INDUSTRIAL PREFORMERS FOR CFRP

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**Abstract**

Glass, carbon, aramid and natural fibers of every type and consistency can be successfully handled and precisely placed in large or small molds and formed into a preform in dozens of different applications. In each application, the preform is then placed into a mold for the application/injection of a thermoset to complete a composite part. The production equipment required to ensure a fast cycle time and a high quality part is described along with important considerations for the equipment. Actual production examples are provided.

**High-Productivity RTM: What’s Required?**

The manufacture of composites using the Resin Transfer Molding (RTM) technology is a well-known process. This method allows for the production of a wide variety of lightweight, high strength parts made with different chemical formulations (Epoxy, Polyester, Urethane) reinforced with various types of fibrous reinforcements (glass, carbon, aramid, etc.). Typically a low-pressure, low-output injection method is used to impregnate these fibers with liquid in a closed mold. This method has been criticized for its rather slow cycle time that allows for the demolding of a polymerized finished part every 20-30 minutes, depending on its size and shape. The limited productivity of a RTM molding line, because of the long cycle times, reduces the financial Return On Investment (ROI) for the production equipment.

The availability of a new family of injection and polymerization tools, combined with fast-reaction chemical formulations, can drastically shorten the demolding time; providing a practical answer to the request for higher-productivity lines.

This faster manufacturing process can be executed if three basic technical requirements are met:

1. A quick positioning of a bi-dimensional fibrous reinforcement in a tri-dimensional mold: the manual positioning takes too much time, killing the productivity of the line. For many complex parts, a preforming process of the reinforcement is a fundamental step to achieve the required short cycle time. The preforming operation must be run in cure time outside the mold, using a chemical binder able to impart a permanent 3D shape to a layer of glass- or carbon-fiber that, on their own, are not formable.
2. A fast injection method for the liquid chemicals using high pressure in the mold.
3. A high-tonnage clamp able to withstand the pressure applied during the injection.
Previous Experiences

During the 1990’s lightweight composites were produced using the Structural Reaction Injection Molding (SRIM) technology, making use of high-pressure dosing machines and high-tonnage clamps. At the time, preforming was often a requirement to speed up the production. Glass fiber, available in roving and mat versions, was mainly used as a reinforcing material (fig. 1), and dedicated industrial preformers were developed. (fig. 2)

The thermoforming concept was applied to the preforming operation: to thermoform a part, a plastic sheet is firmly held in place along its edges while heat is applied on both sides. When properly heated, a forming plug is pushed against it and the sheet is stretched to a given shape. (fig 3) But the stretching operation imparts an irregular thickness to the formed part. Irregular thickness leads to poor mechanical strength. New techniques were required for preforming.

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**Fig. 1 - The glass preform for a top sleeper**

**Fig. 2 - The glass mat preformer was designed for large preforms (up to 3.3 x 3 m) used for truck parts**

**Fig. 3 – In a performer, a textile sheet is stretched to a given shape**
A patented Hold-Slip Frame was developed in which the reinforcement (a drape) is held in position and transferred in the forming mold. (fig 4) When in place, the forming plug starts pushing the drape in the mold’s female half while a series of pre-tensioned grippers mounted on the holding frame release it progressively and with different force according to their position.

By accurately adjusting the pre-tension of each gripper, the reinforcement gets distributed evenly and without wrinkles in the forming mold. Being pre-coated with a polymeric binder, the formed reinforcement keeps a geometrical memory of its shape, and a stable preformed piece of glass fiber can be extracted from the mold after a few seconds of cooling.

The use of thermoplastic and thermosetting binders (used in accordance with the type of resin that will be injected later in the preform) was refined to cope with the shaping times performed by these early machines.

A preformer’s production cycle compatible with the requirements of the automotive industry (one piece per minute) was achieved, and several machines were installed in Europe and in the USA: The example shown here (fig.6) is the preformer, with integrated punching, used for the reinforcement of the BMW Series 7 dashboard (fig. 5) made in the mid 1990’s. The irregular shape of the desired parts requires a trimming operation before they are brought to the impregnation process, therefore, a certain amount of scrap glass is generated in this phase.
An alternative method, suitable for wide and deep-draw parts, was developed for a U.S. auto parts manufacturer who had to produce a wide one-piece preform for a complete pick-up loading bed. In this case the preformer chopped and distributed a glass roving directly on a male plug provided with an extraction of air from inside through a pattern of small holes.

Four anthropomorphic robots, holding one chopping head each, were acting simultaneously on the same plug, dispensing more than 45 kg (100 lbs.) of chopped glass in less than two minutes. (fig 7 & 8)

The roving was held in position by vacuum applied in the plug (fig. 9), and the polymeric binder that coated it was cured in the nearby oven where the plug was transferred for a short period at the end of the glass spraying phase (fig. 10). Part-to-part cycle time in this case was three minutes.
One disadvantage of this method was the lower fiber content of the reinforcement: the chopped fiber is applied with a stochastic distribution pattern and a limited length, resulting in a lighter reinforcement in terms of specific weight and with less mechanical resistance than that provided by a similar part by glass mat.
Automotive CFRP Process

More recently there have been newer developments in the field of industrial preformers for Carbon Fiber Reinforced Plastics (CFRP). The molding process is illustrated in fig. 13: a sandwich of carbon fiber (CF) is prepared, pre-cut to size, and preformed under pressure. It is then positioned into a mold and injected with a reactive polymer formulation.

Here the shaping problem is enhanced by the fact that modern carbon fiber reinforcements are required in numerous configurations of multi-layered, multi-axial sandwiches featuring a poor 3D shape ability. (fig. 14) For this reason, sometimes the most complex preforms are made in different parts and then they are assembled in the mold prior to the injection of resin to form a larger component. (fig. 15) In this way, CFRP can be used, for example, to produce highly integrated components with a large surface area, which would be extremely cumbersome to manufacture from aluminum or sheet steel.
At both process stages, preforming and preform joining, the big challenge lies in ensuring good production repeatability with flexible fabric so that the preforms will maintain a stable shape and can be joined with maximum precision. This precise and delicate operation is performed using a sandwich consisting of various layers of carbon fabric, selected according to the mechanical resistance desired for the final molded part.

The Hold-Slip Frame method developed in the 1990’s has been improved so that these modern reinforcements can be handled in accordance with their specific physical aspect and properties.

A system of individually programmable Smart Grippers holds the drape during the forming phase and progressively releases the sandwich in the forming cavity of the mold. (fig 16) This draping operation allows for the deposition of complex layers of carbon reinforcements greatly reducing the formation of wrinkles and creases.
A Three-Step Operation

The preforming operation of carbon fiber reinforcement occurs in three steps – loading, heating, and forming:

**Loading** can be done either from rolls or cut pieces. Regular parts with rectangular shapes benefit from a roll-loading system (fig. 17), that can work – using appropriate grippers that have been developed to handle different sandwiches of carbon fibers. The gripper movement is synchronized with the rolls unwinding. When the programmed length is achieved, the grippers stop and the transversal cut is made. Then the grippers transfer the cut blanks into the oven. For some irregular shaped parts, material is cut and assembled off line and placed in the molds with special frames lowering the amount of carbon fiber scrap. (fig. 18)

**Heating** methods depend upon the selected material, shape, binder, etc. Well known proper heating solutions have been developed: infrared (IR), contact, and hot air. For the IR system, ceramic heaters are preferred, to avoid short circuits and fire risk. Contact heating must be carefully tested with the selected fibers to avoid sticking and part to part contamination. Hot air heating can be tuned from 100 to 200 °C (212 to 392 °F) according to the type of binder used. (fig. 19 & 20)
Forming occurs in dedicated presses (fig. 21), available in different configurations, characterized by fast transfer and clamping action: the hot reinforcement must reach the forming station in the fastest possible way.

If the binder cools before forming, it loses its capacity of maintaining a given shape; hence the reinforcement must be transferred and clamped in less than 10 seconds to provide the best forming performances.

This time includes the action of the Hold-Slip Frame and Smart Grippers, which require two movements, separated but integrated in terms of sequence control, for a correct draping effect. (fig. 22-23-24)
Horizontal and vertical adjustments can be performed on the Hold-Slip equipment used to control the release of Carbon sandwich during forming.

Large and precise presses with a sophisticated grippers system can be required for preforms with a deep draw. The press can also hold a punching tool for the automatic trimming of the part.

A robotized pick-up of the preform (with the possibility to separate the trimmed excess) is possible. (fig. 25) As an alternative, the lower platen can slide out of the press with a shuttle system, to allow for the manual demolding of large, complex preforms.
The Market

The driving force that makes the production of CRFP one of the most rapidly-developing sectors of the plastics industry is the possibility to obtain large, complex, elegant parts weighing a fraction of those made with any metal (fig. 26), thus contributing to the reduction of mass for cars and vehicles of all types.

![Large, lightweight composite parts contribute to significant weight reduction in modern cars (Photos: BMW)](image)

This is reflected in an energy-savings solution, allowing for the use of other heavier components (such as batteries or the latest generation fuel cells) while maintaining the total weight of the vehicle.(fig. 27)

![Testing a passenger's safe cell in the MegaCity car made with CFRP and aluminum alloy (Photo: BMW)](image)

Other applications can be found in aeronautics and airspace, marine and yachting construction, leisure and sport parts (for cycles, motorbikes, snow mobiles, archery, etc.) and – more recently – in mass production of electronic and mobile communication equipment.

The use of CFRP parts in laptops, notepads and smartphones nowadays is a reality, and a fast preforming system can only contribute to the industrial success of these composites.
A Complete Package Is Available

Cannon has developed a complete range of solutions for this application, and integrates the offer of the hardware (dosing units and mixing heads for Epoxy and Urethanes, preformers, dedicated presses, handling systems, molds, trimming, ancillary and chemical storage equipment) with the possibility of using their development laboratories, in Europe, USA and Asia, for testing, prototyping, pre-production runs, and mold fine tuning. Figure 28 shows an example of such a line, which – in addition to a preformer and a RTM press plus dosing unit for the chemicals – includes a press for Pre-preg molding and an automatic mold-changing station.

Fig. 28 Complete CFRP molding line, including preformer (left, below), robotized handling (center), chemicals injection and polymerization press (right), robotized demolding (far right) and automatic mold change (top left). A Pre-preg injection clamp is also present in this configuration (center, below)

References

Dozens of preformers for glass fibers have been supplied around the world. As far as the carbon fiber preformers are concerned, two of them are worth being mentioned here:

The first performer was supplied to BMW Landshut’s Innovation and Technology Center, originally for development work. (fig. 29) to manufacture a wide series of prototypes. Later, it has been used for industrial production of all the roof preforms of the BMW M3 and M6 models, being the first components in CFRP produced in serial production with a fully-automatic preforming technology (fig. 30).
The second performer was supplied more recently to Lamborghini, Audi VW Group (fig. 31), for the production of all the reinforcements (as well as for the molding of smaller Pre-preg parts) (fig. 32&33) used for their “all carbon” Aventador dream car.
Conclusions

Several preforming alternatives are available today for glass- and carbon-reinforced composites. Industrially used by major car manufacturers, these machines have been a proven and reliable alternative to manual forming.

The next step of Cannon R&D activity in this industrial sector will be the development of preformers for Pre-preg parts: there is an increasing request from the market for preformed Pre-pregs, to speed up this popular industrial process.

This field, in constant and rapid evolution, requires dedicated solutions that Cannon - being exposed on several fronts of the industry, dealing with different chemical and reinforcement alternatives – can study in cooperation with its customers.