# On the effect of solidity and Reynolds number on canopy flows

A. Pinelli*, G. Cavallazzi*, M. Omidyeganeh* and N. Shane *

We have undertaken a series of numerical simulations of a plane, turbulent open-channel flow bounded by a canopy made of slender, rigid filaments. According to Nepf[1], there exist two asymptotic regimes (sparse and dense) that are uniquely characterised by the solidity of the canopy $\lambda = hd/\Delta S^2$ ($d$, $h$ and $\Delta S$ are the diameter, height and mean spacing of the filaments). In practice, one can change $\lambda$ either by changing the height of the stems keeping the spacing constant or by fixing $h$ while changing $\Delta S$. A detailed comparison of the effects on the flow between the two procedures to change $\lambda$ will be presented at the conference. In particular, it will be shown that sparse and semi-dense canopies share the same flow behaviour independently of the way the solidity is changed while denser canopies feature diverging behaviours since packed canopies of the same height limit the wall-normal momentum transfer described in Monti et al.[2]. We also found that it is possible to define a sharp solidity threshold ($\lambda \simeq 0.2$ independently of $h\Delta S$ value) to predict the transition from sparse to dense regimes, i.e. from an almost *rough* wall-turbulent flow to a situation where the outer structures cannot fully penetrate the filamentous layer. The transition is related to the size of the region between the canopy outer layer (influenced by the outer flow) and an inner layer where a localised wall boundary layer develops. The extent of the first is measured by the location of the virtual origin (wall position seen by the outer flow), and the second by the location of the inner inflection point of the mean velocity profile (see Fig. 1). The mentioned set of simulations was performed at the same bulk Reynolds number (i.e.$Re_b = 6000$, based on the height of the channel and the flow speed at the non-slip surface). At the conference, we will also present new results obtained at a higher Reynolds number. In this case, for a dense canopy, we observe a deepening of the region influenced by the outer flow, whilst the location of the inner infection point remains unaltered. Variations of the positions of the virtual origins and the internal inflection points are given in Fig. 1(a), while Fig.1(b) shows the mean velocity profile obtained for the higher Reynolds number, dense canopy flow.

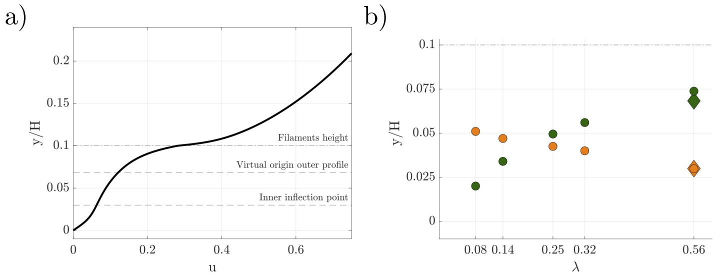


Figure 1: (a) Mean velocity profile at $Re_b = 11000$. (b) Location of the virtual origin and the inflection points as a function of solidity (diamond symbols are for the higher $Re_b$ case.)

*Dep. Engineering, City University of London, London, UK

[1] Nepf, *Ann. Rev Fluid Mech.* **44**, 123 (2012).

[2] Monti, *J. Fluid Mech.* **891** (2020)