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Experimental Investigation of the Flow Field and Wind Drag on Fractal Tree Models

Woei Leong Chan¹, Yong Eng², Yongdong Cui³, Siddharth Sunil Jadhav⁴, Boo Cheong Khoo⁵, Chi Wan Calvin Lim⁶, Like Gobeawan⁷, Hee Joo Poh⁸, Daniel Joseph Wise⁹, Zhengwei Ge¹⁰, Daniel Christopher Burcham¹¹, Daryl Lee¹²

¹ National University of Singapore, Singapore, tslcwl@nus.edu.sg

² National University of Singapore, Singapore, e0023457@u.nus.edu

³ National University of Singapore, Singapore, tslcyd@nus.edu.sg

⁴ National University of Singapore, Singapore, tslsisj@nus.edu.sg

⁵ National University of Singapore, Singapore, mpekbc@nus.edu.sg

⁶ Institute of High Performance Computing, A*STAR, Singapore, limcw@ihpc.a-star.edu.sg

⁷ Institute of High Performance Computing, A*STAR, Singapore, gobeawanl@ihpc.a-star.edu.sg

⁸ Institute of High Performance Computing, A*STAR, Singapore, pohhj@ihpc.a-star.edu.sg

⁹ Institute of High Performance Computing, A*STAR, Singapore, daniel-wise@ihpc.a-star.edu.sg

¹⁰ Institute of High Performance Computing, A*STAR, Singapore, ge_zhengwei@ihpc.a-star.edu.sg

¹¹ National Parks Board, Singapore, Daniel_Christopher_BURCHAM@nparks.gov.sg

¹² National Parks Board, Singapore, Daryl_LEE@nparks.gov.sg

Scaled down fractal tree model reduces the cost of experimental investigation on the flow field around a tree. It also allows the study to be conducted in controlled environment, namely in a wind tunnel, but one of the major challenges is to construct a tree model that resembles the real tree. We have constructed scaled down fractal tree models of the yellow flame (*Peltophorum pterocarpum*) and the African mahogany (*Khaya senegalensis*) based on statistical data gathered through laser scanning on the real trees. The trunk and braches of the yellow flame tree model is constructed using a simple fractal tree design where a branch is recursively split into 3 child branches successively over 3 iterations. Each level of child branch's length is reduced by a fixed ratio. On the other hand, the trunk and branches of the African mahogany tree model is constructed based on the L-System generated Multiscale Tree Graph data structure (MTG) file format.

One of the most difficult tasks in the fractal tree model construction is to accurately construct the foliage of the tree crown. The four main criteria taken into consideration are resemblance to real tree, structural integrity, aerodynamics characteristics, and ease of fabrication. We have designed a methodology to represent the tree crown with porous volume that consists of randomized tetrahedral elements that stack on each other, forming a porous media within a pre-defined tree crown volume. The crown volume of the yellow flame is bounded by three overlapping spheres and a bottom flat plane that encapsulates the branch tips. As the tree model becomes more complex in the later stage of the project, the crown volume of the African mahogany is bounded by multiple spheres centred on the branch tips, giving it a closer resemblance to the real tree. The frontal area ratio of the tree models are adjusted to match the frontal area ratio of the real trees. Frontal area ratio is defined as the frontal projected area of the leaves and branches over the projected area bounded by the shape of the tree crown. This construction methodology allows each tree model to be fabricated as a single piece using 3D-printing technology. Both tree models are printed using Selective Laser Sintering (SLS) technique.

The flow fields at the centre plane of the tree models are observed through Particle Image Velocimetry (PIV) in the wind tunnel, and the drag force is measured using a force balance mounted underneath the tree model. Results show that the drag coefficient for these inflexible tree models are not sensitive to wind speed. Both trees have significantly different wake profile at the centre plane due to the difference in the spatial distribution of the frontal area density (FAD). Frontal area density is defined as the frontal projected

area of the branches and leaves over the crown volume, which can be interpreted as the reciprocal of the effective depth of the crown. In general, it is observed that the higher the frontal area density, the lower the drag coefficient. This implies that the depth of the tree crown plays an important role on the drag coefficient. This research work provides an insight into the wind drag and wake of different tree species, which would enable sustainable landscape planning and mitigate risk of wind damage on trees.

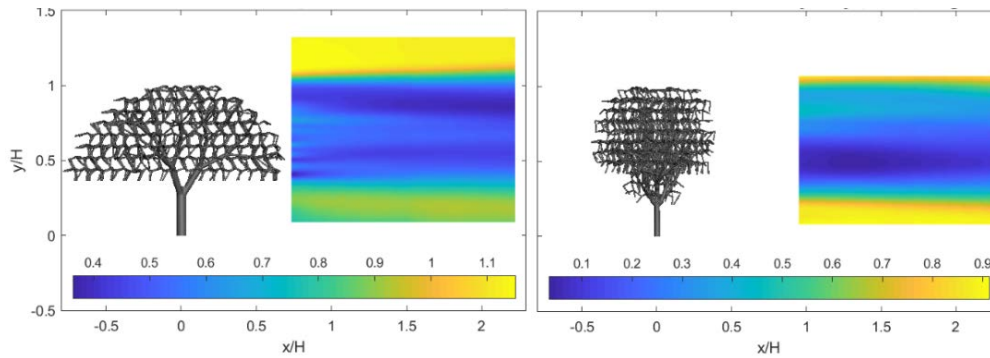


Figure 1: Down stream normalized mean airspeed (U/U_i) of yellow flame (left) and African mahogany (right)

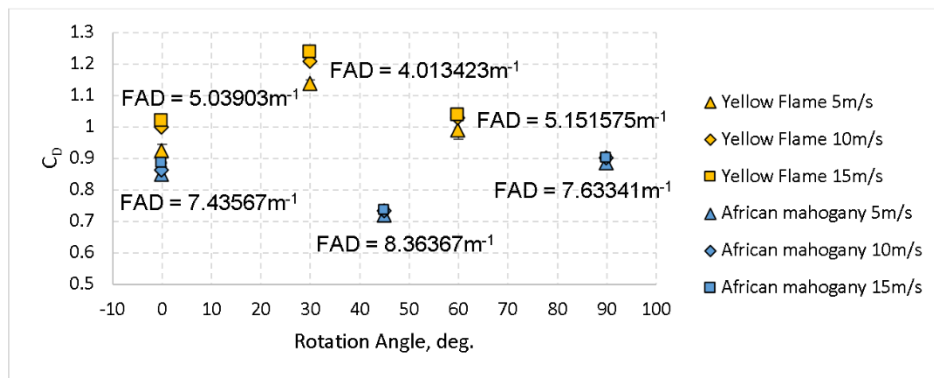


Figure 2: Drag coefficient of yellow flame and African mahogany and the respective FAD

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