

# Thermosetting Technology: processing of thermosettings

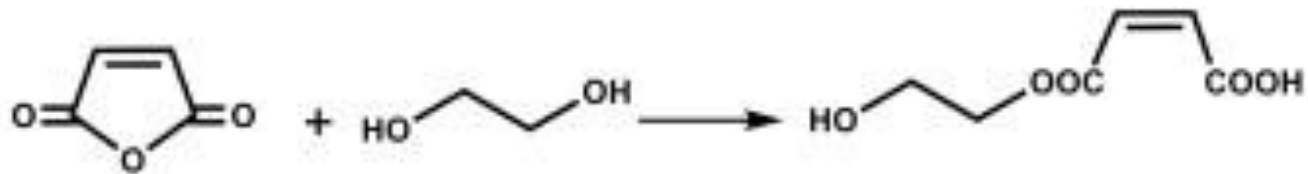
- **Thermoset products** are good **electrical** and **thermal insulators**, and **this property** makes them ideal for electrical and electronic applications.
- They are resistant to corrosion and have high impact strength, depending on the resin, and are cost competitive with engineered thermoplastics.
- **Thermoset molding** is an irreversible molding process that forces thermosetting polymers into a heated mold and forms into their final shape.

### **Remember!!!**

Thermoplastics are transparent/colorless when they are produced, thus their coloring is performed during the shaping in the instrument.  
However, it is difficult to dye a thermosetting polymer during shaping unless it is colored.

- In general, the thermosetting polymers are in the forms of viscous liquid (unsaturated polyesters), granules, and powders.
- Most of the thermoset polymers are prepared to the shaping by mixing the *low molecular weighed-prepolymers* with the crosslinkers and other additive materials. This mixture is called **resin**.
- The resin is hardened by the transformation to the cross-linked structure, during the molding.

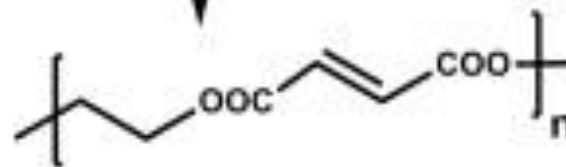
- The thermosets, such as phenolic/vinyl esters/allyl/amine resins can be hardened through heating. These thermosets are taken to the molding in the form of granules or powder. The polymer first softens in the mold with the heat effect and dispersed to the mold space via pressure. The hardening of the polymer occurs through the cross-linking reactions.
- The polyurethane thermosetting polymers are hardened differently. During the reaction between the polyols and diisocyanates (the entries of polyurethanes), the polyurethanes transform to the cross-linked structures. These reactants are preserved in the different cans, and both the polymerization and crosslinking reactions take place at the same time.



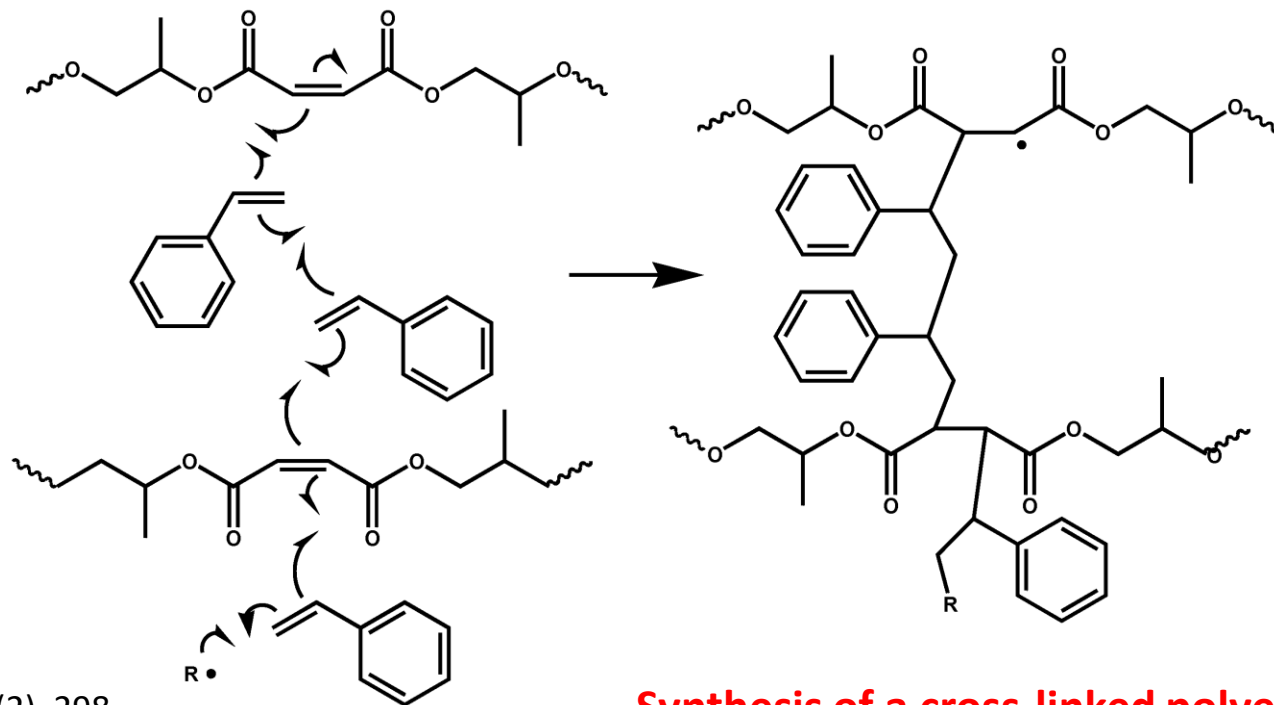
**Maleic anhydride**

**Ethylene glycol**

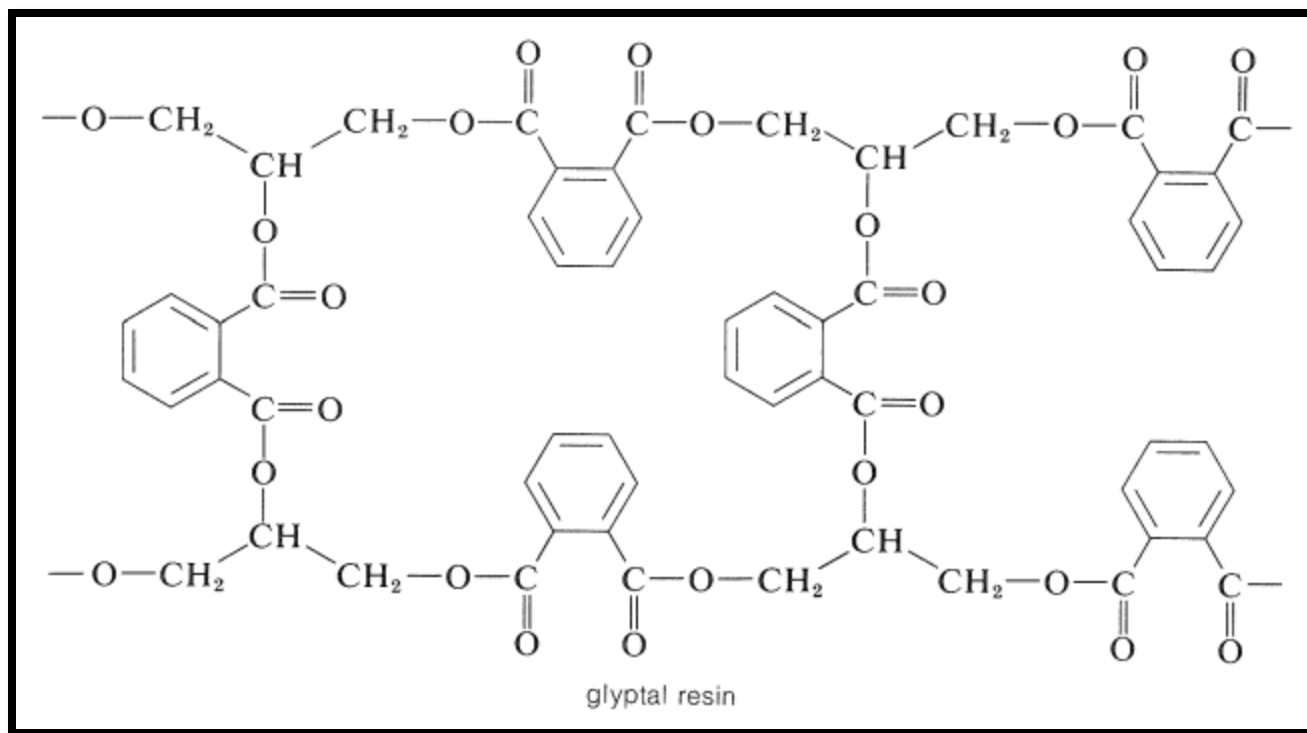
4 h  
 $\text{H}_3\text{BO}_3 + \text{Pyridine}$   
 (Mild catalyst)

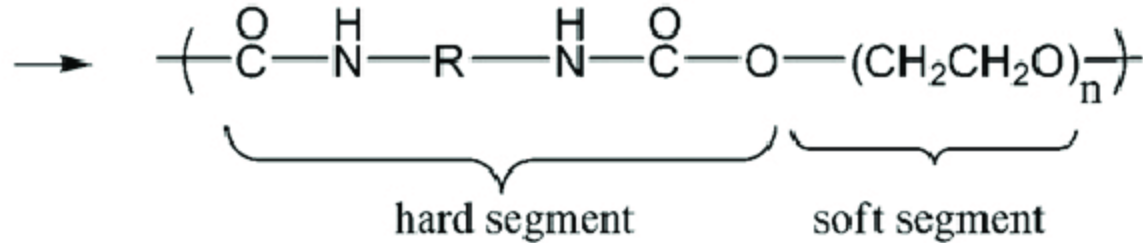
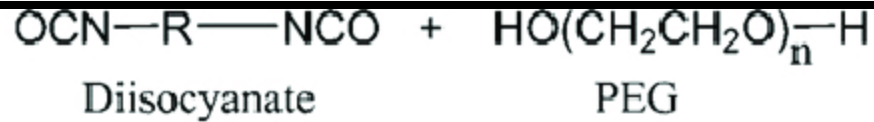


**Synthesis of an unsaturated polyester**



**Synthesis of a cross-linked polyester**





Diisocyanate: hexamethylene diisocyanate, isophorone diisocyanate, and toluene diisocyanate

PEG: Poly(ethylene glycol) ( $M_n$ : 1000 g/mol, 6000 g/mol, and 10000 g/mol)

## Synthesis of a polyurethane

Thermosetting polymers are shaped by;

- Compression molding,
- Transfer molding,
- Injection molding,
- Cast molding.



## Compression Molding

- Compression molding is a method of molding in which the molding material, generally preheated, is first placed in an open, heated mold cavity (female) or form (male) using a two-part mold system.
- Compression molding is an old and common method of molding [thermoset](#) . It now processes thermoset plastics as well as other plastics such as [thermoplastics](#), [elastomers](#), and natural rubbers.
- By this method, plastic raw materials are converted into finished [products](#) [by](#) simply compressing them into the desired shapes by using molds, heat, and pressure.
- Compression molding employs a mold of matched male and female heated platen dies.
- The lower platen contains a recess for the plate or sheet that is charged with resin powder or granules. The platens are then pressed together and heated to consolidate the resin.

## Advantages :

1. Low tooling costs and simple use.
2. Little material is wasted. since there are usually no sprues or runners.
3. TSs are not subject to retaining internal stresses after being cured.
4. Mechanical properties remain high.

## Limitations of the method :

1. Fine pins, blades, and inserts in the cavity can become damaged as the press closes when cold material is used in the cavities.
2. Complex shapes may not fill out as easily.
3. Extremely thick and heavy parts will cure more slowly than in transfer or injection molding, but preheating preforms or powder can shorten these cures.
4. Thermosets with their low viscosity will produce flash during their cure that has to be removed.



PEEK polymer compression molding. Photo shows a 20 ton Compression Molding Press (Rondol Kompres 20T).

<https://www.sciencedirect.com/topics/materials-science/compression-molding>

## Example of applications for compression molded thermoset plastics

Material	Performance	Application
Phenol-formaldehyde		
General-purpose Electrical grade Heat resistant Impact resistant	Durable, lowcost High dielectric strength Low heat distortion Strong	Small housings Circuit breakers Stove knobs Appliance handles
Urea formaldehyde	Color stable	Kitchen appliances
Melamine formaldehyde	Hard surface	Plastic dinnerware
Alkyd	Arc resistant	Electrical switchgear
Polyester	Arc resistant	Electrical switchgear
Diallyl phthalate	High dielectric strength	Multipin connectors
Epoxy	Soft flowing	Encapsulating electronic components
Silicone	Heat resistant	Encapsulating electronic components

# Transfer molding

- ❖ Transfer molding process is similar to the compression molding.
- ❖ In both of the methods, a polymer sample present in a closed mold is hardened by the help of heat and pressure.
- ❖ The difference from the compression molding is the style of the placement of the polymer into the mold.
- ❖ Here, the polymer sample is placed into the mold by the application of the pressure via a channel.
- ❖ This prevents the damaging the molds under high pressure.



transfer molding.mp4

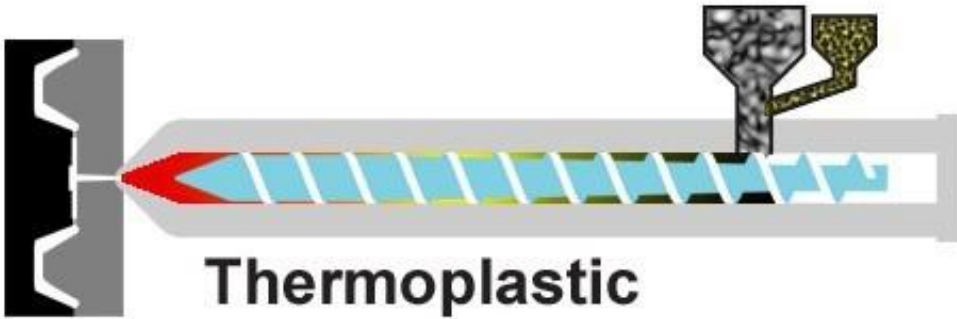
[https://www.youtube.com/watch?v=wCMUCFXA\\_Vo](https://www.youtube.com/watch?v=wCMUCFXA_Vo)

## thermoset injection molding

In **thermoset injection molding**, cold material is injected into an extremely hot mold to create a part. This process cures the part so it can never be melted again.

The differences between thermoplastic and thermoset injection molding can be listed below:

- The ribbon temperature is relatively high for thermoplastic injection. However, the temperature is kept at a moderate value to decrease the possibility of pre-crosslinking reactions .
- For thermoplastics, the polymer is injected to the mold when the mold is cooled. However, in thermosetting, the polymer is kept in a preheated mold.
- No colorant is used for thermosetting.
- For thermoplastics, the tooth height of the screws are gradually increased near to the mold. For thermosetting, the height is almost stable in every section of the screw.



Mold is cooled

## Thermoplastic

Screw root is tapered

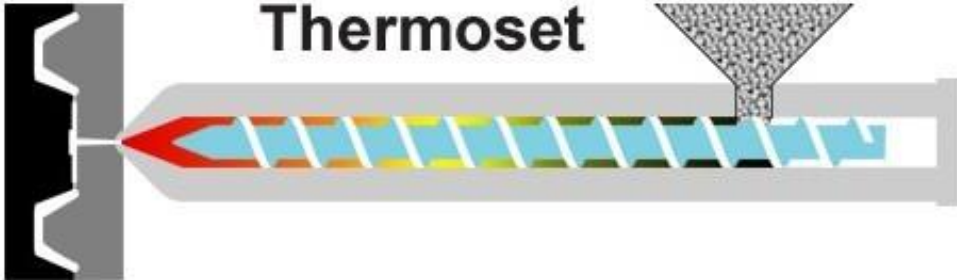
Two hoppers (resin & colorant)

Mold is heated

## Thermoset

Screw root is straight

One hopper (just resin)



# Pouring/casting

- The simplest method for the production of polymeric products.
- Here, the liquid thermosetting polymer and/or initiator added monomer mixture are added into the mold.
- After the crosslinking/polymerization reactions, a product that takes the mold's shape is removed.
- With this method, unsaturated polyesters, acrylics, polyurethanes, and silicone resins can be produced.