

Technical Disclosure¹

1. Title

Life Extension for Wind Turbine Blade Bolts

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Technical Disclosure

5. Abstract

A life-extension approach is disclosed for blade bolts or studs used to connect a wind turbine blade root to a pitch bearing. Such fasteners are susceptible to accelerated fatigue failure, particularly at the first engaged thread, due to joint flexibility and bending stresses. The disclosed approach uses a stud having an extended threaded region and a spacer positioned during an initial operating period. After an estimated fatigue interval, the spacer is removed, the stud is rotated to shift the load-bearing engagement to a different thread region, and a washer is installed in place of the spacer before re-preloading the joint. By relocating the first engaged thread, fatigue damage accumulation is redistributed, and the service life of the stud is extended without full stud replacement.

6. Technical field

The present disclosure relates to wind turbine rotor assemblies and, more particularly, to blade-to-pitch-bearing fastening systems. More specifically, the disclosure relates to methods and hardware arrangements for extending the fatigue life of blade bolts or studs used in blade root joints.

7. Background

Wind turbine blades are commonly attached to a pitch bearing through a bolted or studded joint at the blade root. In service, these fasteners can experience complex loading, including preload, cyclic bending, and fluctuating operational loads. In several turbine platforms, failures have been observed at the first engaged thread on either the hub side or the blade side before the intended design life is reached.

Such failures can be costly and difficult to address. A broken stud may leave a liberated metal part within the hub, where it can strike internal components and create secondary damage. Detection may be delayed until a technician enters the hub, or physical damage becomes externally noticeable. Removal of failed or stuck components from the blade root can be labor-intensive and expensive, and proactive replacement of an entire fastener set may be difficult, especially in misaligned joints. Accordingly, there is a need for a practical solution that extends stud life without requiring wholesale stud replacement or major redesign of the blade root and pitch bearing interface.

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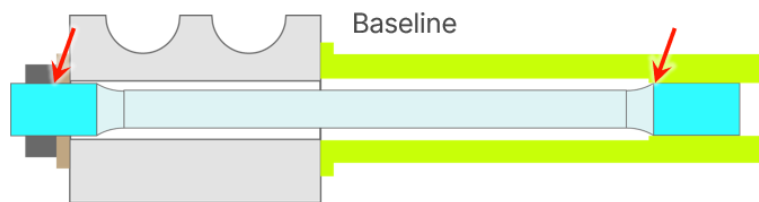
8. Summary of the disclosure

A disclosed solution extends the service life of blade studs by intentionally providing additional usable thread length and by changing the location of the first engaged thread after an initial service period. In one implementation, the stud includes an extended threaded portion on one or both ends beyond the thread length required for a conventional installation. During initial assembly, a spacer having a selected axial thickness is installed on one side of the joint, for example on the hub side.

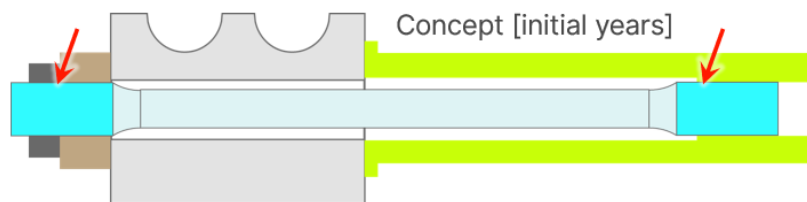
After the stud has accumulated fatigue damage over a defined operating period, the joint is serviced. The nut and spacer are removed, and the stud is advanced by an additional threaded distance so that a previously unloaded or less-loaded thread segment becomes the new first engaged thread. The spacer is then replaced with a washer or other lower-thickness component, and the joint is re-preloaded. In this manner, fatigue damage that would otherwise remain concentrated at the original first engaged thread is redistributed to a different thread location, thereby extending useful stud life.

9. Brief description of drawings

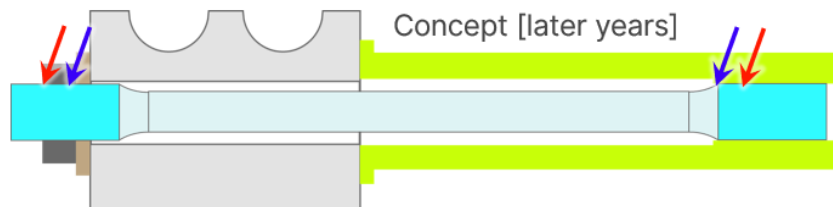
[FIG. 1] may illustrate a conventional blade stud arrangement showing the original first engaged thread location in a blade-to-pitch-bearing joint.



[FIG. 2] may illustrate an example stud having an extended threaded region and an initial installation with a spacer.



[FIG. 3] may illustrate a post-service configuration in which a washer replaces the spacer and a different thread segment becomes the first engaged thread.



10. Detail description

In bolts or studs used in heavily loaded joints, the first engaged thread typically carries the highest share of the load and therefore has the lowest fatigue life relative to other engaged threads. In blade

root joints for wind turbines, this effect can be aggravated by joint flexibility, bending stresses, and installation constraints. The present disclosure addresses this issue by enabling the first engaged thread location to be changed after an initial service interval, thereby resetting or redistributing fatigue accumulation.

In one example, a stud is designed with an extended threaded region relative to a baseline stud. The additional thread length may be provided at one end, or both ends of the stud. For instance, a stud may include approximately 0.5 times the nominal diameter of additional thread length on either end. By way of non-limiting example, an M36 stud may include about 18 mm of additional thread length on each end.

A spacer may be used during the initial installation. In one embodiment, the spacer is positioned on the hub side and has an axial thickness approximately equal to the nominal stud diameter. For example, for an M36 stud, the spacer may have a thickness of about 36 mm. The spacer may function as a thick washer or equivalent stand-off component that establishes an initial axial position of the stud and nut relative to the joint.

For a fresh installation, the stud is installed with the spacer in place, optionally with or without an additional washer, and the joint is preloaded according to the applicable installation procedure. During turbine operation over a first service interval, fatigue damage accumulates primarily at the first engaged thread on one or both ends of the stud.

At or near the estimated fatigue life for the initially loaded thread position, the joint may be serviced during a planned maintenance window. The nut and spacer are removed. The stud is then rotated or advanced further into the blade root by an amount corresponding to the additional threaded length, such as approximately 18 mm in the M36 example. This repositioning places the thread segment that previously acted as the first engaged thread deeper into the joint, while a different thread segment becomes the new first engaged thread.

After the stud has been repositioned, the spacer is removed from the stack-up and replaced with a thinner component such as a washer. A corresponding change may also be made on the opposite side, depending on joint configuration. The nut is then reinstalled and the stud is re-preloaded. Because the new first engaged thread has experienced less prior fatigue loading, the joint can continue operation with extended service life without replacing the stud itself.

This approach may be implemented for studs joining the blade root to the pitch bearing inner ring and may be applied across multiple wind turbine platforms where early thread-root fatigue failures have been observed. The disclosed concept can reduce the need to extract long studs from difficult-to-access locations and can reduce secondary damage associated with liberated broken parts inside the hub.

11. Advantages

- Extends the service life of blade studs without requiring replacement of the full stud.
- Reduces turbine downtime associated with broken stud extraction and major repair activities.
- Lowers the risk of secondary hub damage caused by liberated failed parts.
- Enables implementation during a planned maintenance window.
- Avoids or reduces the need for major redesign of the blade root and pitch bearing interface.

- Improves maintainability and availability of the wind turbine.

12. Example Embodiments

In one embodiment, a wind turbine blade joint includes a stud connecting a blade root to a pitch bearing inner ring, the stud having an extended threaded region beyond that used in a conventional design. A spacer is installed on a hub-side portion of the joint during an initial service period. After a defined operating interval, the spacer is removed, the stud is advanced further into the blade root, and a washer is installed in place of the spacer before the stud is re-preloaded.

In another embodiment, the additional thread length is provided on both ends of the stud so that the first engaged thread location may be shifted on either side of the joint.

In a further embodiment, the spacer thickness is selected to substantially correspond to the nominal stud diameter, although other thicknesses may be used depending on joint geometry, preload requirements, and the desired degree of thread relocation.

In yet another embodiment, the life-extension process is scheduled based on estimated fatigue usage, elapsed operating time, inspection data, load history, or a combination thereof.

13. Industrial Applicability

The disclosed subject matter is applicable to utility-scale wind turbines and other rotating machinery that employ highly loaded threaded joints subject to cyclic fatigue. The disclosure is particularly applicable to blade-to-pitch-bearing joints in installed wind turbine fleets where premature stud failures may otherwise require costly replacement campaigns, difficult extraction procedures, or extensive component repair.

14. Variations and Alternatives

Various modifications may be used while maintaining the underlying concept of changing the first engaged thread location after an initial operating period. For example, instead of using a spacer in an initial configuration and a washer in a later configuration, a tall nut may be used initially and replaced with a regular nut during reset. In another variation, a partially tapped nut may be used, and the nut orientation may be reversed instead of using a spacer. In another alternative, different thread profiles or different thread span configurations may be used to provide a first operating position and a second operating position. The amount of additional thread length, spacer thickness, service interval, preload procedure, and side of repositioning may all vary according to the turbine platform and joint design.

15. Conclusion

The present disclosure describes a practical life-extension technique for wind turbine blade bolts or studs by using an extended threaded region and a staged joint stack-up that permits later repositioning of the stud. By shifting the first engaged thread after an initial fatigue interval, the method redistributes fatigue damage and enables continued use of the stud without full replacement. This approach can reduce repair complexity, downtime, and cost while improving reliability of blade root fastening systems.

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