Pressurised wind turbine design and analysis with Hexagon technologies

By Yijun Fan, Hexagon and Richard Carroll, DOCAN

Renewable energy is vital to reducing CO_2 emissions from fossil fuels and is a key step towards a sustainable energy society. As the most widely-used renewable energy source today, wind energy is not just clean and renewable, but it is also relatively cost-effective. In order to further increase its adoption worldwide, CAE technologies need to be applied to reduce its cost of energy production and to improve its reliability.

H_2O Turbines Ltd is a UK specialist in pressurised wind turbine technology. The company has built an innovative 3kW domestic turbine which converts wind into heat and power using patented technology (Figure 1). The turbine is small enough to be installed in a back garden without planning permission being required and converts rotary motion into stored heat energy. Expressed in the simplest terms, when the wind blows, the top of the turbine spins and a rotating shaft goes to the bottom of the turbine in order to operate it. It uses no electrical components and does not burn carbon or use precious metals during its operation and production of power. Plans are in place to up-scale this technology to provide large amounts of clean heat. DOCAN in the UK, an advanced engineering consultancy and CAE software distribution company, have been providing expert engineering support to H_2O Turbines to support initial development and FEED (Front End Engineering Design) activities. They have been employing tools and technology from Hexagon to support the development of this innovative new renewable energy system.

BRICSCAD, that was acquired by Hexagon in 2018 was utilised to incorporate 2D and 3D geometry generation and 3D visualisation for the novel turbine system.

MSC Apex was then applied to the geometry to allow for rapid structural investigation of different configurations of the blade structure. Natural Frequency Analysis via mid-surface extraction, meshing and running the analysis was completed in a matter of minutes (Figures 2 and 3). This part of the FEED study was important for the design to ensure that the potential for exciting natural frequencies under wind loading and operating can be avoided.

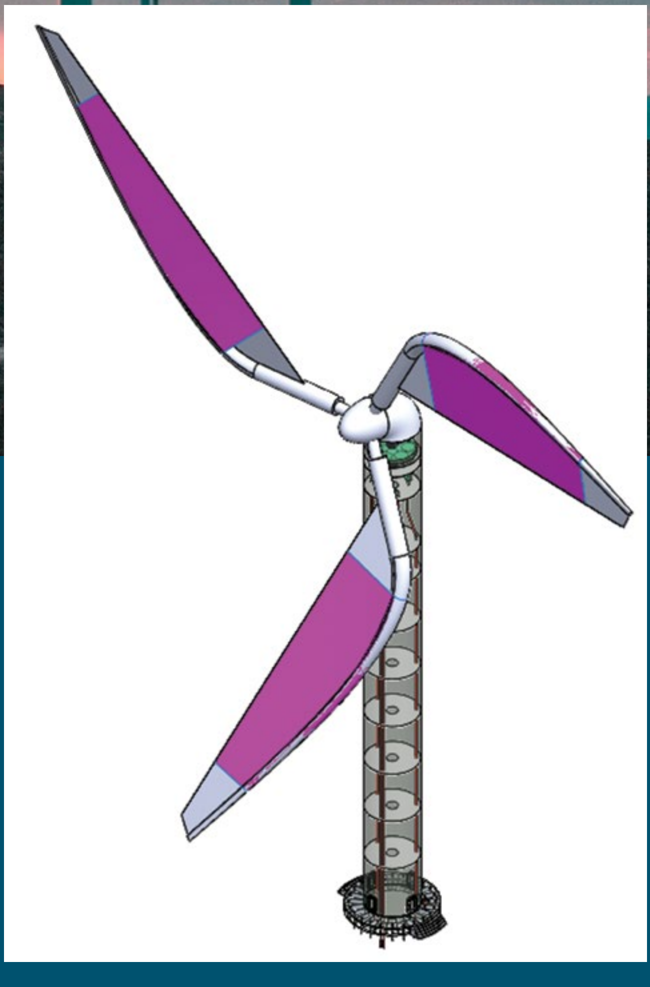

Figure 1: 3D CAD of the turbine system

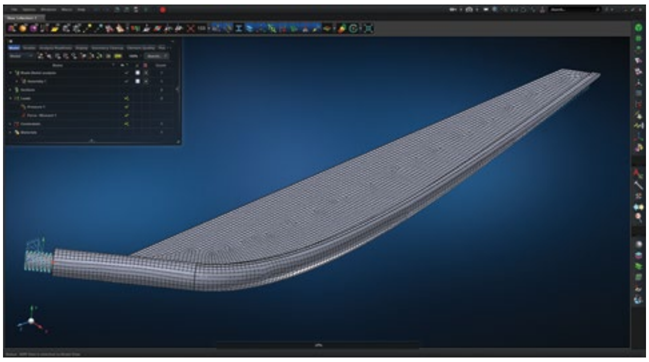

Figure 2: Geometry cleanup using MSC Apex

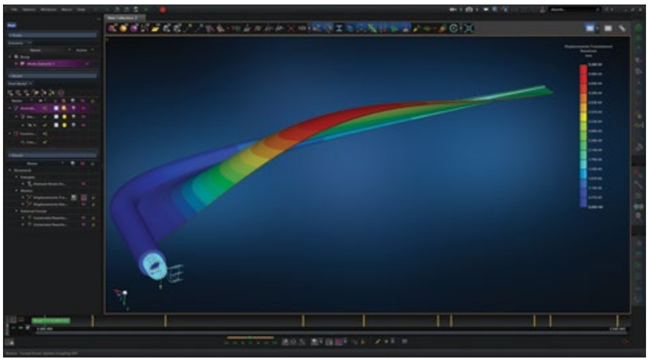

Figure 3: Natural Frequency Analysis

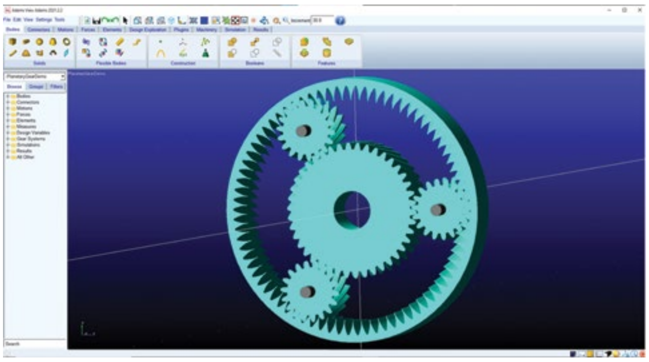

Figure 4: Planetary gear design in Adams

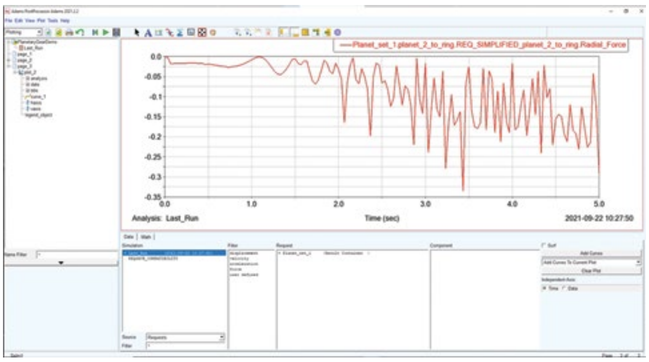

Figure 5: Dynamic loads analysis in Adams

The H_2O turbine actually converts kinetic wind energy into mechanical energy, and then to heat. In order to transmit the power from the turbine to the heating system, a large planetary gear system is to be used. It is therefore necessary not just to correctly design and size the gear components but to determine the mechanical power which can be delivered to the heating system. Power transmission and system dynamics was simulated in Adams (Figures 4 and 5).

As part of the FEED process, all major aspects of the turbine need to be considered. A route through this exercise was to employ AdWiMo from Adams, which considers every major aspect of turbine design including tower, blades, hub, mainframe, gearbox housing, bearings, transmission, controls (generator, pitch, yaw), aerodynamic and centrifugal forces, coriolis acceleration, gyroscopic, moments, point loads, gravity, thermal loads, and wave loads from 3rd parties. AdWiMo is an Adams plug-in with all the necessary features to assemble a complete and parametric wind turbine and to simulate single or multiple wind fields. Adams is the most widely used multibody dynamics simulation software with numerous interfaces to CAD, finite element software and to third party products. This makes Adams and AdWiMo an ideal platform platform for enterprise engineering processes. All features of Adams remain accessible to the AdWiMo user (Figure 6).

For linear FEA structural simulation, MSC Nastran was the optimal choice for complex multidiscipline structural analysis of the H_2O turbine assembly offering advanced solutions to static, dynamic and thermal simulations including vibration and shaft dynamics. On the nonlinear side, Marc was chosen for its versatile solver capable of complex nonlinear assessments both globally and locally including extreme non-linear events and contact. For example, assessing the effectiveness of global plastic collapse analysis due to the forces the turbine will have to undergo due to typical UK wind scenarios (Figure 7).

DOCAN also uses CAEfatigue from Hexagon to conduct fatigue analysis of both low cycle and high cycle fatigue issues, such as blade flutter and vortex streets, to ensure the design meets the required lifetime. CAEfatigue is also advanced at dealing with random inputs and outputs that turbines will experience often due to the unpredictability of wind.

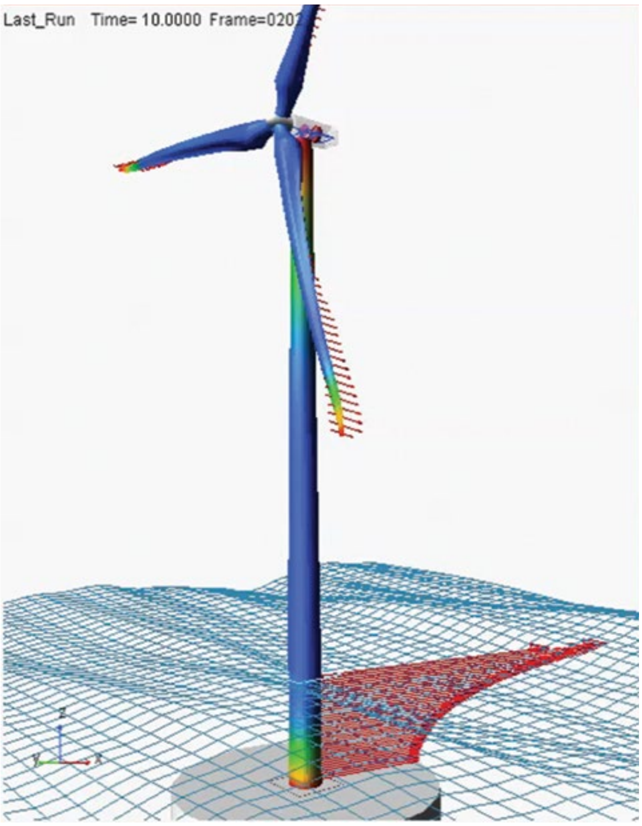

Figure 6: AdWiMo Toolkit for system-level analysis

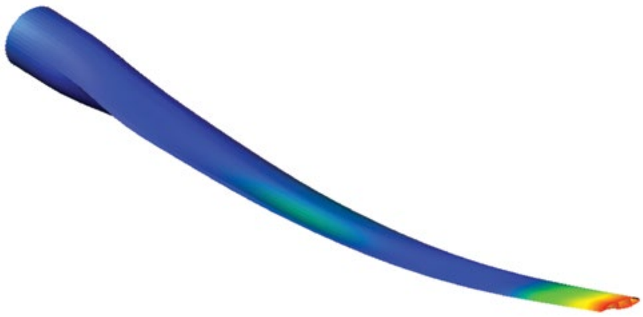

Figure 7: Typical stress analysis of a turbine blade (from Korean Aerospace University)

Finally, powerful CFD and thermo-fluid simulation can also cover many wind turbine issues, such as potential aeroelastic flutter, aerodynamics of blades and design of specialist pumps (Figures 8 and 9). Moreover, Cradle CFD can be coupled with other products, such as Actran, to predict the aero-acoustic noise coming from the turbine blades. Since the turbine will be installed in backyards of residential area, minimising aeroacoustic noise is of great importance to the success of the product.

Commenting on the H_2O turbine design process: "Invention and innovation was much needed, especially with climate change and the depletion of valuable Earth resources. There are currently no providers of heat that burn no carbon or require no electricity to function. Our operation is 100% carbon free, and our fuel (wind) is also free", said Clifford Spilsbury, Research & Development Director, and co-founder of H_2O, " With the engineering expertise from team DOCAN, backed by the world-leading CAD and CAE tools provided by Hexagon, we firmly believe that we will bring this innovative renewable-energy system to market successfully, change the way how society generates heat, and contribute to the goal of us reaching carbon neutrality by 2050 for the planet earth."

Figure 8: Pressure distribution on turbine blades (front/back view)

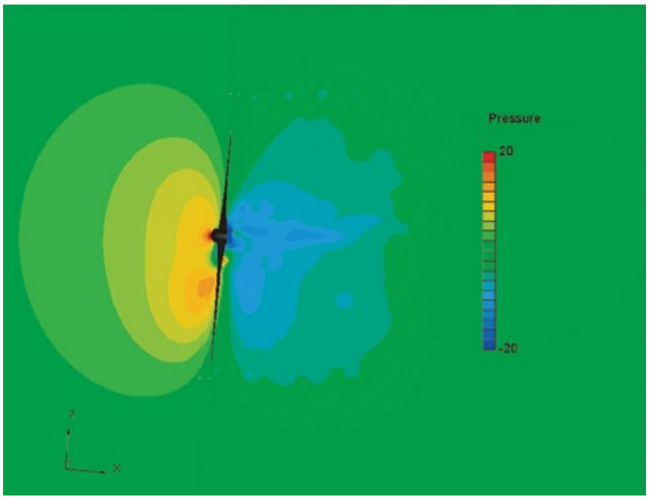

Figure 9: Pressure distribution on blades (side view)