Improving wind blade productivity with glass kits and preforms



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Pre-engineered sets and sub-assemblies offer compelling advantages in quest to boost productivity, quality and cost containment.

Wind turbine blades are growing ever larger, driving a pressing need for cost reduction and higher production efficiency in blade manufacturing. Traditionally, rotor blades account for roughly one-third of a turbine's cost and rely on labour-intensive lay-up processes. This manual approach not only incurs high labour cost but also introduces variability, which negatively impacts safety margins, material usage and quality.

For today's industry majors, the challenge and opportunity are clear: identifying ways to boost productivity and quality while containing costs.

Increasing automation is a key priority, as it promises faster production, more repeatable quality and lower costs per blade. In this context, pultruded parts are seeing rapid adoption in many regions.

Advanced glass fibre kits and preform solutions have emerged as a compelling answer to drive further productivity in wind blade production. By adopting pre-cut material kits and preformed fibre assemblies, manufacturers can transform blade fabrication from a purely manual moulding exercise into a more efficient assembly process.

An analysis of industry practices and technical literature offers valuable insights into the development of glass kits and preforms, and how these innovations are supporting major wind OEMs in ramping up blade production productivity.

Glass fibre kits & preforms: concepts and benefits

Advanced glass fibre kits are pre-engineered sets of all the fibreglass reinforcements (and sometimes core materials) cut to shape for a specific blade design using new technologies that improve accuracy, efficiency and digital control. Rather than cutting fabric and core pieces on the fly, manufacturers receive a high-level "ready-to-use" kit of pre-cut materials that fit each section of the blade precisely according to the structural blade design. These kits are custom-tailored to each blade model, ensuring an exact fit and reducing labour associated with on-site trimming or adjustment. By organising all needed fabrics, core, peel-plies, etc., into one package, kits streamline the lay-up process and simplify inventory management, reducing waste and increasing environmentally friendly aspects.

Preforms are related but go a step further in assembly. A preform is a pre-shaped or partially assembled fibre reinforcement unit that can be placed into the mould as a modular element. Instead of laying individual plies one by one into a blade mould, preforms involve fabricating smaller composite sub-assemblies (e.g., for the root section, transition area, or other blade substructure) and then positioning these "building blocks" into the blade mould in sequence. Preforms can be flat stacks of multiple glass fabrics stitched or bonded together, or 3D-shaped textiles that conform to complex geometries like caps or root pads. In essence, preforms turn the blade fabrication into an assembly of precision parts rather than a massive hand layup operation.

Adoption of advanced glass kits and preforms provides multiple advantages including:

- Improved quality, consistency and scrap control: because all elements of the kits are cut to spec with tight tolerances, there is less variability in fibre placement. In addition, preforms come ready-made to the required shape and thickness, reducing the opportunity for human error in fibre placement. It also becomes easier to integrate quality checks. This consistency enhances the overall quality of the blades, reduces rework and optimises material usage.
- Shorter cycle times: pre-cut kits and multiple preforms enable faster lay-up, since all can be prepared in parallel (even off-line). This means workers (or robots) can handle and position materials directly and quickly without time-consuming on-site or in-mould preparation.
- Labour reduction and ergonomics: handling a few preformed sections is quicker and easier than manually managing hundreds of individual fabric plies. This reduces manual labour hours and lessens physical strain on workers, improving shop-floor ergonomics.
- Lower inventory & JIT supply: kits and preforms enable raw materials to be managed per blade, reducing excess inventory. And they can be delivered just-in-time, which lowers storage needs and ensures fresh material. Waste is dramatically reduced and opportunities for recycling can reduce the carbon footprint impact.

In short, glass kits and preforms contribute to making blade manufacturing lean and repeatable in a more viable process. Advanced kits address the cutting and kitting of materials, ensuring all components are on hand and correctly dimensioned, while preforms add further value by assembling materials into unitised building blocks. Together, these innovations lay the groundwork for higher throughput and more automated, efficient and environmentally friendly blade factories.

Automation and customisation enabled by preform solutions

Among the driving motivations behind preform technology is facilitating automation in blade manufacturing. In the past, attempts to automate the entire in-mould layup with giant gantry robots had limited success; the blade's sheer size and the custom nature of each design made full automation difficult to justify economically.

A large gantry system laying every ply in sequence was complex and expensive; and given the relatively low production volumes per blade model (wind designs often run in the tens or low hundreds of units), the return on investment was similarly unfavourable. In addition, the industry's rapid design cycles, with blade models frequently changing, meant that dedicated automation equipment could become obsolete quickly. As a result, full-scale automation of blade layup proved almost impossible to cost-justify under those conditions.

The advent of modular preforms offers a practical automation path. Instead of automating the entire procedure, the process is reimagined as assembling a blade from a kit of preformed parts. Robotic pick-and-place systems can then be employed to place these pre-cut or pre-shaped modules into the mould in the correct sequence. This approach drastically simplifies the automation challenge: the robot only needs to handle manageable sections (each preform might cover a few square metres or a specific region of the blade) rather than manipulating full-length fabrics that span 50+ metres.

As noted in a 2023 JEC Composites report, the preform concept "requires a simple 'pick and place' unit" with flexibility to handle various blade designs. This means one automation cell can be reprogrammed or tooled for different blade models, providing mass customisation rather than one-size rigidity. The flexibility to accommodate a variety of blade and nacelle shapes was a key design goal of preform-based automation.

Several strategic benefits arise from this modular automation:

- Improved placement accuracy: automation also brings precision. Robots can place preforms with repeatable accuracy within millimetres of the target position. This level of placement tolerance helps ensure overlaps between adjacent preforms are controlled and fibre alignments are as designed. Such accuracy is contributing to blade quality and structural reliability.
- Centralised preform production: small preforms can be manufactured in a central facility (possibly by a supplier or in-house at a single location) and then transported to multiple blade assembly plants. This centralisation yields economies of scale – high utilisation of cutting, stitching, or forming equipment. The blade factories then operate more like assembly lines, receiving ready components to assemble. In practice, companies like InCom have been supplying preformed components to blade makers for decades, demonstrating the viability of an external supply chain for preforms.
- Parallel processing: preparing sub-components concurrently reduces overall blade build time. For example, one approach introduced by Pontis Engineering in 2012 stacked glass fibre layers on separate tooling stations to create multiple preform modules (for spar caps, shear webs, etc.) in parallel, then moved and joined these modules in the main blade mould, significantly improving throughput. This parallelism contrasts with the traditional serial hand layup in which each ply is placed serially in the mould.
- Customisation through software: modern automated cutting tables and robotic systems are highly programmable. When a blade design changes or a new model is introduced, the digital definitions of ply shapes and placement can be updated. This enables manufacturers to implement custom kits and preforms for each blade variant with the same automation hardware. As a result, automation and customisation go together; each blade design gets a tailored kit/preform set, and the robots are simply instructed with the new patterns. This agility is essential in wind energy, where blade designs evolve rapidly for performance gains.

Real-world development reflects these advantages. The Mapretec research

Fig. 1: Stitched fibreglass preform for a wind blade © InCom Group

project, a collaboration between the University of Bremen's BIK institute, Saertex and Areva Blades, exemplified state-of-the-art automation. The project combined computer-generated, ply shape definitions; automated cutting and handling; and an innovative forming device to lay up carbon and glass fibre materials for very large preforms (up to 130 m² area) without wrinkles or misalignment (earning a 2014 JEC Innovation Award). This achievement underscores how industry and researchers have tackled the technical hurdles to make automated preforming a reality at scale. The outcome of these efforts is that automation is no longer an all-or-nothing proposition; it can be incrementally applied via preforms and kits, yielding productivity gains while retaining flexibility.

Industry perspectives and technical insights

The evolutionary progression from manual layup to kits to modular preforms reflects the industry's push for productivity at scale and is backed by both practical industry experience and a body of technical research. Each step – material kitting, partial automation and fully automated preforming – built on the previous one. By leveraging lessons from aerospace composites and investing in dedicated R&D projects, the wind sector has dramatically improved blade manufacturing efficiency over the past two decades.

Insights from key industry sources and technical papers further illuminate the impact of these developments:

- Productivity and quality gains: a comprehensive 2020 review of wind blade production notes that traditional manual, labour-intensive processes resulted in high variability and the need for large safety factors. In contrast, automation (through approaches like preforming) can make blades cheaper, faster to produce and higher in quality, especially as blade sizes grow, which is critical for offshore turbines). This aligns with the on-the-ground results seen by manufacturers who have adopted preforms.
- Widespread adoption of infusion preforms: according to a 2022 industry literature review, most leading wind OEMs, apart from those using prepreg, "typically use vacuum infusion of dry preforms" for blade manufacturing and indeed vacuum infusion is the most widely used fabrication technology for modern blades. This indicates that the concept of laying up dry fibre packs (essentially preforms, whether made in situ or as separate units) has become mainstream. The same source emphasises that automation technologies, while requiring upfront investment, simplify the manufacturing process and ensure repeatability and reliability, which are key to competitiveness in the wind sector.
- Supplier and OEM collaborations: development of kit and preform solutions has been a collaborative effort among material suppliers, technology firms and blade OEMs. Specialist suppliers like InCom have long provided stitched glass preforms to blade manufacturers (Figure 1). And they continue to innovate by introducing more precise, automation-friendly preforms to meet rising quality demands. Material companies like Owens Corning and Saertex have developed fabrics pre-coated with binder powders to aid automated preforming. And engineering firms such as Pontis Engineering advanced new manufacturing concepts (e.g., turnkey preform assembly systems) adopted by blade producers. These examples demonstrate how industry players are sharing expertise to push the technology forward. Many of these advancements have been showcased and honoured at events like JEC World.
- Technical challenges and ongoing R&D: despite successes, implementing glass preforms at blade scale is not without challenges, which continue to be addressed in technical forums. Achieving accurate dimensional tolerances on very large preforms is difficult as even a slight distortion can cause a poor fit in the blade mould. Researchers have been investigating methods like automated ply layup and forming to improve precision. Controlling the resin infusion of thick preforms is another concern – ensuring that binder materials or stitching threads do not impede resin flow. Studies have examined the effects of different binder chemistries on infusion and composite properties, working to optimise those so preforms infuse as thoroughly as hand-laid plies. There is also active development in fastening and handling technology for preforms (e.g., tailored grippers, fixtures and

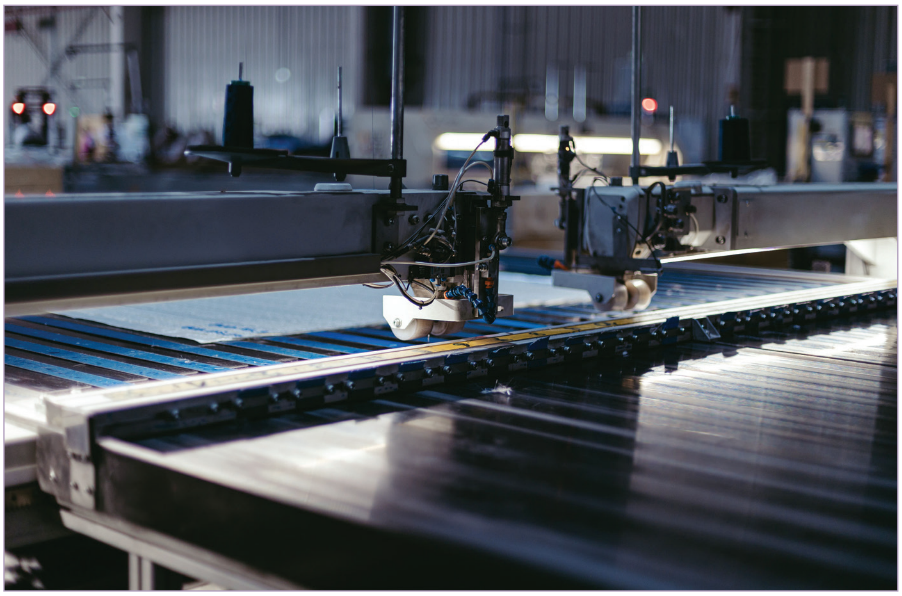

Fig. 2: The assembly of multi-layer sub-segments of the wind blade lay-up can be made with those production lines in a highly accurate and efficient manner © InCom Group

vision systems) that help robots handle pliable textile preforms without distortion.

- Commercial case studies: on the commercial side, published case studies and trials further underscore the benefits of kits and preforms. For example, a DOE-supported project with LM Wind Power successfully implemented an automated finishing system for blades, highlighting how "automation-led design" principles could be integrated into blade production. While that project was focused on finishing, it reflects a broader trend: blade designs themselves are being adapted to better suit automated fabrication (e.g., segmentation of layups to match preforms modules, inclusion of locating features for preforms, etc.). Another example is Siemens Gamesa, which has publicly discussed efforts to automate blade production in stages – starting from material kitting and moving towards more robotics – to keep up with increasing blade lengths. Although specific project details are proprietary, the overall industry direction is clear from conference presentations and press releases: every major blade manufacturer is exploring or implementing kit and preform-based automation to some degree.

In summary, both theoretical research and the practical industry reports align on the value of glass kits and preforms in providing a path to higher throughput, improved quality and reduced cost, which ultimately can lower the Levelized Cost Of Energy (LCOE) for wind power. The literature supports the notion that these methods are essential to scaling up wind turbine production to meet global renewable energy targets.

Outlook for blade manufacturing

Looking ahead, the trend of larger and more efficient wind turbines will only intensify the need for advanced manufacturing solutions. Advanced glass fibre kits and preforms are set to play an even more central role in this future. As blade lengths push beyond 100 m, purely manual fabrication becomes impractical – the components are simply too large and the tolerances too critical.

The industry is likely to see further digitalisation and automation of the preform and kitting process. Imagine smart factories in which laser projectors guide placement of pre-cut kits, robots handle heavy lifting of preforms and integrated sensors verify each assembly step. In fact, composites manufacturing experts note that preforming is one of the most active areas of development, rapidly evolving and incorporating advanced control systems, in-line inspection and data analytics to drive defects towards zero.

We can also expect continued materials innovation (Figure 2). For instance, thermoplastic resin systems might enable hot-formed thermoplastic preforms that can be welded or re-melted, further speeding up cycle times. High-rate manufacturing techniques from automotive, like fibre patch placement or automated tape laying, could also be adapted for wind blade substructures. Moreover, sustainability will influence design (e.g., preforms or bio-based resins in kits), which contribute to the migration to a circular economy and could thus become new selling points in JEC Composites magazine articles of the future.

For the industry majors, adopting glass kits and preform solutions is not just about incremental productivity; it represents a strategic shift to composite manufacturing 4.0 – where automation, customisation and quality assurance converge. With every successful implementation and technical paper published, confidence in these techniques grows.

As a result, we are witnessing a paradigm change: the wind sector embracing manufacturing methods that were once the domain of high-volume industries without sacrificing the tailor-made engineering that wind blades require. This synergy between customisation and automation, enabled by kits and preforms, will underpin the next generation of wind turbine blades that are better, cheaper and built faster than ever before. □

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