Mold Design

2. Injection Molding and Mold

Bong-Kee Lee
School of Mechanical Engineering
Chonnam National University

Injection Molding Process

- Plastic injection molding process
Injection Molding Process

- Overview of injection molding process
  - a cyclic process of forming plastic into a desired shape by forcing the material under pressure into a cavity
    - shaping by cooling (thermoplastics) or by a chemical reaction (thermosets)
    - one of the most common and versatile operations for mass production of complex plastics parts with excellent dimensional tolerance
    - minimal or no finishing or assembly operations
    - other molding materials including fibers, ceramics, and powdered metals, with polymers as binders
**Injection Molding Machine**

- Development of injection molding machine
  - since its introduction in the early 1870s, the injection molding machine has undergone significant modifications and improvements
  - in particular, the invention of the reciprocating screw machine has revolutionized the versatility and productivity of the thermoplastic injection molding process
    - plunger type: inherently simple, but the slow heating rate through pure conduction only
    - reciprocating screw type: quick and uniform plasticization with its rotating motion

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**Injection Molding Machine**

- Plunger and reciprocating screw types
Injection Molding Machine

- Screw
  - plasticization and transport of materials
  - quick injection of molten polymers into cavities

Overview of injection molding machine
Injection Molding Machine

- Structure of injection molding machine
  - injection system
  - hydraulic system
  - mold system
  - clamping system
  - control system

- Machine specification
  - clamping force (or clamping tonnage) and shot size
  - other parameters: injection rate, injection pressure, screw design, mold thickness, and the distance between tie bars

- Machine function
  - general-purpose machine
  - precision, tight-tolerance machine
  - high-speed, thin-wall machine
Injection System

- **Injection system**
  - it consists of hopper, reciprocating screw, and barrel
  - this system confines and transports the plastic as it progresses through the feeding, compressing, degassing, melting, injection, and packing stages

- **Hopper**
  - it holds the small pellets of thermoplastic material
  - the pellets are gravity-fed from the hopper through the hopper throat into the barrel and screw assembly

- **Barrel**
  - it supports the reciprocating plasticizing screw
  - it is heated by the electric heater bands
Reciprocating screw
- to compress, melt, and convey the material
- three zones of the feed zone, the compression or transition zone, and the metering zone
  - melting: viscous heating due to high shear with decreasing the depth of the flights
  - heater bands to maintain the material in the molten stage

Nozzle
- connection of the barrel to the sprue bushing of the mold to form a seal between the barrel and the mold
- temperature of the nozzle: material’s melt temperature (or just below it)

(a) nozzle with barrel in processing position
(b) nozzle with barrel backed out for purging
Mold System

- Mold system
  - tie bars, stationary and moving platens, as well as molding plates (bases) that include the cavity, sprue and runner systems, ejector pins, and cooling channels
    - mold: a heat exchanger in which the molten thermoplastic solidifies to the desired shape and dimensional details defined by the cavity

Two-plate mold
- it consists essentially of two halves
- for parts that are typically gated on or around their edge, with runner in the same mold plate as the cavity
Mold System

- Three-plate mold
  - typically for parts that are gated away from their edge
  - the runner is in two plates, separate from the cavity and core

![Diagram of a three-plate mold system](image)
Mold System

- Cooling channels (circuits)
  - passageways located within the body of a mold, through which a cooling medium (typically water, steam, or oil) circulates
  - for the regulation of temperature on the mold surface
  - cooling channels with other temperature control devices, like bafflers, bubblers, and thermal pins or heat pipes

Other Systems

- Hydraulic system
  - or, servo motor system for electric injection molding machines

- Control system

- Clamping system
Molded Part

- Typical molded system
  - the molded part(s) and the delivery system, like sprue, runner, gate, and so on

- Delivery system
  - it provides passage for the molten plastic from the machine nozzle to the part cavity
    - sprue
    - cold slug wells
    - main runners
    - branch runners
    - gates

  - cold runners
  - hot runners (or runnerless)
Alternative Injection Molding Processes

- Alternative injection molding processes
  - advances in the understanding of materials, improvements in molding equipment, and the needs of specific industry segments have expanded the use of the process to areas beyond its original scope of thermoplastic molding
  - to produce parts with special design features and properties
  - additional applications, more design freedom, special structural features, and so forth

- Co-injection (sandwich) molding
  - sequential or concurrent injection of two different but compatible polymer melts into a cavity
  - to produce parts that have a laminated structure, with the core material embedded between the layers of the skin material
  - inherent flexibility of using the optimal properties of each material or modifying the properties of the molded part
Alternative Injection Molding Processes

- Fusible (lost, soluble) core injection molding
  - to produce single-piece, hollow parts with complex internal geometry
  - after the molding, the core inside the plastic part will be physically melted or chemically dissolved

- Gas-assisted injection molding
  - partial or full injection of polymer melt into the mold cavity and the subsequent injection of compressed gas into the core of the polymer melt to help fill and pack the mold
Alternative Injection Molding Processes

- Gas-assisted injection molding
  - benefits
    • to produce hollow, light-weight, rigid parts that are free of sink marks and less likely to warp
    • reduced cycle time, reduced pressure and clamp force tonnage, part consolidation with both thick and thin sections
  - typical applications
    • tube- and rod-like parts: clothes hangers, grab handles, chair armrests, shower heads, and water faucet spouts
    • large, sheet-like, structural parts with a built-in gas-channel network: automotive panels, business machine housings, outdoor furniture, and satellite dishes
    • complex parts with both thin and thick sections: television cabinets, computer printer housing bezels, and automotive parts

- Injection-compression molding
  - after a pre-set amount of polymer melt is fed into an open cavity, it is compressed (or compression can also take place when the polymer is to be injected)
    • to produce dimensionally stable, relatively stress-free parts, at a low clamp tonnage (typically 20 to 50 percent lower)
Alternative Injection Molding Processes

- Lamellar (microlayer) injection molding
  - use of a feedblock and layer multipliers to combine melt streams from dual injection cylinders, resulting in parts from multiple resins in distinct microlayers
    - enhanced properties such as the gas barrier property, dimensional stability, heat resistance, and optical clarity

![Diagram of Lamellar Injection Molding](image1)

- Live-feed injection molding
  - application of oscillating pressure at multiple polymer entrances to cause the melt to oscillate
    - molten state in the gates while different layers of molecular or fiber orientation in the mold due to solidification
    - to produce simple or complex parts that are free from voids, cracks, sink marks, and weld-line defects

![Diagram of Live-Feed Injection Molding](image2)
Alternative Injection Molding Processes

- Low-pressure injection molding
  - optimized extension of conventional injection molding
  - reduction of the clamp force tonnage requirement, less costly molds and presses, and lower stress in the molded parts

- Push-pull injection molding
  - use of a conventional twin-component injection system and a two-gate mold to force material to flow back and forth between a master injection unit and a secondary injection unit
    - elimination of weld lines, voids, and cracks
    - control of the fiber orientation
Alternative Injection Molding Processes

- Reactive molding
  - simultaneous forming and polymerization during the molding process
    - reactive material with low viscosity
    - cross-linked polymer structure: improved mechanical properties and greater heat and environmental resistance
    - reactive injection molding (RIM)
    - composites processing with a preform: resin transfer molding (RTM), structural reaction injection molding (SRIM)
    - encapsulation of microelectronic IC chips
    - liquid silicone rubber (LSR) injection molding

- Structural foam injection molding
  - to produce parts consisting of solid external skin surfaces surrounding an inner cellular (or foam) core
    - with both low and high pressure, with nitrogen gas or chemical blowing agents
    - suitable for large, thick parts that are subjected to bending loads in their end-use application
Alternative Injection Molding Processes

- Thin-wall molding
  - flow-length-to-wall-thickness ratios: from 100:1 to 150:1 or more
    - more popular in portable communication and computing equipment, which demand plastic shells that are much thinner yet still provide the same mechanical strength as conventional parts
    - high melt temperatures, high injection speeds, and very high injection pressures