Promoting Adhesion in Commercially Compostable Hot Cups

By Darrell Landry, Technical Sales Representative at Mica Corporation, Jaclyn Epstein, Sales and Marketing Strategy Manager at Mica Corporation & Jessi Spadaccino, Communications Manager at Mica Corporation.

Abstract

Adhesion promoters are a critical component in the manufacture of standard polyethylene-coated paper hot cups because they offer added performance and functionality. As the demand for sustainable solutions for single-use packages increases globally, however, many converters have taken steps to create commercially compostable hot cups using inherently compostable materials like bio-based resin and paperboard. The challenge converters are facing, though, is that to create a truly compostable hot cup, all materials must be able to degrade into the environment safely, including adhesion promoters which are not inherently compostable. Without a viable compostable replacement for polyethyleneimine PEI primers, it has been challenging for converters to produce hot cups with the same performance and functionality that consumers have come to expect. However, a new-to-market compostable adhesion promoter may be able to help converters solve this challenge. This paper will compare the application specifics, regulatory requirements, process conditions, and performance of traditional PEI primers and the new water-based compostable adhesion promoter in hot cup applications.

Introduction.

There are more than 105 million disposable hot cups used in the United States every day and many of them end up in landfills and in our environment[1]. Consumers around the world are demanding solutions to this global waste problem, and many major brand owners have responded by setting aggressive sustainability goals and initiatives promising to create packages that contribute to a circular economy. One approach to mitigating single-use packaging waste would be to create 100% compostable hot cups. In the proper conditions, compostable materials do not leave any toxic residues behind and can help condition the soil in which they degrade. However, until recently, the road to creating multi-layer compostable packages and containers for consumables has been challenging.

In order for any hot cup to make it to market, the manufacturing process, performance specifications, and regulatory requirements for all ingredients need to be thoroughly evaluated, understood, and approved. When it comes to compostable cups, all of the above requirements need to be met, but the finished product also needs to pass a series of rigorous compostability tests before a converter can claim the structure is compostable and/or obtain compostable product certification.

Materials like bio-based resins and paper are great for compostable hot cup applications because the manufacturing process is similar, they typically have the proper regulatory compliance, and are inherently compostable. However, most of these materials do not achieve the necessary performance requirements on their own and need an adhesion promoter to enhance seal strength, improve printability, and reduce wicking, or staining.

Due to strict testing requirements, converters are not able to use standard PEI primers to improve performance in compostable products if they want to pass rigorous compostability testing, like the ASTM D6400, and/or obtain compostable certification. A newly developed compostable adhesion promoter is proving to be viable in hot cups, and other mutli-layer compostable structures. Observational and lab data in this paper will compare the performance of the new compostable adhesion promoter and a widely used, water-based PEI adhesion promoter in hot cup applications.

Hot Cup Application Specifics

A typical paper hot cup structure is made from paperboard stock that is extrusion coated on one side, traditionally with low density polyethylene (LDPE). The cup stock is printed, and then die-cut into cup blanks. The blanks are then loaded into a cup-making machine to form and seal into a paper cup.

Cup-making machinery has improved substantially over the years. While older machinery produced up to 180 cups per minute, newer, high-speed cup making machines can make up to 320 cups per minute. At these high speeds, the dwell time in each sealing station is less than one-fifth of a second. These sealing conditions make cup forming more difficult with one-sided LDPE-coated paperboard.

In addition to increased line speeds, in recent years the LDPE extrusion coat weight for hot cup applications has been reduced from 1.0 mil (14.4 lbs./3000 ft^2) to the now typical 0.75 mil (10.8 lbs./3000 ft^2) to keep up with competitive demand. This reduction in coat weight has significantly increased the potential for a common defect in hot cups known as flaggers.

Flaggers occur at the rim of a paper hot cup, at the top of the sidewall seam. In this area, the thickness of the rim sealing area is double that of the rest of the sidewall. Due to the thickness along the sidewall seam, the forming of the cup rim causes an area of higher pressure, which thins the poly extrusion coating significantly. Poly thinning is the primary cause of the flagger defect.

Below is a diagram of the paperboard hot cup (Figure 1), an example of a well-formed rim (Figure 2) and a photo of a rim with a flagger defect (Figure 3).

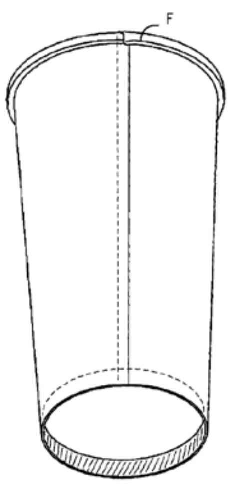

Figure 1

Figure 2

Figure 3

A typical flagger allowance would be two occurrences or less per 1,000 cups made. More than two occurrences would cause the production to be considered substandard, and in many cases, the entire batch of cups would be rejected by the customer.

To minimize the formation of flaggers, many cup makers have traditionally applied modified PEI adhesion promoters on the uncoated side of the paper hot cup sidewall stock. This process allows the extruded coating to have higher bond strengths in the area where flaggers typically occur.

Compostable hot cup structures are similar to standard ones, but instead of an LDPE coating on one side, an inherently compostable bio-based resin, like polylactic acid (PLA) or polyhydroxyalkanoates (PHA), is used. However, just as with typical hot cups, due to the fast-moving cup making machinery and the need for a better performing final product, an adhesion promoter is often needed to manufacture compostable hot cups.

Mica Corporation has recently developed a Compostable Adhesion Promoter (CAP) to meet this market need.

Comparison Testing

A heat-seal screening study was conducted to compare the heat-seal strength of PLA to paperboard with and without the PEI primer and the CAP. In this comparison, a baseline water-based modified PEI adhesion promoter used widely in the industry was tested.

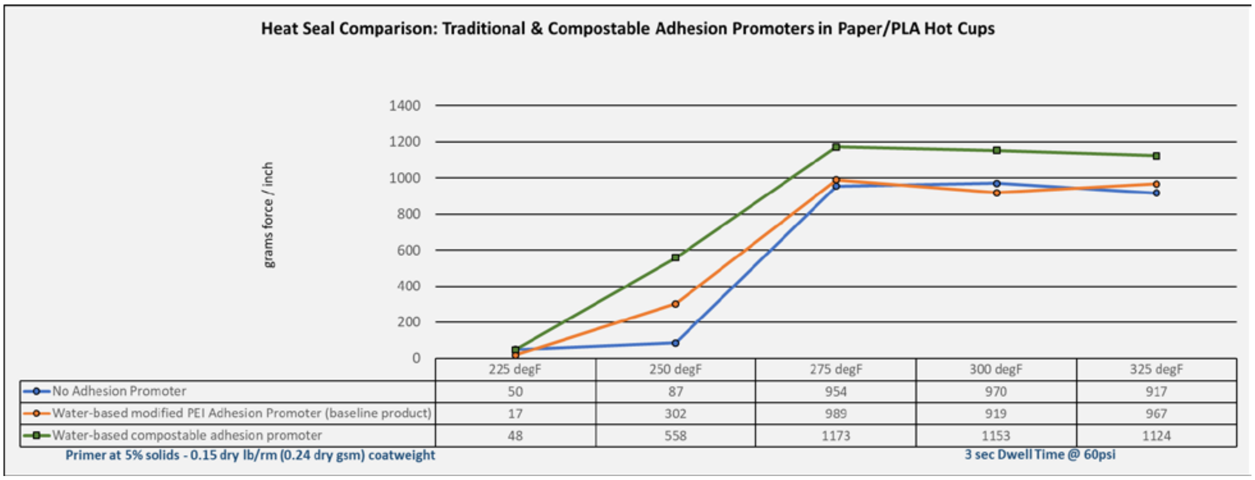

Figure 4: Heat-seal performance comparing traditional PEI adhesion promoter to CAP

The heat seal curves in Figure 4 suggest that the PEI primer and CAP will increase heat-seal strength on PLA-Coated cup stock, but the CAP performs significantly better at higher temperature ranges.

Additional Benefits of Using Adhesion Promoters in Hot Cups

In addition to increasing heat seal bonds, the application of an adhesion promoter, including the CAP, on the uncoated side of the paperboard offers several additional benefits for cup makers.

- <u>Printability</u> – a thin layer of a water-based adhesion promoter enhances the paperboard surface for printing.

- <u>Stain Reduction</u> – the inside edge of the sidewall seam can sometimes show staining when exposed to dark hot beverages, such as coffee. This staining occurs when hot material begins wicking into the exposed edge of the paper. The presence of a traditional or compostable water-based adhesion promoter on the uncoated side of the paperboard has been shown to reduce the rate of wicking, thus reducing staining.

- <u>Non-yellowing technology—</u>the compostable adhesion promoter dries clear

Compostability Testing and Regulatory Compliance

Many companies are choosing to obtain compostable product certification for food packaging and other structures from the Biodegradable Products Institute (BPI), North America's leading certifier of compostable products and packaging. The certification process verifies that the overall structure and all components of the package meet compostability standards, such as passing the ASTM D6400 standard.

Compostability Testing

ASTM International is one of the world's largest international standards developing organizations.[2] Multinational corporations and organizations worldwide have applied and referenced the ASTM D6400 specification[3], which covers plastics and products made from plastics that are designed to be composted in municipal and industrial aerobic composting facilities[4].

BPI uses the ASTM D6400 specification and additional procedures to test all aspects of a product's composting process, including:

- Chemical characteristics (Metal limits for U.S. are 50% of those prescribed by CFR 503.13 (Pollutant Limits) Table 3 (per ASTM 6400-12 requirements)
- Disintegration (Less than 10% particles remaining larger than 2mm)
- Biodegradation (Greater than 90% CO_2 conversion, 6-month time period)
- Ecotoxicity (No harmful effect on plant growth)
- PFAS Fluorine Analysis (additional test outside of ASTM D6400 required by BPI)

The CAP passes all of BPI's compostability testing as a standalone product.

Regulatory Compliance

As in all food packaging, regulatory compliance is critical in hot cups. One way many adhesive manufacturers can determine whether a product is safe in food applications is to go through a review process with a firm that specializes in regulatory law. These firms can determine the appropriate uses and maximum coat weights of the compostable adhesion promoter. Some adhesion promoters, including the CAP, fall under specific FDA Conditions of Use. For food contact substances, if there is a temperature restriction for the products intended use, the Conditions of Use need to be specified by reference.

The CAP has been approved for use as a coating or primer on hot or cold beverage cups with a maximum coat weight of 0.29 lbs./3000^2 or 1.79 dry gsm under FDA's Conditions of Use B-H.

Conditions B-H are as follows[5]:

- Condition of Use B, Boiling water sterilized
- Condition of Use C, Hot filled or pasteurized above 150 °F
- Condition of Use D, Hot filled or pasteurized below 150 °F
- Condition of Use E, Room temperature filled and stored (no thermal treatment in the container)
- Condition of Use F, Refrigerated storage (no thermal treatment in the container)
- Condition of Use G, Frozen storage (no thermal treatment in the container)

• Condition of Use H, Frozen or refrigerated storage: Ready-prepared foods intended to be reheated in container at time of use

Adhesion Promoter Application Processes

The recommended dry coat weight of the CAP can vary based on paperboard type and operating conditions of the extrusion and primer application equipment. The average dry coat weight for the CAP in paperboard hot cup applications is shown below. This coat weight is comparable to the coat weight used when applying PEI adhesion promoters.

Units	Average Dry Coat Weight
lbs./3000 ft^2	0.035
grams/square meter	0.066

Figure 5: Dry coat weight of the water-based compostable adhesion promoter used in Paper and PLA Hot Cup Applications

There are two general processes that can be used in the application of the CAP in paper hot cup structures:

1. In-line coating
2. Off-line coating

<u>In-line Coating Process</u>

In an in-line process, the adhesion promoter is applied on the paperboard during the extrusion coating process. The coating station is generally located between the primary unwind and the extrusion coating station. In most cases, this equipment is located just ahead of the flame treatment equipment. The primary purpose of the flame treatment system is to modify the surface chemistry of the paperboard to promote better bonds to the extruded PLA.

The flame treatment system helps dry the residual moisture left after the adhesion promoter is applied. Some of the residual moisture is absorbed by the paperboard, but the surface moisture on the primed side must be dried thoroughly to activate the adhesion promoter. The level of drying required is dependent on the amount of adhesion promoter applied and the level of residual moisture in the paperboard. When higher coat weights are applied, more flame treatment will be required to dry the adhesion promoter on the paperboard.

The two most common types of applicator systems used in paper hot cup structures are smooth roll applicators (Figure 6) and an enclosed chamber with direct gravure applicators (Figure 7). The smooth roll applicator is more commonly used for in-line paperboard coating operations. Listed below are the advantages of using a smooth roll applicator.

1. Application Rate Adjustment – the application rate can be adjusted in several ways on this system. Roll speeds and directions can be varied to change application rate. The gaps between the rolls can also be varied to change the application rate.

2. Minimal Roll Fouling – the cells of a gravure cylinder can build up (foul) with paper dust. This fouling reduces the applied coat weight over time. The smooth cylinder will not foul, as it is self-cleaning.

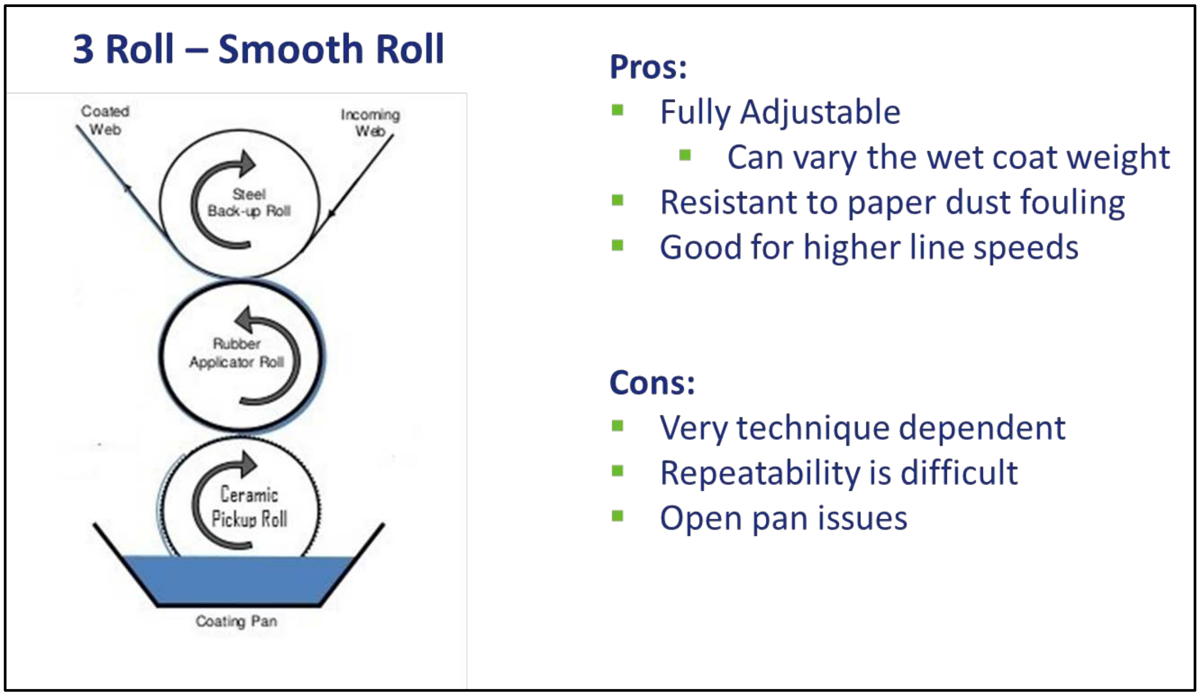

Figure 6: Smooth Roll Applicator

<u>Off-line Coating Process</u>

In an off-line coating process, the adhesion promoter is applied after the extrusion process is complete, generally on a printing press, and in many cases, as part of the printing of the cup stock. Most printing presses have long exit dryers designed to adequately cure inks and coatings. Typically, the last printing station on the press is used to apply the adhesion promoter. The coated paper then immediately goes through the exit dryer to dry completely.

An enclosed chamber with a gravure applicator is the most common type of applicator used when applying an adhesion promoter post-extrusion. The cell volume on the gravure cylinder applies a specific wet coat weight (wet delivery rate) of the adhesion promoter. To apply the correct dry coat weight, the adhesion promoter should be diluted based on the wet delivery rate of the gravure cylinder. Diluting the adhesion promoter reduces the percent solids of the solution to a concentration that applies the desired dry coat weight.

There are several advantages to using this system; ease of use is one of them, as the direct gravure applicator requires very few adjustments and therefore less skill is needed to operate it. However, more maintenance is required for this system. The gravure cylinder should be cleaned between uses to prevent build-up in the cells.

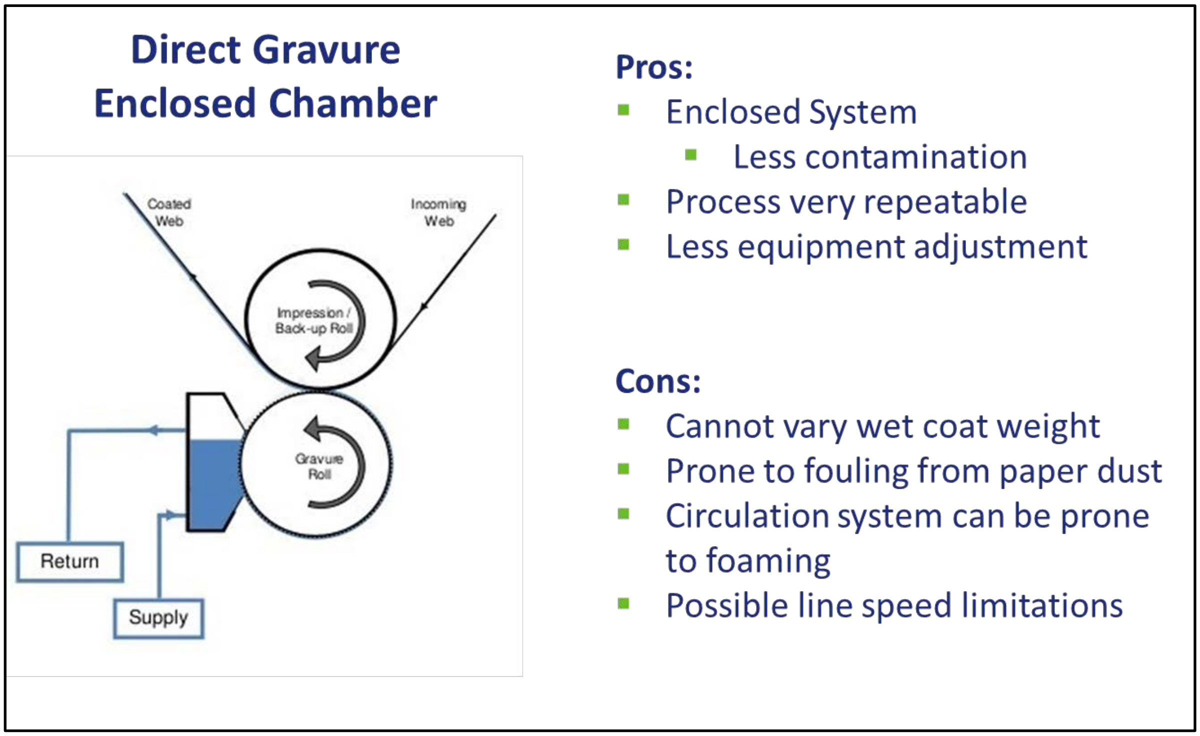

Figure 7: Enclosed Chamber with Direct Gravure Applicator

Conclusions

The data presented in this paper suggests that the new-to-market compostable water-based adhesion promoter can replace traditional adhesion promoters in certified compostable PLA and paperboard hot cup applications while still providing the performance benefits and functionality converters have come to expect from traditional PEI primers. The compostable adhesion promoter can help reduce the occurrences of flagger defects, minimize staining in the sidewall seam, and improved printability without slowing down production or making major changes or improvements to the extrusion line. Furthermore, environmental concerns will likely continue to drive the paper hot cup market to develop products that address sustainability concerns of consumers and brand owners. Compostability is one way to address these environmental concerns. With the introduction of bio-based polymers and an exciting new compostable water-based adhesion promoter, hot cup makers can create certified compostable hot cups.

Acknowledgements

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About the Authors

Darrell Landry is a Technical Sales Representative for Mica Corporation. He has more than 35 years of experience working in the paper, pulp, and packaging industry, and led the application development for Mica's new compostable adhesion promoter in hot cups. He is the Technical Program Chair for the TAPPI International Flexible Packaging and Extrusion Division and is an active member of AIMCAL.
Email: dlandry@mica-corp.com
Phone: 203-446-9729
Website: www.mica-corp.com.

Jaclyn Epstein is the Sales and Marketing Strategy Manager at Mica Corporation. Jaclyn worked in a variety of corporate communications roles at General Electric prior to joining the paper, pulp, and packaging industry in 2014. She is the Division Chair of the TAPPI Young Professionals Division and is a member of AIMCAL.
Email: jepstein@mica-corp.com
Phone: 203-446-9711
Website: www.mica-corp.com

Jessi Spadaccino is Mica Corporation's Communications Manager. She has been working in the paper, pulp, and packaging industry for more than eight years. Jessi is the Director of Communications for the TAPPI Young Professionals Division, is part of the TAPPI International Flexible Packaging and Extrusion Division's Digital Team and is a member of AIMCAL.
Email: jspadaccino@mica-corp.com
Phone: 203-922-8888
Website: www.mica-corp.com