Simulation Study for Wind Loading on Single Fractal Tree Model

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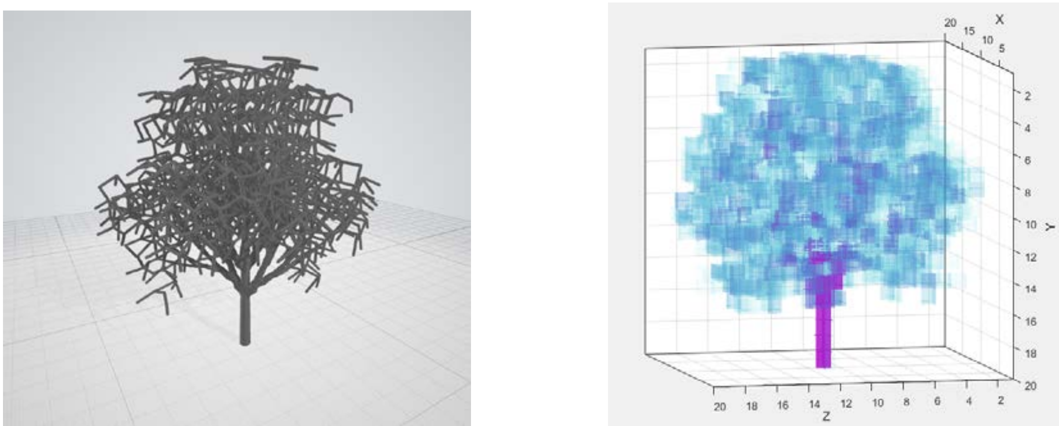
For urban tree management, it is important to understand the complex and dynamic wind-tree interaction phenomena in order to estimate the aerodynamic force that the tree must endure in given locations. This project aims to predict wind load on tree using Computational Fluid Dynamics (CFD) simulation on scaled wind tunnel fractal tree. The model is biologically and visually representative to the actual tree branch architecture. In order to have a better prediction of the flow field and wind load around the tree, high fidelity Large Eddy Simulation (LES) with Wall-adapting Local Eddy-viscosity (WALE) sub-grid scale model is used in this study and validated against wind tunnel experiment. The volumetric tree is modelled using volumetric averaged and discretized momentum sink term for different tree species. The discretized momentum sink has been implemented in Reynolds averaged Navier-Stokes [1]. In this study, the momentum sink term S_u added to the momentum equation is defined as $S_u = -C_d a u_i U$, in which C_d is drag coefficient for tree, a is frontal area density $(\mathrm{m}^2/\mathrm{m}^3)$, u_i is the velocity component $(\mathrm{m}/s)$and U is the velocity magnitude (m/s). The drag coefficient used in the simulation is determined by matching the porous drag with the wind tunnel's drag measurement. Consequently, the flow field obtained from simulation is compared with wind tunnel's Particle Image Velocimetry (PIV) measurement at 1H upstream, 1H and 2H downstream (H is the height of the tree). The results show the wake's velocity deficit is highly depending on the distribution of frontal area density in the tree model. The volume averaged momentum sink performs well for cases with uniformly distributed frontal area density like yellow flame (*Peltophorum pterocarpum*). Both the velocity profile and predicted drag obtained from yellow flame simulation agree well when comparing with wind tunnel result. However, volume averaged momentum sink doesn't have good performance with the African mahogany (*Khaya senegalensis*) which has large spatial distribution on frontal area density as compared with yellow flame. The African mahogany's simulation with volume averaged momentum sink has greater error at leeward side's velocity profile. Therefore, the discretized momentum sink is suggested in this study to represent the African mahogany. The frontal area density is discretized in space with 5, 10 and 20 elements in x, y and z direction (Figure 1). The flow field result improved drastically (Figure 2). The flow field's fluctuation is further examined and compared with measurement in the wind tunnel. This finding shows that discretized momentum source methodology is more applicable for heterogeneous frontal area density (FAD) distribution when carrying out the CFD simulation for wind load prediction on tree.



(a) (b)

Figure1: (a) African mahogany's fractal model (b) discretized frontal area density (20x20x20 elements).

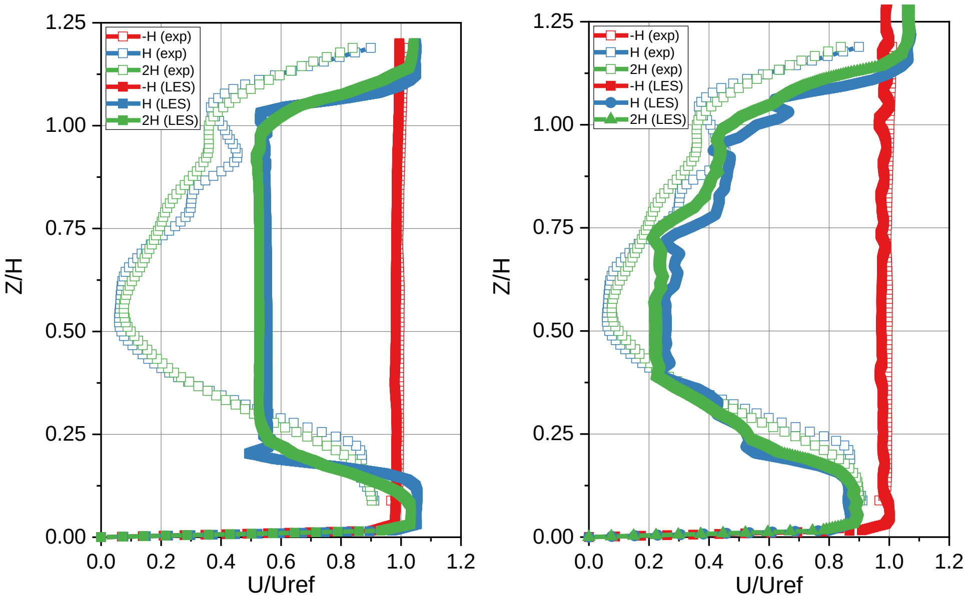


Figure2: Comparison between wind tunnel and LES simulation for African mahogany at 15m/s.
(a) volume averaged momentum sink *(b) discretized frontal area density (10x10x10 elements).*

Acknowledgement

The authors gratefully acknowledge the financial support of the research grant under Virtual Singapore Programme (NRF2017VSG-AT3DCM001-029) from the National Research Foundation of Singapore

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Preferred session/format

Single trees/group of trees/woodlots/forests