TORQUE CALIBRATION OF A NACELLE TEST BENCH

NEWSLETTER NO. 4 – JANUARY 2018

Welcome to the fourth edition of the newsletter for the EMPIR MN·m Torque project. After the detailed preparation of a torque calibration procedure under rotation in the beginning of the project's second half, the measurement campaign was successfully carried out. The present newsletter gives a short summary of the executed measurements and an update on the development of force lever systems.

INTRODUCTION

It is very important to have knowledge on the precise efficiency of nacelles to be able to continue improving the power output. This requires a very accurate torque measurement. In multi-megawatt test benches with torque loads up to several MN·m, the current measurement methods are not fulfilling the demands of nacelle and component producers. Therefore, a calibration procedure for torque under rotation was developed using a torque transfer standard with a capacity of 5 MN·m. The feasibility of this procedure was investigated within a three-week measurement campaign at the Center for Wind Power Drives (CWD) of the RWTH Aachen in September 2017. The performed measurements are part of the calibration procedure and first investigations are introduced in the following.

EXPERIMENTAL SETUP

Within a research measurement campaign, the torque calibration procedure under rotation was tested on the 4 MW nacelle test bench at the CWD Aachen. The applied torque was limited by the installed research nacelle to 1.5 MN·m with a rotational speed between 6.5 rpm and 17.5 rpm.

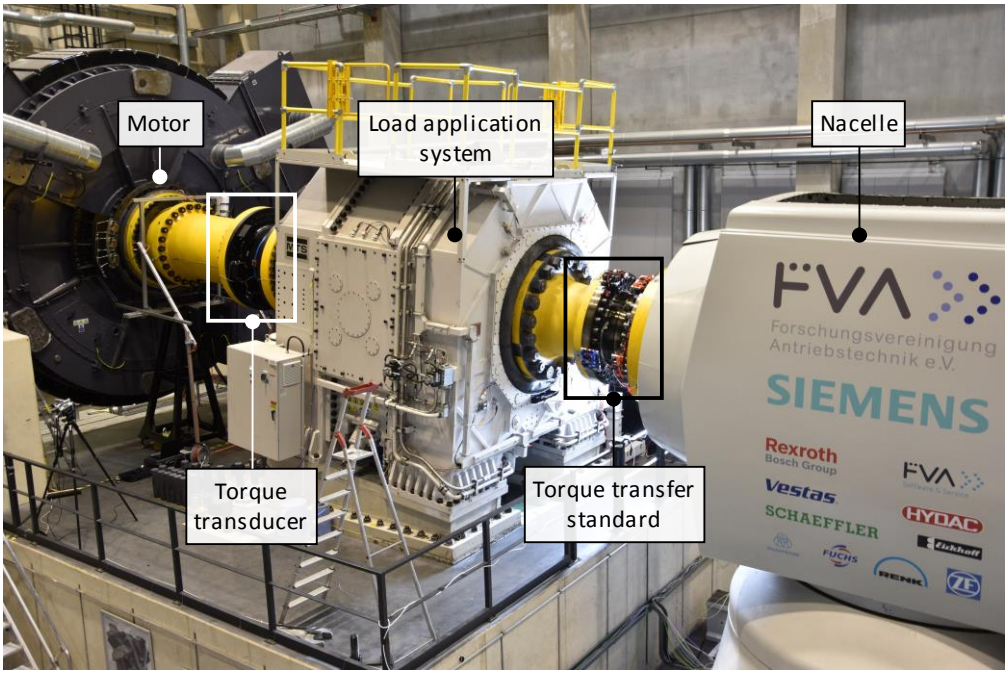

FIGURE 1 THE 5 MN·M TORQUE TRANSFER STANDARD IN THE NACELLE TEST BENCH OF THE CENTER FOR WIND POWER DRIVES AT THE RWTH AACHEN.

With the help of specially designed adapters, the torque transfer standard was mounted directly at the nacelle's rotor hub, where the torque input is intended to be measured. In this nacelle test bench, the torque transducer to be calibrated is located between the motor and the load application system as shown in Figure 1. The rotational speed was recorded by an incremental encoder, which is measured in every nacelle test bench.

5 MN·M TORQUE TRANSFER STANDARD

To realise rotational torque measurements, the 5 MN·m torque transfer standard (Figure 2) was equipped with an autarkic data acquisition system including the signal amplifiers. In order to transmit data within a decent time during the measurement, two access points connected via a wireless local area network were used. The energy supply is guaranteed by battery packs. Detailed pictures have already been presented in the last issue of our newsletter.

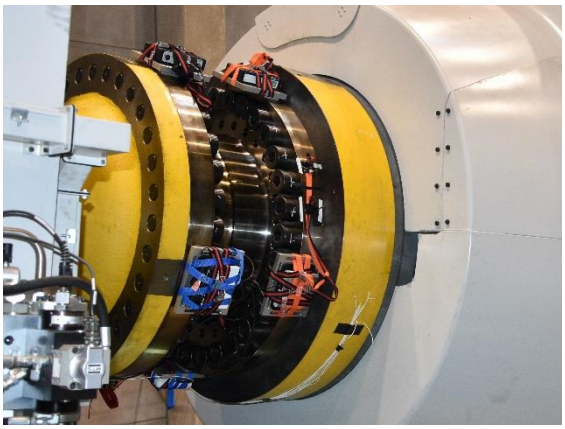

FIGURE 2 TORQUE TRANSFER STANDARD EQUIPPED WITH AN AUTARKIC DATA ACQUSITION.

TIME SYNCHRONISATION

The signals of the two torque transducers, transfer and test bench, were gathered separately by two different data acquisition systems. One square wave signal was recorded by both systems to ensure a time synchronisation. In the post processing, this signal was used to shift the data and minimise the time offset.

TEST OF CALIBRATION PROCEDURE

Before the planned calibration measurements were performed on the test bench, several pre-investigations were executed. Thus, the effects of influences, such as variation in temperature and humidity, temperature gradients due to warming up of mechanical components, brake modes and rotational speed on the torque measurement were analysed. Other than for static calibrations, the data was recorded continuously to enable an investigation of the angular acceleration and its impact on the torque measurement.

ZERO-POINT DETERMINATION

As for any calibration, the zero-point determination is of great importance. Thus, the offset caused by tension due to the assembly has to be considered. Two approaches were tested: a static and a rotational zero-point determination. In order to determine the static zero-point, the drive train including the torque transducers was rotated in defined steps around the main axis and the torque signal was averaged over one full rotation. Since this method is very time-consuming, an alternative zero-point determination under rotation was tested. Here, the nacelle test bench was operated with minimum rotational speed and the signal was averaged over an integer number of revolutions.

TORQUE CALIBRATION UNDER CONSTANT ROTATIONAL SPEED

With the aim to obtain a qualitative comparison between the measurements under rotation on the nacelle test bench and the

static measurements at the PTB, torque measurements under constant, low rotational speed were executed. The same load steps were applied as those used for the calibration of the torque transfer standard at the PTB.

CHARACTERISTIC MAPS

To cover the entire operating range of the nacelle test bench and the possible devices under test, so-called characteristic maps (Figure 3) were developed. Within these maps several possible combinations of torque load and rotational speed were applied. Depending on the control mode of the nacelle test bench, either the applied torque is hold periodically constant while the rotational speed is increased stepwise or vice versa.

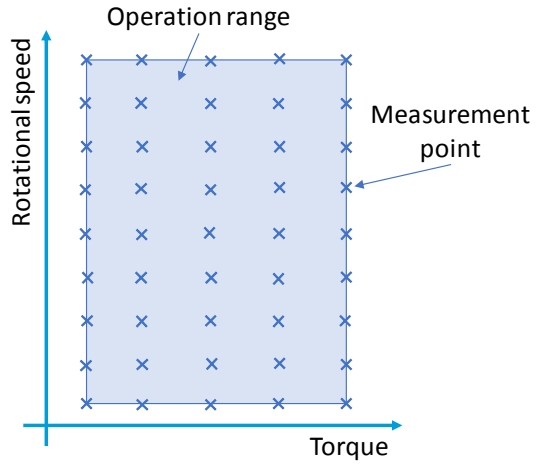

FIGURE 3 CHARACTERISTIC MAP TO COVER THE OPERATING RANGE IN A CALIBRATION.

CROSS-TALK EFFECTS

The analysis of cross-talk effects of additional mechanical loads on the torque measurement requires the application of different combinations of longitudinal and lateral forces and bending moments. These mechanical loads were generated by the special load application which simulates wind loads in the test bench (Figure 1). Due to the fact, that the 5 MN·m torque transfer standard is not only made for measuring torque, but all components within six degrees of freedom, these loads could also be recorded during the measurement at the CWD.

FORCE LEVER SYSTEMS

Force lever systems are torque sensors consisting of several force transducers which are connected to the drive train of a nacelle test bench and to each other by means of a lever arm. In the course of the last months, the four different design proposals for these systems have been fully developed. They are depicted in Figure 4. Some of the main components, such as the lever arm and the force transducers, which have a relevant impact in the final torque measurement, have been studied and improved separately.

FIGURE 4 CURRENT DEVELOPMENT OF FORCE LEVER SYSTEM

At the moment, several analyses and influence studies are being carried out for each design in order to develop an uncertainty budget. Additionally, the designs are being modified in order to upscale their layout to an operating range of 20 MN·m.

PUBLICATIONS

G. Foyer, P. Weidinger and S. Kock, "Drehmomente unter Rotations- und Mehrkomponentenbelastung", in Werkstofftechnisches Kolloquium "Mess- und Kalibriertechnik"

S. Kock, G. Jacobs, D. Bosse and G. Foyer, "Influences on MN m torque measurement in multi-MW nacelle test benches", in DEWEK 2017

PTB press release on the measurement campaign (in German, press release from 24 November on PTB website)

Several publications are planned for 2018 including presentations at the Torque 2018, IMEKO World Congress 2018 and Sensoren & Messsysteme 2018.

PROJECT MEETINGS

PAST MEETINGS

A project meeting was held on 19 October 2017 in Aachen. The entire consortium discussed the status of the project. Stakeholders will be informed via the newsletter and a planned web meeting.

FUTURE MEETINGS

A web conference will be held on 25 April 2018 to inform interested stakeholders about the results of the calibration test at RWTH Aachen.

The **final stakeholder workshop** of the project *Torque measurement in the MN·m range* will take place on 30 August 2018 at the Physikalisch-Technische Bundesanstalt in Braunschweig, Germany.

Please contact us if you are interested in attending any of our meetings.

INVOLVEMENT IN THE PROJECT

We are always looking for further input to our project. If you are interested in working with us, please contact us via email or use the short questionnaire on our website to give us an idea of your capabilities in the field of torque measurement.

HOW TO CONTACT US

Project coordination:
Dr. Rolf Kumme (rolf.kumme@ptb.de)
Physikalisch-Technische Bundesanstalt

Project web page:
www.ptb.de/empir/torquemetrology.html

THE CONSORTIUM

PTB Physikalisch-Technische Bundesanstalt Braunschweig und Berlin

CENER NATIONAL RENEWABLE ENERGY CENTRE ADItech

CEM CENTRO ESPAÑOL DE METROLOGÍA

CMI CZECH METROLOGY INSTITUTE

CWD Chair for Wind Power Drives | RWTH AACHEN UNIVERSITY

Fraunhofer IWES

VTT MIKES METROLOGY

ACKNOWLEDGEMENTS

EMPIR EURAMET

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Editor: Paula Weidinger & Gisa Foyer