Final report of IEA Task 29, Mexnext (Phase 1):

Analysis of Mexico wind tunnel measurements

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Abstract

This report describes the work performed within the first phase of IEA Task 29 Mexnext.

In this IEA Task 29 a total of 20 organisations from 11 different countries collaborated in analysing the measurements which have been taken in the EU project 'Mexico'. Within this Mexico project 9 European institutes carried out a wind tunnel experiment in the Large Low Speed Facility (LLF) of the German Dutch Wind Facilities DNW on a rotor with a diameter of 4.5 m. Pressure distributions were measured at five location along the blade along with detailed flow field measurements around the rotor plane using stereo PIV.

The following organisations (and persons) cooperated in the projects:

- Canada: École de technologie supérieur, Montréal, ETS (C. Masson, S. Breton, C. Sibuet), and University of Victoria, UVIC (C. Crawford)
- Denmark: RISØ-DTU (H. Madsen, N. Sørensen, P. Rethouré) and the Technical University of Denmark DTU-MEK (W. Z. Shen)
- Germany: University of Stuttgart, Ustutt (T. Lutz, K. Meister), University of Applied Sciences at Kiel/CEWind EG (P. Schaffarczyk and A. Jeromin), ForWind (B. Stoevesandt and I. Hernandez)
- Israel: Technion, Israel Institute of Technology (A. Rosen, V. Ognev. R. Gordon)
- Japan: Mie University/National Institute of Advanced Industrial Science (T. Maeda, Y. Kamada, J. Murata)
- Korea: Korea Institute of Energy Research KIER, (H. Shin) and Korea Aerospace Research Institute, KARI (C. Kim, T. Cho)
- Netherlands: Energy Research Center of the Netherlands, ECN (G. Schepers, K. Boorsma, H. Snel), Delft University of Technology, TUDelft (G. van Bussel, N. Timmer, D. Micallef), Suzlon Blade Technology, SBT (A. Verhoeff), Technical University of Twente, TUTwente (E. van der Weide)
- Norway: Institute for Energy Technology/Norwegian University of Science and Technology, IFE (A. Knauer, J. van Rij)
- Spain: National Renewable Energy Center, CENER (X. Munduate, S. Gomez-Iradi, A. Gonzalez, A. Irisarri) and National Institute for Aerospace Technology, INTA (C. Redondo Calle)
- Sweden: Royal Institute of Technology/University of Gotland, KTH/HGO (S. Ivanell and K. Nilsson)
- USA: National Renewable Energy Laboratory, NREL (S. Schreck)

The Energy Research Center of the Netherlands, ECN acted as Operating Agent.

As a result of the international collaboration within this task a very thorough analysis of the data could be carried out and a large number of codes were validated not only in terms of loads but also in terms of underlying flow field.

The detailed pressure measurements along the blade in combination with the detailed flow field measurements gave a unique opportunity to better understand the response of a wind turbine to the incoming flow field. Deficiencies in modelling have been established and directions for model improvement could be given.

Contents

1 Introduction

This report summarizes the results from the first phase of IEA Task 29 Mexnext. Mexnext is a joint project in which 20 parties from 11 different countries cooperate:

- Canada: École de technologie supérieur, Montréal, ETS (C. Masson, S. Breton, C. Sibuet), and University of Victoria, Uvic (C. Crawford)
- Denmark: RISØ-DTU (H. Madsen, N. Sørensen and Pierre-Elouan Rethore) and the Technical University of Denmark DTU-MEK (W. Z. Shen)
- Germany: University of Stuttgart, Ustutt (T. Lutz, K. Meister), University of Applied Sciences at Kiel/CEWind EG (P. Schaffarczyk and A. Jeromin) and ForWind (B. Stoevesandt and I. Hernandez)
- Israel: Technion - Israel Institute of Technology (A. Rosen, V. Ognev. R. Gordon)
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- Spain: National Renewable Energy Center, CENER (X. Munduate, S. Gomez) and National Institite for Aerospace Technology, INTA (C. Redondo Calle)
- Sweden: Royal Institute of Technology/University of Gotland, KTH/HGO (S. Ivanell and K. Nilsson)
- USA: National Renewable Energy Laboratory, NREL (S. Schreck)

The focus of Mexnext lies on improving and understanding aerodynamic calculational models by means of dedicated wind tunnel measurements. These measurements have been performed within the EU project Mexico in the year 2006.

Aerodynamic calculational models are extremely important since they form the backbone of every computer program for the design of wind turbine. It is however known from several validation projects, see e.g. [1] and [2], that the uncertainties in the aerodynamic models are very large.

The availability of high quality measurements is considered to be the most important pre-requisite to gain insight into model uncertainties and to validate and improve aerodynamic wind turbine models. However, conventional experimental programs on wind turbines generally do not provide sufficient information for this purpose, since they only measure the integrated, total (blade or rotor) loads. These loads consist of an aerodynamic and a mass induced component and they are integrated over a certain spanwise length. In the late 80's and the 90's it was realized that more direct aerodynamic information was needed in order to improve the aerodynamic modelling. For this reason several institutes initiated experimental programs in which pressure distribution and the resulting normal and tangential forces at different radial positions were measured. Under the auspices of the IEA Wind, many of these measurements were stored into a database in Task 14 and Task 18, see [3]. The results of these measurements turned out to be very useful and important new insights on e.g. 3D stall effects, tip effects and yaw were formed. However, the measurements were taken on turbines in the free atmosphere, where the uncertainty due to the instationary, inhomogeneous and uncontrolled wind conditions formed an important problem (as it is in all field measurements). This problem was overcome in NREL's NASA-Ames wind tunnel experiment which was carried out in 2000 [4]. In this experiment a heavily instrumented rotor with a diameter of 10 meter was placed in the world's largest wind tunnel, i.e. the NASA-Ames (24.4×36.6 m^2) wind tunnel. As such, measurements were performed at stationary and homogeneous conditions. The huge size of the wind tunnel allowed a rotor diameter of 10 m, with little blockage effects. Obviously this rotor diameter is still (much) smaller than the diameter of the nowadays commercial wind turbines, but nevertheless the blade Reynolds number (in the order of 1 Million) is sufficiently high to make the aerodynamic phenomena at least to some extend representative for modern wind turbines. NREL made the measurements from this experiment available to other institutes and they were analysed within IEA Wind Task 20. This Task was finished in December 2007 see [5]. The Mexnext can be considered as the successor of IEA Task 20. It focussed on the wind tunnel measurements which became available in December 2006 within the EU project Mexico [6]. In this project detailed aerodynamic measurements were carried out on a wind turbine model with a diameter of 4.5 m, which was placed in the largest European wind tunnel, the German Dutch Wind Tunnel, DNW with a size of 9.5 x 9.5 m^2. A unique feature of the Mexico measurements lies in the fact that the flow field around the rotor plane was measured simultaneously with the blade properties. At the end of the Mexico project the database with measurements was still in a rather rudimentary form and only limited analysis were carried out.

For this reason the Mexnext project was initiated in which the measurements from the Mexico project are analysed. Thereto it should be realised that the amount of Mexico data is very vast by which the time needed to analyse all data is extremely long for a single country. As such it was considered very beneficial to organise the analysis of the Mexico data under IEA Wind, since this make it possible to share tasks. Added value also lied in the fact that the task served as a forum for discussion and interpretation of the results. It is then possible to generate more value from the data than the summed value from the individual projects.

The Mexnext project started on June 1, 2008. This report describes the first phase which ended on June 1, 2011.

The report is structured as follows: The goal of Mexnext is described in section 2. Since the subject of Mexnext is aerodynamics it is considered important that the reader understands the value of aerodynamic research. This is explained in section 3.

The Mexico experiment is described in section 4. The working procedure and the work plan of Mexnext is described in section 5. It is then explained that the project is carried out in different tasks, the results of these tasks are reported in the sections 6 to 16. Conclusions and recommendations are given in section 17.