

Particle Image Velocimetry Analysis of Granular Material Flows



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Particle Image Velocimetry

Particle Image Velocimetry (PIV) is applied to analyze the flow. The experimental setup consists of high resolution camera (*SensiCam*) permitting to acquire about 200 pairs of 1280x1024 pixels images with frequency of 3.75 Hz. Evaluation of grains displacement (*and velocity*) is performed for each of images, taken at the interval of 0.266 s. High speed camera is used to obtain temporal characteristics of the flow.

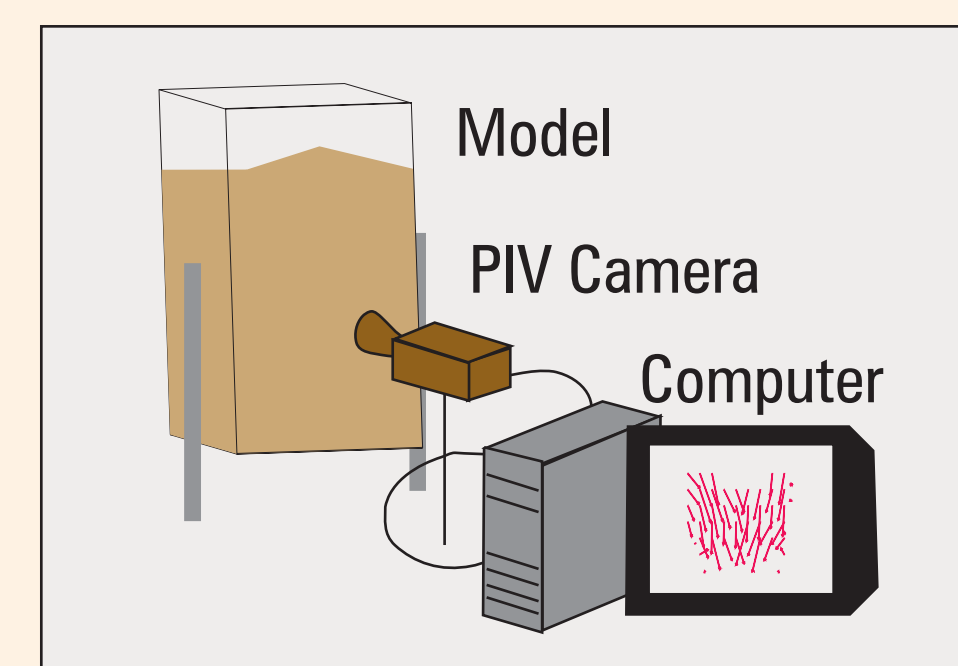


Fig. 1. Experimental setup.

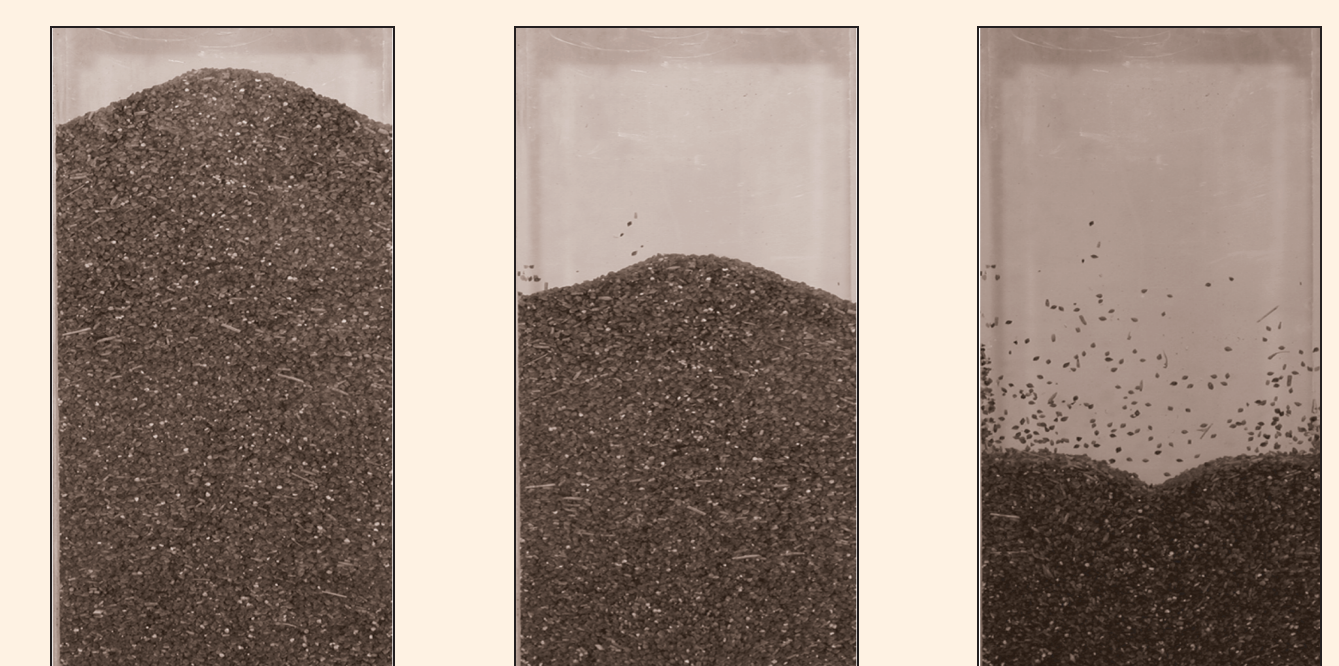


Fig. 2. Model with vertical side walls.
Configuration of free surface.

Experiments in granular materials

Semi-mass flow of amaranthus grain is investigated in a bottomed flat model of silo with vertical walls made of Plexiglas. The model is of 80 cm height, 26 cm width and 5 cm depth, replicates the geometry of a silo. The width of the outlet is 1 cm. Transparent walls of the silo allow for flow visualization and DPIV measurements of velocity fields, stream lines of individual particles, velocity profiles and local stresses in the material. When discharge starts, a plug zone in the flowing material expands upward. This material show certain static electricity when flowing and sliding over Plexiglas. To obtain uniform and repeatable packing of the material with no particle segregation, a sieve was suspended above the model and through it a rain of flowing material was supplied to the model. The total flow time was measured 60 s.

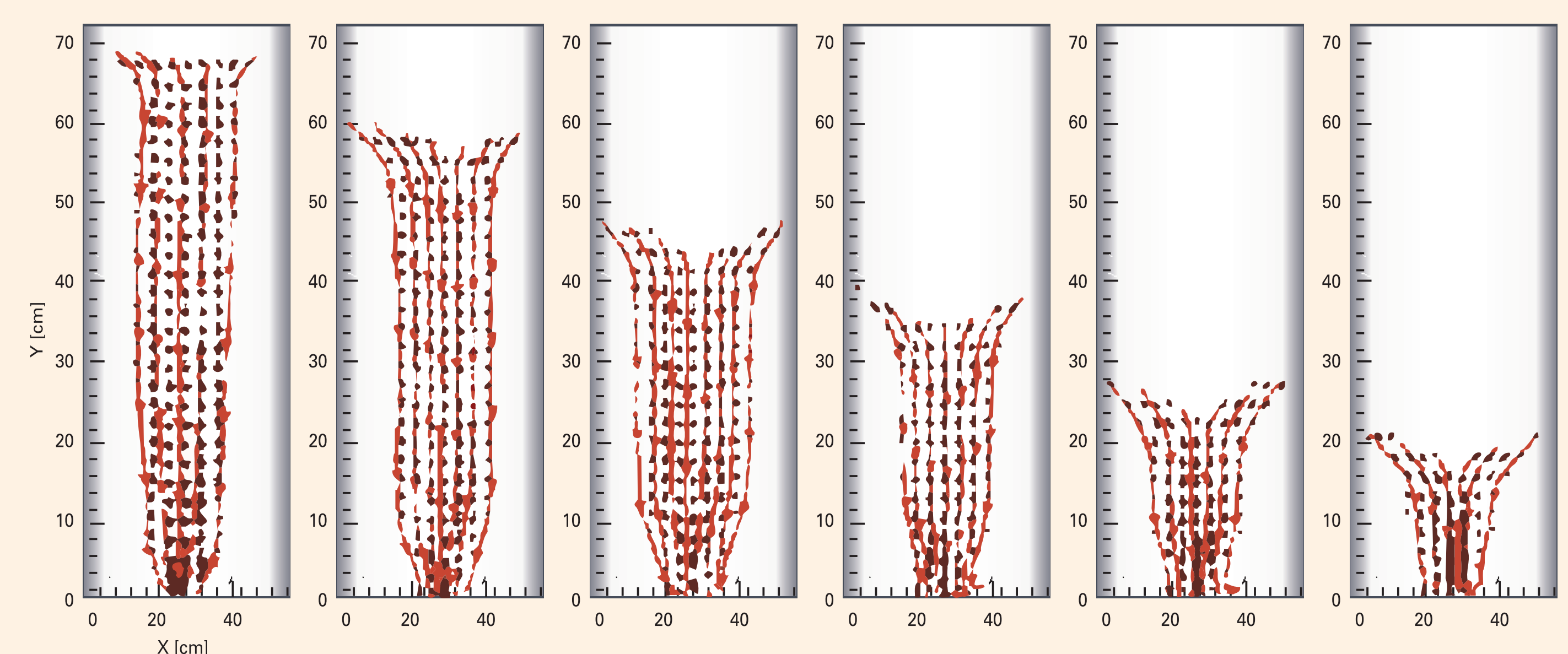


Fig. 3. Stream lines of individual particles.

Results

Evolution of flow region, velocity fields, velocity magnitude vectors, traces of flowing particles, profiles of vertical velocity distributions, measurements of stagnant boundaries, evolution of the height and width of the plug flow zone are presented. In the initial phase of the flow the whole material lowers vertically with rapidly developing a plug flow zone which quickly reaches (*about 3.75 s.*) the upper surface. The boundaries of the plug flow zone are vertical. Then the plug flow zone widens and reaches the walls of the model. The vectors in the plug flow zone are vertical directed to the outlet and only near the upper surface and near the outlet the vectors pass to the outlet along the curved lines. In the advanced stage of the flow the material still lowers. The boundaries of the flow zone become concave. Vectors indicated in the Figures in red colours depict the direction of the flow. Some irregular vector lines detect the phenomenon of static electricity of the grains and they correspond to the properties of the grains and conditions of the flow.

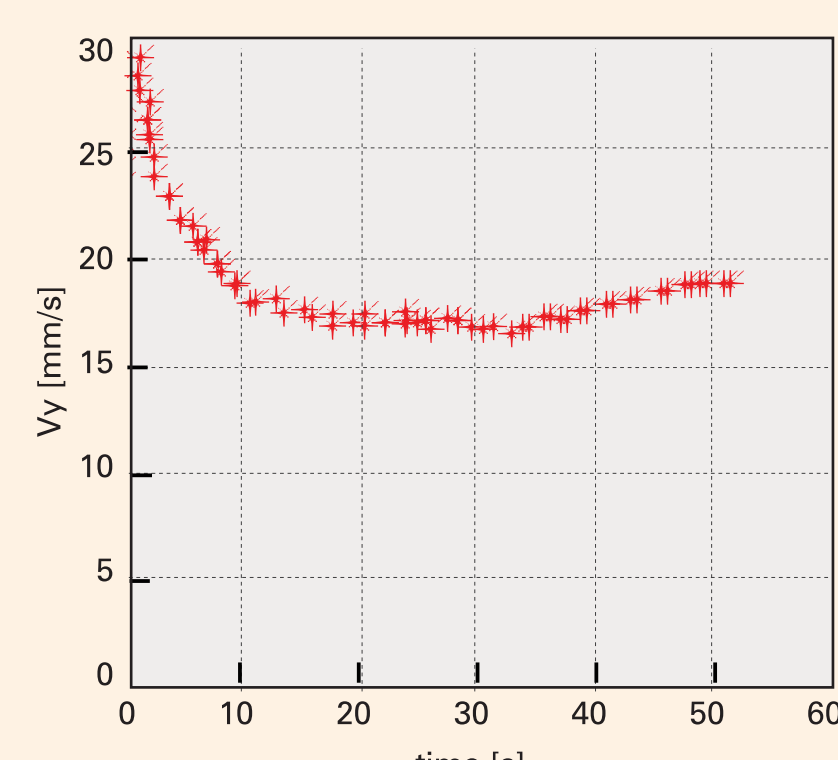


Fig. 8. Evolution of the vertical velocity in the plug flow zone as a function of time, measured at the symmetry axis of the model at the height 20 cm for the amaranthus seed.

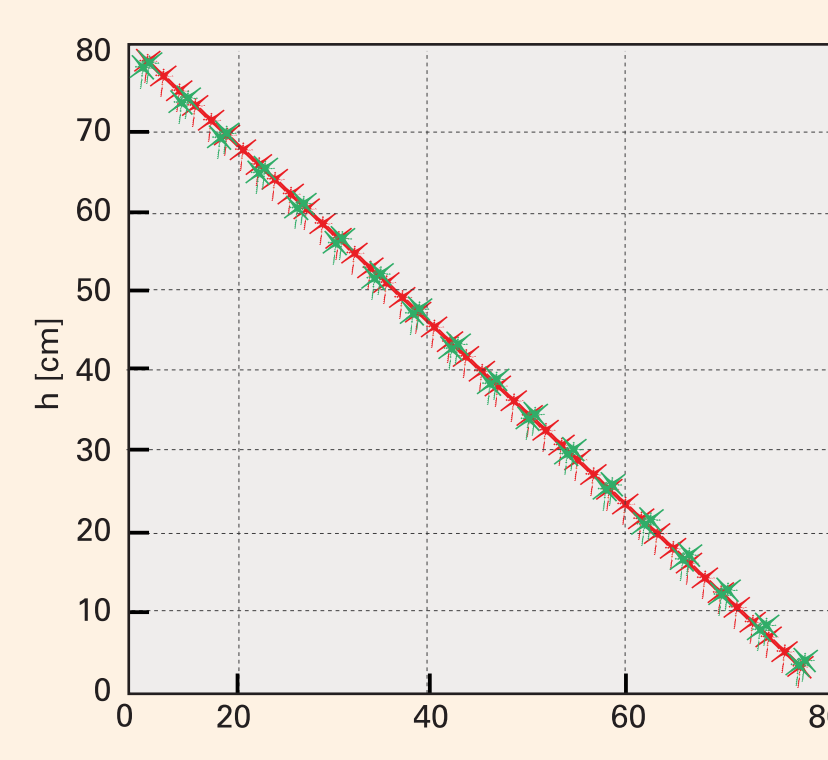


Fig. 9. Evolution of the height of the plug flow zone as a function of time measured at the symmetry axis for the flow of amaranthus seed.

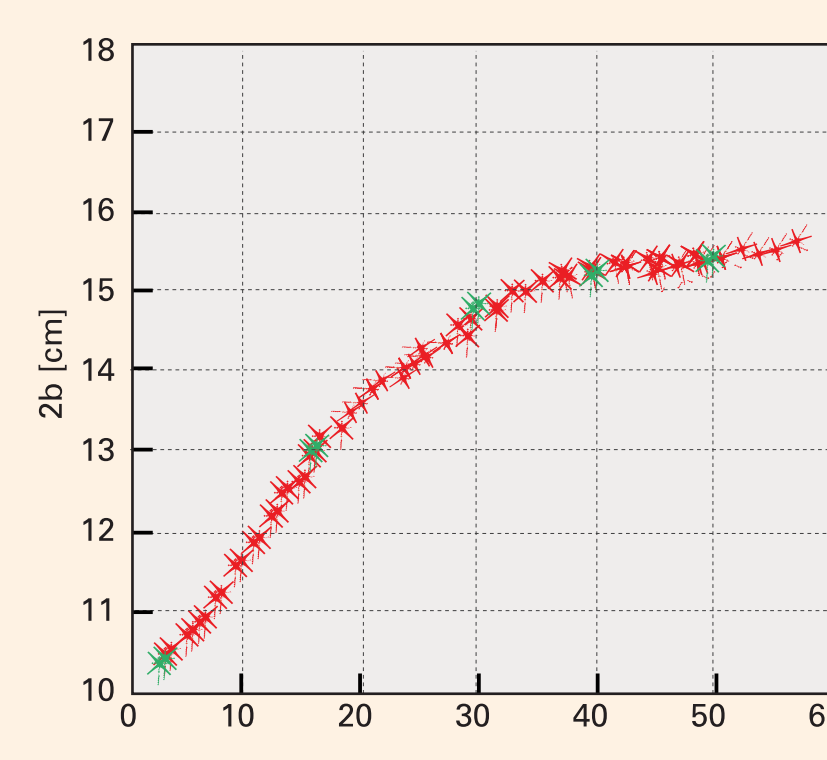


Fig. 10. Evolution of the width of the plug flow zone as a function of time in the symmetry axis at the height 20 cm for the amaranthus seed; 2b - total width of the plug flow zone between the stagnant boundaries.

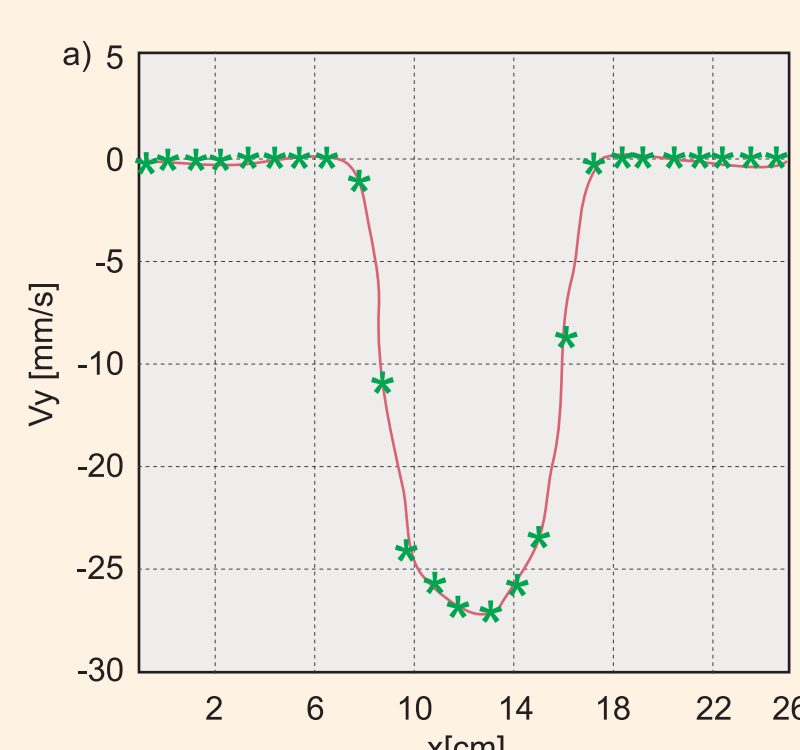


Fig. 11. Profiles of the vertical velocity components across the cavity obtained at heigh $h=15$ cm at time steps: 3.75 s (a), 30 s. (b), and 52.5 s. (c), after beginning of the experiment. Points of the profiles are extracted from the PIV measured velocity vector fields and smoothed with splines (solid lines).

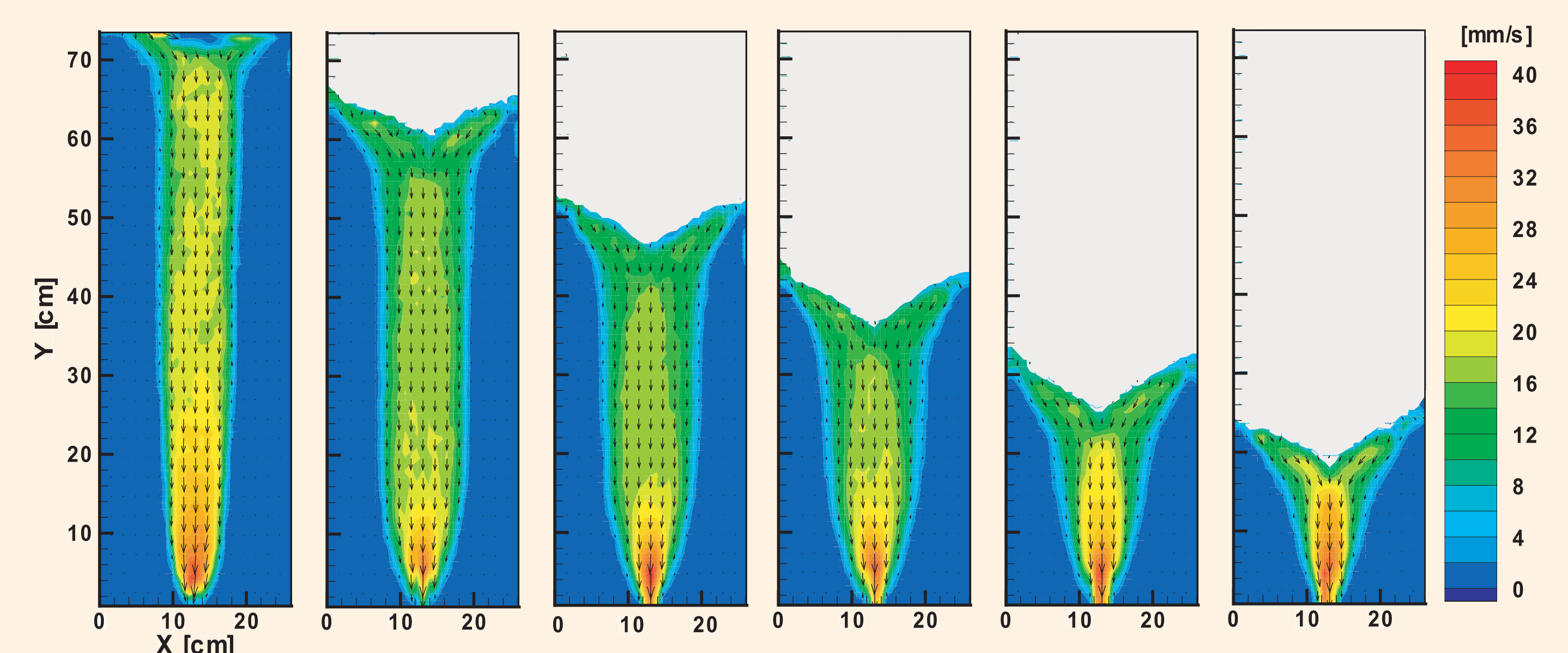
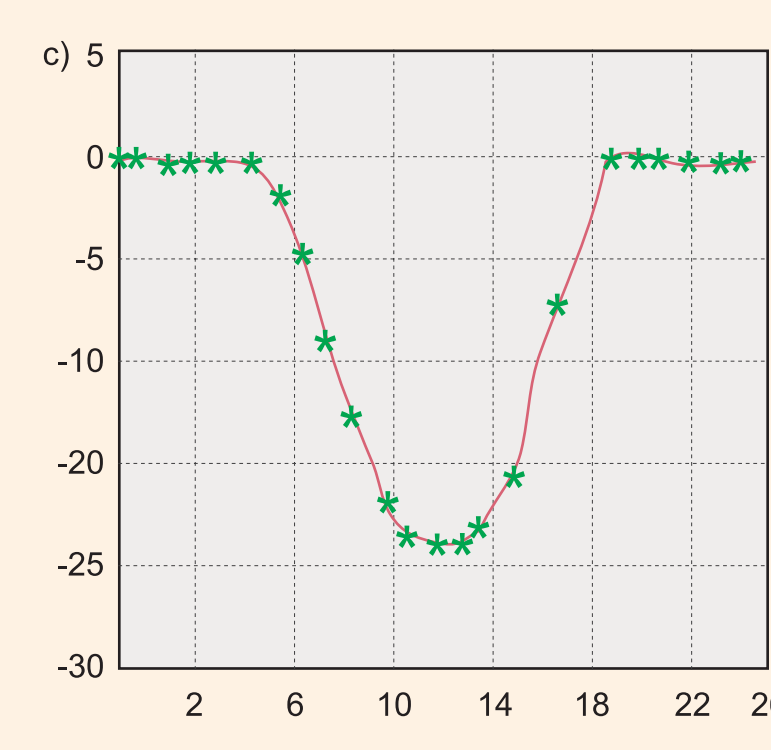
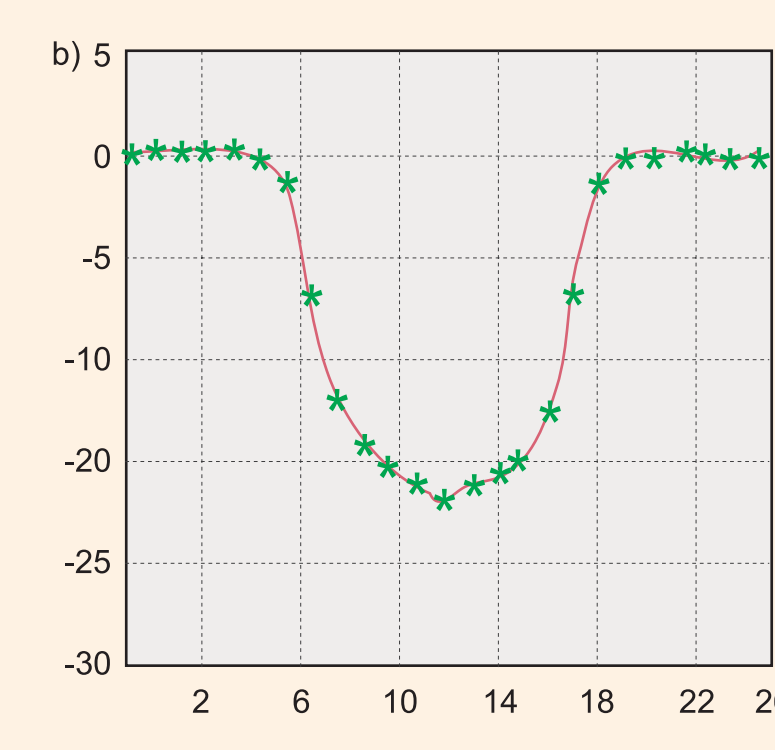


Fig. 4. Velocity distributions on the certain section in the model at time steps: 3.75 s., 15 s., 30 s., 40 s., 52.5 s. and 60 s.

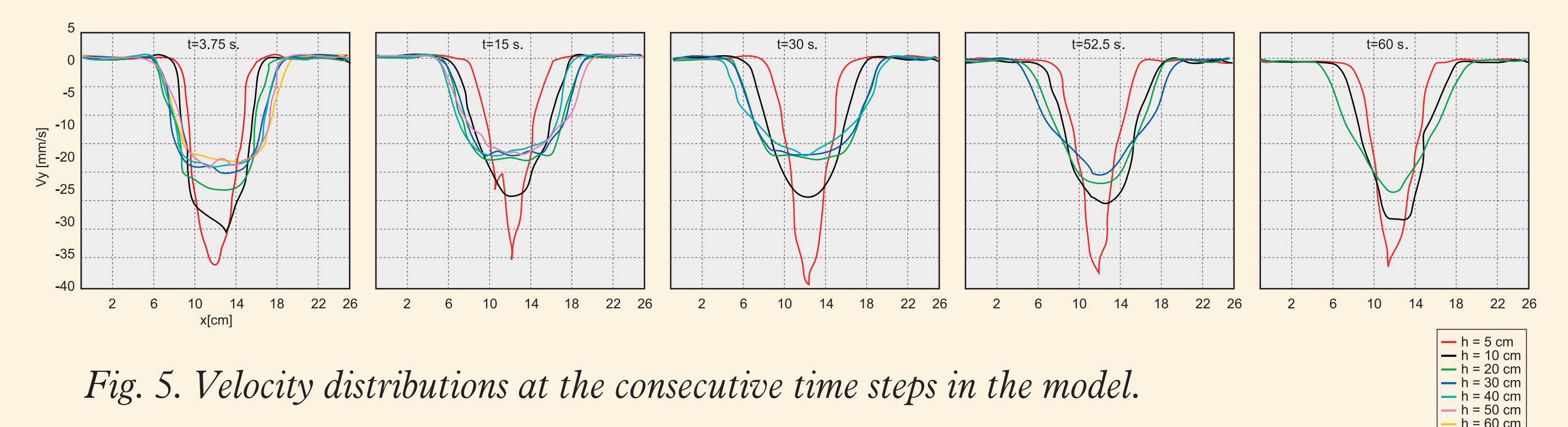


Fig. 5. Velocity distributions at the consecutive time steps in the model.

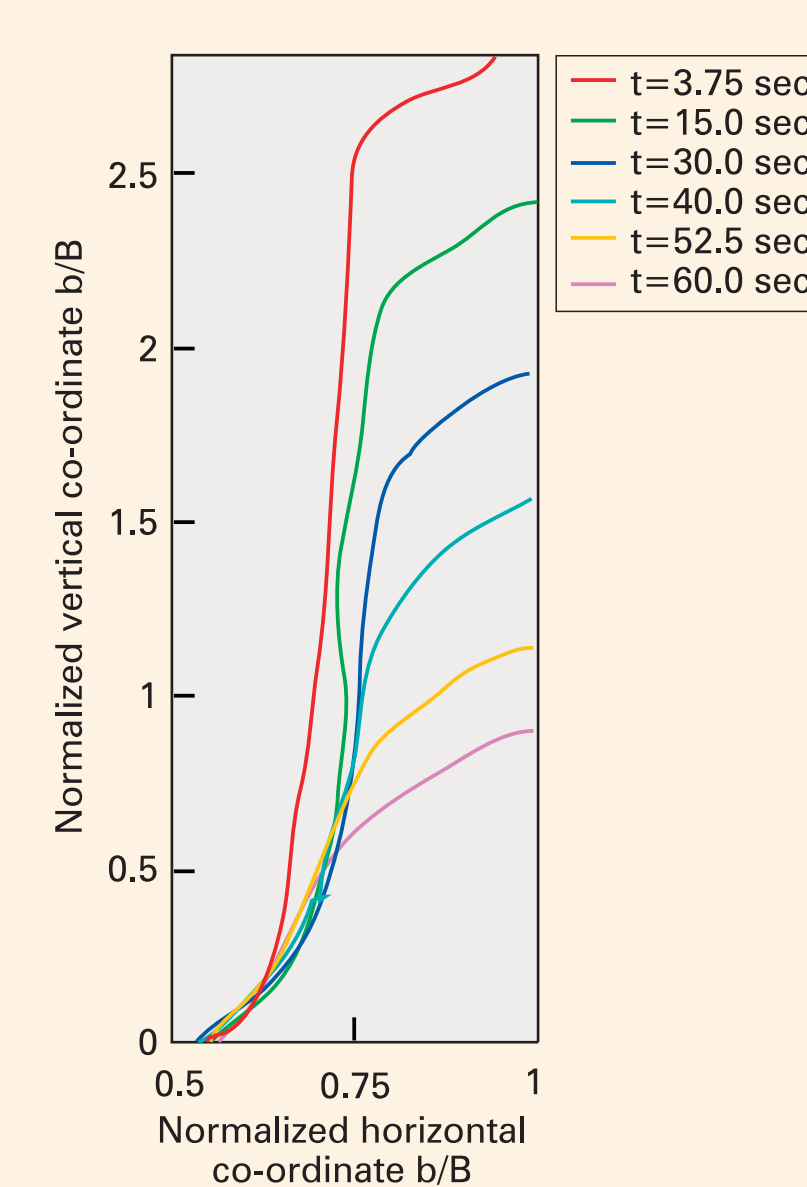


Fig. 6. Experimental measurements of the stagnant boundary - flow of amaranthus

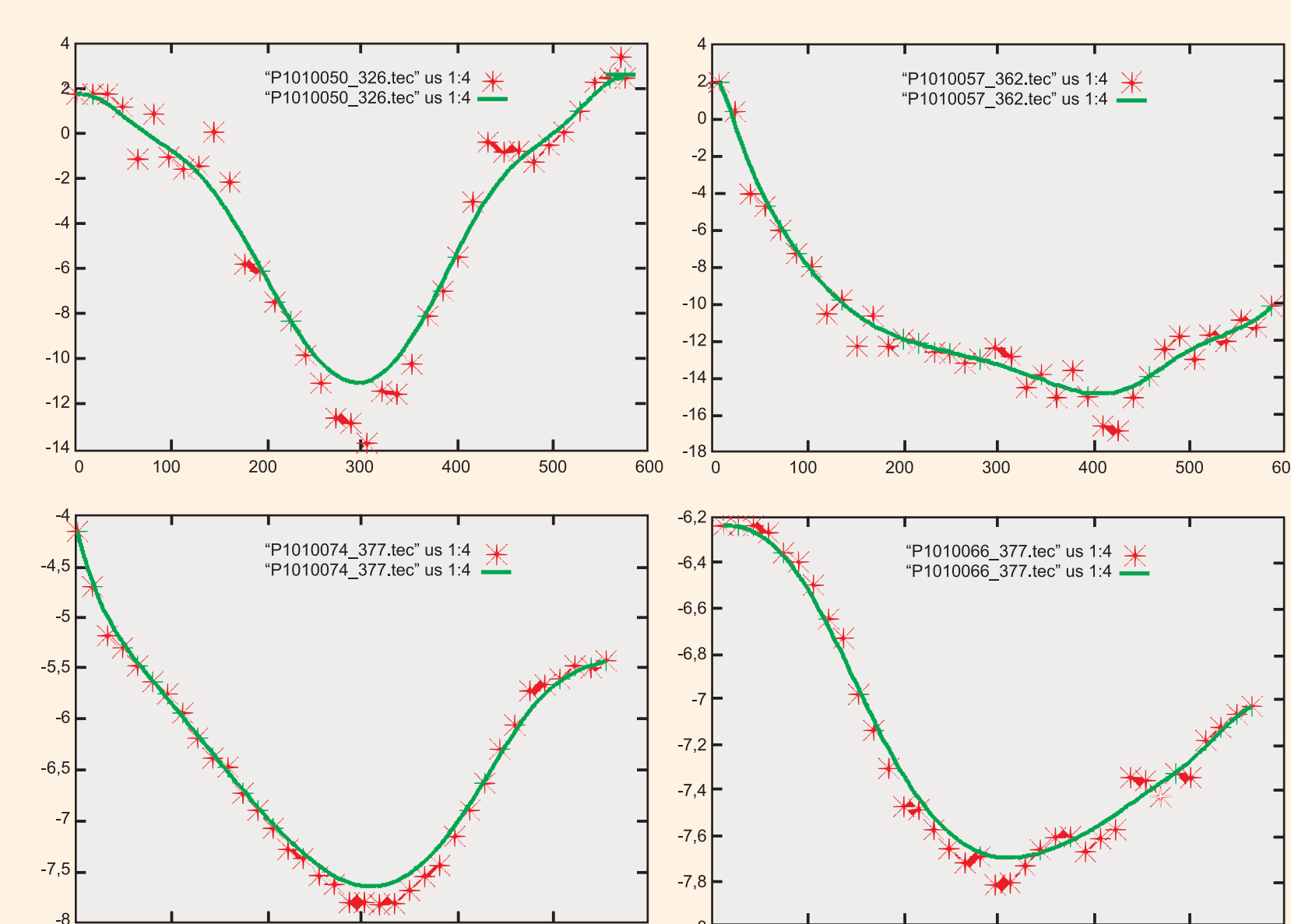


Fig. 7. Velocity distributions on the certain sections in the model.