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Large wood dynamics in a bended channel: experiments and numerical simulations

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ABSTRACT

The prediction of how large wood is transported by the flow is essential for reliable flood risk assessment. The combination of experimental and numerical analyses helps in investigating the influence of flow conditions on large wood motion.

1 INTRODUCTION

River ecosystems and dynamics are highly affected by the presence of instream wood (referred also as large wood LW). Although its beneficial contribution to biodiversity is largely recognized, LW may increase the potential damages of the flood when it is transported by the flow to critical sections, such as bridges and weirs. At these hydraulic bottlenecks LW tends to be trapped, and it may cause important backwater effects with adjacent floodplains inundation, embarkment or bridge collapse, which represent a serious risk for human population. Therefore, predicting how LW is transported along the river and which are the mutual effects with the current is of great importance in the risk management.

Several works have dealt with LW transport in different fluvial conditions, but its distribution according to the flow patterns is still poorly understood. This analysis combines experimental and numerical evidences to understand the influence of the flow and of the initial conditions on the final dispersion of wood.

2 FLUME EXPERIMENTS

The experimental tests were carried out at the laboratory of hydraulic in Trento (Italy), in a distorted physical model (2m wide and 22m long) having a rectangular cross-section and a double bend (Fig. 1). The immobile bed was made up of coarse material having a mean diameter of 0.8mm, and an average slope of 0.45‰. The experiments were run by imposing a liquid discharge of 50l/s, which resulted in a mean flow-depth of almost 10cm. ADV measurements were performed at six cross-sections of the channel, taking three verticals for each section to reconstruct the velocity field.

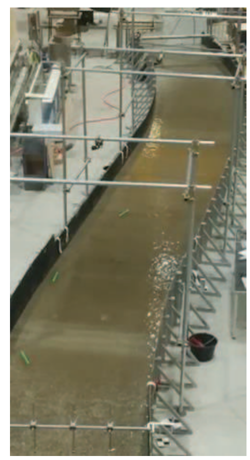

Figure 1. View of the channel with the wood elements.

The LW elements were simulated by cylindrical dowels without rootstocks and branches, having a mean density of 790.19±11kg m^{-3}, a diameter of 2cm and a length of 30cm, which correspond to real trunks of 18m and 0.80m (see Table 1 for the experimental characteristics).

Table 1. Experimental setting

Channel		Wood	
Width [m]	2	D_m [m]	0.02
Length [m]	22	L_m [m]	0.3
Q [l/s]	50	ρ_m[kg m^{-3}]	790.19±11
$h_{w\ mean}$ [m]	0.105	Draft/D_m [%] (immersion)	79
d_{50} [mm]	0.8		
Slope [‰]	0.45	Release points: distance from the right bank [m]	[0.4, 0.8, 1.2, 1.6]
Ks [$m^{1/3}s^{-1}$]	49.88		
Froude [-]	0.21		

50 cylinders were released individually at four different points from the initial cross section of the channel, parallel to the flow direction, and they were recorded by three synchronized GoPro cameras, placed along the channel to cover a total length of around 13m. Their trajectories were derived through a detecting/tracking algorithm, together with their velocity and orientation at each instant along the channel.

The data obtained by the experiments are analyzed statistically to reconstruct the distribution of the wood at different cross-sections with respect to the velocity field.

3 NUMERICAL SIMULATIONS

ORSA2D_WT is a numerical model that simulates the transport of floating bodies in a flow [1]. It couples (one-way coupling) the Eulerian solution of the Shallow Water Equations (performed with the finite volume code ORSA2D, [2]) with a dynamic Lagrangian module. Both the translation and rotation of floating cylinders are computed from the forces exerted by the flow. The translation equation is adapted from [3], as shown in [4, 5], while an original formulation is proposed for the computation of rotation. Since the model computes the distribution of the forces on the cylinder, the angular momentum can be calculated. In addition, a term of resistance to rotation, which takes into account the different angular velocity of the flow and of the cylinder, is introduced, named *added inertia term*. This term requires the calibration of a proper coefficient [1].

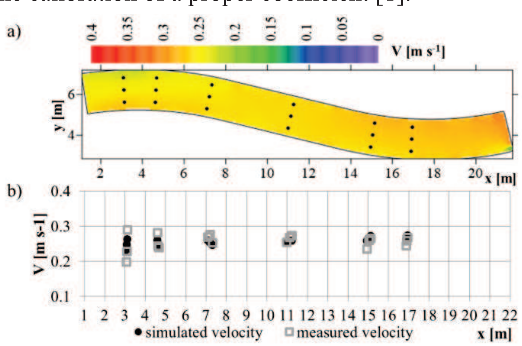

Figure 2. (a) Flow field with points of measure; (b) Comparison of the measured and simulated flow velocity.

4 DISCUSSION

As a first step, the experiments performed in Trento are used to provide additional clues for the calibration of the model. Given the test and flow condition, as well as the initial position and orientation of the cylinder, the trajectory and rotation can be simulated. The flow field in the channel is uniform (Fig. 2a) and the simulated velocity results in agreement with the measured absolute values (R^2 = 0.66, Fig. 2b). Note that the points where ADV measurements were performed are shown in Fig. 2a.

The trajectory and the orientation of one cylinder (dimensions from Tab. 1, density 811.3kg m^{-3}) are displayed in Fig. 3, together with the measured values. For the simulation, the initial linear and angular velocities are obtained from the measured data.

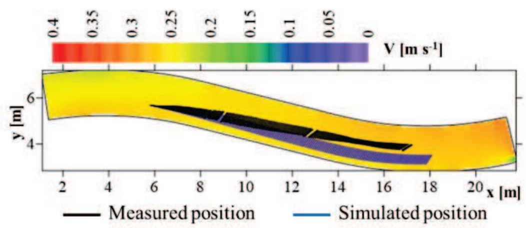

Figure 3. Planar view of the sequential positioning of the dowel axis.

The simulated trajectory (blue line) tends to the right side of the channel and the real orientation appears more variable than the simulated one. However, on overall, the figure shows that the model can reproduce quite well the motion of floating cylindrical bodies.

By validating the code on the entire set of tests available, it will be possible to better calibrate the model and to obtain a good instrument to investigate the effects of complex flow conditions on floating elements.

5 ACKNOWLEDGE

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