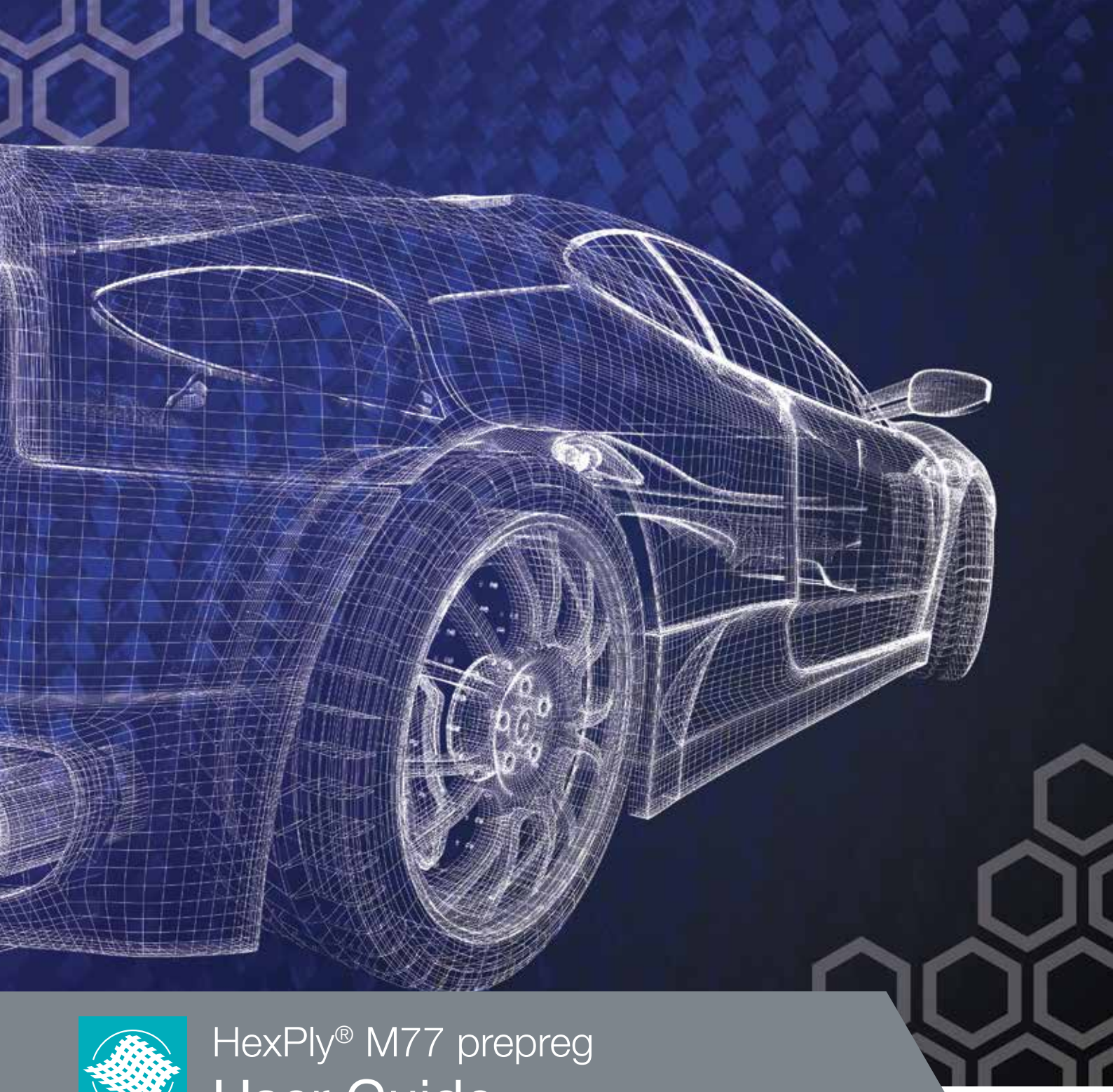

HexPly® M77 prepreg
User Guide

HEXCEL®

HexPly® M77 prepreg
User Guide

Introduction

This document is an introductory guide to familiarize the reader with HexPly® M77 products.

Contents

Introduction ____ 2

Content ____ 2

1 General ____ 3

2 Benefits ____ 3

3 General Applications ____ 3

4 Nomenclatures ____ 3

5 Product ____ 4

- 5.1 Reinforcements ____ 4
- 5.2 Delivery Forms ____ 4

6 Technical Data ____ 5

- 6.0 General Resin Description ____ 5
- 6.1 Resin Properties ____ 5
- 6.2 Laminate Properties ____ 8

7 Transports and Storage ____ 9

- 7.1 Shelf Life and Out Life ____ 9

8 Process ____ 10

- 8.1 Conditioning Before Use ____ 10
- 8.2 Handling ____ 10
- 8.3 Manufacturing Processes ____ 10
  - 8.3.1 Autoclave Process ____ 11
  - 8.3.2 Compression Molding ____ 15

9 FAQs ____ 16

10 Health and Safety ____ 18

11 Glossary ____ 19

12 Contacts ____ 20

1 General

Hexcel is a world leader in prepreg technology with its HexPly® prepregs.

Prepregs are specially formulated resin matrix systems which are reinforced with man-made fibers such as carbon, glass and aramid. Hexcel holds a unique advantage over many of the competitors in that it produces its own in-house supply of carbon fiber and has world-class weaving facilities for the development of optimum reinforcement technologies to complement the prepreg resin formulations.

Prepreg is the ultimate composite material. The thermoset resin cures at elevated temperatures and undergoes a chemical reaction that transforms the prepreg into a solid structural material that is highly durable, temperature resistant, exceptionally stiff and extremely lightweight.

For general information regarding prepreg manufacturing and about fabric types please use following guides (can be found on the Hexcel website).

- Prepreg guide
- Fabric guide

2 Benefits of HexPly® M77 prepreg

- Extra fast cure in 2 min @150°C (302°F)
- High T_g 135°C/275°F (DSC, 10K/min, $T_{g\ onset}$)
  125°C/257°F (DMTA, 10K/min, loss modulus max, torsion)
- Long shelf life and excellent tack life at RT
- Designed for fully automated processes
- Designed for hot-in/ hot-out compression molding

3 General Applications

Major applications for HexPly® M77 prepreg:

- High volume production of structural components
- CFRP reinforced metal structures (single step process)

4 Nomenclatures

Non-crimp-fabrics (NCF) or Unidirectional (UD) prepregs

M77 / 38% / UD300 / CHS

Resin type
Resin content
% in weight
Reinforcement type & FAW
NCF: Longitudinale **(L)**, Biax **(BB)**,
Transversal **(T)**, Unidirectional **(UD)**
Fiber type
Carbon High Strength **(CHS)**,
Glass **(G)**, Aramide **(A)**

Fabric prepregs

M77 / 42% / 200T2 / CHS

Resin type
Resin content
% in weight
FAW & Fabric weave
Plain **(P)**, Twill (e.g. **T2/T4**),
Satin (e.g. **H4/H8**)
Fiber type
Carbon High Strength **(CHS)**,
Glass **(G)**, Aramide **(A)**

5 Product Range

Hexcel offers a wide range of HexPly® M77 prepregs and composite materials. Please see our web-based selector guides to get more detailed information.

5.1 Reinforcements

Common product examples:

Product Type	Fabric	Item Description	Product Width	
			(mm)	(in)
Prepreg Glass	UD	M77/32%/UD800/G	1200	47.2
	Plain weave	M77/52%/106P/G	1260	49.6
	Plain weave	M77/38%/395P/G	1250	49.2
	NCF	M77/40%/LT570/G+CV	1240	48.8
Prepreg Carbon	UD	M77/38%/UD150/CHS	460	18.1
	UD	M77/38%/UD300/CHS	1300	51.2
	UD	M77/39%/UD600/CHS	1300	51.2
	Twill weave	M77/42%/200T2/CHS	1250	49.2
	NCF	M77/42%/BB600/CHS	1250	49.2
Prepreg Aramide	Plain weave	M77/60%/60P/A	1200	47.2

For detailed info regarding customized products please contact the Hexcel Sales Department.

5.2 Delivery Forms

Hexcel primarily delivers prepreg materials in roll form with easy-to-peel release foil (PE: 25µm-75µm/0.0098in-0.0295in) and an inner core diameter of 75mm (2.95in), 150mm (5.91in) or 300mm (11.8in). Typical roll lengths are between 50lm to 400lm.

Prepreg widths are available from 300 (11.81in) up to 1500mm (59.05in), depending on reinforcement type. Roll weights also vary according to reinforcement type.

6 Technical Data

6.0 General Resin Description

HexPly® M77 is an epoxy resin matrix specifically designed for prepreg applications and short cure cycles. It is a very versatile matrix that allows for a range of processing temperatures from 80°C (176°F) up to 160°C (320°F).

HexPly® M77 is a highly toughened resin that exhibits a long outlife at room temperature which allows for shop floor storage.

6.1 Resin Properties

High T_g	135°C/275°F (DSC, 10K/min, $T_{g\ onset}$)
	125°C/257°F (DMTA, 10K/min, loss modulus max, torsion)
Density:	1.1 – 1.2g/cm³
Color:	milky

Viscosity behavior:
The snap cure behavior of the system is shown in the graphs below (measured by rotary rheometer).

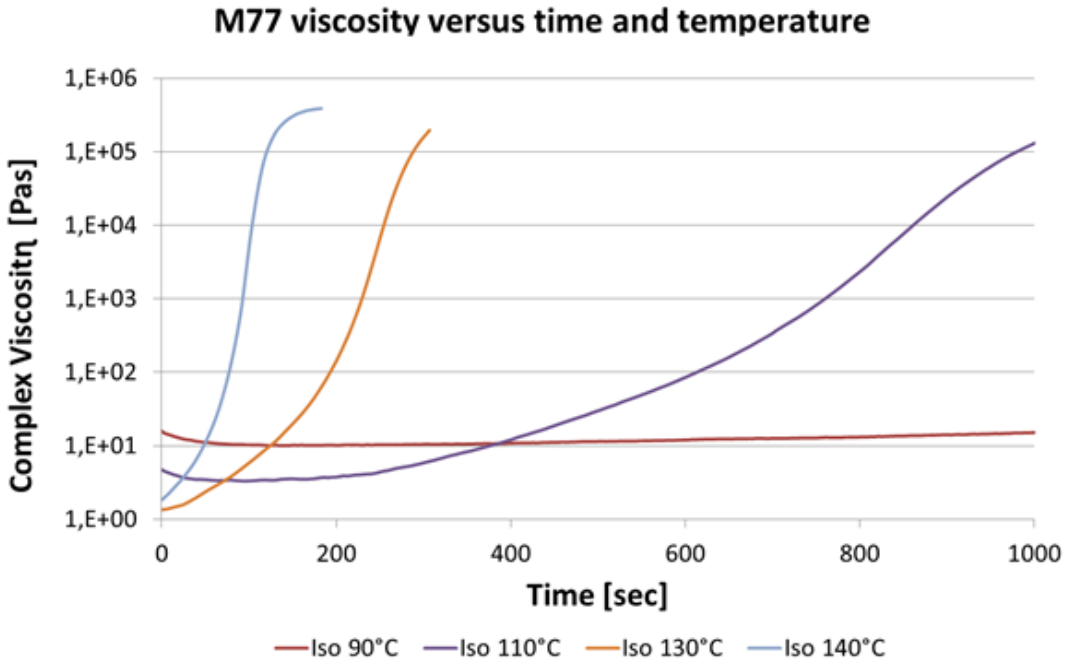

Figure 1: Complex viscosity measured by rotary rheometer

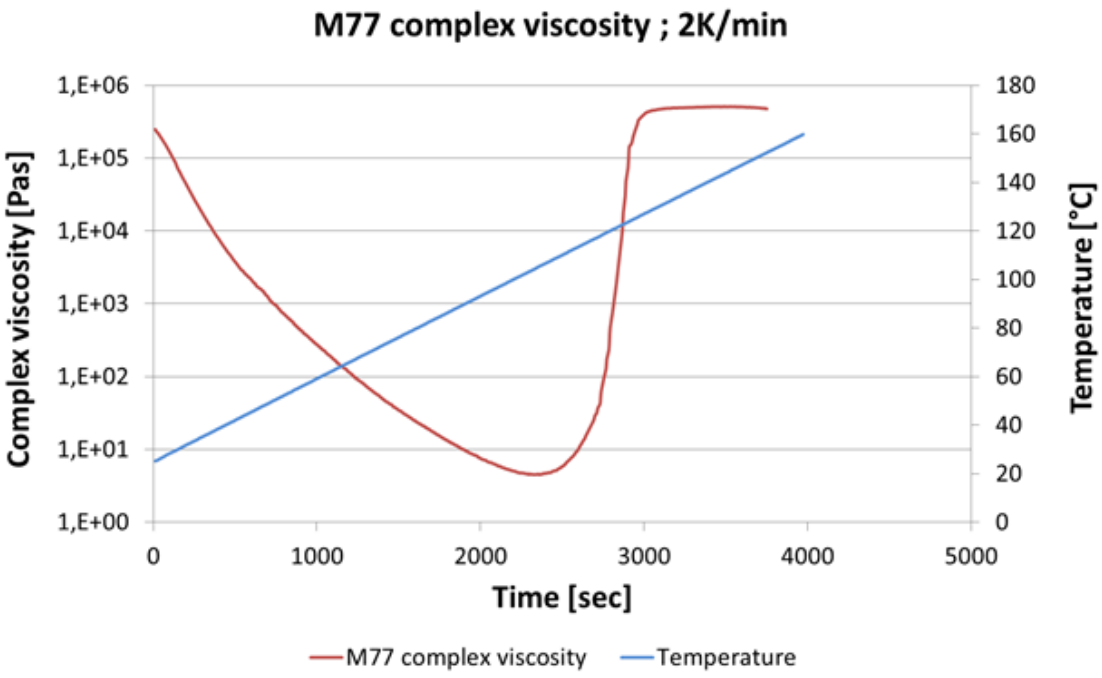

Figure 2: Complex viscosity 2K/min

The graph below can be used as guidance on the process condition definition. This data is based on in-situ viscosity measurements (DEA) on component manufacture in compression molding. The starting point of the measurement is the insertion of the part.

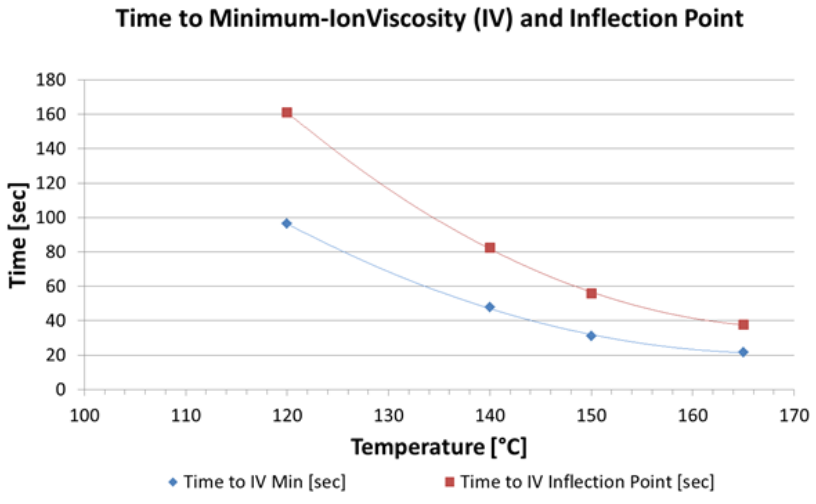

Figure 3: Ion-viscosity of HexPly® M77 resin matrix

The following isothermal cure times can be used:

Temperature		Time
80°C	176°F	480 min
90°C	194°F	90 min
100°C	212°F	40 min
110°C	230°F	18 min
120°C	248°F	7 min
130°C	266°F	5 min
140°C	284°F	3 min
150°C	302°F	2 min
160°C	320°F	1.5 min

6.2 Laminate Properties

Mechanical properties are based on 130°C (266°F) cure for 10min at 5bar (72.51psi) pressure. For unlisted products please contact Hexcel product management.

Product	Tensile Strength EN ISO 527		Tensile Modulus EN ISO 527		Flexural Strength EN ISO 14125	
	[MPa]	[ksi]	[GPa]	[msi]	[MPa]	[ksi]
M77/38%/UD150/CHS	2300*	333	137	1.98	1600	232
M77/38%/UD300/CHS	1900*	275	130	1.88	1460	211
M77/39%/UD600/CHS	2030*	294	137	1.98	1470	213
M77/42%/200T2/CHS	990	143	58	0.84	1060	153
M77/52%/106P/G	480	69	26.8	0.38	605	87
M77/60%/60P/A	490	71	22	0.32	339	49

**Normalized to 53% fiber volume*

Typical results for M77/38%/UD300/CHS G1C measurements according to ASTM D 5528-01 standard:

G1C [J/m²]	
First Crack	Second Crack
547	514

7 Transports and Storage

Prepreg should be stored as it is received, in a cool dry place or in a refrigerator and be sealed and out of the sunlight.

Do not lay the prepreg roll with the prepreg side on a flat surface (e.g. floor) for longer than 15 min. Due to its weight, the shape will slightly modify and wrinkles may result.

Do not store horizontally stored rolls vertically, as the prepreg may deform due to its weight.

If you want to store a re-bagged prepreg roll in cold storage, please ensure that it is perfectly sealed.

Hexcel recommends:
Prepreg should always be stored at temperature below +5°C.

7.1 Shelf Life and Out Life

Storage temperature		Values	Unit
-18°C (sealed bag)	0°F	18	Months
23°C	73°F	6	Weeks

Note: The actual freezer storage life and out life are dependent on a number of factors. Please contact technical support for more detailed information.

Shelf Life: the maximum storage life for HexPly® prepreg upon receipt by the customer, when stored continuously in a sealed moisture-proof bag at -18°C/0°F. To accurately establish the exact expiration date, please consult the box label.

Out Life: the maximum accumulated time allowed at room temperature between removal from the freezer and cure.

8 Process

8.1 Conditioning Before Use

After removal from the cold store, prepreg should be allowed to reach room temperature before opening the polyethylene bag, thus preventing condensation (a full packaged roll can take up to 48 hours).

Hexcel recommends:
As a minimum duration, leave the material at room temperature for 24 hours before using.

8.2 Handling

Environmental conditions influence the handling properties of the prepreg as well as on the resulting laminate quality.

Shop floor temperature should range between +18°C (64.4°F) and +28°C (82.4°F).

Shop floor humidity should not exceed 70% relative humidity.

Constant environmental conditions are required to assure consistent quality and handling properties.

8.3 Manufacturing Processes

Prepreg can be processed in different ways. The following sections demonstrate the most appropriate processes for particular applications.

Regardless of the chosen process, the coverage area should be greater than 98% to achieve an equal form filling. A lower coverage area can lead to resin richened areas in the edge areas of the form/part.

Equipment: The following tools may be needed for working with HexPly® prepregs:

- Stanley knife
- Scissors
- Heat gun (optional)
- Protective equipment (gloves, PPE, etc.)

8.3.1 Autoclave Process

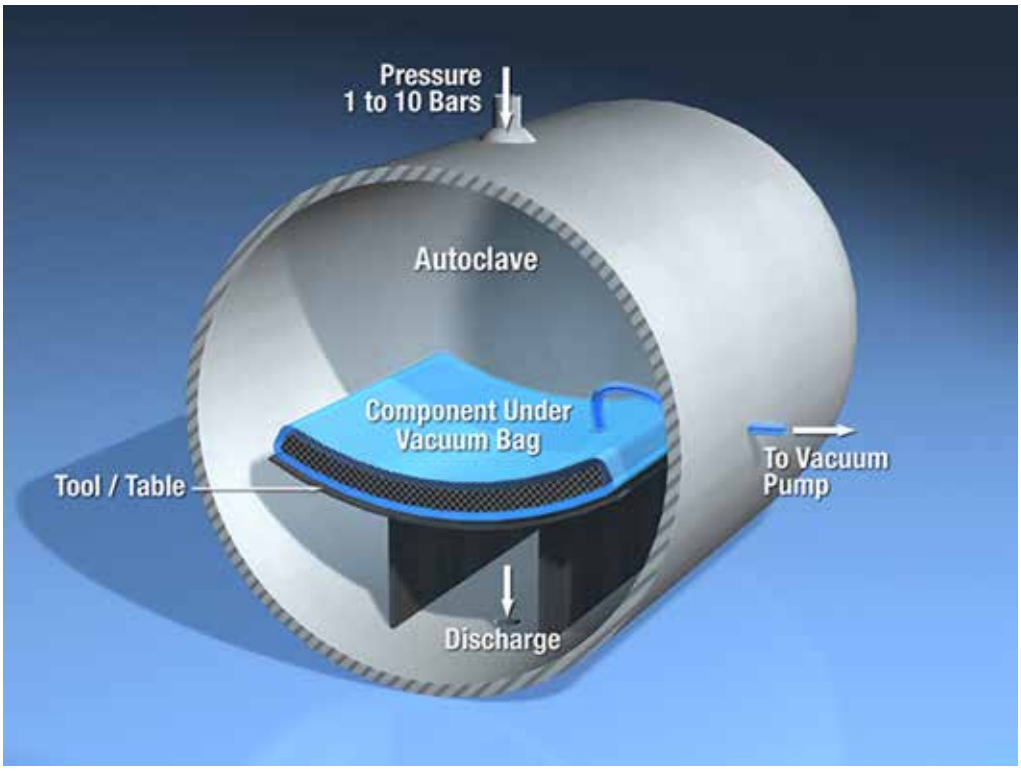

Figure 4: Schematical autoclave process

Autoclave processing is used for manufacturing superior quality structural components containing high fiber volume and low void contents. The autoclave technique is similar to vacuum bag-to-oven curing but the oven is replaced by an autoclave. An autoclave is a pressure vessel which provides the needed curing conditions for the composite where the application of vacuum, pressure, heat-up rate and cure temperature are controlled. High processing pressures allow for the molding of thicker sections of complex shapes. Longer cure cycles (compared to compression molding) are required due to fact that the large autoclave mass takes a long time to heat up and cool down. Sometimes slow heat-up rates are required to guarantee even temperature distribution on the tooling and composite components.

The following steps explain a standard autoclave process:

a) Preform preparation (cutting and layup)
The layers have to be cut out of the roll by hand or automatically with a cutter. A typical plybook features a symmetrical setup of the layers to provide a consistent stress distribution along the whole product throughout the process and prevents cupping of the product. The plybook has to be defined and adjusted for every process and part individually. If needed, tack can be increased by localized heating (heat gun).

Hexcel also offers ready to use preforms for high volume production. For more information contact the Hexcel Sales department.

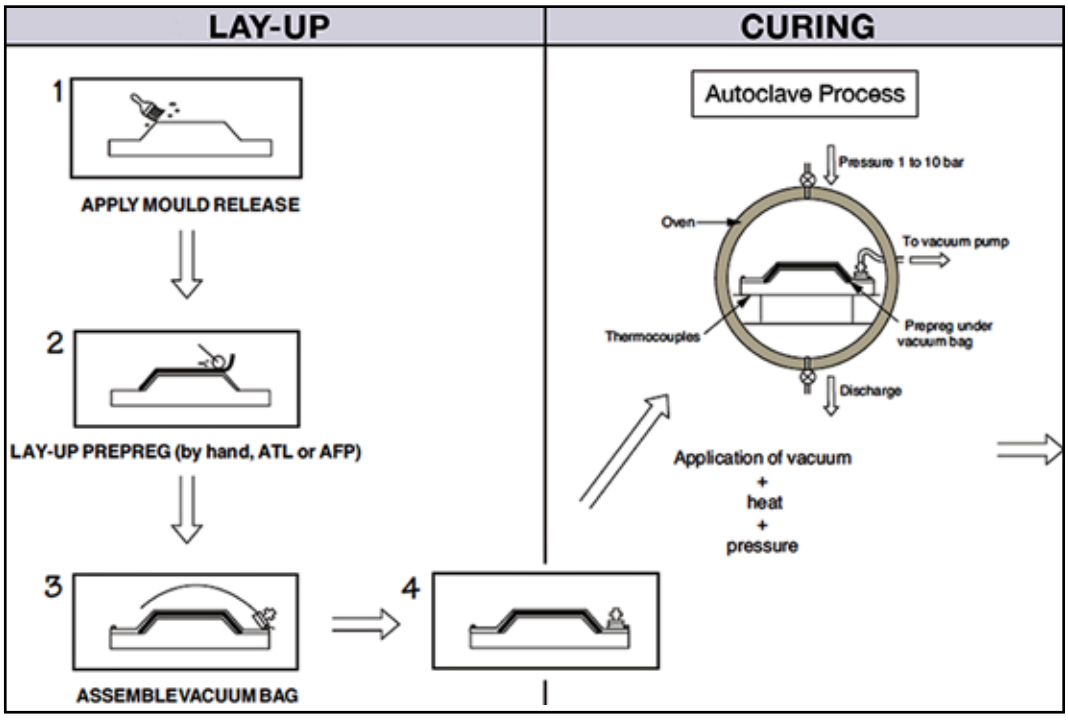

Figure 5: Typical steps for autoclave process

b) Mold preparation

For good quality surface products, the optimized finish of the used tool has to be defined individually. As a baseline, internal trials using a polished tool with a nitrated surface and a surface roughness (Rz) of 3µm provided products with a good surface finish.

Before working with the tool, it has to be sealed and treated with a re-lease agent, to prevent the product from sticking to the mold when hardened. Therefore, various release agents are available on the market, which are commonly water or solvent based.

In combination with HexPly® M77 prepregs following release agents/films can be recommended:

- Chemlease 2191W (water based)
- Frekote 700NC (solvent based)
- PFTE, PET with release coating, siliconized films

Many more release agents are compatible with Hexcel systems and have to be defined individually. The release agents should be applied according to the product datasheet instructions.

Note: These release agents are just suggestions based on internal uses. Typically a lot more RA`s are compatible with the M77 system

c) Bagging

The following layup is used to produce test plates in the autoclave.

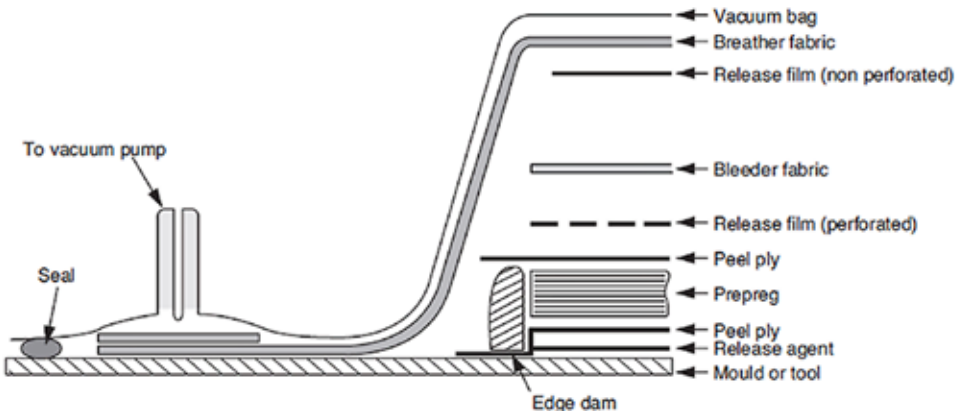

Figure 6: Vacuum bag assembly and consumables

When working with a 3D tool form, the prepreg is directly placed on the coated tool. On the other side peel ply and/or a perforated foil plus a bleeder fabric can be applied for soaking surplus material. At last apply the vacuum bag and seal the edges with tacky tape

- **Release agent**
  Allows release of cured prepreg component from the tool
- **Peel ply (optional)**
  Allows free passage of volatiles and excess matrix during the cure. Can be removed easily after cure to provide a bondable or paintable surface
- **Bleeder fabric (optional)**
  Usually made of felt or glass fabric and absorbs the excess matrix. The matrix flow can be regulated by the quantity of bleeder, to produce composites of known fiber volume.
- **Release film**
  This layer prevents further flow of matrix and can be slightly porous (with pin pricks) to allow the passage of air and volatiles into the breather layer above.
- **Breather fabric**
  Provides the means to apply the vacuum and assists removal of air and volatiles from the whole assembly. Thicker breathers are needed when high autoclave pressures are used.
- **Edge dam**
  Contains resin flow and component shape.
- **Vacuum bag/Sealant tape**
  Provides a sealed bag to allow removal of air to form the vacuum bag.

d) Cure Cycle

A typical cure cycle for parts made in an autoclave is described below. The parameters are strongly dependent on the part geometry, thickness and capability of the autoclave. Due to the fast curing behavior of HexPly® M77 prepreg, higher pressure and heat build-up rates (e.g. rapid clave process) can reduce the cycle time.

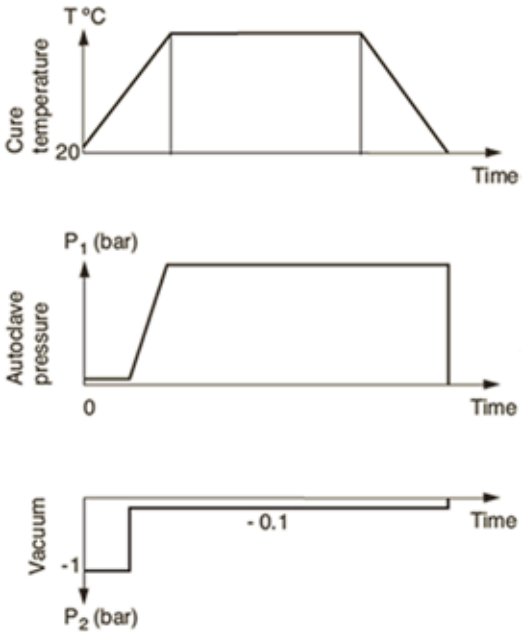

Figure 7: Standard autoclave cure cycle

Time to T.	Temperature	Dwell	Pressure	Time to cool down
10 min.	140 °C	7 min.	7 bar	6 min.

When reaching the minimum viscosity, the pressure should be increased to achieve a good degassing and impregnation of the fibers. Be sure to keep the pressure and vacuum stable for the entire process. A decline of the pressure/vacuum can have negative effects on the quality. At least 7bar (102psi) should be used to produce high quality parts, A homogeneous thorough heating of the form and part must be assured to receive a full hardened product. Cooling cycles should be controlled to avoid a sudden temperature drop which may induce high thermal stresses in the component. Pressure and/or vacuum should be maintained throughout the cooling period.

8.3.2 Compression Molding

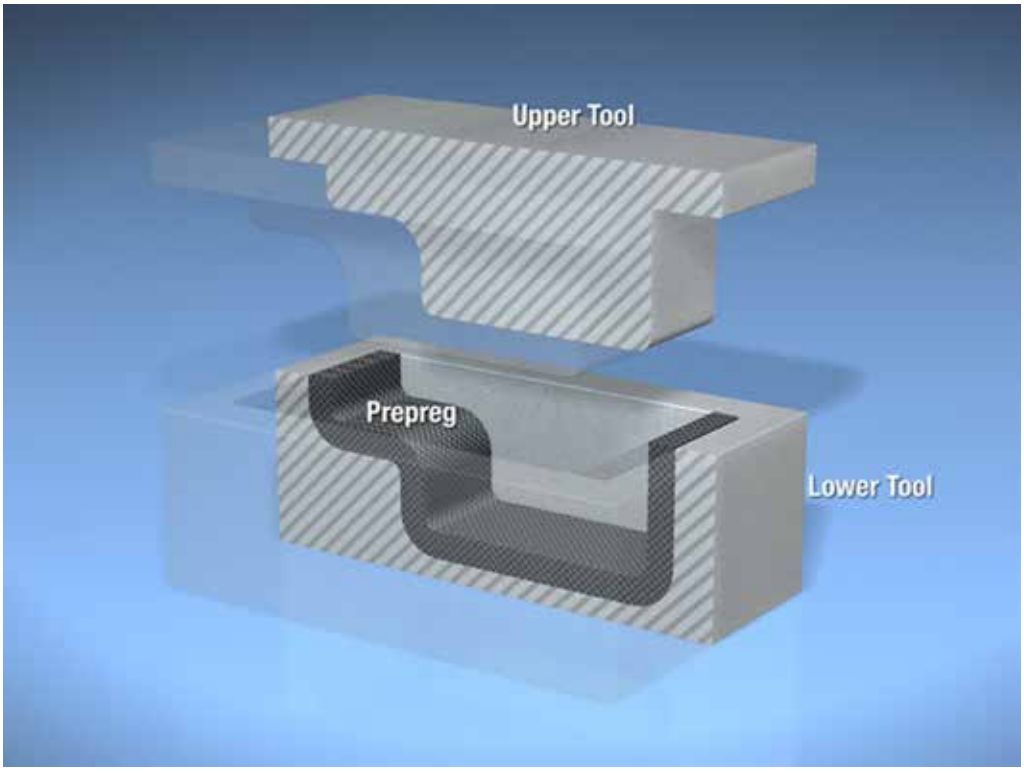

Figure 8: Schematical press process

a) Preform preparation before laminate curing
(See section 9.3.1 a)

b) Mold concept and preparation
Tool surface and preparation are similar to the autoclave process (See chapter 9.3.).

A shear edge tool can be used to allow excessive resin to flow and minimizes friction. For better degassing, additional vacuum canals can be integrated in the tool concept.

The tool surface can be coated with different release coatings to ensure a proper demolding in addition to the other release methods described in the autoclave process

c) Procedure and cure cycle
It is necessary to close the mold quickly (see DEA graph → minimum viscosity) and apply pressure to produce high quality parts (especially when applying higher temperatures). The pressure must remain constant until the product is fully cured. For UD products and woven fabrics, at least 15bar (218psi) should be applied for the highest quality parts.

A minimum coverage of 98% is recommended. References using a cycle of 120°C for 7 minutes and 20-30bar showed a smooth surface.

The cure time is based on the thickness, product type and applied temperature. If a thin part (< 8mm) is used and the mold provides an equal heat input, the cure times mentioned in chapter 6.1. are appropriate. Thicker parts take longer and the curing time should be determined individually to obtain fully cured parts.

The actual cure cycle may vary with the part geometry, flow path and thickness.

In the compression process, the M77 preform can be combined with an adhesive for single-step hybrid applications. This configuration provides the following benefits:

- Hybridization in a one-step process
- Adhesive with high lap shear strength properties
- No need to change process technologies
- E-coating and painting process compatibility

9 FAQs

What is the maximum storage time at room temperature?
The storage time at room temperature and -18°C is mentioned in the datasheet. For a typical reaction process of an epoxy resin it can be said that the gel time halves by every 10°C temperature increase (approximate value). Storage at higher temperatures can also influence the uncured T_g and the tack of the system and it can get brittle. In order to prove resin advancement, DSC measurements can be performed.

Can Hexcel provide mechanical values?
Hexcel has different products in the standard portfolio from which it can provide mechanical values. For more detailed information please contact Hexcel Technical Support.

What's Hexcel`s minimum order quantity?
The minimum quantity order depends on the product. For further information please contact the customer service or product management. Minor quantities can be obtained from official Hexcel distributors (a list of official distributors can be found on the Hexcel website).

Is it possible to get customized products?
If you wish to get any products that are not listed in our standard portfolio please don't hesitate to contact the Hexcel Sales Department.

Is it necessary to pre-treat a mold (external release agent)?
Yes. Even if release films or internal release agents are used, there is the possibility (unstable process, wrong parameters, new product, etc.) that the resin may come in contact with the mold and stick to it after the cure. Cleaning a contaminated mold is much more time consuming than a pre-treatment.

How can we determine an optimized cure cycle?
An optimized cure cycle can be determined by using a DSC or other accurate measurement systems like DEA, etc.

Cured ply thickness calculation
The cured ply thickness can easily calculated by using the Hexcel CPT - Calculator (available on the Hexcel website).

How "tacky" is HexPly® M77 prepreg?
HexPly® M77 is a low-tack resin designed for automated processes, especially compared to standard autoclave resins systems there is no physical tack.

Do we need vacuum for degassing?
The use of vacuum enhances the quality of the product, assists in lowering the air content in the resin mix and decreases the amount of pressure needed to get a part with good surface quality, but it is not mandatory. A good surface quality can still be achieved without vacuum.

Do I need to wear gloves, protective eye wear and respirators when working with HexPly® M77 prepregs?
Protective eye wear and gloves (latex, vinyl, rubber, etc.) that are impermeable to resin are recommended to reduce the risk of skin irritation. For detailed information see the MSDS.

What are the best processing methods for thick industrial components (>10mm)?
For components above 10mm thickness, using internal bleed layers of dry fabric is recommended. These absorb excess resin and become an integral part of the cured composite. This procedure has the following advantages:

- Vacuum is easily distributed, eliminating any void content in the composite
- Excess matrix accumulation between the layers is absorbed
- Fiber volume is controlled
- For monolithic structures, any dry fabric plies must be evenly distributed throughout the thickness of the component
- For sandwich structures, any dry fabric plies must only be placed in the outer 2/3 of the skin
- Dry fabric layers must always overlap the prepreg stack to allow connection to the vacuum system

For compression molding, a less aggressive cure cycle is recommended (130°C/5min).

To avoid exotherms it is advised to incorporate a dwell and a controlled heat-up rate.

Are there major differences between curing:

carbon or glass prepreg?

When working with part thicknesses >10mm the heat capacity of glass has to be taken into account.

thin or thick parts?

Thicker parts need more time for complete heat diffusion, but reach a higher maximum temperature due to the exothermal reaction of the matrix. This effect could have an impact on the cycle time.

high or low resin content prepreg?

Higher resin content leads to a stronger exothermal reaction (See question above). The pressure level must be adapted to the resin content and desired resin flow. If the resin content of the product should be high and the flow low, a lower pressure should be used.

fast or slow/ high or low temperature

Higher temperature results in a shorter cure cycle and a faster start of the minimum viscosity of the resin. The gel time also has to be considered when changing the temperature (see graphs chapter 6.1). In both options it is necessary to keep the pressure up in the process to provide an optimal curing behavior and better part quality. Additionally when using low temperatures, higher pressure should be used, because of the higher viscosity of the system.

Troubleshooters: *We see a lot of …, what can we do?*

subsurface bubbles

This can emerge out of insufficient degassing of the resin and can be improved by applying vacuum in the forming process. Dry interlayers may help for additional degassing during the process. Moisture in the prepreg can also result in subsurface bubbles. This may be caused by improper storage and exposure to high humidity.

porosity

Surface porosity is primarily associated with air that is trapped at the tool/prepreg interface during layup and can be improved with a vacuum assisted process and less aggressive cure cycles combined with higher pressure. Keeping a long dwell without pressure can also result in porosity.

dry surface spots

Either the resin content is too low, too much resin is bled off during the process or the reaction of the resin is completed before enough pressure is applied on the part. Same as with porosity, a long dwell without pressure can lead to dry surface spots.

white spots

Solvent-based release agents can lead to white surface spots. Water based release agents may used instead.

yellow areas

Measure the temperature in the process. Yellow areas are a sign that the matrix is starting to degrade because of excessive heat.

uncured areas

Uncured areas can appear due to an incorrect curing cycle. Control the heat/ heat-flow during the process and check for possible errors in the machine settings.

brown areas (exothermic)

Control the heat in the process. Matrix is already degrading. An optimized cure cycle with dwell times at various temperatures can remedy the problem.

non-filled areas

Non-filled areas can result out of unsuitable part dimensions (too thin, long ways, etc,) or gel time issues.

soft material when demolding

Soft material occurs when demolding with temperatures above or around cured T_g. This can be managed by using a handling device or local ejector pins. For detailed information please contact Hexcel Technical Support.

10 Health and Safety

The usual precautions when handling uncured synthetic resins and fine fibrous materials should be observed. The use of clean disposable inert gloves provides protection for the operator and prevents contamination of material and components.

Please refer to product MSDS for further and up-to-date information specific to this product.

11 Glossary

Following common terms especially regarding prepreg technologies (in alphabetical order).

- **Anisotropy:** The tendency of a material to exhibit differently along the directions parallel to the length or width of the lamination planes; or parallel to the thickness into the planes perpendicular to the lamination.
- **Autoclave:** A closed vessel that permits application of pressure and heat used for processing composite materials
- **Compression Molding:** A technique for molding thermoset plastics in which a part is shaped by placing the fiber and resin into an open mold cavity, closing the mold, and applying heat and pressure until the material has cured or achieved its final form.
- **Cure Cycle:** This is the time duration and temperature needed for the resin in the prepreg to harden.
- **DEA (Dielectric Analysis):** Used for investigating the curing behavior of resin systems and other curing systems.
- **Debulking:** The application of vacuum pressure at specific points in the lay-up sequence to ensure full consolidation of the prepreg plies.
- **DSC (Differential Scanning Calorimetry):** A thermoanalytical technique that is used to measure heat driven processes in a sample by measuring the amount of energy absorbed or released by the sample when it is heated or cooled.
- **Fiber Volume Fraction (FVF):** Percentage of fiber in the prepreg (by volume).
- **Flow:** The ability of the resin to move under pressure allowing it to saturate all parts of a laminate.
- **Fiber Areal Weight (FAW):** The weight of fabric used in a prepreg (gsm).
- **Glass Transition Temperature (Tg):** Temperature at which a phase change occurs in the matrix. This gives an indication of the maximum service temperature.
- **Lay-Up:** The number of plies and their orientation needed to produce a given part.
- **Out Life:** Period of time that a prepreg remains usable at workshop temperature. Out life is lost progressively each time the prepreg is defrosted. Manufacturers normally state out life at a standard temperature, usually 21°C.
- **Peel Ply:** Layer of material applied to a prepreg layup surface that is removed from the cured laminate prior to bonding operations and leaves a clean resin-rich surface ready for bonding.
- **Ply:** A layer of prepreg.
- **Resin Weight (%RW):** Percentage of resin in the prepreg (by weight).
- **Shelf Life:** The length of time the prepreg can be stored under specified conditions and remains usable.
- **Tack:** Measurement of the capability of an uncured prepreg to adhere to itself or to the tool.
- **Tack Life:** Period of time at a given temperature that the prepreg has sufficient tack.
- **Vacuum Bagging Technique:** This refers to the arrangement of vacuum bagging materials used when molding a part via vacuum or autoclave processing.
- **Viscosity:** A measure of the flow characteristics of a resin with respect to time, temperature and heat up rates.

12 Contacts

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Hexcel is a leading worldwide supplier of composite materials to aerospace and industrial markets. Our comprehensive range includes:

- HexTow® carbon fibers
- HexForce® reinforcements
- HiMax™ non-crimp fabrics
- HexPly® prepregs
- HexMC® molding compounds
- HexFlow® RTM resins
- Redux® adhesives
- HexTool® tooling materials
- HexWeb® honeycombs
- Acousti-Cap® sound attenuating honeycomb
- Engineered core
- Engineered products

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