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Technical Information:
Resin Uptake of ArmaFORM® PET Core

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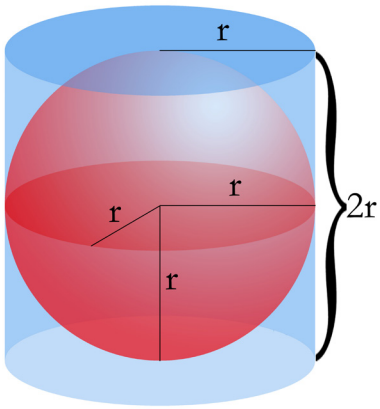
Why Do We Need to Test Resin Uptake?

With open methods, i.e. hand lay-up or spray-up, resin uptake is not really important. With these methods, the problem is rather to get enough resin into the core surface to avoid a resin starved interface between the core and the laminate, since this can result in lowered peel strength or even no bond at all. Therefore, core producers often recommend minimum "primer" amounts depending on the core's density, since lower densities normally require more resin to fill the surface cells that have been cut open during slicing process.

Also for pre-pregs, RFI (Resin Film Infusion) etc., the resin uptake is not really crucial since the amount of resin available in the pre-preg is fixed. There just has to be enough resin to get a good enough bond between the core and the laminate, but this will likely require a film adhesive or a resin rich pre-preg layer next to the core.

But for all LM (Liquid Moulding) methods—especially those that use vacuum—resin uptake is crucial for controlling weight and cost purposes. Resin uptake is not only clearly linked to the cell size, but also to the shape of the cells. Consider the sphere and the cylinder with the same diameter in the picture below; they may look the same from above, but the cylinder's volume is clearly larger than the sphere's volume. This in turn means that an elongated cell will have a larger volume than a spherical one of the same diameter.

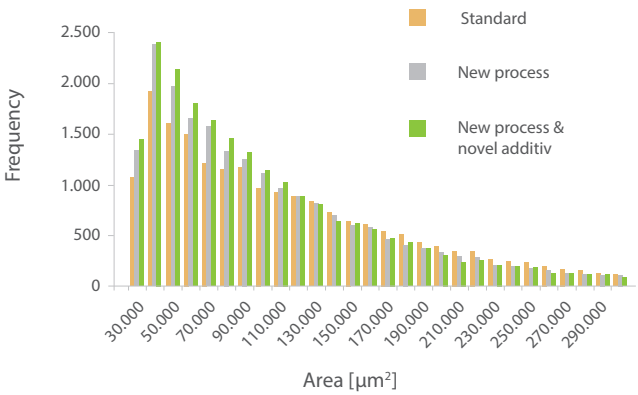


Picture 1:Volume of Cylinder vs. Sphere

The cells of the extruded PET core are more elongated, and will therefore absorb more resin than a rounder cell made from PVC, PUR foam etc. with the same diameter. In order to get to the same level of resin uptake as PVC or PUR cores, we have to have an even smaller cell size than they do.

But it is not only the average size that matters, but also the distribution of the cell size. A few "large" cells will absorb as much resin as many "small" cells, since the volume is a function of the cube that takes the radius of the cells into account. Therefore, it is just as important to minimize the number of big cells, and not just the average cell size. Today, we have the required tools to scan and count the cell size and distribution; see Pic. 2.

Histogram of Cell Sizes



Picture 2: Cell Size Distribution

Methods for Resin Uptake

One big problem when talking about resin uptake is that there is no formal standard for resin uptake. There are several different ways to test the resin uptake and measure the weight increase in the core. Two different main ways of doing these tests have been identified.

With fibres:

Cover the core with fibres and peel-ply/release film/ distribution media, taper off the core to a "reference" section with single skins. Infuse the panel, clean-cut section with both the sandwich and the single skin section and then deduct the single skin area weight from the sandwich area weight to get the resin uptake.

+ More realistic lay-up.
+ Less scatter.
- More material used.
- Longer lay-up time.
- Even resin uptake / fibre fraction in single skin versus sandwich.

Without fibres:

Cover the core material only with peel-ply/release film/ distribution media. Infuse the panel, remove the peel-ply and other layers from the core, clean cut section of the sandwich and measure the core's infused weight.

+ Less time consuming.
+ Less material used.
- More scatter.
- Uneven wet out due to tearing when removing the peel-ply.

As mentioned previously, there is no commonly accepted standard for resin uptake testing. Therefore, it is not possible to compare values from different manufacturers or test institutes etc. Armacell have developed a proprietary method based on infusion processing to measure the resin uptake of the ArmaFORM® PET Core. Looking at the industry today, most companies use some kind of infusion method for resin uptake testing. However, due to differences in resin type, viscosity, temperature, curing time, vacuum level etc. results can vary significantly and it is not possible to compare results from different sources. For Armacell's internal test method, the results are presented in "kg/m²" and "side", which is in line with how other core producers present their information. To obtain the true uptake per m² for a plain sheet of core material, the result needs to be doubled. This is also to make it possible to combine results, e.g. for a core with one grooved side and one plain side, and in order to get a realistic estimate on the resin uptake for that combination.

Results for Resin Uptake

If we start by looking at the evolution of the resin uptake, remember that the result is in "kg/m²" and "side". For PET GR115 we have plenty of results, but scatter is relatively high due to many factors that influence resin uptake. Therefore, it's important to perform a number of tests in order to be able to draw conclusions. For the other densities, the number of tests are fewer but may still be enough to show a pattern. In general, a falling trend in resin uptake is expected, as cell sizes normally become smaller as the density increases.

Resin Uptake and Density

Graphic 1: Correlation of resin uptake and density

For a number of years, progress was made to reduce the resin uptake of PET AC grade. After that, another step was taken with the new PET GR grade technology (r-PET raw material), indicating further possible development with the r-PET technology. To take the next step in reducing resin uptake requires an even finer cell structure, and this is in development for the 3rd generation of ArmaFORM® PET foam cores. Full scale trials have been made and the results show that it will be possible to compete with PVC cores in this respect.

Surface Treatment

With all core materials, there is the option of using a surface treatment to minimize the resin uptake. This has been used mainly with end-grain balsa wood due to its very high resin uptake. For end-grain balsa wood, the common method is to coat the surface with a very thin layer of ultra-fast curing resin. With this coating, the resin uptake can at least be limited for open moulding methods. However, for closed moulding the coating layer is most often not strong enough to withstand the pressure of the resin and the uptake will once again be even higher. The peel strength for coated surfaces is often lower as well, making this a trade-off that needs to be taken into account (as well as making sure that the coating is compatible with the resin system).

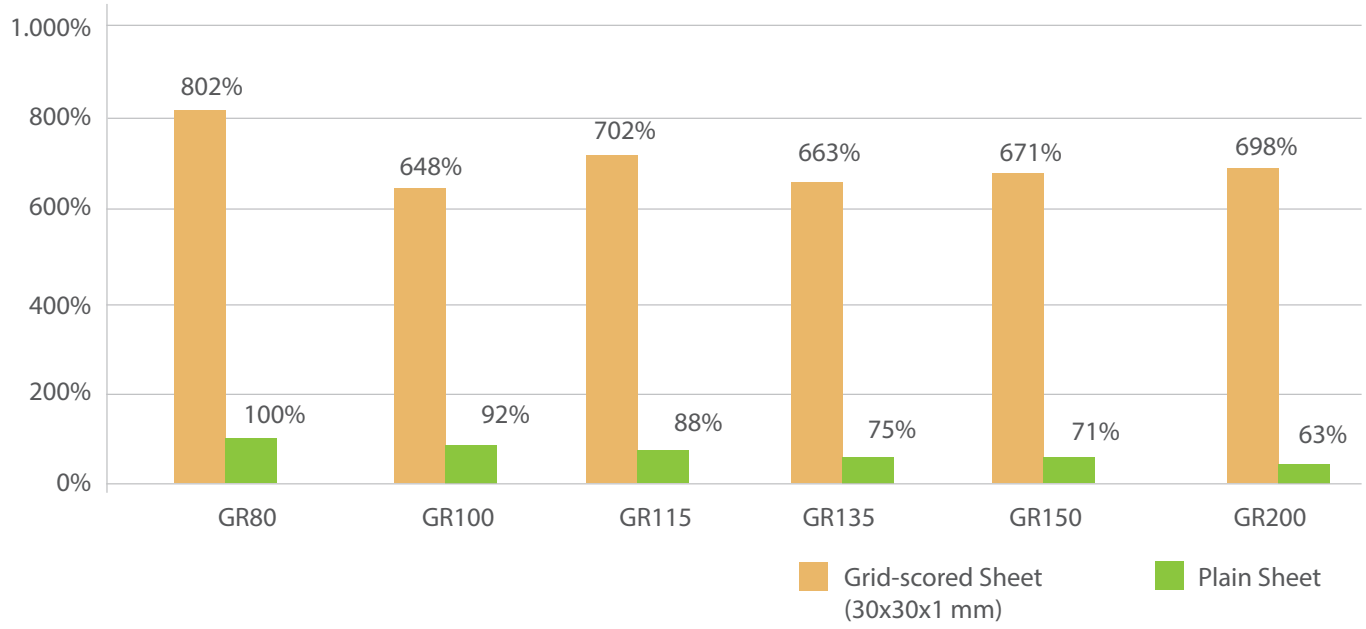
It is less common to use coating for foam core materials, but PET-based core gives you the option of using a surface treatment without having to add an additional material. Instead you can seal most of the surface cells without introducing any additional materials. For plain core material sheets, you can typically save about 40-50% of the resin uptake without compromising the adhesion and peel strength. It is fully possible to close the surface completely as well and minimize the resin uptake, but the compromise here is that this also will lower the peel strength.

For surface treatments, it is important to bear in mind that it only affects the top and bottom surface of the core. Any converting will open up new surface cells that will in turn take up resin, and converting can often take up several kilograms of resin per m^2, while the surface treatment maybe only saves a couple of hundred grams. Also, any grinding or chamfering will of course also destroy the surface treatment—rendering the savings for those areas null.

Converting vs. Thermoforming

A factor that is often forgotten when discussing resin uptake is that the surface uptake usually is of secondary importance as soon as any converting (perforation, grooving, grid-scoring etc.) is used. Graph 2 shows the heavy influence on the resin uptake for the core when using converting methods such as GS (grid-scoring) or DC (double conturing). Scatter from testing is even higher for converted specimens, and is probably related to the manufacturing process of the GS.

Resin Uptake: Grid-scored vs. Plain Sheet



Graphic 2: Resin uptake compared for plain and grid-scored sheets

For example, grid-scoring of the core in combination with infusion for a 20 mm core will increase the weight by >3 kg/m^2.

The standard solution to forming the core material to single or slightly double-curved surfaces is by using grid-scored sheets or striated sheets. This is acceptable for basic sandwich application that has less need for weight and cost optimisation, but it does have two major disadvantages: Weight increase due to resin uptake in the GS slits. A standard GS sheet takes up at least 2–3 kg of extra resin per m^2, even for flat sheets with a moderate thickness. When applied with curvature this will increase the resin uptake by up to an additional 50%. Another factor to take into account when infusing GS cut cores is the stress concentrations that are created. Although a filled GS cut is just as strong and also stiffer than normal plain core material, an empty or half-filled GS cut is up to 40% weaker than the plain core material. This makes it crucial to have a reliable manufacturing process and a way to assure that the voids are well filled.

To complicate things, another factor to take into account is that different thicknesses will have converting alternatives that are better or worse. For example, be aware that thick sheets absorb a lot of resin with perforations. The hole diameter will affect the resin uptake significantly, going from 3 to 5 mm drills means a 66% higher increase, which raises the resin uptake by 277%. Most often, drills with a larger diameter is required for thicker core sheets.

Thermoforming is carried out by heating the PET foam core to its softening point and then forcing it against the contour of a female or male mould. The GR grade thermoforms very well to single sheets, and also to double curved surfaces when thinner sheets are used.

The advantages of thermoforming are a homogenous core material, without any stress concentration in the form of stiff resin filled GS cuts (or worse; empty GS cuts). In addition, the lay-up time in the mould is shorter and the final weight is lowered thanks to the resin uptake being significantly lower. Additionally, the freedom of design offered with the thermoforming concept opens up a wide scope of design concepts even for limited series.

Further Work

Clearly, the most efficient way to minimize resin uptake is to use the minimum of converting on the core. This is of crucial importance, since cores with finer cell structures will soon take advantage of this.

Over the past few years, we constantly improve our cell structure to reduce the resin uptake. For the coming generation of ArmaFORM® PET cores, we are working to achieve an even finer cell structure compared to current PET GR grade. This will be done by installing novel extrusion equipment that has been developed using CFD-Simulations (Computational Fluids Dynamics), and provides a more homogeneous cellular structure of the foam. Using novel additives also provides a significantly finer cellular structure than the conventional solution. In the near future, pressure optimization in the extrusion process can also influence the cellular structure in a positive manner.

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