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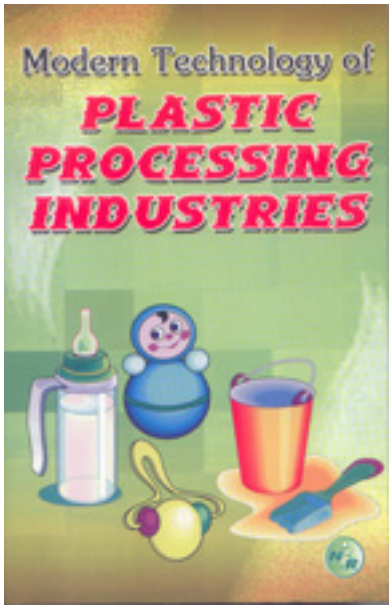
Modern Technology of Plastic Processing Industries (2nd Edition)



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Plastics are contemporary, synthetic materials. Plastics are oil and gas based, and consumes less than four per cent of our oil and gas reserves. Plastic in fact saves the energy it takes less energy to convert into plastic from raw materials. Throughout their whole life circle one-third less energy needs than making paper bags. Without plastic, whole packaging would take almost double energy by around 160 percent. The better-quality properties of plastics such as sanitized or germ free barrier properties, light weight, and durability contribute appreciably to our health and quality to way of life.

The Plastic industry has been witnessing a continuous increase in demand from a long time attracting many towards it. To all those who are looking forward for a proper understanding of technology and methodology used in the plastic industries so that they could penetrate into plastics industries with a consideration of the current industry trend then this book provides you about certain very essential information about Plastic. PVC can be processed by all the conventional conversion processes as used for other thermoplastics but with some modifications. This book covers an intensive study of Current Trends in Conducting Polymers with a significant and detail explanation of thermosetting, thermoplastic material and products environment health and the future prospects.

The content of the book includes information about plastic and allied products equipped with latest technology. It also includes comprehensive information on the development of the sector and manufacturing process. The several chapters of the book contain information about: Processing of PVC, Applications of PVC and so on. The book also has chapter that will provide you with some very interesting, feasible and profitable plastic project profiles that will act as guide in proper understanding and analysis of the sector. Recent Developments in Plastics Extrusion and Environment Health and Future Prospects, Constructive use of HDPE, The Processing of Fibre Re-in forced Thermo-
plastics Using Co-Rotating Twin Screw Extruders, Economical Film Extrusions with Modular Systems these are few chapters that are very informational and will help you in deep penetration of the industry. Along with these feature the book also encloses a directory section which list all major manufacturers of plastic processing machinery and raw material suppliers.

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Sample Chapter:

PROCESSING OF PVC

INTRODUCTION

PVC can be processed by all the conventional conversion processes as used for other thermoplastics but with some modifications. PVC Resins in unmodified form are virtually unprocessable and therefore, have to be modified by incorporating. Additives modifiction is also required to enhance polymer properties and to ensure the service life of the end-product.

Some additives are used to enhance polymer processability.

Other additivies are used to enhance mechanical and electrical properties.

In addition, additives modifictions is also used as briefed below:

Some stabilizers like dibasic lead phosphite provide a unique balance of properties such as excellent heat stability improved electrical insulation and outstanding weather resistance.

Achieving a balance of these additives to obtain the desirable processability and heat stability service life as expected compliance with the Government Regultions particularly for the food-contact applictions and an acceptable level of performance at the affordable cost is mainly the Compounder's or Formulator's reponsibility.

The importance of producing consistent, homogeneous dry blendor pelletized compound to obtain quality end-product on day-to-day basis has to be properly understood for success in PVC processing. Variability in a compound bulk density homogeneity, flow characteristics translate directly to variations in subsequent melt processing, requiring constant readjustment of the processing conditions or higher wastages, if not properly monitered.

Factors of utmost importance for successful processingare as follows :-

PVC Resins :

Three types of resins are generally used in the processing of rigid PVC.

Bulk PVC resin absorbs plasticizer faster than an equivalent K-Value suspension resin. It is pure with no emulsifier or suspending agent and with lowest wet absorbency among all PVC resins. Products with excellent clarity and sparkle can be manufactured from bulk PVC Resins.

Because of use of emulsifiers, this resin is less transparent. It gels less and has antistatic properties. It has an advantage that the products manufactured are free of fish-eyes and flow-lines.

Generally, these resins are used by blending with suspension or bulk resin to :

- reduce extrudate swelling
- improve surface finish
- improve impact resistance
- reduce plate-out tendency
- reduce static charge of resin

Molecular Weight :

Resin Molecular Weight influence the physical properties of the end-product as well as the inherent compound heat stability and processing characteristics, very generally, as shown earlier.

Injection Moulding :

A grade generally used is of 50,000 to 70,000 average molecular weight which corresponds to K-Values between 54 and 63. This range is also suitable for injection blow moulding, extrusion blow moulding and calendering.

Extrusion :

For the manufacture of pipes, profiles, conduits and sheets, PVC Resins in the Mw range of 70,000 and 1,20,000 or K-values between 63 and 75 are preferred since the properties of importance for the end-

products are higher modulus of elasticity, heat distortion temperature and impact resistance.

ADDITIVES FOR IMPROVING PROCESSING

Heat Stabilizers :

PVC Resins as such are very heat sensitive and have to be processed at low temperature and as such, heat stabilization is extremely important.

Whatever stabilization may be used, all of them have a common function to arrest or retard PVC degradation by :

- neutralizing hydrogen chloride atoms with other groups which are more stable;
- exchange or displace labile chlorine atoms on the polymer chain with other groups of greater stability; and
- inactivating stabilizer degradation products.

Processing Aids :

Compatibility of these additives is very high, which is achieved without any detectable plasticizer action, at least at the low levels (1.0 to 5.0 phr) and perform the following functions :

- Perform fusion rate with adversely affecting melt viscosity of the compound, the heat distortion temperature or the impact resistance of the end-products.

Plasticizers, one of the earlier usage as processing aids, lower apparent melt viscosity, reduce heat distortion temperature and have a detrimental effect on impact strength.

- Increase melt strength and homogeneity.
- Reduce plate-out to enable faster production.
- Reduce surface imperfections like flowlines.

Lubricants :

These are indispensable in PVC Compunding Proper Lubrication balance is very important for the processing of rigid PVC, which use between 2 or more lubricants. They perform the following functions :

- Reduce apparent melt viscosity therby improving melt flow
- Control frictional heat built-up by reducing friction.
- Promote release of the melt from hot metal surface of the processing equipment.

Impact Modifiers :

Effect Modifiers have the following requirements :

- Must be insoluble in the PVC matrix and must have good adhesion between the continuous glassy phase and dispersed rubber phase.
- For applications like bottles, films, blister packaging requiring clarity, the refractive index should have the same value as that of matrix.
- It should not adversely affect other properties like low permeability and low order of taste and odour.
- It must retain the elasticity at low temperature particularly for the outdoor applications in colder climates.
- It must have good thermal and light stability.

Compounding :

The selection of the compounding equipment is based on the following major parameters :

- Type of Compounds-Dry Blend or Hot Melt
- Expected productivity
- Space available

Some of the commonly used equipments are :

Low Shear Horizontal Mixers (Ribbon Blenders) :

They provide distributive blending only ensuring uniform distribution of all particles throughout the mix. These blenders are usually equipped with a drive having ratio of 1 hp to 51 to 10 kgs. of product. These blenders, however, have insufficient radial and axial flow to transfer all the materials into the zone of higher

intensity and therefore, their overall efficiency is low. They are not able to produce a good dispersion of small quantities of liquid additives like epoxidized soyabean oil. They also cannot disperse satisfactorily agglomerates of organic substances like the benzophenone, UV absorbed. Another limitation is that at low temperature at which they operate, moisture or other volatiles are not removed. Also, it is very difficult to flush out the system, if carbon blocks and some organic pigments like phthalocyanine blue and green are added and may result in colour contamination problems.

Best results are obtained with freshly mixed powders.

Higher Shear Vertical Non fluxing Mixer :

These prduce a complete random distribution of all particles throughout the mix leaving mostly no original particle identify. There are several types commercially available with the common major feature such as :

- A bottom mixing impeller assembly rotating at high speed.
- Impellers produce two patterns of flow, one around the circumference of the fowl (that is centrifugal action) and the other a lifting casacading action from bottom to top.
- Drives with a ratio of approximately 1 hp to 2 kg of resin, which results, in rapid heating of the resin powder.
- A vertically mounted stationery blade that acts as a deflector baffle of the powder.
- Two speed motors to minimize high torque while starting.

Major functions of such mixers are :

- Densification of the powder (increse in bulk density).
- Homogenization of powder and additives and the uniform coating of resin particles with additives.
- Removal of volatiles, mainly moisture.

Dry Blend Properties :

The dry blend properties are very critical for extrusion, more so for the single extrusion. The properties that greatly influence the extrusion are Bulk Density, Molecular weight of the Resin and the Flow Properties of the powder. Dry blend properties can broadly be divided in two categories : The fundamental properties, which are mostly resin realated such as grain shape, grain size, size distribution, nature of grain surface moisture content, coefficient of friction and chemical effects and the associated properties which cover bulk density, packing, grain density, angle of repose, permeability and rate of discharge.

Low Shear and High Shear Mixing in Horizontal, Jacketed Cylinderical Blenders

These mixers resemble ribbon blenders and can be very versatile with proper modifications.

They consist of plough-shaped mixing tools or the bakery ploughs which rotate at a very high sppeed. The ploughs mechanically finalize the materials and achieve homogenity by intersecting trajectories from adjacent ploughs. The high shear mixing is achieved by means of choppers mounted on the walls of the blender. Each chopper consists of 4 blades, two tiers, mounted on the extender motor shaft on the inside of the mixing drum. The impacters consist of a series of pins mounted peripherically and perpendicularly in a moving plate, which rotates inside a pinned stationery cage. These mixing rools supplement the mixing action of ploughs and help to increase the temperature which in turn improves dispersion of the additives.

Hot Melt Compounding :

The extrusion of rigid PVC directly from the powder blend is gaining wider acceptance, yet melt compunded materials are also widely used particularly by processors with no compounding facility and conventional moulding machines or extruders. Pelletized PVC certainly has a relatively high and uniform bulk density and can, therefore, be processed much easily even on the conventional processing machines.

Melt compounding of rigid PVC formulation is generally done using twin screw extruders where temperature control is better as compared to a single screw extruder because in a multiscrew system, the mechanical energy source contributes around 54% and the thermal energy the rest 46% to the melting of the material.

The various types of extruders used are :

- single screw
- multiscrew
- co-rotating, intermeshing, parallel twin screw.
- counter-rotating, intermeshing, cylinderical twin screw
- two stage compounding extruders
- two screw compounding extruders

Two Stage (Farrel) Continous High Intensity Fluxing Mixers :

This is a further improvement over the Bandury Mixers. In these machines, the first section of each rotor is the feed screw which runs in separate bores. The next section begins at the end of the screw and extends as far as the apex of each rotor. This section, helical in shape is known as the Forward Helix because it pushes the material towards the discharge end of the chamber. The next rotor section starts immediately after the apex. This is also helical in shape but in opposite direction. This part of the rotor forces the material back against the new material coming in therby helping through mixing.

In two stage version, back-pressure and degree of mixing are controlled by the extruder screw-speed.

]Compounding Lines Batch Type :

]

In batch type, hot melt compounding process centered on Bandury internal high-intensity fluxing mixers and two-roll-mix mixers, there is a great flexibility and despite the inceasing popularity of continuous equipment, these machines are still in use.

One advantage of these compounding lines is that they are less sensitive than any of the compounding lines and as such, resins with a wide range of particle sizes, moisture content, bulk density as well as dry blends, cold or warm, can be successfullyu processed in these compounding lines.

Despite the high initial costs, the present trend with medium and large scale processors is to develop their own compound and compounding process built around specialized continuous mixers. This definitely results in Economy and Secrecy of Formulations.

Suggested K-Value of PVC Resins

Application	*Process*	*K-Value*
Rigid		
Rigid Transparent	Calendering Extrusion Blown	57-60
Blister Pack	Calendering/ Extrusion with T-Die	57-60
Bottles, Containers	Blow Moulding	55-60
Blow Moulding	Stretch Blow Moulding	55-60
Free Foam Boards	Extrusion	55-60
Rigid Opaque	Blow Moulding Bottles, Containers	57-62

Application	*Process*	*K-Value*
Pipe Fittings	Injection Moulding	
Rigid Transparent Films	Extrusion Blown	65-69
Rigid Pipes, Profiles	Extrusion	65-69
Conduits, etc.		
Flexible		
Leather Cloth	Calendering	65-69
Coated Fabrics		
Flexible Films	Extrusion Blown	65-69
Cables	Extrusion	65-69
Speciality Cables	Extrusion	69-75
Footwears	Injection Moulding	65-69

Influence of Formulation on Processing Behaviour

1. The polymer

a. Grain size and morphology :

The ideal polymer for powder feed stocks would be completely devoid of porosity to give maximum density. There is no ideal combination of particle properties for all precessing machines and applications. What is important is the consistency of properties so that optimum relationship between formulation, output and quality can be established by a processor.

b. K-Value

Molecular weight of the polymer has marked influence on the processing behaviour of rigid PVC compound. The higher the K-value, the higher is the molecular weight. A lower J-Value PVC has low melt viscosity at a given temperature and generally easier to process, while a higher K-Value PVC is gererally associated with superior mechanical properties of the end-product. Thus, generally:

K-Value range 55-62	:	Rigid Injection Moulding Blow Moulding Extruded Foils Calendered Foils

K-Value range 60-68	:	Extruded Clear Sheet
K-Value range 66-68	:	Large diameter pipes
K-Value range 65-75	:	Plasticized applications

Relation of Polymer K-Values with Threshold Temperature

Threshold Temp. (°C)	*Polymer K. Value (ISO Scale)*
155	58
157	68
159	61
165	71

c. Copolymerization

The majority of rigid PVC applications is based on homopolymers. Copolymers, inspite of their unique role, are restricted to specific applications. Specialised coating materials such as PVC-PVDC Copolymer and Copolymer with Vinyl acetate and with olefin are the two types commercially in use.

A very specific application of Vinyl Acetate Copolymers is the maufacture of gramophone records. Higher acetate copolymers are used in the production of vinyl floor tiles. Medium acetate copolymers are employed in the production of calendered flooring and extruded foil, particularly the clear foil for packaging applications.

2. Lubricants :

They are incorporated, either internal type or/and external type for improving the flow and prevent sticking to the metal surfaces.

In addition to their influence on melt behaviour, lubricants can have a considerable effect on the gelation of polymer in a dry blend feedstock.

3. Heat Stabilizers :

The presence of heat stabilizers is very necessary to protect PVC melt from degradtion at temperature encountered during processing.

4. Processing Aids :

These additives assist the melt processing of PVC formulations but in a different way than the lubricants. They do not reduce the melt viscosity and may sometimes even increase the melt viscosity, but they improve the elastic behaviour of the melt. Also, in processing of rigid PVC, even a small addition considerably reduces the incidence of procesing defects associated with melt rupture, which is very desirable in the production of extruded sheets and profiles and for post-extrusion forming. In calendering of

foils, flow marks and edge shredding are much reduced and overall quality improved. In injection moulding, improvement in the quality of finished products is remarkable.

In addition to improved melt behaviour, processing aids can produce a faster rate of plastificatin of a polymer in an extruder or internal mixer.

5. Impact Modifiers :

Most of these additives have a rubbery nature and their effect on processing depends on the physical form of the additive. The impact modifiers are chosen mainly for their effect on finished products properties but they do have a benefecial effect on processing too, particularly in the case of ABS and MBS systems. Some increase in melt extensibility is also observed.

6. Fillers :

Rigid PVC formulations very rarely have high levels of fillers, as in the case of plasticized PVC because of its adverse effect on the impact properties.

Small additions of fine particle fillers can aid in the flow of powder blend feedstocks but higher levels of fillers may complete with the surface for lubricant during the powder mixing. It has been observed that higher levels of Coarie fillers impede gelation.

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