OCV™ Reinforcements

Twintex®

Glass Polypro

Thermoplastic composite solutions

Vacuum Moulding Manual

Foreword

The aim of this manual is to give the readers the experience in the field of Twintex® fabrics implementation by vacuum molding technology. It is up the reader to take all necessary technical precautions adapted to his choice in the design and achievement or vacuum molding Twintex® parts without leaving out the validity of the product. In no case will the responsibility of the author be involved in any way.

CONTENTS

Introduction

Vacuum molding technology allows a composite part to be produced with Twintex® from a woven structure. This material is composed of continuous commingled fibers of glass and thermoplastic polypropylene. The fabric is first draped into position within the mold cavity, and enveloped by vacuum films, as in the case of conventional prepregs. When the vacuum is applied (# 1 bar), the air entrapped between the fibers and the different layers of Twintex® fabrics is able to escape. The assembly is then heated to the melting temperature of the polypropylene fibers. The vacuum exerts a pressure which allows the thermoplastic matrix to impregnate the glass fibers. After cooling, the composite part obtained is perfectly impregnated, with a controlled volume fiber content.

This processing method is very interesting for small and medium volume parts, by virtue of relatively low investment costs. It meets regulations concerning clean working conditions, and in particular it allows the fabrication of thermoplastic composite parts, thereby also proposing a solution to the problem of styrene evaporation into the working atmosphere. Moreover, the working environment is clean, and the storage requirements of the material are free from restrictions.

The use of Twintex® fabric confers increased mechanical properties on the parts produced, notably in terms of impact. Twintex® may be combined with PU foams, wood or even honeycombs to make sandwich structures. In addition, the surface appearance after molding is of a good quality. Some techniques, such as the application of a painted finish, a gel coat or a surface film then permit the production of thermoplastic composite parts suitable for the transport, marine and sports & leisure markets.

I – Part design

The nature and shape of the part should be studied with care before undertaking production. The vacuum molding process with Twintex®, having continuous fibers, imposes some limitations which will determine the possibilities to produce some shapes and the design of the part. The following disadvantages may, however, be avoided:

- Difficulty of placing the Twintex®
- Loss of time, involving a reduction of productivity and an increase in labor
- Poor part consistency
- Bad influence on the surface appearance of the part in these zones

I.1. Geometry

- The thickness of parts produced may go from 2 mm to 4 mm. Local variations may be present. However, the placing of the Twintex® and of any other materials (wood, PU foam,…) will penalize the cycle time. Moreover, temperature control in these zones will be necessary in order to ensure a homogeneous consolidation of the composite structure.
- The maximum part dimensions depend on the complexity of the part, and of the possibility of tooling design. With composite molds it is possible to produce a vacuum molded part of about 6 to 7 m² area.
- Sharp angles are not permitted, and must be replaced by a curve of radius at least 5 mm, on the interior face of a 3 mm thick part. Within this zone, it is difficult to obtain a homogeneous material, and the outside of the angle consists only of resin, which results in mechanical weakening. Moreover, in the case of sharp angles, the resin is not able to fill the impression in the mold, creating a lack of material necessitating reworking after molding.

I.2. Draft

Demolding will always be facilitated with parts having a large draft angle. Generally, parts of less than 80 mm height should have a draft angle greater than 3°. Undercuts may be accommodated provided that removable elements are incorporated into the tool design. In this case, proper sealing of the mold will need to be verified. If not, the process of bladder molding also allows the production of 3-D hollow parts with undercuts (canoes, masts,…).

I.3. Ribs

Ribs are not possible, because the material does not flow.

I.4. Inserts

Usable inserts must have a melting temperature higher than 210 – 220 °C. Radius of curvature should comply with the rules stated above in order to ensure a perfect adhesion with the Twintex® material. This adhesion may be mechanical, in preparing the surface of the insert (sanding,…). If not, an interfacial film may be used to give a bond between the Twintex® and a type of material such as wood, aluminum honeycomb, etc…

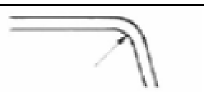
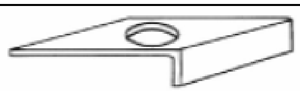
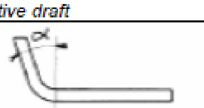
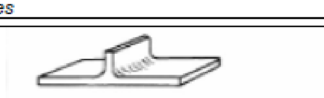
I.5. Openings, holes

Large openings are possible (above about 10 cm²). However, for smaller openings, machining of the part will be necessary.

I.6. Surface appearance

The molding of Twintex® material takes place in one half of the mold. The produced part will therefore only have one face with a finish which reflects the surface of the mold. In all cases, to avoid fiber pattern on the surface, a low area weight Twintex® fabric should be used in the first layer. The structure of the surface layer may be modified by applying a gel coat before the vacuum molding operation. The addition of a gel coat reduces the productivity by increasing the occupation time of the mold.

Table 1: General principles for molded part design made by Twintex® vacuum processing.

	Remarques	*Remarks*
 Rayon minimal intérieur *Minimum inner radius*	- 5 mm. - Epaisseur pièces = 3-4 mm.	- *5 mm.* - *Part thickness= 3-4 mm.*
 Trou d'ouverture *Hole opening area*	Impossible pour des petites dimensions.	*Not possible for small dimensions.*
 Verticale contre-dépouille *Vertical negative draft*	Oui. - Si présence d'éléments mobiles dans le moule.	*Yes.* - *If the tool is designed with removable elements.*
 Angle de dépouille *Draft angle*	> 3° pour une pièce profondeur de pièce de 80 mm.	*> 3° for a part depth of 80 mm.*
 Epaisseurs *Thickness*	De 1,5 mm à 10 mm.	*From 1,5 mm to 20 mm.*
 Variations de forme *Shape change*	Simple.	*Simple.*
 Inserts *Cores*	Possible.	*Possible.*
 Nervures *Ribs*	Non.	*No.*
Aspect de surface *Smooth surface*	1 seule face.	*Only one side.*

I.7. Technical - economic approach

This process is suitable for small and medium production rates, (1 to 30 parts/day), that is 1100 to 33 000 parts over 5 years. This is in large part due to the relatively low investments, which may change according to the volumes. In effect, the choice of mold, its material and design, will also determine its life. Independently of the technical criteria, in order to optimize the choice, the volume requirement and daily production rate must be well known.

I.7.1. Process / material comparisons

If several processes are in competition, the choice of production technique can be made on technical criteria, on the volume requirement, and on the size of the investment to be made.

Table 2: Low and medium volume process comparison.

	Contact / Projection *Contact /Spray up*	**RTM light**	**RTM**	**Moulage sous vide du Twintex®** ***Twintex® Vacuum moulding***
Production (16 heures) *Rate (16 hours)*	1 à 15 pièces / jour. *1 to 15 parts / day.*	5 à 15 pièces / jours. *5 to 15 parts / day.*	15 à 40 pièces/ jour. *15 to 40 parts/ day.*	1 à 30 pièces /jour. *1 to 30 parts / day.*
Investissements machines *Machine investments*	Pinceau , rouleaux dé bulleurs. Machine et cabine de projection. Machine Gel-coat. *Brush, rolls for removing air bubbles Spray up machine and spray booth. Gel coating machine.*	Pompe à vide, machines d'injection et de gel-coat, porte moule. *Vacuum Pump, injection & gel coat machines, tool handling system.*	Thermo-régulateur, machines d'injection, de gel-coat et de préformage, porte moule. *Heat controllers, injection, preforming and gel-coat machines, tool handling device.*	Pompe à vide, système de chauffage (étuve, autoclave, thermo-régulateur,…). Consommables (films, membranes silicone). *Vacuum pump, heating system (oven, autoclave, heat controllers,…). Consumables (films, silicone membrane).*
Investissement moule	Moule composite : UP résines.	Moule et peau composite : résine	Moule composite (résines UP, époxy),	Moule composite (résines époxy,

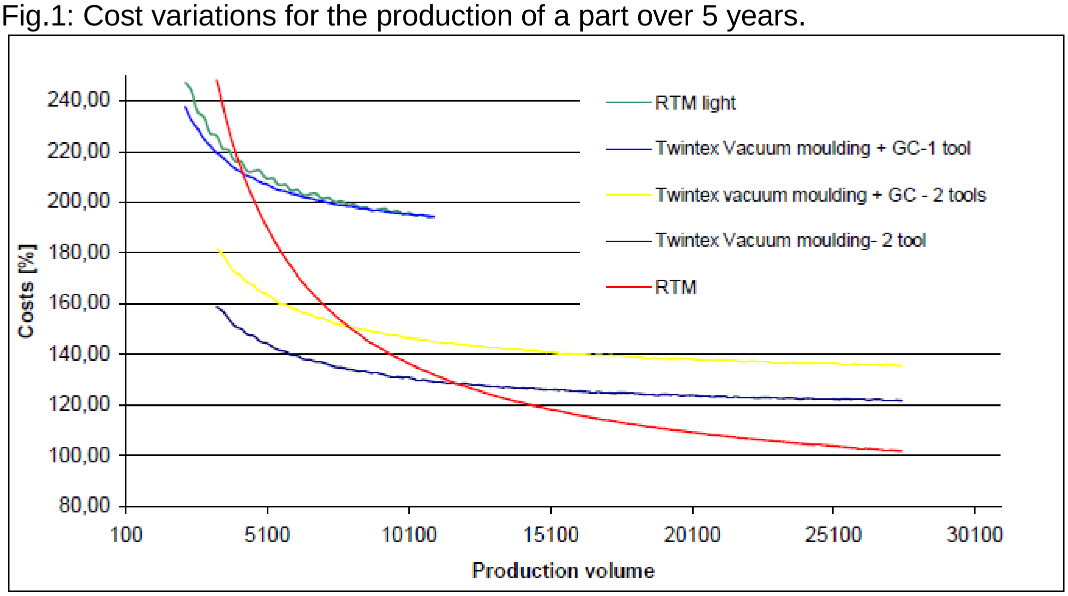
	Matrice ou poinçon.	UP. Matrice et poinçon.	aluminium (coulé, usiné) Nickel électroformé. Matrice et poinçon.	céramique), aluminium coulé, Nickel électroformé, tôle mécano-soudée. Matrice ou poinçon.
Tool investment	*Composite tool : UP resins.* *Male or female tool.*	*Composite tool and skin : UP resin.* Male & female tool.	*Composite (UP or Epoxy resin) or aluminium (cast, machined), or Nickel electroformed skin.* *Male and female tool.*	*Composite (Epoxy, ceramic resins) or cast aluminium, or Nickel electroformed skin or welded metal sheet.* *Male or female tool.*
Renfort Reinforcement	Mât fils coupés. Tissu – roving. Roving projection. Complexes. *Chopped strand mat.* *Fabrics – roving.* *Spray up roving.* *Complexes.*	Complexes : Rovicore® ou Multimat or Unifilo®. *Complexes :* *Rovicore® or Multimat. or Unifilo® mat.*	Complexes : Rovicore® ou Multimat or Unifilo®. *Complexes :* *Rovicore® or Multimat. or Unifilo® mat.*	Tissu Twintex® ou Twintex®.multiaxial *Twintex® Fabrics or multiaxial Twintex®.*
Propriétés mécaniques *Mechanical properties*	Taux de verre en poids *(glass weight content)* : 25 à 35%. E # 6 000 to 10 000 Mpa. σ_{Flex} # 150 Mpa.	Taux de verre en poids *(glass weight content)* : 25 à 35%. E # 6 000 to 10 000 Mpa. σ_{Flex} # 150 Mpa.	Taux de verre en poids *(glass weight content)*: 25 à 35%. E # 6 000 to 10 000 Mpa. σ_{Flex} # 150 Mpa.	Taux de verre en poids *(glass weight content)* : 60%. E # 12 500 Mpa. σ_{Flex} # 300 Mpa.
Dimensions *Dimensions*	Pas de limite. 2 à 20 mm d'épais. Pas de limitations de formes. No limit. 2 to 20 mm thick No shape limitations	Pièce de grande dimensions. 1 à 10 mm d'épais. Large dimension parts. 1 to 10 mm thick. Sandwich construction.	Pièce de grande dimensions. 1 à 10 mm d'épais. Construction sandwich. Large dimension parts. 1 to 10 mm thick. Sandwich construction.	Pièce de grande dimensions 1 à 10 mm d'épais Construction sandwich. Large dimension parts. 1 to 10 mm thick. Sandwich construction.
Avantages *Advantages*	Faibles investissements. Coût matière faible. *Low investments.* *Material cost lower.*	Faible taux de vide Contrôle de l'épaisseur du laminé. Procédé propre. *Low void content* *Control of laminate thickness.* *Clean process*	Contrôle de l'épaisseur du laminé. Procédé propre. Temps de cycle. *Control of laminate thickness.* *Clean process.* *Cycle time.*	Faible taux de vide. Contrôle du taux de fibres en volume. Contrôle de l'épaisseur du laminé. Procédé propre. *Low void content.* *Control of fibre volume fraction.* *Control of laminate*

				thickness. *Clean process.*
Inconvénients	Prix main d'œuvre (personnel qualifié). Taux de vide élevé. Faible contrôle de l'épaisseur. Emission de styrène. Stockage matière chimique. Manipulation de verre. Contrôle du taux de fibres en volume.	Emission de styrène (faible). Stockage matière chimique. Manipulation de verre. Contrôle du taux de fibres en volume.	Investissement machines. Emission de styrène (faible). Stockage matière chimique. Manipulation de verre. Contrôle du taux de fibres en volume.	Une seule face d'aspect. Coût matière plus élevé. Consommables (films, membrane silicone).
Disadvantages	*Labour cost (Skilled people).* *Higher void content.* *Poor control of laminate thickness.* *Styrene emission.* *Chemical product storage.* *Dry glass handling.* *Control of fibre volume fraction.*	*Styrene emission (low).* *Chemical product storage.* *Dry glass handling.* *Control of fibre volume fraction.*	*Machines investments.* *Styrene emission (low)* *Chemical product storage.* *Dry glass handling.* *Control of fibre volume fraction.*	*One finished surface.* *Material cost higher.* *Consumables (films, silicone membrane.)*

I.7.2. Production rates

Figure 1 shows that the machine occupation time determines the cost of the final produced part. An investment of several molds for the vacuum molding process will permit a reduction in the machine occupation time and also the final cost of the part. The figure also shows that for low production rates, Twintex® vacuum molding is also competitive with RTM light. For rates of 12,000 to 15,000 parts over 5 years, this process is also competitive with standard RTM.

Fig.1: Cost variations for the production of a part over 5 years.



II – Vacuum molding tools

The choice of material to make the mold will depend on economic factors such as the cost, tool life, the number of parts to be produced and the cycle time. The final surface appearance of the part will also depend on the quality of the mold finish. There are five general types of mold:

- High temperature epoxy composite molds
- Ceramic matrix composites tools
- Electroformed nickel skin molds
- Aluminum molds
- Welded metal molds

II.1. Tools for film, membrane and bag molding

In the cases of vacuum molding with films, a bag or a membrane, the molds used consist of a cavity or a punch. Parts obtained from the mold will have only one smooth face (the mold side) and one rough molded face (the vacuum side).

II.1.1. Epoxy composite molds

The molds are constructed from a model representing the shape of the part, and a peripheral flange to form a vacuum seal with the film or membrane. The structure of the mold includes a layer of gel coat specially suited to the surface requirements (abrasion resistance), a thickness of composite materials composed of Glass/Epoxy prepregs or made by Glass/Epoxy lamination. Stiffening elements may be added to ensure the dimensional stability of the assembly.

Dimensions:

- The maximum reasonable dimensions may be estimated to correspond to an area from 6 to 7 m^2.
- The thickness of the mold should be no greater than 5mm in order to reduce the thermal inertia.

Surface finish:

- This will reflect the mold surface finish. Always, hurried production, resulting in an imbalanced structure or differential shrinkage, may degrade it. The use of gel coat on tool surfaces is not recommended for this technology. Cracking will inevitably occur sooner or later. A good surface finish can be achieved without resorting to a gel coat.

Resins and reinforcements used:

- The resins used will depend on the operating temperatures of the tooling. For our process, high temperature epoxy resins are employed (Tg > 200 °C). Moreover, it is most important to follow the curing cycle of the resin stated by the resin suppliers. Curing of an epoxy system in an autoclave will permit an increase in the longevity of the mold. Reinforcement of the resin by glass fiber will assure the stability and rigidity of the mold. The choice of reinforcement types, their positioning within the thickness of the structure and the level of reinforcement in the material will influence both the surface finish and the correct geometry of the mold.

3 types of reinforcement are generally used :

- Low weight chopped strand mat: from 200 to 300 g/m². It is used in the first laminate layers on the gel coat.
- Chopped strand mat of 450 g/m²
- Fabric of a flat and deformable structure which may be used from the fourth layer upwards and alternatively with the mat to increase the bonding between the layers.

The percentage of glass by weight should not be less than 33% for the mat and 50% for the fabric. Prepregs may also be used to make the mold. With this material, the level of reinforcement is much better controlled than with laminating, avoiding an imbalance in the structure of the mold.

Table 3: Thickness structure obtained with each type of glass reinforcement.

Renfort *Reinforcement*	**% Verre en poids** *Glass % weight.*	**Epaisseur [mm]** *Thickness [mm]*
Mat 200 g/m² - 1 couche / *1 layer*	33	0.4
Mat 300 g/m² - 1 couche / *1 layer*	33	0.6
Mat 450 g/m² - 1 couche / *1 layer* 2 couches / *2 layers*	33 33	0.9 1.9
Mat 450 g/m² - 1 couche / *1 layer* 2 couches / *2 layers*	33 33	1.2 2.5
Tissu 270 g/m² - 1 couche / *1 layer*	50	0.3
Tissu 500 g/m²- 1 couche / *1 layer*	50	0.6
Tissu 800g/m² - 1 couche / *1 layer*	50	1

Construction principle:

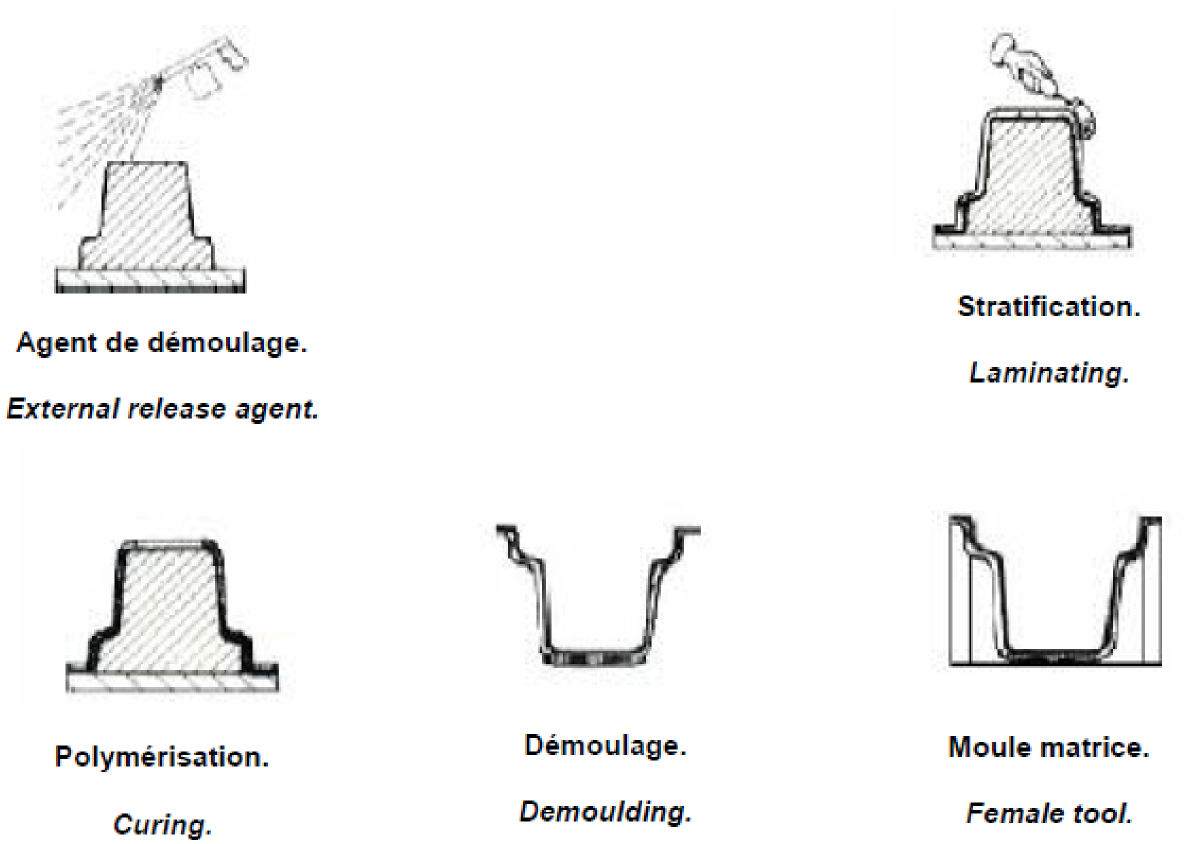
Generally from only one model of the male half continued out to the cavity sides.

- Construction of the mold cavity.
- Application of the release agent.
- Laminating the structure.
- Stiffening system and complementary equipment

Each layer is applied after the previous layer has attained a tacky state of cure. After the assembly has cured, the laminating may then continue.

It is recommended to wait for each layer to cure for 2 to 4 hours followed by rubbing down before applying another layer.

Fig. 2: Composite tool: Female tool manufacturing principle.



Advantage:
Low tooling cost

Disadvantages:
- Low productivity
- Fragile surface
- Low thermal conductivity

Heated composite molds:

This option avoids the need of an oven to heat the assembly. Heating is achieved by the circulation of oil through a coil embedded in high temperature epoxy cement. Another possibility may be a mechanism of electrical heaters embedded in high temperature epoxy cement.

This complicates the design and manufacture of the tooling. Given the short life of these tools, this option must be technically and economically validated against the standard option for this process (mold & oven).

Potential suppliers:

Speak directly with a Fiber Glass Industries, Inc. sales representative at 800 842 4413.

II.1.2. Ceramic matrix tool

These molds are constructed from a model representing the shape of the part, and a peripherical flange to form a vacuum seal with the film or membrane. The structure of the mold includes a layer of gel coat with a high abrasion resistance. This will reflect the mold surface finish. The thickness giving stiffness of the mold is given by laminating prepreg made of glass fibers reinforced with a ceramic resin. The mold is developed to get a maximum stiffness. This mold has a heat resistance close to 400°C continuously.

- Dimensions :

The maximum dimensions may be estimated to correspond to an area of 20 m². The thickness of the mold, depends on the size, can be between 5 and 10 mm. But the thickness has to be the lowest for decreasing the thermal inertia.

- _ Surface finish:

This will reflect the mold surface finish. The required gel coat thickness is about 1mm. Its shrinkage and its thermal expansion coefficient of the gel coat have to be the same than the composite to avoid cracks.

- _ Resins and reinforcements used:

The laminate layers are made with glass fibers, generally fabric of a flat structure of 500 g/m², impregnated with ceramic matrix. The percentage of resin is about 50 % by weight. This prepreg is stored at –20°C, and its life time at this temperature is about 6 months. To get optimum characteristics, it is recommended to follow strictly the using instructions given by the supplier. The using of glass fibers reinforces the ceramic resin, limits the shrinkage and ensures the dimensional stability of the assembly.

- Construction principle:

Generally from one model, we make a mold cavity made with composite (polyester or epoxy) resting at 70°C. The construction of the ceramic mold is as follows in Fig. 3.

Fig. 3 : Principle.

Fig. 3 : Principe.

Fig. 3 : Principle.

Application de l'agent de démoulage.
Application of the release agent.

Application et dosage du gel coat.
Application of the gel coat.

Dé-bullage du gel coat.
Out gazing of the gel coat.

Stratification de la structure.
Laminating of the strucure.

Préparation de la bâche à vide.
Preparation of the vacuum bag.

Réalisation de la bâche à vide.
Making the vacuum bag.

Cure at 60-70°C in a ventilated oven.
De-mold

Dry finished part at 90 °C for 12 hours.
• Apply a sealer
• Apply a release agent

Characteristics of ceramic molds:

- Possible to make large size molds
- Possible to make molds with special shapes
- Low cost
- Require same know-how as organic resin
- Heat resistance to 400°C (possibility to mold different kind of thermoplastics)
- Shrinkage lower than 0.1%
- Thermal expansion coefficient about 5.10E-6
- Possible to treat the mold with PTFE (release agent) at 400°C

II.1.3. Nickel electroformed tools

These moulds must have a peripheral flange all around the impression of the part to be produced so that it can be molded under a film or a membrane. These molds are obtained by the electrode position of a nickel skin with a thickness between 3 and 6 mm.

- **Dimensions :**

The maximum dimensions which may be produced are determined by the size of the galvanic plating vats of the manufacturer, and which should be of the order of 5 meters by 2 meters approximately. Deep draw features may be incorporated into a cavity mold (the metal is deposited onto a male plug).

The thickness of electroforming is not limited. The metal deposition rate is 0.02 mm/hour. For our molding technology, a thickness of 4 mm will be required.

- **Surface finish :**

It offers the best reproduction of the model surface, but always duplicates gross defects.

- **Metallic material used :**

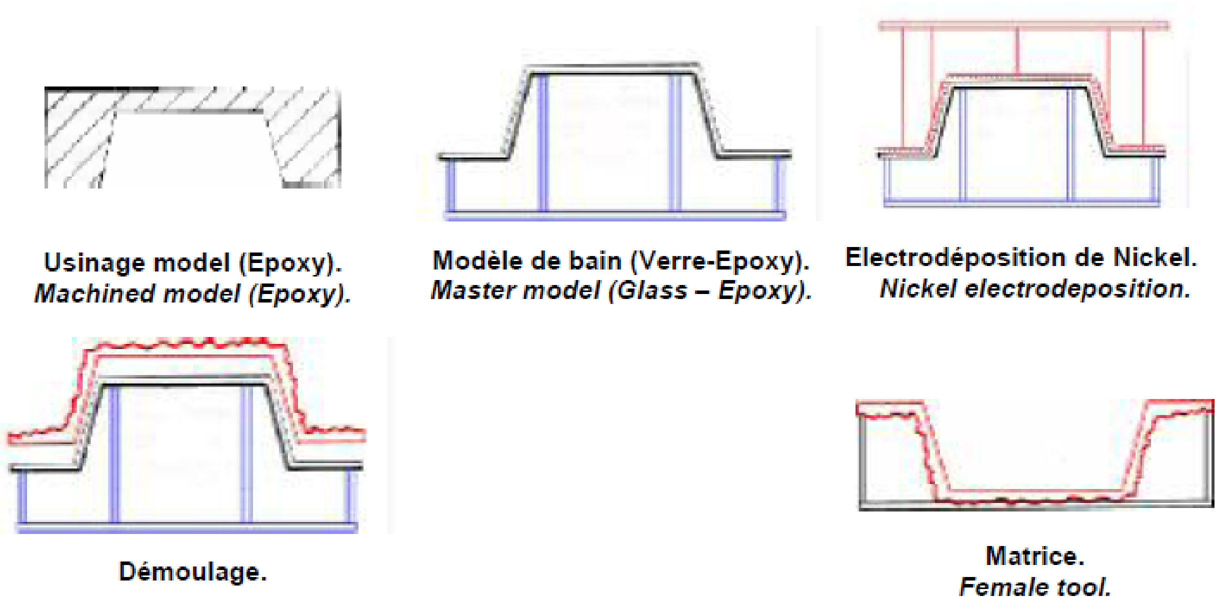
The metal used for our process is nickel. The manufacturers may suggest the use of a copper - nickel alloy to reduce the final mould cost but also to optimize the heat transfer due to the copper. However, a delamination between the two metallic materials may be produced, given the thermal limitations (200 °C) imposed by the process which is accompanied by a difference in expansion between the two materials.

- **Manufacturing principle :**

The mold is produced by the deposition of a layer of nickel by electrolysis onto the surface of the model rendered conductive. For the production of the mold, 5 steps are necessary:

- Production of the model
- Production of the galvanized plated impression of the model
- Basin model
- Manufacture of the electroform
- Demolding

Fig 4: Nickel tool electroforming: Female tool manufacturing principle.



Advantages:

- Excellent surface quality
- 50°C higher operating temperature
- Unlimited tool life
- Good thermal conductivity

Disadvantages:

- Production cost
- Not suitable for very small volumes
- Production lead time

Self heating electroformed molds:
This option avoids the use of an oven to heat the assembly. Heating is through the circulation of oil within pipes fixed under the surface skin. This option should be validated technically and economically against the standard system for this process (mold & oven).

Potential Suppliers: Please contact a sales representative from Fiber Glass Industries, Inc. for this information at 800 842 4413.

II.1.4. Cast or machined aluminum tools

These molds must have a peripheral flange all around the impression of the part to be produced so that it can be molded under a film or a membrane. These molds are obtained by the machining or casting of aluminum. Aluminum offers the advantage of being easily machined compared with steel. Also, the lead times and fabrication costs are lower.

In the case of producing a mold by aluminum casting, the surfaces may be porous delaying the attainment of a vacuum of 0.75 to 0.9 bars of pressure. Some chemical sealers resistant to high temperature (450°C) may be used to treat the mold in order to overcome this microporosity.

Dimensions:
The maximum dimensions which are produced are from 2 to 3 m^2. The mould thickness should be 3 to 4 mm.

Surface finish:
Surfaces are polished and can have a very good finish.

II.1.5. Welded sheet metal tools
The moulds produced from sheet steel do not have a peripheral flange. They are used for bag molding. They are used for simple shapes.

Dimensions:
The maximum dimensions are from 1 to 5 m^2 . The mould thickness should be 3 to 4 mm .

Surface finish:
Surfaces are polished and may have a very good finish.

II.2. Tool comparison

II.2.1 Cycle Time

The cycle time from rising to close to 200 °C and descending towards 50 °C will depend on the material from which the mould is produced, the thickness and the heating system. For the most optimized systems, the total time for heating and cooling of the part is from 30 minutes, for 3 mm of Twintex®. In order to facilitate proper heat transfer, thicknesses of from 5 to 7 mm are required. The molds may be heated by means of an oven or even by a heating system integrated within the mold (heat transfer fluid, electrical heaters,…).

II.2.2. Summary
The complexity of the parts, the number to be produced, the life time of the molds, the production costs and the molding cycle time are the important parameters for the final cost of the molded parts.

Table 4: Main tool features.

Matériaux. *Materials.*	Stratification Verre/Epoxy. Verre/céramique *Laminated Glass/Epoxy. Glass/Céramic*	Prepregs Verre/Epoxy Verre /Céramique *Glass/Epoxy Glass/Ceramic Prepregs.*	Tôle chaudronnée-mécano soudée. *Welded sheet metal.*	Aluminium coulé ou usiné. *Cast or machined aluminium alloy.*	Peau Nickel électroformé. *Electroformed nickel skin.*
Taille limitée par : *Size limited by :*	Autoclave – Four. *Autoclave – Oven.*	Autoclave – Four. *Autoclave – Oven.*	Installation d'usinage. *Machining facilities.*	Installation d'usinage ou de coulé. *Machining or casting facilities.*	Bac de galvanoplastie. *Galvanoplasting tank.*
Etat de surface. *Surface finish.*	Avec ou sans gel-coat. Dépend de la qualité du modèle. *With or without gel-coat. Depends on model quality.*	Avec ou sans gel-coat. Dépend de la qualité du modèle. *With or without gel-coat. Depends on model quality.*	Qualité moyenne. *Medium quality.*	Surface polie. *Polished surface.*	Dépend de la qualité du modèle. *Depending of model quality.*
C.T.E. (mm/mm/°C).	$14.2*10^{-6}$	$14.2*10^{-6}$ *Glass/Epoxy* $5*10^{-6}$ *Glass/Ceramic*	$12.\&*10^{-6}$	$22.5\ 10^{-6}$	$13.3\ 10^{-6}$
Durée de vie (pièces). *Tool durability (parts).*	1 000 à/to 3 000.	1 000 à / to 3 000.	5000 à / to 10 000.	5 000 à / to 30 000	50 000 à / to 100 000.
Amortissement série. *Production rates.*	Petite série (5 à 10 pièces/jour). *Low rate(5 to 10 parts/day).*	Petite série (5 à 10 pièces/jour). *Low rate (5 to 10 parts/day).*	Petite série (5 à 10 pièces/jour). *Low rate (5 to 10 parts/day).*	Moyenne série (15 à 20 pièces/jour). *Medium rate (15 to 20 parts/day).*	Moyenne série (15 à 20 pièces/jour). *Medium rate (15 to 20 parts/day).*
Prix [%]. *Cost [%].*	15	20 - 30	30 - 40	40 - 60	80 - 100
Procédé. *Process.*	Film, membrane.	Film, membrane.	Sac. *Bag.*	Film, membrane.	Film, membrane.
Forme des pièces. *Shape of part*	Simple – moyenne. *Planar – medium.*	Simple – moyenne. *Planar – medium.*	Simple. *Planar.*	Toutes formes. *All shapes.*	Toutes formes. *All shapes.*
Remarques. *Remarks .*	Conductivité thermique faible. *Low thermal conductivity.*	Conductivité thermique faible. *Low thermal conductivity.*	Solution intéressante pour prototypage. *Interesting possibility for prototyping.*	Solution intermédiaire demandant des précautions pour pièces d'aspect. *Intermediary solution. Caution needed to achieve good part surface finish.*	Excellent compromis coût durée de vie. La qualité du modèle est essentielle. *Excellent cost life compromise. Essential to have good model quality.*

III– Tooling

The process consists of draping a reinforced thermoplastic composite textile over one half of a mold. The part is then put under vacuum using a sealing system (films and/or membrane) and a pump. The evacuated mold is then heated close to the melting temperature of the matrix to impregnate the reinforcement. Demolding is carried out after cooling the evacuated mould to about 50 °C.

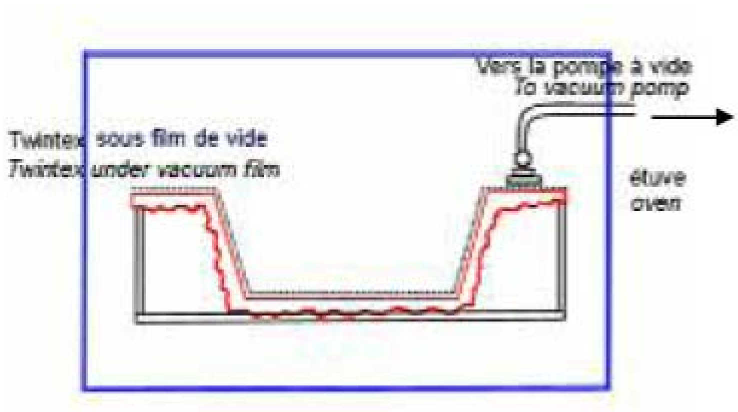
III.1. Heating system

Several possibilities exist to heat the evacuated tool. It is important to have even heating at all points on the part to avoid problems of consolidation of the structure. Generally, the heating system (ovens, autoclaves or heated moulds) is chosen according to the size of the part to be produced.

III.1.1. Oven

This method allows the production of large dimension parts (flagpoles, boat hulls,...). The installed heating system should allow a temperature rise up to 250 °C. The investment for such a system is relatively high; however, it does allow all types of part to be molded and, above all, to work in a clean environment.

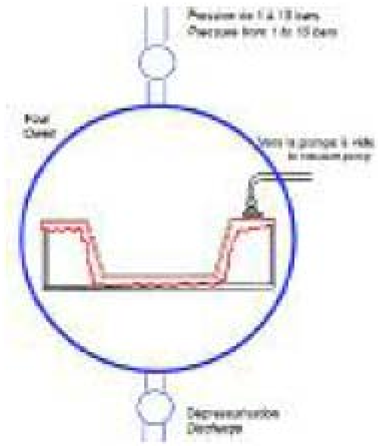
Fig. 5 : The principle of vacuum molding in an oven.



III.1.2. Autoclave

An autoclave is a large, heated, pressure vessel. The autoclave is similar to the oven except for the fact that an additional external pressure of 7 bars (100Psi) is applied to the part in the heated vessels. The external pressure applied on the part may be from 3.5 bars (50Psi) to 7 bars (100 Psi). This device allows the production of composites structures of high quality with minimum void content, and control of part thickness is much better than that achieved when using an oven. Naturally the capital costs are higher, and the output relatively low. This method is used for manufacturing and guaranteeing high quality composite parts with good reproducibility.

Fig. 6: Principle of vacuum molding in an autoclave.



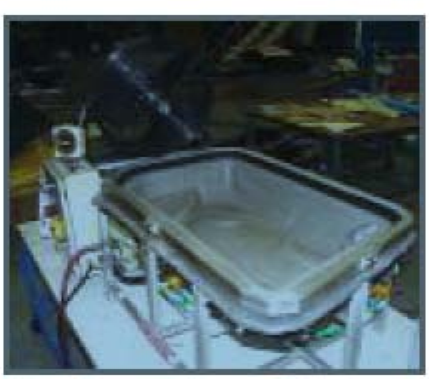
III.1.3. Heated tools

This option avoids the use of a heated enclosure. During the manufacture of the mold, a heating system may be incorporated. The heating may be by oil circulation through a coil fixed under the surface skin or even by an electrical system which supplies sufficient energy.

This option must be technically and economically validated against the standard system for the process (mold & oven). The production costs are higher than in the case of the production of a simple mold. Moreover, the durability of this type of tooling is less due to the differential shrinkages between the different materials used to make heated molds.

Such moulds are generally considered for parts from 1 to 3 m². It is necessary to count on a supplementary cost 1524 to 2286 €/m².

Fig. 7: PPA Limited electric tool



III.2. Vacuum system

The application of vacuum is intended to exert a pressure on the Twintex® material. This action gives the part its final shape and confers on it a perfect consolidation and impregnation of the reinforcement. The pressure generally applied by the vacuum is closed to 1 bar (14 psi).

The method to produce the vacuum consists of a vacuum pump connected to the part by means of a vacuum plug fixed to the sealing system (vacuum film, membrane).

The vacuum pump characteristics used (output, vacuum tank) will depend on the size of the molded parts (volume of vacuum to pull) as well as the number of parts to be molded per day.

Installations may be a simple vacuum pump or even a vacuum main consisting of a vacuum pump connected to a vacuum tank, called a vacuum tank. With a vacuum main several moulds may be connected, productivity is therefore increased.

Table 5: Investment for vacuum production

1 to 3 parts/day(1 to 2m²).	*Pump : output 16 to 25 m^3/hour :* ***1 300 to 1 500 €*** *Vacuum plug : #* ***30.5 €/plug***
15 parts / day (1 to 2m²).	*Vacuum tank :* *Pump: output 25 to 65 m^3/hour + Vacuum tank 70 to 300 Litres :* ***4 100 to 5 565 €.*** *Vacuum plug : #* ***30.5 €/plug.***
30 parts/day (1 to 2m²).	*Vacuum tank :* *Pump: output 65 to 100 m^3/hour + Vacuum tank 300 to 500 Litres :* ***5 565 to 6 100 €.*** *Vacuum plug : #* ***30.5 €/plug.***

III.3. Consumables

The principle of film, bag or membrane molding consists of applying a pressure exerted by the vacuum onto the composite structure while removing air contained within it. The laminate produced is therefore fully consolidated and conforms to the mold shape. The seal is achieved by combining different films, called consumables.

III.3.1. Release agents

The application of an external release agent is important for tool maintenance and for the final surface finish of the molded parts. The choice of which to use must take into account of the nature of the resin used in the case of applying a gel coat, the type of mould (surface) and the processing temperature. In the case of Twintex®, it is recommended that the mold be treated with a release agent to facilitate demolding of the parts, in spite of the fact that the matrix is polypropylene. The consumption of release agent in production will naturally depend on the type being used and its efficiency. In principle, 1 liter of release agent will treat an area of 30 to 40 m².

- **Types of release agents :**

The release agents used may be semi-permanent or otherwise should be applied for each molding. These are aqueous or solvent based. Waxes are not recommended because they cause a gradual build up on the mould as molding proceeds.

The semi-permanent release agents are efficient on composite or metal molds, with the exception of electroformed nickel. The surface energy of nickel is very low and the cured release agent film is not able to remain attached to the nickel skin constituting the mould. In this case the mold is treated at each molding with a standard release agent.

- **Mold treatment :**

The mould is treated with the release agent using a cloth or a spray gun. The first time that a mould is treated, it is advised to use a surface cleaner to clean the tooling. Then a pore sealer is applied (2 coats), to protect the mould surface and to prepare it to receive the release agent. Finally, between 2 and 4 coats of release agent are necessary to treat the surface. According to the complexity of the parts, one single application will allow several de-molds. The conditions of application of the release agent should conform to those in the technical data sheet of the product to ensure its efficiency.

- **Post-molding operations :**

Post-molding operations such as painting, bonding and so on, are possible. However, precautions should be taken when certain release agents are used (silicon or Teflon based). Before painting, the parts should be cleaned to avoid contamination of the paint line.

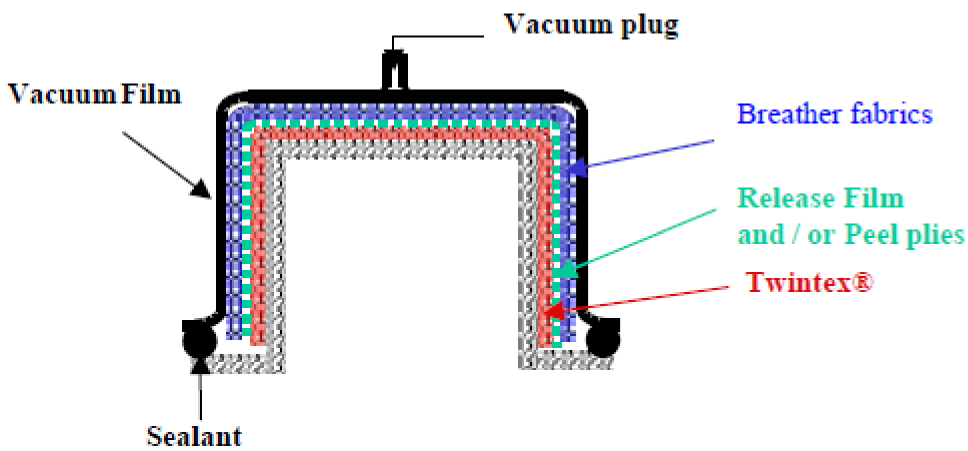
Table 6: Release agents and their main features

Références produits *Product references*	Distributeurs. *Distributors.*	Nature du démoulant. *Release characteristic.*	Efficacité avec *Efficiency with*
CIREX 600 **CIREX 660**	Airetec	*Semi- permanent.* *Service temperature limit: 400°C* *Cloth application.* *High gloss surface.*	*Gel coat (Epoxy, UP)* *Post-moulding operations (Painting, bonding operations).*
PAT 808	Airetec	*Service temperature limit: 400°C* *Spray application.*	*Gel-coat (Epoxy, UP)* *Metallic tool, thermoplastics resins (PP, PET, PBT, PA,…) and thermoset resins (Epoxy, UP).*
ZYVAX composite Shield	Diatex	*Semi permanent.* *Service temperature limit: 370°C*	*Gel-coat (Epoxy, UP).*
FREEKOTE Aqualine C-200/C210	Dexter Scott-Bader	*Semi permanent.* *Water-based* *Service temperature limit: 205°C*	Gel-coat (Epoxy, UP).
Tooltec A005, Teflon coated fibreglass with adhesive **Tooltec CS5, Teflon film with adhesive** **Release All Safelease®30, water based PTFE** **Release All®50**	Airtech International Inc. Airtech Europe S.A. Tygavac Advanced Materials Ltd.	*Semi- permanent.* *Service temperature limit: 400°C* *Cloth application.* *High gloss surface.*	*Gel coat (Epoxy, UP)* *Post-moulding operations (Painting, bonding operations).*

III.3.2. Films

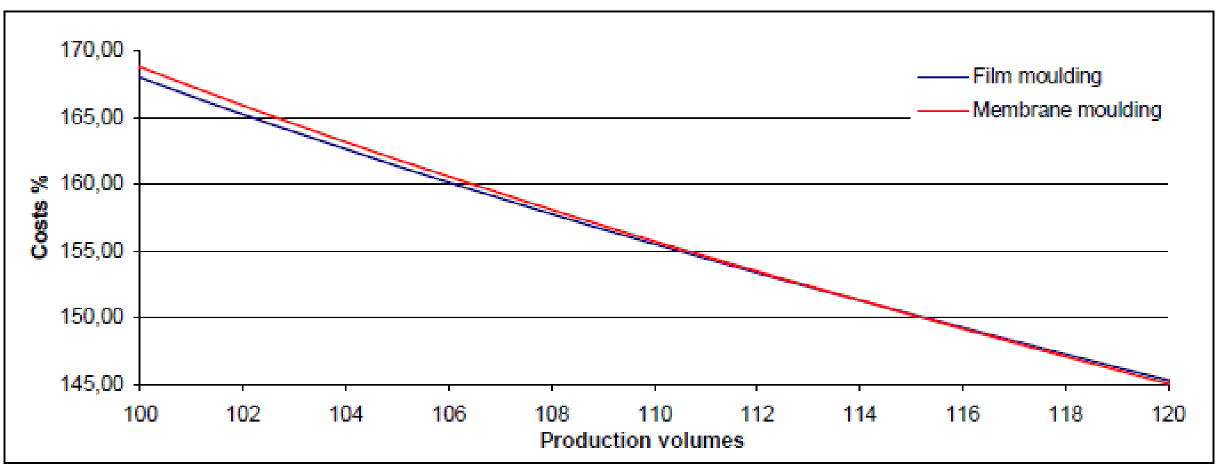
The diagram below illustrates a cross section of a standard vacuum bag lay-up device.

Fig. 8: Vacuum molding process.



The films employed must have a melting temperature greater than 200°C. The durability of the films to ensure the molding reproducibility is one part. However, depending on the number of parts to be produced and their complexity; the presence of a peripheral flange around the mold, the combination of films or even the use of a silicon membrane will allow a reduction in the consumables costs, and hence the final price of the molded part. The graph in fig. 8 shows that the payback time for a silicone membrane for a 1 m² part is very short (about 110 parts).

Fig. 9: Pay back of silicone rubber



III.3.2.1. Release films

The release films are in direct contact with the Twintex® structure and prevent sticking between the breather felt and the molded material. Perforated, it allows extraction of entrapped air when the vacuum is applied.

III.3.2.2. Sealants

The vacuum sealants are applied onto the peripheral flange of the mold to ensure sealing between the vacuum film and the mold.

III.3.2.3. Silicone membranes

This membrane replaces the vacuum bag. The possibility to use it several times over allows a reduction in price on the molded parts despite the initial investment of such a system. The membrane durability is increased by the addition of a release film or a peel ply to facilitate demolding from it.

To accurately achieve the part shapes, their use depends on the geometrical complexity of the parts to be produced. The use of a membrane compared with a traditional vacuum system also allows a reduction in the time necessary to position vacuum system and the molding reproducibility.

Fig. 10: Silicone membrane

III.3.2.4. Vacuum bags

Flexible nylon films of 50 to 75 µm are used to make vacuum bags. The role of these films is to ensure sealing of the system. No air leaks must be present when the vacuum is applied, in order to guarantee the optimum consolidation of the part.

III.3.2.5. Breather felts

In our case, breather felts are non-woven nylon or nylon-PET felts from 100 to 300 g/m². The main function of these felts is to remove the enclosed air towards the vacuum plugs. In certain cases, the use of a breather felt is not absolutely necessary. In effect, Twintex®, unlike other prepregs, is a fabric made up of continuous fibers of glass and thermoplastic, and this type of material also acts as a breather felt when vacuum is applied to the part, up to about 120°C.

III.3.2.6. Peel plies.

Like release films, peel plies are found in contact with the Twintex® structure. Their purpose, after removal, is to leave a sufficient roughness for secondary bonding or the application of paint. Their use with Twintex® also allows them to play the role of an air removal film. The weight of these films should not be more than 100 g/m². This may avoid the necessity of using a breather felt, on condition of having a very good consolidation of the part during molding.

III.3.2.7. Contacts

For suppliers within the U.S. please contact a Fiber Glass Industries, Inc. sales representative directly at 800 842 4413.

Table 7: Summary of supplies needed

Moulding process	***Bag moulding*** 	***Film moulding*** 	***Membrane moulding*** 
Caractéristiques moules. *Tool caracteristics.*	Sans plage périphérique. *Without a sealing flange.*	Avec plage périphérique. *With a sealing flange.*	Avec plage périphérique. *With a sealing flange.*
Consommables utilisés. *Consumables uses.*	Film séparateur. Feutre. Sac à vide. *Release film.* *Breather.* *Vacuum bag.*	Film séparateur ou tissu d'arrachage. Feutre. Film à vide. *Release film or peel ply.* *Breather.* *Vacuum film.*	Film séparateur ou tissu d'arrachage. Membrane silicone. *Release film or peel ply.* *Silicon membrane.*
Remarques. *Remarks.*	Prototypage ou série inférieure à 80 pièces. Moule sans plage périphérique. *Prototyping or production volume inferior to 80 parts.* *Too periphery without a flat sealing surface.*	Série inférieure à 150 et/ou pièces très complexes. Temps de drapage long. *Production volume* below 150 and/or very complexe shape. Long hand laying time.	Série supérieure à 150 pièces. Reproductibilité de mise en œuvre. *Production volume* *Serie over150 parts.* *Processing reproducibility.*

IV- Twintex®

www.fiberglassindustries.com

- Twintex® T PP is a fabric woven with commingled E-glass and polypropylene rovings.
- Twintex® is processed by heating above the melting temperature of the PP matrix. (170°C –200°C) and then consolidated by applying low molding pressure. Twintex®, by intimately mixing glass and thermoplastic filament, has solved the problem of economically impregnating continuous glass fibers with thermoplastic resins. It permits high glass level content (60% in weight) in composite parts.

IV.1. Properties

- The polyolefin thermoplastic matrix (polypropylene, polyethylene) are amongst the most chemically inert plastics and the least affected by water absorption. For example, Twintex® PP shows no sign of visual or mechanical degradation after being immerged in 65°C water for 1,200 hours.
- Mechanical properties depend on the fabrics pattern. In case of balanced fabrics (as many strand in the weft or warp direction), the longitudinal and transversal mechanical properties will be the same. On the other hand, in case of pre-oriented fabrics, mechanical properties will be higher in the preferential reinforced direction.

Table 8: Twintex® mechanical properties

				Balanced Fabrics 1/1	***Preoriented fabrics 4/1***
Traction ***Tensile***	Contrainte *Strength*	ISO 527	MPa	350	400 / 130
	Module *Modulus*		GPa	15	28 / 6
Flexion ***Flexural***	Contrainte *Strength*	ISO 178	MPa	280	380 / 160
	Module *Modulus*		GPa	13	18 / 6
Choc Charpy sans entaille ***Un-notched Charpy***		ISO 178	kJ / m²	220	330 / 90
Choc Izod entaillé ***Notched Izod***		ISO 180	kJ / m²	180	260 / 95
Taux de verre		en poids *weight*	%	60	60
Glass content		en volume *volume*	%	35	35

Mechanical property data developed in accordance with standard ISO specifications. Relative values shown are accurate to the best of our knowledge, but should not be used for design purposes since absolute values can be influenced by fabricator processing conditions.

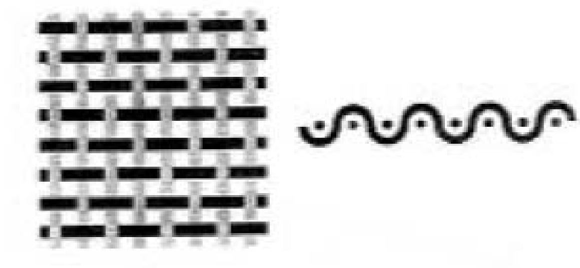
IV.2. Reinforcement types

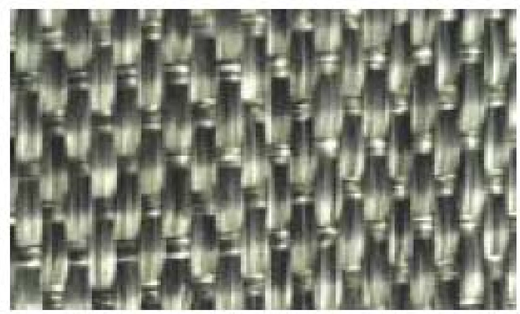
Fabrics are produced from Twintex® rovings. Twintex® rovings are interlaced between each other in different configurations allowing different structures (twill, plain) and to offer balanced and oriented fabrics. The assembly of rovings in the longitudinal direction constitutes the warp of the fabric. Those in the transverse direction represent the weft. The following are the fabrics used most often :

- **Plain weave Fabrics :**

Plain weave fabrics are those where the warp strands are interlaced alternatively above and below with those of the weft. The fabric obtained is very stable and difficult to stretch, as well as to place over complex shapes. Among the Twintex® fabrics, the Fabric 4/1 is a plain weave structure oriented with 80% of the strands in the warp direction and 20% in the weft. This signifies that we have four times more fibers working in the warp direction than in the weft direction.

Fig. 11: Plain weave (Twintex® pre-oriented 4-1, 935 g/m², 60%)

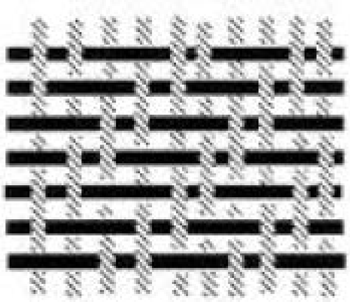




- **Twill weave Fabrics :**

In a twill weave, the rovings pass above and below a certain number of other rovings. For example, a 2*2 twill structure signifies that two strands pass over and under two other strands. Therefore, the fabric has a diagonal pattern. Twill weave fabrics are more open, more deformable than plain fabrics They are employed to produce complex shapes. Their balanced structure gives them identical mechanical properties in both warp and weft directions.

Fig. 12: Twill weave (Twintex® 1-1, 745 g/m² or 1485 g/m², 60%)



- **Stitched reinforcements (biaxial or quadaxial) :**

Multilayered stitched reinforcements may equally be used. In this case, the rovings are not interlaced (no crimp), but are stitched together by a joining polyester yarn. Consequently, the pattern of the fibers on the surface of a painted or gel coated part is weaker than in the case of a fabric.

Fig. 13: Twintex® fabric +/- 45°or +45/0/90/-45°

V- Molding process

V.1. Tool preparation

- It is recommended that the mold surface is cleaned well in order to avoid appearance faults due to contamination of the mold. The first time a mold is used, it is necessary to treat it with a surface cleaner and then a sealer to maximize the efficiency of the release agent applied subsequently.
- If the part contains openings, these must be sealed using Teflon adhesive tape.

V.2. Draping the Twintex®.

- This operation consists of laying up the Twintex fabrics in the treated mold with the aid of a low molecular weight polyolefin spray Fig.13. supplied by The positioning of the layers and keeping them in place is done by applying the spray contact adhesive.

Fig. 14: Draping the Twintex®

3 M (Ref. 3M77, IA 34)
Aerovac (Ref. Sprayfix)
Airtech (Ref. Airtac 2, Econotac)
Everbuild Building Products Ltd
(Ref. Everbuild stick 2)

- In sharp angles, pattern fabrics cutting and a careful placement (fiber orientation at +/6 45°) of it will be necessary to avoid resin squeeze out that can cause bridging problems.

Fig. 15: Sharp angles

- The thickness of the molded part is determined by the area weight of the Twintex® fabric and the number of plies.
- For parts needing several plies, it is necessary to take care to avoid joins in the same region which would result in mechanical weakening of the part.

V .3. Vacuum application.

1 - The **release film** or **peel ply** is placed over the whole Twintex® fabric surface. To facilitate its positioning, the spray contact adhesive may be employed at certain points on the part. These films are used within the molding process (bag, film or membrane).

Fig. 16: Release film

2 - In the case of vacuum film molding, the breather felt only is placed on the release film. For vacuum bag molding, the breather felt covers all the release film and also the non draped face of the mould. Sharp edges are also covered in order to avoid tearing of the vacuum bag, as well as ensuring a good application of pressure at every point.

Fig. 17: Breather film

3 - In the case of vacuum film molding, a sealing strip is fixed onto the flat peripheral flange around the mould. Air-tightness between the mold and the vacuum film is thus assured.

Fig. 18: Air tight sealant

In the case of vacuum bag molding the sealing strip is used to close the bag.

4 - For vacuum film molding, the dimensions of the vacuum film are adjusted to those of the mould cavity with its peripheral flange. The film is bonded around the edge of the part with the aid of a mastic sealant. When a silicon membrane is used, this is simply laid onto the mold. Air-tightness is then assured by peripheral sealing of the frame supporting the membrane. A fixing system between the mold and the membrane may be imagined in order to bolt the membrane onto the mold.

For vacuum bag molding, the vacuum film dimensions should take into account the developed area of the mold in order to make a bag.

Fig. 18: Vacuum film Molding

Fig. 19: Vacuum bag molding.

Fig. 20: Silicone membrane molding.

5 - The vacuum plug is fitted outside the part area in such a way as to avoid marking it. A piece of breather felt is inserted between the vacuum plug and the mould to ensure a link with the breather covering the part, allowing a good vacuum over the whole assembly.

6 - Finally, the pump is connected via a flexible hose to the vacuum plug. It is important to check that no leak is apparent when the vacuum is applied to the part. More so in complex areas, the vacuum film is guided into position with blunt tools in

such a way as not to tear the vacuum system. This operation will ensure a good consolidation of the part.

Fig. 21: Tool and vacuum pump system

7 - The heating temperature will be 190°C at the centre of the material. Heating time is determined by the experience of the molder, the thickness of the part, the shape, the type and thickness of the mold. During the development of a vacuum molded part, the first test should be to record the temperature increase and decrease curves in order to determine the optimum cycle time.

V.4. Demolding

The part should be de-molded at a temperature below 70 °C so as not to distort the part and avoid the risk of burns. The vacuum pump is also stopped, and disconnected from the vacuum plug. In the case of silicon membrane molding, take care not to tear this. Part demolding may be assisted with compressed air, or tools made from wood or Teflon. Tools used for demolding parts should have a lower hardness than the tool so as not to damage it.

VI – Part finishing

Parts are de-burred with wet abrasive paper. Trimming may be carried out using a band or circular saw. Filling of unfinished parts, notably sharp edges, may be accomplished by adding polyester putty for car body (cf photo). Rubbing down of the part afterwards is carried out with wet abrasive paper.

Fig. 22: Filling

VII - Surface appearance

A part obtained by this molding process will only have one good surface reflecting the mold face. If necessary, a supplementary coating, such as a surface finish veils (Glass, PET) may be applied in order to reduce Twintex® print through.

VII.2. Gel coat

Several types of gel coat may be used with Twintex® material, such as either epoxy or polyester gel coats. The gel coating operation has the disadvantage of increasing the molding cycle time and hence the productivity. In effect, before draping the Twintex® fabric within the mold, the gel coat must have reached an advanced state of cure to prevent the fibers from marking the good surface. It is very important to well treat the mold surface with a release agent appropriate to both the nature of the mold and to the gel coat employed. Adhesion of the Twintex® to the gel coat is made by adding a thermoplastic interfacial film. These gel coats must be resistant to temperatures of 200°C imposed by the molding process.

Table 9: Gel coat features

High Température Gel coat	**Liquid Polyester**	**Powder polyester**	**Acrylic powder TP Powder**	**Epoxy**
				
Application	*Spray equipment* *Brush grade*	*Spray equipment*	*Spray equipment*	*Brush grade*
Thickness	500 à *(to)* 700 µm	100 à *(to)* 150 µm	500 à *(to)* 800 µm	500 à *(to)* 700 µm
Polymérisation *Curing*	3 à *(to)* 5 mn à *(at)* 80 °C	15 sec à *(at)* 150 °C	3 mn à *(at)* 185°C et *(and)* 1 mn à *(at)* 120°C	3 à *(to)* 5 mn à *(at)* 80 °C
Demolding temperature	50°C	70-80°C	< 80 °C	50°C
Advantages	*Good UV ageing*	No styrene emission	*No styrene emission* *Good adhesion with Twintex®*	*No styrene emission*
Drawbacks	Styrene emission 20% loss during spraying	Less efficient UV ageing	20% loss during spraying	*Bad UV ageing*
Contacts	**Ferro** Sogel	**Ferro**	**Teknos** **Plascoat**	**Vantico Adhesives & Tooling**

VII.3. Paint

The application of paint to a Twintex® part is very tricky. It is important to follow the application conditions of the materials very closely. Several pre-treatments are often necessary to improve the prospects of adhesion to a Twintex® part. Several types of paint exist in more formulations based on organic solvents. Paints of high solids contents, water solubles and powder formulations are more environmentally friendly in limiting emissions of VOCs.

VII.3.1. Surface treatment

Where surfaces contain traces of release agents, it is important to well clean or degrease the surfaces. Adhesion of paint to the part may be obtained by a mechanical keying (rubbing down) or chemically (flaming, adhesion primer).

- **Rubbing down :**

This is a delicate operation which risks bringing with it some micro-porosity to the part surface.

- **Flaming :**

This operation chemically modifies the surface with the aid of a flame. The oxidized and hydroxyl bonds at the Twintex®/paint interface will react and create a chemical adhesion. Other methods also exist, such as Plasma treatment, UV and Corona to activate the surface of a Twintex® part. However, these techniques are expensive.

- **Adhesion primers :**

The application of an adhesion primer is intended to create chemical bonds of the chlorinated polyolefin type between the Twintex® substrate and the subsequent finish. There are also powder UV primers, which polymerize under UV radiation. They are used mainly to fill pores. Primers are employed when the under and top coats do not permit a good adhesion to Twintex®. The primer thickness should be from 5 to 10 µm.

VII.3.2. Priming and finishing

A painted part is covered by a primer coat and a top coat which bring both the appearance and weathering properties to the final part.

- **The primer :**

Primers consist of a binder (Polyester, Epoxy or Acrylic), pigments, fillers and additives, notably for UV stability. Applied in a thickness from 30 to 40 µm, they provide a regular surface condition. Polyester binders provide a good wettability of the paint to the surface. Epoxy binders have very good mechanical characteristics, and chemical resistance. Acrylic binders are a compromise between Polyester and Epoxy binders. Primers are often cured under hot air (convection oven) at 50°C – 60°C for 20 to 30 mins.

- **Top coat :**

These are two component polyurethanes (isocyanates and acrylic or polyester polyols). Depending on the formulation, parts will be gloss or mat, the color being due to the pigments. The top coat thickness is 40 µm. The curing cycle is from 20 to 30 mins. at 60-70°C.

VII.3.3. Contacts.

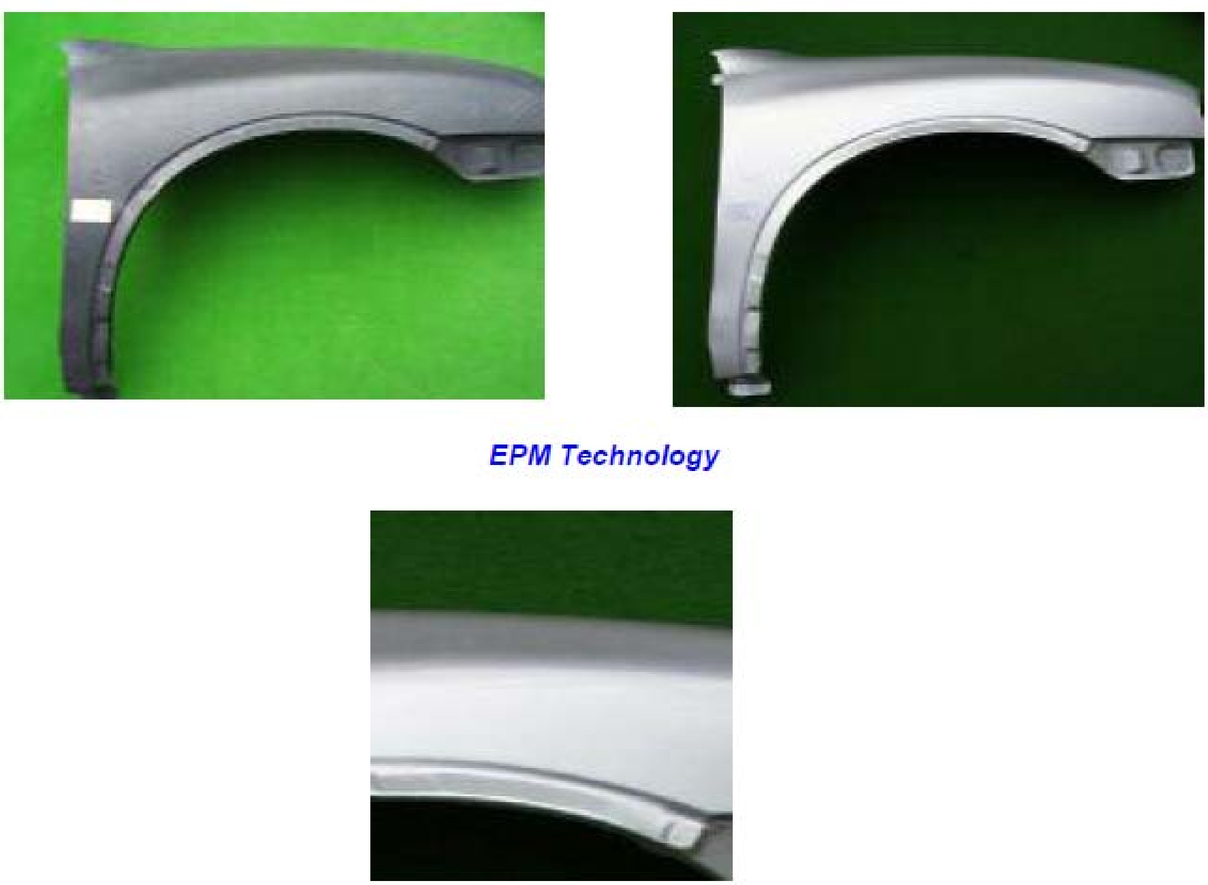
Contact a sales representative from Fiber Glass Industries, Inc. at 800 842 4413

CAB :
Adhesion primer: 4616KK & 4617KX
Polyurethane paint bases (building primer, top coat).

DuPont Performances coating:
Adhesion primer: D901 or D975, 901 R primer 2K.
Polyurethane paint bases (building primer, top coat).

Strathmore Products:
Dirck Clear polyethylene primer

Fig. 23: Front wing Opel Corsa Race Car manufactured by EPM Technology Ltd.



VII.4 Surface finish thanks sublimation

The aim of this solution is to have an ink transfer on the final part to reproduce a logo or to achieve Twintex in mass pigmentation. To achieve the transfer we need to have a processing temperature over 160°C and a pressure applied of 1 bar. The best processing solutions are with a temperature of 180-190°C during a residence time in a hot air oven of 90 min.

With this molding technology, there are 2 solutions to make a sublimated Twintex® part. The first one is to remove the sublimated carrier after molding the part. We can then achieve maximum 2mm thick Twintex part with in mass pigmentation.

Molding example 1

a- Twintex ® hand layup on the tool
b- Sublimated support hand laying 1 layer
c- Release film
d- Replacement of the breather felt by a reusable glass fabric (500g/m²)
e- Vacuum film or bag or silicone membrane
f- Curing Time: 90 min (from the entrance to the exit of the tool) in a hot air oven set at 210°C
g- Using a composite epoxy tool 10 mm thick The second one is to have the sublimated carrier embedded in the Twintex® part. We can then pigment Twintex part with a thickness of 5 mm.

Molding example 2

a- Twintex ® hand laying : 2mm
b- 1 layer of Sublimated support
c- Twintex ® hand laying : 2 mm
d- Release film
e- Breather felt
f- Vacuum film or bag or silicone membrane
g- Curing Time: 90 min (from the entrance to the exit of the tool) in hot air oven set at 210°C
h- Using a composite epoxy tool 10 mm thick

Contacts North America:
Contact a Fiber Glass Industries sales rep at 800 842 4413 or North America Kolorfusion International, Steve NAGEL, www.kolorfusion.com at 303 690 290.

VIII - Twintex® bonding with other materials

Twintex® may be combined with other types of material in order to bring specific properties to a molded part.

VIII.1. Interfacial thermoplastic films

- The adhesion between Twintex® and these different families of material may be mechanical depending on the surface preparation of the material which will be in contact with the Twintex®.
- Otherwise the use of an interfacial thermoplastic film will provide a chemical adhesion between the two materials. Using bonding films can also have other advantages:

    - They are environmentally friendly (no solvents or volatile organics).
    - Long shelf-life and stable at normal temperatures.
    - Uniform and rapid application of the adhesive substance. The use of bonding films also gives adhesion between Twintex® and other materials such as aluminum, epoxy, leather, steel, wood, polyurethane foams,…

VIII.2. Glues

The polypropylene PP has low superficial tension (#30 dyne/cm). It is difficult to make it bond and a chemical or physical pre treatment is required:

- Alcohol degreasing (ethanol, isopropyl), rubbing-down
- Flaming
- Adhesion primers
- Twintex® may, for example, be combined with a piece of locally positioned aluminum foil. The aluminum will be able to serve as a bonding zone to another piece with the aid of an epoxy adhesive

Many glues family exist:

Structural glues :

- Epoxy mono or bi components.
- Acrylic bi components.
- Polyurethane bi components or hot melt.
- Soft solvent or aqueous glues :
- Neoprene contact glues (aqueous or solvent) needing the gluing of the both surfaces.
- Synthetic solvent elastomers (SBR,…).
- Acrylic (aqueous).

The gluing operations can be done by many different processes which may be automated.

- Dosing pump, mono or bi components
- Heat gun for hot melt PP or PU
- Spraying for mono or bi components solvent and aqueous glues

Examples:

- 3M DP-8005 or 3M DP-8010 (without surface treatment)
- 3M DP-125 (with surface treatment)
- 3M DP-190 (with surface treatment)
- Ashland Pliogrip 7779 (with surface treatment)
- Vantico 2015,2021,2027 (with surface treatment)

VIII.3. Welding with electro fusion Device

The assembly of two Twintex® molded parts can be done thanks to Electro-fusion System (carbon, metallic strands) connected to a electrical power supply. A variable AC or DC power supply is connected, and a current flows through the Welding device for a pre-determined length of time causing the entire device to heat up and thermally fuse the parts together.

Powercore

IX - Sandwich structures

A sandwich structure allows a part to be designed with a significantly increased stiffness without having an increase in mass. The sandwich core is often of a weak material such as a honeycombs or foams, indeed even of balsa or wood complexes. These cores must have a melting temperature higher than 180-200°C so they do not deteriorate and collapse during the molding process. To avoid any track of sink marks on the surface finish side , it is advised to cut the core material with edge draft angle. This let us achieve a better material adhesion. It is also important to have a thicker thickness of Twintex® on the surface finish side (refer to the photo below).

Fig. 23 : Sandwich construction

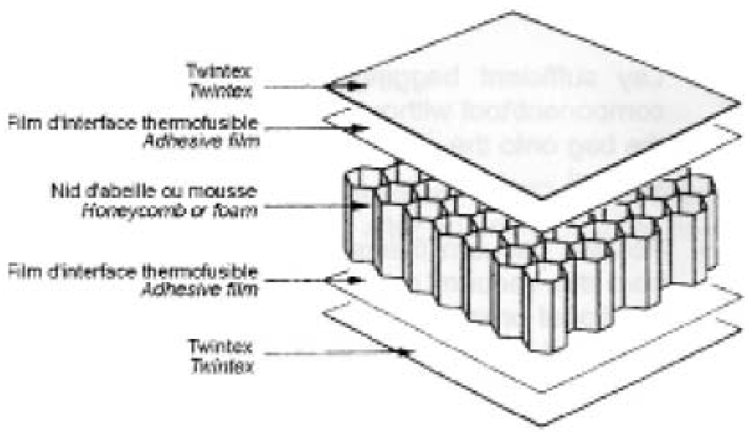


Table 24: Molding of Twintex® with other materials

Twintex® - Balsa wood

Twintex® - Kapex®C51 (Airex) or Twintex® - SAITPUR Free 150Kg/m3 (Saitec)

Twintex® – Aluminum Film

Twintex® – Aluminum honeycomb (Alcore Brigantine)

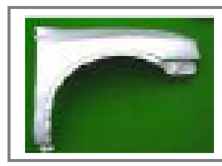
X– Metallic insert

It possible to have metallic inserts embedded in a Part while draping the part. These metallic insert will be then very well fixed in the structure of the part after molding it.

XI – Applications

Bumper Beam
Under Body Protextion

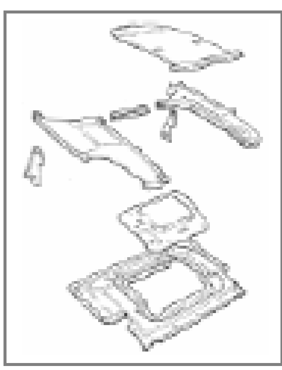
Bumper Beam
Under Protection



Wing

Instrument Panel

Door module



Engine Cover

Bumper Beam
Bus Floor

Manuel Moulage sous vide du Twintex® 02-20 50
Twintex® Vacuum moulding Manual

Rigid Inflatable Boat

XI – Acknowledgements

The Twintex® R&D Department of Saint-Gobain Vetrotex Company and Fiber Glass Industries, Inc. of Amsterdam, NY wish to thank every company included in this manual for their contributions and assistance in the preparation of this manual.

For more information please contact:

Fiber Glass Industries, Inc.
69 Edson Street Amsterdam, NY 12010

Telephone (518) 842-4000
Fax (518) 842-4408

Website: www.fiberglassindustries.com