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HMEL POLYSURE

TECHNICAL GUIDE TO
Cast Film Process

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Contents

INTRODUCTION

The cast film extrusion is a process to make polymer films with high clarity and low thickness. The cast film extrusion process is gaining increased popularity and enjoying sustained growth worldwide. New lines are being installed in a significant number and the market segments penetrated by this technology are on the rise. Cast film is traditionally produced in either polyethylene (PE) or polypropylene (PP) but can also include EVOH, Nylon, Vinyl and Polyester for barrier in multilayer materials. These applications generally cover a thickness range from 10 to 50 µm.

The cast film process offers better gauge control than blown film. Generally, cast film thickness variation is ±3-5%, whereas blown film can be ±7-10%. Cast film shows its advantage over blown film processing by its high output and increased widths to produce mass product in high volumes. The introduction of new high-performance polymers, the development of new processing equipment technology, and the emergence of many new packaging applications has resulted in high growth rates in co-extrusion. The shift to Co-extrusion is being made because the technology can meet a wide range of application needs, including the ability to achieve specific performance properties, to reduce costs, to use fewer processes and to reduce waste generation.

Polysure Polypropylene (PP) & Linear Low Density Polyethylene (LLDPE) cast film grades cover a wide range of Melt Flow Index (MFI) for cast film extrusion process. Different additive packages ensure that they meet the processing, handling and service requirements of various applications. This technical article includes a brief overview of cast film extrusion process, its benefits, applications, attributes of Polysure polypropylene and polyethylene grades and a troubleshooting guide.

Cast Film Manufacturing Process Description

The cast film extrusion is a process which involves melting of the polymer and the molten polymer passes through a die (T-die or Coat hanger die) where the molten polymer takes the shape of a sheet. The die system is formed by the die and feed block (if the process requires co-extrusion) or simply the die, if the process is that of mono-layer extrusion. Immediately after exiting the die, the molten curtain enters the cooling unit where its temperature is lowered with a water cooled chill roll to "freeze" the film. The film is then passed downstream where the edges are trimmed, corona treatment is applied (if a fabrication process such as printing or coating is required) and the film is wound into rolls. The basic steps of cast film extrusion are explained below along with the description on Machine direction oriented film and coextruded films.

Cast Film Extrusion Steps

The cast film extrusion process involves the following steps:

A. Feeding

B. Extrusion of polymer

C. Filtration of the melt

D. Melt Curtain formation through flat die

E. Quenching of the Melt curtain

F. Machine Direction Orientation (MDO) Stretching

G. Surface treatment and winding

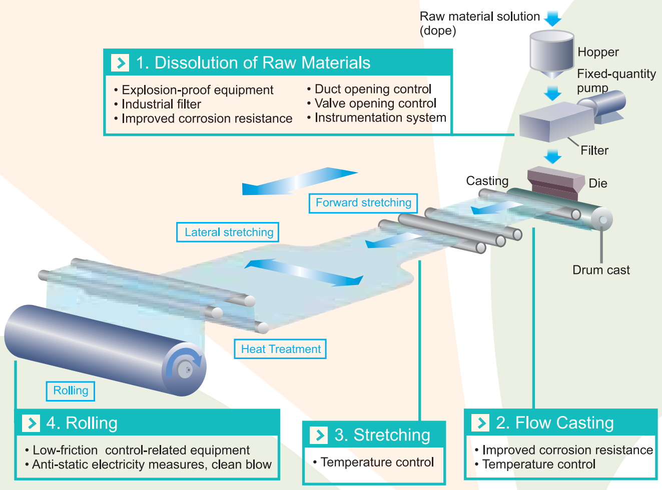


Fig. 1 – Cast Film Manufacturing Process

A. Feeding

Gravimetric feeding systems control the amount of material that is fed into the extruders by weight, not volume. Volumetric Feeding systems control the amount of material that is fed into the extruders by volume. The gravimetric system is more precise than its volumetric counterpart and features a reduced error tolerance in the order of ± 0.5%. Special care is needed to prevent premature melting of the pellets, especially when materials with low melting temperatures are processed, or when the pellet size is small. Vibration and cooling of the feeding hoppers are options recommended to alleviate this problem. It is also important to ensure that the material being fed carries no moisture that could give rise to the appearance of small bubbles, also known as "fish eyes", in the final film. In some cases, drying of the material is required. This may be performed by a separate unit or by a highly sophisticated feeding system with built-in drying capabilities.

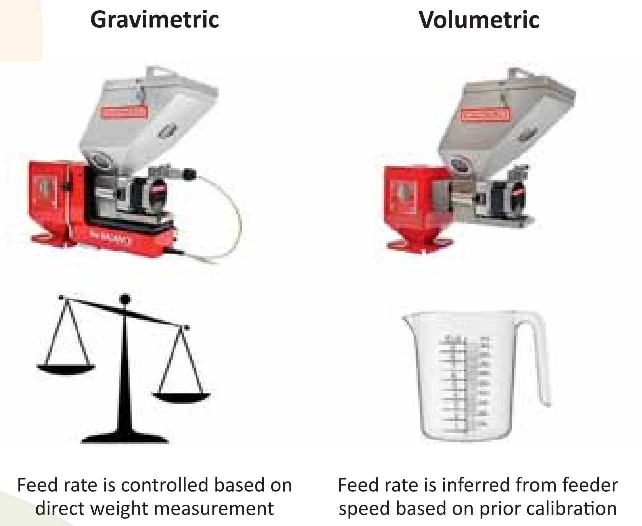


Fig. 2 – Feeding System: Volumetric and Gravimetric

B. Extrusion of Polymer

The main functions of an extruder are to melt the plastics pellets and mix the resulting molten polymer to achieve a homogeneous melt. This is done by conveying the material along a heated barrel with a rotating screw. Screw length to diameter (L/D) ratios commonly lie in the range of 26:1 to 30:1. It is critical to ensure that the polymer flow exiting the extruder is well controlled and constant with variations on the screw's rotational speed not exceeding ±1%. A failure to accurately control the screw speed typically results in undesired pulsating flow that can cause periodic changes in film thickness in the machine direction. In co-extrusion lines, the number of extruders depends on the number of different materials being extruded and not necessarily on the number of layers. This is because the existing feedblock technology allows the flow from one extruder to be split into two or more layers in the final coextrudate.

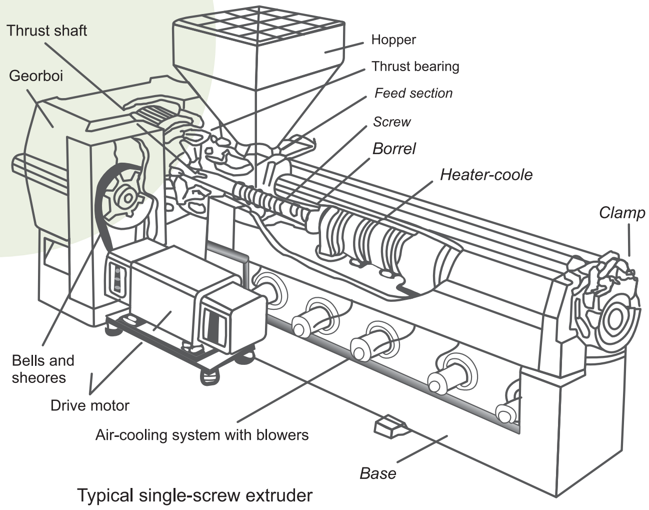


Fig. 3 – Schematic of Extruder

C. Filtration of the Melt

The objective of the filtration system is to prevent downstream passage of melt impurities and/or gels that are formed during the extrusion process. Proper control at this stage is imperative to prevent melt contamination. The most common filters are those containing a metallic mesh. The case hosting the filter media has to be capable of bearing the forces exerted by the polymer flow when subjected to the maximum pressure allowed by the extrusion process. It is highly recommended to use continuous screen changers, in which the dirty mesh is replaced without interrupting the process, to minimize the machine downtime.

D. Melt Curtain Formation Through Flat Die

It can be said that the die system is the heart of any co-extrusion line. The die system is formed by the co-extrusion feed block, the flat die and the melt transfer adapters that transport the different molten polymers from the extruders to the feedblock inlet ports. The quality of the coextruded film and the productivity of the process are greatly dependent on the design and performance qualities of the die system.

The primary function of the die system is to form a mono or multi-layered film that is uniformly distributed across the width of the die with thickness variations on the film and thickness variations on each individual layer within industry accepted tolerances (not to exceed ±2.5% for the total thickness and within ±15 to ±20% for each layer). The co-extrusion feedblock arranges the different melt streams in a predetermined layer sequence and generates as many melt streams as layers are to be in the final co-extrudate. Once this is done, each stream adopts a planar geometry, meets its neighbouring layers and the final planar co-extrudate is formed.

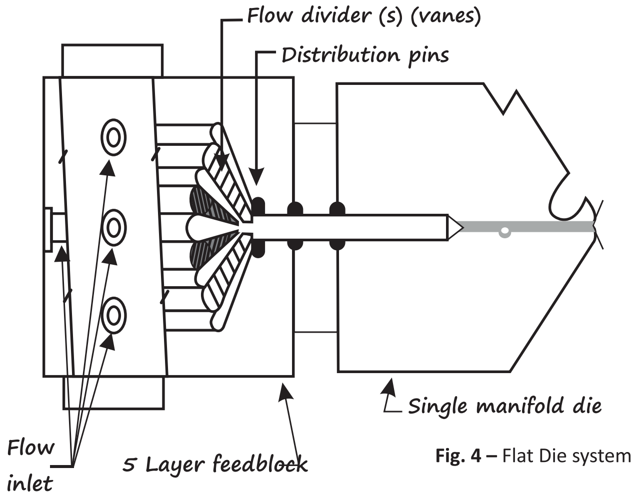


Fig. 4 – Flat Die system

E. Cooling of the Melt Curtain

The cooling unit is comprised of a primary quenching roll, a secondary roll, a motorized roll positioning system for proper vertical and cross machine direction alignment of the rolls, and in many cases a vacuum box and/or air knife. The rolls are typically chrome plated to achieve a better surface finish and to enhance the heat transfer process during film cooling. The cooling agent is commonly water that circulates inside the rolls. The primary quenching roll cools one side of the film while the secondary roll cools the opposite side of the film. The die is positioned above the primary quenching roll at an angle that varies from 45° to 90°. The distance between the die lips exit and the roll ranges from 0.8 to 2 inches. The cooling system allows the line to operate at high speeds. As the line speed requirement increases, so do the diameters specified for the rolls.

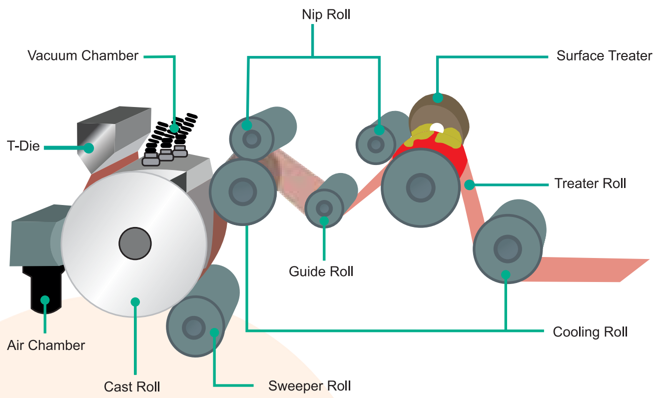


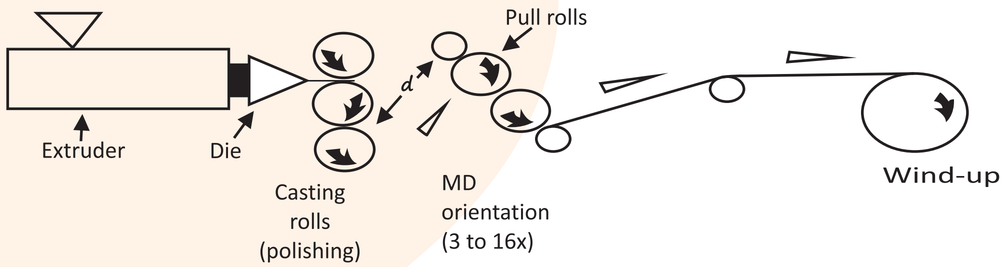
Fig. 5 – Cooling System in Cast extrusion

F. Machine Direction Oriented (MDO) Film

Some of the end applications require an additional MDO stretching. The benefits of MDO technology are numerous. The process enhances the qualities of the film as a packing material, and reduces immediate costs by stretching it, sometimes by more than 6 times. MDO process produces a superior product. Stretched film exhibits greatly enhanced optical properties, which can be tailored to your requirements. If you require a film with low or high gloss, polarization or haze, these options are achievable by scaling the MDO machine settings. Film treated in this way also has better mechanical properties such as improved puncture resistance and easy tearing in a particular direction.

The first step in the MDO process is preheating, where a film is fed into the stretching unit and evenly warmed to the desired temperature. This is followed by orientation, where the film is stretched between a series of rollers that are revolving at different speeds. Next, during the annealing stage, the film's new properties are locked in and made permanent. Finally, it is cooled, when the film is brought back nearly to the room temperature.

The process also confers resistance to moisture because of which the MDO products are not only used as packing materials, but as the impermeable layer in nappies, sanitary products and incontinence pads.



(Note: Distance d is small to diminish "necking" and improve web control.)

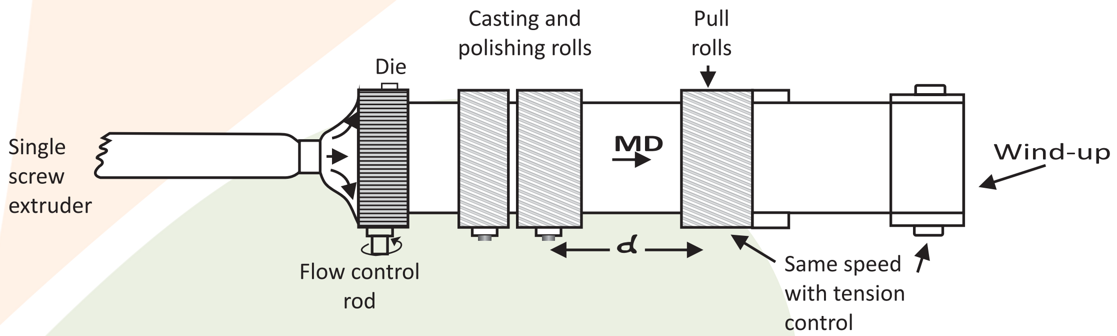


Fig. 6 – MDO Stretching Process

G. Surface Treatment and Winding

In order to facilitate the adherence of inks or coatings onto the film surface it is necessary to apply a surface treatment. Corona treatment is the most commonly used technique among the existing methods. Corona treatment increases the surface energy of the film and consequently its surface tension. Corona treatment can be done inline or as a separate downstream process once the film is produced. If performed inline, special consideration must be given to the potential generation of toxic ozone. In some cases, it is necessary to provide a ventilation system in the production area.

Winders are used to convert the extruded film into rolls of material. The winding process has to be such that the film preserves its properties and dimensions when these rolls are unwound and converted in other down-stream processes. Films can be tacky or have some degree of slip, have high or low elasticity, thin or thick, the required roll diameter can be large or small; rolls can be narrow or wide, soft or hard. In order to evenly distribute defects on the extruded film (thickness variations) a randomizer is used. The randomizer moves the film back and forth, as it is slit and wound. An alternative approach is to move the slitter and winder back and forth relative to the film.

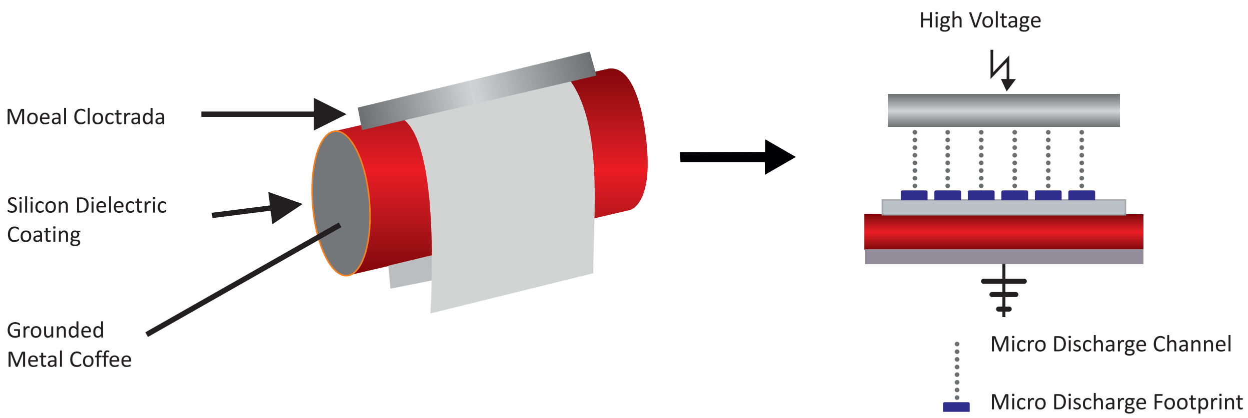


Fig. 7 – Corona treatment Process

Cast Film Process Attributes

- Structure Versatility (Feedblock Mechanism)
- Better Unit Conversion Cost
- Gauge Uniformity
- Higher Production Capacity
- Faster Production Changes
- Excellent Optical Characteristics

Co-extrusion Process and its Advantages

Co-extrusion combines two or more molten polymer layers into a composite extruded web which provides functional, protective, or decorative properties. The majority of new equipment being installed for cast film extrusion will be capable of co-extrusion. The co-extruded films will exit the die via feedblock present in the flat die. Immediately after exiting the die, the melt curtain enters the cooling unit where its temperature is lowered with water cooled chill roll to "freeze" the film.

The film is then passed downstream where the edges are trimmed, corona treatment is applied (if a fabrication process such as printing, or coating is required) and the film is wound into rolls.

Fig. 8 – Co-extrusion process

Advantages of Co-extrusion in Cast Film Process

- Coextruded films result in superior properties compared to equivalent monolayer film
- Thickness reduction is possible by optimizing the layer composition of multilayer film, without sacrificing the film performance, thus reducing the cost.
- In coextruded film, surface defect (like pinhole, die lines) of one layer may be hidden with the other layer, which is not possible in monolayer film.
- Coextruded film helps to increase barrier properties by incorporation of certain resins in inner layers.

Cast Film Resin Selection

Polypropylene (PP) homopolymer serves the cast film segment offering excellent performance, great appearance and easy conversion for the flexible packaging applications. The medium MFI PP resins in the range of 6 to 8 g/10 min cater for the cast film applications. The thickness variation has to be minimum and the film has to be stable with no vibrations. The film formed must be free from gels and unmelts. The resin has to offer low neck-in to achieve maximum film width. The films produced by this process offer low blocking to run smoothly on the FFS line and offers good clarity and surface gloss. There are various types of Cast PP (CPP) film like general CPP, retort grade CPP, metalized CPP, solid white CPP and several others depending on the requirement and end application. CPP has higher tear resistance, better cold temperature performance and heat- sealing properties as compared to BOPP.

Linear Low Density Polyethylene (LLDPE) resins are used in cast film applications offering excellent mechanical properties and high elongation making it suitable for the stretch wrap applications.

Effect of Resin Variables on Cast Film Process

Sl.No.	Resin Properties	Indicator	Cast film Product Properties
1	**Molecular Weight** is directly responsible for mechanical, environmental resistance and processing of polymer.		
1.1	Molecular Weight ↑	MFI ↓	Melt strength ↑
1.2	Molecular Weight ↓	MFI ↑	Melt strength ↓
2	**Molecular weight distribution** is a function of catalyst system and polymerisation process. PE and PP with broad MWD is easier to process due to more shear sensitivity than the one with narrow MWD.		
2.1	MWD (Broad)	FRR ↑	Processability ↑ Haze ↑
2.2	MWD (Narrow)	FRR ↓	Processability ↓ Haze ↓
3	**Stereo regularity** measured by Isotacticity		
3.1	Isotacticity ↑	Xylene solubility ↓	Clarity ↓ Gloss ↓
3.2	Isotacticity ↓	Xylene solubility ↑	Clarity ↑ Gloss ↑

Table 1 – Correlation between Resin & Product Property

Polysure PP and LLDPE Grade Offerings for Cast Film Sector

Polysure PP

HMEL offers Polysure PP grades F08RR and F08RR1 for the cast film applications. Polysure F08RR and F08RR1 are Polypropylene Homopolymers, produced by Novolen and latest Spheripol – II Technologies respectively & primarily suitable for Cast PP film extrusion process. F08RR / F08RR1 combines exceptional processability at high line speed with low neck-in, high heat seal strength, excellent clarity & gloss.

Sector	Grade	MFI*	Typical Applications	Special Characteristics
Polysure PP – Homopolymer (Novolen / Spheripol - II Technology)				
Cast film	F08RR / F08RR1	8	Metallisable cast film, Cast Film for Textile Overwraps, Garment Bags, Snacks and Food Packaging	Low neck in and Excellent opticals

**MFI in g/10 as per ASTM D1238*

Table 2 – Characteristics of Polysure Cast Film grades

Typical Properties of Polysure PP Grades

Sl. No	Property	Test Method	Unit	F08RR	F08RR1
1	Melt Flow Index (230°C & 2.16 kg)	ASTM D1238	g/10 min	8	8
2	Tensile Strength at Yield, Type I Specimen	ASTM D638 (50 mm / min)	MPa	35	35
3	Tensile Elongation at Yield, Type I Specimen		%	10	10
4	Flexural Modulus (1% Secant)	ASTM D790A	MPa	1500	1500
5	Notch Izod Impact Strength (23°C)	ASTM D256A	J/m	30	30
6	Vicat Softening Point (10N)	ASTM D1525	°C	154	154
7	Heat Deflection Temperature (0.455 MPa)	ASTM D648	°C	100	100

*****All the mechanical properties are tested on Injection molded Test Specimen, prepared in accordance with ASTM D4101*

Table 3 – Properties of Polysure PP Cast Film grades

F08RR / F08RR1 Grade Benefits Include

Smooth and consistent processability

Low neck-in and great control over thickness

Excellent opticals

Good adhesion

Polysure LLDPE

Polysure F0218L is a 1-butene comonomer based Linear Low Density Polyethylene, produced by Gas Phase – UNIPOL™ PE technology and primarily suitable for Cast Film Extrusion Process. This grade does not contain Slip & Anti-block additives. Film produced with F0218L offers excellent optical, superior mechanical, tear resistance & good heat seal properties.

Polysure LLDPE (Univation)

Sector	Grade	MFI*	Density**	Typical Applications	Special Characteristics
Cast Film	F0218L	2	0.918	Liner, Agricultural Films, Air Bubble Film, Cast Film & Stretch Wrap Film	Excellent Clarity Without Slip & Anti-block

**MFI in g/10 as per ASTM D1238 **Density in g/cc as per ASTM D1505 at 23°C*

Table 4 – Characteristics of Polysure LLDPE Cast Film grades

Typical Properties of Polysure LLDPE Grade

Sl. No	Property	Test Method	Unit	F0218L
1	**Resin Properties**			
1.1	**Melt Flow Index (190°C & 2.16 kg)**	ASTM D1238	g/10 min	2.0
1.2	**Density (23°C)**	ASTM D1505	g/cc	0.918
2	**Film Properties***			
2.1	**Tensile Strength @ Yield (MD/TD)**	ASTM D882 (500 mm / min)	MPa	9 / 9
2.2	**Tensile Strength at Break (MD/TD)**		MPa	29 / 22
2.3	**Tensile Elongation at break (MD/TD)**		%	650 / 760
2.4	**Elmendorf Tear Strength (MD/TD)**	ASTM D1922	g/micron	5.3 / 15.2
2.5	**Dart Impact Strength**	ASTM D1709A	g/micron	2.7
2.6	**Haze**	ASTM D1003	%	11
2.7	**Gloss**	ASTM D2457, 60°	GU	95

** The film properties have been measured on 25.4 µm (1.0 mil) thick films (Blow-up ratio: 2.5, Die Gap: 1.8 mm)*

Table 5 – Properties of Polysure LLDPE Cast Film grade

F0218L Grade Benefits Include

- Smooth and consistent processability
- Great thickness control & wrinkle free films
- Superior opticals
- Good elongation and strength
- Great puncture resistance

Processing Guidelines

For PP (F08RR/ F08RR1)

- Barrel Temperature: 200 - 260°C
- Quench Temperature: 15 - 20°C

For LLDPE (F0218L)

- Barrel Temperature: 175 - 220°C
- Quench Temperature: 15 - 20°C

Storage & Handling

Bags should be stored in dry & dust free environment at temperature below 50°C and Prevent from direct exposure to sunlight & heat to avoid quality deterioration.

Regulatory Requirements

Polysure Polypropylene grades are manufactured complying the requirements specified in IS 10910 on "Specification for Polypropylene & its Copolymers for safe use in contact with Foodstuff, Pharmaceutical & Drinking water". Furthermore, the Additives added in this grade formulation compiles to the "Positive list of constituents for Polypropylene, Polyethylene and their Copolymers for its safe use in contact with Foodstuffs & Pharmaceuticals' as laid down under IS 16738:2018. In general, the additives & constituents used in the grade are in line with requirement laid down under FDA: CFR Title 21,177.1520, Olefin Polymers.

Polysure Polyethylene grades are manufactured complying the requirements specified in IS 10146 on "Specification for Polyethylene for its safe in contact with Foodstuff, Pharmaceutical & Drinking water". Furthermore, the Additives added in this grade formulation compiles to the "Positive list of constituents for Polypropylene, Polyethylene and their Copolymers for its safe use in contact with Foodstuffs & Pharmaceuticals' as laid down under IS 16738:2018. In general, the additives & constituents used in the grade are in line with requirement laid down under FDA: CFR Title 21,177.1520, Olefin Polymers.

Cast Film Applications

In recent years, there has been an increase in the number of applications in cast film sector. Film with Special Performance based on several types of polymers are available in the market to choose from.

Industrial

- Surface Protection films
- Stretch wrap for transportation
- Lamination


Household

- Thermoformable sheet
- Stationary and Packaging
- Window Covering film


Food Industries

- Candy/Confectionery packaging
- Semi-Rigid Packaging
- Deep freeze application
- Bakery Products


Agriculture

- Mulch films


Textile

- Garment Covers/Bags


Troubleshooting Guide for Cast Film Process

Many a times, we face processing & performance related difficulties during manufacturing of cast film. Although these issues vary from machine to machine, but most of them can be addressed easily with proper selection of resin powder or little adjustment in operating procedures. The probable cause and remedy for few generic issues of cast film extrusion process are recommended here.

ISSUES	POSSIBLE CAUSES	TYPICAL SOLUTIONS
NECK-IN	▪ High melt temperatures ▪ Melt strength of polymer is too low	▪ Decrease the melt temperature ▪ Select higher melt strength resin
EDGE TEAR	▪ High draw ratio ▪ Low melt temperature	▪ Decrease the die gap ▪ Increase melt temperature
THICKNESS VARIATION	▪ Extruder Surging ▪ Flow Variation at Die	▪ Check screen pack or filter, change if necessary ▪ Check melt temperature fluctuation and pressure fluctuations
POOR OPTICS - HIGH HAZE LOW GLOSS	▪ Low extrusion heats ▪ Slow cooling in casting section	▪ Raise melt temperature ▪ Decrease casting drum temperature ▪ Decrease bath temperature
BUBBLES OR VOIDS	▪ Resin air entrapment	▪ Increase the transition zone temperature ▪ Increase the back pressure
HIGH BACK-PRESSURE	▪ Screen pack chocking	▪ Replace screen pack ▪ Check die lip clearance; confirm die selection. Check extruder temperature settings
DIE LIP BUILD-UP	▪ Machine ▪ High Melt Temperature	▪ Minimize resin shear - increase feed zone temperatures ▪ Decrease the melt temperature to avoid thermal degradation
BLACK SPECKS	▪ Resin/ Machine	▪ Replace screens ▪ Check operating temperatures

ISSUES	POSSIBLE CAUSES	TYPICAL SOLUTIONS
FISH EYES	▪ Contamination or degradation	▪ Check the screen pack for discoloured material, which would indicate contaminant with a hopper origin
EXTRUDER SURGING	▪ Resin / Machine	▪ Clear hopper throat ▪ Check hopper feed
SURFACE ROUGHNESS	▪ Die or Resin	▪ Clean die lips. Remove lips and inspect for nicks or edge distortion ▪ Check melt temperature and if required increase die temperatures
SHARKSKIN	▪ Die, resin, or operation	▪ Raise die / melt temperature ▪ Reduce extruder speed or back pressure
WRINKLING	▪ Poor Gauge Control ▪ Non Uniform Quenching	▪ Check & Adjust Thickness ▪ Ensure Optimum Cooling
FLOW LINE / STREAKS	▪ Die is Dirty ▪ Die Lip Adjustment	▪ Clean Die ▪ Check Die Gap & Bolt setting
POOR WINDING QUALITY	▪ Non Uniform Gauge ▪ Poor Tension Control ▪ High Blocking	▪ Adjust the thickness ▪ Monitor Drive Load, Adjust Tension or Taper Tension ▪ Add Anti-block additives
DRAW RESONANCE	▪ Improper Melt Temp ▪ Improper Die Gap ▪ Inconsistent Polymer Release from Die	▪ Adjust Melt Temp ▪ Adjust Die Gap ▪ Add PPA

ISSUES	POSSIBLE CAUSES	TYPICAL SOLUTIONS
DISCOLORATION	▪ Met Temp Too High ▪ Resin Contamination	▪ Reduce Melt Temp ▪ Avoid Contaminated Material
POOR HEAT SEAL STRENGTH	▪ Improper Additive level ▪ Excess Corona Treatment	▪ Adjust Additive Level ▪ Reduce Treatment Levels
POOR STRENGTH	▪ Processing Temp/ Casting Temp ▪ Excess Pressure & ▪ Temperature at Nip Rollers	▪ Adjust / Reduce Temp ▪ Adjust Nip Roll Setting & Temperature
SCRATCHES	▪ Drag at Idler Roll ▪ Abrasive Surface Roll	▪ Idler Roll not running at Line speed ▪ Inspect & Modify the Roll
FILM BLOCKING	▪ Inadequate Cooling ▪ Winding Tension Too High ▪ Static charge Build Up	▪ Reduce Cooling Temp & Reduce Line speed ▪ Reduce Winding speed ▪ Add Static charge eliminator
METALLIZATION	▪ Stearate Presence ▪ Treatment Levels	▪ Use Stearate Free Grade ▪ Increase Surface Tension

Table 6 – Trouble shooting solutions for Cast film application

Customer Services & Development Center

HMEL has chartered on a goal to emerge as a responsible player in the Petrochemical Industry. HMEL has set up a state-of-the-art Customer Services & Development Center (CSDC) at Noida to strengthen its customer value proposition through Research & Development.

HMEL's CSDC is equipped with sophisticated and advanced testing equipment and is aptly designed to have flexibility which allows diverse modes of testing. We are committed to produce consistent quality products in line with industry needs & always stand by our customers for all-round support for product, application and market development initiatives.

Accreditation of CSDC

- This center is accredited to **ISO/IEC 17025:2017** by National Accreditation Board for Testing and Calibration Laboratories (NABL), Govt. of India.
- Further, Customer Services & Development Center (CSDC), Noida has been recognized and registered as one of the key scientific and industrial R&D facility by **Department of Scientific & Industrial Research (DSIR),** Ministry of Science and Technology, Govt. of India.

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