

Referee comment for wes-2025-94

Title: Hollow Forged AHD Steel Rotor Shafts for Wind Turbines – A Case Study on Power Density, Costs and GWP

Author(s): Christian Hollas et al.

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Objective and Strengths

Objective

The study investigates the feasibility and performance of using hollow forged rotor shafts made from **Air Hardening Ductile (AHD) steel** in wind turbine **main bearing units (MBUs)**, comparing them to **conventional cast iron shafts**. The focus is on:

1. Power density
2. Manufacturing costs
3. Global Warming Potential (GWP)

Strengths

1. Relevant Topic

The paper addresses a critical challenge in wind turbine drivetrain design: increasing power density while reducing environmental impact—aligned with industry trends and world climate goals.

2. Comprehensive Methodology

The integration of structural analysis, cost modeling, and life cycle GWP assessment provides a holistic view, enhances by the use of real turbine data (*maxcap141*).

3. Clear Engineering Insight

The explanation of how hollow forging improves section modulus and material utilization is technically sound and well-illustrated.

4. Transparency and Reproducibility

The authors provide detailed assumptions, equations, and even offer to share the predesign tool, which supports reproducibility.

Clarifications needed

(1) Line 53: **DrivetrainSE** does not consider hollow forged rotor shafts

The Claim in Question

In the paper, the authors state:

“Open source WT predesign tools like NREL’s DrivetrainSE (implemented into WISDEM) cannot consider hollow forged rotor shafts.”

This suggests that DrivetrainSE lacks the capability to model hollow forged shafts — but this is **misleading** or at least **oversimplified**.

What DrivetrainSE Can Actually Do

DrivetrainSE, as part of NREL’s **WISDEM** framework, **does support modeling hollow shafts**. Specifically:

- **Hollow Shaft Geometry:** DrivetrainSE allows users to define **outer and inner diameters** of the main shaft, enabling the modeling of **hollow geometries**.
- **Mass and Inertia Calculations:** It computes mass properties, stiffness and modulus based on these geometric inputs.

- **Material Properties:** Users can specify different materials, including high-strength steels, though not necessarily AHD steel by default.

Evidence from cited 'Hollas et al. (2024)'

In same authors' earlier 2024 paper, they used DrivetrainSE to benchmark their custom MBU predesign tool. They acknowledged that DrivetrainSE could model **hollow shafts**, but not the **specific manufacturing constraints of hollow forging** — such as:

- Maximum diameter jumps between shaft segments
- Forging surcharges and material flow constraints
- Air-hardening behavior of AHD steel

Clarifying the Distinction

So, the **correct interpretation** is:

- **DrivetrainSE can model hollow shafts geometrically and structurally.**
- **It cannot model the manufacturing constraints and process-specific limitations of hollow forging**, such as those relevant to AHD steel.

This nuance is important. The present paper could have been clearer, avoiding confusion and improving technical accuracy and transparency, by stating:

"DrivetrainSE does not natively support the manufacturing constraints and material behavior specific to hollow forged AHD steel shafts."

(2) Sec.3.2: Bearing usage inconsistency: CRB-TRB or SRBs?

There seems to be a **terminological inconsistency** in the paper that could be considered an error or at least a point needing clarification.

Comparison of the 2 Statements about Bearing usage

Section 3.2, First Sentence:

“The original MBU comprises a cast rotor shaft with a mass of 16.2 t, a non-locating 2.1 t cylindrical roller bearing on the rotor side (upwind) and locating 0.9 t double-rowed tapered roller bearing on the gearbox side (downwind).

This clearly specifies:

- **CRB** (non-locating, upwind)
- **TRB** (locating, downwind)

Line 155:

“Both variants have similar bearing configurations, sharing the downwind spherical roller bearing and using a comparable spherical roller bearing upwind with a 60 mm inner diameter difference”

This contradicts the earlier statement by referring to **SRBs** on both sides.

Technical Implication

- **CRBs and TRBs** are fundamentally different from **SRBs** in geometry, load capacity, and misalignment tolerance — and the authors do have knowledge of this.
- The choice of bearing type affects:
 - Load distribution
 - Shaft deflection
 - Fatigue life
 - Assembly and alignment strategies

If the design truly uses CRB and TRB, then referring to SRBs later is incorrect — unless the predesigned variants differ from the original configuration and this change was not clearly stated.

Suggested Clarification

It is recommended for the authors clarify:

- Whether the **bearing types were changed** in the predesign variants.

- If so, why SRBs were selected instead of CRB/TRB — especially given their different stiffness and misalignment behavior.
 - If not, then line 155 should be corrected to match the original bearing specification.
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Improvement Suggestions

1. Material Property Uncertainty

The fatigue behavior of AHD steel is extrapolated using FKM **guidelines, which are not validated for this alloy** (line 105). The paper acknowledges this but does **not quantify the impact on reliability or safety margins**.

2. Lack of Reliability Analysis

The paper addresses structural integrity well, however there is **no formal reliability-based design or probabilistic treatment of uncertainties** (uncertainty quantification; e.g., in loads, material properties, forging tolerances). This limits confidence in the robustness of the design.

3. Economic Viability Discussion

The cost model is insightful but heavily reliant on assumed surcharges and outdated references (eg. Knight, 1992). A sensitivity analysis on cost drivers (e.g., alloy price, forging complexity) would strengthen the conclusions.

4. Digital Twin or Monitoring Integration

Given the trend toward condition-based maintenance, the study could benefit from discussing how hollow forged shafts might affect monitoring strategies or digital twin integration.
