Pinning and Polishing Ingeo™ Biopolymer

Casting a web of Ingeo biopolymer incorporates the two functions of pinning and polishing. They are treated separately in this note because either or both are of importance depending on customer needs for heat transfer & finish on the surface of the web. The physics of each function are described, and afterwards, more specific recommendations are given for Ingeo biopolymer webs.

1.0 Pinning

It is very important that the web intimately contact the roll that will cool or solidify the molten material. The following discussion is a description of the physics of the process and lays out the perspective from which specific recommendations for Ingeo biopolymer are based.

The goal of all the pinning methods is to force the molten material against a polished roll so that maximum heat transfer can occur. The surface characteristics of the roll are selected to accomplish the objectives for surface characteristics needed in the finished sheet, as the web surface against the roll takes on the surface characteristics of that roll. The surface of the web that is not pressed into the main cooling roll should also be free from optical blemishes, and should present a uniform appearance that is acceptable for customer use.

Pinning and polishing takes place on the side that contacts the roll only.

The roll and the plastic will run at different linear speeds as the molten plastic cools. If the force that the length of sheet exerts on the cooling portion of the plastic web is greater than the frictional force between the plastic and the roll, then the plastic will slip on the roll causing scuffing of the web or air entrapment between the roll surface and the web. This slipping or poor contact causes scratching of the web surface, and dramatically affects heat transfer from the web to the roll. This leads to plate-out on the roll and less than optimum finish on the web. Remember, the finish of the web on the side that touches the roll, will be the finish of the roll if the material is warm and pliable enough to accept that surface. (Above solidification point)

As the web becomes thicker, there is more mass and therefore more heat in the web. This additional heat that comes from increased speed of processing, thickness, melt temperature or roll temperature, makes the surfaces of the web more pliable and easier to maneuver. The warmer the web is, the easier it is to coerce the material into flatter form. The higher the solidification temperature of the material being processed, the more force would be required to accomplish this flattening or smoothing of the web. The small incremental changes in thickness across the web can be pushed by a force that would try to flatten the web and make the overall gauge more uniform. If the web is thick enough, (Greater than 50 mils [1270 microns]), a second chrome roll with a force capable of applying 300 pounds per linear inch (pli) (525 N/linear cm) could maneuver the web so that the high spots or mountains of the web were squeezed into the lower spots or valleys across the width of the web.

Because the second chrome roll does not deflect in small increments like the molten plastic web, there must be enough force on the roll to push the excess material mountains into the valleys on the web. The greater the force capability (pli or pounds per linear inch), the easier it is to maneuver the material's mountains & valleys. If there is ***insufficient*** nipping force available on the chrome roll, the soft plastic will lift the roll at the point where there is excess material, causing the chrome roll to float & possibly not make contact with the web in other areas. This may lead to plate-out on the pinning chrome roll.

One way to get around this floating roll problem would be to make a pinning roll that can deflect in small increments like the molten plastic. This type of pinning roll would be a silicone rubber roll that would be able to withstand the molten temperatures of the plastic material, but be able to deflect in small increments so the roll surface would give rather than the solidified regions of the web. This method of pinning works well, but the web surface exposed to the silicone roll will lose gloss and become a matt finish.

A similar method that allows deflection in small increments is an air knife where high velocity air is used to apply a force to the web pinning it against the flat surface of a chrome roll. The chrome roll does not deflect, but the air can be easily diverted and the resultant web's irregularities simply pass under the air curtain & divert the air to another area. The drawback to use of an air knife is dealing with the spent air from the pinning air knife. The high velocity air used to force the web against the roll sometimes causes flutter in the molten web. This flutter may create marks in the web that are unacceptable to customer requirements. It can also create problems with material that has a low viscosity. Another similar method is using a vacuum box, which sucks the material into the chrome roll, but this method also must deal with the surrounding air that is pulled into the vacuum box and it also has problems with low viscosity materials.

A method that does not have to deal with excess air and its problems is the use of an electro-static pinning wire. This device sets up a magnetic field around the pinning wire, and pushes the material against the grounded chrome roll. Although there is no excess air to worry about, the pinning wire exerts the least force on the web of all pinning methods, and there is also a high voltage (10 to 15kv) present on the wire that generates the magnetic field to provide the nipping force.

Finally, a newer method for pinning is the use of a flexible polished metal web that partially sandwiches the material between the polished & non-deflecting chrome roll and the flexible foil. At present, this method is not widely used and is still being evaluated for different materials.

2.0 Polishing

Having covered the physics of pinning, we now turn to polishing and describe the perspective from which the more specific Ingeo biopolymer recommendations are based. The polish that the web takes on is a function of the roll surface that the material is pressed against; the solidification temperature of the material being processed; the length of time the material is in contact with the surface of the polishing device; and the pressure or force applied against the material.

One can easily see how the surface of the molten material will take on the surface of the roll that it is pinned against. However, as the material cools below its solidification point, the force required to maneuver the surface of the material to comply with the surface being pressed against it becomes very high and in some cases impractically high. It is important to note that polishing on both sides of the material requires that the material's temperature be well enough above the solidification point, so that it will take on the surface being pressed against it. As material thickness increases or line speed increases, the temperature of the web will be warmer as it leaves the first main cooling roll, and the surface of the material is more likely to be maneuvered by the next roll that it encounters.

On a conventional three roll vertical stack, the bottom roll has less nipping force capability than the top roll. This is because the weight of the roll due to gravity, subtracts from the nipping force available at the material contact point. For a down stack configuration, the reduction in nipping force happens when the web is cooler and therefore more difficult to maneuver. Polishing the second side (or double polishing) is obviously more difficult.

Polishing both sides of the web can be accomplished only if the material's temperature is above its solidification point. This can be accomplished by elevating the temperature of the first cooling roll, or increasing the speed of the line, or making the first contact roll smaller in diameter, & therefore have less cooling capability. All of these methods have limitations. The first roll cannot be set above a temperature where the material will stick and cause "pick marks". An increase in line speed may cause higher melt temperature and therefore create sag between the die and the first contact point. If the material is run on an existing machine, it is almost impossible to change the diameter of the roll due to roll support design and nip points.

We hasten to add that because extruded Ingeo biopolymer has such an inherently high gloss, double polishing is usually not necessary, and additional cooling rolls do not need to nip & polish the second side of the material. Adequate downstream tension control will keep the material against the cooling roll to allow heat transfer without affecting surface finish.

3.0 Specific Recommendations for Pinning and Polishing Ingeo Biopolymer

The viscosity of Ingeo biopolymer climbs rapidly as it cools down to the solidification temperature, therefore, as it hits the chill roll, it becomes stiff and becomes increasingly difficult to deform with the chill rolls. IF there is not excessive sag, actually going up in melt temperature can help because the material stays warmer and thereby softer longer as it has further to cool than a cold melt. Of course, it is necessary to balance the benefit in malleability from a warmer cooling web with the sag, which can be troublesome, if it is too much and causes premature contact on the chill roll. Because we are balancing issues that sometimes have contradictory actions for correction, it can be reasonable to test the impact of both increasing and decreasing a variable.

1. A hydraulic nip can supply enough pressure to alleviate most casting and polishing problems, especially when used in conjunction with the advice below.

2. Assure that contact with the casting roll (middle roll in the 3-roll stack) happens at the nip point.
    - o This avoids polishing blemishes from trapped air or folds in web that do not polish out
    - o Reduce melt temperature to reduce sag (and neck-in)
        - Ideal melt temperature is 410°F +/- 20°F. (210ºC +/- 10ºC) Temperatures of 440°F (225ºC) and higher can be of concern.
            - Most excessive heat is from shear – improved screw design, lower rpm's and shorter L/D is better
            - Open mesh screen packs are better -- 40-60 mesh is better than 125, but 325 is of concern with respect to excessive sag and neck-in.
            - Reducing the melt pump inlet pressure will lower melt temperature
    - o Decrease the distance from the die lips to the nip
        - Die design has an impact – sharper angled die preferred to blunt nose
        - A smaller diameter top roll (3-roll down stack assumed) permits die to be closer
    - o Elevate the height of the die relative to the height of the nip point so with sag, the first contact is still at the nip point
        - A smaller diameter top roll (3-roll down stack assumed) permits die to be higher and closer

3. Assure that there is no perceptible bank at the nip point
    - The pli (pounds per linear inch) (N/linear cm) required to polish out the bank is in excess of what a pneumatic nip can typically deliver
    - Set the die gap so that the web thickness is uniform across the web, and preferably so the gap is no more than 10% or a couple mils thicker than the desired sheet thickness
    - Set the nip gap to be equal to the desired sheet thickness or 1 mil (25 microns) less – to kiss the surface. Especially important for pneumatic nips.

4. Excessive neck-in forms an edge bead that requires hydraulic nips to apply enough pressure to keep the roll from floating and bouncing on the web.
    - Reduce neck-in by reducing melt temperature and reducing air gap distance between die and nip point
    - For thin sheet, use an air knife instead of a pneumatic roll to pin the sheet. There is not enough pli in a pneumatic system to pin sheet less than 10-15 mils. (250-375 microns)
    - Alternatively, use directed air (like edge pinners for cast film) to push the web edges into the roll and slightly outward (counteracting the neck-in). Idea is to have one-eighth inch copper tubing directing air (maybe 10 psi) to the edges of the sheet at the nip. The nozzle would be pointing both to the edges of the chill rolls and down so that the edge bead is fanned out, flattened and pinned to the middle roll.

Two lessons from our biax film experience

1. Are the chill rolls too cold? It is necessary to have cool rolls to remove heat and stiffen the web prior to MDO orientation, but there is a need to balance the requirements of cooling the sheet and pinning the sheet. On biax trials, we run the chill roll (just a large diameter chill roll compared to a 3roll stack) very warm so we get good pinning. In fact we run it so warm to the point is just starts to stick at the release point, then we back it off about 2 - 3 C (5 F). Finding the stick point and backing off 5°F works best for us. If the chill roll is too cold, we can't pin and the roll fogs.
2. Biax film involves casting a sheet that is 6-25 mils thick and then orienting it. An air knife causes too much fluttering of the sheet, so isn't a good enough pinning device for biax film. We use electrostatic pinners. It should be possible to pin a 30 - 40 mil (760-1016 micron) sheet with electrostatic pinners in a down stack chill roll system. The difficulty

lies in getting a pinning wire (or bar) arranged in a 3 roll stack. We have never seen this done but suppose it could be engineered. It would probably take some time and possibly trial and error to implement.

Safety and Handling Considerations

Safety Data Sheets (SDS) for Ingeo biopolymers are available from NatureWorks. SDS's are provided to help customers satisfy their own handling, safety, and disposal needs, and those that may be required by locally applicable health and safety regulations. SDS's are updated regularly; therefore, please request and review the most current SDS's before handling or using any product.

The following comments apply only to Ingeo biopolymers; additives and processing aids used in fabrication and other materials used in finishing steps have their own safe-use profile and must be investigated separately.

Hazards and Handling Precautions

Ingeo biopolymers have a very low degree of toxicity and, under normal conditions of use, should pose no unusual problems from incidental ingestion or eye and skin contact. However, caution is advised when handling, storing, using, or disposing of these resins, and good housekeeping and controlling of dusts are necessary for safe handling of product. Pellets or beads may present a slipping hazard.

No other precautions other than clean, body-covering clothing should be needed for handling Ingeo biopolymers. Use gloves with insulation for thermal protection when exposure to the melt is localized. Workers should be protected from the possibility of contact with molten resin during fabrication.

Handling and fabrication of resins can result in the generation of vapors and dusts that may cause irritation to eyes and the upper respiratory tract. In dusty atmospheres, use an approved dust respirator.

Good general ventilation of the polymer processing area is recommended. At temperatures exceeding the polymer melt temperature (typically 175ºC), polymer can release fumes, which may contain fragments of the polymer, creating a potential to irritate eyes and mucous membranes. Good general ventilation should be sufficient for most conditions. Local exhaust ventilation is recommended for melt operations. Use safety glasses (or goggles) to prevent exposure to particles, which could cause mechanical injury to the eye. If vapor exposure causes eye discomfort, improve localized fume exhausting methods or use a full-face respirator.

The primary thermal decomposition product of PLA is acetaldehyde, a material also produced during the thermal degradation of PET. Thermal decomposition products also include carbon monoxide and hexanal, all of which exist as gases at normal room conditions. These species are highly flammable, easily ignited by spark or flame, and can also auto ignite. For polyesters such as PLA, thermal decomposition producing flammable vapors containing acetaldehyde and carbon monoxide can occur in almost any process equipment maintaining PLA at high temperature over longer residence times than typically experienced in extruders, fiber spinning lines, injection molding machines, accumulators, pipe lines and adapters. As a rough guideline based upon some practical experience, significant decomposition of PLA will occur if polymer residues are held at temperatures above the melting point for prolonged periods, e.g., in excess of 24 hours at 175°C, although this will vary significantly with temperature.

Combustibility

Ingeo biopolymers will burn. Clear to white smoke is produced when product burns. Toxic fumes are released under conditions of incomplete combustion. Do not permit dust to accumulate. Dust layers can be ignited by spontaneous combustion or other ignition sources. When suspended in air, dust can pose an explosion hazard. Firefighters should wear positive-pressure, self-contained breathing apparatuses and full protective equipment. Water or water fog is the preferred extinguishing medium. Foam, alcohol-resistant foam, carbon dioxide or dry chemicals may also be used. Soak thoroughly with water to cool and prevent re-ignition.

Disposal

DO NOT DUMP INTO ANY SEWERS, ON THE GROUND, OR INTO ANY BODY OF WATER. For unused or uncontaminated material, the preferred option is to recycle into the process otherwise, send to an incinerator or other thermal destruction device. For used or contaminated material, the disposal options remain the same, although additional evaluation is required. Disposal must be in compliance with Federal, State/Provincial, and local laws and regulations.

Environmental Concerns

Generally speaking, lost pellets, while undesirable, are benign in terms of their physical environmental impact, but if ingested by wildlife, they may mechanically cause adverse effects. Spills should be minimized, and they should be cleaned up when they happen. Plastics should not be discarded into the environment.

Product Stewardship

NatureWorks has a fundamental duty to all those that use our products, and for the environment in which we live. This duty is the basis for our Product Stewardship philosophy, by which we assess the health and environmental information on our products and their intended use, and then take appropriate steps to protect the environment and the health of our employees and the public.

Customer Notice

NatureWorks encourages its customers and potential users of its products to review their applications from the standpoint of human health and environmental quality. To help ensure our products are not used in ways for which they were not intended or tested, our personnel will assist customers in dealing with ecological and product safety considerations. Your sales representative can arrange the proper contacts. NatureWorks literature should be consulted prior to the use of the company's products.

For additional information please contact NatureWorks via our website on the tab called FAQ's or by clicking here.

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