

Innovative Blade Tips for Wind Turbines (/editorial-features/innovative-blade-tips-for-wind-turbines)



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What do Shark Fins, Winglets and Turbulators Have in Common?

Ambitions and developments in offshore wind energy have forced us to re-evaluate our approach and methods in wind turbine blade design once more. With the ultimate goal of reducing the levelised cost of energy (LCoE) through optimised tip design, the InnoTip research project ran as a collaboration between LM Wind Power's aerodynamics team and ECN. During this project three new tip designs were delivered and two were tested by extending the blades on ECN's 2.5MW test turbines with a temporary add-on tip extension – a unique process.

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Project Overview and Motivation

Because of the differences between onshore and offshore operating conditions and constraints, the tip region of the blades for offshore turbines should be designed differently to obtain more power. In this research project, three different tip configurations were investigated. These were then designed and manufactured to be tested on LM 38.8-metre blades on the 2.5MW test turbines at ECN's wind turbine test site (EWTW). It was quite a challenge to equip operating wind turbines with blade tip extensions for a limited period of time. However, the experiments were successfully completed and valuable data was collected. With the implementation of new tips, the measurement data showed an average of 6% power increase below rated speed, which was

higher than the expectations. The results of this project prove that there is significant power enhancement potential when the tips of offshore wind turbine blades are designed differently.

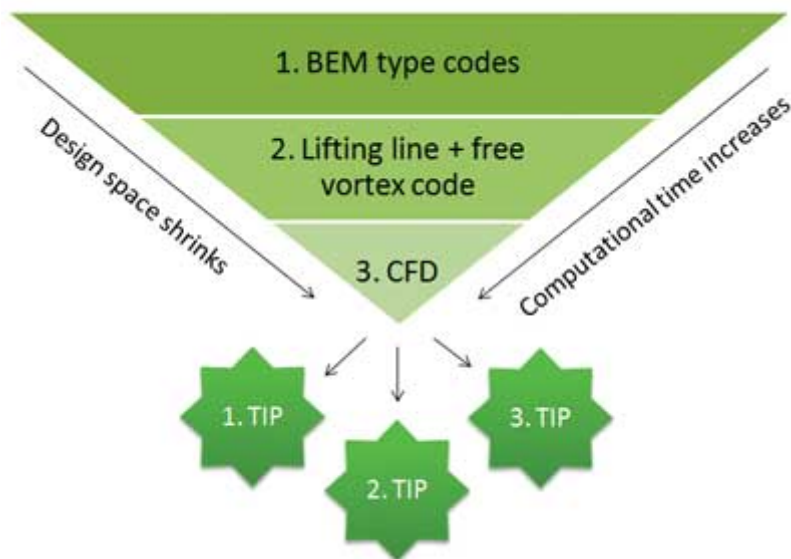
Which Blade Tips and Why?

The blade tip is the most sensitive source for noise, loads and power output from a wind turbine, so there are significant potential gains from further optimising this part of the blade. The noise constraint in onshore wind turbine blade designs works in opposition to power production, and therefore the design is a trade-off between the noise reduction and power production improvement (and other potential design constraints). For offshore wind turbines the noise is generally not a problem because these turbines are located far from residential areas. The conventional tip, a 'shark fin', is designed by removing the noise constraint from the design requirements. The winglet type of blade tip is a known concept which brings advantages in terms of power coefficient (C_p) improvements with low noise. In this project, the winglet was investigated as a competitor for the 'shark fin' or a plain blade tip extension but was not installed on the test site. The third type of tip, the turbulator, is ECN's patented concept. This tip reduces the wake effects of the wind turbine it is applied to. As a result, the machines that are further downstream in the wind farm can generate more power. In offshore wind turbines, wake effects are one of the biggest loss mechanisms. The power output of an offshore wind farm is more important than the power output of the stand-alone

wind turbine. Taking this into consideration, the turbulator tip is designed to accelerate the mixing in the wake by breaking down the tip vortex earlier so that the wake can recover faster. These three tip concepts (Figure 1) were investigated during the project and two of them (the shark fin and the turbulator) were implemented on the 2.5MW test turbines at ECN's test site to compare their performances in the field.

Optimal Blade Tip Design

For design of the innovative tips, different fidelity design and analysis codes were used in the InnoTip project. Low fidelity tools enable designers to get quick results from the configuration changes in the beginning of the design process. However, these tools are not very reliable in terms of assessing the actual effects of the designs. In particular, the widely used BEM (blade element momentum) based tools are not valid at the tip part of the blades. Therefore, higher fidelity tools are required for the designs. The flowchart going from lower fidelity to higher fidelity tools is shown in Figure 2. During the project, a wide design space was chosen initially. The design space was reduced by running several analyses to find the optimum and by introducing several constraints to the designs.



Manufacturing and Preparations for the Field Tests

The developed tip concepts were taken into a detailed design phase where the issues such as lightning protection, structural strength, attachment and drainage were solved. During this design period input from a large number of stakeholders (including the LM service team) was used to optimise the methodology. Once the designs were in the finalisation state, prototypes of the tips were made at full-scale and an installation test on a scrapped blade tip was performed in a controlled environment (Figure 3).

This was done in order to remove any potential issues, to make sure that the original blade on the test site was not damaged. Following the installation test, a structural test for extreme loads was done to verify the structural strength of the system. Finally, the extension was removed and the original blade tip was successfully restored.

Experiments in the Field

The field tests were performed at ECN's test site where five 2.5MW turbines were available for use (Figure 4). The turbines were instrumented with many sensors to collect data for the assessment of the tips. The turbines are assisted by a met mast which was used to verify the wind/atmospheric conditions. The turbulators and the 'shark fin' concepts were installed and tested mainly by monitoring the turbine performance change compared to the other turbines before and after the application of the tips. Prior to the field test the turbines were monitored for several weeks to compare the performance with and without the innovative blade tips.

The test results for the 'shark fin' tip showed an increase of more than 4% in power at higher wind speeds (the effect of having a longer blade). When correcting for the increased length, the increase due to geometry change alone was of the order of 2% to 9% for wind speeds above 8m/s. Data for the turbulator wake-influenced turbine did not show an actual increase in power mainly due to lack of measurement time when the turbine was operating in

the wake. On the other hand, the turbulators increased the power on the retrofitted turbine itself, which was not expected. Here the increase in power was of the order of 2% to 10% for wind speeds above 8m/s. These results prove the significant potential of these new tip designs.

Meaning for the Future of Offshore Wind

Results of this project prove that with these new tips it is possible to increase annual energy production (AEP) by about 3% assuming that the solution is a retrofit. However, the actual benefits will probably be higher when the solution is integrated in the design such that no interference effects are present as well as the possibility for a better optimisation for the complete blade. The turbine costs account for approximately 25% of the total cost (LCoE) and 22% of those costs are due to the blades. This means that blades are



responsible for 5.5% of the overall energy cost. The costs of the new tips, even if they result in a 1% increase in the blade cost, would be negligible compared to a yield increase of 3%. Therefore, all three options are good for implementation to help reduce LCoE. The team will soon be looking at further improvements to these innovative tip designs and design tool validations to improve the predictions of the tip effects in upcoming projects.

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Biographies of the Authors

Ozlem Ceyhan Yilmaz holds a master's degree in aerospace engineering. She is an aerodynamics researcher at ECN – Energy Research Centre of the Netherlands. Previously, she was a design engineer on aircraft design projects. In total she has 15 years of professional experience in the topic.

Jordy van Kalken

Jordy H.N. van Kalken is an aerodynamicist who graduated from Delft University of Technology. He worked in offshore wind foundation design at Rambøll for three years after which he joined LM Wind Power where he has now worked for about five years as an aerodynamicist and project manager in their wind tunnel.