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TORQUE TRACEABILITY FOR NACELLE'S TEST BENCHES: A DESIGN PROPOSAL

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Abstract: This paper describes CEM's design proposal for a new torque transfer standard. This research arises from the new EMPIR project (*14IND14: Torque measurement in the MN·m range"*) [1], which aims to provide traceability in the MN·m range for nacelle test benches. Improving the quality of these measurements will lead to a more accurate diagnosis of wind turbines' performance and a better efficiency in wind power generation.

Keywords: wind turbine, torque, standard, nacelle test bench.

1. INTRODUCTION

Nacelle test benches (NTB) are employed to assess the performance of wind turbines. Current methods for torque measurement are not traceable to torque standards machines, as they are based in electric measurements instead of direct torque measurements. Moreover, there aren't traceable torque measuring systems for the operating range of nacelle test benches (5 MN·m and higher).

CEM, in collaboration with other NMI's, is working in the development of a transfer standard to ensure traceability in the MN·m range. CEM's design proposal is based on the force-lever system's working principle that is the one to be presented here.

Torque measurements are obtained through the measurement of the tangential forces generated during nacelle test benches operation and the distance to their application point.

As these forces are measured in several points along the system's perimeter, the maximum force values at each transducer are much lower than if measured at a single point like torque standard machines usually do. In this way, those force values (operating range will be between 2 MN and 3 MN) are traceable to force standards; therefore, this system ensures torque measurements traceability through traceable measurement of force and arm distance.

This kind of system is used in other force and torque standard machines for different applications: torque measurement, measuring range increase, multi-component load evaluation, etc. [2], [3].

2. NACELLE TEST BENCHES CHARACTERISTICS AND OPERATION

Nacelle tests are performed simulating field conditions. An engine, named main drive, is placed at the beginning of the driving chain, and a brake at the end. The nacelle under test (or DUT, device under test) is place in between this two endpoints.

Between the main drive and the DUT there is the Load Application System (LAS) which generates radial forces and bending moments, to emulate lateral forces during wind turbine operation in field conditions (values of force loads and bending moment loads will be in the 100 kN and 100 kN·m ranges).

An example of the drive chain of a nacelle test bench can be seen under these lines. It belongs to *Rheinisch-Westfälische Technische Hochschule Aachen*, one of the external funded partners of the project (Fig. 1)

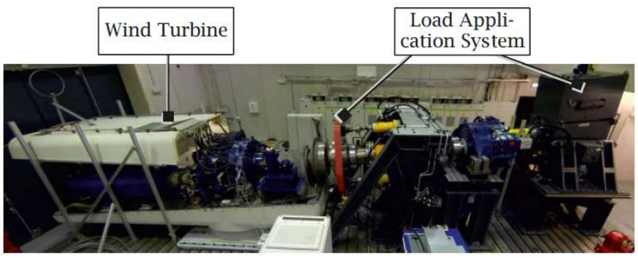

Fig. 1 RWTH's nacelle test bench [4]

Following the instructions of NTB owners who are participating in the project, the force-lever system to be designed should withstand the torque load as well as the additional and parasitic loads generated within the drive chain. Load values are estimated based on nacelle test benches owner know-how and their particular experience on benches performance. The lateral force loads values shall not exceed 100 kN, meanwhile, the limit is 100 kN·m for the bending loads. Nacelle test bench design features and mechanical properties are shared as well.

There are several approaches for torque measurement in the range above 1 MN•m. All of them determine torque based on the input data obtained from different types of measurements along the drive chain: strain measurements (using strain gauges), low torque measurements on the high speed shaft in transmission test benches, electrical power measurements, etc.

All of the available options have drawbacks: the use of strain gauges lacks accurate knowledge of material properties and dimensions; electric or high speed shaft measurements on different parts of the transmission line requires estimations of friction loses or efficiencies in different components, such as gears or engines. And the main drawback for all these options is that they do not ensure traceability to torque standards.

With the new developments in the EMPIR project, traceability will be ensured through direct torque or force measurements, as the SI states.

3. CEM DESIGN PROPOSAL FOR THE FORCE-LEVER SYSTEM TRANSFER STANDARD

CEM design is based on force-lever system working principle. A force lever system includes a lever arm with known length and a force transducer. One lever arm's side is connected to a torque generator device and the other side to a force transducer. When the torque is generated, the lever arm will transmit the torque load and the tangential forces generated will be measured by means of the force transducers.

The knowledge of the lever arm length and the load value measured by the transducer it will make possible to achieve a traceable measurement of the generated torque.

CEM's force-lever system for nacelle test benches is based on the same working principle, where the main drive is in charge of generating the torque to be measured (Fig.2).

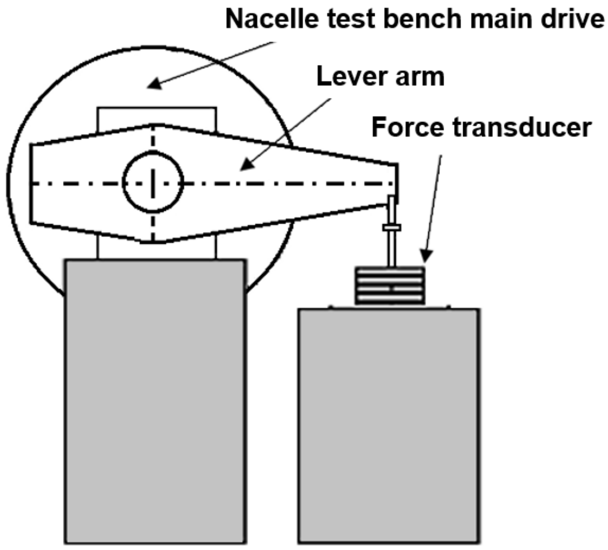

Fig. 2 Force-lever system working principle applied to torque measuring in nacelle test benches

Traditional force-lever systems are used in non-rotating torque measurement applications, while nacelle tests are dynamic; consequently, it is needed to implement some variations on the original design. During its operation, the whole force-lever system will be rotating together with the DUT and the rest of the drive chain.

Therefore, the designed force-lever system should be fixed to the other components of the drive chain. Our design will include two flanged ends in order to build-up the force-lever system and to ensure load transmission at the same time (Fig.3). It will be placed between the load generation systems (main drive and LAS) and the DUT.

The in-flange, which is assembled to the main drive and the LAS system, includes several housings for the force transducers that will obtain the tangential force measurements.

The out-flange, which is downstream the drive chain and is connected to the DUT, includes built-in lever arms, which are engaged with the force transducers placed in the in-flange. The proposed connection between both parts of the system is similar to the one used in couples of gears. This kind of connection will ensure direct pure torque transmission from the main drive to the nacelle under test.

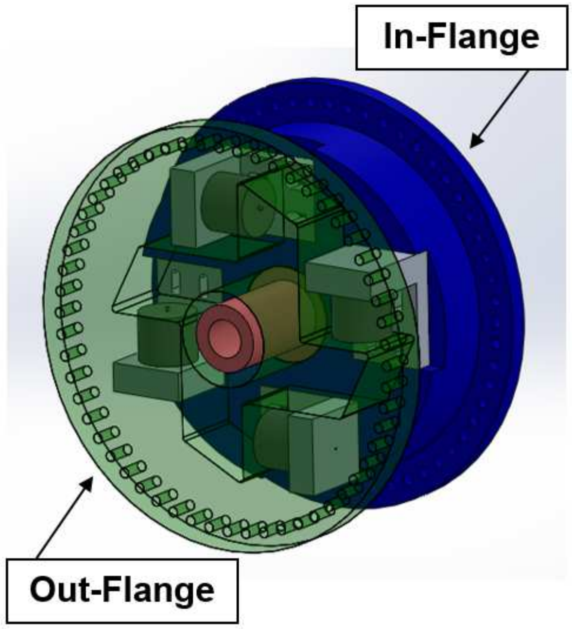

Fig. 3 CEM's design proposal for a force-lever system transfer standard

The additional loads generated by the LAS system should be transmitted throughout the whole test bench, so that the nacelle under test will support theses load as well as direct torque loads, emulating field conditions. Therefore, additional loads from LAS system are included during the FEM analysis of the system, as well as the torque load, in order to evaluate its effects on the final performance of the system, even if the force-lever system is only supposed to measure direct torque load.

Consequently, the whole system will include an inner support not only for supporting and lining up both parts of the system, but also for ensuring any additional load transmission (from LAS system to the rest of the drive chain) but avoiding its effects on the torque measurement.

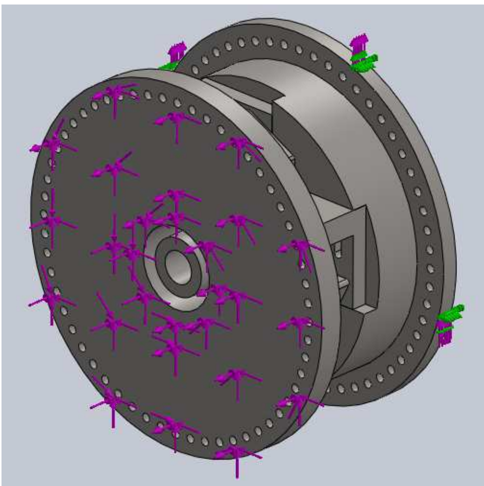

Fig. 4 Loads applied to the force-lever system.

Two different materials were considered for the force-lever systems. Both of them have high stress resistance, although material B is more suitable for parts with smaller sections. Different FEM analyses were carried for each material selection, considering safety coefficients and several loads distribution.

Both materials did successfully withstand normal operation values of the previously described loads. However, material A was finally selected, as it also withstands loads for a stress safety factor of 30%, while material B did not (Fig.5, Fig.6).

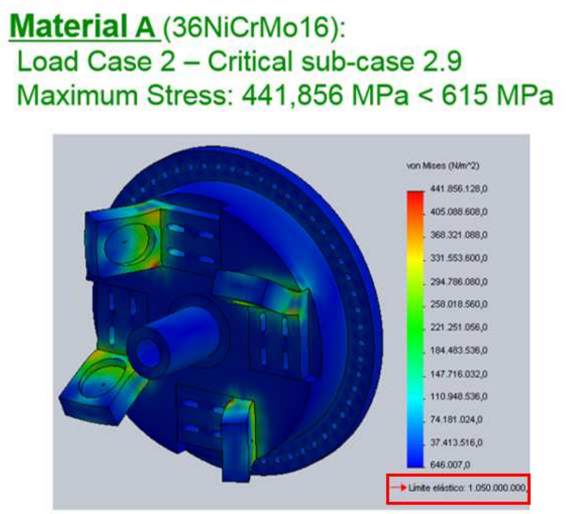

Fig. 5 Material A performance – Von Misses test results

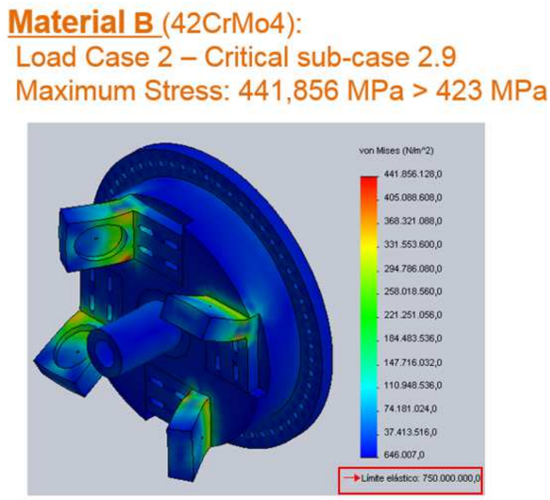

Fig. 6 Material B performance – Von Misses test results

4. CONCLUSIONS

CEM design proposal fulfills the mechanical and constructive requirements for nacelle test bench operation (secured assembly, dynamic operation, load transmission, etc.). At this moment, an improvement of the design and further analysis of the system are under development.

Force-lever system is an innovative solution to ensure torque measurement traceability. With this new design, it will be possible to manufacture a new transfer standard for measurements of high torque values.

CEM applies its knowledge about torque measurement to the development of this new transfer standard. Several researches has been carried out in the Force and Torque unit at CEM [5].

The quality improvement of torque measurements in nacelle tests, as well as other industrial applications, will lead to an improvement of the efficiency of wind power energy generation.

Acknowledgments

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