2: melting the plastic billet,
heating the mold





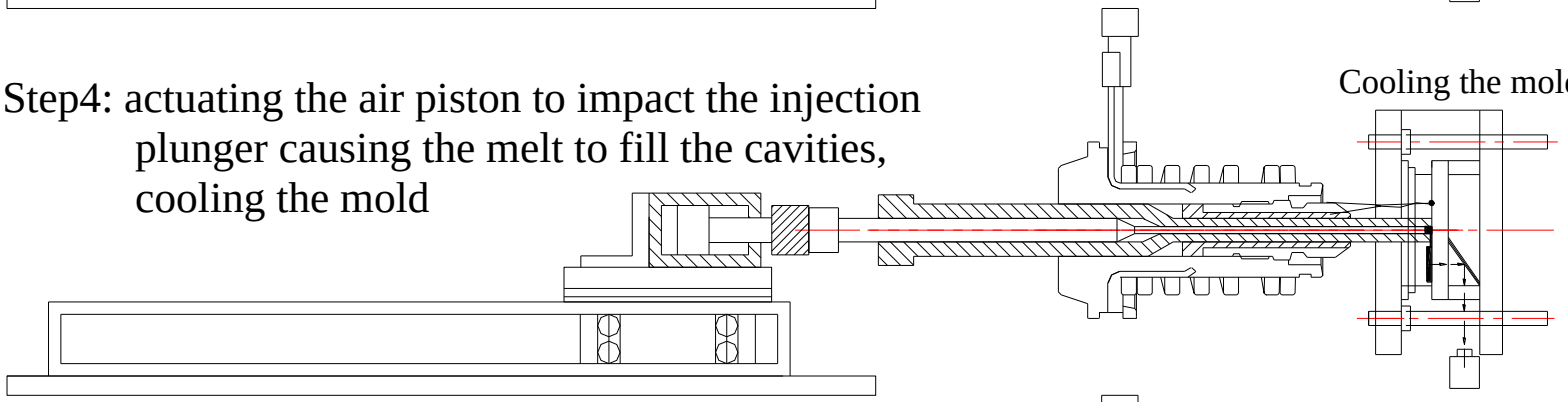
The Procedures of Impact Type Micro-Injection Molding 2/2

Step3:closing the mold,
moving forword the injection unit

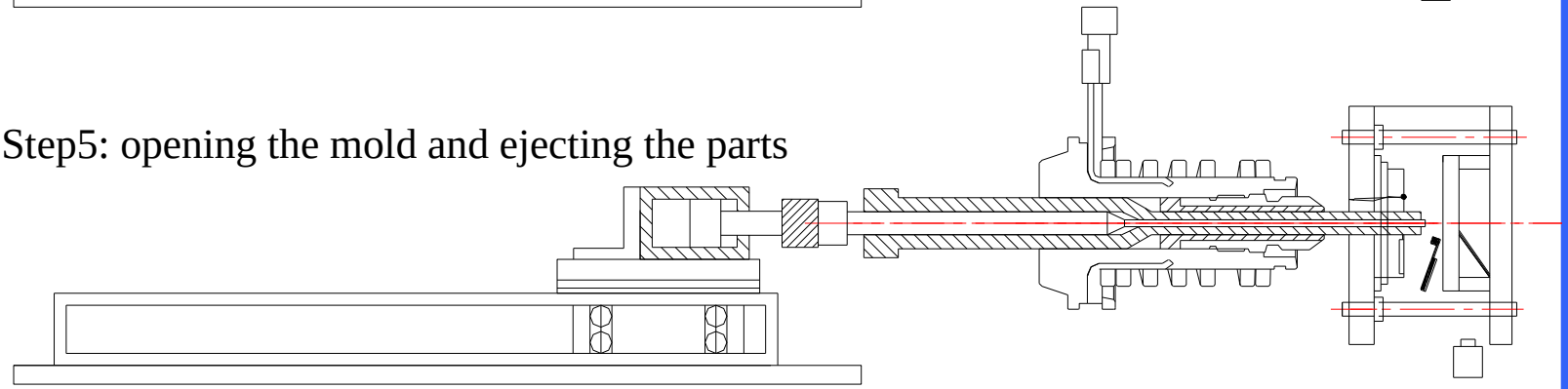


Step4: actuating the air piston to impact the injection plunger causing the melt to fill the cavities, cooling the mold

Cooling the mold

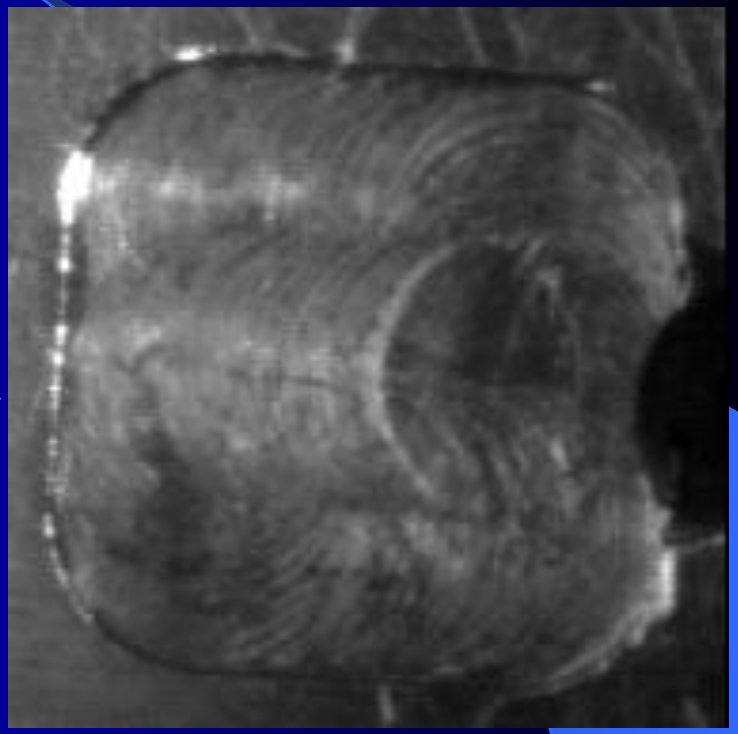


Step5: opening the mold and ejecting the parts

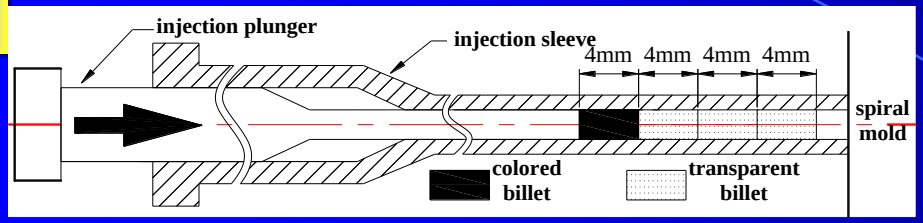


The Three Stage of Impact Injection Molding

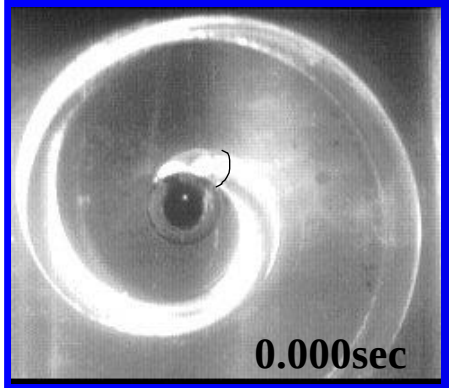
- Impact-filling stage
  - occurs at the impact twinkle
  - driving force : impact energy
- Pressure-filling stage
  - after the impact energy dissipation
  - driving force : plunger thrust
- Pressure-holding stage
  - after the cavity be filled
  - driving force : plunger thrust

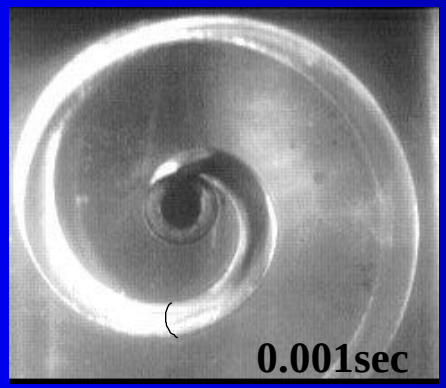


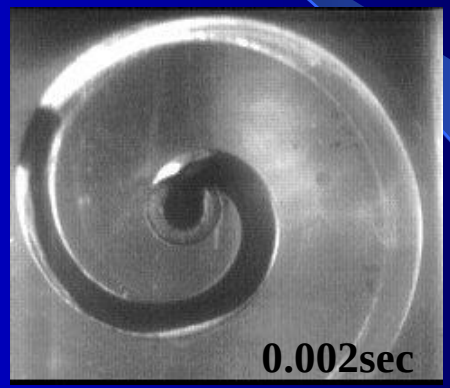
The Images of Melt Flow in Spiral Mold With 300μm Depth Cavity and 2mm Width

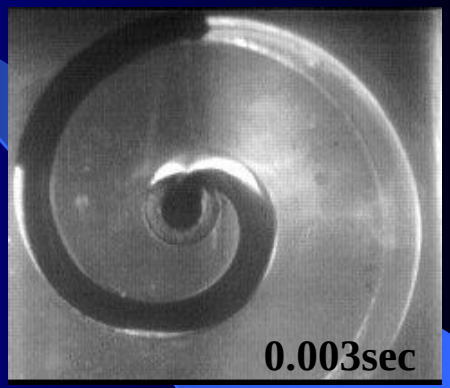


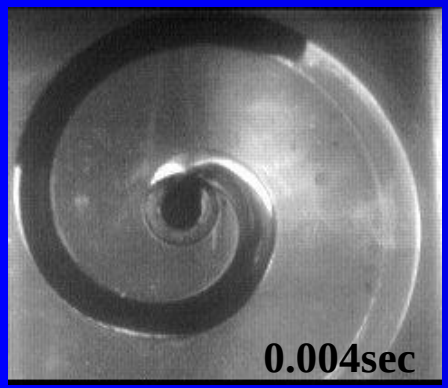
Melt Temp.= 230℃
Mold Temp.= 80℃,
Pressure of Accelerating Cylinder = 0.8MPa
Pressure of Accelerating Cylinder = 0.6MPa

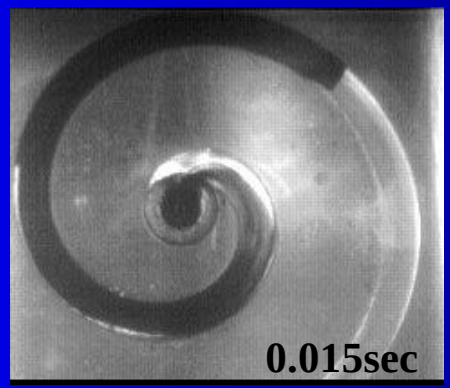


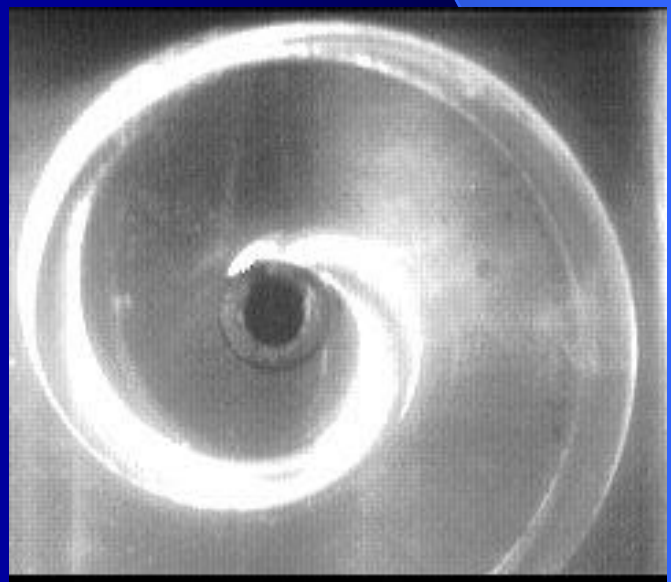




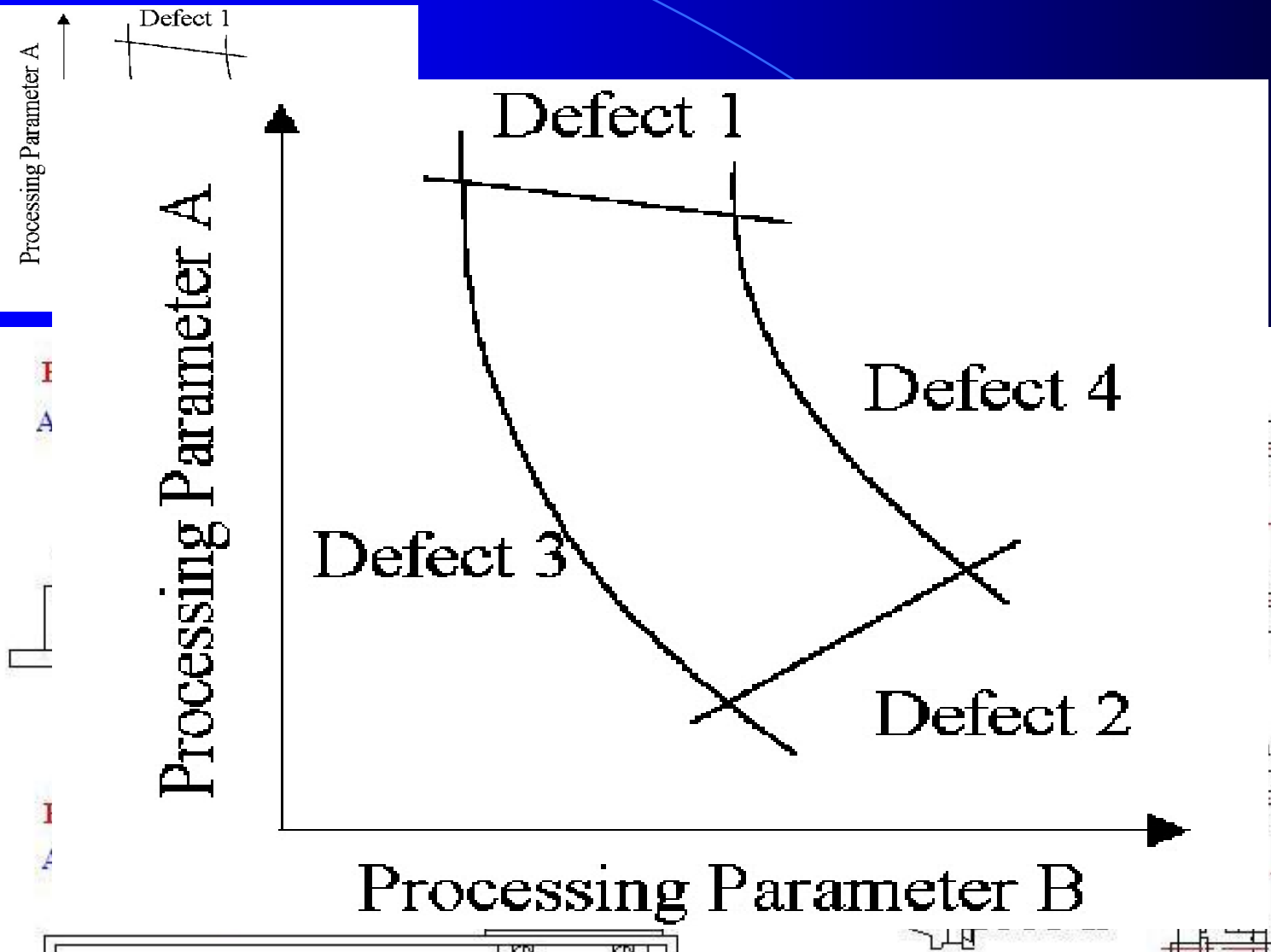




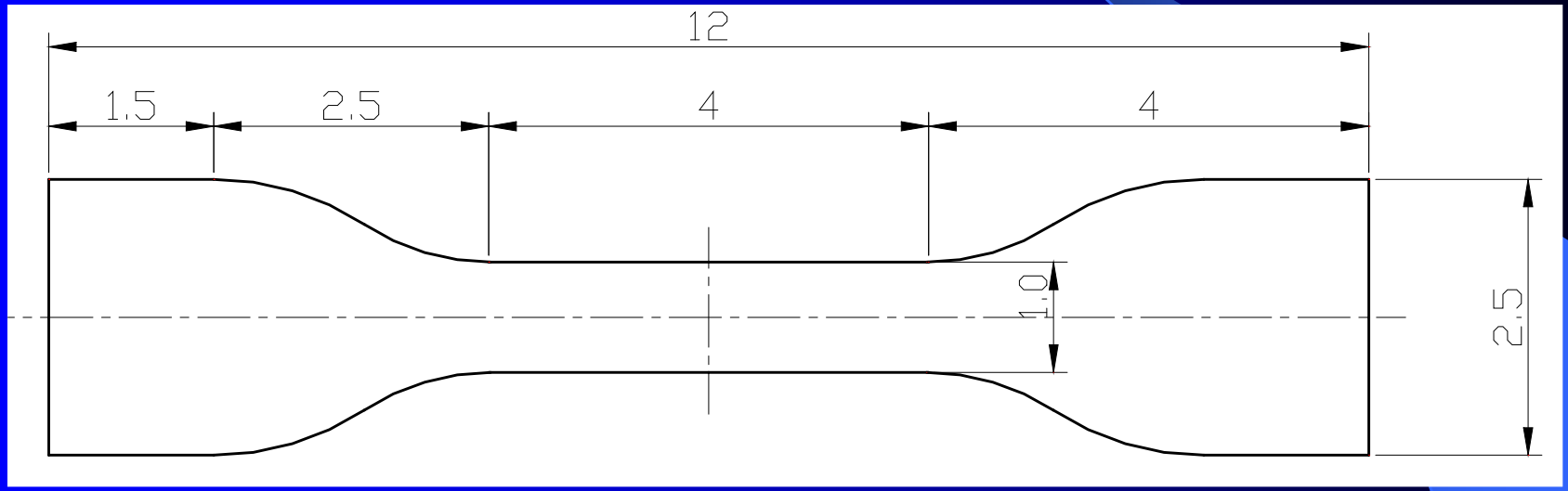




The definition of Operation Window



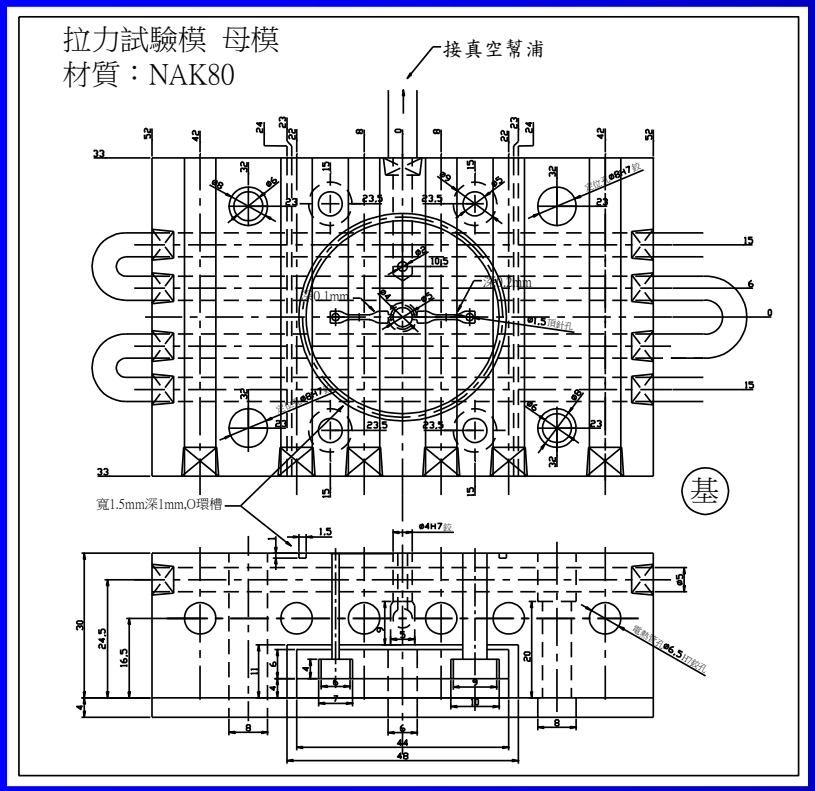
The Dimensions of the Test-Sheet

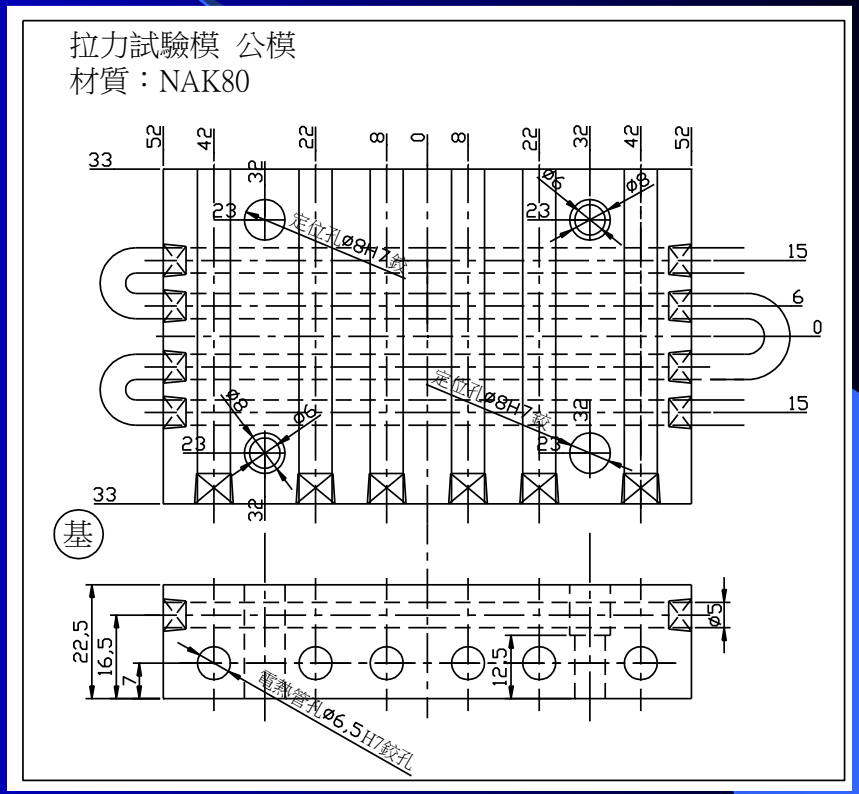


The Experiment Parameters of Test-Sheet Molding

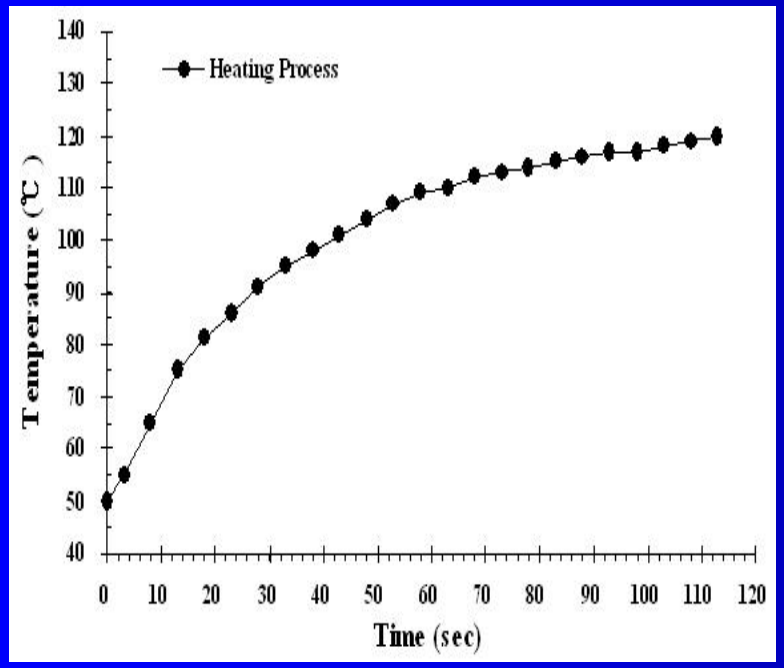
Parameters	Cavity Depth (Depth)	Melt Temp. (Tmelt)	Mold Temp. (Tmold)	Air Pressure of Accelerating Cylinder (Pa)	Air Pressure of Packing Cylinder (Pp)
Levels	100μm 200μm	230℃	30℃ 60℃ 90℃ 120℃ 150℃	0.4MPa 0.6 MPa 0.8 MPa 1.0 MPa	0 MPa 0.2 MPa 0.4 MPa 0.6 MPa 0.8 MPa 1.0 MPa

The Dimensions of Test-Sheet Mold

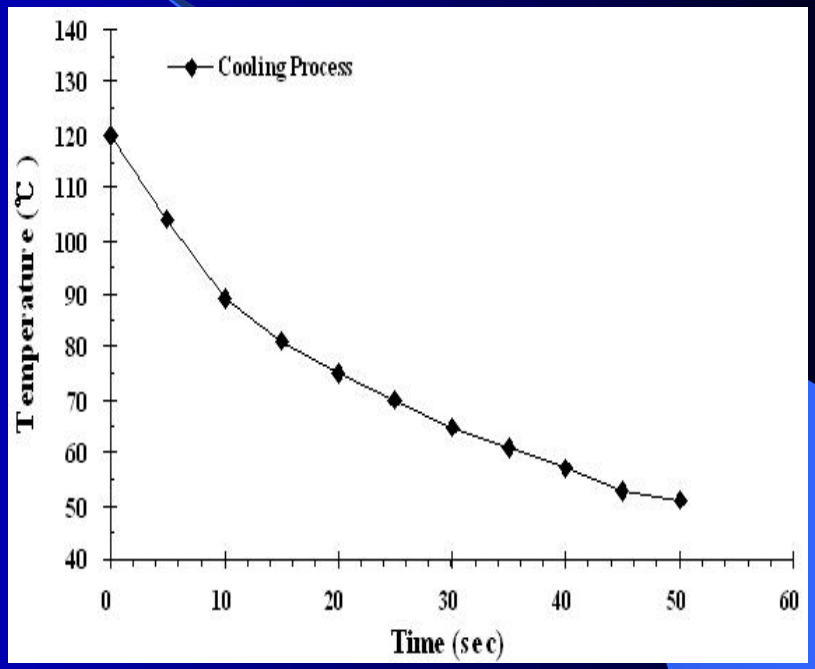




The Variotherm Process of Molding Test-Sheets

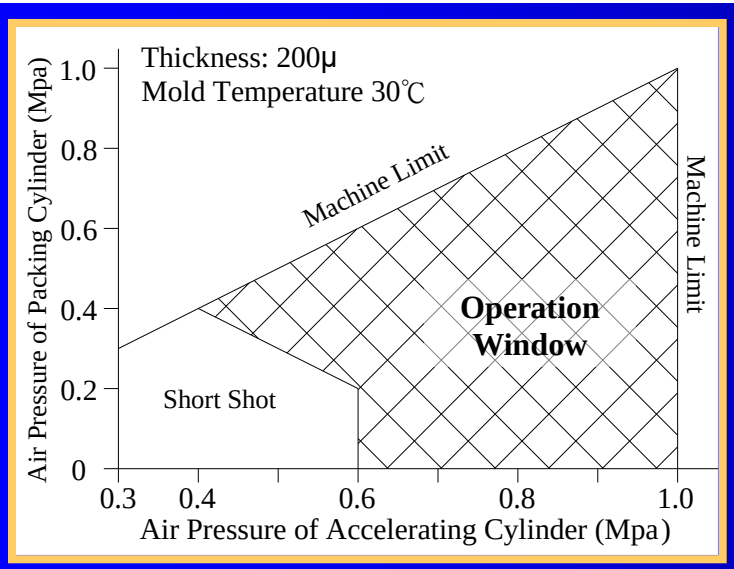


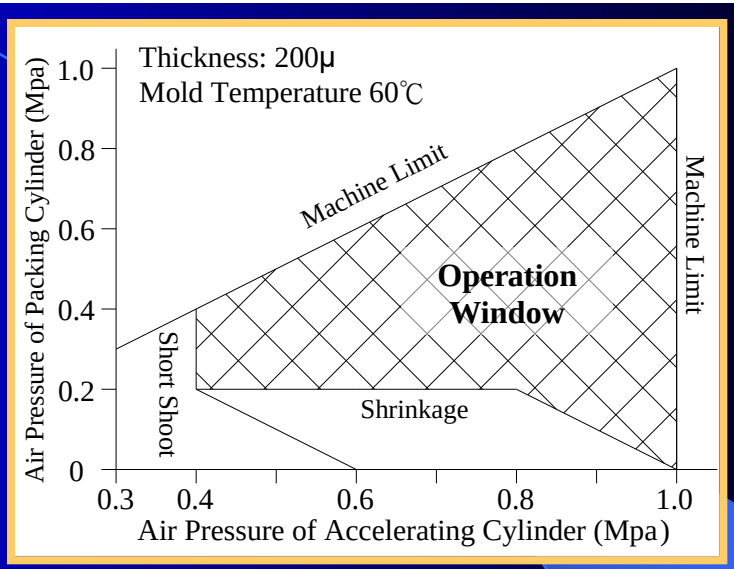
Heating

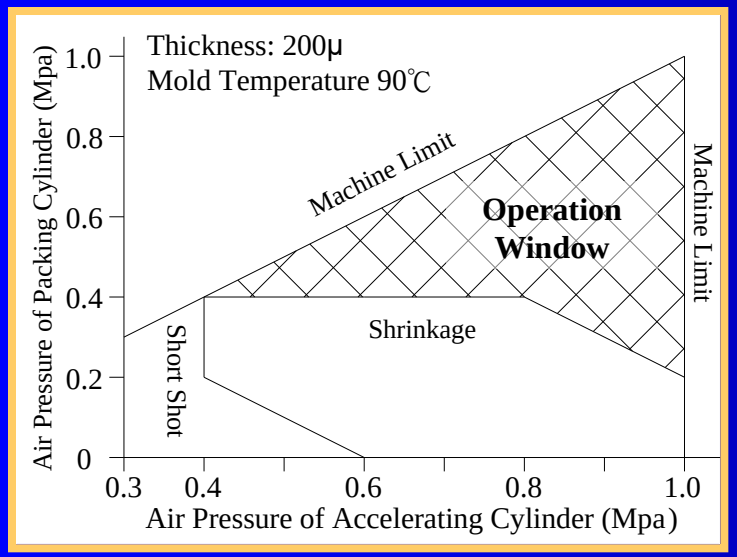


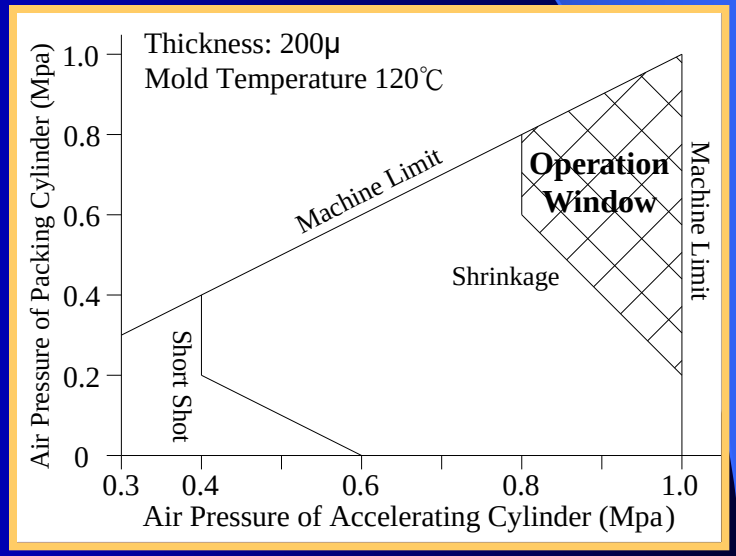
Cooling

The operation windows for molding test-sheets of 200μm Thick 1/2

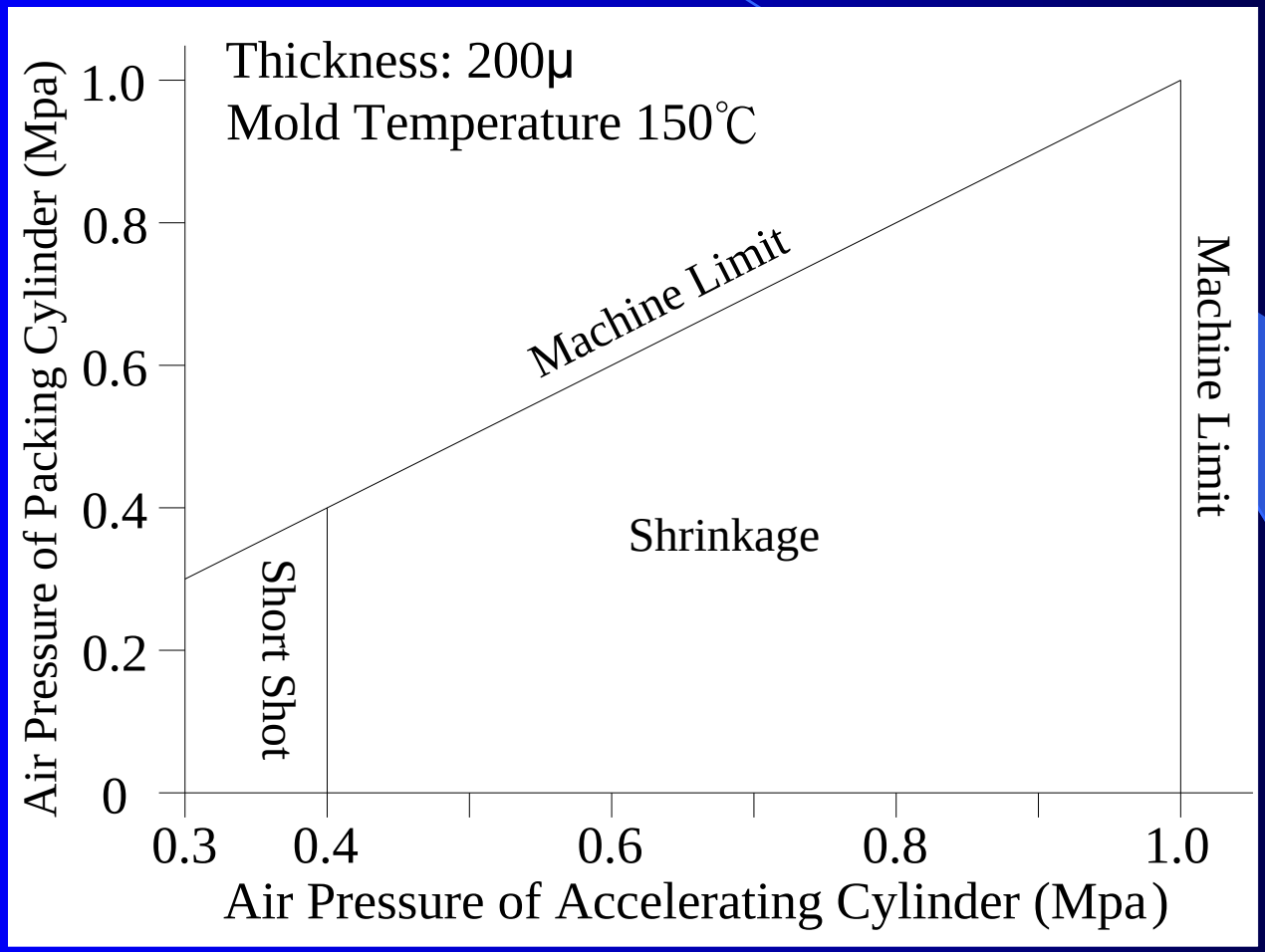




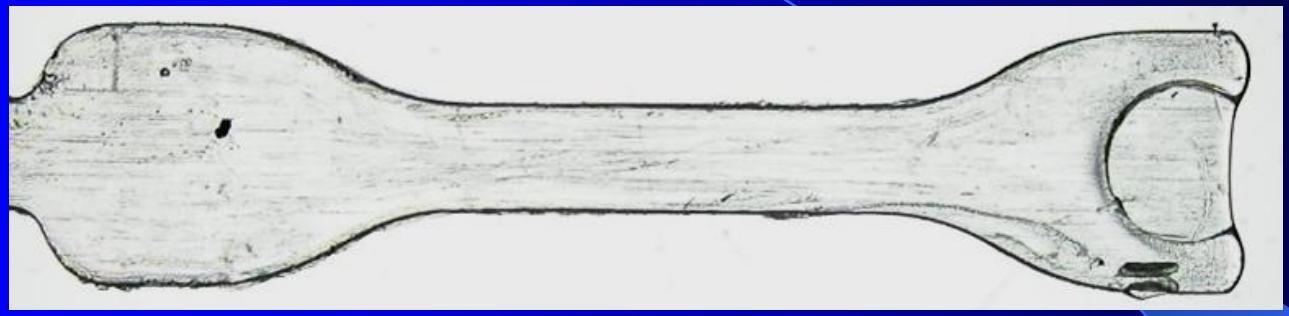




The operation windows for molding test-sheets of 200μm Thick 2/2

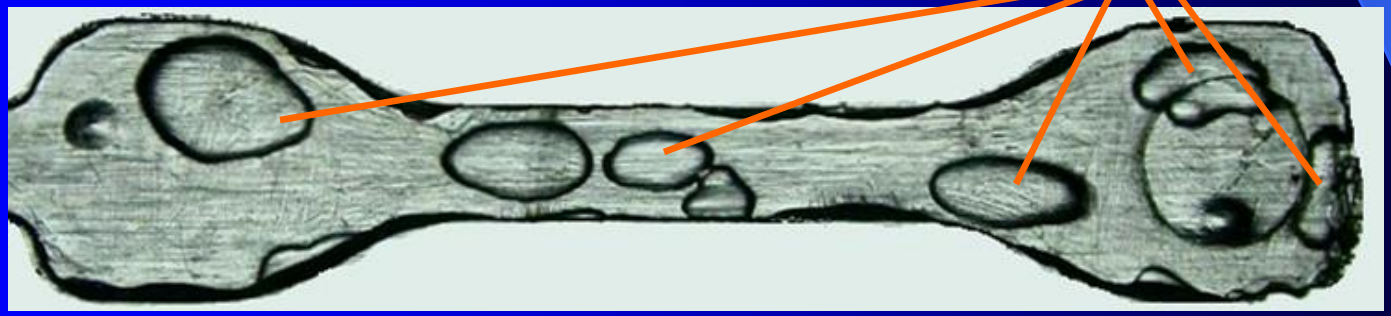


The Test-Sheets of 200μm Thick in Molding with Mold Temperature 30℃ and 150℃



T_{mold}=30℃, Pa=0.4MPa, and Pp=0.2MPa (short shut)

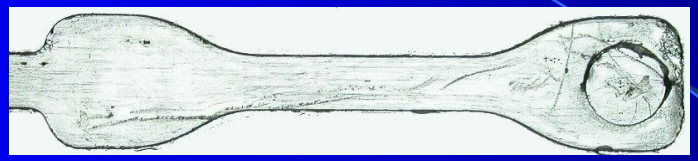
circular shrinkage pits

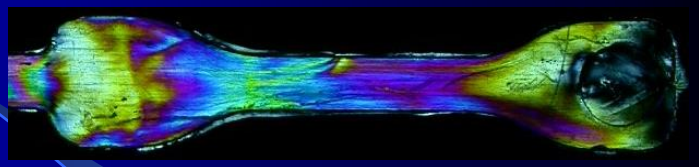


T_{mold}=150℃, Pa=1MPa, and Pp=1MPa (shrinkage)

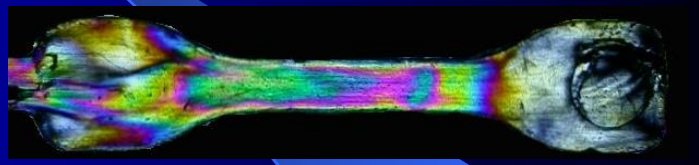
The Birefringence of Test-Sheets of 200μm Thick

a. Tmold 30℃
Pa 0.6 Pp 0

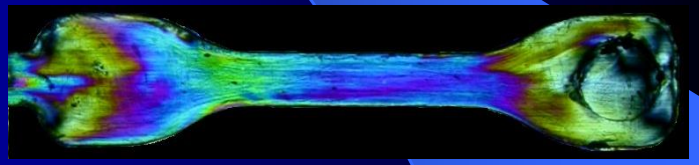




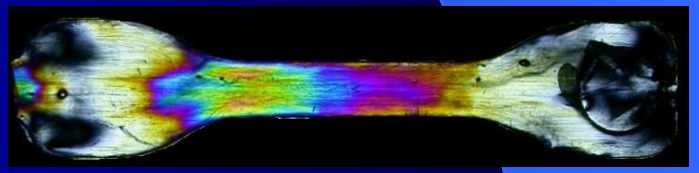
b. Tmold 30℃
Pa 0.6 Pp 0.6



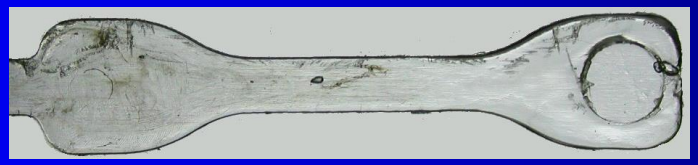
c. Tmold 60℃
Pa 0.8 Pp 0.6

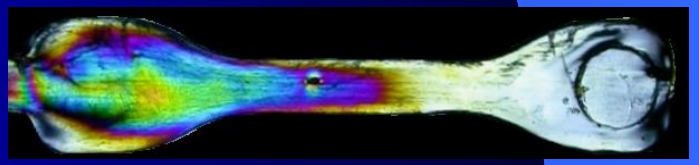


d. Tmold 90℃
Pa 0.8 Pp 0.6



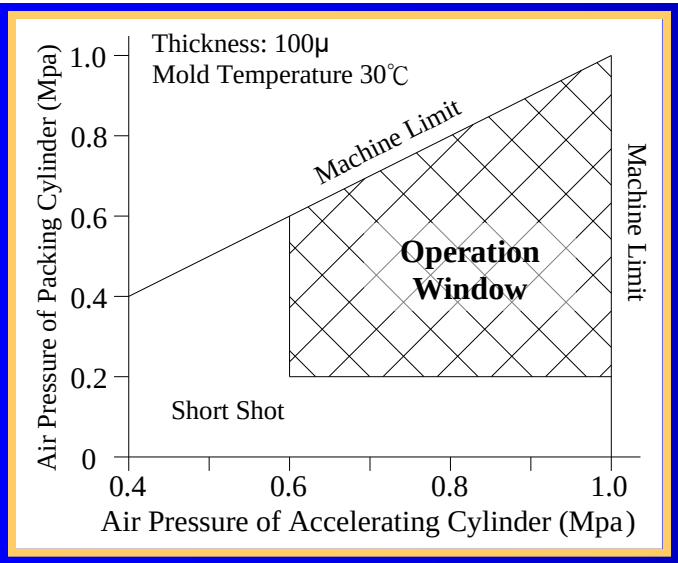
e. Tmold 120℃
Pa 0.8 Pp 0.6

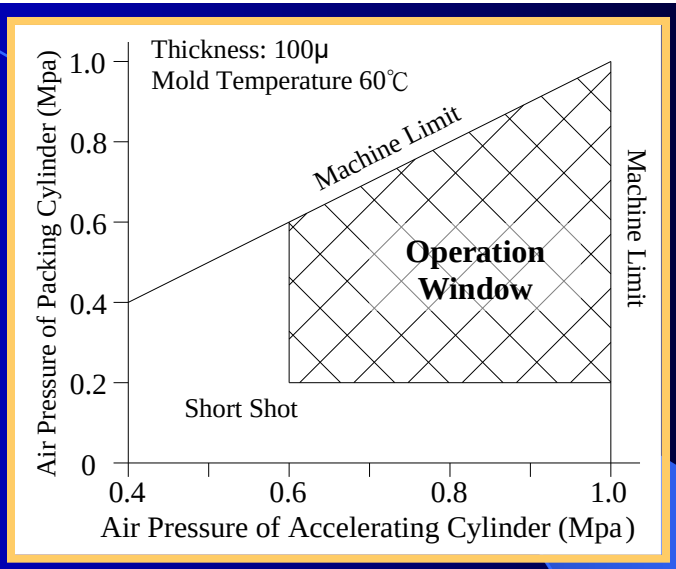


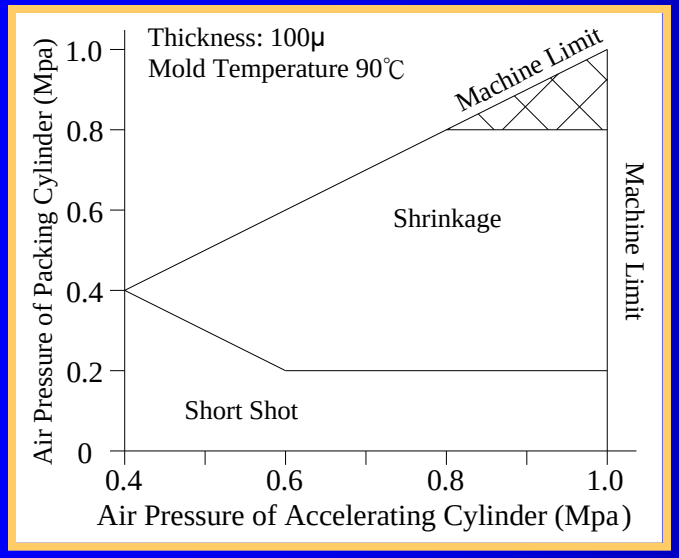


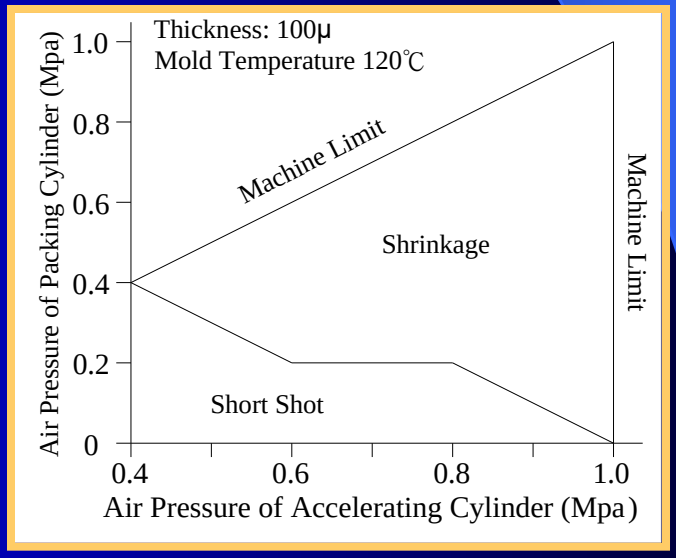
（Tmelt230℃）

The Operation Windows for Molding Test-Sheets of 100μm Thick



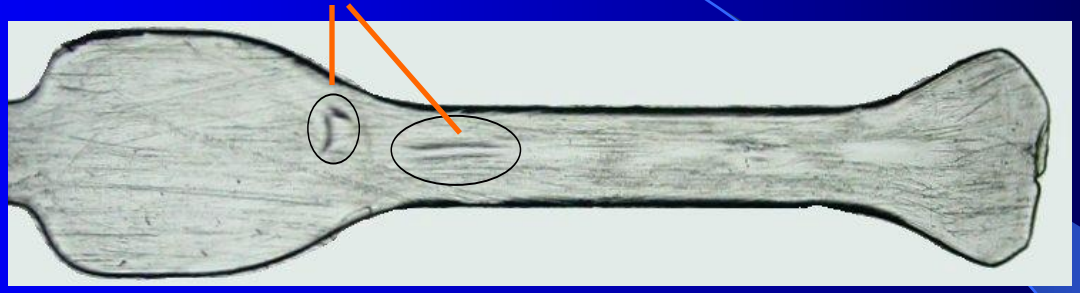






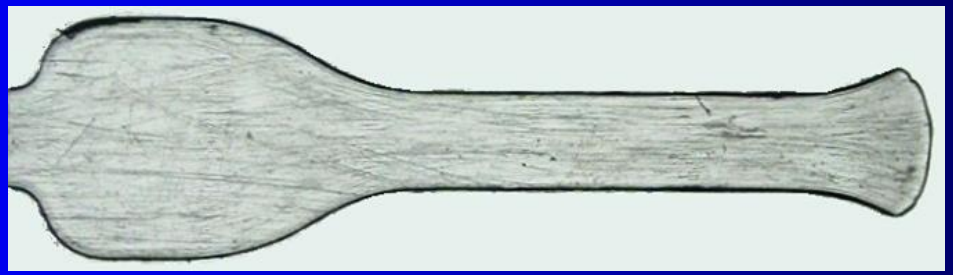
The Test-Sheets of 100μm Thick in Molding with Mold Temperature 30℃

Irregular-shaped shrinkage marks



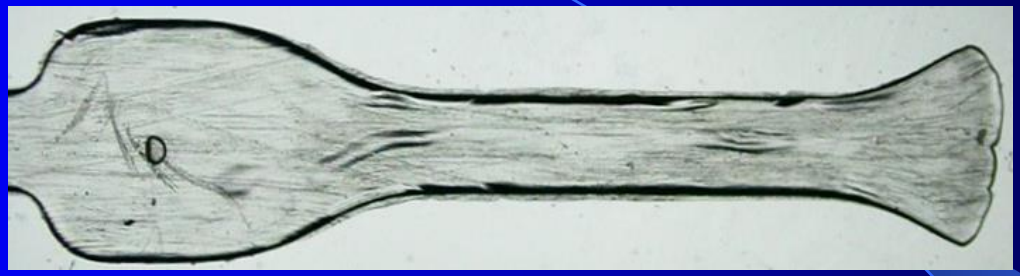
T_{mold}=30℃, Pa=0.6MPa, and Pp=0MPa (short shot and shrinkage)

T_{mold}=30℃, Pa=1MPa, and Pp=0MPa (short shot)



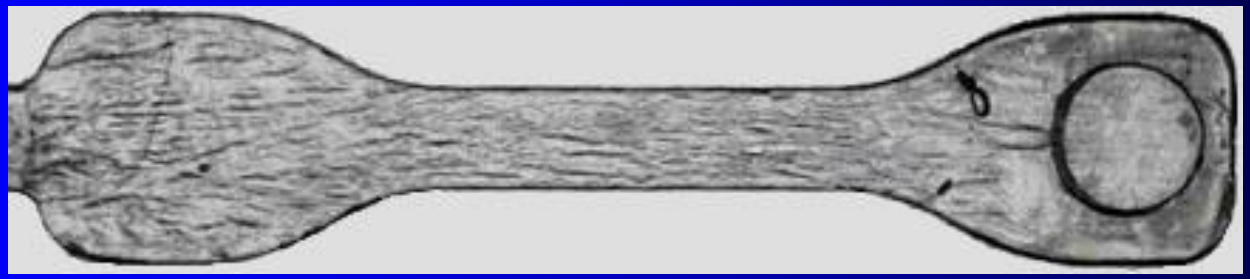
T_{mold}=30℃, Pa=0.4MPa, and Pp=0.3MPa (short shot)

The Test-Sheets of 100μm Thick in Molding with Mold Temperature 60℃, 90℃, and 120℃



T_{mold}=60℃, Pa=6MPa, and Pp=0MPa (short shot and shrinkage)

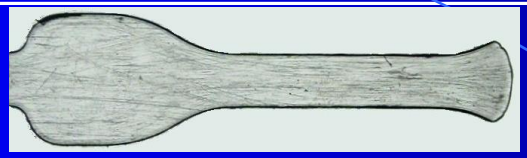
T_{mold}=90℃, Pa=0.8MPa, and Pp=0.6MPa (shrinkage)

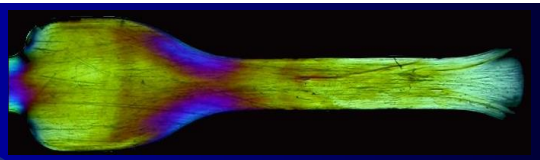


T_{mold}=120℃, Pa=1MPa, and Pp=0.6MPa (shrinkage)

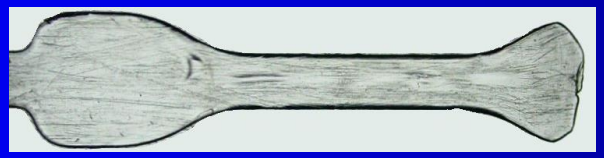
The Birefringence of Test-Sheets of 100μm Thick in Molding with Mold Temperature 30℃

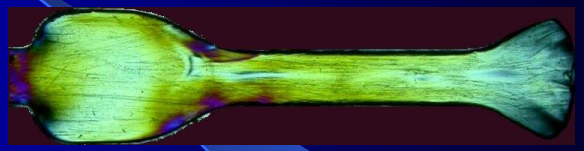
a. Pa 0.4 Pp 0.2



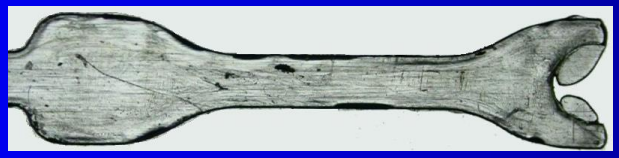


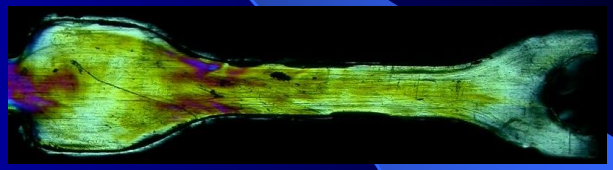
b. Pa 0.6 Pp 0



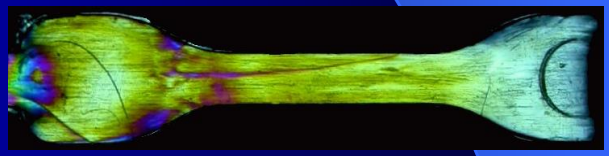


c. Pa 0.8 Pp 0

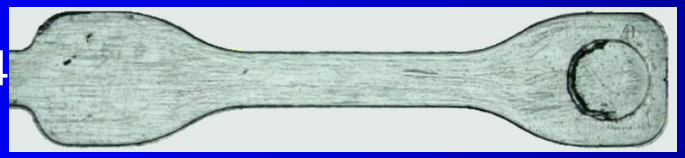


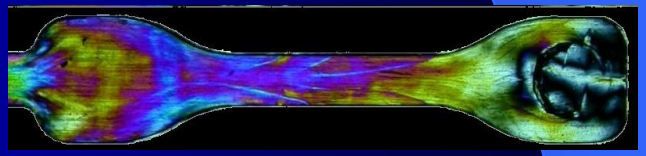


d. Pa 1.0 Pp 0

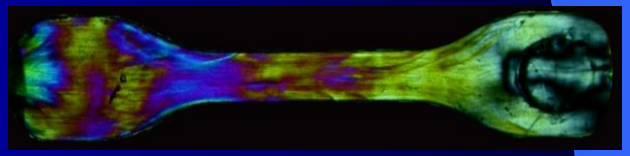


e. Pa 0.8 Pp 0.4





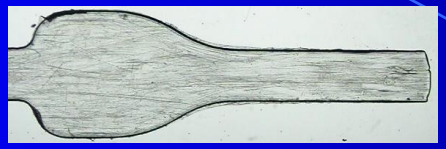
f. Pa 0.8 Pp 0.6

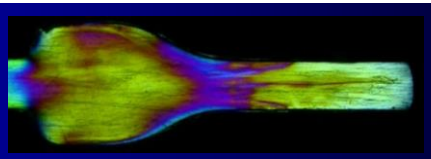


（Tmelt230℃）

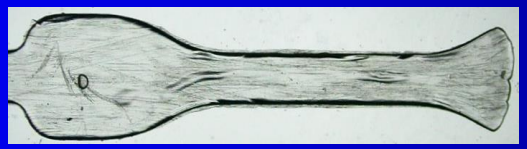
The Birefringence of Test-Sheets of 100μm Thick in Molding with Mold Temperature 60 and 90℃

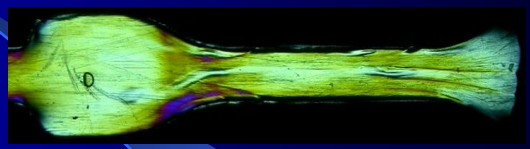
a. Tmold 60℃
Pa 0.4 Pp 0.2



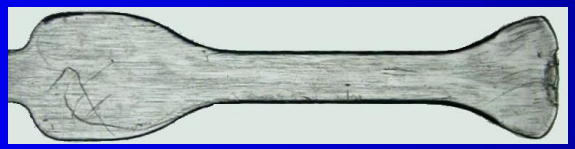


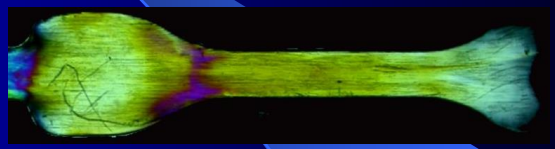
b. Tmold 60℃
Pa 0.6 Pp 0



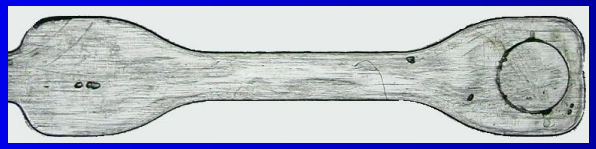


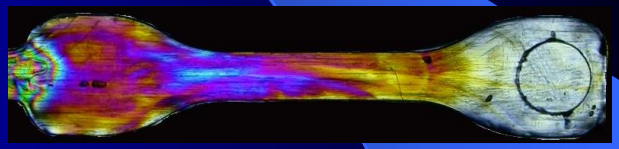
c. Tmold 60℃
Pa 1.0 Pp 0



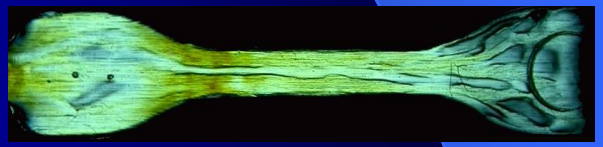


d. Tmold 60℃
Pa0.8 Pp 0.6

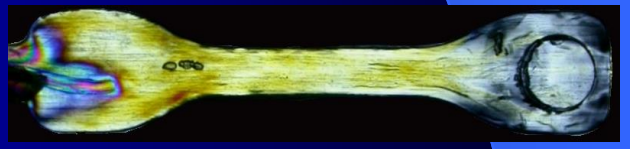




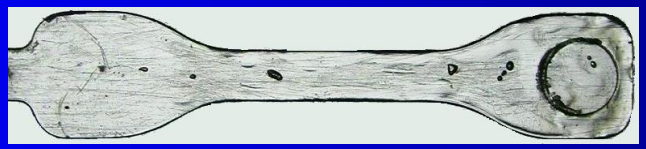
e. Tmold 90℃
Pa 1.0 Pp 0



f. Tmold 90℃
Pa 0.8 Pp 0.6



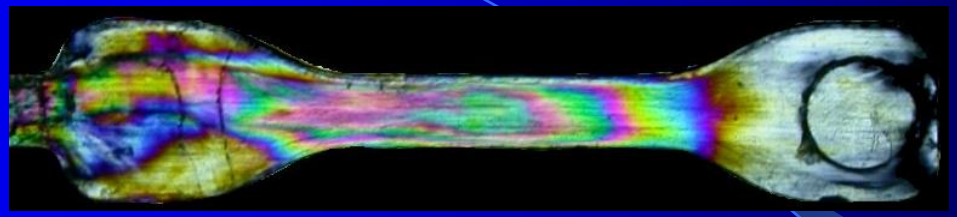
g. Tmold 90℃
Pa 1.0 Pp 0.8



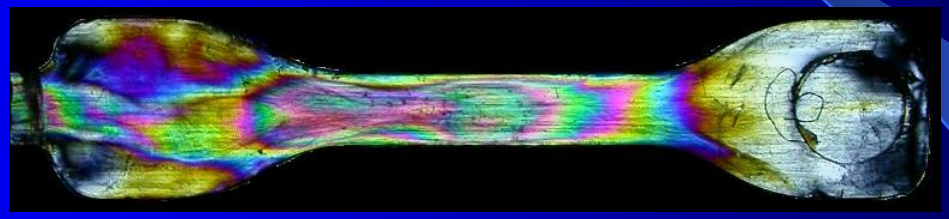
（Tmelt230℃）

The Birefringence of Test-Sheets of 100μm Thick in Molding with Different Melt Temperature

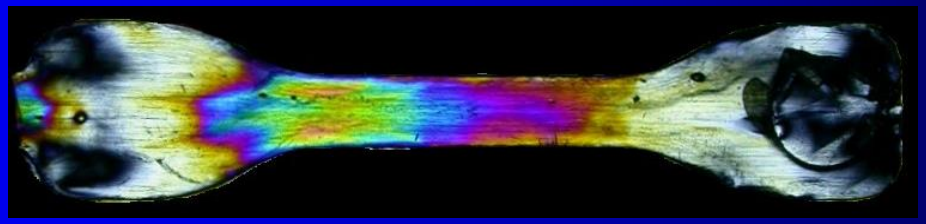
Tmelt = 210℃



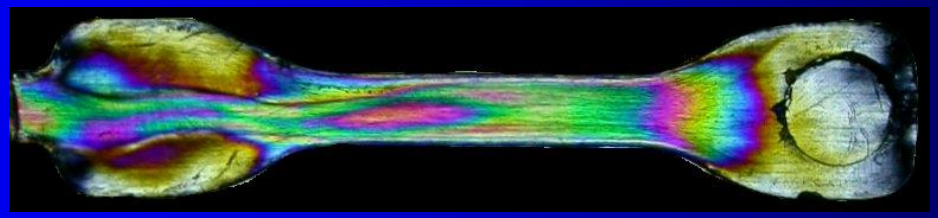
Tmelt = 220℃



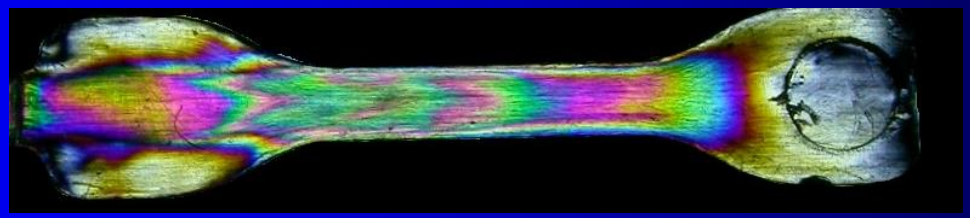
Tmelt = 230℃



Tmelt = 240℃



Tmelt = 250℃

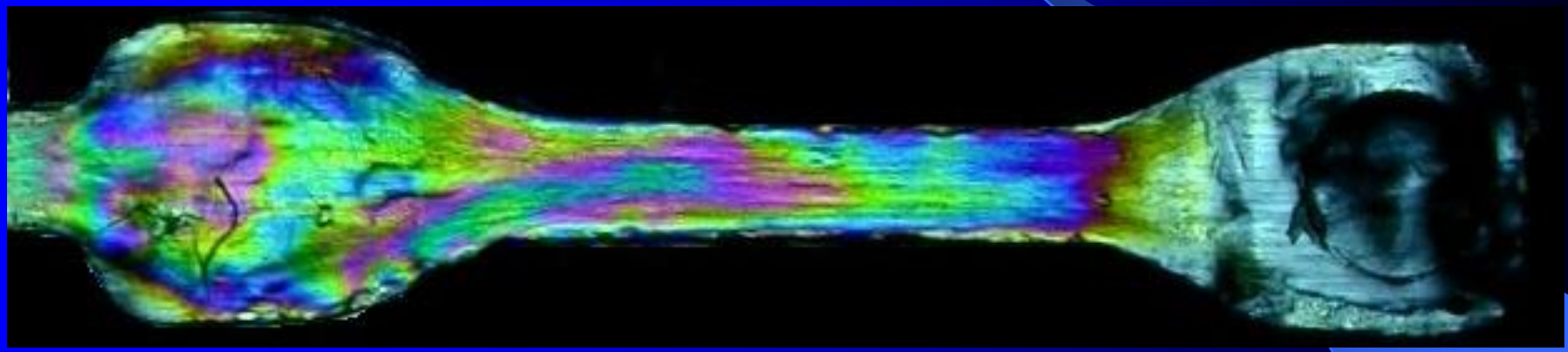


Tmold = 230℃

Pa = 0.8MPa

Pp = 0.6MPa

The Birefringence of Test-Sheets of 200μm Thick in Molding with Low Melt Temp. and High Mold Temp.



T_{melt} =100℃, T_{mold} =110℃, Pa=1MPa, Pp= 0.8MPa

Conclusions

1. Fewer short shots and shrinkage marks are observed in molding test sheets of 200μm thick than molding those of 100μm thick.
2. Increasing in mold temperature will reduce the possibility of short shots, but increase shrinkage.
3. To prevent short shot, increasing the air pressure in accelerating cylinder is more effective than increasing that in packing cylinder.
4. To prevent shrinkage, increasing the air pressure in packing cylinder is more effective than increasing that in accelerating cylinder.
5. Irregular-shaped shrinkage marks appear in test sheets molded with low mold temperature. Circular shrinkage pits are found only in test sheets of 200μm molded with high mold temperature.
6. The circular shrinkage pits appear everywhere in entire sample and are growing during a short interval before the molding is detached from the cavity wall.

Thank You !

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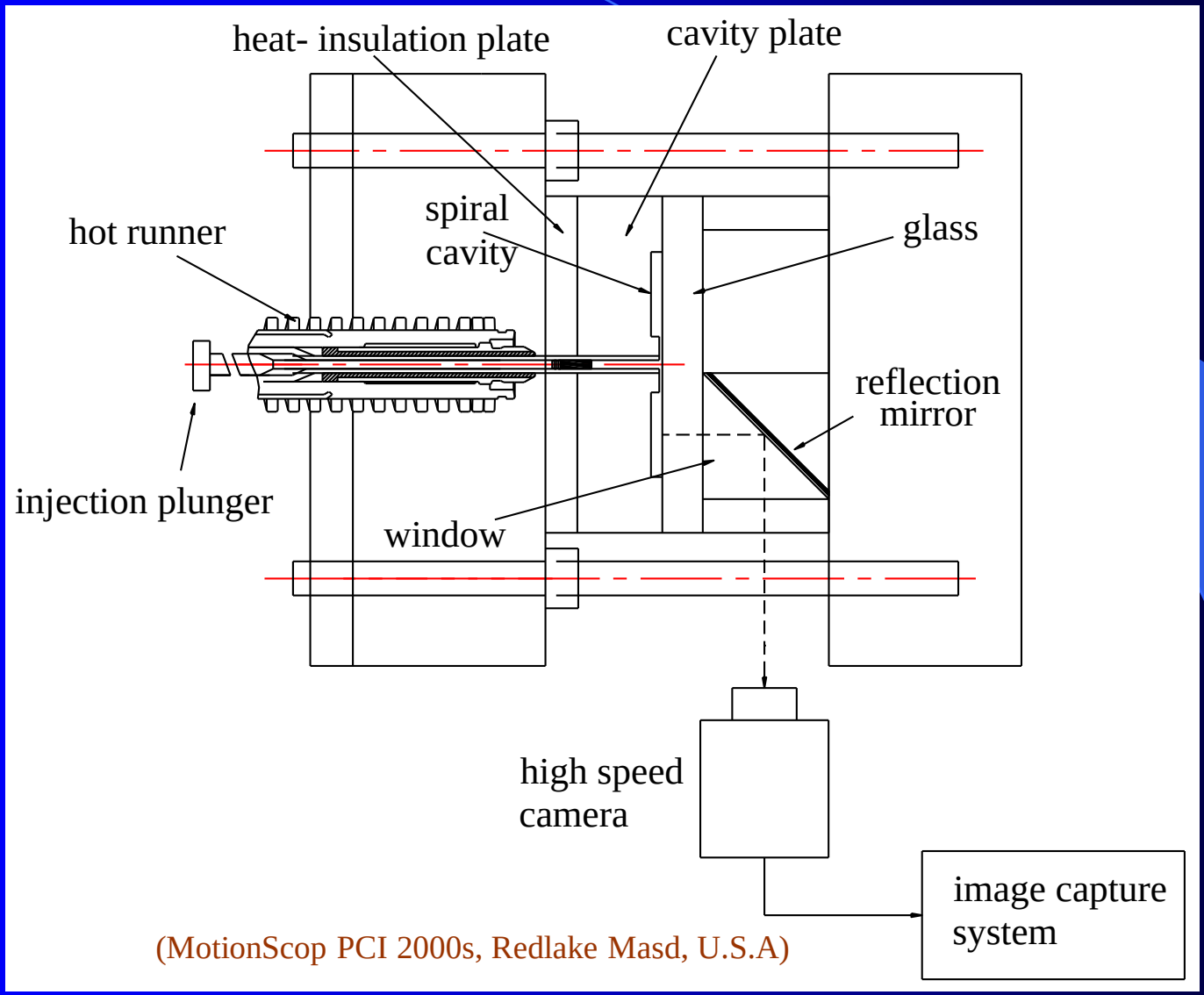
E-mail: Syyang@ntu.edu.tw

The Setup of Images Capture System



(MotionScop PCI 2000s, Redlake Masd, U.S.A)

The forming process of shrinkage pits during molding test-sheet of 200μm depth with Pa 0.8MPa and Pp 0.1MPa

=4.5sec;
ature=135℃

=5sec;
rature=129℃

=5.5sec;
rature=126℃

=6sec;
ature=124℃

=6.3sec;
ature=123℃