A Revolutionary Approach to Rotomoulding – Evolve

Introduction

Even though rotomoulding continues to attract an increasing level of interest globally, it seems that this extraordinary and very versatile method of polymer processing maintains its inherent peculiarities and characteristics such as long cycle time, a very limited selection of rotomouldable materials and an inefficient heat exchange. Moulders today are still facing the same issues that moulders were confronted with many years ago - pinholes, voids, clogged breathing systems, basic design errors and so on. It appears that this flexible way to process resins such as polyethylene, polypropylene, polyamide and their like has not been transformed by the introduction of revolutionary and advanced technologies that could help to address these specific issues. For example, for many moulders it can be extremely difficult to eradicate pinholes entirely from the surface of rotomoulded articles; cycle time is incredibly long if compared to other plastic processes; the rotomoulding process is not an efficient process because of the lack of thermal efficiency in the heat exchange from the burner to the air, to the tool and finally to the powder.

As a material supplier, Matrix Polymers has conducted intensive research and studies in order to tackle some of the common issues that many rotomoulders still face today. In this article, we describe a new technology called Evolve - a technology that could help moulders avoid pinholes on their products' surface, shorten cycle time and reduce gas consumption without sacrificing material performance and product quality.

Formation of Pinholes

During the heating part of the rotational moulding process, the mould containing the powder is heated up in the oven from ambient temperature to the melting temperature for the resin. When the mould rotates in the oven, its metal wall becomes hot and the outer surface of the powder particles becomes tacky. The particles stick to the mould wall and to each other, thus building up a loose, powdery mass against the mould wall. A major portion of the cycle is taken up in the coalescence of the powder until it forms an homogeneous melt: this part of the process is known as the sintering phase. Pockets of air are randomly formed and these remain trapped between the powder particles. Slowly they transform themselves into spheres and, under the continuing influence of heat over an extended period of time, they will eventually disappear. However extended period of time in the oven would eventually eradicate the pinholes but the polymer could be degraded which would lead to a loss of mechanical and physical properties.

These pinholes do not move through the melt. The viscosity of the melt is too great for this to happen, so the bubbles remain where they are formed and slowly diminish in size over a period of time (see Figure 1). Commonly, the only controls on the process are the oven temperature, the time in the oven and the rate of cooling. Each of these variables has a major effect on the properties of the end product. If the oven time is

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too short, or the oven temperature is too low, then the sintering and consolidation of the resin will not have time to complete.

This results in low impact strength, low stiffness and a lack of toughness in the end product.

Conversely, if the plastic is heated for too long, then degradation of the plastic will occur and this results in brittleness. In commercial production an easy and practical 'tool' used by moulders is to look at the extent to which the moulded articles have pinholes in a small shaving taken through the thickness of the part.

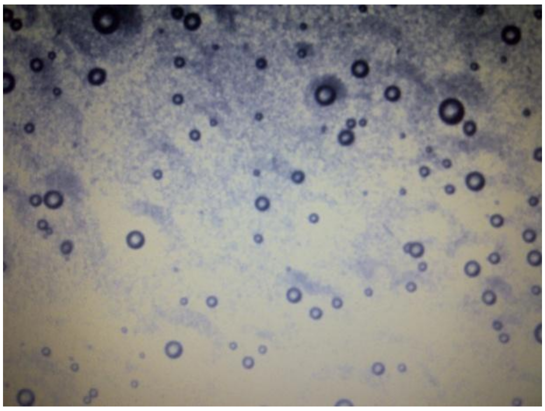

Fig. 1 – formation of pinholes

If there are no pinholes then there is a danger that the part has been overheated or heated for too long and this will result in brittleness. If there are too many pinholes then the part is 'undercooked'.

The ideal condition is thought to be a small number of pinholes towards the inner, free surface although the optimum moulding conditions should be established by performing tests on the moulded part to verify whether the material (and the part) achieves the performance levels targeted.

Evolve – its mode of action

Evolve would speed up the coalescence of the powder in its molten phase by reducing the surface tension of the bubbles of air which are randomly formed during the sintering phase. This means that less heat (energy) is required for them to disappear. Evolve is not a flow promoter and would not have any effect on the rheological (viscosity) properties of the resin. Other factors may influence the sintering stage of the process such as particle size and its distribution, particle shape and how the heat is transferred from the oven (burner) to the polymer.

Test results

As per good manufacturing practice, whenever the chemistry of a material is changed or even slightly modified, it is recommended to assess the mechanical and physical properties of the resin. In this study Revolve N-307 with and without Evolve were compared. To ascertain the impact properties of the Evolve N-307, rotationally-moulded hexagonal bins were produced at various moulding conditions on a Ferry RS1.90 carousel machine as illustrated in figure 2. The oven temperature was fixed at 250 °C and the oven time was varied.

The rotomoulded hexagonal shaped items were cut in square plaques (125 x 125 x 3 mm) and then conditioned at -40 °C for 24 hour before being impacted. The plaques were finally impacted in accordance

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to the falling dart method developed by ARM-I. The ARM Impact strength values at each of the moulding conditions are plotted in figure 3.

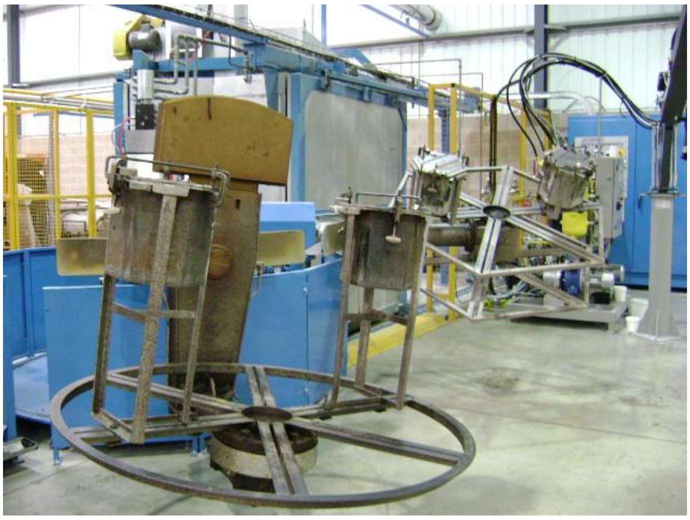

Fig. 2 – Test mould hex-bin on the Ferry RS 1.90

The mathematical model applied to the falling dart test methodology also enables us to calculate the number of brittle failures. This number is plotted against cook time in figure 4.

By evaluating the number of brittle failures it is possible to determine a range of moulding conditions within which a good quality resin has zero brittle failure. This determines the operating or processing window of a polymer.

By applying the Evolve technology of N-307 it is possible to observe that N-307 reaches the same impact energy but sooner and maintains the same operating window of N-307 without Evolve.

This means that N-307 maintains the same mechanical performance and the technology does not influence the short term properties of the polymer.

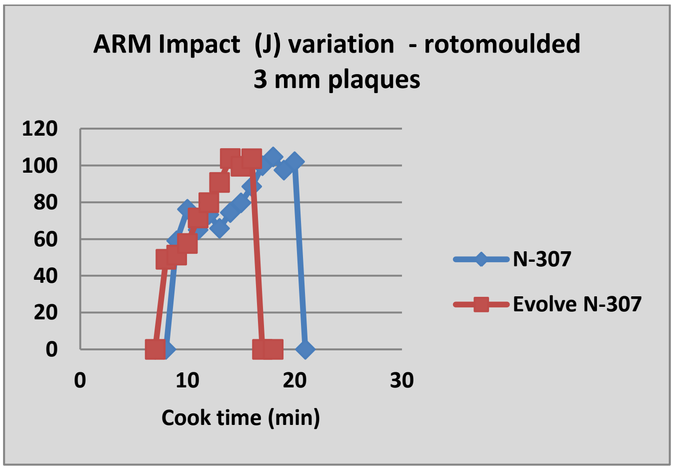

Fig. 3 – ARM Impact comparison

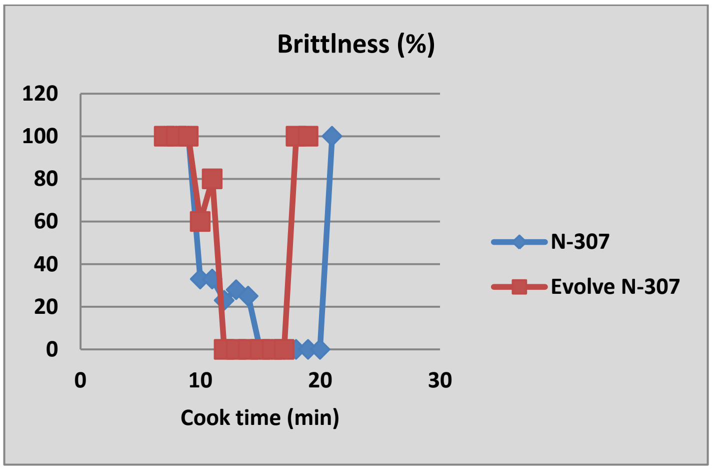

Fig. 4 – Brittleness comparison

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Densification

Another way to assess how the technology influences the sintering stage of the rotomoulding process is to measure the development of the part-density. This simple and easy test is based on Archimedes' principle. In simple terms, the principle states that the buoyancy force on an object will be equal to the weight of the fluid displaced by the object, or the density of the fluid multiplied by the submerged volume times the gravitational acceleration. At each of the moulding conditions, the density of a moulded part taken from the hexagonal bin was measured: the performance of N-307 with and without Evolve was measured as shown in figure 5.

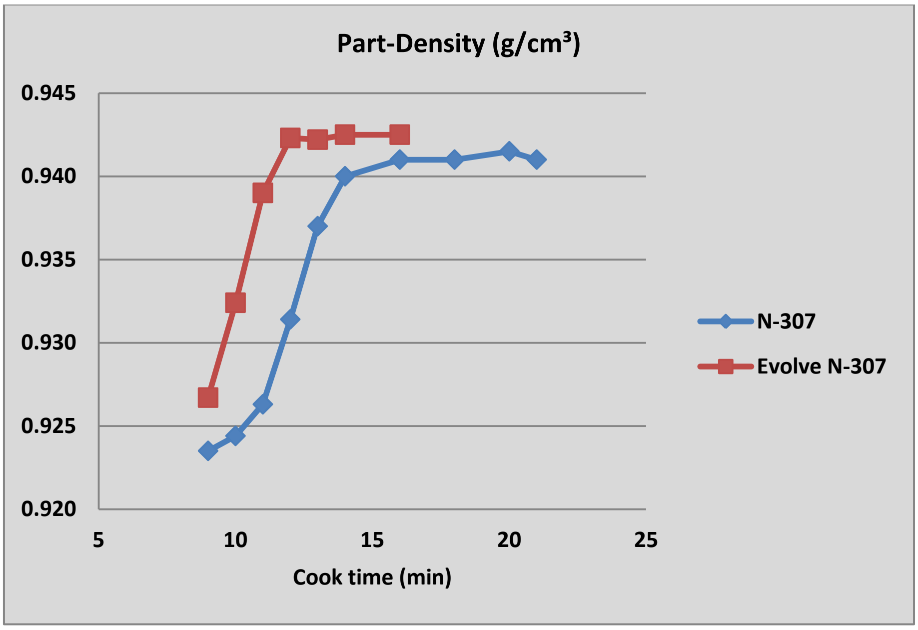

Fig. 5 – Part-density development of Evolve N-307

As can be seen in figure 5, the technology influences the sintering process and the polymer achieves its nominal density sooner.

Gas consumption

As described in the mode of action, this technology can reduce the surface tension of the powder in the molten state. Therefore the powder, when molten, might require less energy to coalesce. To prove this, it was necessary to create a correlation between a material's property and the temperature of the oven. In this study it was decided to measure the density of a moulded part and monitor the gas consumption required to cook the part at the optimum moulding conditions. N-307 with and without Evolve was used and hexagonal shape bins were moulded on the Ferry RS1.90 carousel machine. The time in the oven was kept fixed and the temperature of the oven was varied as illustrated in figure 6. For each moulding

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condition, the peak internal air temperature was also measured as shown in figure 7 and the gas consumed was recorded by an Actaris gas meter located on the back of the Maxon burner within the Ferry.

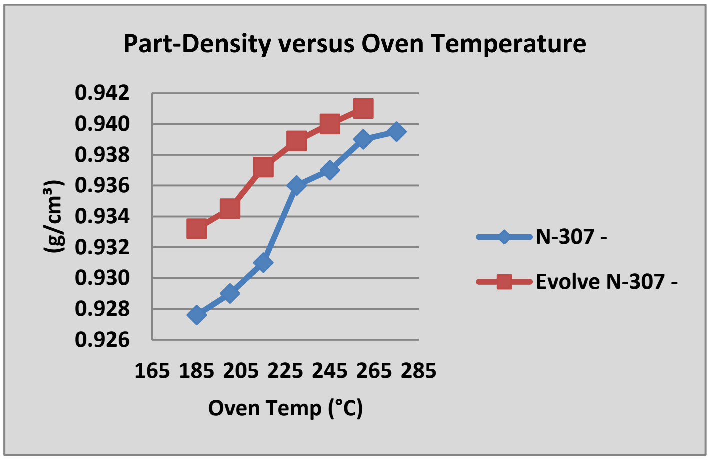

Fig. 6 – Part-density vs. Oven Temp

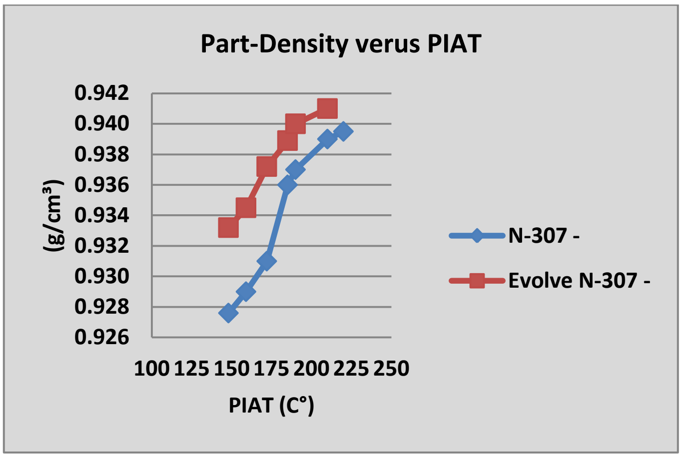

Fig. 7 – Part-density vs. PIAT

Fig. 8 – Actaris gas meter

PIAT (°C)	N-307	Evolve N-307	Gas (m³)
120	-	-	0.64
148	0.9276	0.9332	1.58
159	0.9271	0.9345	1.72
172	0.9286	0.9372	1.93
185	0.936	0.9389	2.37
190	0.937	0.94	2.81
210	0.939	0.941	3.25

Table 1 – Summary of the measurement

All measurements taken during the analysis are listed in table 1.

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Conclusions

As described in this article the Evolve technology influences the optimum moulding condition of a resin by affecting the sintering process. This leads to a number of potential benefits such as a reduction in the quantity of pinholes on the surface a moulded product, a reduction of cycle time with a potential increase of productivity per shift and reduction of gas consumption with a significant reduction of CO_2 emissions. In order to assess the advantages of the technology it is required to compare the same polymer without Evolve and establish an optimum moulding condition. For further information about the Evolve technology please contact the author at aldo.quaratino@matrixpolymers.com

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