Out-of-Autoclave Component Prepreg System

Processing Guide

Introduction

XPREG® XC110 is remarkable component prepreg system designed for out-of-autoclave cure.

Using XPREG® XC110 it is now possible to produce carbon fibre components with cosmetic finish and mechanical properties to rival autoclave cured laminates whilst avoiding the heavy initial investment and ongoing cycle costs of an autoclave.

To achieve these exceptional results however, XPREG® XC110 needs to be processed correctly. The key areas of importance being the tool surface compatibility, the bagging procedure and the two stage cure cycle. The aim of this guide is to explain in detail the recommended procedure in each of these areas and to also provide additional processing information that may be required in certain circumstances along with defect diagnosis and remedy.

This document will be kept up to date with the latest information and findings.

Tooling and Mould Preparation

Compatible Tooling

Fully Compatible

XPREG® XC110 component prepregs are suitable for use with most tooling materials with a suitable service temperature; these include:

- High-temperature wet laid/infused epoxy moulds such as the Easy Composites EG/EMP/EL160 system
- Prepreg tooling surfaces such as the XPREG® 'XT' tooling materials
- Epoxy tooling board such as EP700 (following suitable surface sealing, e.g. S120 Advanced Board Sealer)
- Aluminium/steel moulds
- Glass platens

NOT Compatible

XPREG® XC110 is NOT suitable for use with the following tooling materials due to either service temperature or chemical compatibility constraints:

- Polyester tool surfaces, such as those used for traditional 'fibreglass/GRP' moulds
- Polyurethane model/tooling board (due to cure inhibition of epoxies by polyurethane at elevated temperature)

All mould tools should be post-cured (if required) before use to ensure that their full service temperature is realised. If in doubt of the compatibility of any mould material, we would strongly advise conducting a test prior to component manufacture.

Uni-Mould™ & Other Vinylester Tooling

Although it is possible to use Uni-Mould™ tools with XC110, they are not recommended due to the increased possibility of surface imperfections (pin-holes) which can occur when XPREG® XC110 is cured in contact with vinylester.

If it is necessary to use a Uni-Mould™ tool with XC110 then the tool should be post-cured to 90°C before use with XC110. The recommended maximum cure temperature for XC110 in a Uni-Mould™ tool is 85°C which means the normal XC110 cure cycle (with a final cure temperature of 120°C) should not be used. Instead, the special *Low Temp Cure Cycle* should be used. See 'Cure Cycles' section for more details.

S120 Advanced Board & Mould Sealer

If the Uni-Mould tool is new and has not previously had any release agent applied to it then its compatibility for use with XC110 prepreg can be significantly improved with the application of several layers of Easy Composites' *S120 Advanced Board & Mould Sealer*. This will provide a barrier between the vinylester gelcoat and the XC110 prepreg, greatly reducing the risk of any minor surface imperfections.

After application of S120 board sealer, multiple applications of release agent will be required (see next section).

Release Agent

We recommend the use of chemical release agent, particularly *Easy-Lease™ Chemical Release Agent* which has proven to be perfectly reliable when used with XPREG® XC110 compatible mould surfaces. The release agent should be designed for use at elevated temperatures and compatible with both epoxy prepregs and the tooling surface.

Traditional mould release waxes or PVA will not provide a release for prepregs and should NOT be used. If in doubt, conduct a trial to test for suitability.

Porous mould surfaces such as epoxy model board should be sealed using *S120 Advanced Board & Mould Sealer* or similar prior to release agent application.

New mould surfaces should have at least 6 applications of *Easy-Lease™* prior to layup, please refer to application guidelines for further information. 1 further application is recommended between every component release, especially for complex components.

Layup & Bagging

Laminating

Laminating should be conducted in a clean and dry working environment at 17-20°C this temperature range provides the optimum tack level and workability for the material.

XPREG® XC110 does not have a specific 'surface' ply therefore any fibre option from the range can be used in any combination throughout the laminate, however for optimum surface finish it is generally recommended to use a lighter woven material choice, particularly the XC110 210g 3k. Please note that unidirectional reinforcements do not vent sufficiently to provide void free surface finishes, ideally unidirectional fibres should be surfaced by at least 2 plies of 3k woven reinforcement.

The laminating procedure matches that of all common prepreg systems; The plies of material should be positioned into the mould as required, great care must be taken to ensure complete and proper conformity to the mould surface without bridging is achieved, the use of rollers and blunt 'dobber' tools can assist with achieving proper placement and consolidation but care must be taken not to damage the fibres. Gently heating the material using a low-temperature heat-gun or a hair-dryer can aid to soften the resin system allowing the material to conform and drape more easily. Care must be taken to ensure that the material is not overheated as this may lead to partial curing of the resin or the resin becoming displaced.

Debulking

For laminates of less than 3 plies generally a debulk is not needed unless particularly complex geometry requires it. For laminates of 4 or more plies we would recommend a standard debulk procedure; every 2-3 plies; Apply P3 perforated release film followed by a breather cloth, vacuum bag and hold at full vacuum for 20mins, remove vacuum bagging stack and proceed with subsequent plies of XPREG® XC110. This debulking procedure reduces air entrapment and improves the laminate consolidation.

Vacuum Bagging

Consumable Stack

- Vacuum bagging film: *Aerofilm® VB160 Vacuum Bagging Film*
- Sealant tape: *VBGT15 Gum Sealant Tape*
- Breather layer: *BR180 Breather Layer Cloth* (for airflow only, exclude from laminate surface)
- Release Film: *Aerofilm® R210 Unperforated FEP Release Film*

Release Film

An unperforated release film with suitable service temperature should be applied onto the entire open surface of the prepreg, care should be taken to ensure an intimate contact without bridging is achieved. If required, the loose film around the perimeter of the part can be occasionally secured in place using flash/release tape.

Breather

For best results, it is advised that breather cloth is NOT used on top of the release film across the laminate. Instead, breather should be used on the reverse of the mould and on the surface of the mould underneath the through-bag connector and up to the start of the laminate in such a way as to ensure an air path from the connector to the laminate surface.

If multiple components are being cured in the same bag then breather should be used between each component to ensure a continuous air path between them.

Vacuum Draw-down

The vacuum bag can then be applied and vacuum should be drawn gradually, taking time to position and reposition the bag as air is removed.

It is essential to the quality of the end result that during the pull-down the bag should be adjusted and positioned such that it does not bridge or stretch anywhere on the component's surface. This is a critical step to ensure proper consolidation of the laminate. Air may need to be re-introduced to allow repositioning if bridged or stretched areas are identified.

Hand tools (sometimes referred to as 'dobbers') should be used to to push the vacuum bag firmly into the inside of tight corners or details. After correct layup, consolidation and bagging, it should be impossible to feel any 'bridging' or movement when pressing a suitably shaped hand tool into corners or details of the moulding.

Towards the end of the bagging process, if there is any doubt over whether the vacuum bag is sufficiently large to to avoid bridging then the bag should be abandoned and a new larger bag made.

Cure Cycle

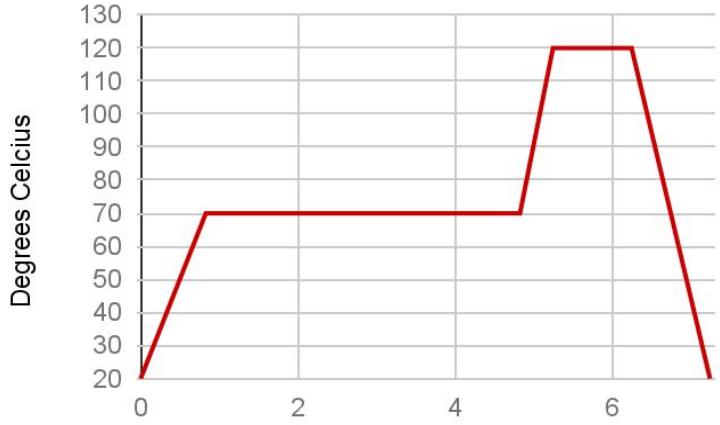
To achieve optimum surface finish and mechanical performance from XPREG® XC110 it is essential that the proper cure cycles are used.

The cure cycles specified are for oven air temperature, these allow for typical lag caused by standard composite tooling. If particularly bulky or heavy mould tools are used the tool surface temperature should be monitored to ensure that the lag does not go beyond acceptable limits. Temperatures should be held +/- 3°C where possible. Ovens should be periodically checked to ensure that they are achieving the required levels of accuracy and stability.

Controlled Ramp-Rate Cycles

Standard Cycle

This cure cycle is recommended for use on moderate complexity laminates up-to 4 plies, it offers the minimum processing time of 7hr 15min it achieves excellent surface finish and low void content in most applications.



Step #	Start Temp	Ramp Rate	Time	End Temp	Elapsed Time
1	~20°C	1°C /min	00:50	70°C	00:50
2	70°C	Soak	04:00	70°C	04:50
3	70°C	2°C /min	00:25	120°C	05:15
4	120°C	Soak	01:00	120°C	06:15
5	120°C	Natural Cool	--	~20°C	07:15

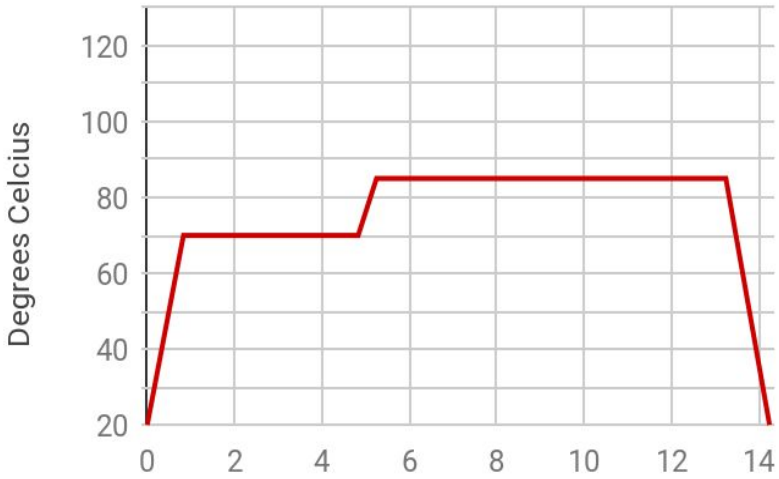
Extended Soak Cycle

This cure cycle is recommended for use on laminates above 4 plies, or components of high complexity, with the extended initial soak of 6hrs this capitalises on the full flow time available and will yield the lowest void content possible in nearly all applications, the only downside of this cycle against the 'Standard' cure cycle is the processing time as it is 2 Hours longer at 9hr 15min.

Step #	Start Temp	Ramp Rate	Time	End Temp	Elapsed Time
1	~20°C	1°C /min	00:50	70°C	00:50
2	70°C	Soak	06:00	70°C	06:50
3	70°C	2°C /min	00:25	120°C	07:15
4	120°C	Soak	01:00	120°C	08:15
5	120°C	Natural Cool	--	~20°C	09:15

Low Temp Cycle

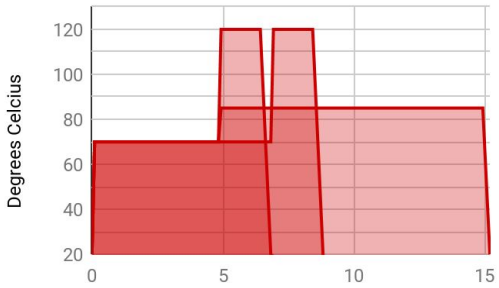
This cure cycle is recommended when the maximum temperature capability of either the mould or the oven is lower than 120°C used in the 'Standard' cure. This cycle does not reflow the resin to the same degree and may in rare cases lead to an increased void content and reduce surface finish. The reduced final cure temperature increases the process time and reduces the final HDT (max temp) of the laminate unless subsequently post-cured.



Step #	Start Temp	Ramp Rate	Time	End Temp	Elapsed Time
1	~20°C	1°C /min	00:50	70°C	00:50
2	70°C	Soak	04:00	70°C	04:50
3	70°C	2°C /min	00:08	85°C	04:58
4	85°C	Soak	10:00	85°C	14:15
5	85°C	Natural Cool	--	~20°C	15:00

Switched Cycles

Switched cycles should only be used where your oven controller does not have ramp control. This does not provide optimal flow or cure control but will still in many cases offer excellent results. These cycles should not be used on laminates above 3mm in thickness as there is a risk of thermal runaway from excessive exotherm. The cycles are essentially the same as the 3 primary cure cycles with the ramp time added to the soak time at each step in the profile. This processing method allows simple control by timer switches or manual control.



Standard (Switched) (only for use when oven ramp control is not available)

Step #	Start Temp	Ramp Rate	Time	End Temp	Elapsed Time
1	~20°C	Full	N/A	70°C	00:00
2	70°C	Soak	04:50	70°C	04:50
3	70°C	Full	N/A	120°C	00:00
4	120°C	Soak	01:25	120°C	06:15
5	120°C	Natural Cool	--	~20°C	07:15

Extended Soak (Switched) (only for use when oven ramp control is not available)

Step #	Start Temp	Ramp Rate	Time	End Temp	Elapsed Time
1	~20°C	Full	N/A	70°C	00:00
2	70°C	Soak	06:50	70°C	06:50
3	70°C	Full	N/A	120°C	00:00
4	120°C	Soak	01:25	120°C	08:15
5	120°C	Natural Cool	--	~20°C	09:15

Low Temperature (Switched) (only for use when oven ramp control is not available)

Step #	Start Temp	Ramp Rate	Time	End Temp	Elapsed Time
1	~20°C	Full	N/A	70°C	00:00
2	70°C	Soak	04:50	70°C	04:50
3	70°C	Full	N/A	120°C	00:00
4	120°C	Soak	01:25	120°C	06:15
5	120°C	Natural Cool	--	~20°C	07:15

Storage and Handling

Shelf-life

XPREG® XC110 has a shelf-life of 12months from date of manufacture, this is subject to a storage temperature of -18°C to -25°C. For structurally critical applications this expiry period should be adhered to. It is often possible to have the life of a particular batch extended if this is needed please contact Easy Composites for further details. In the case of non-critical/cosmetic applications normally the specified shelf life can be exceeded greatly, it is recommended that customers conduct their own trials to establish whether the systems is still performing as required.

The prepreg is delivered in sealed packaging suitable for freezing, upon removal from frozen storage the material should be allowed to defrost and reach room temperature before removal from the sealed packaging a short 1m roll may take as little as 1hr where as a full 30m roll may take upto 8hrs. The reason for the sealed defrost is to ensure that water condensation does not form directly on the material itself, also disturbing the frozen and embrittled resin can cause damage to the fibres and resin distribution.

Prepregs can be re-frozen multiple times but this must always be done in sealed packaging, ideally a log should be kept to keep track of the sum total hours of outlife accrued.

Out-life

The out-life of the system is 28 days at an ambient temperature of 20°C beyond this time the resin systems cure and flow characteristics will be compromised, it may be possible to moderately exceed this expiry period for non-critical/cosmetic applications. The storage temperature should not exceed 20°C, higher temperatures will dramatically reduce the out-life of the system.

Typically material that has surpassed its outlife will exhibit reduced resin flow leading to increased void content and surface pinholes, if outlife is a suspected cause of defects a side-by-side trial with fresh material should be conducted.

Defect Diagnosis

Defect: **Pinholes/voids in negative features**

This is the most common issue found in prepreg laminates, its root cause can be one or a number of the following factors:

(listed in order of likelihood)

- **Improper layup, bridging in corners**
  Ensure that the layup is properly consolidated into the corners, relieving potential bridging areas with cuts/joins may help.
- **Improper vacuum bagging**
  Ensure that both the release film and the bag fully conform against the laminate without bridging or stretching. If breather is used between the vacuum bag and release film then eliminating it from complex areas may help to get better conformity from the vacuum bag.
- **Incorrect cure cycle**
  Ensure that the cure profile is being accurately followed by the oven controller. Check that the temperature lag to the tool is within acceptable limits. If the 'Normal' cure cycle is being used try running the 'Extended' cycle as it may help to improve flow in complex geometries.
- **Insufficient debulking on thicker laminates**
  Ensure that the proper debulking procedure has been followed, this is especially important for female mould tools and geometries, in some cases increasing the number of debulk stages may prove advantageous.
- **Expired material**
  Ensure that both the shelf-life and outlife have not been exceeded (out life is a much more likely cause of defect above shelf-life) if you are uncertain of storage condition and times a side-by-side trial with fresh material should be conducted.

Defect: **Pinholes/voids in all / most areas**

Pinholes and voids in most or all of the part are rarely caused by laminating or vacuum bagging error but normally indicate a more general problem, its root cause can be one or a number of the following factors:

(listed in order of likelihood)

- **Incorrect cure cycle**
  Ensure that the cure profile is being accurately followed by the oven controller. Check that the temperature lag to the tool is within acceptable limits. If the 'Normal' cure cycle is being used try running the 'Extended' cycle as it may help to improve flow in complex geometries.
- **Incompatible mould surface**
  Ensure that the mould is made from a compatible tooling system, (please refer to the 'Compatible tooling' section) the most common mistake is using vinylester tooling such as unimould which is not compatible with XPREG XC110.
- **Insufficient debulking on thicker laminates**
  Ensure that the proper debulking procedure has been followed, this is especially important for female mould tools and geometries, in some cases increasing the number of debulk stages may prove advantageous.
- **Expired material**
  Ensure that both the shelf-life and outlife have not been exceeded (out life is a much more likely cause of

defect above shelf-life) if you are uncertain of storage condition and times a side-by-side trial with fresh material should be conducted.

Defect: **White ‘stress’ marks on angular features**

Marks such as these are caused by fast ramp rates or inaccurate or fluctuating temperature control, ensure that your oven is maintaining accurate and stable temperature control. In some rare cases the ‘switched’ cure cycles may generate this defect.

Defect: **Pinholes in areas where there is overlap in the material**

Pinholes and voids that appear where the material is cut and overlapped is normally caused by inaccurate or fluctuating temperature control, ensure that your oven is maintaining accurate and stable temperature control. The problem can sometimes be reduced by the removal of the breather in these areas (if used).

Defect: **White hazy areas**

Hazy or milky patches or areas may be caused by release agent build-up on the mould tool, inspect the mould surface and clean/polish if identified. Another possible cause is moisture contamination either during material storage or during layup, ensure that proper storage procedures and clean working environments are upheld.

Defect: **Mild print-through of weave on the surface**

A small amount of print-through of the reinforcement’s weave pattern onto the surface of the part is perfectly normal. Surface print-through will be more obvious when using heavier reinforcement, such as the 12k 450g, as the surface layer. When using the 3k 210g as the surface layer, print through will be reduced by using a second layer of 210g 3k behind the first layer, thus protecting the surface from the texture of the heavier layers of backing.

Defect: **Strong print-through of weave on the surface**

Distinct fibre pattern print-though on the component will either be caused by a problem in the cure cycle or the part being removed from the mould still ‘hot’ (i.e. without having first cooled to room temperature). The cure cycle may have been terminated before completion or the actual temperature may differ from the indicated temperature, check the cure cycle with a separate thermometer for accuracy and conformity to a specified cure profile.

Additional Information

Standard Reinforcements

XPREG XC110 is available from stock in 3k and 12k variants.

- **210g, 3k, 2/2 Twill**
  Made using 3k Pyrofil TR30S high strength carbon tow, this is typically used as a surfacing ply or in multi-ply laminates it exhibits excellent drapability and handling characteristics as well as impressive mechanical performance (see chart below). Approximate final ply thickness is 0.22mm.
- **450g, 12k, 2/2 Twill**
  Made using 12k Pyrofil TR50S high strength carbon tow, this is typically used as backing plys to the 210g to build thickness cost-effectively and quickly, it can also be used as a surface ply if desired but does have reduced drapability and will have slightly more surface 'print'. Approximate final ply thickness is 0.47mm.

See XC110 Technical Datasheet for full details. A range of alternative reinforcements including multiaxial and unidirectional can be produced on request, subject to MOQ. Please contact us with you requirements.

Compatibility with XPREG® XC130 Prepregs

XPREG® XC110 is designed to be co-curable with XPREG® XC130 prepregs which means that a wider range of reinforcements can be used, including unidirectional reinforcement.

When including XPREG® XC130 prepregs in an XC110 laminate (for out-of-autoclave cure) it is important that they should not be used as either of the first two plies in the laminate. This will ensure that the special flow properties of the XC110 prepreg (that allow the pin-hole free surface finish) are not compromised. Use of the XC130 prepreg for any plies from the third ply onwards should not affect the surface finish of the cured part.

Unidirectional Reinforcement

If your project requires the use of a unidirectional (UD) reinforcement as the surface ply then XC130 *can* be used however it should be expected that the density of a UD reinforcement used as either the first or second ply of the laminate will affect the surface finish of the component.

XC130 UD used as the surface ply will have some minor surface voiding aligned with the fibre orientation whilst XC130 UD used as the second ply (after an XC110 surface ply) will suffocate the correct resin flow of the surface layer and cause some minor pin-holing.

Compatibility with XPREG® XA120 Adhesive Film

XPREG® XC110 is fully compatible with *XPREG® XA120 Prepreg Adhesive Film* allowing complex structures, including those using Nomex® or aluminium honeycomb or suitable foam cores, to be created. XA120 will co-cure alongside XC110 (and XC130) and will reach full cure using any of the XC110 cure cycles listed in this Processing Guide.

Using Peel-Ply for Secondary Bonding

In common with all prepreg systems, most laminate constructions using a honeycomb core will require a '2-shot' or '3 shot' cure whereby the inner and outer skins are laminated and cured first and then assembled either side of the honeycomb core (using resin film) before being vacuum bagged and oven cured again to flow and cure the adhesive film. When following this procedure, peel-ply can be layered onto the laminate where the resin film will be applied to aid with bonding and eliminate the need for surface preparation or keying.

The use of peel-ply will absorb some of the resin from the XC110 laminate. Testing has shown that peel-ply applied to the reverse (inside) of a laminate made up of three or more plies will not affect the surface finish of the component. Peel-ply applied to the reverse of a laminate of only one or two plies will absorb some of the resin needed for the laminate itself and therefore could locally affect the surface finish. In this situation, a layer of *XPREG® XC120 Prepreg Adhesive Film* can be positioned under the peel ply to provide additional resin content.

When using peel-ply with any XPREG® prepreg, it is recommended to use a Nylon 66 peel-ply such as *AeroFilm® PP230 Aero-Grade Nylon 66 Peel-Ply* due to the increased ease with which this grade of peel-ply will release from the prepreg.

Disclaimer

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Easy Composites Ltd
Park Hall Business Village, Stoke on Trent
Staffordshire, ST3 5XA. United Kingdom

Tel. +44 (0)1782 454499
Email sales@easycomposites.co.uk
Web www.easycomposites.co.uk

Distributed in China by:

Easy Composites (Beijing) Ltd
No.20# A , U Gu Mid Area Liandong,
Majuqiao, Beijing 101102, China

Tel. +86 (0) 1057485810
Email sales@easycomposites.asia
Web www.easycomposites.asia