AEROLITE CARBON THERMOFORMING GUIDE

Document Goal

To provide a reference guide for thermoformers providing details on key process and mold design parameters when adopting Aerolite Carbon to current equipment. Additionally, this document can serve as a guide for OEMs to learn about key parameters while also educating them on thermoforming common practices and terminology.

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NORTH AMERICAN HEADQUARTERS
PHONE: 1.800.999.1700
FAX: 1.877.789.0601

EUROPE
ORDERS-MATERIAL@WP-EUROPE.COM

PLACE ORDERS
NORTH AMERICA

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Sheet Preparation

1.1. Protective Film: Aerolite Carbon is delivered with a protective surface film to prevent sheet damage during shipping. An optional version of this film is compatible with the thermoforming process and can be left on the sheet during forming and remain on the sheet in supplicant operations. This film is easily removed without leaving residue and mark-off. These films are commonly used as processing aids to achieve complex parts and smooth surfaces.

1.2. Sheet Drying: Aerolite Carbon is not hydrophilic and therefore does not require sheet drying prior to forming the sheet. If you suspect the sheet was contaminated with moisture, dry at 175ºF (80ºC) for one hour.

Mold Setup & Design

2.1. Positive vs. Negative Mold: The as molded texture ofAerolite Carbon on non-tool surfaces will have an 'avocado skin' texture due to the carbon reinforcement in the sheet. For this reason, it is recommended to use the mold surface on the cosmetic side of the part during tool design. The use of a silicone membrane can be used on the non-tool surface to eliminate or reduce this carbon fiber textured effect on the non-cosmetic side of the part.

2.1.1. Cosmetic Surface (Negative Surface): It is recommended to use the tool surface as the cosmetic surface of the part when designing thermoforming molds for Aerolite Carbon. This is also considered best practice in thermoforming to achieve better part definition and quality in terms of part tolerances. Non-tool surfaces will have an 'avocado skin' texture due to the carbon fiber reinforcement in the sheet, unless a silicone membrane or similar upper film surface is applied during forming.

2.1.2. Use of Silicone Membrane: As described above, the use of a silicone membrane can reduce the carbon fiber surface effect on the non-tool surface of the part. The use of textured membranes can also be used to introduce as molded texture to the non-tool part surface.

2.1.3. Reduced Sheet Sag: IMPORTANT, Aerolite Carbon has minimal sag during heating due to the added strength of the carbon fiber reinforcement in the sheet. Therefore, new molding cycles should not be developed based on visual sheet sag during heating (a common practice with unfilled plastic sheets). Additionally, the use of a plug assist or blow step may be beneficial to achieve the desired sheet elongation prior to forming the sheet in deep draw molds. It should also be noted that molds should not be designed to accommodate large sheet sag with additional steps and tool height. Aerolite Carbon can typically form over geometry near-flush to the vacuum bed without additional design accommodations required.

2.1.4. Use of Plug Assist: A plug assist is a physical tool or plug that is plunged into the pre-heated sheet just prior to forming in order to strategically stretch the sheet in specific areas requiring

NORTH AMERICAN HEADQUARTERS
PHONE: 1.800.999.1700
FAX: 1.877.789.0601

EUROPEAN HEADQUARTERS
PHONE: +33 (0)3 20 68 30 35

PLACE ORDERS
NORTH AMERICA
ORDERS@WESTLAKEPLASTICS.COM

EUROPE
ORDERS-MATERIAL@WP-EUROPE.COM

additional elongation. Due to the lack of sheet sag during the heating step, the use of a plug assist can help pre-stretch the sheet to achieve the desired depth of draw. Plug assists are commonly used for this purpose and to also help control cross-sectional thickness uniformity in the part by strategically stretching parts of the sheet that would otherwise result in an overly thick region.

2.1.5. Blow Step: A blow step refers to a process where the sheet is inflated prior to contact with the mold surface in order to increase the depth of draw capability or to improve thickness uniformity. Due to the lack of sheet sag during the heating step, the use of a blow step can help pre-stretch the Aerolite Carbon sheet to achieve the desired depth of draw. Blow steps are commonly used for this purpose and to also help control cross-sectional thickness uniformity in the part by pre-stretching the sheet to a uniform thickness prior to molding.

2.1.6. Twin Sheet Forming: Aerolite Carbon is compatible with twin sheet forming which is a process that forms two sheets simultaneously on opposing mold surfaces to ultimately create a hollow body structure. This is an excellent way to maximize the performance of Aerolite Carbon in a streamlined single step process.

2.2. % Elongation / Depth of Draw: The depth of draw is highly dependent on the part size, geometry, and equipment/mold setup. Depth of draw can be maximized with the use of a plug assist or blow step. Aerolite Carbon has demonstrated an elongation of >100% in some applications. It is recommended that customers evaluate the material for elongation in their setup to determine the optimal mold design.

2.3. Heated Mold: A heated mold can be used when forming Aerolite Carbon to improve part consistency. Recommended mold temperatures are in the range of 120-200ºF.

2.4. Mold Texture & Embossment: Aerolite Carbon easily conforms to complex mold textures and embossments. This allows increased mold design flexibility, elimination of secondary operations, and improved cosmetics and part value.

Heating / Oven Settings

3.1. Sheet Surface Temperature (Measured): The recommended temperature range for forming Aerolite Carbon is 330-380ºF. Molding trials should start at 330ºF and increase temperature incrementally until full part definition is achieved.

3.2. Heat Time & Uniformity

3.2.1. Soak Time: The sheet should be heated such that the cross-section of the sheet is heated uniformly prior to forming. Oven dwell times in the range of 1-3 minutes are typical.

NORTH AMERICAN HEADQUARTERS
PHONE: 1.800.999.1700
FAX: 1.877.789.0601

EUROPEAN HEADQUARTERS
PHONE: +33 (0)3 20 68 30 35

PLACE ORDERS
NORTH AMERICA
ORDERS@WESTLAKEPLASTICS.COM

EUROPE
ORDERS-MATERIAL@WP-EUROPE.COM

3.2.2. Multi-Zone Heating: In multi-zone ovens, the heating zones should be adjusted such that the measured sheet temperature, edge-to-edge, is uniform in all directions.

3.3. Oven-to-Mold Time: Standard transfer times indexing the sheet from the oven to the mold are suitable. Excessive time between the heating and forming could result in excessive sheet cooling and reduced draw and part definition.

Sheet Forming

4.1. Vacuum Forming: The vacuum forming process utilizes vacuum pressure from below a one-sided mold to draw the sheet down tight against the mold surface while cooling the sheet. Once the part is cooled sufficiently, the part can be removed and the cycle repeats.

4.2. Pressure Forming: Pressure forming utilizes the same process and one-sided tooling as vacuum forming while also incorporating a simple 'pressure box'. The pressure box seals against the mold with the heated sheet sandwiched between the seal. Air pressure is then applied in the box above the heated sheet while vacuum is drawn from under the heated sheet. This process improves the final part definition and dimensional tolerance. With Aerolite Carbon this process is highly recommended since the additional pressure helps overcome the resistance of the carbon fiber reinforcement in the sheet during forming.

4.3. Membrane Assist: A membrane, typically silicone based, can be incorporated in the molding process to assist with the application of vacuum and part draw down. The use of a membrane with Aerolite Carbon can also be incorporated to reduce or eliminate the 'avocado skin' texture on the non-tool surface. Textured membranes can also be used to impart a uniform texture to the non-tool surface of the molded part.

4.4. Cool Down: It is recommended to remove parts once the sheet temperature has reached a temperature of 180ºF or less.

Final Trim

5.1. Equipment Required: Aerolite Carbon does not require special machining equipment or end-mills. Blades, drills, end-mills and other machining equipment typically used on plastic parts are recommended. The use of dust collectors and respiratory PPE is recommended, as typical for other thermoplastic materials machining.

NORTH AMERICAN HEADQUARTERS
PHONE: 1.800.999.1700
FAX: 1.877.789.0601

EUROPEAN HEADQUARTERS
PHONE: +33 (0)3 20 68 30 35

PLACE ORDERS
NORTH AMERICA
ORDERS@WESTLAKEPLASTICS.COM

EUROPE
ORDERS-MATERIAL@WP-EUROPE.COM

5.2. Edge Finish: High quality edge finish is achievable using standard cutting equipment. End mill and cutting blade speeds should be evaluated for best results.

5.3. Protective Film: Aerolite Carbon offers an optional thermoformable protective film delivered on the sheet. Keeping this film on the sheet during final machining operations is encouraged to prevent damage to the part surface during handling.

NA HEADQUARTERS
PHONE
+ 1.610.459.1000
+ 1.800.999.1700
EMAIL
orders@westlakeplastics.com

EU HEADQUARTERS
PHONE
+ 33 (0)3 20 68 30 35
EMAIL
contact@wp-europe.com

ASIAN SALES
PHONE
+ 86 15206218357
EMAIL
orders@westlakeplastics.com.cn

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