Semester -5

CAFP

Lecture – I & II

Processing Aids

FILLERS: Fillers are mainly used for cost reduction the important advantage of using fillers in plastic industry is that they increase the rigidity, decrease in flex resistance, increased hardness and density of compound. Fillers can be classified as functional or non-functional fillers. The functional fillers effect the properties such as hardness, rigidity and specific gravity of the compound.Whereas non- functional fillers donot affect the properties but only help in cost reduction by increasing the weight of polymer. Fillers can further be classified as particulate filler which can be reinforcing or non –reinforcing particulate fillers generally effect the properties of final plastic for example:

If the plasticizers are added in the formulation then they will improve the flexibility where as the fillers like china clay, Talc and barium sulphate are non – reinforcing or inert fillers. They only affect the density of compounded material. The inert fillers in case of plasticized PVC reduced the die swell and increased. The hardness while reducing the cost of the material.

fillers also be classified on the basis of their origin and chemical structure such as natural and synthetic fillers or organic or non-organic fillers are mostly used in thermosetting resin such as phenols, urea and melamine formaldehyde. The basic purpose of adding fillers in thermosetting resin is to improve the heat resistance as well as the weight of the compound filler generally added 10 to 50 of total weight of the mixture some of the considerations of selecting filler are:

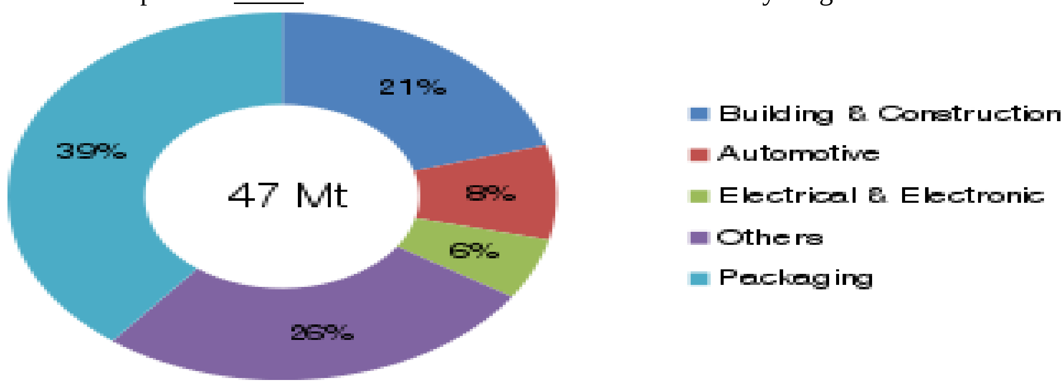
1. The cost availability and uniformity of filler.
2. Compatibility of filler with polymer resin.
3. Moisture absorption should be less.
4. Thermal stability to the mold temperature is also important for selecting a filler.
5. Resistance to chemicals.
6. Effect on the flow properties of plastic resin.
7. Abrasiveness of the filler.

One of the most widely used fillers used in thermosetting plastics is wood flour. It is finally ground powder which can be used with DMC (Dough molding compound) can be used for reducing the cost , without increasing the weight, increasing the strength and easily wetted by the polymer resin but the main disadvantage of this filler is that it absorb moisture and generally show poor electrical characteristics .

Note – Example of fillers- Mica – dust, $CaCo_3$, Silica , Metal dust , Talc , Clay , Barium sulphate .

Mineral filler can be used such as metal dust inorganic materials like different types of rocks can be used as non – expensive mineral filler which can be important color and hardness to the plastic material similarly , the pure form of silica such as quartz can also be used for improving the heat and electrical properties of the compound while at the same time the rigidity and strength will also improve but it may induced the brittleness in the structure .

Filler materials are particles added to resin or binders (plastics, composites, concrete) that can improve specific properties, make the product cheaper, or a mixture of both. The two largest segments for filler material use is elastomers and plastics. Worldwide, large applications where fillers are used are paper, plastics, rubber, paints, coatings, adhesives, and sealants. As such, fillers, produced by more than 700 companies, rank among the world's major raw materials and are contained in a variety of goods for daily consumer needs. The top filler materials used are ground calcium carbonate (GCC), precipitated calcium carbonate (PCC), kaolin, talc, and carbon black. Filler materials can affect the tensile strength, toughness, heat resistance, color, clarity etc. A good example of this is the addition of talc to polypropylene. Most of the filler materials used in plastics are mineral or glass-based filler materials. Particulates and fibers are the main subgroups of filler materials. Particulates are small particles of filler which are mixed in the matrix where size and aspect ratio are important. Fibers are small circular strands that can be very long and have



Calcium carbonate ($CaCO_3$)

Calcium carbonate is derived from limestone and marble. It is used in many applications including PVC's and unsaturated polyesters. As much as 90% $CaCO_3$ can be used to make a composite. These additions can improve molding productivity by decreasing cooling rate. They can also increase operating temperatures of materials and provide insulation for electrical wiring.

CaCO3 is used in filler masterbatch as a base with large percentage in composition. Calcium carbonate powder accounts for 97% of composition will bring for white/opaque products more whiteness. So, manufacturers can reduce the usage of white masterbatch. With smaller percent, calcium carbonate powder can be used for color products. In addition, it brings for final plastic products brighter and glossier surface.

Magnesium hydroxide (talc)

Talc, a soft mineral and generally more expensive than calcium carbonate. It is derived from layering sheets of magnesium hydroxide with silica. In the plastic industry it is used for packaging and food application due to its long-term thermal stability

Block of talc.

Glass

Glass filler materials come in a few diverse forms: glass beads, short glass fibers, long glass fibers. in plastics by tonnage. Glass fibers are used to increase the mechanical properties of the thermoplastic or thermoset such as flexural modulus and tensile strength, There is normally not an economic benefit for adding glass as a filler material. Some disadvantages of having glass in the matrix is low surface quality, very viscous when melted, low weldability and warpage. The addition of glass beads will help with oil absorption and chemical resistance.

Plasticizers (softners or chain extenders): plasticizers are generally added in the formulation to improve the flexibility resistance and melt flow properties of polymer plasticizer generally extends the chain of polymer therefore also referred to as extender depending on the capability of the resin the plasticizer may be classified as primary plasticizer are highly compatible with different types of resin where as the secondary plasticizer are less compatible therefore they are added in combination with primary plasticizer secondary plasticizer quantities can be used in small in plasticizer) The plasticizer are also referred to as softer or chain extenders because they have flexibility by extended the chain polymer . Plasticizer can be different type of plasticizers are polymeric plasticizers, phosphate plasticizer, some vegetables oil and wax also etc. following **characteristics must by taken into concentration while**

1. The materials should have molecular weight at least of 300.
2. It should be easily soluble.
3. The polymer must have suitable interaction with plasticizer for bond formulation.
4. It should not be crystalline solid at room temperature.

(Nearly 50% of plasticizer are mainly used in PVC formulation other then is they are also often in cellulose, nylon, ABS, Polystyrene etc.)

Plasticizers are mainly classified into different types.

1. ***Phthalates:***
   DOP (Di – octyl phthalate)
   DIOP (Di – Isooctyl phthalate)
   DINP (Di – Iso nonyl phthalate)
   The generally exhibit high volatility, poor external surface resistance, phthalate are the compound which can be mostly used for low temperature performance and mostly in PVC formulation.
2. ***Phosphate plasticizer***: Used in plastic Industry are tri-aryl phosphate, tri-alkyl phosphate generally offer excellent flame resistance and very good high frequency PVC welding characteristics. They are mostly good compatibility with PVC extrusion these can be used for high temperature application.
3. ***Tri – militates:*** These are the (TMTD,TMTM) based plasticizer such as TMTM or TMTD. These are mostly used in rubber industry because they are characterized by excellent Antioxidant properties as well as very good resistance to most of the solution.
4. ***Polymeric / epoxy plasticizer :*** The majority of polymers such as saturated polyester and different monomers unit can be used as plasticizer because these monomer unit can also extends the chains of polymer, which result in softening of final product. **The addition of monomer unit generally result in improve performance and lowers the volatility of compound. They generally improve the abrasion resistance, traction properties of the compound**. It consists of epoxy plasticizer epoxy is a three membered ring chain structure which consist of two carbon and one oxygen in their chain the epoxy plasticizer can be used in combination with different type of acid to improve plasticizing rate of molten plastic materials and also improve the stability of compound. It can be used for high viscosity and cry stability of the compound.
5. ***Chlorinated paraffin's***: Chlorinated paraffin's are the wax compound which can be used a cheap secondary plasticizer which lower the cost without effecting the property of compound.

1. Polymeric plasticizer are generally added to improve heat, light., Abrasion resistance
2. Phosphate plasticizer shows the high flame resistance but poor heat and light stability.
3. Polyester and trimellitate are used for durability but show low temperature properties.
4. Aliphatic di – esters show good low temperature flexibility.

Lecture -3

Anti- ageing additives: These are the additives which improves the service life of plastic material. They prevent the attack of sunlight,humidity,fungus, bacteria and microbial action.Anti- ageing additives prevents the degradation of material from all these phenomena like UV light, oxidation attack, fungus and microbial attack. Some of the commonly used ant ageing additives are:

1) Antioxidants
2) Antiozonants
3) UV stabilizers
4) Anti- microbials (micro- organisms)(fungus, bacteria and termites))

1) Antioxidants:It is well known that plastics are easily attacked by small quantity of oxygen present in the atmosphere. This effect can be readily seen in case of rubber material. An oxygen molecule can be easily attacking the carbon atom present in the rubber hydrocarbon which can leads to the formation of free – radical as shown in radical below:

The thermo-oxidative degradation of polyolefins and many other plastics is usually an auto-accelerated process, that is, the rate of oxidation is low or negligible in the beginning but steadily increases and often reaches a constant rate of oxidation.

Like ordinary chain reactions, the overall oxidation process can be divided into three stages, called initiation, propagation, and termination of degradation. The first stage, the so-called initiation, is the formation of free radicals via C-C and/or C-H bond cleavage which may be induced by heat, UV light, mechanical stress or by trace amounts of initiators such as peroxides and/or hydroperoxides.

$$R{-}H \rightarrow R\cdot + H\cdot$$

$$R{-}R \rightarrow R\cdot + R\cdot$$

Alkyl radicals can undergo a number of "chain" reactions. Propagation or decomposition usually starts when (atmospheric) oxygen reacts with the newly formed free chain radicals R·. This reaction produces highly reactive peroxy radicals ROO· which then react with hydrogen of polymer chains to form more free radicals R· and hydro peroxides ROOH.

$$R\cdot + \cdot O\text{-}O\cdot \rightarrow ROO\cdot$$

$$ROO\cdot + RH \rightarrow R\cdot + ROOH$$

The second reaction involves breaking C-H bonds which requires considerable energy unless the polymer contains reactive hydrogen. Thus, this reaction is often the rate determining step.

The ROOH can decompose via homolytic cleavage to alkoxy and hydroxy radicals which, in turn, also abstract free hydrogen from polymers which leads to the formation of even more free chain radicals.

$$ROOH \rightarrow RO\cdot + \cdot OH$$

$$RO\cdot + RH \rightarrow R\cdot + ROH$$

$$\cdot OH + RH \rightarrow R\cdot + H2O$$

However, the cleavage of an O-O bond has a rather high activation energy. For example, the dissociation energy of hydroperoxide is in the range of 200 kJ /mol. For this reason, a bimolecular decomposition mechanism with lower activation energy is more likely to occur.

$$ROOH + RH \rightarrow RO\cdot + R\cdot + H2O$$

The autocatalytic decomposition reactions are usually very fast when compared to (heat induced) initiation reactions (C-C bond cleavage). Since the concentration of hydroperoxide is very low at the beginning of an autooxidation process, the rate of decomposition is very low but steadily increases until the hydroperoxide concentration reaches a steady state which means the rate of peroxide decomposition is equal to that of formation.

Unsaturated polymers such as polyisoprene and polybutadiene are most susceptible to metal-catalyzed oxidation because double bonds markedly decrease the activation energy of oxidation reactions. Branching and crystallinity also affect the thermo-oxidative stability of a plastic. In general, polymers with high crystallinity and no branching are more stable than amorphous polymer of low density and low crystallinity such as low-density polyethylene. The general order of stability is

HDPE > LLDPE > LDPE> PP > PS> Poly isoprene

To prevent or at least to slow down oxidative chain reactions, antioxidants are usually added. Typically, a combination of sterically hindered phenols and organic phosphites are added. The phosphites decompose the hydroperoxides into harmless inert products and the hindered phenols scavenge the free radicals.

The oxidation reactions stop when either two radicals recombine (dimerization or cross-linking) or when a chain radical abstracts a hydrogen from another polymer chain (disproportionation / hydrogen abstraction). These reactions always occur but can be accelerated by addition of stabilizers. Recombination of two chain radicals results in an increase of the molecular weight and cross-linking density:

$$R\cdot + R\cdot \rightarrow R{-}R$$

$$2\ ROO\cdot \rightarrow ROOR + O2$$

$$RO\cdot + RO\cdot \rightarrow ROOR$$

$$R\cdot + RO\cdot \rightarrow ROR$$

$$HO\cdot + ROO\cdot \rightarrow ROH + O2$$

These reaction cause embrittlement and cracking of the plastic. Termination by chain scission, on the other hand, decrease the molecular weight and thus, softens the plastic.

This presence of oxygen can lead to the autoxidation phenomena in polymers. The mechanism for oxygen attack is given above.

This reaction is an autocatalytic process in which hydroperoxide formed as a primary product of reaction decomposition and free – radical can further generate the new reaction with other hydrocarbon forming a hard and brittle structure which is a common cause of plastic product failure.

Antioxidants are generally used to protect the material from oxidation caused by heat, light and chemically induced mechanisms. The brittleness, loss of tensile property, melt flow, instability and discoloration of plastics.

There are three main preventive mechanisms to control the effects onpolymers:

1) Deactivating the formation of free radical in the reaction.
2) Decomposing the formation of hydroperoxide into non-radical products. All these mechanisms will prevent the attack of oxygen on plastics.

Primary antioxidants (radical scavengers)

Primary antioxidants (also known as chain-breaking antioxidants) act as radical scavengers and remove peroxy radicals (ROO•), as well as to a lesser extent alkoxy radicals (RO•), hydroxyl radicals (HO•) and alkyl radials (R•). Oxidation begins with the formation of alkyl radials, which are formed when the high temperatures and high shear stress experienced during processing snaps the polymer chains in a homolytic manner. These alkyl radicals react very rapidly with molecular oxygen to give peroxy radicals, which in turn abstract hydrogen from a fresh section of polymer in a chain propagation step to give new alkyl radials. The overall process is exceedingly complex and will vary between polymers but the first few steps are shown below in general:

$$R\text{-}R \rightarrow 2\ R\bullet$$

$$R\bullet + O2 \rightarrow ROO\bullet$$

$$ROO\bullet + RH \rightarrow ROOH + R\bullet$$

Due to its rapid reaction with oxygen the scavenging of the initial alkyl radical (R•) is difficult and can only be achieved using specialized antioxidants, the majority of primary antioxidants react instead with the longer lasting peroxy radicals (ROO•). Hydrogen abstraction is usually the rate determining step in the polymer degradation and the peroxy radicals can be scavenged by hydrogen donation from an alternative source, namely the primary antioxidant. This converts them into an organic hydroperoxide (ROOH). The most important commercial stabilizers for this are hindered phenols and secondary aromatic amines such as alkylated-diphenylamine. Amines are typically more effective, but cause pronounced discoloration, which is often undesirable (i.e., in food packaging, clothing). The overall reaction with phenols is shown below:

ROO• + phenol (ArOH) → ROOH + ArO•

ArO• → nonradical products (inert compound)

Secondary antioxidants (hydroperoxides scavengers)

Secondary antioxidants act to remove organic hydroperoxides (ROOH) formed by the action of primary antioxidants. Hydroperoxides are less reactive than radical species but can initiate fresh radical reactions:

ROOH + RH → RO• + R• + H_2O

As they are less chemically active, they require a more reactive antioxidant. The most commonly employed class are phosphites esters, often of hindered phenols e.g. Tri(2,4-di-tert-butylphenyl) phosphites. These will convert polymer hydroperoxides to alcohols, becoming oxidized to organophosphates in the process:

ROOH + $P(OR')_3$ → $OP(OR')_3$ + ROH

This exchange further stabilizes the polymer by releasing a primary antioxidant, because of this phosphites are sometimes considered as multi-functionalantioxidantsas they cancombine both types of activity. Organosulfur compounds are also efficient hydroperoxide decomposers, with thioethers being particularly effective against long-term thermal aging, they are ultimately oxidize up to sulfoxides and sulfones.

Some of the commonly used antioxidantsare:

a) Secondary amines($R-NH_2$)
b) Phenol bodies(R-OH)
c) Phosphites$(RO)_3P$

The most commonly used antioxidant is amine-basedantioxidant i.e. PBN (Phenyl B – Napthyl). It can be effectively used as an electron transferring agent which prevents autoxidation. The amine antioxidant additives which are used for better protection for discoloring or staining. The phosphates are mostly used as a stabilizer for SBR rubbers phenol antioxidants are less effective, but mostly used for non-discoloring and non-staining properties.

2) **Anti-ozonants :**These are the materials which prevents the degradation of plastics by the ozone (O_3)attack present in the atmosphere. The degradation of rubber and plastics products are faster with high concentration of ozone and can be seen when the stress applied on the plastics sample.Ozone has no visible effect,until the sample is untreatedbecause the brittle,**ozonide layer** is formed on the surface. But as soon as a little stress is applied, then it gives rise to the crack formation on the surface which grows in the direction perpendicular to the extension.The initiation of ozone crack is generally favored by high stress, high ozone concentration and high temperature conditions. To prevent this attack by ozone on the elastomeric different types of materials.**Petroleum waxes, secondary amines and quinoline are**

generally used as an antiozonants. The effect of ozone can be seen with the change in service life of plastics material. It may fade in color,stiff and brittle and begins to crack during their use. The ozone shows more harmful effect than oxygen.

Examples: ***p*-Phenylenediamines(p-PDA*),* *Ethylene di urea* *(EDU),Paraffin waxes*** that form a surface barrier.

Note: Thus Antiozonants are the organic compound that prevents or retards the degradation of material caused by ozone (ozone cracking).

3) **UV-stabilizers:Ultra- violetstabilizers: Every plastics material degraded in presence of sunlight in number of ways such as discoloration, loss of physical properties. The job of stabilizer is to protect plastic material against "Photo Degradation", i.e. it stabilizes the color and length of service life of the product which is exposed to ultraviolet light.**

Black in any form such as carbon black, paint black or dye black is most effective ultraviolet absorber, but it cannot be accepted for all the applications.Therefore, some other chemicals are also used for preparing plastic products of different color and shades.

The ultraviolet degradation is greatly caused by the ultraviolet light of wavelength in the range (315-400nm). The type of wavelength up to 315 nm is mostly absorbed by the atmosphere of earth. But the long wavelength in the **range 315-400nm** is escaped from the earth atmosphere which causes the severe damages to plastics products. The UV –absorber can be of three types:

1) ***Light screens:*** Light screen functions by absorbing the damaging radiations before it reaches to the plastic surface. These light screens can be in the form of powder such as carbon black, titanium – di – oxide which are used for the purpose of ultraviolet stabilizers.

2) ***Ultraviolet absorber:***Ultraviolet absorber are the material such **as hydroxybenzophenone,salicylicacid**chemicals are used to dispose the absorb energy by converting them into other forms like heat and chemical changes.***Benzotriazoles and hydroxyphenyl triazines*** are used to stabilize polycarbonates and acrylics, ***oxanilides*** are used for polyamides and polyurethanes, while ***benzophenones*** are used for PVC.

3) ***Quenching agents:*** These agents suppress the formation of active peroxide which are develop due to the energy gained by the molecules from ultraviolet light. These agents form a chemical complex which is commonly known as ***Hindered amine light stabilizers (HALS),***other than this **the chelating agents of nickel** can also be used as a quenching agent. Because they trap the free – radical and stops the further reaction which leads to the degradation of polymers.

Lecture – 4

Batch high-shear mixers

In a batch high-shear mixer, the components to be mixed (whether immiscible liquids or powder in liquid) are fed from the top into a mixing tank containing the mixer on a rotating shaft at the bottom of the tank. A batch high-shear mixer can process a **given volume** of material approximately twice as fast as an inline rotor–stator mixer of the same power rating; such mixers continue to be used where faster processing by volume is the major requirement, and space is not limited. When mixing sticky solutions, some of the product may be left in the tank, necessitating cleaning.

Inline high-shear mixers

In an inline high-shear rotor–stator mixer, the rotor–stator array is contained in housing with an inlet at one end and an outlet at the other, and the rotor driven through a seal. The components to be mixed are drawn through the generator array in a continuous stream, with the whole acting as a centrifugal pumping device. Inline high-shear mixers offer a more controlled mixing environment, take up less space, and can be used as part of a continuous process. Equilibrium mixing can be achieved by passing the product through the inline high-shear mixer more than once.

Two roll Mill:

Operation:

To produce the rubber used in tires, hoses, shoes and many other applications, the rubber first has to be created using a two roll rubber mill.

1.A rubber mill consists of two **horizontally opposed stainless steel rolls** that rotate in **opposite directions, at different speeds.**

2. The rolls rotate towards each other, one faster than the other. The distance between the two rolls can also be adjusted by the operator.

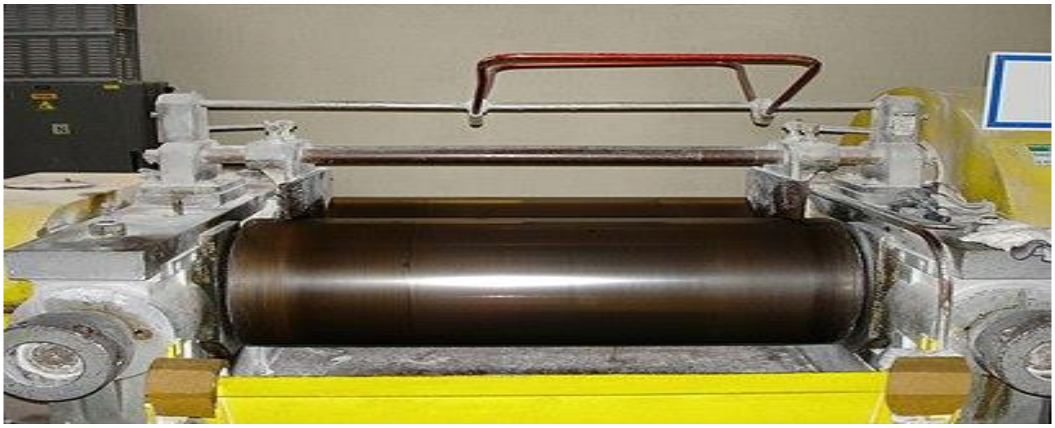
3. The opposing rotation directions and different speeds produces a combined shear and compression force on the material being mixed on the mill.

With open roll rubber mills, the operator may also be in charge of adding ingredients to the rubber while it is being mixed on the mill. Because chemical reactions are occurring during the process of mixing a rubber compound, the compound often heats up. To help keep the rubber compound cool, often one of the rolls is hollow and can be hooked up to a cooling water line which then allows cool water to flow through the roll, cooling the metal roll and therefore the rubber.

While the process of operating a rubber mill sounds simple enough, it is very dangerous and many precautions are added to ensure the safety of the operator. Operators and safety personnel must go through extensive training in order to be certified to operate a rubber mill. Because the two rolls of the mill are rolling inwards, it is easy for an individual's hand to get sucked into the mill. This not only crushes the hand, but if the individual quickly removes their hand, it can result in degloving.

Rubber compounding means incorporating rubber ingredients into a rubber mixture so it is evenly dispersed, then the rubber mixture is called a rubber compound. The mill aids in two main steps of rubber processing - **mastication and mixing**. Mastication is when the raw polymer is sheared and the broken down to create an easier flow. This allows for better incorporation of materials, which leads to the mixing component, when the other materials for a compound are added.

To create a rubber compound on a mill, first a raw polymer, or base polymer, is needed. The polymer can be a number of things, including natural rubber, such as of SMR CV, SMR 20, SMR L or a variety of synthetic rubbers such as nitrile(NBR) , ethylene propylene diene monomer (EPDM), butyl, polycholorprene (CR), Polyisoprene (IR) and others.



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Lecture -5

Internal Intensive Batch Mixer:

Internal batch mixers have been widely used in the production of vinyl film and sheeting since the introduction of these products. In fact, every large manufacturer of vinyl film and sheet uses internal mixers for dispersion and fluxing. High-speed operation, which is used extensively, results in overall cycles of 2 to 4 minutes. Internal mixers also are used for processing plastics such as vinyl's, polyolefins, ABS, and styrene, along with thermosets such as melamine's and urea's because they can hold materials at a constant temperature. Essentially, internal mixers consist of cylindrical chambers of shells within which materials to be mixed are deformed by rotating blades or rotors (Fig. A). In most cases ashell actually consists of two adjacent cylindrical shells with a rotor describing an arc concentric with each shell section. Because the rotor blade tips clear the cylindrical segment of the shell by a small amount, the blade motion causes the mixture to be sheared between the blade tip and the shell. The blades also interact between themselves to cause folding or "shuffling" of the mass. The shuffling is further improved by the helical arrangement of the blade along the axis of the rotor, thereby imparting motion to the mass in the third, or axial, direction. Frequently, the blade is divided into two helices of opposite direction of pitch in order to further the shuffling of components within the mixture. In some cases, the rotor blades are Z-shaped arms instead of elliptical. Still further variations are haben and fishtail blades.

The shell and rotor are cored or otherwise provided with means for heating or cooling for the purpose of controlling the batch temperature. The principle of internal batch mixing wasfirst introduced in 1916 with the development of the "**Banbury mixer"**. The mixer consists of a completely enclosed mixing chamber in which two spiral-shaped rotors operate, a hopper to receive the material for mixing, and a door for discharging the batch. Revolving in opposite directions and at slightly different speeds, the two rotors keep the stock in constant circulation. The ridge between the two cylindricalchamber sections help force mixing; and the acute convergence of the rotors and the chamber walls impart shearing. This combination of intensive working produces a highly homogeneous mix. The batch is confined within the sphere of mixing action by an air-operated ram in the feeding neck. The ram also greatly facilitates the flow between the blade tip and shell, where shearing is most extensive.

Cooling water or steam is circulated through the cored rotors and through a multiplicity of drilled holes in the mixing chamber liner to provide the optimum machine temperature. Internal mixers range in size from laboratory models with a capacity of about 2 pounds of mixture to models of approximately **100 to 150 pounds capacity**. Comparable power ranges are from **10 to 100 hp.** The thermoplastic mixture discharged from the internal mixer is usually in the form of large

shapeless lumps; it frequently is convenient to roll these lumps into sheets with a two-roll mill for eventual grinding or dicing, or to feed them directly into an extruder-pelletizer. Thus, a mill or extruder-pelletizer is placed beneath the internal mixer. However, they may also perform additional mixing and dispersing. More recently, mixers have been built with the capability of dewatering and devolatizing of a variety of plastics. **Slurries containing more than 70% moisture can be dewatered in 3 to 4 minutes**. Most of the liquid is drained or pumped out of the machine; the remainder is vaporized by heat produced by mechanical action of the stock and contact with the mixer’s heated working elements. Steam escapes through an exhaust system. Color and formula changes can be made easily in internal mixers because mixing chambers are self-cleaning. Thus, a variety of stocks of different color or formulas can be handled in succession. Many internal mixers in operation today are used for repeated changes of color in the same machine-from white to green, to gray, to red, to brown, to black, all in the course of one day. The same adaptability applies to formula changes.

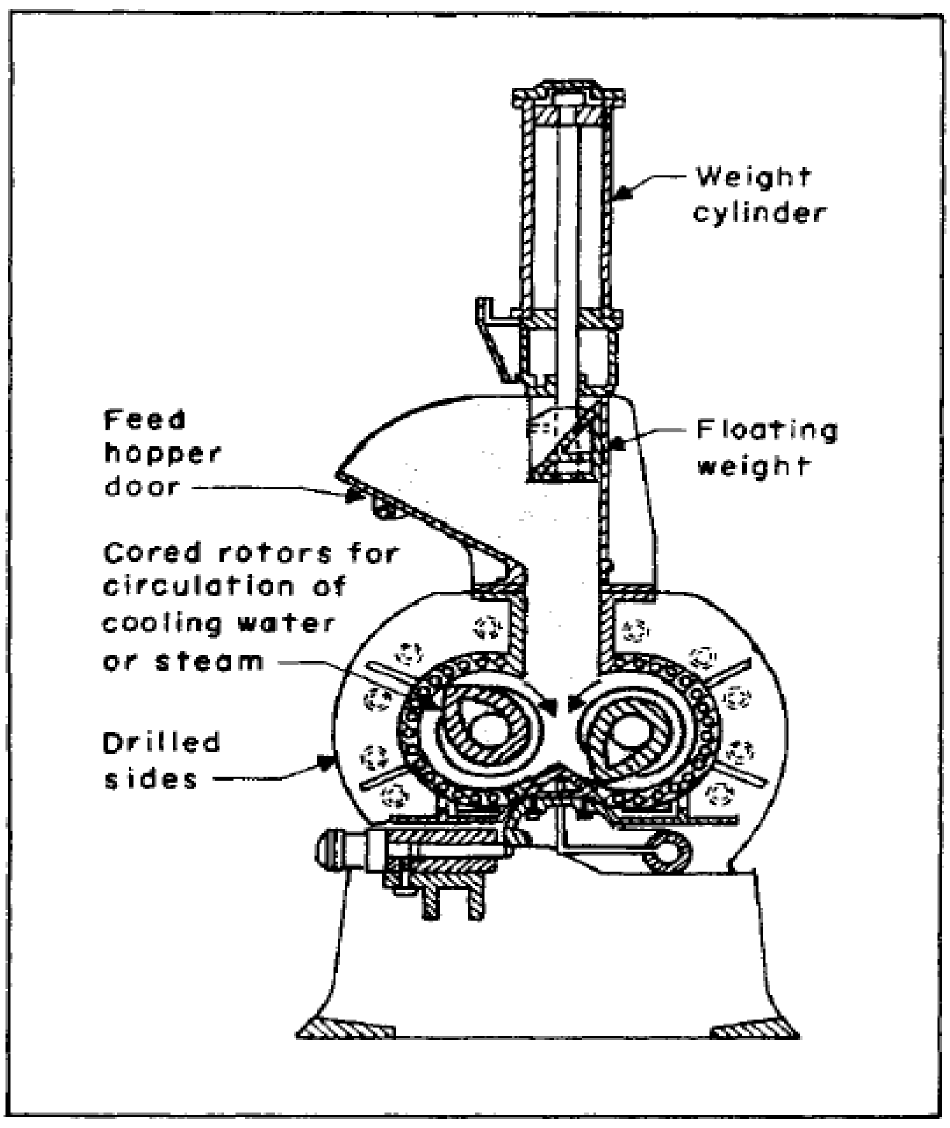


Fig. A. Rotors within cylindrical chambers deform material in the tight clearances between the rotor blade tips and the chamber walls. Rotated at fairly high speeds, the blades provide kneading, shearing, smearing, pulling, and compressing action. Cored rotors provide channels for cooling water or steam. The batch is held confined by a ram in the feeding neck.

DDM-I

Lecture -I

Mould Design

When designing a mold, there are several concept considerations that need to be taken into account. These considerations ensure that the mold will function effectively and produce high-quality parts. Here are some key concept considerations in mold design:

1. Part Design: The first consideration is the design of the part itself. The mold design should align with the part's shape, size, and features. It's crucial to analyze the part's draft angles, undercuts, and wall thickness to determine the type of mold required.

2. Material Selection: The choice of mold material is essential. Factors like the expected production volume, part material, and part complexity influence the selection. Common mold materials include steel and aluminum alloys, each with their own advantages and limitations.

3. Parting Line: The parting line is the line where the two halves of the mold separate to remove the molded part. It is important to identify an appropriate parting line that minimizes the complexity of the mold design and allows for smooth ejection of the part.

4. Gate Design: Gates are the entry points through which molten material is injected into the mold cavity. The gate design must ensure proper filling of the cavity, prevent air entrapment, and minimize part defects like weld lines or flow marks. Gate location, size, and type (e.g., sprue, edge, or tunnel gates) should be considered.

5. Cooling System: Efficient cooling is crucial for maintaining cycle times and ensuring consistent part quality. Proper cooling channel design should be implemented to control temperature distribution and promote uniform solidification of the part.

6. Ejection System: The ejection system is responsible for removing the molded part from the mold. It typically consists of ejector pins, slides, or lifters. The design should allow for smooth ejection without damaging the part or affecting its dimensional accuracy.

7. Venting: Proper venting is necessary to release trapped air or gases during the molding process. Insufficient venting can lead to defects like burning, gas traps, or incomplete filling. Vent placement and design should be carefully considered.

8. Moldability Analysis: Conducting moldability analysis using simulation software can help identify potential design issues before manufacturing. It allows for optimization of the mold design by evaluating factors such as fill pattern, weld lines, sink marks, and shrinkage.

9. Maintenance and Repair: Designing molds for ease of maintenance and repair is crucial for minimizing downtime and extending the mold's lifespan. Considerations include accessibility of components, ease of disassembly, and availability of spare parts.

10. Cost Optimization: Balancing the mold's performance and cost is essential. Optimize the design to minimize material usage, reduce cycle times, and improve productivity while maintaining the required quality standards.

Lecture -2

Materials used for moulds and dies-Dies and molds are often made from materials that can withstand the high temperatures, pressures, and abrasive forces involved in the manufacturing process. The choice of material depends on factors such as the type of manufacturing process, production volume, desired tool life, and budget. Here are some commonly used materials for dies and molds:

1. Tool Steel: Tool steels, such as P20 (P20 Mold Steel), H13 (H13 Tool Steel), and D2 (D2 Tool Steel), are widely used for molds and dies. They offer good toughness, wear resistance, and heat resistance. Tool steels are commonly used in injection molding, extrusion, and die casting applications.

2. Stainless Steel: Stainless steel, particularly 420 stainless steel, is used in molds and dies when corrosion resistance is required. It is often used for molding plastic parts, food processing, and certain forming applications.

3. Aluminum: Aluminum alloys, such as 6061 and 7075, are lightweight and offer good thermal conductivity. They are commonly used for low-volume production, prototype molds, and molds for casting non-ferrous metals.

4. Copper Alloys: Copper alloys, such as beryllium copper (BeCu), are known for their excellent thermal conductivity and high strength. They are often used for molds and dies that require rapid heat transfer, such as in plastic injection molding.

5. Cast Iron: Cast iron, especially ductile iron, is utilized for molds and dies in applications where high wear resistance is required. It is commonly used in metal casting processes, such as sand casting and permanent mold casting.

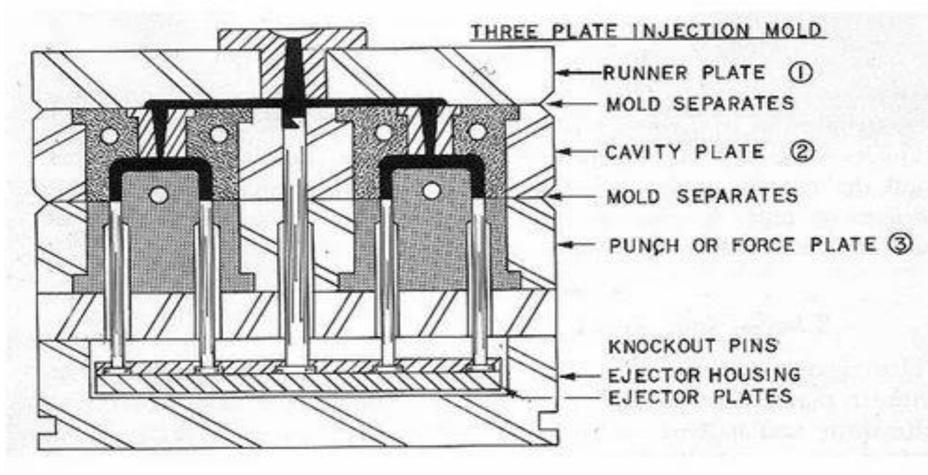
6. Carbide: Carbide materials, such as tungsten carbide, are extremely hard and wear-resistant. They are used for cutting dies, forming dies, and certain high-pressure applications.

Composite Materials: Composite materials, such as epoxy-based composites, are sometimes used for low-volume or prototype molds. They offer good dimensional stability, ease of machining,

Lecture – 3

Classification of Molds:

1. Integrated Molds:
    - Integrated molds are also known as "integral" or "single-piece" molds.
    - They consist of a single unit where the core and cavity are integrated into one solid mold.
    - Integrated molds are typically used for simple parts with no undercuts or complex features.
    - They are cost-effective and relatively easy to manufacture.
    - However, they are limited in their ability to produce complex parts.
2. Two-Plate Molds:
    - Two-plate molds are the most common type of molds used in injection molding.
    - They consist of two main plates: the cavity plate and the core plate.
    - The cavity plate forms the outer surface of the part, while the core plate forms the inner surface.
    - When the mold is closed, the cavity and core plates come together to form the mold cavity.
    - Two-plate molds are suitable for parts with simple to moderate complexity and can accommodate moderate undercuts.
    - They are relatively cost-effective and easy to maintain.
3. Three-Plate Molds:
    - Three-plate molds, as the name suggests, consist of three main plates: the cavity plate, core plate, and a third plate called the stripper plate.
    - The stripper plate is positioned between the cavity and core plates and is used to eject the part from the mold.
    - Three-plate molds allow for the ejection of parts with complex shapes or large undercuts.
    - The stripper plate moves in a horizontal direction to push the part out of the mold.
    - Three-plate molds are more complex and costly to manufacture than two-plate molds, but they offer greater design flexibility.

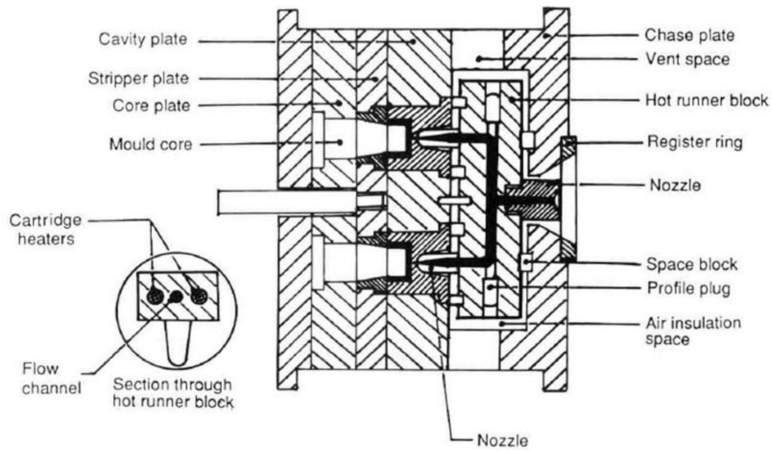


4. Split Molds:

    - Split molds, also known as "side-action" molds or "sliding-core" molds, are used to produce parts with complex shapes or deep undercuts.
    - They incorporate additional mechanisms to create side-actions that enable the mold to release the part with undercuts.
    - Split molds consist of multiple moving parts, such as slides, lifters, or rotating cores, which are activated during the ejection process.
    - These mechanisms allow for the creation of complex features, such as threads, undercuts, and internal holes.
    - Split molds are more expensive and require precise manufacturing and maintenance due to the additional moving parts.

5. Runnerless Molds:

    - Runnerless molds, also referred to as "hot runner" molds, are designed to eliminate the need for a separate runner system.
    - In traditional molds, a runner system is used to transport molten plastic from the injection machine to the mold cavity.
    - Runnerless molds utilize a heated manifold system that directly injects the molten plastic into the cavities, eliminating the need for a runner.
    - This results in reduced material waste, faster cycle times, and improved part quality.
    - Runnerless molds are more complex and expensive to manufacture than traditional molds, but they offer several advantages in terms of efficiency and cost savings.



Each type of mold has its own advantages and limitations, and the selection depends on factors such as the complexity of the part, desired features, production volume, and cost considerations. Manufacturers evaluate these factors to determine the most suitable mold type for their specific requirements.

Lecture -4

Parting surface

In mold design and manufacturing, a parting surface refers to the dividing line between the two halves of a mold, known as the "cavity" and "core." The parting surface allows the mold to be opened and closed, enabling the removal of the molded part. There are several types of parting surfaces used in different mold configurations. Here are some commonly used parting surface types:

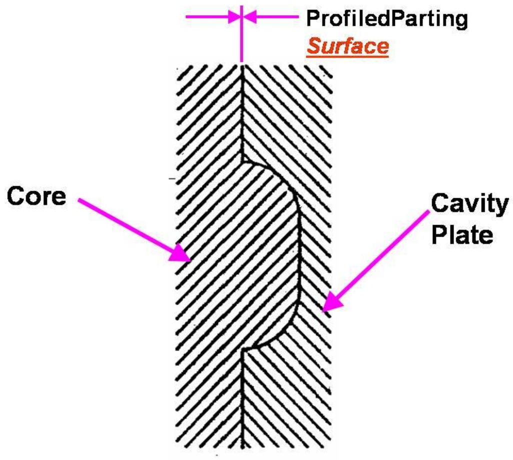
1. Flat Parting Surface: This is the simplest type of parting surface, where the dividing line between the mold halves is a flat plane. It is commonly used for simple, flat-sided parts.

2. Stepped Parting Surface: In this type, the parting line includes one or more steps or ledges to accommodate features or undercuts on the molded part. Stepped parting surfaces are utilized when the part design has varying levels or protrusions.

3. Angular Parting Surface: An angular parting surface follows an angled line instead of a straight line. It is used when the part design requires draft angles or when there are certain design constraints that can be better accommodated with an angled parting surface.

4. Complex Parting Surface: Complex parting surfaces are used for intricate part designs that cannot be adequately accommodated by a simple flat or angular surface. They may include curves, contours, or irregular shapes to match the complex geometry of the part.

5. Combination Parting Surface: Sometimes, a mold requires a combination of different parting surfaces to accommodate the various features and design requirements of the molded part. Multiple parting surfaces are used in such cases to ensure proper moldability and easy part removal.



Selection of parting line-The selection of a parting surface in mold design is a crucial step that affects the moldability and ease of part production. Several factors should be considered when choosing the appropriate parting surface:

1. Part Design: Analyze the part's geometry, including its shape, features, undercuts, and draft angles. The parting surface should be able to accommodate these design elements without hindering mold release or causing damage to the part during demolding.

2. Mold Construction: Consider the type of mold construction, such as a two-plate mold or a multi-plate mold. The parting surface should align with the mold construction and allow for proper mold opening and closing.

3. Manufacturing Process: Understand the manufacturing process requirements, such as the injection molding machine's capabilities and the molding parameters. The parting surface should enable efficient and consistent molding without causing defects or complications.

4. Demolding: Ensure that the chosen parting surface allows for easy and efficient removal of the molded part from the mold. The part should be able to release smoothly without getting stuck or causing damage.

5. Complexity and Cost: Evaluate the complexity and cost implications of the parting surface design. More complex parting surfaces may require additional mold features, increased machining or tooling complexity, and potentially higher production costs.

6. Mold Maintenance: Consider the ease of maintenance and repair of the mold. The parting surface should be designed in a way that allows for easy access, cleaning, and potential repairs or modifications.

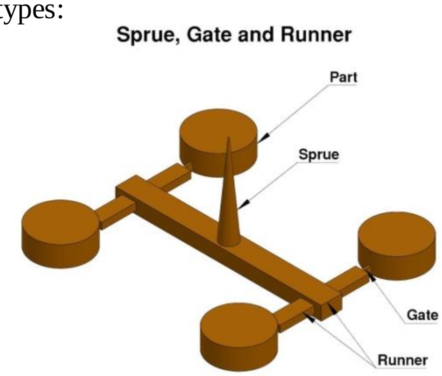
7. Material Selection: The material being molded can also influence the choice of the parting surface. Some materials may have specific requirements, such as higher mold temperatures,

8. which need to be considered when selecting the parting surface.

Lecture – 5

Feed system

In injection molding, the feed system refers to the channels or passages through which the molten material is delivered from the injection molding machine into the mold cavity. The feed system consists of several components, including the runner, sprue, and gates. Here's an overview of each component and their types:



1. Sprue: The sprue is the main channel through which the molten material enters the mold from the injection molding machine. It is usually located at the center of the mold and connects the machine's nozzle to the runner system. The sprue diameter is typically larger than the runner diameter to ensure sufficient material flow into the mold.

Types of Sprue:

- Cold Sprue: A cold sprue is a separate piece that is manually or automatically inserted into the mold during setup. After each cycle, the cold sprue is removed and a new one is inserted for the next cycle.

- Hot Sprue: A hot sprue is an integral part of the mold that remains attached during the entire molding process. It is heated to maintain the molten state of the material and eliminates the need for manual sprue removal.

2. Runner: The runner is a network of channels that distribute the molten material from the sprue to multiple cavities or gate locations within the mold. It helps maintain consistent flow and pressure throughout the molding process.

Types of Runner:

- Cold Runner: In a cold runner system, the runner channels are solid and remain in the mold after the part is ejected. The excess material in the runner system is typically recycled or discarded.

- Hot Runner: In a hot runner system, the runner channels are heated to keep the material in a molten state throughout the molding process. Hot runner systems offer advantages such as reduced material waste, faster cycle times, and greater design flexibility. They can be further classified into various types, including:

  - Insulated Runner: Insulated runners have a layer of insulating material surrounding the molten material to minimize heat loss and maintain consistent temperature.

- Valve Gate: Valve gate systems use mechanical valve pins to open and close the gate, controlling the flow of material into the cavity. This allows for precise control over gating, reducing part defects.
- Manifold System: Manifold systems have a central manifold that distributes the molten material to individual nozzles, which then supply the material to each cavity.

PPT-III

Lecture – 1

TYPES OF BLOW MOLDING:

1) **Extrusion blow molding.**
2) **Injection blow molding.**
3) **Stretch blow molding.**
4) **Multilayer co – extrusion blow molding.**

1. EXTRUSION BLOW MOLDING:

In an extrusion blow molding process molten plastic material is extruded as a tube into free air. The tube also called a parison is compressed by the two halves of the blow mold. A blow pin is inserted through which air enters and expands and then cools, extrusion blow molding is used for bottles 250 ml minimum or large size. Extrusion blow molding basically two types as following:

1) **Continuous Extrusion.**
2) **Intermittent Extrusion.**

1) **CONTINUOUS EXTRUSION:** One of the basic forms of extrusion blow molding is based on producing a molten tubular parison without interruption. The many variations on continuous extrusion blow molding come about because of the need to move the blow molds in and area to capture the needed length of tubing for each part and remove it for blowing and cooling.

   The continuous extrusion blow molding further three types:

1) **Rising mold method.**
2) **Rotary or wheel type blow molding.**
3) **Shuttle mold system.**

1) **RISING MOLD METHOD:** In the common rising mold type of machine the blow mold rise from below to close around the tube, the blow pin enters from the bottom. After blowing the mold cools & opened the product is remove and process is repeated.
2) **ROTRY BLOW MOLDING:** Rotary or wheel type blow molding is referred to as “MILLS” machine. As the wheel rotates molds close around the continuously extruded parison and more away for blowing and cooling. Blow air is introduced through a hollow needle inserted into the parison from the side. After blowing excess material is removed in a downstream deflashing operation.

   Rotary equipment may use as many as 20 molds sets and provide very

EXTRUSION BLOW MOULDING:

Basic principles of blow moulding, Types of blow moulding
Extrusion blow moulding, injection blow moulding. Blow moulding irregular containers

PARISON:

- **An uniform parison is of paramount importance.**
- **Extruder must deliver an extrudate with in close dimensional tolerance.**
- **Irregular extruder output causes weight variations from one blow part to the next.**
- **Temperature of the parison should be controlled.**
- **parison “draw down” results from gravitational pull on the plastic during extrusion.**

Lecture – 2

Objectives:
A method of minimization of the weight at its maximum mechanical performance.

Cost Saving.
Techniques:
parison Programming & Die Shaping.

PARISON PROGRAMMING

Programming controls the wall thickness as the parison emerges from the die.
The draw bar is attached to a mandrel that forms the inside of the parison.
A bushing shapes the outside of the parison. The parison thickness changes with vertical movement of the mandrel.
The sequence of mandrel & bushing movements constitute the parison programming.

The programming is accomplished electronically, either by mechanical means, with a patch panel, or by a microprocessor.

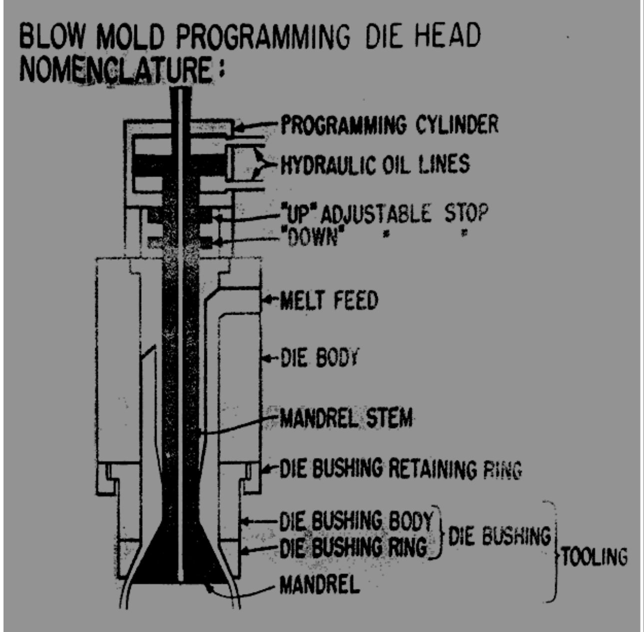


Fig - 4.8 A Programming Die Head

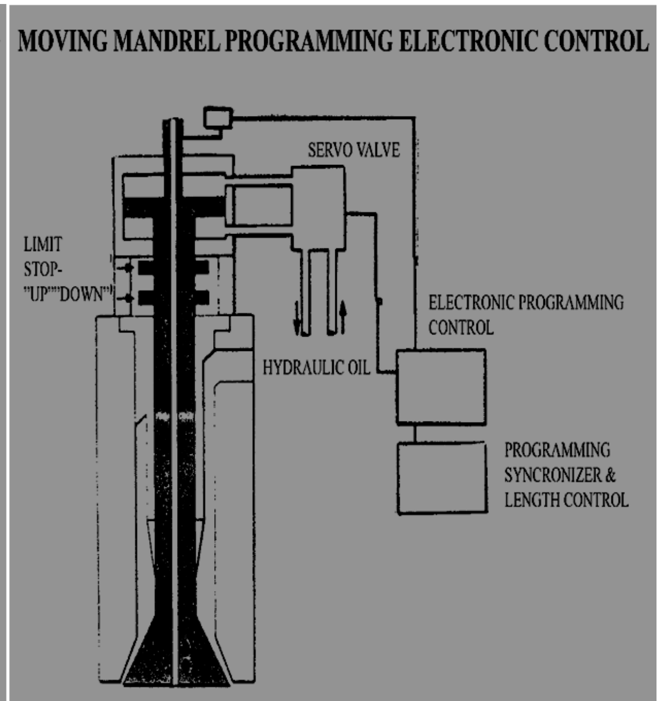


Fig- 4.8 B Moving mandrel programming.

Blow Ratio :

- **The blow ratio is the ratio of the outer diameter of the blown container divided by the outer diameter of the parison.**
- **The required die gap can be approximately calculated multiplying the desired wall thickness of a blown bottle by the blow ratio.**

Lecture – 3

INJECTION BLOW MOULDING

1. **An ideal combination of Injection & blow moulding.**
   It includes three stages:

1. **Formation of preform by using injection moulding.**
2. **Transferring the preform into the blow moulding.**
3. **Passage of air or gas pressure through the core rod to blow the thermoplastic resin into the cavity walls of the blow mould.**

There are three station & four station Injection blow moulding system.
The difference between the three & four station indexing heads is the dry cycle time.
Injection unit,a blow station,& a ejector or stripping station are the three station in Injection blow moulding machine using three station.
The four station machine has a safety or core rod conditioning station.

STRETCH BLOW MOULDING

Principles

- **It is mass production process**
- **Stretch blow moulding is a process on which stretching is done before blowing.**
- **The stretch blow moulding method can be applied to both injection and extrusion blow moulding process.**
- **Each plastic material has a temperature limit at which it can be stretched to get optimum orientation and properties.**
- **Biaxial stretch blow moulding is the method in which the stretching is done in both longitudinal and transverse direction.**
- **Biaxial orientation increases the tensile strength,gas barrier properties,drop impact strength and clarity of plastics.**
- **The various materials suitable for stretch blow moulding are PET,PVC,PS,SAN,POM,PP.**

Lecture – 4

Rotational Molding:

- **Rotational moulding is a process of making hollow articles.**
- **The part is formed inside a closed female mould.**
- **In this process the mould rotates biaxially during heating and cooling cycle.**
- **Rotational moulded pieces are stress free because the pieces are produced without any external pressure.**

- **The ability to manufacture large containers of capacity 30,000 gallons as well as small items like golf ball is responsible for the growth of this process.**
- **The Process requires relatively in expensive equipment and exerts on only small pressure on the material being formed.**

<u>ROTATIONAL MOULDING PROCESS</u>

- **Loading**
- **Heating & Moulding**
- **Cooling**
- **Unloading**

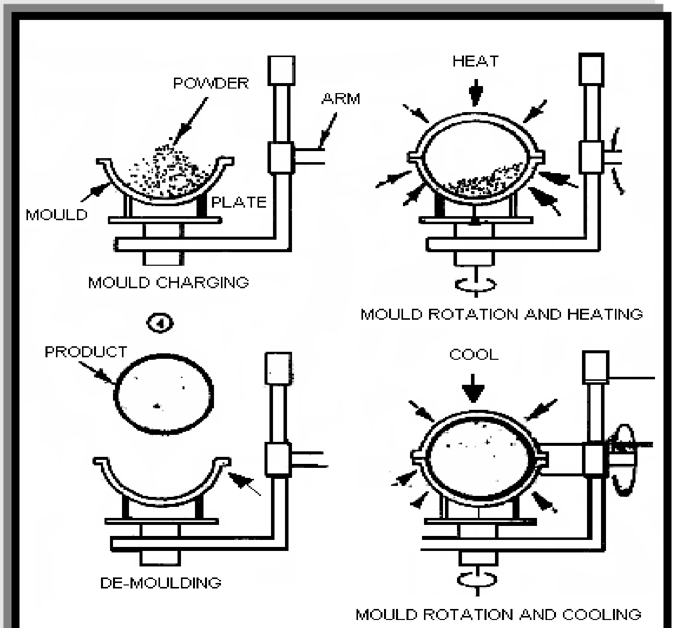


FIG-6.1 PRINCIPLE OF ROTATIONAL MOULDING

<u>LOADING</u>

- **This step includes weighing of the charge for a particular product then transferring it to the open cold mould.**
- **The mould surface usually coated with a mould releasing agent.**
- **The raw material can be in the form of powder or liquid state.**
- **The wall thickness can be controlled by varying the amount of raw material charged.**
- **After the material is charged the mould is closed and clamped to the arm of the machine.**
- **Then the mould is moved to an oven for heating**

HEATING & MOULDING

- **The mould fixed to the arm now moved to a closed chamber where it undergoes intense heating.**
- **During heating the mould rotates in two planes perpendicular to each other.**
- **The rotational speed varies in the range of 0-40 rpm on minor & 0-12 rpm on the major axis.**
- **4:1 ratio is the most commonly used for symmetric article.**
- **For moulding unsymmetrical products a wide variability of ratios is necessary.**
- **The revolving motion distributes the plastic material uniformly over the inside surface of the mould.**
- **The plastic material fuses into layers to form a hollow article.**
- **In case of hot air oven the temperature should be between 200ºc to 500ºc.**

COOLING

- **For cooling the mould is transferred to the cooling station while still rotating.**
- **The cooling should be made as quickly as possible to avoid the plastic part to shrink away form the mould.**
- **Otherwise the part will get distorted.**
- **Cooling can be done by air or water. To provide faster cooling cold water is sprayed over the mould.**

UNLOADING

- **After cooling the mould is transferred to the unloading station.**
- **In this step the mould is opened and the cooled part is taken out.**
- **It can be done manually or with mechanical assistance.**
- **The ejection can also be done by forced air.**
- **The mould is cleaned and the charge is loaded for the next cycle.**

Lecture- 5

Injection moulding:

Principle: Injection moulding is a processing technique for converting thermoplastic materials. The basic concept of injection moulding is the ability of a thermoplastic material to be softened by heating, formed under pressure, and hardened by cooling.

The process was first patented by John and Hyatt in 1872 to mould camphor-plasticized cellulose nitrate (celluloid). The first multi-cavity mould was introduced by John Hyatt in 1878.

Type of Injection Moulding Machine:

Injection moulding machines are of different type as given below:

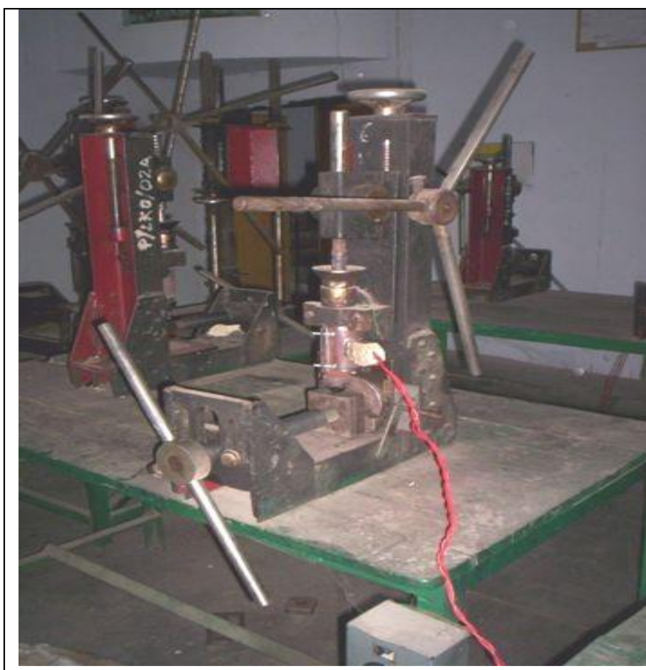
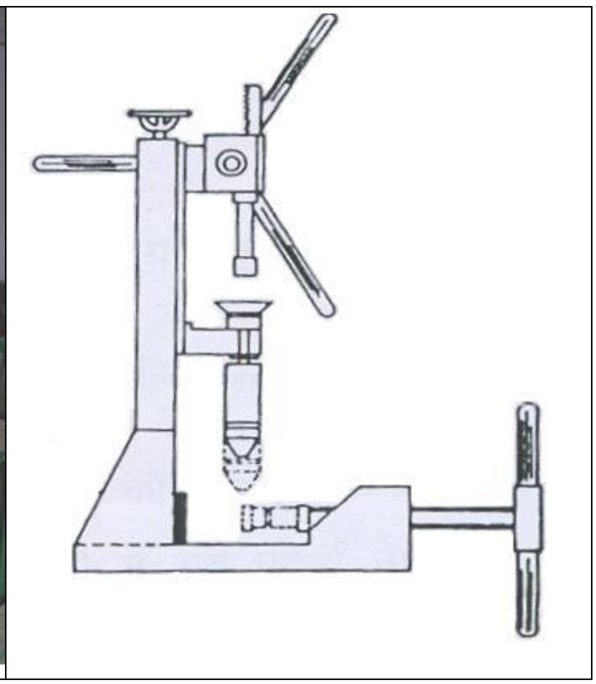
1. **Hand Injection Moulding Machine**
2. **Plunger type Injection Moulding Machine (Two Stage)**
3. **Reciprocating Screw Type Injection Moulding Machine**

1. **Hand Injection Moulding Machine:**

Principle & Working: Hand injection moulding machine is a vertically mounted machine. It consists of Barrel, Plunger, and Band Heaters along with energy regulator, Rack & Pinion system for injecting the material by the plunger, a torpedo and nozzle.

Material is measured volumetrically and fed into barrel from the hopper to fall in front of the plunger. The injection plunger moves downward and forces the cold granules into the plasticizing chamber over the torpedo and out through the nozzle tip into the mould.

The heat is supplied by heater and controlled by the regulator. When the heater reached desired set-temparture, then material is manualy pushed with the help of plunger into the mould. After some times the mould is opened and the product is removed for the next cycle.

2. **Plunger Type Injection Moulding Machine**

Plunger type machines are of two types:

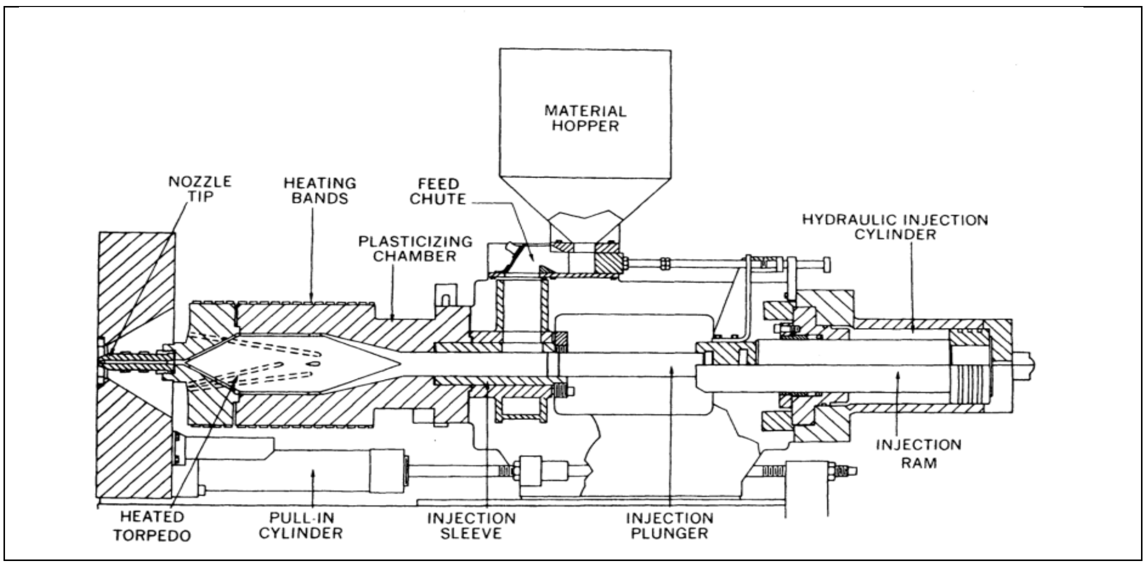
2 A. Horizontal plunger type

2 B. Vertical plunger type

2A. Horizontal plunger type:

Principle and working: Material from the hopper is measured volumetrically and fed into the barrel to fall in front of the plunger. The injection plunger moves forward and forces the cold granules into the plasticizing chamber over the torpedo and out through the nozzle tip into the mould.

The heat is supplied by resistance heaters on the outside of the barrel, and the material is melted by conduction of the heat from the heating bands through the cylinder wall into the plastic. Because there is relatively little convection in a plunger machine and the plastic has good insulating (or poor thermal conduction) properties there is little if any mixing and the temperature of the material at the wall of the torpedo is significantly higher than that of the material in the centre. This condition makes for poor temperature homogeneity, which will adversely affect the moulded part.



Pressure is transmitted from the injection plunger through the cold granules and melted material into the mould. The smaller the clearance is between the plunger and the cylinder wall, the higher the resistance to flow and the greater the pressure loss. Increasing this distance would decrease the pressure loss and increase the capacity of the cylinder, but it would lead to a progressively deteriorating temperature variation in the melt because of the poor conduction of the plastic material. Therefore, the straight plunger is limited in its capacity, as these two design requirements oppose each other. Straight plunger machines larger than 16 oz. in capacity were rarely found.

The amount of heat that the plastic receives in a given plunger-type cylinder is also a function of the residence time. Therefore, uneven cycles change the temperature of the melt and prevent good mouldings. When the machine is off cycle, even for a short period of time, it is necessary to purge out the overheated material and continue with the moulding. One of the principal advantages of the screw plasticizer is that its heating is done by shearing action caused by the screw rotation. This mechanical working puts the heat directly into the material. When the screw is not turning, the only heat the material gets is from the barrel heaters, which is a comparatively small amount. The pressure in a plunger system is transmitted inconsistently through cold granules, making it difficult to control the injection pressure in the mould. This increases the variations in the amount of material in the mould and causes variations in its physical properties.

3. The Reciprocating Screw

Reciprocating injection moulding machines are conventional type where plastic is melted using a combination of conductive heat from heater bands surrounding the barrel and frictional heating created by a rotating screw inside the barrel.

The screw moves backward to allow melted plastic to accumulate ahead of it, then moves forward, injecting all the melt into the mould in a single stage. The accumulation of melt at the screw tip forces the screw towards the rear of the machine until enough melt is collected for a shot. The back pressure required on the screw during this plasticising action is low, and when the shot size is produced, the screw stops rotating.

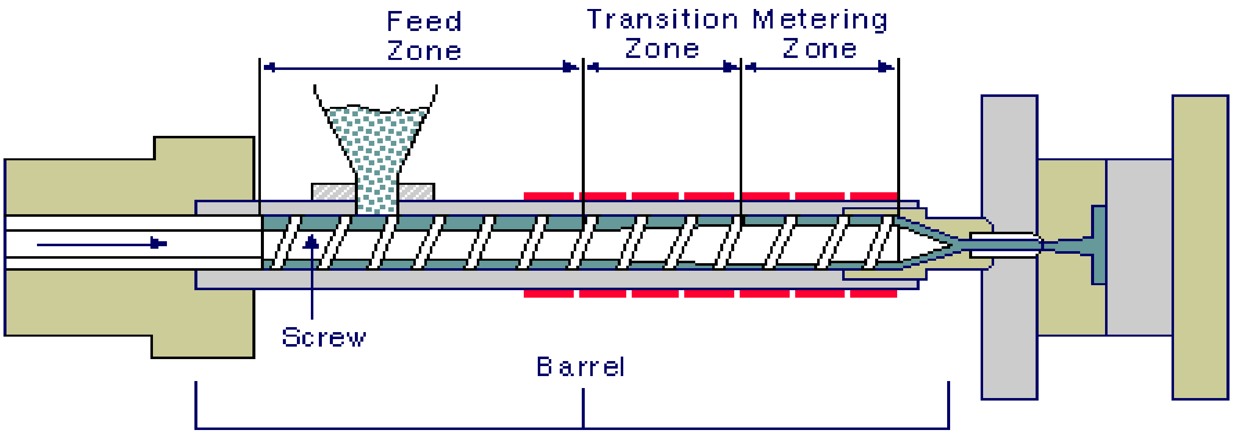
With the mould halves closed, the non-rotating screw acts as a plunger and rams the melt into the cavity or cavities, using controlled injection pressure and rate of travel. After injection of the melt is complete, the screw rotates to prepare the next shot.

The advantages of the reciprocating screw injection moulding machines over the two-stage injection moulding machines include the following:

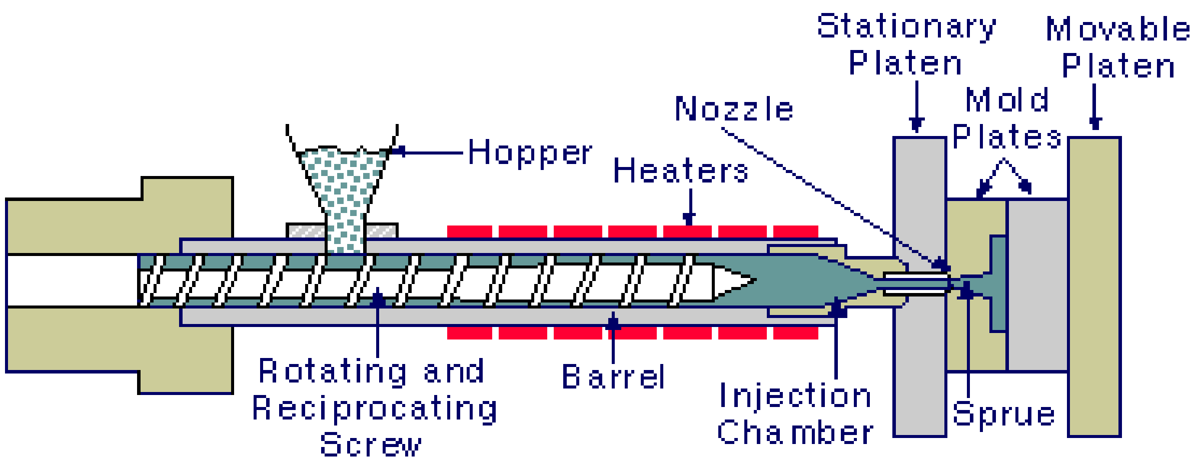
1. Reduced residence time
2. Self-cleaning screw action, and
3. Responsive injection control.

These advantages are key to processing heat-sensitive plastics. One complete cycle of the IMM operation is shown in the figure. In the single-stage IMM, melt is fed into a shot chamber (in front of the screw). This motion generates controllable low back pressure [usually 50 to 300 psi (0.34 to 2.07 MPa)] that causes the screw to retract at a pressure-controlled rate. A preset device (such as a screw position transducer) is activated when the shot size is attained, to stop the rotation of the screw. If the IMM does not have sufficient shot capacity, the screw is instead allowed to continue rotating, permitting additional melt to enter the cavity prior to shot. However, for plastics with certain melt characteristics melt flow problems can develop in this case.

At a preset time the screw acts as a ram to push the melt into the mould. Depending on the plastic's melt flow characteristics, the injection pressure at the nozzle is between 2,000 and 30,000 psi (14 and 200 MPa). The required pressure is determined by the plastic being processed and the melt pressure required in the cavity or cavities, taking into account pressure drops as the melt travels through the mould. While the shot is injected into the mould, an adequate clamping pressure must be used to keep the mould from opening (flashing) during and after the filling of the cavity. Moulds are designed to meet different requirements. They include hot runners or cold runners (for TPs or TSs) with different lengths of runners, gates, etc.



Machine components



Injection Moulded Items

Advantages of Injection Moulding Process

- Parts can be produced at high production rates.

- Large volume production is possible.
- Relatively low labour cost per unit is obtainable.
- Process is highly susceptible to automation.
- Parts require little or no finishing.
- Many different surfaces, colours, and finishes are available.
- Good decoration is possible.
- For many shapes this process is the most economical way to fabricate.
- Process permits the manufacture of very small parts which are almost impossible to fabricate in quantities by other methods.
- Minimal scrap loss result as runners, gates, and rejects can be reground and reused.
- Same items can be moulded in different materials, without changing the machine or mould in some cases.
- Close dimensional tolerances can be maintained.
- Parts can be moulded with metallic and non-metallic inserts.
- Parts can be moulded in a combination of plastic and such fillers as glass, asbestos, talc and carbon.
- The inherent properties of the material give many advantages such as high strength-weight rates, corrosion resistance, strength and clarity.

Limitations of Injection Moulding

- Intense industry competition often results in low profit margins.
- Mould costs are high.
- Moulding machinery and auxiliary equipment costs are high.
- Lack of knowledge about the fundamentals of the process causes problems.
- Lack of knowledge about the long-term properties of the materials may result in long-term failures.

PRWM

Lecture -1

Pollution caused by Plastics

Plastics as pure are not harmful. They are inert or neutral in the environment. However, they harm the environment due to the lack of an efficient collection and disposal system, as they are non-biodegradable. Plastics are most commonly used in the form of carry bags, packaging material, containers etc.

People, after use polythene carry bags are thrown on land and recycled. In the absence of a proper collection and disposal system, they are usually strewn around in our surroundings or accumulate in garbage and heaps.

Multilayer and laminated packaging such as gutka pouches, oil packagings, biscuit/ namkeem packing etc. are neither collected nor recyclable. Due to accumulation of plastic bags, and other packaging wastes as they are non- biodegradable, some of them are non-recyclable pose a serious threat to the environment.
Animals specially cattle after consuming them often choke and die. These polybags are deep enough to act as receptors of water sufficient enough for mosquito breeding. According to environmentalists, they float on the rivers close to the cities, settle on their beds, and cutting off oxygen to aquatic life.
They clog sewage pipes and prevent methane gas from evaporating which often causes explosions. They block off air supply to anything they rest on. Since they are non-biodegradable they cannot be destroyed and on burning emit toxic gases.
They also affect soil fertility and water percolation in the ground preventing the growth of plants. Even though plastic bags are an efficient and economical packing material however their non- biodegradable nature and absence of a safe mechanism for their disposal makes them an environmentalist's nightmare.

Hazardous caused by Plastics:
It is reported that so-called "Oxo-biodegradable" additives pose several concerns regarding safety and ecotoxicity. These additives are based on ionic metals that trigger polyethylene (PE) fragmentation. Some metal compounds used in these products are classified and labelled under the EU Directive 67/548/EEC on 'Dangerous Substances' as causing adverse effect on humans and the environment.

The biodegradable or compostable thermoplastics raw material such as corn-starch and cotton seed appears to be genetically engineered seeds so that fully grown crop may contain less synthetic polymer, therefore, its biodegradability need to be tested. It may also be required to look that biological breakdown of plastics releases C02 and CH4, both heat trapping green house gases (GHGs). There is now an international effort to reduce these emission (Kyoto Protocol).

Many chemical additives that give plastic products desirable performance properties also have negative environmental and human health effects. These effects include

- Direct toxicity, as in the cases of lead, cadmium, and mercury
- Carcinogens, as in the case of diethylhexyl phthalate (DEHP)
- Endocrine disruption, which can lead to cancers, birth defects, immune system supression and developmental problems in children.

People are exposed to these chemicals not only during manufacturing, but also by using plastic packages, because some chemicals migrate from the plastic packaging to the foods they contain. Examples of plastics contaminating food have been reported with most plastic types, including Styrene from polystyrene, plasticizers from PVC, antioxidants from polyethylene, and Acetaldehyde from PET.

Plastic	*Common Uses*	*Adverse Health Effects*
Polyvinyl chloride (#3PVC)	Food packaging, plastic wrap, containers for toiletries, cosmetics, crib bumpers, floor tiles, pacifiers, shower curtains, toys, water pipes, garden hoses, auto upholstery, inflatable swimming pools	Can cause cancer, birth defects, genetic changes, chronic bronchitis, ulcers, skin diseases, deafness, vision failure, indigestion, and liver dysfunction
Phthalates (DEHP, DINP, and others)	Softened vinyl products manufactured with phthalates include vinyl clothing, emulsion paint, footwear, printing inks, non-mouthing toys and children's products, product packaging and food wrap, vinyl flooring, blood bags and tubing, IV containers and components, surgical gloves, breathing tubes, general purpose labware, inhalation masks, many other medical devices	Endocrine disruption, linked to asthma, developmental and reporoductive effects. Medical waste with PVC and pthalates is regularly incinerated causing public health effects from the relese of dioxins and mercury, including cancer, birth defects, hormonal changes, declining sperm counts, infertility, endometriosis, and immune system impairment.
Polycarbonate, with Bis-phenol A (#7)	Water bottles	Scientists have linked very low doses of bis-phenol A exposure to cancers, impaired immune function, early onset of puberty, obesity, diabetes, and hyperactivity, among

		other problems (Environment California)
Polystyrene	Many food containers for meats, fish, cheeses, yogurt, foam and clear clamshell containers, foam and rigid plates, clear bakery containers, packaging "peanuts", foam packaging, audio cassette housings, CD cases, disposable cutlery, building insulation, flotation devices, ice buckets, wall tile, paints, serving trays, throw-away hot drink cups, toys	Can irritate eyes, nose and throat and can cause dizziness and unconsciousness. Migrates into food and stores in body fat. Elevated rates of lymphatic and hematopoietic cancers for workers.
Polyethelyne (#1 PET)	Water and soda bottles, carpet fiber, chewing gum, coffee stirrers, drinking glasses, food containers and wrappers, heat-sealed plastic packaging, kitchenware, plastic bags, squeeze bottles, toys	Suspected human carcinogen
Polyester	Bedding, clothing, disposable diapers, food packaging, tampons, upholstery	Can cause eye and respiratory-tract irritation and acute skin rashes
Urea-formaldehyde	Particle board, plywood, building insulation, fabric finishes	Formaldehyde is a suspected carcinogen and has been shown to cause birth defects and genetic changes. Inhaling formaldehyde can cause cough, swelling of the throat, watery eyes, breathing problems, headaches, rashes, tiredness

Polyurethane Foam	Cushions, mattresses, pillows	Bronchitis, coughing, skin and eye problems. Can release toluene diisocyanate which can produce severe lung problems
Acrylic	Clothing, blankets, carpets made from acrylic fibers, adhesives, contact lenses, dentures, floor waxes, food preparation equipment, disposable diapers, sanitary napkins, paints	Can cause breathing difficulties, vomiting, diarrhea, nausea, weakness, headache and fatigue
Tetrafluoro-ethelyne	Non-stick coating on cookware, clothes irons, ironing board covers, plumbing and tools	Can irritate eyes, nose and throat and can cause breathing difficulties

Lecture - 2

Recycling:

Plastic recycling is the process of recovering scrap or waste plastic and reprocessing the material into useful products. Since plastic is non-biodegradable, recycling is a part of global efforts to reduce plastic in the waste stream. This helps to reduce the high rates of plastic pollution.

Before recycling, most plastics are sorted according to their resin type. In the past, plastic reclaimers used the resin identification code (RIC), a method of categorization of polymer types, which was developed by the Society of the Plastics Industry in 1988.

Types of Recycling:

There are three types of recycling, known as

1. Primary recycling
2. Secondary recycling and
3. Tertiary recycling.

1. **Primary recycling** means that the recyclable material/product is recovered and reused without being changed in any way and usually for the very same

purpose. The scrap from household or from local shop collected is primary recycled. Secondhand use of a product without changing or altering the product, such as giving clothes to a charity shop or selling, leaving newspapers & magazines in a dentist/doctors surgery for other people to read. It is simply to reuse it.

2. Secondary or Mechanical Recycling:

Secondary recycling means that the material/product is reused in some other way, mechanical or material recycling of plastics involves a number of treatments and operations:

1. separation of plastics from scrap,
2. washing to remove dirt and contaminants,
3. grinding and crushing to reduce the plastic particle size,
4. extrusion by heat and reprocessing into new plastic

Because thermosets cannot be remoulded by the effect of heat, this type of recycling is mainly restricted to thermoplastics.

Mechanical recycling is limited by the compatibility between the different types of polymers when mixed, as well as by the fact that the presence of small amounts of a given polymer dispersed in a matrix of a second polymer may dramatically change the properties of the latter, hindering its possible use in conventional applications. Thus, the presence of low amounts of PVC in recycled PET strongly reduces the commercial value of the latter, due to the possible release of HCL during the PET reprocessing. This problem is enhanced by the fact that PVC and PET are difficult to separate from other plastic wastes. Another difficulty with mechanical recycling is the presence in plastic wastes of products made of the same resin but with different colours, which usually impart an undesirable grey colour to the recycled plastic.

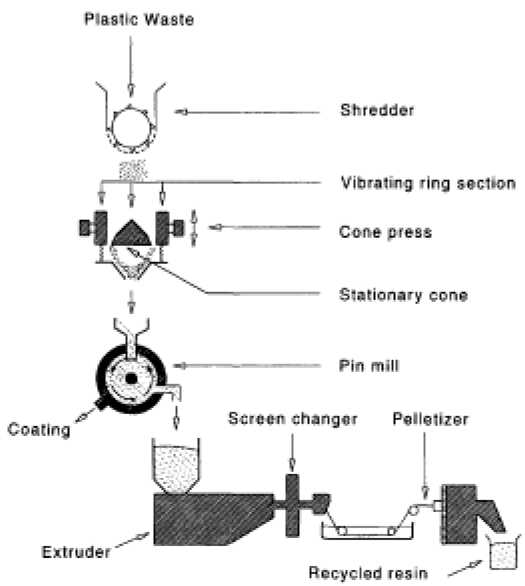


Figure *Process for the mechanical recycling of plastics.*

In addition, most polymers suffer certain degradation during their use due to the effect of a number of factors such as temperature, ultraviolet radiation, oxygen and ozone. This degradation leads to a progressive reduction in length and to a partial oxidation of the polymer chains.

Therefore, recycled polymers usually exhibit lower properties and performance than the virgin material, and are useful only for undemanding applications.

Recycling plastics without prior separation by resin produces a material with mechanical properties similar to timber; hence it is often used for the replacement of timber in certain applications. A higher quality of recycled plastics is achieved when separation by resin is carried out prior to the remolding step. However, even in this case, recycled plastics cannot be used in food containers, unless direct content with the food can be avoided. An alternative developed in recent years for promoting the use of recycled plastics has been the preparation of containers with a three-layer wall. The middle layer is the thickest and is made of recycled polymer, whereas the thinner external and internal layers are made of virgin material. With this approach direct contact between the recycled polymer and both the consumer and the product in the container is avoided.

3. Tertiary or Feedstock Recycling:

The several limitations on the mechanical recycling of plastic wastes highlight the interest and potential of feedstock recycling, also called **chemical or tertiary recycling**. It is based on the decomposition of polymers by means of heat, chemical agents and catalysts to yield a variety of products ranging from the starting monomers to mixtures of compounds, mainly hydrocarbons, with possible applications as a source of chemicals or fuels. The products derived from the plastic decomposition exhibit properties and quality similar to those of their counterparts prepared by conventional methods.

Different methods have been used for the tertiary recycling of plastic and rubber wastes. These methods are as following :

1. **De-polymerization**
2. **Gasification**
3. **Catalytic cracking and reforming**
4. **Hydrogenation**
5. **Pyrolysis**
6. **Thermal decomposition**

Lecture 3

plastic waste and their segregation in various groups.

various type of thermoplastic waste can be recycled therefore it is necessary to collect various plastic waste of different groups like PET is mainly obtained in the from different type of containers and cold drink bottles and the product obtained from recycled PET are various type of fibers used in textile industries. Similarly, there are different types of plastic which can be collected and reused in application.Collection of plastic is an important activity in the recycling operation becauseit only affects the cost of plastic but also reduces the various landfills. There are three most effect techniques used for the plastic.

1. Bring back (Bottle back).

2. Collection from waste.

3. Centralized treatment.

After collecting different types of plastic waste, it is necessary to separate them according to their class. So that similar types of plastic waste can be used for processing, e.g., if we have different mixtures of PVC, PE and PS, then we can separate them by using two methods:

1. Float and Sink methods.

2. Froth floatation methods.

Other then two methods, sometimes special identification marks are printed on the component. So, we can identify by seeing the number printed on the product. These types of number are issued by **Society of plastic Industry (SPI)** under the guidelines for identification of codes for plastic.

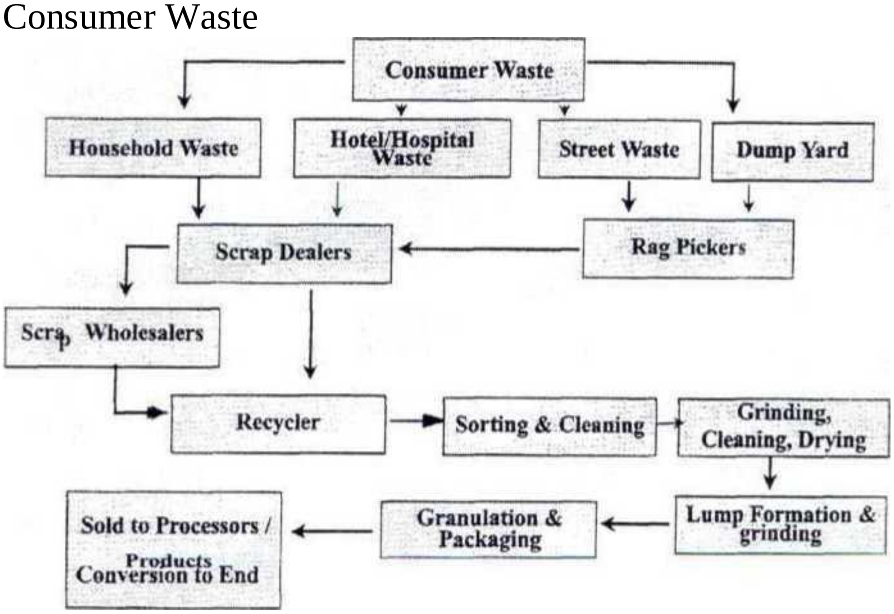
There are different types of plastic waste which can be collected from different location and sites. We can collect various types of plastic waste from landfills rides different curbsides location as well as controls collection point. After collecting the considerable quantity of plastic waste, it can be sold to the recycled plastic product manufacturer. The recycle plant generally consists of large extruder machine from which the separated homogeneous plastic waste can be convert into continuous types or filled rods of small diameter is taken out into a cooling tank and after cooling, these floodable rods are take up by resizing machine and after this, they are putout in the form of granules. In this process, only thermoplastic waste can be converted into granules but it cannot be used for thermoplastic material.

Waste management is the collection, transport, processing, recycling or disposal of waste materials. The term usually relates to materials produced by human activity, and is generally undertaken to reduce their effect on health, aesthetics or amenity. Waste management is also carried out to reduce the materials' effect on the environment and to recover resources from them. Waste management can involve solid, liquid or gaseous substances, with different methods and fields of expertise for each.

Waste management practices differ for developed and developing nations, for urban and rural areas, and for residential and industrial, producers. Management for non-hazardous residential and institutional waste in metropolitan areas is usually the responsibility of local government authorities, while management for non-hazardous commercial and industrial waste is usually the responsibility of the generator.

Flow diagram for recycling of consumer waste

Consumer Waste



Lecture - 4

Management of Plastic Wastes

The general concerns about environmental protection and resource conservation have led to the development of a variety of solid waste management techniques to reduce both the environmental impact of the different types of waste and the depletion of natural resources. Management of plastic wastes cannot be treated as an individual problem; it must be considered as an integral part of the global waste management system. Current waste management is based on a four-level hierarchical approach:

- **Reduction.** Minimizing the consumption of raw materials through improvements in the design of products may allow a significant reduction in the amount of wastes generated when they reach the end of their life cycle. **As** examples of the progress in this area, Table 1.4 shows the decrease in the weight of different food containers over the period 1970- 1990. However, it is clear that there is a limit to the advances which can be made by weight reduction, since the mechanical properties and performance of the products are also affected by this decrease.
- **Reuse.** This is mainly applied operation by which packaging items are refilled or used for the same purpose for which they were conceived, with or without the support of auxiliary products. **l4** Consumers and industries are encouraged to promote the reuse of goods and packaging instead of disposal. This option can be applied especially for containers such as bottles, bags, *etc.*
- **Recycling.** This allows the wastes to be reintroduced into the consumption cycle, generally in secondary applications because in many cases the recycled products are of lower quality than the virgin ones. Recycling must be applied only when the amount of energy consumed in the recycling process is lower than the energy required for the production of new materials. Plastics can be recycled using two different approaches:
- **Mechanical and feedstock recycling**. In the first case, the plastics are recycled as polymers, whereas in the second, plastic wastes are transformed into chemicals or fuels.
- **Energy recovery.** When the recycling of wastes is not feasible or there is no market for the recycled product, incineration can be used to generate energy from the waste combustion heat. Plastics are materials of high calorific value, hence plastic wastes greatly contribute to the energy produced in incineration plants. Alternatively, they can be used as fuels in a number of applications: power plants, industrial furnaces, cement kilns, *etc.* Incineration of Cl-containing plastics has been the subject of great

controversy due to the possible formation and release into the atmosphere of dioxins. However, the relationship between PVC content in the waste stream and dioxin concentration has not been clearly demonstrated. In fact, it seems that the formation of dioxins depends mainly on the incineration conditions rather than on the waste composition.

Lecture – 5

LANDFILL

A **landfill**, also known as a *dump*, is a site for the disposal of waste materials and is the oldest form of waste treatment. Historically, landfills have been the most common methods of organized waste disposal and remain so in many places around the world.

Landfills may include internal waste disposal sites (where a producer of waste carries out their own waste disposal at the place of production) as well as sites used by many producers. Many landfills are also used for other waste management purposes, such as the temporary storage, consolidation and transfer, or processing of waste material (sorting, treatment, or recycling).

A landfill also may refer to ground that has been filled in with soil and rocks instead of waste materials, so that it can be used for a specific purpose, such as for building houses. Unless they are stabilized, these areas may experience severe shaking or liquefaction of the ground in a large earthquake

Operations: During landfill operations the waste collection vehicles are weighed at a weigh-bridge on arrival and their load is inspected for wastes that do not accord with the landfill's waste acceptance criteria. The waste collection vehicles use the existing road network on their way to the tipping face or working front where they unload their load. After loads are deposited, compactors or dozers are used to spread and compact the waste on the working face. Before leaving the landfill boundaries, the waste collection vehicles pass through the wheel cleaning facility

in the working face, the compacted waste is covered with soil daily. Alternative waste cover materials are several sprayed-on foam products and temporary blankets. Blankets can be lifted into place with tracked excavators and then removed the following day prior to waste placement. Chipped wood and chemically 'fixed' bio-solids, may also be used as an alternate daily cover. The space that is occupied daily by the compacted waste and the cover material is called daily cell. Waste compaction is critical to extending the landfill life. Factors such as waste compressibility, waste layer thickness and the number of passes of the compactor over the waste affect the waste densities

Incineration:

Incineration is a waste treatment technology that involves the combustion of organic materials and/or substances. Incineration and other high temperature waste treatment systems are described as "thermal treatment". Incineration of waste materials converts the waste into ash flue gases, particulates, and heat, which can in turn be used to generate electricity. The flue gases are cleaned for pollutants before they are dispersed in the atmosphere.

Incineration with energy recovery is one of several waste-to-energy (WtE) technologies such as gasification and anaerobic digestion. Incineration may also be implemented without energy and materials recovery.

In some countries, incinerators built just a few decades ago often did not include a materials separation to remove hazardous, bulky or recyclable materials before combustion. These facilities tended to risk the health of the plant workers and the local environment due to inadequate levels of gas cleaning and combustion process control. Most of these facilities did not generate electricity.

Incinerators reduce the volume of the original waste by 95-96 %, depending upon composition and degree of recovery of materials such as metals from the ash for recycling. This means that while incineration does not completely replace landfilling, it reduces the necessary volume for disposal significantly.

Incineration has particularly strong benefits for the treatment of certain waste types in niche areas such as clinical wastes and certain hazardous wastes where pathogens and toxins can be destroyed by high temperatures. Examples include chemical multi-product plants with diverse toxic or very toxic wastewater streams, which cannot be routed to a conventional wastewater treatment plant.

When the polymers contain a large amount of impurities and other combustible solids (if such is a case, it is important to keep them away from landfills).it is more recently called “quaternary recycling”, and consists of the energy recovery from the wastes by burning. With the help of incinerators higher temperature of their operation and reduction of the level of air pollution.

PET has a calorific value of ca. 30.2 MJ/kg, which is about equivalent to that of coal. It is thus suitable for the incineration process. The combustion of plastics, however, requires 3 to 5 times more oxygen than for conventional incineration, produces more soot, develops more excessive heat, and incineration equipment had to be adapted in order to cope with these problems. Several processes have been worked out to overcome these technological draw-backs.

Examples include Leidner's continuous rotary-kiln process, Baliko's process for glass-reinforced PET, Crown Zellerbach Corporation's combined system for wood fibre and PET to provide steam to power equipment, and ETH-Zu-rich's fluidized bed system for pyrolysis, especially of photographic film, i.e., in combination with silver recovery. The latter system raises the additional problem of the formation of toxic halogenated compounds, stemming from the presence of silver halides. Typical operation conditions take place at temperatures around 700 oC.
At lower temperatures, waxy side-products are formed, leading to clogging. At higher temperatures, in turn, the amount of the desirable fraction of mononuclear aromatics decreases. A representative sample, pyrolysed under optimized conditions, yields, in addition to water and carbon, aromatics like benzene and toluene, and a variety of carbon-hydrogen and carbon-oxygen gases. Studies have been performed to avoid formation of dioxines and disposal of residual ashes containing heavy metals and other stabilizers.

<u>The Advantage of Incineration</u>

- Much of the debate over incineration has focused on the traces of residual by-products of incineration, some of which are highly toxic in minute amounts. As a result, attention often focuses on non-combustible by-products, such as mercury and dioxin, that are equivalent to far less than 1% of the overall waste stream.

- Incinerators can be used for generating electricity or provide energy in other ways such as generating steam for heat. Such a use is known as waste to energy or energy recovery. However, a significant amount of energy is lost due to "scrubbers", and other methods used to clean up the exhaust. Furthermore, with increased recycling the quality of the garbage as fuel often gets worse (no paper, plastic etc. left) and sometimes additional energy is needed to burn the garbage.

- In densely populated areas, space for landfills is not easily available.

- In processing medical waste, the end product (iebottom ash) is sterile and unrecognisable as medical waste.

<u>The Dis-advantage of Incineration</u>

- Concerns over the unknown potential side effects of Dioxins and Furans released into the air.

- The expense of building and running an incinerator.
- Once an incinerator is built, waste is required to run it. This provides a dis-incentive to reducing waste production and reusing waste products.
- The remaining bottom ash must still be dealt with.

Plastic Packaging and Printing

Chapter -1

Co-extrusion:

The coextrusion technique is used to make multilayer materials that combine the advantages of each component. The final form can be film or sheet, or it can be tubing for blow molding. Coextruded products can incorporate specialty polymers with gas barrier properties and can serve as a way to encapsulate regrind so that it is shielded from the product inside the container. Each material in the composite structure requires its own extruder; because adhesive or tie layers may be needed to hold the dissimilar materials together, a typical coextrusion blow molding machine will be equipped with a main extruder and as many as four satellite extruders. It involves the extrusion of two or more layers of different or similar materials using Two or more extruders and Input combining adapter.

It consists of CARRIER LAYER usually of LDPE, HDPE, LLDPE, PC, PET, EVA etc'. BENDING LAYER Or TIE LAYER:These materials adhere to different types of Polymers.Ionomer used for good adhesion to LDPE, PA, EVA and LLDPE. EVA is used for good adhesion to LD, LLDPE, PA, PC, PET.Barrier Layer is used of PA, PET, PVDC(Best), EVOH.

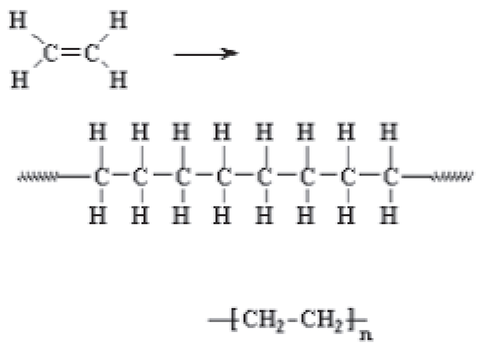
Advantages of Multi-layer Film:

- Two to seven layers depending on the application.
- It possesses good barrier properties against gas and moisture.
- High tensile, impact and tear strength.
- Good stiffness, optical, carrier and printing properties.
- e.g. LDPE/HDPE/LDPE, LLDPE/LDPE.etc.

Polyethylene

Polyethylene is probably the polymer; we see most in daily life. It is the most popular plastic in the world. This is the polymer that makes grocery bags, shampoo bottles, children's toys, and even bullet proof vests. For such a versatile material, it has a very simple structure, the simplest of all commercial polymers. A molecule of

**polyethylene is nothing more than a long chain of carbon atoms, with two hydrogen
atoms attached to each carbon atom.**

polyethylene, or High-Density Polyethylene (HDPE). Linear polyethylene is much stronger than branched one.

A molecule of Linear and branched polyethylene, or LDPE

**It is normally produced with molecular weights in the range of 200,000 to 500,000,
but it can be made even with higher M.W. Polyethylene with molecular weights of
three to six million is referred to as ultrahigh molecular weight polyethylene, or
UHMWPE. This can be used to make strong fibers used in bullet proof vests.**

Low Density Polyethylene (LDPE)

This is the largest volume single polymer used in food packaging in both film and blow-molded forms. It is a polymer of ethylene, a hydrocarbon gas available in large quantities as a byproduct of petroleum refining and other process. Polyethylene was first produced by Imperial Chemical Industries (ICI) Limited in 1933, under extremely high pressure on chain reactions.

Linear Low-Density Polyethylene (LLDPE)

The first production of LLDPE was made in a solution process in 1960. Attempts in the 1970's to produce LDPE either by low-pressure gas phase polymerization or by liquid phase process similar to those used for producing HDPE, led to the development of LLDPE, which has a molecular structure similar to HDPE. LLDPE shows improved puncture resistance and tear strength. At a density of 0.92 g/cm³, the melting points of LDPE and LLDPE are 95°C and 118°C, respectively. LLDPE commonly has a density of around 0.92 g/cm³.

High Density Polyethylene (HDPE)

Ziegler prepared HDPE by polymerizing ethylene at a low pressure and at ambient temperatures using mixtures of tri-ethyl-aluminum and titanium tetrachloride Relatively low pressure/low temperature polymerization processes at 27-34 atmospheres and 100- 175°C or 20 atmospheres and 85-100°C are used to produce HDPE. HDPE film has a white, translucent appearance and therefore tends to compete with paper. HDPE is blow molded into bottles, Jars, jerricans, etc., for a variety of food packaging applications

Polypropylene (PP)

PP is a vinyl polymer and is similar to polyethylene except that the backbone chain has a methyl group attached to it on every other carbon atom. Polypropylene can be made from the monomer propylene by Ziegler-Natta polymerization and by metallocene catalysis polymerization.

PP has a lower density (0.90 g/cm3) and a higher softening point (140°-150°C) than the polyethylene, low water vapor transmission, medium gas permeability, good resistance to greases and chemicals, good abrasion resistance, and high temperature stability, as well as good gloss and high clarity, the latter two factors making it ideal for reverse printing.

Chapter 2:

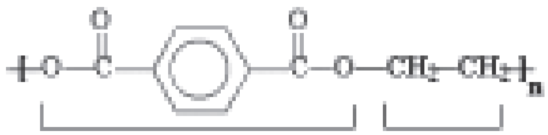
Poly (Vinyl Chloride) (PVC)

PVC is a vinyl polymer. It is similar to polyethylene, but on every other carbon in the backbone chain, one of the hydrogen atoms is replaced with a chlorine atom. It is produced by the free radical polymerization of vinyl chloride.

PVC is Extremely clear and glossy films can be produced having a high tensile strength and stiffness. The density is high at around 1.4 g/cm^3. PVC is inert in its chemical behavior, being self-extinguishing when exposed to a flame. Thin plasticizer PVC film is widely used in supermarkets for the stretch wrapping of trays containing fresh red meat and produce. The relatively high water vapour transmission rate of PVC prevents condensation on the inside of the film.

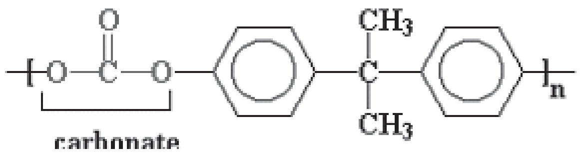
Polyesters:

polyesters are derived from condensation of polyhydric alcohol and a polyfunctional acid and are sometimes described as alkyds (from alcohol and acid). Each component needs a functionality (i.e., number of reactive groups such as -OH, -COOH, per molecule of 2 to form a linear chain, while if one (or both) monomers have a functionality of at least 3, cross-linkage can occur resulting in a much more rigid 3-D lattice structure. PET(ethylene terephthalate) can be produced by reacting ethylene glycol with terephthalic acid, although in practice the dimethyl ester of terephthalic acid is used to give a more controllable reaction.



Polycarbonates

Polycarbonates (PC) are polyesters of unstable carbonic acid and have carbonate linkages. They were originally produced by the reaction of phosgene ($COCl_2$) with bisphenol A [2, 2' - bis (4-hydroxyphenyl) propane]. Bisphenol A is still the most commonly used phenol but diphenyl.



A common application for PC is ovenable trays for frozen foods and prepared meals where its low temperature impact strength adds durability and toughness; it is commonly co-extruded with PET. The film has been used for boil-in-bag packs and, when coated with LDPE, for skin packaging.

Polyamides (Nylons)

polyamides, said to be derived from a contraction of the names of two cities coined by Du Pont between 1928 and 1937. In an attempt to circumvent the Du Pont patents on nylon 6,6, German chemists investigated a wide range of synthetic fiber forming polymers in the late 1930's. Biaxial orientation of nylon films provides improved flex-crack resistance, mechanical and barrier properties. These films have new applications in packaging foods such as processed and natural cheese, fresh and processed meats, and frozen foods. They are used in pouches and bag-in-box structures.

Polystyrene

ethylene and benzene are reacted together with a suitable catalyst, ethyl benzene is formed. Further, a process of dehydrogenation produces styrene (PS). Polystyrene is made by the addition polymerization of styrene.

Polystyrene is an inexpensive and hard plastic and it is also made in the form of foam packaging and insulation (Styrofoam is one brand of polystyrene foam). Clear plastic disposable drinking cups used for serving tea and ice creams are made of polystyrene.

HIPS:

HIPS is an excellent material for thermoforming. Because it is transparent, the useof radiant heat for thermoforming isinefficient and pigmented sheet is oftenused. It is injection molded into tubes,which find wide use in food packaging,despite being opaque. Crystal grade PS canbe made into a film but it is brittle unlessthe film is biaxially oriented.

Orientation:

ORIENTATION OF FILMS:

- ✓ Orientation of film by stretching it under heat is widely applied to films such as PP, PS, PA and PET to improve clarity, impact strength, and (particularly of PP) barrier properties.
- ✓ Basic PS film in its non-oriented form is brittle and has only a limited use as a dielectric in capacitors. When biaxially oriented, the film is tough and can be thermoformed into crystal clear tubs, trays and larger items such as cake covers.
- ✓ The largest application of orientation techniques, however, is in the manufacture of PP films and the various processes will be illustrated mainly with respect to this film.
- ✓ The main processes can be divided into linear and tubular.
- ✓ The principle of the linear type can be illustrated by considering the two-stage process shown in fig 3.27 (a) and (b).

Chapter 3:

Packaging of Processed Food Products:

Packaging of processed food products plays a crucial role in ensuring food safety, extending shelf life, and providing consumer convenience. Here are some key aspects:

Plastic packaging is widely used for processed food products due to its versatility, durability, and cost-effectiveness. Here's an overview of its key features, benefits, and considerations:

Types of Plastic Packaging

- **Flexible Films:** Used for bags and pouches, ideal for snacks, frozen foods, and ready-to-eat meals.
- **Rigid Containers:** Includes bottles, jars, and trays, suitable for sauces, beverages, and dairy products.
- **Blister Packs:** Common for single servings of medications and snacks, offering protection and convenience.

Packaging of Ready-to-Use Foods:

Plastic packaging for ready-to-use foods is essential in the convenience food sector, providing solutions that meet consumer demands for ease, safety, and shelf life. Here's an overview of its key aspects:

Plastic packaging for ready-to-use foods plays a crucial role in delivering convenience, safety, and quality. As consumer preferences evolve towards sustainability, the industry is adapting by developing more eco-friendly options and innovative packaging technologies that maintain the benefits of plastic while addressing environmental concerns.

Packaging of Meat:

The packaging of meat is critical for ensuring safety, preserving quality, and enhancing convenience. Here's a comprehensive overview of the key aspects of meat packaging:

1. Types of Meat Packaging

- **Vacuum Packaging:** Removes air from the packaging to minimize oxidation and spoilage, extending shelf life.
- **Modified Atmosphere Packaging (MAP):** Replaces the air inside the package with a gas mixture (usually carbon dioxide and nitrogen) to slow spoilage and maintain freshness.
- **Shrink Wrap:** A plastic film that tightly conforms to the product, providing a tight seal to protect against contamination and dehydration.
- **Trays with Overwrap:** Common for retail cuts, these use a plastic film over a rigid tray to allow visibility while providing protection.

Packaging of Fish and Poultry

The packaging of fish and poultry is crucial for ensuring safety, maintaining freshness, and enhancing convenience for consumers. Here's an overview of the key aspects for both types of products:

1. Types of Packaging

Fish:

- **Vacuum Packaging:** Removes air to extend shelf life and prevent freezer burn, commonly used for fresh and frozen fish.
- **Modified Atmosphere Packaging (MAP):** Uses a gas mixture to reduce spoilage and preserve quality, particularly important for fresh fish.
- **Ice Packaging:** Fish may be packaged with ice to maintain freshness during transport and display.

Poultry:

- **Tray Packaging with Overwrap:** Common for retail sales, this method provides visibility and protection, often using a plastic film over a rigid tray.
- **Vacuum and MAP:** Similar to fish, these methods are used to extend the shelf life of fresh and frozen poultry products.
- **Bulk Packaging:** For whole birds or larger quantities, using cardboard boxes or bulk vacuum bags for distribution.

Packaging of Fresh Foods

The packaging of fresh foods is essential for maintaining quality, ensuring safety, and providing convenience to consumers. Here's an overview of the key aspects of fresh food packaging:

1. Types of Fresh Foods and Their Packaging

- **Fruits and Vegetables:**
  - **Clamshell Containers:** Provide protection and visibility for items like berries, salads, and cut fruits.
  - **Plastic Bags:** Common for bulk fruits and vegetables, allowing for breathability to reduce moisture buildup.
  - **Shrink Wrap:** Used to keep items fresh and secure while minimizing exposure to air.
- **Dairy Products:**
  - **Plastic Jugs and Containers:** Used for milk, yogurt, and cream, often with resealable lids for convenience.
  - **Tetra Paks:** Common for long-life dairy products, providing protection against light and air.
- **Bread and Bakery Items:**
  - **Bags:** Plastic or paper bags that maintain freshness while allowing for some ventilation to prevent sogginess.
  - **Wraps:** Often used for individual items like pastries or rolls.

Packaging of Dairy Products

The packaging of dairy products is essential for ensuring product safety, extending shelf life, and meeting consumer needs. Here's a detailed overview of key aspects related to dairy packaging:

1. Types of Dairy Products and Their Packaging

- **Milk:**
  - **Plastic Jugs and Bottles:** Common for whole, low-fat, and flavored milk; often with resealable lids for convenience.
  - **Cartons (Tetra Paks):** Used for long-life milk, providing excellent protection against light and air.
- **Yogurt:**
  - **Plastic Cups:** Typically resealable, allowing for easy portion control.
  - **Multi-Packs:** Often sold in packs for family use, with each cup individually sealed.

- **Cheese:**
    - **Vacuum-Sealed Packs:** Helps maintain freshness and prevents spoilage for blocks and slices of cheese.
    - **Clamshell Containers:** Used for shredded cheese and cheese spreads, providing visibility and protection.
- **Butter and Margarine:**
    - **Foil Wraps:** Protects flavor and freshness; often wrapped in paper or plastic for added protection.
    - **Plastic Containers:** Resealable tubs for easy spreading.

Packaging of Fruit Juices

The packaging of fruit juices is crucial for preserving freshness, ensuring safety, and enhancing consumer convenience. Here's a comprehensive overview of the key aspects related to fruit juice packaging:

1. Types of Packaging for Fruit Juices

- **Cartons (Tetra Paks):**
    - Widely used for both shelf-stable and refrigerated juices. They provide excellent protection against light and air, helping to maintain freshness and flavor.
- **Plastic Bottles:**
    - Commonly used for chilled juices, these bottles are lightweight and resealable, making them convenient for on-the-go consumption.
- **Glass Bottles:**
    - Often used for premium juice brands, glass provides a premium feel and is highly effective at preserving flavor and freshness. However, it is heavier and more fragile than plastic.
- **Pouches:**
    - Flexible packaging that is lightweight and often resealable, ideal for single servings or children's juice products.

Sterilization of packaging materials is crucial in various industries, especially food, pharmaceuticals, and medical devices, to ensure the safety and integrity of the products. Here are some common methods and considerations:

Methods of Sterilization

1. **Steam Sterilization (Autoclaving)**:
    - Utilizes high-pressure steam to kill microorganisms.

   - Effective for heat-stable materials.
   - Requires careful temperature and pressure control.
2. **Dry Heat Sterilization**:
   - Involves heating materials to high temperatures without moisture.
   - Suitable for items that may be damaged by steam.
3. **Chemical Sterilization**:
   - Uses chemical agents (e.g., ethylene oxide, hydrogen peroxide) to eliminate microorganisms.
   - Often used for heat-sensitive materials.
4. **Radiation Sterilization**:
   - Involves ionizing radiation (gamma rays, electron beams) to kill microbes.
   - Effective for sterilizing large volumes of packaging.
5. **Filtration**:
   - Uses membrane filters to remove microorganisms from liquids or gases.
   - Common in pharmaceutical applications for sterilizing packaging materials.

Sterilization:

Sterilization by irradiation is a method that uses ionizing radiation to eliminate or inactivate microorganisms, including bacteria, viruses, and fungi. This technique is commonly employed in the sterilization of medical equipment, pharmaceuticals, and food products.

Types of Radiation Used

1. **Gamma Rays**: Often from cobalt-60 or cesium-137 isotopes, gamma radiation penetrates deeply and is effective for sterilizing large batches of products.
2. **Electron Beams (E-beams)**: These have lower penetration power but can sterilize items quickly and are often used for smaller or more sensitive items.
3. **X-rays**: Similar to gamma rays but produced by machines, they offer a compromise between the depth of penetration and energy.

Chapter -4

Packaging of horticultural crops:

Packaging of horticultural crops plays a crucial role in maintaining quality, extending shelf life, and enhancing marketability. Here are some key aspects to consider:

1. Purpose of Packaging

- **Protection:** Safeguards against physical damage, pests, and disease.
- **Preservation:** Helps maintain freshness, moisture levels, and prevents spoilage.
- **Information:** Provides details about the product, including nutritional information, handling instructions, and origin.

2. Types of Packaging Materials

- **Plastic Containers:** Lightweight and moisture-resistant, commonly used for fruits and vegetables.
- **Cardboard Boxes:** Eco-friendly option, good for bulk shipping, allows for ventilation.
- **Clamshell Packaging:** Offers visibility of the product while protecting it from damage.
- **Netting:** Often used for citrus fruits, allows for ventilation and easy handling.

3. Design Considerations

- **Ventilation:** Ensures airflow to reduce condensation and maintain freshness.
- **Size and Shape:** Tailored to the specific crop to minimize movement and bruising.
- **Branding:** Attractive designs can enhance product appeal and communicate quality.

4. Sustainability

- Increasingly, growers are seeking eco-friendly packaging solutions to reduce environmental impact. Biodegradable materials and recyclable options are becoming more popular.

5. Regulatory Compliance

- Packaging must meet local regulations regarding food safety, labeling, and traceability.

6. Technological Innovations

- **Modified Atmosphere Packaging (MAP):** Alters the composition of gases in the packaging to extend shelf life.
- **Active Packaging:** Incorporates substances that actively interact with the product to maintain quality.

7. Transportation and Storage

- Proper packaging is essential for safe transportation and optimal storage conditions, minimizing the risk of spoilage during transit.

Packaging of pharmaceutical products:
Packaging of pharmaceutical products is a critical aspect of the healthcare industry, as it ensures the safety, efficacy, and quality of medications. Here are some key points to consider:

1. Regulatory Compliance

- Pharmaceutical packaging must comply with regulations set by agencies like the FDA (U.S. Food and Drug Administration) or EMA (European Medicines Agency).
- Labels must include necessary information such as dosage, ingredients, storage conditions, and expiration dates.

2. Types of Packaging

- **Primary Packaging**: Directly contains the product (e.g., vials, blister packs, syringes).
- **Secondary Packaging**: Groups primary packages (e.g., cartons, boxes).
- **Tertiary Packaging**: For bulk handling and transportation (e.g., pallets, shipping containers).

3. Material Considerations

- Common materials include glass, plastic, aluminum, and laminates.
- Must be compatible with the drug to prevent contamination or degradation.
- Considerations for barrier properties, moisture, and light protection.

4. Safety Features

- Child-resistant packaging to prevent accidental ingestion by children.
- Tamper-evident seals to ensure product integrity.
- Serialization for tracking and combating counterfeit products.

5. Patient Compliance

- Easy-to-use designs that enhance patient adherence, such as blister packs with clear labeling.
- Instructions for use and clear labeling to reduce medication errors.

6. Sustainability

- Increasing focus on eco-friendly materials and reducing packaging waste.
- Development of biodegradable and recyclable packaging solutions.

7. Technology Integration

- Smart packaging that may include QR codes for tracking or NFC technology for product information.
- Temperature-controlled packaging for sensitive products like biologics.

8. Market Trends

- Personalized medicine leading to smaller batch sizes and customized packaging.
- Growth in e-commerce requiring robust packaging solutions for safe shipping.

Packaging of textiles:

Packaging of textiles is essential for protecting, preserving, and promoting fabric products. Here are some key considerations and practices in the textile packaging industry:

1. Types of Packaging

- **Primary Packaging**: Directly encloses the textile (e.g., poly bags, boxes, and wraps).
- **Secondary Packaging**: Groups primary packages for bulk handling (e.g., cartons, bundles).
- **Tertiary Packaging**: For shipping and logistics (e.g., pallets, containers).

2. Materials Used

- **Plastic**: Polyethylene and polypropylene are common for moisture protection.
- **Paper**: Recyclable and biodegradable options for eco-friendly packaging.
- **Textile Bags**: Reusable and durable, often made from jute or cotton.

3. Protection and Preservation

- **Moisture Control**: Using moisture-proof packaging to prevent mold and mildew.
- **UV Protection**: Packaging that blocks harmful UV rays to prevent fading.
- **Dust and Dirt Protection**: Enclosing items in protective layers to keep them clean.

4. Labeling and Branding

- Clear labels that include product information, care instructions, and branding.
- Use of tags and inserts to provide additional details and enhance brand visibility.

5. Sustainability

- Growing emphasis on eco-friendly materials and processes, such as recycled or biodegradable packaging.
- Reduction of plastic usage through innovative packaging designs.

Packaging of fertilizers and chemicals:

Packaging of fertilizers and chemicals is crucial for ensuring safety, stability, and effective distribution. Here are some key aspects to consider:

1. Types of Packaging

- **Primary Packaging**: Encloses the product directly (e.g., bags, bottles, drums).
- **Secondary Packaging**: Groups primary packages (e.g., cartons, boxes).
- **Tertiary Packaging**: For bulk handling and transportation (e.g., pallets, containers).

2. Materials Used

- **Plastic**: High-density polyethylene (HDPE) and polypropylene are common for their durability and resistance to chemicals.
- **Paper**: Kraft paper bags with inner liners for moisture protection.
- **Metal**: Steel or aluminum drums for bulk chemicals, providing robust protection.

3. Safety Features

- **Hazard Labels**: Clearly marked packaging with appropriate hazard symbols and handling instructions.
- **Tamper-Resistant Seals**: Ensures product integrity and safety.
- **Child-Resistant Packaging**: For consumer products that could pose a risk.

4. Environmental Considerations

- Emphasis on recyclable and eco-friendly materials.
- Development of biodegradable options for packaging, reducing environmental impact.

5. Storage and Transportation

- Packaging must be designed to withstand various conditions (e.g., moisture, temperature fluctuations).
- Bulk packaging for ease of transport and storage, minimizing space and maximizing efficiency.

6. Market Trends

- **Smart Packaging**: Integration of technology for tracking and monitoring conditions during transport.
- **Customized Solutions**: Tailored packaging designs to meet specific needs of different products.

7. Regulatory Compliance

- Adherence to local and international regulations regarding hazardous materials and safety standards.
- Proper documentation and labeling as required by regulatory bodies.

8. Cost Efficiency

- Balancing quality and cost in packaging solutions.
- Use of bulk packaging to reduce per-unit costs.

Conclusion

The packaging of fertilizers and chemicals is a vital part of the supply chain, ensuring safe handling, compliance with regulations, and effective transportation. As sustainability and technological advancements become more important, the industry continues to innovate in packaging solutions.

Chapter -5

Printing techniques:

Printing techniques encompass a wide range of methods used to reproduce images and text on various surfaces. Here are some of the most common techniques:

1. **Offset Printing**: A widely used commercial printing technique where ink is transferred from a plate to a rubber blanket, then to the printing surface. It's ideal for large print runs.
2. **Digital Printing**: This method involves printing directly from digital files using inkjet or laser printers. It's cost-effective for small runs and allows for quick turnaround times.

3. **Screen Printing**: Ink is pushed through a stenciled mesh screen onto the printing surface. Commonly used for textiles, posters, and promotional materials.
4. **Flexography**: Often used for packaging, this technique employs flexible relief plates and fast-drying inks, making it suitable for printing on a variety of materials.
5. **Gravure Printing**: In this method, the image is engraved onto a cylinder. It's excellent for high-volume printing and produces high-quality images, often used for magazines and packaging.
6. **Letterpress**: An older technique where raised letters are inked and pressed onto paper. It’s known for its tactile quality and is often used for specialty items like wedding invitations.
7. **Lithography**: Based on the repulsion of oil and water, this technique uses a flat surface to print images. It's historically significant and is still used for fine art prints.
8. **3D Printing**: A modern technique that creates three-dimensional objects by layering materials based on digital designs. It’s revolutionizing manufacturing and prototyping.
9. **Sublimation Printing**: Involves transferring dye onto materials like fabric or metal using heat. It's popular for producing vibrant, full-color designs on apparel and promotional items.
10. **Inkjet Printing**: A digital printing method that sprays tiny droplets of ink onto paper. It’s commonly used for home and office printing as well as photo printing.

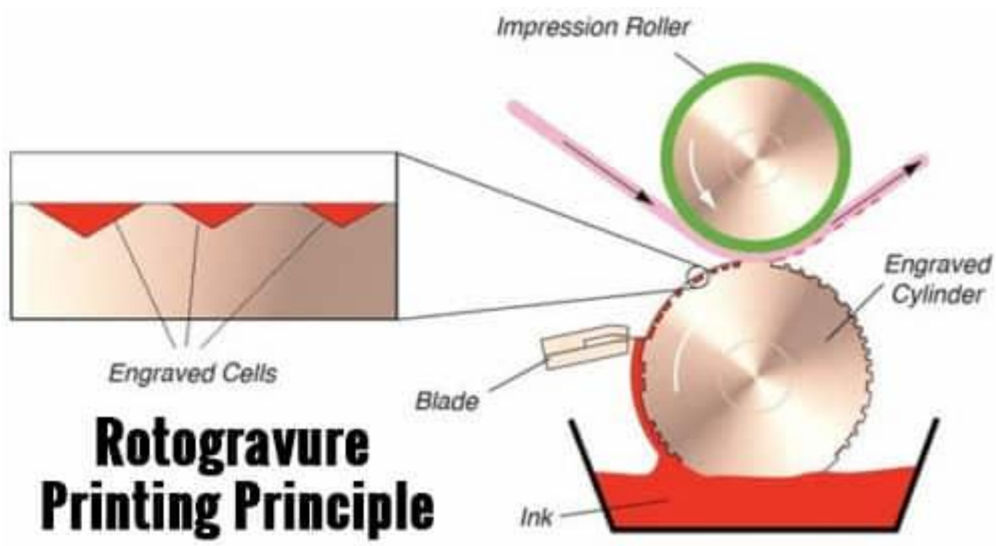
Gravure printing:

Gravure printing, also known as rotogravure, is a high-quality printing process that uses a cylindrical etched plate to transfer ink onto a substrate. Here are some key points about the technique:

Process Overview

1. **Cylinder Preparation**: The gravure cylinder is engraved with the image or design to be printed. This engraving can be done using a variety of methods, including laser engraving or chemical etching.

2. **Ink Application**: The engraved cylinder is submerged in ink, which fills the cells created during the engraving process. The surface of the cylinder is then scraped clean, leaving ink only in the recessed areas.
3. **Printing**: The cylinder rotates and makes contact with the substrate (like paper, plastic, or metal). The pressure from the cylinder transfers the ink from the cells onto the substrate.
4. **Drying**: After the ink is transferred, the substrate passes through a drying process to remove any excess moisture.



Advantages

- **High Quality**: Gravure produces very fine details and smooth color gradients, making it ideal for high-quality images.
- **Speed**: The process allows for high-speed printing, making it efficient for large print runs.
- **Versatility**: It can print on a variety of materials and is commonly used for packaging, labels, wallpaper, and magazines.

Disadvantages

- **Cost**: The initial setup costs for engraving cylinders can be high, making it less economical for short runs.
- **Limited Color Changes**: Changing colors or designs can be time-consuming and costly due to the need for new cylinders.

Applications

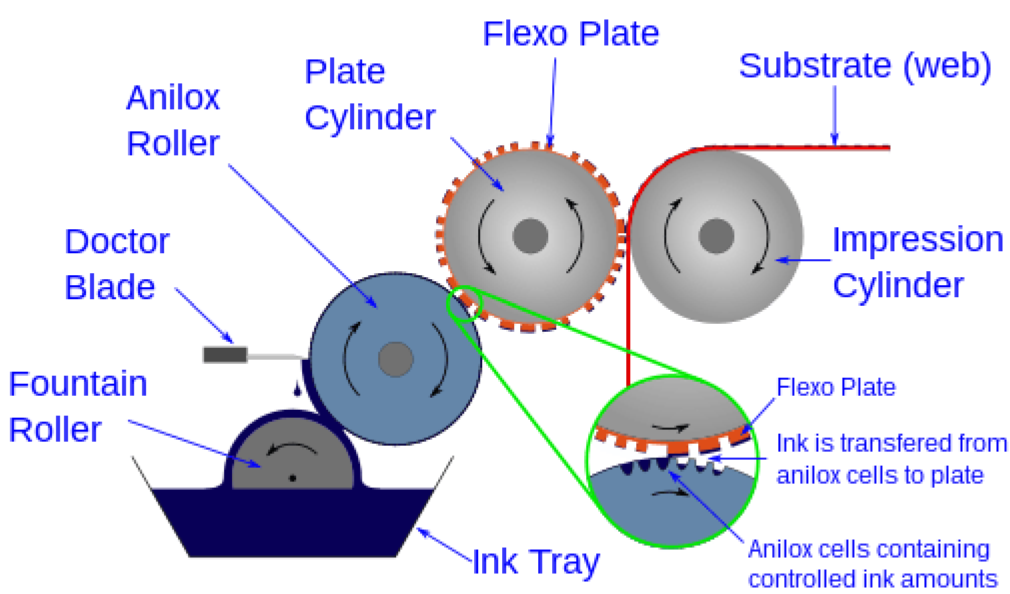
Gravure printing is widely used in the packaging industry, particularly for flexible packaging, labels, and product wraps, as well as in publishing for high-quality magazines and catalogs.

Flexography:

Flexography printing is a versatile and efficient printing process that uses flexible relief plates. It's commonly used for packaging materials, labels, and various substrates, including paper, plastic, and film.

Key Features:

1. **Fast Drying Inks**: Flexo printing often utilizes quick-drying inks, which helps in high-speed production.
2. **Versatility**: It can print on a wide range of materials, making it ideal for different applications, from food packaging to textiles.
3. **High Quality**: Advances in technology have improved print quality significantly, allowing for fine details and vibrant colors.
4. **Cost-Effective for Large Runs**: While the setup can be expensive, it becomes economical for large print runs due to its speed and efficiency.
5. **Eco-Friendly Options**: Many flexo inks are water-based, making them a more environmentally friendly option compared to solvent-based inks.



Applications:

- **Packaging**: Food wrappers, cartons, and labels.

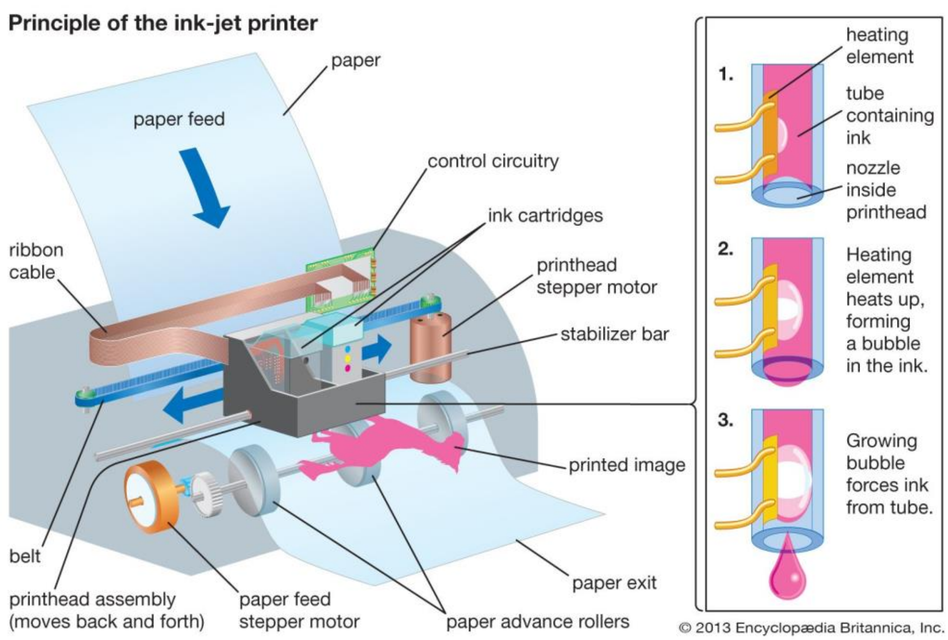
- **Labels**: Product labeling for various industries.
- **Flexible Packaging**: Pouches, bags, and films.

Inkjet printing:

Inkjet printing for coding is a widely used method for marking and labeling products during manufacturing and packaging processes. This technology offers a fast and efficient way to print variable information, such as batch numbers, expiration dates, and barcodes, directly onto products or packaging.

Key Features:

1. **Versatility**: Inkjet printers can print on various surfaces, including paper, plastic, glass, and metal, making them suitable for diverse applications.
2. **High Speed**: These printers can operate at high speeds, allowing for real-time coding on production lines without slowing down the manufacturing process.
3. **Variable Data Printing**: Inkjet systems can easily change the information being printed, enabling the production of customized or serialized items.
4. **Non-Contact Printing**: Inkjet technology allows for printing without direct contact with the surface, reducing the risk of damage to products.
5. **Integration**: Inkjet printers can be easily integrated into existing production lines and can work in conjunction with other systems for automation.



Applications:

- **Food and Beverage**: Coding on packaging to indicate expiration dates, ingredients, or batch numbers.
- **Pharmaceuticals**: Marking labels and packaging with crucial information for safety and compliance.
- **Consumer Goods**: Printing barcodes, QR codes, and other product information on packaging.
- **Industrial Products**: Marking parts and products with identification codes.

Benefits:

- **Cost-Effective**: Reduces the need for separate labeling processes.
- **Quick Setup**: Easy to switch between different codes and designs.
- **Improved Traceability**: Enhances product tracking and inventory management.

Printing inks:

Printing inks are essential materials used in various printing processes to transfer images, text, and designs onto surfaces. The composition, properties, and applications of printing inks can vary significantly based on the printing method and intended use. Here's an overview of the main types of printing inks:

Types of Printing Inks:

1. **Water-Based Inks**:
    - **Composition**: Primarily made with water as the solvent.
    - **Applications**: Commonly used in flexography and screen printing.
    - **Benefits**: Environmentally friendly, low VOC emissions, and suitable for food packaging.
2. **Solvent-Based Inks**:
    - **Composition**: Made with organic solvents.
    - **Applications**: Used in various printing methods, including wide-format and outdoor applications.
    - **Benefits**: Excellent adhesion and durability, particularly on non-porous surfaces.
3. **UV-Curable Inks**:
    - **Composition**: Contain photoinitiators that cure when exposed to UV light.
    - **Applications**: Used in digital and screen printing.
    - **Benefits**: Fast curing, high gloss finish, and strong adhesion; ideal for a wide range of substrates.

4. **Oil-Based Inks**:
    - **Composition**: Made with oils, typically used in traditional letterpress printing.
    - **Applications**: Less common in modern printing but still used for specific applications.
    - **Benefits**: Provide rich colors and excellent print quality.
5. **Electrophotographic Inks (Toner)**:
    - **Composition**: Powdered ink used in laser printers.
    - **Applications**: Common in digital printing and office settings.
    - **Benefits**: High-speed printing with consistent quality.

Corrosion and its effects on printing:

Corrosion is the gradual degradation of materials, typically metals, due to chemical reactions with their environment. In packaging, corrosion can significantly impact the integrity, safety, and shelf life of products, particularly those in industries like food, pharmaceuticals, and electronics. Here's a detailed look at corrosion and its effects on packaging:

Types of Corrosion

1. **Uniform Corrosion**: Evenly distributed corrosion that affects the entire surface, often resulting in thinning of the material.
2. **Pitting Corrosion**: Localized corrosion that leads to small pits or holes, which can compromise structural integrity.
3. **Galvanic Corrosion**: Occurs when two different metals come into contact in the presence of an electrolyte, leading to accelerated corrosion of one metal.
4. **Crevice Corrosion**: Happens in confined spaces where stagnant solutions can promote localized corrosion.

Preventive Measures

1. **Material Selection**:
    - Using corrosion-resistant materials, such as stainless steel, aluminum, or specialized coatings, can help mitigate corrosion risks.
2. **Protective Coatings**:
    - Applying protective coatings or barriers can shield materials from corrosive environments and extend the lifespan of packaging.
3. **Proper Storage Conditions**:

    - Controlling environmental factors, such as humidity and temperature, can reduce the likelihood of corrosion.
4. **Regular Inspections**:
    - Implementing routine inspections can help detect early signs of corrosion, allowing for timely intervention.
5. **Use of Inhibitors**:
    - Corrosion inhibitors can be added to packaging systems to reduce the rate of corrosion.

Adhesive tapes:

Adhesive tapes are versatile tools used for bonding, sealing, and securing materials in various applications. They consist of a backing material coated with an adhesive on one or both sides. Here's an overview of adhesive tapes, including their types, properties, and applications.

Types of Adhesive Tapes

1. **Masking Tape**:
    - **Use**: Primarily for painting and surface protection.
    - **Properties**: Easy to remove, leaves minimal residue, and provides clean lines.
2. **Packing Tape**:
    - **Use**: Sealing boxes and packages for shipping.
    - **Properties**: Strong and durable, often made of polypropylene or PVC.
3. **Duct Tape**:
    - **Use**: General-purpose repairs and maintenance.
    - **Properties**: Highly durable and water-resistant, with a strong adhesive.
4. **Double-Sided Tape**:
    - **Use**: Bonding two surfaces together without visible tape.
    - **Properties**: Adhesive on both sides, ideal for mounting and crafts.
5. **Electrical Tape**:
    - **Use**: Insulating electrical wires and connections.
    - **Properties**: Made from vinyl, it's flexible and resistant to moisture and heat.
6. **Foam Tape**:
    - **Use**: Sealing gaps, providing cushioning, and mounting.
    - **Properties**: Made of foam, it offers good insulation and vibration dampening.

7. **Medical Tape**:
    - **Use**: Securing bandages and dressings.
    - **Properties**: Gentle on the skin, hypoallergenic, and breathable.
8. **Biodgradable Tape**:
    - **Use**: Eco-friendly packaging and sealing.
    - **Properties**: Made from renewable materials, it's designed to break down over time.

Applications

- **Packaging**: Sealing boxes and cartons for shipping.
- **Construction**: Joint sealing, insulation, and temporary bonding.
- **Automotive**: Wire harnessing, securing components, and repairs.
- **Electronics**: Insulating wires and components, providing strain relief.
- **Crafting**: Various arts and crafts projects for mounting and decorating.
- **Healthcare**: Securing medical devices and dressings.

BOPP (Biaxially Oriented Polypropylene) pressure-sensitive tapes:

BOPP (Biaxially Oriented Polypropylene) pressure-sensitive tapes are commonly used for packaging, sealing, and various industrial applications. Here are some key points about them:

Characteristics:

1. **Material**: Made from BOPP film, which is strong, lightweight, and has good clarity.
2. **Adhesive**: Typically features an acrylic or rubber-based adhesive, providing strong adhesion to a variety of surfaces.

3. **Temperature Resistance**: Can perform well in a range of temperatures, making them suitable for different environments.

Applications:

1. **Packaging**: Ideal for sealing cartons, boxes, and packages due to their durability and adhesion.
2. **Labeling**: Used in labeling applications because of their clear or printed options.
3. **Stationery**: Common in office supplies for general-purpose taping.

Benefits:

- **Strong Bonding**: Provides excellent adhesion, ensuring packages remain secure.
- **Tear Resistance**: Offers good resistance to tearing and puncturing.
- **Clarity**: Clear options are available, which can be important for presentation.