

Technical Disclosure¹

1. Title

Wind Blade Internal Laminate Repair Beyond Confined Space Using an Arm Extender

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4. Publication type

Technical Disclosure

5. Abstract

Disclosed is a manual internal repair technique for repairing laminate defects in a wind turbine blade at locations beyond an approved confined-space access limit. In conventional practice, cracks or delamination located beyond the allowable internal access region are repaired by creating an external window in the blade shell, repairing the affected laminate through the window, and then repairing the window itself. The disclosed approach instead uses an arm extender assembly to prepare, access, position, and apply repair laminates from inside the blade at least about 1 meter beyond the confined-space limit. The approach reduces repair duration, avoids removal of outer skin and core material from outside the blade, and enables a simpler and lower-cost repair process without requiring robotic equipment.

6. Technical field

The disclosure relates to repair of composite wind turbine blades. More particularly, the disclosure relates to internal laminate repair of cracks and/or delamination in blade shell structures located beyond confined-space access limits using a manually operated arm extender tool.

7. Background

Internal laminate defects, including cracks and delamination, may occur in wind blade shell structures such as upwind and downwind shell regions. In some cases, the affected area is positioned beyond a confined-space region approved for technician access under applicable EHS guidelines. A conventional response is to create a repair window from the outside of the blade, repair the damaged laminate through the window opening, and then restore the window area.

This external window repair procedure is laborious and time consuming. It may require grinding through outer skin, core, and inner skin layers from outside the blade. For up-tower repair, the process may also require rope access or a platform, increasing complexity and cost.

Accordingly, a need exists for a simpler repair technique that allows technicians to repair internal laminate defects farther inside the blade without creating an external shell window.

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8. Summary of the disclosure

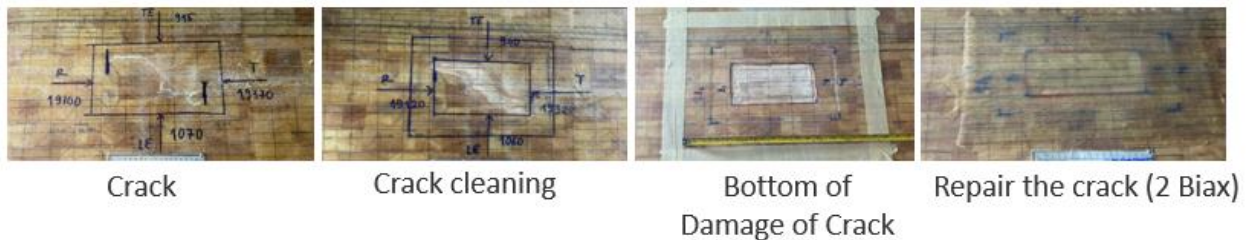
The disclosure provides a manually operated arm extender system and associated repair procedure for internal repair of wind blade laminate defects located beyond confined-space limits. The arm extender serves as a carrier and placement aid for surface preparation accessories and repair laminate layers. In one implementation, sandpaper or another abrasive element is attached to an extension member to roughen a damaged area, and a cleaning cloth is similarly attached to clean the repair location.

Repair layers are then positioned on an arm extender base, optionally over peel ply, and the arm extender is inserted and extended toward the target defect location in the spanwise direction. Once the arm extender reaches the repair location, the extender is manipulated, such as by flipping or rotating the base, to transfer the laminate layers onto the prepared internal blade surface. A roller or similar finishing tool may then be used to smooth the applied layers.

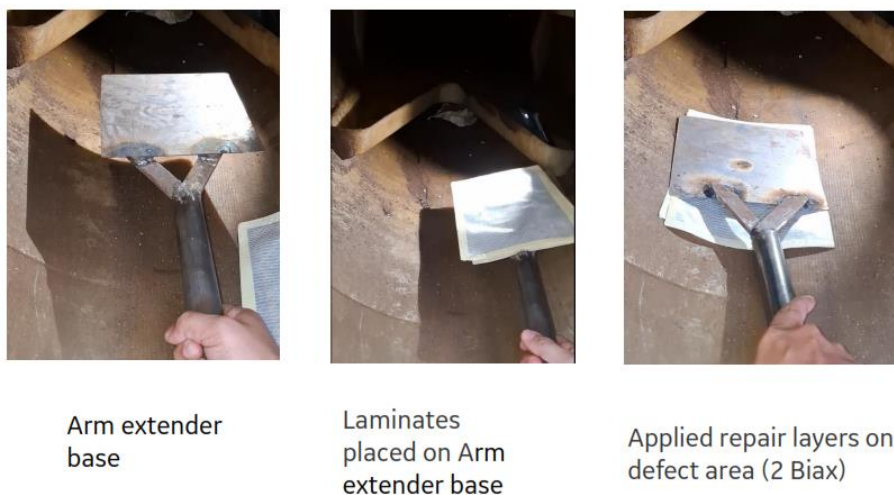
In representative examples, the method is used where only inner biaxial layers are affected and no core damage is present. The technique enables internal repair at least about 1 meter beyond the confined-space limit and may be further extended in future implementations.

9. Brief description of drawings

[FIG. 1] illustrates a conventional repair process in which a crack area is cleaned and repaired using a more limited internal access approach.

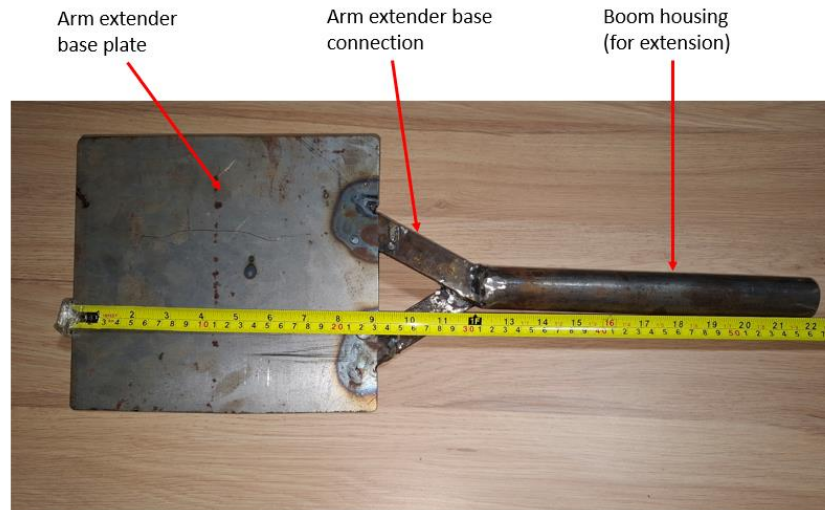


[FIG. 2] illustrates a proposed repair process using an arm extender base carrying laminate layers for application at an internal defect area.



[FIG. 3] illustrates an example arm extender configuration including an extender base plate, connection region, and boom housing.

Arm extender dimension



10. Detail description

In example embodiments, the disclosed repair system includes an arm extender having a base portion configured to support repair consumables and one or more extension portions configured to increase reach within the blade interior. An example configuration includes an arm extender base plate, an arm extender base connection, and a boom housing for extension.

In one repair workflow, the technician first identifies an internal damaged region, such as a crack or delamination in shell laminate located beyond the confined-space limit. The blade may be positioned such that the repair layers are applied generally horizontally while the technician remains in a standing position, rather than against gravity.

The damaged area is prepared by attaching sandpaper or another abrasive material to a boom extender and roughening the defect area. A cleaning cloth may then be attached to the extender and used to clean the prepared area.

To prepare the laminate delivery assembly, peel ply may be applied to the arm extender base. In one example, the peel ply extends at least about 50 mm longer and is folded on the back side of the arm extender. One or more repair laminate plies are then placed and rolled over the arm extender base. For example, the repair may restore affected biaxial laminate layers, such as two biaxial repair plies.

The boom extender is then inserted into an extender pipe or other extension housing to achieve additional reach. The arm extender is advanced toward the desired repair location, for example in a spanwise direction inside the blade cavity. After the arm extender reaches the target location, the technician manipulates the arm extender to apply the laminate layers to the required location. In one example, the arm extender is flipped so that the repair layers are transferred from the base to the internal blade surface.

If the repair layers do not release fully from the arm extender base, the boom extender may be used to assist release. After transfer of the laminate plies, the arm extender is retracted. A roller may then be connected to the boom extender and used to smooth the applied repair layers. If unintentional creases or folds are observed, additional smoothing may be performed.

The method may be used under assumptions such as: the technician follows applicable confined-space EHS guidelines throughout the procedure; no core damage is present; only inner biaxial layers are affected; the damage is on shell regions rather than leading-edge or trailing-edge unidirectional layers; and the damaged areas have already been identified during internal inspection.

The disclosure also contemplates refinements to the arm extender, including improved handling features, improved base plate design, detachable clips for layer release, improved shaping to avoid sharp corners, and use of composite materials for reduced weight and improved performance. In some examples, repair capability may be extended up to about 1.5 meters beyond confined-space limits.

11. Advantages

The disclosed technique provides several advantages over conventional external window repair procedures, including:

- Avoidance of grinding through outer skin, core, and inner skin from outside the blade;
- Elimination or reduction of the need to create and subsequently repair an external shell window;
- Shorter repair duration, with example comparisons indicating about 0.5 to 1 day versus about 4 to 5 days for a conventional process;
- Significantly reduced repair cost, with example comparisons indicating approximately \$500 per repair versus approximately \$2,500 with rope access or approximately \$5,000 with a platform for conventional approaches;
- A simpler manual process that does not require robot-assisted repair; and
- The ability to repair internal damage at least about 1 meter beyond the approved confined-space limit.

12. Example Embodiments

In a first example embodiment, a manually operated arm extender is used to carry abrasive material, a cleaning cloth, and repair laminate plies to an internal blade defect beyond a confined-space limit, allowing internal laminate restoration without creating an external repair window.

In a second example embodiment, a peel-ply-backed laminate stack is placed on an arm extender base and transferred to an internal shell defect by extending the tool to the damage location and flipping the base to deposit the repair layers.

In a third example embodiment, the repair is applied to an internal shell crack affecting only biaxial layers and not core material, with a roller subsequently used to consolidate the repair laminate after transfer.

In a fourth example embodiment, the arm extender includes a lightweight structure, such as a composite-based tool body, and attachment features that improve laminate handling and release at the repair location.

13. Industrial Applicability

The disclosure is applicable to repair and maintenance of composite wind turbine blades in manufacturing, service, refurbishment, and field repair operations. The technique is particularly useful where an internal defect is located beyond a technician's approved confined-space access limit and where minimizing downtime, repair complexity, and field equipment requirements is desirable. The disclosure is relevant to onshore wind blades and may also be adapted for other large composite hollow structures requiring remote internal laminate placement.

14. Variations and Alternatives

Various modifications may be implemented without departing from the scope of the disclosure. For example, the arm extender may use different lengths, shapes, joints, or locking mechanisms. The base may be configured to carry different ply stacks, adhesives, films, peel plies, or release features. The transfer motion may involve flipping, rotating, pivoting, sliding, or other deposition actions.

Different accessories may be attached for surface preparation, cleaning, laminate placement, compaction, or inspection. In some alternatives, the system may be enhanced with robotic or semi-robotic control for some operations. In other alternatives, clips, detachable carriers, or drop-off mechanisms may be used so that rolling on the arm extender is reduced or unnecessary. The method may also be adapted for different blade geometries, laminate schedules, damage types, and reach distances.

15. Conclusion

This disclosure describes a practical and concise internal repair solution for wind blade laminate defects located beyond confined-space access limits. By using a manually operated arm extender to prepare the surface and place repair laminates internally, the disclosed method avoids the complexity of external window repair while reducing time and cost. The disclosure provides a useful technical publication for establishing public knowledge of a manual arm-extender-based blade repair technique and its variations.

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