CADENCE COPOLYESTER RESINS FOR CALENDERED FILM

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Abstract

Eastman Chemical Company's *Cadence* Copolyesters are specially designed for calendering. Calendering is a process for the production of plastic film and sheet. Thickness ranges are typically .002-.030" and widths from 36-120". Production rates range from 1000-10000 pounds per hour. This process is predominantly used for flexible and rigid Polyvinyl Chloride. This unique combination with *Cadence* Copolyester resins provides the physical performance and attributes of the copolyester polymer with the efficiency and quality advantages of the calendering process.

Introduction

Eastman Chemical Company recently introduced a new line of copolyesters for use in making film or sheet via calendering. These copolyesters, sold as *Cadence*, and their use in the calendering process are covered by claims in U.S. Patents 6,068,910 and 6,551,699. Corresponding patents have been issued in Japan and Europe. Patent and Trademark Licenses in this area are being considered.

Calendering is an economic and highly efficient means to produce film and sheet from plastics such as plasticized and rigid poly (vinyl chloride) (PVC), These film and sheet products are then subjected to secondary processes for various end uses. They are readily thermoformed into various shapes and are used for a wide variety of packaging applications. They can be decoratively or functionally printed, laminated to various substrates and/or Rf heat sealed. They can then be used in a wide range of applications including graphic arts, transaction cards, security cards, veneers, wall coverings, book bindings, folders, floor tiles. Thermoplastic Polyolefins, Thermoplastic Polyurethanes, and ABS or MBS Alloys can also be calendered but don't always have the secondary processing characteristics of the PVC products.

In a typical calendering process line, the plastic resin is blended with specific ingredients such as stabilizers to prevent thermal degradation; modifiers for clarity, heat stability or opacity characteristics; plasticizers for flexibility; pigments; lubricants and processing aids; anti-static agents; UV inhibitors; and flame retardants. The blended ingredients are Fused or gelated in an intensive mixer, such as a Banbury, a kokneader or an extruder. Through heat, shear and pressure, the dry powders are fused to form a homogeneous, molten material. Depending on the intensive mixer (batch or continuous) it may be necessary (or individually preferred) to introduce an interim holding station, such as a two roll mill, to facilitate the transition to a continuous process. The molten material is then fed, in a continuous process matched to the calender output, to the top of the calendering section of the calendering line in between first and second heated calender rolls. Typically, four rolls are used to form three nips or gaps although there are 2, 3, 5, and 6 roll configurations. The rolls can be configured in an "L" shape, an inverted "L", or a "Z" shape. The rolls vary in size to accommodate different film widths, with roll diameter generally a factor of roll width. The rolls have separate temperature and (preferably) speed controls. The material proceeds through the nip between the first two rolls, referred to as the feed nip. The rolls rotate in opposite directions to help spread the material across the width of the rolls. The material winds between the first and second, second and third, third and fourth rolls, etc. The gap between rolls decreases in thickness between each of the rolls so that the material is thinned between the sets of rolls as it proceeds. After passing through the calender section, the material moves through another series of rolls where it is stretched. It can then be fed through an embossing nip to impart a finish or texture and gradually cooled forming a film or sheet. The cooled material is trimmed to the desired width and wound into master rolls. General descriptions of calendering processes are disclosed in Jim Butschli, Packaging World, p. 26-28, June 1997 and W. V. Titow, PVC Technology, 4.sup.th Edition, pp 803-848 (1984), Elsevier Publishing Co., and the Encyclopedia of PVC, Volume 3, Chapter 3, incorporated herein by reference.

Calendering, as a process, offers a unique advantage for the *Cadence* copolyesteresins and other polymers. There is no need to "pre-dry" the polymer prior to the calendering process. Lower processing temperatures and inherent venting opportunities, of the process, avoid the problems of moisture and degradation or transesterification.

Modern extrusion rates will approach calender rates but the "pre-drying" requirements present another challenge to economic and efficient manufacturing operations.

The *Cadence* series of copolyester resins was developed specifically to take advantage of the calender process strengths and robustness. Five grades were originally designed for distinct properties.

GS1 – Base Grade
GS2 – High Clarity
GS3 – High Melt Strength
GS4 – High Flow
GS5 – Calendering Rate Improvements

A series of lubricant packages was developed, again designed for distinct properties.

ADD2 – High Clarity
ADD3 – High Temperature and Efficiency
ADD5 – Specific to GS5 for Rate Improvement

Experimental

Initial development work was accomplished on a Dr. Collin, instrumented, two roll mill. The *Cadence* series of copolyester resins and their corresponding lubricant packages were evaluated for various processing parameters and the physical effects that the processing equipment would experience.

Table 1 exhibits the total resistance to roll, measured in Newton meters at the appropriate roll temperature and increasing roll speeds for each of the *Cadence* resin systems.

Table 2 exhibits the bearing pressure, measured in kiloNewtons at the appropriate roll temperature and increasing roll speeds for each of the *Cadence* resin systems.

Table 3 exhibits the melt or bank temperature, in degrees Celsius, at the appropriate roll temperature and increasing roll speeds for each of the *Cadence* resin systems.

The Dr. Collin two roll mill work was then transferred to Nippon Roll six roll, and five roll Dr.Collin pilot line calenders. An example of the trial conditions for the six roll pilot line is outlined below.

Feed from a Planetary Gear Extruder:

Zone 1	175C
Zone 2	175C
Screw	175C
Melt Actual	188C

Calender

Roll	Temp: Set/Actual	Speed (m/min)
Roll 1	157C / 154C	0.95
Roll 2	157C /	1.39
Roll 3	168C / 162C	1.59
Roll 4	185C / 178C	1.97
Roll 5	190C / 186C	2.53
Roll 6	180C / 176C	3.16

Take-off Rolls

Rolls 1 – 3	6.87
Rolls 4 – 6	6.92

Discussion

Cadence materials have the ability to be processed on existing calendering equipment and bring many performance attributes comparable to existing film and sheet products that the market place is accustomed to seeing.

Cadence resins for use in calendered films bring improved performance over some other materials. When compared to PET *Cadence* materials will not crystallize, they have a wide calender window and a wide thermoforming window. They have good low-temp toughness and are less susceptible to hydrolysis. They perform well in secondary processes such as cutting, bonding and decorating.

Calendered polypropylene has been used in some applications. By comparison, *Cadence* materials have improved performance in scratch resistance and toughness as well as secondary processing such as printing and bonding compared to PP.

There is also the comparison of Calendered Films made from *Cadence* resins to PVC films. In general, PVC films are considered to fall in three categories; rigid, semi rigid and flexible. The semi rigid and flexible forms of PVC are obtained by adding plasticizers to the formulations. *Cadence* materials in general are more flexible than rigid PVC materials. *Cadence* materials without plasticizer would typically fall into a semi-rigid category. *Cadence* resins can be made flexible with the addition of plasticizers as needed.

Calendered Films made from Cadence resins can be processed on existing calendering equipment at commercially acceptable rates. In heavier gauges, films made from *Cadence* GS5, have shown a tendency to run faster and process smoother. The data shown in tables 1, 2 and 3 indicate that the force required to run *Cadence* GS5 resins on a calender process is less than the other *Cadence* GS resins.

This translates into faster running speeds and less tendency to form melt fracture during the process (see table 4).

The physical property comparison shown in Table 5 only shows properties for *Cadence* GS2 resins. The physical properties for *Cadence* GS1-5 resins are all similar.

Additionally, additives have been developed for *Cadence* materials, including release additives, color concentrates, impact modifiers, flame retardants and the like.

There are many applications that can be served with *Cadence* resins. These fall into three general categories; decorative laminates, industrial films and packaging applications.

Decorative laminate films are used in furniture films for both home and office use. The simplest application is flat lamination where the film is glued to a surface at room temperature. This is used for ready to assemble furniture, some styles of cabinets and home electronics for example. Some films are wrap laminated around a profile for some furniture and cabinet applications. The more demanding performance requirement in furniture laminated products is in thermoformed applications. Here the film is typically membrane pressed onto a preformed cabinet door and shaped to the door top, edges and routed decoration in the door panel. This process is conducted at elevated temperature and has a high requirement on the material for emboss retention and thermoformability to obtain good aesthetics. (Reference; Wood Digest, July 2004, p. 108)

Additional Decorative laminate applications include lamination to metal for ship building, elevators and appliances.

The industrial films applications include label films, and card applications. *Cadence* resins can be produced as card base stock as well as clear overlay films.

Packaging applications include all of the current places that extruded films are found such as lidding films, thermoformed packaging (clamshells, boxes, and blister packaging) and shrink films.

Conclusion

Calendered films made from Cadence copolyester resins can be produced on existing calendaring equipment. This combines the physical performance and attributes of the copolyester polymer with the efficiency and quality advantages of the calendering process

References

Packaging World, June 1997, p.26-28 Jim Butschli,

PVC Technology, 4.sup.th Edition, pp 803-848 (1984), W. V. Titow, Elsevier Publishing Co.

The Encyclopedia of PVC, Volume 3, Chapter 3, Marcel Dekker, Inc.

Wood Digest, July 2004, p. 108

Table 1

Effect of Roll Speed on Total Resistance to Roll at a Roll Gap of 0.2mm

Roll Speed	Sample 1	2	3	4	5
5 RPM	337	331	440	265	252
10 RPM	431	396	406	337	313
15 RPM	471	454	425	369	359
20 RPM	487	481	451	400	378

Roll temperatures at 170^{o}C except for sample 4 at 160^{o}C

Table 2
Effect of Roll Speed on Bearing Pressure at a Roll Gap of 0.2mm

Roll Speed	Sample 1	2	3	4	5
5 RPM	32	31	41	27	24
10 RPM	38	37	34	34	28
15 RPM	41	44	36	35	32
20 RPM	44	47	38	39	33

Roll temperatures at 170^{o}C except for sample 4 at 160^{o}C

Table 3
Effect of Roll Speed on Bank temperature at a Roll Gap of 0.2mm

Roll Speed	Sample 1	2	3	4	5
5 RPM	166	166	144		168
10 RPM	174	175	169		170
15 RPM	176	183	174		175
20 RPM	181	186	178		175

Roll temperatures at 170^{o}C

Table 4
Effect of Roll Speed on Melt Fracture at a Roll Gap of 0.2mm

Roll Speed	Sample 1	2	3	4	5
5 RPM	Clear	Clear	Clear	Clear	Clear
10 RPM	Slight MF	Slight MF	Clear	Clear	Clear
15 RPM	MF	MF	Slight MF	Clear	Clear
20 RPM	MF	MF	MF	Clear	Clear

Roll temperatures at 170^{o}C except for sample 4 at 160^{o}C

Table 5
Physical Property Comparison of Typical Calendered Materials

Test	Units	Method	APET	*Cadence* GS2	PVC	K-Resin	PP
Haze	%	D1003	0.5	0.5	1.2	>2	NA
Density	g/cm^3	D1505	1.33	1.27	1.35	1.01	0.905
Tensile Strength	MPa	D822	58	52	44	26	36
Break Strain	%	D822	200	400	235	160	500
Flexural Modulus	MPa	D822	2206	1930	2344	1413	1241
Dart Impact @ 23°C	g	D1709A	425	425	410	50	91
HDT @ 1.82 MPa	°C	D648	63	63	65	73	130