H2020 MARIE SKŁODOWSKA-CURIE ACTIONS

Smart Mitigation of flow-induced Acoustic Radiation and Transmission for reduced Aircraft, surface traNSport, Workplaces and wind enERgy noise

Grant Agreement No 722401

D5.5 – Final WP5 report

Final public industrial application report

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Introduction

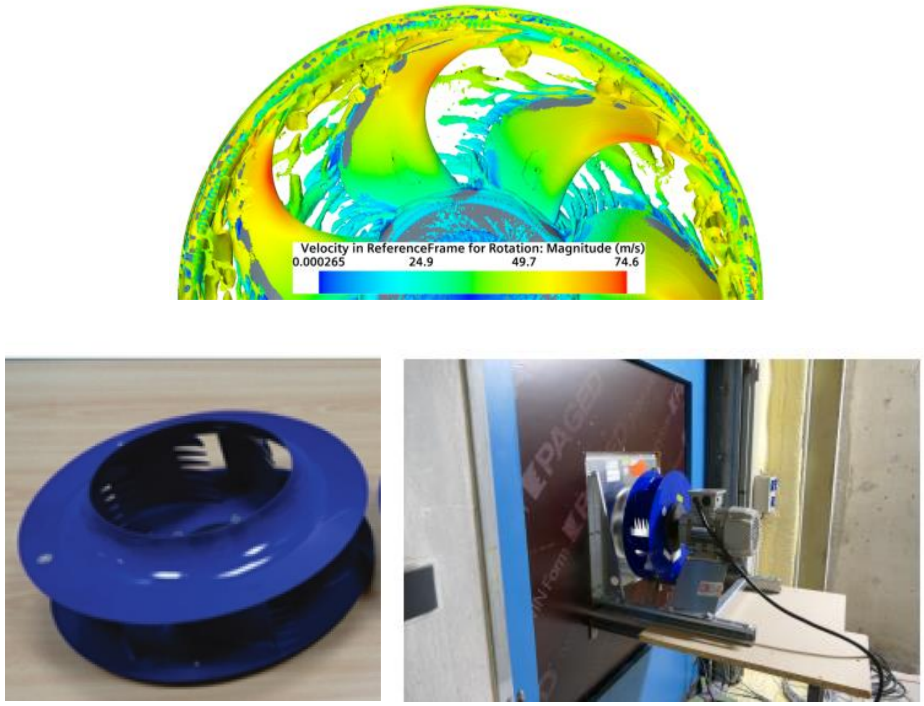
This deliverable summarizes the findings of D5.1, 5.2, 5.3 and 5.4, examining the applicability of several innovative flow-induced noise mitigation strategies on real-life industrial configurations.

In WP4, laboratory-scale experiments were put in place, involving a combination of experimental diagnostics, on geometrically simple, but representative enough configurations. In WP5 on the other hand, the configurations of interest were examined on full-scale industrial prototypes or demonstrators, put at disposal of the ESRs by the industrial Beneficiaries and Partners of the project. The components were investigated in a laboratory environment permitting detailed measurements and concept validation, but including all the complexity found in the full-scale devices, in terms of non-dimensional numbers (Re, M, Sr, He), multiple-component interactions, integration aspects, etc.

1. Trailing-Edge and Leading-Edge serrations for low-speed cooling fan applications

In Deliverable 5.1, a design and optimization process of leading and trailing edge **serrations** for a plug fan has been carried out to reduce noise. Six impeller prototypes with serrations were manufactured and tested to investigate their aerodynamic and acoustic effects. For both solutions, a certain degradation of the aerodynamic performance has been measured. Leading edge serrations tend to reduce noise under 1000 Hz but can increase the noise at higher frequencies, depending on the operating point. **The impact of the Leading-Edge serrations on the overall sound level is rather limited and serrations increase the overall noise if we consider the degradation of aerodynamic performance**. All impeller prototypes have been designed and optimized to yield substantial noise reductions. The discrepancies between the measured and expected values could be due to the uncertainty of the simulations or the inaccuracy of the turbulence estimation and averaging. The latter is done over a rectangular spanwise area, whereas using the maximum value of the turbulence length scale instead could be a better serration design strategy.

Trailing edge serrations on the other hand, reduce noise for all frequencies at some operating points, with a maximum decrease of around 1-2 dBA at nominal speed. **For low flow values and low rotating speed, a substantial noise reduction of up to 8 dBA is observed due to the mitigation or even cancellation of a high-frequency peak**. This peak is generated by a source near the trailing edge. The most likely hypothesis points towards laminar boundary-layer vortex shedding, but this yet needs to be confirmed.

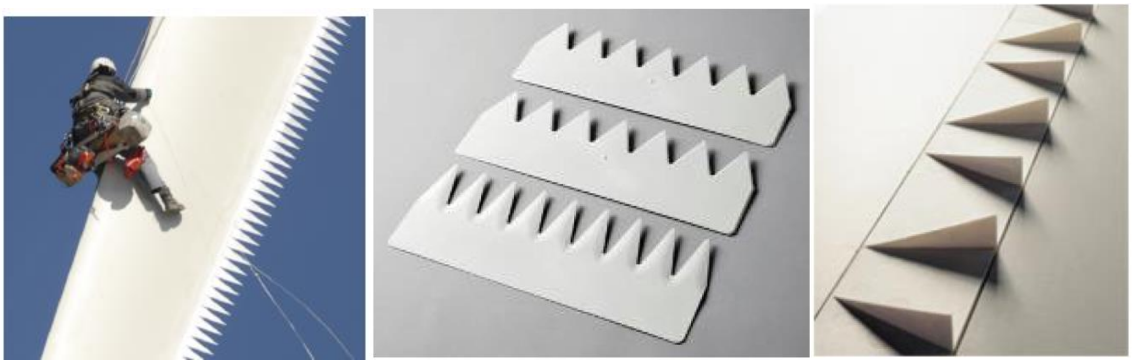


Excerpt from Deliverable 5.1: Numerical and experimental research were carried out on the influence of Leading-Edge and Trailing-Edge serrations on aerodynamic and noise performance of a low speed cooling fan industrial application

2. Trailing-Edge serrations and Vortex Generators for a wind turbine application

The measurements of an airfoil on a wind tunnel have demonstrated the ability of trailing edge add-ons in reducing trailing-edge noise. The noise is reduced by the less efficient acoustic scattering in slanted trailing edges. Nevertheless, important changes occur in the flow near the trailing-edge serrations, as captured with the surface pressure sensors over the trailing-edge serrations. These changes are a function of the serration geometry and the incoming flow conditions. In Deliverable 5.2 measurements using PIV and surface mounted pressure sensors are carried out to characterize the flow near the trailing edge, showing the modifications that will ultimately contribute to the noise increase captured at the far field.

Well–designed modern wind turbines are relatively quiet compared to other large industrial machines. Despite increasing rotor diameters, noise levels from on shore wind turbines have stabilized or even reduced. Trailing edge noise from the outboard part of the blades is usually the dominant noise source provided that other potential sources are adequately suppressed. To reduce sound emissions, turbine manufacturers have implemented several technologies, such as optimized control settings, low–noise blade design, and blade add–ons. Two important blade add–ons used for noise reduction are trailing edge serrations and vortex generators. In the future, further blade noise reductions may be obtained by optimizing existing technologies or by introducing more disruptive concepts like brushes, boundary layer suction, or active blade add–ons. As aerodynamic noise from the blades is reduced, secondary sources such as mechanical noise may become more important and require more attention in the design phase. Further reductions in neighbor noise levels may be achieved by spectral improvements and farm optimization. The wind industry is committed to develop new noise reduction technologies and implement them in their products. In this way the cost of wind power can be reduced while addressing societal concerns.

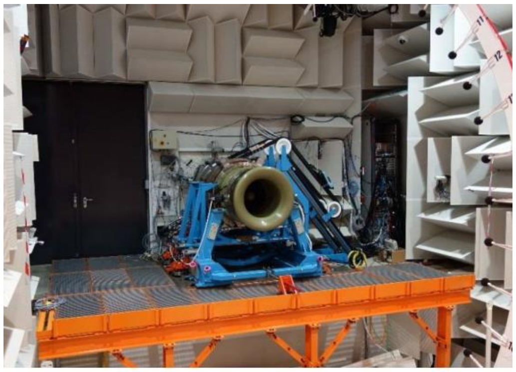


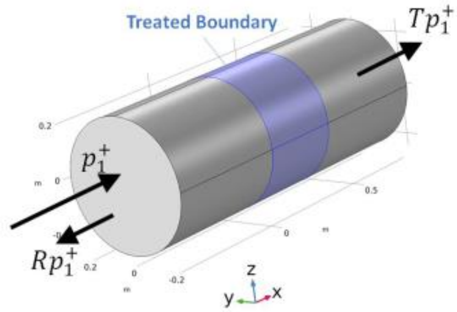
Excerpt from Deliverable 5.2: Numerical and experimental research were carried out on the influence of Trailing-Edge serrations and turbulence generators noise performance of wind turbines.

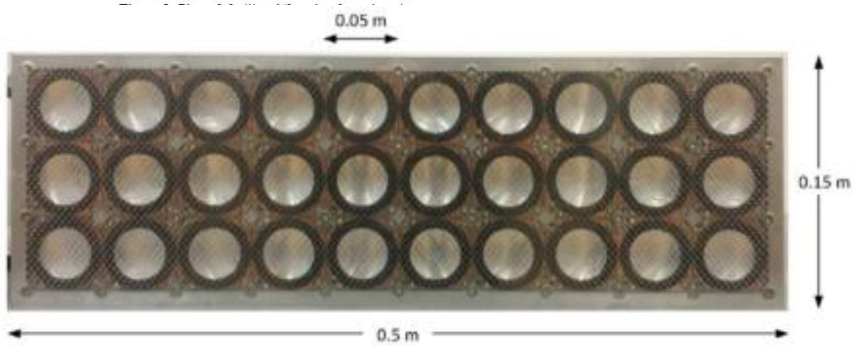
3. Simulation of noise transmission attenuation in the nacelle of a ducted low-speed axial fan

In Deliverable 5.3, the performance of active liners is compared to the state-of-the-art passive liners for the noise transmission in a nacelle. Low-frequency sound absorption is hardly achievable by passive liners because of high thickness demanded. In the attempt to target the Cremer impedance, **the Active Liner exhibits higher flexibility thanks to the possibility to enlarge the frequency bandwidth, compatibly with the electrical energy and stability constraints.** Next steps in simulations are the analysis of the multi-modal scattering problem, and the inclusion of mean-flow.

Both for the Passive and Active Liners, the experimental campaign in the Phare-2 facility will result to be fundamental to assess the Active Liner performances and limitations in a harsh environment, where Passive Liners have already proved to be robust, being currently applied in the aeronautic industry.





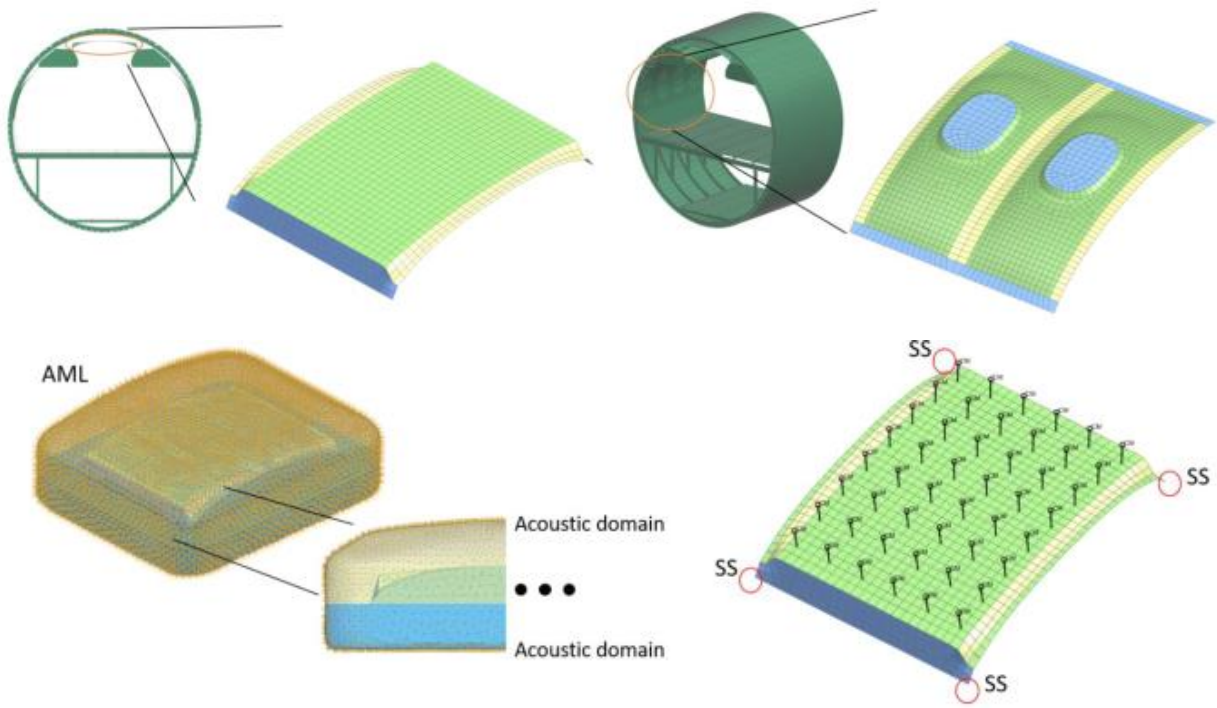


Excerpt from Deliverable 5.3: Numerical research was conducted to evaluate the performance of active liners w.r.t state-of-the-art passive liners for reducing ducted sound transmission in a nacelle.

4. Industrial application report on low-transmission technologies implemented in a generic fuselage Demonstrator

The use of lightweight materials has become crucial to several engineering applications due to ecological trends. Nevertheless, lightweight designs can exhibit worse Noise, Vibration and Harshness (NVH) behavior and to enhance it, novel low mass and low volume solutions are needed. The Deliverable 5.4 focused on showing the potential of metamaterials to improve the sound transmission loss (STL) of structures present in the fuselage demonstrator at Airbus facilities Hamburg, Germany.

The report evaluated the potential of using locally resonant metamaterials to improve the acoustic performance of an aircraft. This investigation is performed numerically by analyzing the sound transmission loss of two lining panels present in an Airbus Single Aisle, namely ceiling and side-wall panels, which, amongst others, are in one dominant transmission path of the considered aircraft. The structures are then treated with tuned vibrations absorbers (TVAs) as means to improve the noise radiated into the aircraft's cabin. **It has been shown that the metamaterial solution improved the sound transmission loss in both structures around the frequency range of interest.** Furthermore, it seems that for a given mass, the highest gain in acoustic performance can be obtained for when the ceiling panels are treated with a smaller number of added resonators, when compared with side-wall panels.



Excerpt from Deliverable 5.4: Numerical research was conducted to evaluate the performance of the addition of tuned vibrations absorbers (TVAs) on the fuselage dominant noise transmission paths, in order to improve the noise radiated into the aircraft's cabin

5. Conclusions

A variety of innovative noise mitigation strategies, including active noise control, leading/trailing-edge serrations, vortex generators, and metamaterials were evaluated on several real-life industrial applications, using advanced experimental and numerical methods. While promising results were obtained, some research still needs to be conducted to more closely understand the physical phenomena at play (e.g. in trailing-edge serrations). In addition, noise emission improvements often come at the cost of a degradation of other functional performance attributes (e.g. weight or aerodynamics), showing the importance of including multi-objective optimization strategies at the core of the research methodology.