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# Validation of Aero and Aero-Acoustics simulation for HAWT Model through LBM based technology

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**Key Words :** Aerodynamics, Aeroacoustics, CFD, PowerFLOW, Wall Pressure Fluctuations, Noise Sources

**ABSTRACT**

A computational study to capture the flow around a floor mounted greenhouse shaped HAWT model was performed using the commercial software PowerFLOW 4.2b. The simulation kernel of this software is based on the numerical scheme known as the Lattice Boltzmann Method (LBM), combined with an RNG turbulence model. Simulations were performed at 60 and 140 km/h free stream air speeds. Selective results from these computational simulations are presented to show the capability of this numerical approach to predict the aerodynamics and aeroacoustics characteristics of the 3-D flow field around the HAWT model.

## 1. Introduction

Meeting fuel efficiency and passenger comfort targets are essential requirements in the vehicle design process. Therefore automobile manufacturers put a lot of effort into reducing the forces on the vehicle body and the noise sources produced by the vehicle shape. CFD is making it possible to accomplish this task at the early stages of the design, helping to fuel the drive towards virtual development and testing.

The current study demonstrates the capability of the commercial software PowerFLOW 4.2b to predict the aerodynamics and aero-acoustics characteristics of the 3D flow field around the HAWT model which represents the greenhouse of an automobile. Simulations were performed at 60 and 140 km/h free stream air speeds. The aerodynamics characteristics of the flow was analyzed a both speeds. Selective flow visualizations showing the time average flow field around the HAWT model are presented here. Aero-acoustics characteristics of the flow field around the HAWT model was investigated for 140 km/h free stream air speed only since the wind induced noise becomes dominant at high speeds. Noise sources on the side of the HAWT model which represents the side glass of an automobile are presented in the form of surface dB map.

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## 2. Numerical Scheme

The CFD/CAA code used in this study is based on the Lattice Boltzmann Method (LBM). The LBM starts from a "mesoscopic" level kinetic equation based on the Boltzmann equation for the particle distribution function, and correct macroscopic fluid dynamics is obtained as a result of evolving the underlying particle distributions. Details of the numerical scheme, including the fundamental LBM dynamical equation, wall boundary conditions, and turbulence modeling, are identical to those given in [2] and thus are not repeated here.

## 3. Aerodynamic Results

Mean flow characteristic of the Aerodynamics simulation at 140 kph are presented in this paper. The separated region at the leading edge of the model is shown in Fig. 1. The horse-shoe vortex peels off from the base of the model is very sensitive to the boundary layer development upstream of the model and is crucial to capture the accurate turbulent separated region on the side wall of the HAWT model.

Fig.2 depicts the topology of the regions of flow losses due to turbulent vortical structures colored by static pressure. The interaction between the horse shoe vortex at the base of front face and the separated region on the side wall has been captured.

Static pressure measurements were recorded at 39 pressure taps of the side panel, in the simulation. These pressure taps were distributed well on the side panel of the HAWT model to capture the pressure levels inside the separated region on the side wall and in the attached flow region. This will give us a detailed measure of the pressure losses inside the separated region and the pressure recovery after the flow re-attaches on the side wall. Fig.3 shows the cross section vortex colored by static pressure at a height of 400mm from the Floor. These results will be presented in [1].

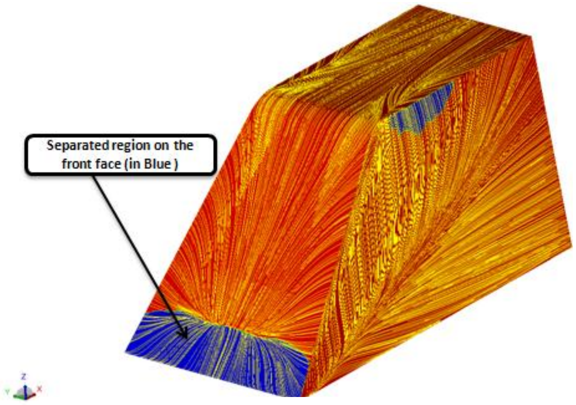


**Fig 1: Surface Streamlines/Surface colored by Stream wise Velocity (X-Velocity between -0.01 m/sec to 0.01 m/sec)**

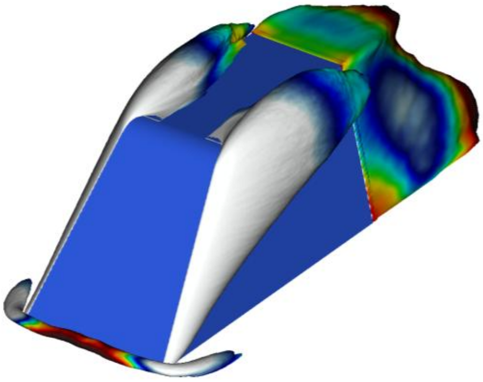

**Fig 2: Iso-surfaces of Total Pressure=0, colored by Static Pressure**

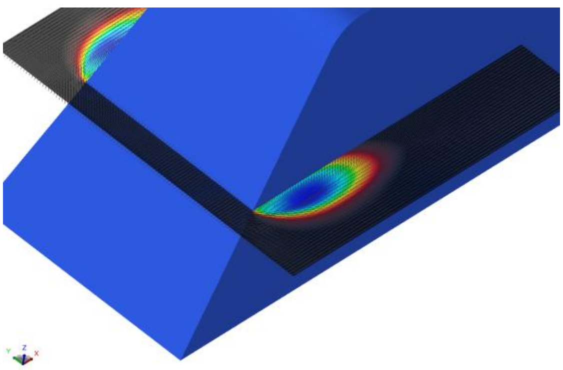

**Fig 3: Slice cutting through the Side Panel Vortex at a height of 400mm from the Floor**

## 4. Aeroacoustics Simulation Results

The wall pressure fluctuation dB map (WPF dB map) from the simulation, showing the noise sources on the side panel of the HAWT for 1 kHz octave band, is presented in Fig 4. This shows the complex topology of the pressure fluctuations on the side glass captured by the simulation. It can be seen that the vortical structure due to separation from the leading edge is the primary noise source on the side panel. Noise sources from the horseshoe vortex can also be seen on the lower part of the side panel. Pressure fluctuation spectra for 8, ¼" diameter flush mounted microphones on the side panel and the radiated noise to a microphone located at 4.5 m from the side panel were also predicted in the simulation. These results and additional flow visualizations will be presented in [1].

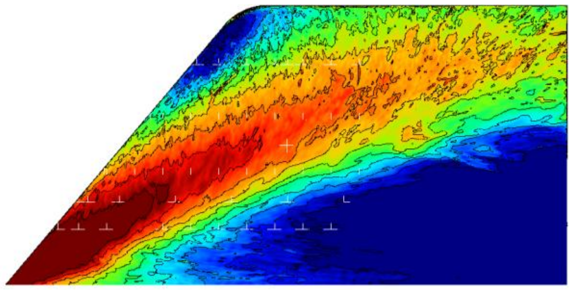

**Fig 4: WPF dB map for 1 kHz Oct. Band**

## 5. Conclusions

The capability of the Lattice Boltzmann method implemented in the commercial software PowerFLOW 4.2b to predict the aerodynamic and the aeroacoustic characteristics of the transient flow around the HAWT model is presented in this study. The results show that the complex nature of the flow field can be captured in detail using this numerical approach. More flow visualizations and quantitative results will be presented in [1].

## References

(1) Senthooran, S., Kandasamy, S. and Balasubramanian, G., 2010, "Validation of Aero and Aero-Acoustics Simulation for HAWT Model through LBM Based Technology", Presentation at 2010 Spring Conference of KSNVE

(2) Senthooran, S., Crouse, B., Balasubramanian, G., Freed, D., Caridi, D., 2006, "Numerical simulation of wind noise on the sideglass of a production automobile", FISITA Paper F2006D124