CORIAN® SOLID SURFACE

THERMOFORMING

Introduction

This fabrication bulletin addresses basic thermoforming of Corian® Solid Surface sheet.

Overview

Thermoforming is a process by which Corian® Solid Surface sheet is heated until it softens, then is formed into a two or three-dimensional shape and cooled. Applications with simple two-dimensional bends can be fabricated fairly easily, while complex three-dimensional shapes can be complicated to fabricate and are beyond the scope of this document. A key principle is to favour compressing the Solid Surface over stretching it. Thermoforming can be an iterative process, with the mould design, the shape of the blank to be formed, and the forming conditions all important.

A. Tools Required

Protective equipment

Both the ovens and heated sheet have the potential to cause serious burns. In addition to standard protective equipment insulated gloves are required. Inspect the gloves before use as thin spots, holes, adhesive or moisture can all reduce insulation resulting in burns. If forming multiple parts consider having multiple gloves per person as sweat will reduce the effectiveness of the insulation. Gauntlets are recommended to protect arms if long sleeves aren't worn.

Leather gloves should be worn for handling room temperature sheet and moulds. Eye protection and steel-toed safety shoes should be worn at all times.

Oven

Dual platen ovens are preferred for their consistency and speed of heating. Air circulating ovens may be used, but it may be more difficult to obtain uniform sheet temperatures and heating takes approximately five times as long as a platen oven. The ovens should be capable of reaching 200°C (392°F). Temperature uniformity is a key to consistent forming. If the lower platen of an oven does not slide out and therefore reaching into the oven is required, the upper platen should be blocked so it cannot close while someone is reaching for a part.

Moulds

Moulds can vary greatly depending on application and desired mould lifetime. Surfaces should be smooth and the mould material should not cool the formed part rapidly.

A vacuum membrane press is often used with single-sided moulds.

Moulds can also serve to hold parts for trimming operations.

Temperature Measurement

There are a variety of methods to measure temperature. For sheet temperatures, infrared thermometers are very useful as they can read temperatures by simply pointing the thermometer at the sheet or the membrane of a vacuum press. There are also indicator strips, which change colour to indicate the maximum temperature reached. While cheaper, these are not as accurate.

Infrared thermometers however, are not as effective for determining oven temperatures as the accuracy of the measurement is affected by the cleanliness and oxidation of the metal surface. A contact thermocouple is best for measuring platen temperatures. A standard thermocouple is best for air temperatures in an air circulating oven and internal sheet temperatures. Digital thermometers are available that accept multiple types of thermocouples.

Timer

A clock or stopwatch may suffice, but it is best to have a timer that will alarm after a set time period.

Location

Variable room conditions will cause variable results. Ideally the room with the oven and moulds will be temperature controlled. If air currents are an issue, consider installing curtains in the thermoforming area to minimise temperature variation.

B. Material Capability

Thermoformability varies by sheet colour. The limits provided here are the best performing colours. Solid, lighter colours will perform better than darker colours and colours with larger particulates. It is important to understand the characteristics of the Corian® colour to be formed. Prior success with a different colour is not a guarantee of success.

Table B-1 is a guide to the minimum inside radius for two-dimensional bends. Three-dimensional forming is much more complex, localised material elongation should not exceed 10%. A simple way to evaluate whether a part can be formed on three dimensional moulds is to use kraft paper to represent the Corian® Solid Surface as a trial. Try forming the paper over the mould. Areas with excessive wrinkling will be potential problems. Consider forming in multiple pieces and seaming to address these areas.

TABLE B-1. MINIMUM INTERNAL RADIUS

	COLOUR TYPES		
SHEET THICKNESS	SOLID, CLEAR, PASTEL	MEDIUM SEIZED PARTICLES AND HEAVILY SATURATED	LARGER PARTICLES
6 mm	25 mm	30 mm	-
12 mm	50 mm	75 mm	150 mm
19 mm	125 mm	-	-

Temperature is also a key element. Some Corian® Solid Surface colours might perform better at different temperatures. Table B-2 is a guide to the recommended temperatures or temperature ranges related to the sheet colour types.

TABLE B-2. RECOMMENDED TEMPERATURES PER COLOUR TYPES

COLOUR TYPE	TEMPERATURE RANGE (°C)
Pastel, solid	145-165 °C
Translucent	140-145 °C
Medium size crunchies	145-165 °C
Large size crunchies	145-150 °C
Veins and crunchies	145-150 °C
Heavily saturated solid	145-165 °C
Deep Colour T. solid	145-165 °C
Deep Colour T. crunchies	150 °C
Resilience Technology	145-165 °C

C. Thermoforming Blanks

The shape of the blank or piece to be formed can be a critical factor in successful thermoforming. For two-dimensional forming the blank will be close to the final dimensions. Some excess should be allowed for trimming. The edges will not be square after forming due to deformation.

For three-dimensional forming it is often desirable to have as little excess as possible. In many shapes the maximum deformation is near the edge of the part and there will be a strong tendency to wrinkle.

When developing prototypes, it is often useful to mark a grid on the Corian® Solid Surface before forming. The deformation of the grid will help you understand how the material deforms and what the blank shape should be.

When creating blanks that require a tight dimensional tolerance to work successfully it is important to track the original orientation of the blank within the sheet it is cut from. The sheet retains some residual stress from manufacturing that is relieved during thermoforming. This results in a very slight reduction in length and growth in width and thickness. Alternatively, the sheet could be annealed before cutting. Annealing is performed by heating the sheet to thermoforming temperatures and then cooling very slowly and evenly, typically by just turning the oven off. This process does take hours and generally isn't necessary.

Corian® Solid Surface is sensitive to notches when formed. Any notches or defects at the edge of the sheet can lead to tearing. Remove any rough edges from cutting. It is also recommended that the edges be eased slightly by sanding or with a router.

Do not attempt to form seamed sheet. If seams are required, the sheet must be formed, trimmed, and then seamed.

D. Moulds

Moulds can be a significant part of the overall cost of a project, particularly for large moulds that only need to be successfully used once. Mould material selection can vary, taking into account the number of parts needed, shape required, surface finish required, etc.

Wood-based materials (MDF, plywood, pine, hardwood) are commonly used for low cost, rapidly manufactured moulds. Wood-based materials do have disadvantages. Grain may leave a pattern on the moulded surface. Sap or glue may leave residue on the surface. Longevity is also limited, as water in the mould heats up rapidly it damages the mould over repeated cycles. The moulds are also heavy. Aluminium filled epoxy paint applied to the surface of the mould will create a smoother surface and extend the mould lifetime.

Synthetic mould materials are also available. These materials machine well and last longer, but are heavy and expensive.

Both wood-based and synthetic moulds are most commonly made using a CNC, though they may also be fabricated by hand.

For high volume moulding, composite or metal moulds may be attractive. They provide a good finish and long life, but are much more expensive and require skill and equipment that most fabrication shops may not have. Metal moulds do have special requirements. Due to the high heat conductivity and heat capacity, metal moulds can cool the solid surface too rapidly. In many cases metal moulds should be heated to allow slow cooling of the moulded part.

Other Design Considerations:
Moulds may be male, female, a combination of both, or two-sided. A two-sided matching mould with both male and female sections is shown in Figure D-1. To reduce the risk of wrinkling when moulding deep shapes, a male mould is preferable to a female mould. If a piece is to have a surface texture imparted by the mould, the mould is determined by the convexity/concavity of the surface to be textured: a textured concave surface requires a male mould, while a textured convex surface requires a female mould.

Many moulds have features to help locate the blank on the mould.

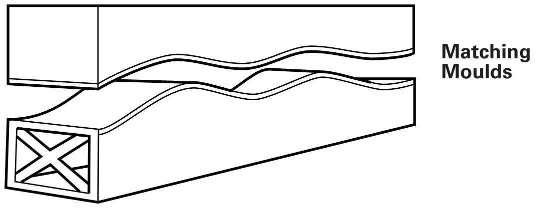

Figure D-1

Release of moulded parts is another consideration. A deep and/or steep piece formed over a male mould will shrink around the mould as it cools and may stick to the mould. Incorporate a 5° (minimum) release angle into the mould (See Figure D-2). If a negative draft angle is required, a multiple-part mould that comes apart to release the solid surface is required.

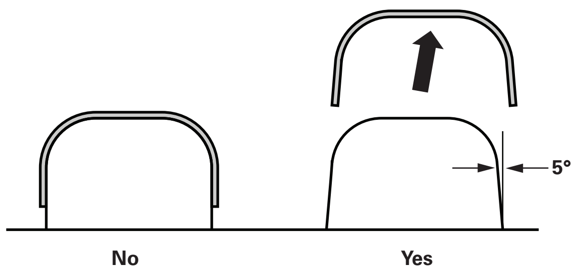

Figure D-2

"Helper pieces" can be used in addition to the mould to do some initial shaping before the vacuum membrane is activated or to work with the vacuum membrane to help forming in difficult spots as shown in Figure D-3.

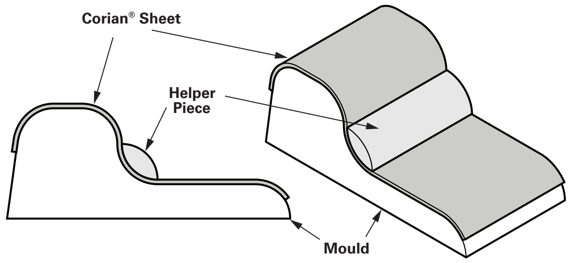

Figure D-3

When using a female mould, bevel the cavity edges to prevent the material from being trapped between the forming membrane and the edge of the cavity. Make sure nothing inhibits smooth motion of the material as the membrane presses it into the cavity. This will allow the material to move fully into the mould. Above all, do not allow the material to get caught over a sharp edge. This is shown in Figure D-4 where excess material is trapped between the mould and the membrane, preventing it from drawing into the cavity.

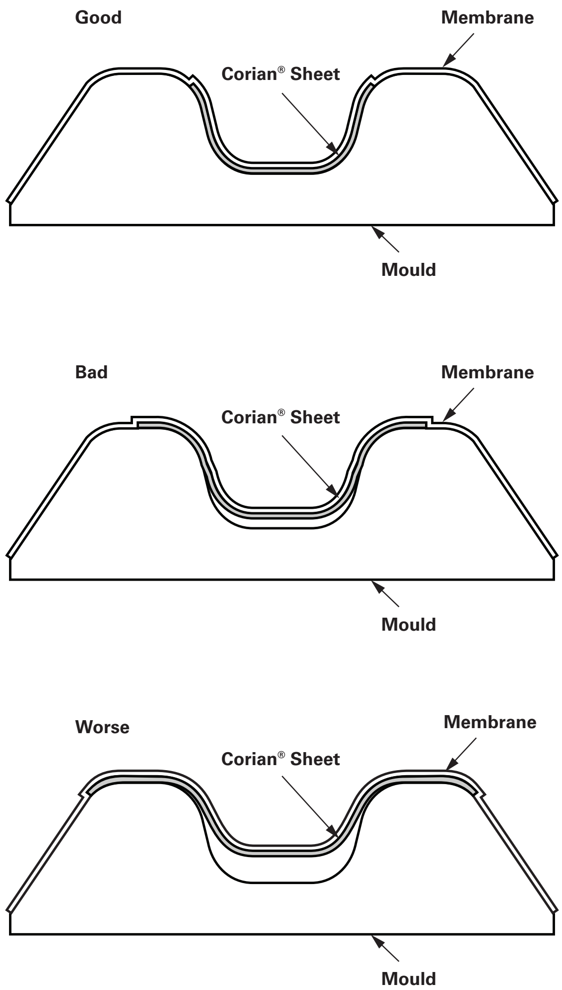

Figure D-4

E. Oven Calibration

Steps to completion:

1. Drill a 1 mm diameter hole halfway into a test piece of Corian® sheet. The sample should be at least 150 mm x 150 mm. Put the hole near the centre of the sample.

2. Insert the thermocouple wire into the hole, bend it to fit and tape it in place.

3. Insert the thermocouple wire plug into a digital thermometer. Turn on the thermometer; which should now show the temperature of the sample.

4. If not using an infrared thermometer, apply a temperature-indicating label near the end of the wire.

5. Set the oven to the intended temperature and allow the oven to come to a stable temperature for at least 20 minutes.

6. Put the test sample in the oven and start the timer.

7. When the temperature on the thermometer reaches within 5°C (10°F) of the oven set point temperature write down the timer reading and remove the piece from the oven. This is the time parts should be heated.

8. Read the surface temperature with the infrared thermometer or inspect the temperature-indicating label and note which dots turned black.

   The surface temperature should be approximately the same as the oven temperature. If not, check the calibration of the temperature monitoring equipment.

9. Place the hot sample into the mould, and allow the piece to cool until the thermometer reads 82°C (180°F).

10. Note the timer reading. This is how long each piece should be cooled in the mould. This is the minimum time that parts should be cooled. If multiple parts are formed the cooling time will be extended as the mould warms.

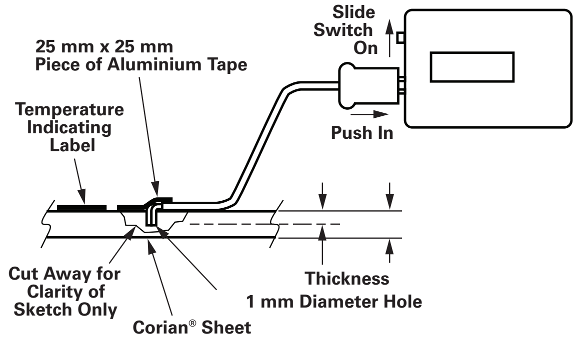

Figure E 1

F. Heating Sheet in a Platen Oven

A platen oven has heated plates that will heat sheets much more quickly than an air circulating oven. This results in higher productivity. The platen press must be capable of uniform heating up to 200°C (392°F).

The upper platen is hot and heavy. If the design requires reaching into the oven the upper platen should be blocked when adding or removing sheet. This will prevent the oven from closing on someone who is reaching for a part.

The platen oven should be set to the desired sheet temperature. Place the Corian® sheet into the preheated platen press with the heat setting between 150°C and 165°C (300°F and 325°F). A rough guideline is that the Corian® sheet should be heated one minute for every millimetre in thickness, so 6 mm sheet for 6 minutes, 12 mm sheet for 12 minutes.

These times may vary with oven design. Follow the oven calibration procedure to determine the proper heating times. Note that the time for heating may vary with the size of the part and the rate at which the oven returns to its temperature set point after the sheet is inserted.

HELPFUL HINTS

The heating times provided assume the sheet is at typical room temperatures and top and bottom platens are heating the material. Temperatures well above or below room temperature will affect heating times.

If sheet is not stored in a climate controlled building, consider bringing it into the workshop the day before so it conditions overnight.

Steps to completion:

1. Preheat the platen oven to the desired forming temperature. Make sure the temperature is stable.

2. Have everything needed (safety equipment, thermometer, mould, etc.) ready and accessible.

3. Wearing thermal gloves and gauntlets place the blank in the platen oven. If you are forming a small sample insert spacing blocks if necessary.

4. Close the oven and start the timer. Generally allow 6 minutes for 6 mm sheet or 12 minutes for 12 mm sheet.

5. When the blank has been in for the designated time open the oven. If the platen oven has a sliding lower surface it is good practice to scan the surface with an infrared thermometer to check that the sample is the correct and uniform temperature.

6. Transfer the blank to the mould.

7. Follow the instructions in the following sections for the specific type of mould used.

The upper platen is hot and heavy. If the design requires reaching into the oven the upper platen should be blocked when adding or removing sheet. This will prevent the oven from closing on someone who is reaching for a part.

HELPFUL HINTS

Make sure the oven is clean. Any dirt or residue will transfer to the sheet and may become embedded in the surface, requiring additional sanding to remove.

If thermoforming small pieces, use some scrap samples evenly spaced in the oven so the platen lowers evenly on the part to be formed.

If writing on the on the sheet to identify parts, be aware that the ink can transfer to the oven platens and onto future sheets. Consider removing labels before heating sheets.

G. Heating Sheet in a Air Circulating Oven

Air circulating ovens can be used successfully, but it is important to understand the oven. Heating is much slower than in platen ovens. It can take up to 5 minutes per millimetre (6 mm - 30 minutes, 12 mm - 60 minutes) in order to uniformly heat sheet to the oven temperature. It is important to calibrate and understand the characteristics of the oven.

Air circulating ovens rely on air circulation to maintain uniform temperatures. This air circulation will be disrupted by the thermoforming blank. An oven that heats uniformly with small samples may have poor temperature control if the blank is near the size of the oven.

Fabricators will often set the oven temperature slightly higher than the desired sheet temperature to reduce the heating time. This is feasible, but it is important not to set the temperature above 205°C (400°F). The sheet itself should not be allowed to exceed 170°C (338°F) as there is a risk of overheating. As a guide the more translucent the material, the lower this temperature should be. The sheet temperature will not be uniform when removed from the oven. The blank should be allowed to "rest" 1-2 minutes so the centre and surface temperatures can equilibrate. Careful calibration studies should be done to develop an understanding of the proper times and temperatures (note this may vary with blank size) if setting the oven to a higher temperature. High temperatures and long exposures will increase the risk of discolouration.

Steps to completion:

1. Preheat the air circulating oven to the desired forming temperature. Make sure the temperature is stable.

2. Have everything needed (safety equipment, thermometer, mould, etc.) ready and accessible.

3. Wearing thermal gloves and gauntlets, place the blank in the air circulating oven.

4. Close the oven and start the timer. Generally, 30 or 60 minutes (for 6 mm and 12 mm sheet, respectively) will be required.

5. When the blank has been in for the designated time, open the oven. It is good practice to scan the surface with an infrared thermometer to check that the sample is the correct and uniform temperature.

6. Transfer the blank to the mould.

7. Follow the instructions in the following sections for the specific type of mould used.

H. Infrared Ovens (not recommended)

Infrared or radiant ovens are commonly used for heating unfilled plastics. When used with unfilled plastics the infrared radiation can partially penetrate the sheet, heating uniformly. Filled polymers, such as Corian® Solid Surface do not transmit infrared radiation, all the energy is absorbed at the surface. The ability to heat the surface faster than the interior often results in thermal damage at the surface with a centre still too cool to form. Infrared ovens are NOT recommended for heating Corian® Solid Surface materials.

I. Spot Heating (not recommended)

Corian® Solid Surface should always be uniformly heated and cooled to minimise stress in the final part. Spot heating will create stress within the material. This stress may lead to failure in later processing steps or in use. Spot heating is NOT a recommended practice.

J. Forming

The forming process will vary depending on the mould type. It is important to remember that the thermoforming blank starts cooling as soon as it is removed from the oven. The amount of time that one can work with the material will vary based on the room conditions and the mould type and temperature.

The mould should be ready before beginning to heat the sheet. If using lubricants such as vegetable oil, wax or talc, apply them before starting the heating process. Make sure the lubricant used does not damage the mould (i.e. use dry powder lubricant on uncoated MDF/wood moulds). Sometimes it is desirable to have the mould heated before forming. If forming multiple parts sequentially the mould will warm up, increasing the cooling time of the part and perhaps changing the results. Preheating the mould before the first part will aid in having a consistent process. More time is available to work with the blank if the mould is warm.

Placing the blank in the correct place on the mould is important. One can also start to shape the blank in the mould using hands (using proper thermal gloves). If forming using a vacuum membrane press, forming can be assisted using hands pressing on the membrane. This helps control wrinkling.

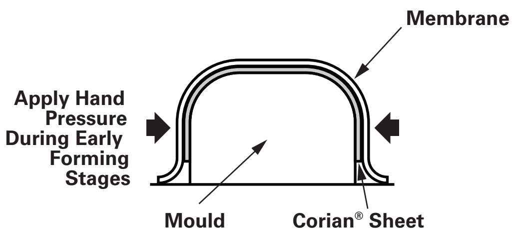

Figure J-1

Steps to completion:

1. Remove the hot blank from the oven.

2. Position on the mould. Having alignment features built into the mould facilitates proper positioning.

3. Do any hand pre-shaping or use auxiliary forming pieces.

4. Depending on the mould, the blank should be clamped in place, the mould closed, or the vacuum membrane lowered.

5. Allow the part to cool to 82°C (180°F). The time required to cool will depend on the room temperature, mould temperature and the mould construction. Expect up to 30-45 minutes for 12 mm sheet. Some parts can be cooled to room temperature, but if a male mould is used a part can be difficult to remove if completely cooled. If using a vacuum membrane an infrared thermometer can be used to read the temperature of the membrane. It will generally be a few degrees cooler than the sheet. For other moulds, use scrap pieces with thermocouples to establish cooling times.

HELPFUL HINTS

Vacuum membrane presses are very useful, but the silicone membranes are prone to tearing and are expensive to replace. A little extra care in mould design and forming techniques can greatly extend the life of the membrane. Some tips are:

- *Eliminate sharp corners on moulds.*

- *Look for places where the membrane would have to bridge a gap and stretch significantly and fill that space.*

- *Use helper pieces such as in Figure D-3. The membrane will not have to stretch as much.*

K. Rebating Technique

Selectively thinning or rebating the blank is useful in some designs. Impact resistance will be lower in the thinned sections. Thin the material using a router. It is important to have a 6 mm radius at the transition between the two thicknesses. An example is shown in Figure K-1 where a dished area is being formed in a horizontal top. Make sure the routed area is smooth. Any variation in thickness may telegraph to the top surface.

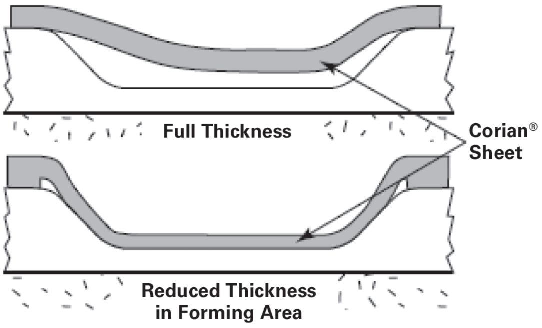

Figure K-1

L. Trimming and Finishing

Thermoformed parts will generally need some trimming and finishing. The edges of the formed part will no longer be square. If precise dimensions are required the part needs to be trimmed after forming. Sometimes the mould can be used to hold the part for finishing. Other times a dedicated fixture will be required.

In general, some finishing will be required. The degree of finishing required will depend on the colour formed and the quality of the mould surface. A solid colour with a high-quality mould surface may need only to be touched up with an abrasive pad. Colours with particulates or formed on a rougher mould will need to be sanded smooth.

M. Process Development and Troubleshooting

Developing an economical and reliable thermoforming process takes advance planning and attention to detail. It is important to keep good records to understand which techniques give the best results to aid in troubleshooting. Thermoforming, more than most processes, can be affected by external factors. Something as simple as a door being left open that creates a draft in the thermoforming area could affect results. An example process record is listed below. Depending on the goal, different data would be recorded. One workshop may be looking at mould economics and want to know how long a mould lasts. Another may be trying to understand why they are having inconsistent results, only to find that they always have problems for the first few parts on Mondays and institute a practice of preheating moulds.

Example Process Record

- Corian® material (colour and thickness)
- Operating procedure
- Blank template or program
- Oven temperature
- Mould ID
- Mould material/coating
- Mould temperature (before and after)
- Heating and cooling time
- Trim fixture or program
- Number of parts produced on mould
- Day/Time
- Ambient temperature
- Operator
- Success or failure
- Process aids used (talc, wax, heat resistant oil, etc.)

Having a written operating procedure helps ensure consistency and also helps identify changes in techniques that occur.

There is no "best" way to form parts. A shop that does custom, one-of-a-kind parts will have different considerations than one trying to manufacture many identical parts.

The following is a list of considerations for process and part design, optimisation, and troubleshooting.

Process Development/Optimisation

- If the goal is increasing your production rate, what is the limiting factor? A platen oven can provide blanks for several moulds as heating is faster than cooling. But an air circulating oven may only be able to provide blanks for one mould.
- Forming broad arcs? Form at a lower temperature. The increased stiffness will help form a natural arc.
- Minimise deformation as much as possible. It is preferable to have the material slide across the mould versus stretching. Also, compression is preferable to stretching.
- Understand the trade-offs in mould material design including cost, lifetime, quality, etc.
- There may be a slight colour shift when heating lighter colours. If the thermoformed part will be seamed to a flat sheet it is a good idea to heat the flat sheet as well.

Troubleshooting

1. Whitening is caused by many small failures in the part that scatter light. Possible causes include:
- Temperature isn't high enough – possible causes include: wrong set point, oven not operating correctly, sheet not heated long enough, or sheet was excessively cold going into oven.
- Surface cooled off before forming – possible causes include: too much time from oven to mould or too much time positioning on the mould.
- Exceeding tensile limits of the material – possible causes include: too tight a bend, too much elongation, or the blank may be trapped during the moulding process and unable to move relative to the mould.

2. Wrinkling generally occurs in areas where the material is compressed and it is easier for the sheet to buckle than compress. Possible causes include:
- Excessive compression – make sure compression is under 10%. It may be necessary to break the part into multiple pieces and seam after forming. Kraft paper can be used as a trial to predict where the material will begin to buckle.
- Mould design doesn't provide resistance to buckling – sometimes this can be addressed by hand assistance during forming, but changes to mould design may be required such as moving to matched moulds, switching from female to male moulds, etc.
- Blank has excess material – the greatest compression is often at the edge of the part. Optimise the blank geometry to minimise excess material.

3. Tearing can have multiple causes:
- If the tear starts at the edge of the blank or if multiple small fractures are visible then check the quality of the blank edge. A rough saw cut or nick can cause failures during forming. Edges should be smooth and eased slightly.
- The blank may be pinched by the mould or by the vacuum membrane, preventing it from moving. Try preforming by hand or with a helper piece. A lubricant (talc, wax or oil) may help the part slide.
- The part tears in or around particulates. The capability of the colour may have been exceeded. Colours with large particulates do not form as well and some may require radii of 150 mm or more. Better success may be obtained by lowering the temperature slightly. Rebating in the formed area is also an option.

4. The surface requires excessive sanding:
- If the show face is against the mould, check the mould finish.
- Colours with larger particles will tend to be rougher. The roughness will be greater if the show face is away from the mould during forming. If possible, form the show face against a smooth mould.

5. Inconsistent results – this is where a good process record is essential:
- If consistent success changes to constant failure double check your equipment. There may be problems with the oven (either heater, or calibration). Verify that the part is coming out of the oven at the correct temperature and that the temperature is uniform. Use a scrap piece and a thermocouple to check the internal temperature.
- If results become erratic, track the mould temperature before and after forming, as well as the ambient temperature. Is the sheet always the same temperature going into the oven? Has the thermoforming area temperature changed? Is there a new airflow pattern (i.e. a door is open creating a draft)? Are there problems with the first part of the day, or do problems develop as the mould warms up?
- Different personnel get different results – There is a bit of art involved in forming that is gained by experience and may not be captured by formal procedures. Observe personnel closely. One may be positioning the blank slightly differently or assisting by hand where the other is not.

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