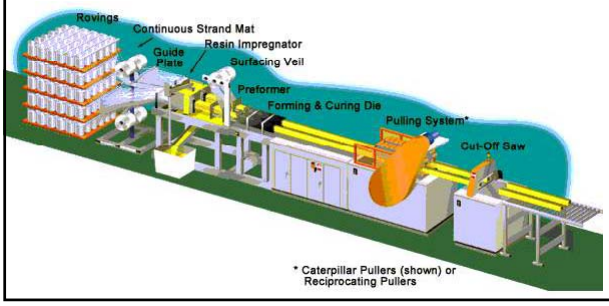
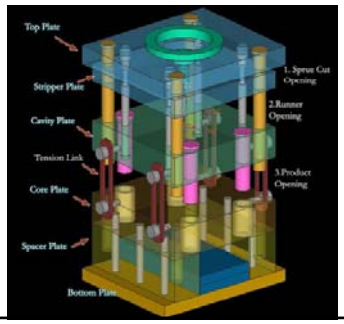
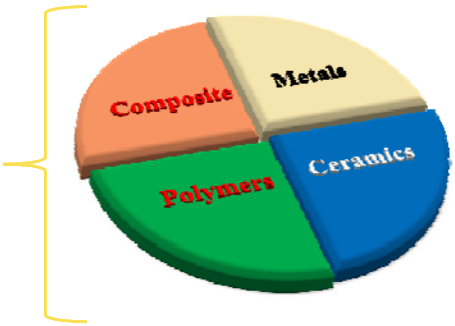
Plastics Industry

Jariyaporn Saothong, (Ph.D.)



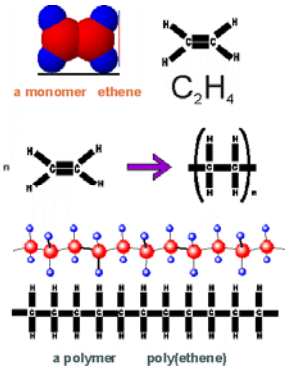


Four Types of Engineering Materials



POLYMERS

A compound consisting of long-chain molecules, each molecule made up of repeating units connected together. Most polymers are based on carbon and are therefore considered organic chemicals



สารประกอบอินทรีย์ (มีคาร์บอนเป็นองค์ประกอบ) ที่มีโมเลกุลเป็นเส้นยาว จากการต่อหน่วยที่ซ้ำๆ กัน

***polymer* = *poly*(many) + *mer* (part)**

Plastic Products

- Plastics can be shaped into a wide variety of products:
  - Molded parts
  - Extruded sections
  - Films (thickness less than 0.5 mm), Sheets
  - Insulation coatings on electrical wires
  - Fibers for textiles
  - Packaging materials
  - Printed circuit boards

More Plastic Products

- Ingredient in other materials, such as
  - Paints and varnishes
  - Adhesives
  - Various polymer matrix composites
- The starting plastic materials are normally supplied to the fabricator in the form of powders or pellets in bags, drums, or larger loads by truck or rail car

- Plastics can be molded into intricate part shapes, usually with no further processing

  Very compatible with ***net shape*** processing
- Polymers **require less energy** to produce than metals
- Certain plastics are translucent and/or transparent, which makes them competitive with glass in some applications
- Painting or plating is usually not required

Properties of Polymers

- Low density relative to metals and ceramics
- Good strength-to-weight ratios for certain (but not all) polymers
- High corrosion resistance
- Low electrical and thermal conductivity
- Low strength relative to metals and ceramics
- Low modulus of elasticity (stiffness)
- Service temperatures are limited to only a few hundred degrees
- Viscoelastic properties, which can be a distinct limitation in load bearing applications
- Some polymers degrade when subjected to sunlight and other forms of radiation

Limitations of Polymers

- Low strength relative to metals and ceramics
- Low modulus of elasticity (stiffness)
- Service temperatures are limited to only a few hundred degrees
- Some polymers degrade when subjected to sunlight and other forms of radiation

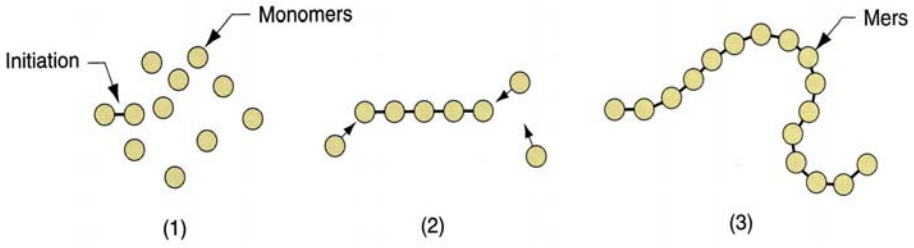
Two Types of Plastics

1. Thermoplastics
   - Chemical structure remains unchanged during heating and shaping
   - More important commercially, comprising more than 70% of total plastics tonnage
2. Thermosets
   - Undergo a curing process during heating and shaping, causing a permanent change (*cross-linking*) in molecular structure
   - Once cured, they cannot be remelted

Polymerization

The synthesis of polymers can occur by either of two methods:

1. **Addition polymerization**



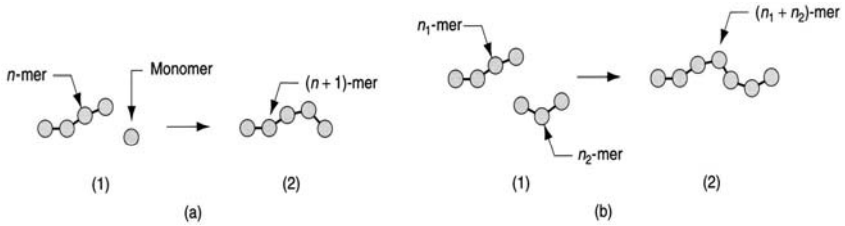
Model of addition (chain) polymerization:

(1) Initiation, (using a chemical catalyst (called an *initiator*) to open the carbon double bond)

(2) Rapid addition of monomers, and

(3) Resulting long chain polymer molecule with *n* mers at termination of reaction.

2. Step polymerization



Model of step polymerization showing the two types of reactions occurring: (a) n-mer attaching a single monomer to form a (*n*+1)-mer; and (b) n_1-mer combining with n_2-mer to form a (n_1+n_2)-mer. Sequence is shown by (1) and (2).

n for the batch is an average (Its statistical distribution is normal)
The mean value of *n* is called the ***degree of polymerization*** **(DP)** for the batch

Higher DP increases mechanical strength but also **increases viscosity in the fluid state, which makes processing more difficult**

Polymer Molecular Structures

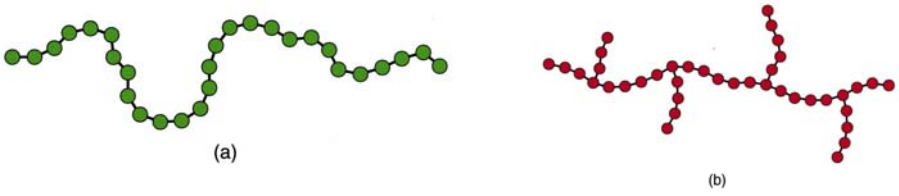
Linear structure:

chain-like structure ,

Characteristic of thermoplastic polymers

Branched structure:

chain-like but with side branches, also found in thermoplastic polymers

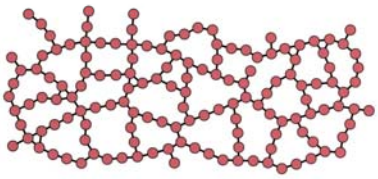


- **TP** always possess linear or branched structures, or a mixture of the two
- **Branches** makes the polymer Stronger in the solid state but more viscous at a given temperature in the plastic or liquid state

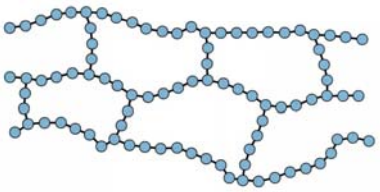
Cross-linked structure

Tightly cross-linked, characteristic of **thermosets**

Loosely cross-linked, characteristic of **elastomers**



(d)



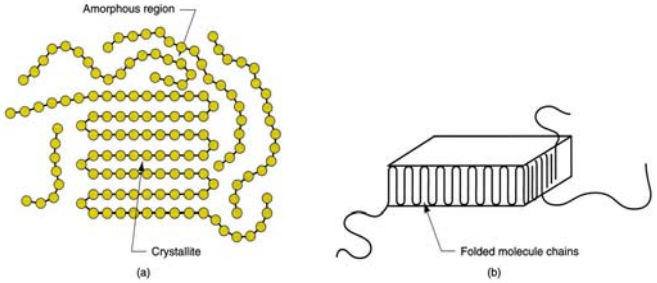
(c)

Thermosets possess a high degree of cross-linking, while **elastomers possess a low degree of cross-linking**

- Thermosets are hard and brittle, while elastomers are elastic and resilient
- Cross-linking causes the polymer to become chemically set

The reaction cannot be reversed. The polymer structure is permanently changed; if heated, it degrades or burns rather than melt.

Crystalline Polymer Structure



Crystallized regions in a polymer:

(a) long molecules forming crystals randomly mixed in with the amorphous material; and

(b) Folded chain lamella, the typical form of a crystallized region

A polymer that crystallizes is a two phase system
crystallites interspersed throughout an amorphous matrix

High density : High degree of crystalline

Additives

- Properties of a polymer can often be beneficially changed by combining it with additives
- Additives either alter the molecular structure or
- Add a second phase, in effect transforming the polymer into a composite material

Types of Additives by Function

Fillers – to strengthen polymer or reduce cost

Plasticizers – to soften polymer and improve flow

Colorants – pigments or dyes

Lubricants – to reduce friction and improve flow

Flame retardents – to reduce flammability of polymer

Cross-linking agents – for thermosets and elastomers

Ultraviolet light absorbers – to reduce degradation from sunlight

Antioxidants – to reduce oxidation damage

Cross-Linking in TS Polymers

- Three categories:
  1. Temperature-activated systems
  2. Catalyst-activated systems
  3. Mixing-activated systems

Curing is accomplished at the fabrication plants that make the parts rather than the chemical plants that supply the starting materials to the fabricator

เกิดในขั้นตอนของการขึ้นรูปมาก มากกว่าขั้นตอนของการผลิตเม็ดพลาสติก

Temperature-Activated Systems

Curing caused by heat supplied during part shaping operation (e.g., molding)

- Starting material is a linear polymer in **granular form** supplied by the chemical plant
  - As heat is added, material softens for molding, but continued heating causes cross-linking

Most common TS systems

Catalyst-Activated Systems

Cross-linking occurs when small amounts of a catalyst are added to the polymer, which is in **liquid form**

- Without the catalyst, the polymer remains stable and liquid
- Once combined with the catalyst it cures and changes into **solid form**

Mixing-Activated Systems

Mixing of two chemicals results in a reaction that forms a cross-linked solid polymer

Elevated temperatures are sometimes used to accelerate the reactions

Classification of Shaping Processes

- Extruded products with constant cross-section
- Continuous sheets and films
- Continuous filaments (fibers)
- Molded parts that are mostly solid
- Hollow molded parts with relatively thin walls
- Discrete parts made of formed sheets and films
- Foam Products

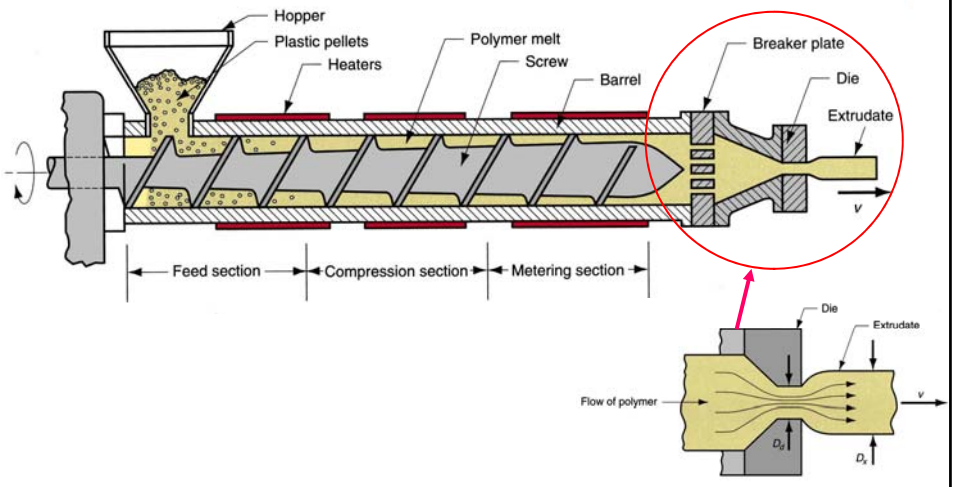
Many plastic shaping processes can be adapted to produce items made of rubbers and polymer matrix composites

Extrusion

:Material is forced to flow through a die orifice to provide long continuous product whose cross-sectional shape is determined by the shape of the orifice

- Widely used for thermoplastics and elastomers to mass produce items such as tubing, pipes, hose, structural shapes, sheet and film, continuous filaments, and coated electrical wire
- Carried out as a continuous process; *extrudate* is then cut into desired lengths

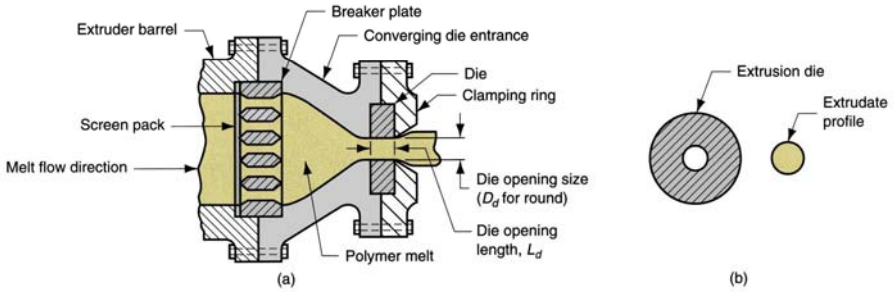
Extruder



Components and features of a (single-screw) extruder for plastics

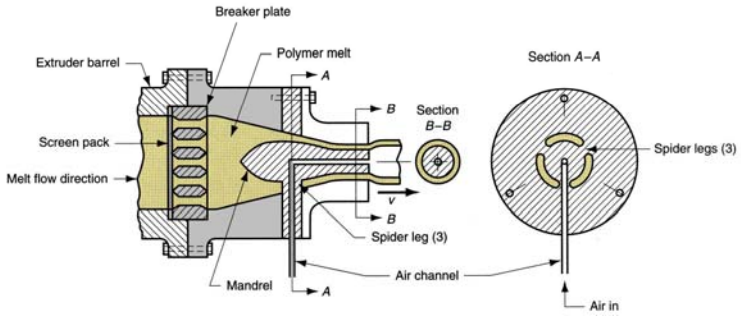
Die Configurations and Extruded Products

- The shape of the die orifice determines the cross-sectional shape of the extrudate
- Common die profiles and corresponding extruded shapes:
  - Solid profiles (Round, Square, Structural shapes, Door and window moldings, Automobile trim, House siding)



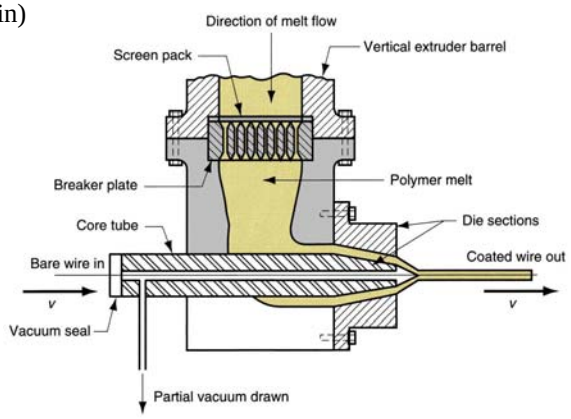
Hollow profiles, such as tubes

- Hollow profiles require mandrel to form the shape
- Mandrel held in place using a spider
- Polymer melt flows around legs supporting the mandrel to reunite into a monolithic tube wall
- Mandrel often includes an air channel through which air is blown to maintain hollow form of extrudate during hardening



Wire and cable coating (electrical wire)

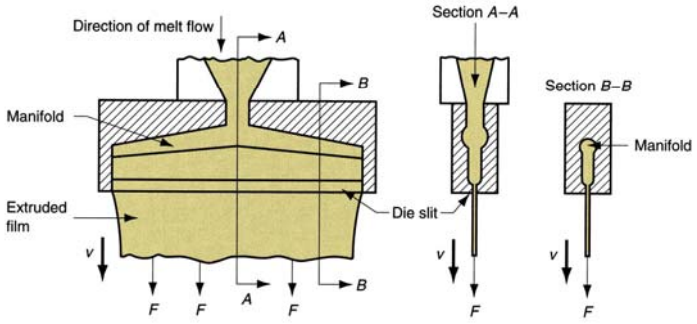
- Polymer melt is applied to bare wire as it is pulled at high speed through a die (A slight vacuum is drawn between wire and polymer to promote adhesion of coating)
- Wire provides rigidity during cooling - usually aided by passing coated wire through a water trough
- Product is wound onto large spools at speeds up to 50 m/s (10,000 ft/min)



Sheet and film (Most widely used process continuous, high production operations)

Processes include:

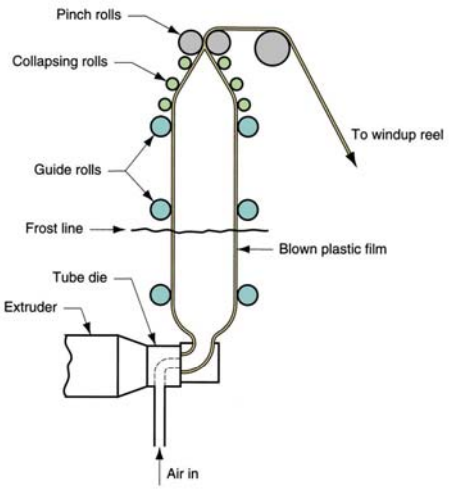
- Slit-Die Extrusion of Sheet and Film (Production of sheet and film by conventional extrusion, using a narrow slit as the die opening)
- A problem is uniformity of thickness throughout width of stock, due to drastic shape change of polymer melt as it flows through die
- Edges of film usually must be trimmed because of thickening at edges

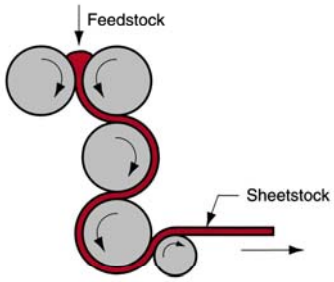


Blown-Film Extrusion Process

(Combines extrusion and blowing to produce a tube of thin film)

- Process sequence:
  - Extrusion of tube
  - Tube is drawn upward while still molten and simultaneously expanded by air inflated into it through die (Air is blown into tube to maintain uniform film thickness and tube diameter)





Calendering (Feedstock is passed through a series of rolls to reduce thickness to desired gage)

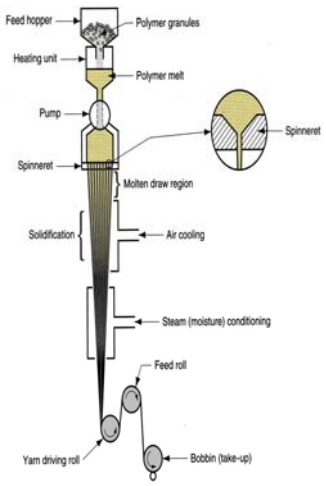
- Expensive equipment, high production rates
- Process is noted for good surface finish and high gage accuracy
- Typical materials: rubber or rubbery thermoplastics such as plasticized PVC
- Products: PVC floor covering, shower curtains, vinyl table cloths, pool liners, and inflatable boats and toys

Fiber and Filaments

- *Fiber* - a long, thin strand whose length is at least 100 times its cross-section
- *Filament* - a fiber of continuous length

spinning = extrusion of polymer melt or solution through a *spinneret*, then drawing and winding onto a *bobbin*

- Spinneret = die with multiple small holes
- The term is a holdover from methods used to draw and twist natural fibers into yarn or thread



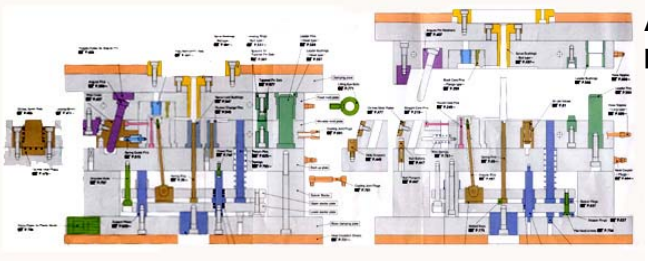
Injection Molding

- Polymer is heated to a highly plastic state and forced to flow under high pressure into a mold cavity where it solidifies and the *molding* is then removed from cavity
- Produces discrete components almost always to net shape
- Typical cycle time ~10 to 30 sec, but cycles of one minute or more are not uncommon
- Mold may contain multiple cavities, so multiple moldings are produced each cycle

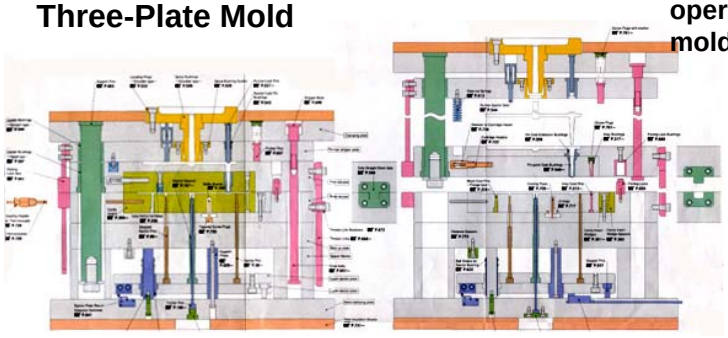
Injection Molded Parts

- Complex and intricate shapes are possible
- Shape limitations:
  - Capability to fabricate a mold whose cavity is the same geometry as part
  - Shape must allow for part removal from mold
- Part size from ~ 50 g (2 oz) up to ~ 25 kg (more than 50 lb), e.g., automobile bumpers
- Injection molding is economical only for large production quantities due to high cost of mold

Two-Plate Mold



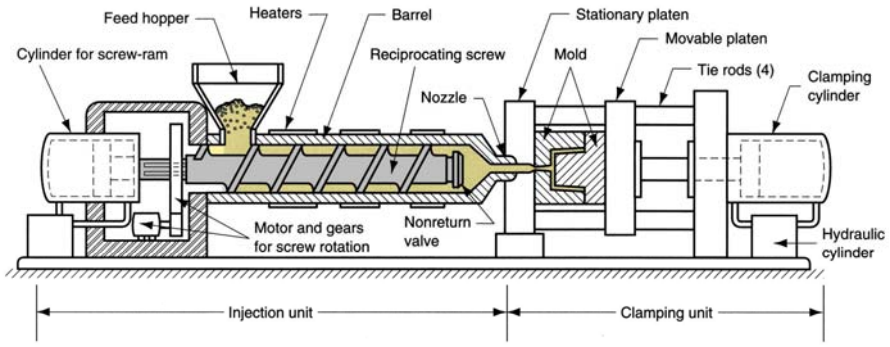
Three-Plate Mold



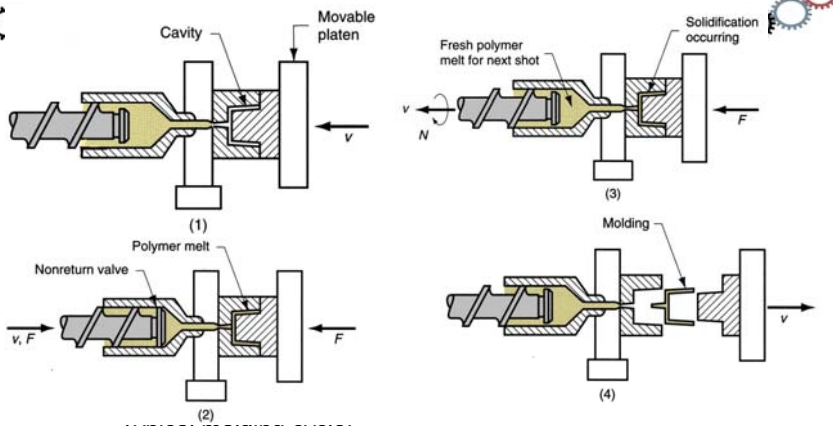
Three plates separate
Advantages over two-plate mold:

- As mold opens, runner and parts disconnect and drop into two containers under mold.
- Allows automatic operation of molding mach.

Injection Molding Machine



Injection Molding Cycle



Typical molding cycle:
(1) mold is closed ; (2) melt is injected into cavity

(3) screw is retracted. ; (4) mold opens and part is ejected.

Thermoplastic Foam Injection Molding

Molding of thermoplastic parts that possess dense outer skin surrounding lightweight foam center

- Part has high stiffness-to-weight ratio suited to structural applications
- **Produced either by introducing a gas into molten plastic in injection unit or by mixing a gas-producing ingredient with starting pellets**
- A small amount of melt is injected into mold cavity, where it expands to fill cavity
- Foam in contact with cold mold surface collapses to form dense skin, while core retains cellular structure

Injection Molding of Thermosets

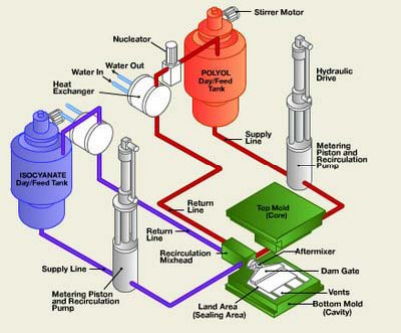
- Equipment and operating procedure must be modified to avoid premature cross-linking of TS polymer

Reciprocating-screw injection unit with shorter barrel length

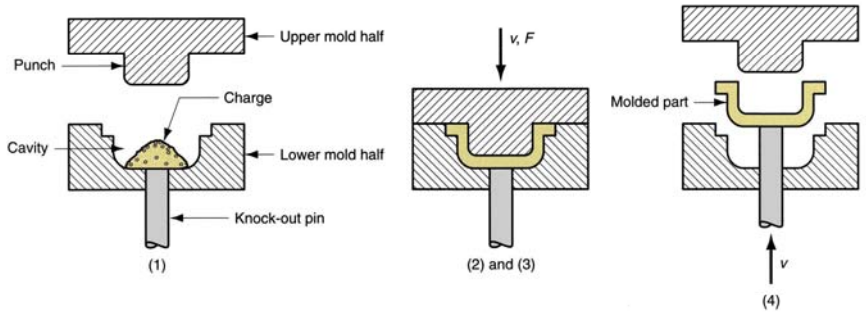
- Temperatures in barrel are relatively low
- Melt is injected into a heated mold, where cross-linking occurs to cure the plastic. (Curing in the mold is the most time-consuming step in the cycle)
- Mold is then opened and part is removed

Reaction Injection Molding

- Two highly reactive liquid ingredients are mixed and immediately injected into a mold cavity where **chemical reactions leading to solidification** occur
- RIM was developed with polyurethane to produce large automotive parts such as bumpers and fenders



Compression Molding



Compression molding for thermosetting plastics: (1) charge is loaded, (2) and (3) charge is compressed and cured, and (4) part is ejected and removed.

Molds for Compression Molding

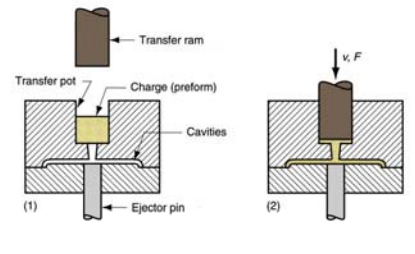
- Simpler than injection molds
- No sprue and runner system in a compression mold
- Process itself generally limited to simpler part geometries due to lower flow capabilities of TS materials
- Mold must be heated, usually by electric resistance, steam, or hot oil circulation

Transfer Molding

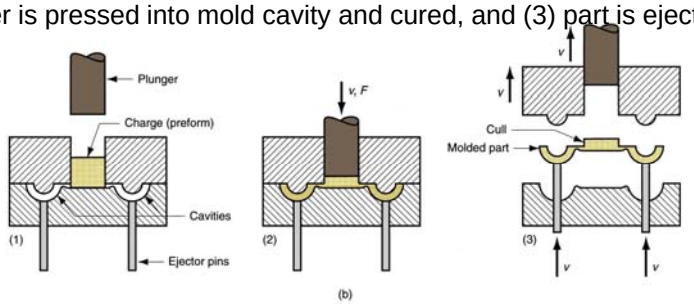
TS charge is loaded into a chamber immediately ahead of mold cavity, where it is heated; pressure is then applied to force soft polymer to flow into heated mold where it cures

Two variants:

- **Pot transfer molding** - charge is injected from a "pot" through a vertical sprue channel into cavity
- **Plunger transfer molding** – plunger injects charge from a heated well through channels into cavity



(a) Pot transfer molding: (1) charge is loaded into pot, (2) softened polymer is pressed into mold cavity and cured, and (3) part is ejected.



(b) plunger transfer molding: (1) charge is loaded into pot, (2) softened polymer is pressed into mold cavity and cured, and (3) part is ejected.

Compression vs. Transfer Molding

- In both processes, **scrap is produced each cycle as leftover material (TS cannot be recovered),** called the *cull*
- **Transfer molding** is capable of molding more intricate part shapes than compression molding but not as intricate as injection molding
- **Transfer molding** lends itself to molding with inserts, in which a metal or ceramic insert is placed into cavity prior to injection, and the plastic bonds to insert during molding

Blow Molding

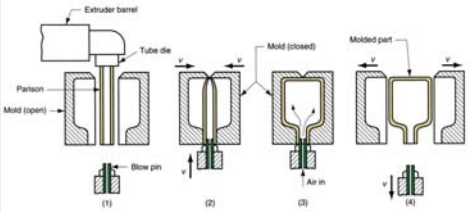
Molding process in which air pressure is used to inflate soft plastic into a mold cavity

- Important for making one-piece hollow plastic parts with thin walls, such as bottles
- Because these items are used for consumer beverages in mass markets, production is typically organized for very high quantities

Blow Molding Process

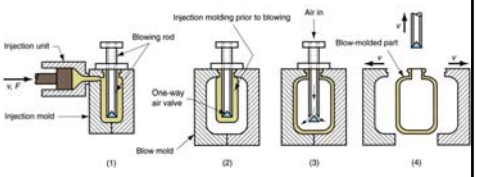
- Accomplished in two steps:
  1. Fabrication of a starting tube, called a ***parison***
  2. Inflation of the tube to desired final shape

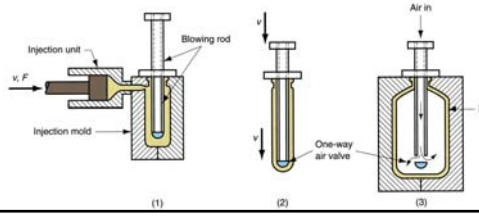
- Forming the parison is accomplished by either extrusion or injection molding



Extrusion blow molding: (1) extrusion of parison; (2) parison is pinched at the top and sealed at the bottom around a metal blow pin as the two halves of the mold come together; (3) the tube is inflated so that it takes the shape of the mold cavity; and (4) mold is opened to remove the solidified part.

Injection blow molding: (1) parison is injected molded around a blowing rod; (2) injection mold is opened and parison is transferred to a blow mold; (3) soft polymer is inflated to conform to the blow mold; and (4) blow mold is opened and blown product is removed.





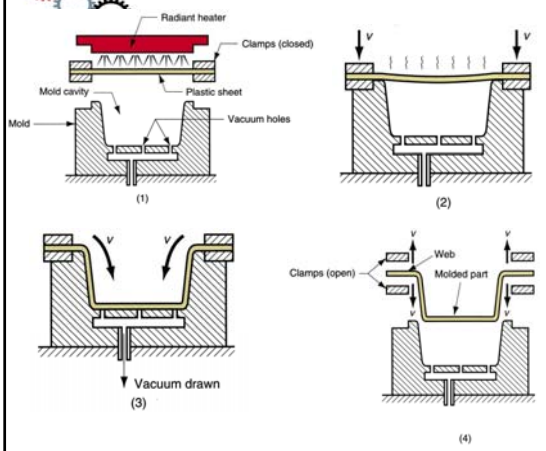
Stretch blow molding: (1) injection molding of parison; (2) stretching; and (3) blowing.

Thermoforming

Flat thermoplastic sheet or film is heated and deformed into desired shape using a mold

- Heating usually accomplished by radiant electric heaters located on one or both sides of starting plastic sheet or film
- Widely used in packaging of products and to fabricate large items such as bathtubs, contoured skylights, and internal door liners for refrigerators

Vacuum Thermoforming



Vacuum thermoforming:

(1) a flat plastic sheet is softened by heating

(2) the softened sheet is placed over a concave mold cavity

(3) a vacuum draws the sheet into the cavity

(4) plastic hardens on contact with the cold mold surface, and the part is removed and subsequently trimmed from the web.

Casting

Pouring liquid resin into a mold, using gravity to fill cavity, where polymer hardens

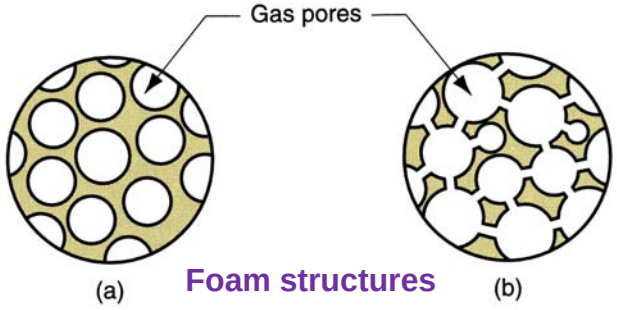
- Both thermoplastics and thermosets are cast
  - Thermoplastics: acrylics, polystyrene, polyamides (nylons) and PVC
  - Thermosetting polymers: polyurethane, unsaturated polyesters, phenolics, and epoxies
- Simpler mold
- Suited to low quantities

Polymer Foam

A polymer-and-gas mixture that gives the material a porous or cellular structure

Properties of a Foamed Polymer

- Low density
- Good thermal insulation
- Good energy absorbing qualities



Foam structures

(a) closed cell
(b) open cell.

Applications of Polymer Foams

- Characteristic properties of polymer foams, and the ability to control elastic behavior by selection of base polymer, make these materials suitable for certain applications
- Applications: hot beverage cups, heat insulating structural materials, cores for structural panels, packaging materials, cushion materials for furniture and bedding, padding for automobile dashboards, and products requiring buoyancy

Occupational Health and Safety

- Physical Hazards
- Chemical Hazards

Physical Hazards

- Use of electrical switch off systems and mechanical brakes to stop blade rotation when workers are in close proximity to the revolving parts / blades;
  ใช้ระบบปิดหรือกลไกหยุดอัตโนมัติ เมื่อมีพนักงานเข้าใกล้บริเวณที่อาจจะเกิดอันตรายได้
- Installation of emergency stop switches within reach of operating stations;
  ติดตั้งปุ่มหยุดฉุกเฉินไว้ในบริเวณที่ผู้ปฏิบัติงานสามารถเอื้อมถึงได้สะดวก
- Use of guards to prevent access to material feed openings and discharge points near rotors, cutters, blades and screws / rams. To facilitate maintenance
  ใช้อุปกรณ์ป้องกันไม่ให้พลาสติดเข้าไปติดในแกนหมุน เครื่องตัด ใบมีด และสกรู เพื่อป้องกันการหยุดของเครื่องจักรและไม่เสียเวลาในการซ่อมแซม

Physical Hazards

- Interlocks may be used to prevent access at granulators, agglomerators, and extruders;
  อาจจะใช้ระบบนิรภัยเพื่อป้องกันไม่ให้เข้าถึงเครื่องมือที่อาจจะก่อให้เกิดอันตรายต่าง ๆ
- Use of screens or flaps to protect against material flying out from machinery feed openings;
  ใช้ตาข่ายหรือฝาช่องปิดเปิดเพื่อป้องกันไม่ให้เม็ดพลาสติกกระเด็นออกมาก
- Use of Lock Out – Tag Out procedures, in addition to other guidance on the prevention and control of physical hazards
  ใช้การปิดป้ายเตือน บอกย้ำบ่อย ๆ เพิ่มเติมกับการป้องกันและควบคุมอันตรายทางกายภาพอื่น ๆ

Chemical Hazards

- Particulate matter
- VOCs
- Polymeric Dust
- Pentane
- Air quality and Dermal Exposure

Prevention and Control of Particulate Matter Emission

- Optimize processing conditions for handling and mixing of dry additives, temperature, and polymer granulation;

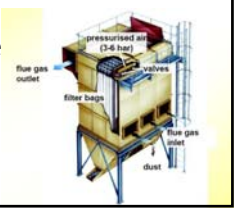
  เลือกปัจจัยการผลิตที่เหมาะสมสำหรับการลำเลียงและการผสมของสารเติมแต่งกับพลาสติก

- Filter air exhaust from material handling and granulation areas using a cyclone and / or baghouse;

  กรองอากาศ กำจัดละอองฝุ่นจากการบริเวณที่มีการเผลิตโดยใช้เครื่องเก็บฝุ่น

- Capture and control fugitive emissions from production de

  ควบคุมละอองฝุ่นที่เล็ดลอดจากขบวนการผลิต



Volatile Organic Compounds (VOCs)
สารประกอบจำพวกไอระเหย

- Use of enclosed storage for all solvent and cleaning fluids, and for all low boiling point reagents;

  สารละลาย, สารเคมีทำความสะอาดต่าง ๆ และสารไอระเหยต่าง ๆ ควรบรรจุในภาชนะที่ปิดมิดชิด
- Installation of ventilation control systems, especially at the points of highest processing temperatures along the production line;

  ติดตั้งระบบระบายอากาศ โดยเฉพาะบริเวณที่ร้อนที่สุดในสายการผลิต
- Installation of local exhaust extraction systems and **activated carbon adsorbers (**ระบบกำจัดสารไอระเหย**)**;

  ติดตั้งระบบกำจัดสารไอระเหย
- Development and implementation of a Solvent Management Plan.

  พัฒนาและมีการวางแผนจัดการระบบสารละลายในโรงงาน

Polymer Dust

- Facilities should be designed to avoid or minimize the creation of surfaces onto which polymer dust can settle or stick (e.g. due to electrostatic forces);

  ควรออกแบบให้มีสะสมและการเกาะติดของผงฝุ่นให้น้อยที่สุด
- Dust formation should be minimized through proper maintenance of cutter knives and settings;

  พยามลดหรือให้มีการเกิดฝุ่นน้อยที่สุด
- Sources of ignition should be eliminated. Metal parts should be grounded to reduce sparks formation due to static electricity. The use of open flames and smoking should be forbidden. A magnetic separator should be installed to reduce the risk of metals pieces entering the granulator.

  กำจัดแหล่งที่ก่อให้เกิดเชื้อเพลิง เช่น ชิ้นส่วนโลหะควรที่จะทำต่อสายดินเพื่อลดการติดไฟอันเนื่องมาจากไฟฟ้าสถิต, ห้ามสูบบุหรี่, ติดตั้งแม่เหล็กเพื่อดูดเอาโลหะไม่ให้หลุดเข้าไปในเครื่องจักร เพื่อลดการเสียดสีจนเกิดประกายไฟ

Pentane

Raw expandable polystyrene (**EPS**) bead typically contains pentane, an extremely flammable gas. **Pentane** is released during storage and transportation of EPS and also from finished products for a short time after manufacture.

Pentane เป็นกาซที่ลุกติดไฟได้ง่าย

Control and Prevent of Pentane

- A work permit system should be established in areas where EPS is stored;
  แยกบริเวณสำหรับเก็บ **EPS** โดยเฉพาะ
- Smoking should be prohibited anywhere EPS bead is manufactured, used, or stored;
  ห้ามสูบบุหรี่บริเวณที่ใกล้กับบริเวณที่มี **EPS**
- During pre-expansion, pentane vapor is mixed with steam which reduces its flammability. Pentane / steam vapor should be vented;
  ระหว่างที่มีการผลิต **EPS** ควรที่จะฉีดไอน้ำเพื่อเจือจางไอของเพนแทนลดความสามารถในการติดไฟ และไอของเพนแทนควรจะระบายออกนอกตัวอาคาร

Control and Prevent of Pentane

- Conveying ducts should be grounded, and product conveyed at slow speeds, to minimize static electricity generation;
  เครื่องกำจัดฝุ่นของ EPS ควรที่จะต่อสายดิน และเคลื่อนย้ายด้วยความเร็วต่ำเพื่อป้องกันการเกิดไฟฟ้าสถิตย์

- Expandable beads and pre-forms should be stored in a well-ventilated area. In the maturing silos, explosive mixtures may be generated in the head space. Silos should be grounded and ventilated to keep levels of pentane below the lower explosive limit. Finished goods should also be kept in a ventilated and fire proof place after molding;
  EPS ควรเก็บในที่มีการระบายอากาศอย่างดี และในถังผสม มีโอกาสที่จะเกิดการระเบิดได้ ควรติดตั้งสายดินและลดการสะสมของเพนเทนเพื่อป้องกันการระเบิด และ ผลิตภัณฑ์ที่ขึ้นรูปเสร็จแล้ว ควรเก็บในที่ที่ระบายอากาศได้ดี และบริเวณที่ป้องกันการติดไฟ

Air quality and Dermal Exposure

- Isolation (e.g. isolated storage, separate process areas, enclosures, closed systems) and local exhaust ventilation should be adopted as the primary engineering controls in plastics and rubber manufacturing processes. Controls should be implemented in compounding and mixing areas; แยกบริเวณการทำงานว่าส่วนใดต้องเป็นระบบเปิด หรือระบบปิดอย่างชั ดเจน การระบายอากาศต้องให้ความสำคัญมากในขบวนการผลิตพลาสติก
- Adequate ventilation control systems and exhaust extraction with activated carbon absorbers should be installed to prevent operator exposure to toxics, dusts and fibers. Adequate ventilation should be provided and should not be less than six air changes per hour; ควรมีระบบระบายอากาศอย่างเพียงพอ เพื่อป้องกันอันตรายจากกาซพิษ ผงฝุ่น และไฟเบอร์ต่าง ๆ และควรทำการระบายบ่อยๆ เพื่อถ่ายเทอากาศที่มีพิษออกจากอาคาร
- The residence time and processing temperature of used polymer formulation in the barrel should be set to minimize plastics overheating and prevent fume generation; ป้องกันการเกิดความร้อนเกินขนาดในระหว่างการผลิตเพื่อลดการติดไฟ

Air quality and Dermal Exposure

- Temperatures should be monitored and controlled in all sections of the production line. Adequate and reliable thermocouples should be installed to verify that the material is processed at the correct temperatures. ควรมีการตรวจสอบและควบคุมอุณหภูมิทุกส่วนของสายการผลิต และใช้เครื่องมือตรวจสอบที่จะเชื่อถือได้
- Proportional-Differential-Integral controllers or PC controlled heating systems are recommended to minimize the cycling thermal fluctuation responsible for production instabilities and release of fumes. ระบบควบคุมความร้อนควรแยกเป็นส่วน ๆ เพื่อลดความแปรปรวนเนื่องจากความแตกต่างของอุณหภูมิในกระบวนการผลิต ความไม่เสถียรของระบบ จนอาจจะเกิดไฟไหม้ได้
- Gloves, protective clothing, eye protection, and other relevant PPE should be worn, especially when working with resins, curing agents, and solvents; ควรมีการใช้อุปกรณ์ป้องกันอันตรายส่วนบุคคล

Air quality and Dermal Exposure

- Proper selection, use, maintenance, and cleaning of PPE. Provision of adequate gloves is especially important due to permeation characteristics of industrial chemicals; อุปกรณ์ป้องกันอันตรายส่วนบุคคลควรเลือกอย่างเหมาะสมกับประเภทของงาน โดยเฉพาะที่ใช้กับสารเคมีที่อันตรายมาก ๆ
- Respirators should be used where airborne solvent and dust levels are potentially high (e.g. during resin mixing, and finishing / repair activities), where large surface areas and significant hand work are involved, where exotherms are experienced, and whenever polyurethane-based materials are produced or handled at temperatures that might degrade the polymer; ควรใช้เครื่องช่วยหายใจ เมื่ออยู่ในบริเวณที่มีสารระเหยหรือฝุ่นบริมาณมาก ๆ
- Operators should be provided with Material Safety Data Sheet (MSDS) from the supplier / distributor for the particular formulation used. พนักงานควรที่จะได้รับข้อมูลของสารเคมีที่เกี่ยวข้องอย่างละเอียด

- **White gold** is an alloy of gold and at least one white metal, usually nickel , Rhodium , or palladium. Rhodium is a metal very similar to platinum and Rhodium shares many of the properties of platinum including its white color.

- **Platinum** is a white metal, but unlike gold. it is used in jewelry in almost its pure form (approximately 95% pure). Platinum is extremely long wearing and is very white, so it does not need to be Rhodium plated like white gold. Platinum is very dense (heavy), so a platinum ring will feel heavier than an 18kt gold ring.