ArmaPET® Insights THERMOFORMING

Thermoforming is carried out by heating our ArmaPET products up to their softening point and forcing them against the contour of a female or male mould to give the desired shape. As they are pure thermoplastic core materials, the ArmaPET products thermoform very well, for both single and double curved surfaces.

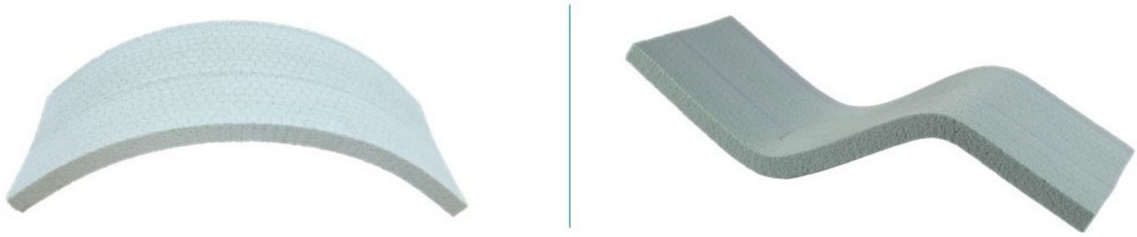

Figure 1: Thermoformed ArmaPET Struct single and double curved

ArmaPET materials exhibit a glass transition temperature (Tg) close to 75°C. As a rule, foam cores cannot be used at much higher temperatures than their Tg. However, crystallisation in ArmaPET cores produces a structure that will act as a static, non-moveable system until melting begins in the crystalline phase, at about 240°–250°C (melting point Tm).

That is why ArmaPET Struct is usually thermoformed at around 200°C, although a wide range of processing temperatures is possible. Indeed, it will take hours to melt all crystalline structures at temperatures of 180°C, while they will melt rapidly at 240°C.

There are at least a dozen thermoforming methods: vacuum-assisted, pressure, drape, sweep, match mould and free forming, to name just a few. All the figures in this section are derived from previous production experience and testing. Adjustments should be made depending on individual production factors such as core density, thickness used and the radius in the mould.

Please feel free to contact our technical services to help you build your thermoforming project with ArmaPET products.

MOULDS

If production moulds are not available, thermoforming moulds can be made of most common materials. For a small batch, or if you are working on a prototype or trials, a plywood mould or simple metal mould is easy to make and offers an acceptable level of performance (see Figures 2 and 3 on the next page).

The disadvantage of wood is the heat build-up in the mould which results in a long cooling time, therefore affecting productivity in the case of continuous production. Steel or aluminium moulds are preferable for industrialisation due to their high thermal conductivity and stability. Plastic/composite moulds can be used but they also accumulate heat.

For thermoforming, the mould material is of course important, but the curvature also plays a major role. Three key product classes can be noted here

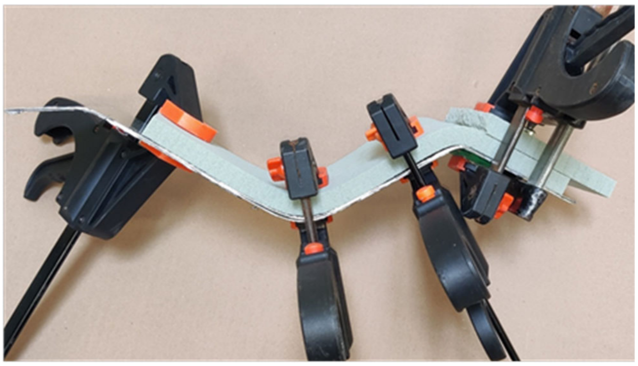

Figure 2: Simple thermoforming moulding with thin metal sheet

// Single curved products with a radius larger than 400 mm

These are best formed on a male mould, using a sweep forming process with a thin steel foil, or a vacuum bagging process.

Vacuum bagging is a simple operation with low tooling costs, but it has some disadvantages. The bag must be carefully placed so it does not compress edges or corners. It also takes time to apply the vacuum bag, meaning that the material may cool down too much in the interim. This can be avoided if the vacuum bag is assembled on a cold sheet and mould. The mould is then placed in a hot air oven. The temperature inside the sheet is measured with a thermal gauge and when the right temperature is reached, the vacuum is applied. The mould is then taken out of the oven and allowed to cool, with the vacuum being maintained. Consideration must be given to time, temperature and vacuum to avoid creep effects.

// Single curved products with a radius below 400 mm

If the radius is below 400 mm, a female mould should be used. The product could either be vacuum bagged or match-mould formed. The latter process should be used if the radius is small, the thickness or density is high and a high load is required. Fixed stops must be used to avoid compression of the core.

// Double curved products

In the case of double curved products, the radius needs to be considered from a design standpoint in order to determine what type of mould is the most appropriate. The criteria from the two previous points should be used to aid the decision-making.

HEATING

Several different methods can be used to heat up ArmaPET products, although a heated platen press with fixed stops or a circulating hot air oven are often chosen.

Another option is to use infrared heaters that have the advantage of heating through the thickness. The IR waves will in fact penetrate uniformly deep through the thickness. Short-wave

IR heaters are preferred as they have an immediate ramp up, ensuring high heating efficiency. On top of that, IR heat conversion offers fast and uniform heating. The best compromise found here is ARMA6 (36kW short wavelength IR), but there are numerous similar solutions on the market. For thicker material, the heat normally has to be applied on both sides of the sheets to avoid warping during the heating cycle.

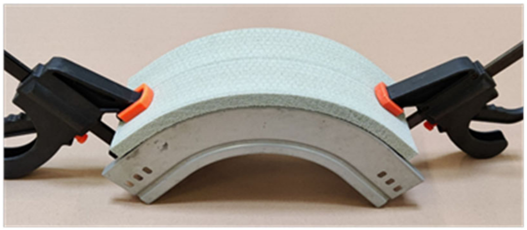

Figure 3: Example of thermoforming with radius and female mould

Irrespective of the heating method used, the uniformity is crucial: the temperature along the part should be kept within ±5°C. If the temperature is too high, the dimensional stability will be affected and if it is too low, the increase in stiffness can result in springback of the sheet. An uneven temperature distribution can make the ArmaPET core twist or warp, so it is important to have an even temperature on both sides of the sheet. It is also critical to have a fully calibrated means of heating and a comprehensive cartography of the part you are trying to thermoform, to make sure the uniformity is respected at all points of the product.

TEMPERATURE AND TIME

// ArmaPET Struct, ArmaPET Eco

The following **oven temperatures** should be used, independent of the radius.

Thickness (mm)	<20	>20
Temperature (°C)	+185 to 195	+200 to 210

The following **times** should be used for the different thicknesses, independent of the radius and grade.

Thickness (mm)	10	20	30	40	50	60
Time (min)	5-7	10-15	20-25	30-35	1 min per additional mm of thickness	

The temperature and duration of heating are also dependent on the local conditions and should be calibrated prior to the start of manufacturing, especially if the mould and materials you used during trials are not the same as the ones that will be used in production. Start with the lowest time and temperature.

// ArmaPET Curve

The low thickness of the ArmaPET Curve means it does not follow the same heating requirements.

Regardless of the grade, the product temperature should uniformly be between +180 and 200°C at all points on the parts, using a vacuum process (bag, suction or other method) to form the product. It is important not to overheat the ArmaPET Curve as this will result in the loss of its smooth surface.

The time between removal from the heating unit and the application of pressure must not exceed 30 seconds, to avoid the ArmaPET Curve sheet cooling down.

- Heating at +180 to 200°C for 70 seconds.
- Forming for 20 seconds under vacuum.

Figure 4: Examples of thermoformed ArmaPET Curve

DIMENSIONAL STABILITY

ArmaPET Struct and ArmaPET Eco grades will change their dimensions when heated without any restriction, as in a vacuum bag, in accordance with the temperatures and times mentioned above. As a result, the product's density will decrease, a change that needs to be taken into consideration during the design phase.

The following values represent those changes as percentages of the original dimension:

- Length & width: from 0 to +5%
- Thickness: from -2 to 0%

The **springback** of ArmaPET is normally **negligible**, as we can see in Figure 5.

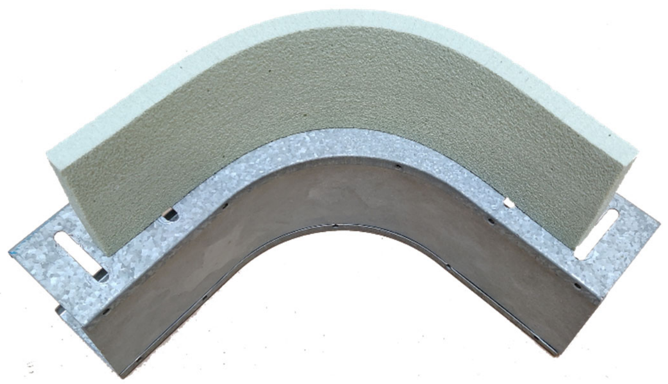

Figure 5: Thermoformed sheets have very little springback

It should also be noted that the edges of thermoformed parts tend to straighten out.

If the sheets are not to be edge-trimmed after the thermoforming process, special attention must be paid to the orientation of the weld lines. In this case the weld lines must be oriented along the line of curvature, otherwise there is a risk that the edge will be uneven around them after thermoforming.

For the ArmaPET Curve, close attention should be given to the temperature used. Within the advised range, the thickness may increase a little due to the gas trapped inside, with a parallel decrease in density. Outside the advised range, the products will be over-stretched, causing a reduction in thickness locally which could lead to internal stresses, cracks and poor aesthetics.

EFFECT ON PHYSICAL PROPERTIES

ArmaPET Struct and ArmaPET Eco grades are affected in two ways during thermoforming:

1) Decrease in density during heating due to the expansion of the sheet.
2) Stretching of the outer radius.

Both of these phenomena will decrease the physical properties slightly. A typical decrease is 0-5%, but from a design standpoint, 10% should be used as a safety criterion. This must be verified for the actual structure and heating method used.

ArmaPET Curve will only see a decrease in density, as the low thickness and the specificities of the product makes the stretching less significant.

STORAGE AND LONG-TERM PROPERTIES

The thermoformed core parts have excellent long-term stability with no relaxation or springback even after 6 months' storage. However, initial results from storage at higher temperatures indicate that the products must be kept below 40°C to avoid relaxation and springback. If the thermoformed core parts must be transported with a risk of exceeding 40°C, it is recommended that they are strapped to a fixture in such a way as to avoid springback.

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