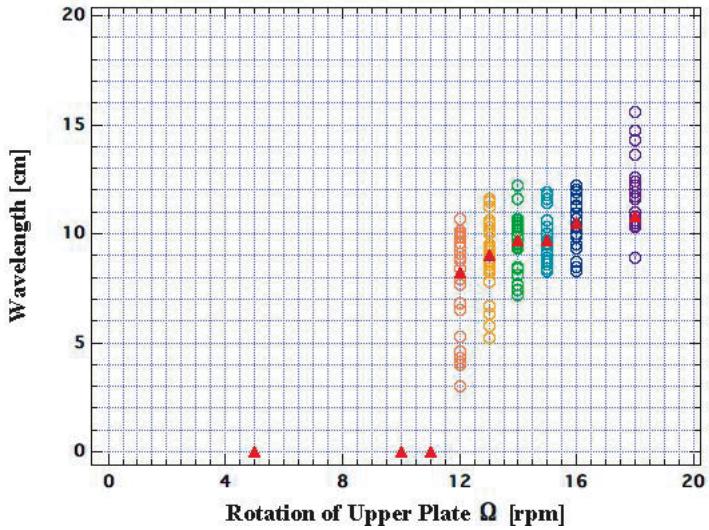
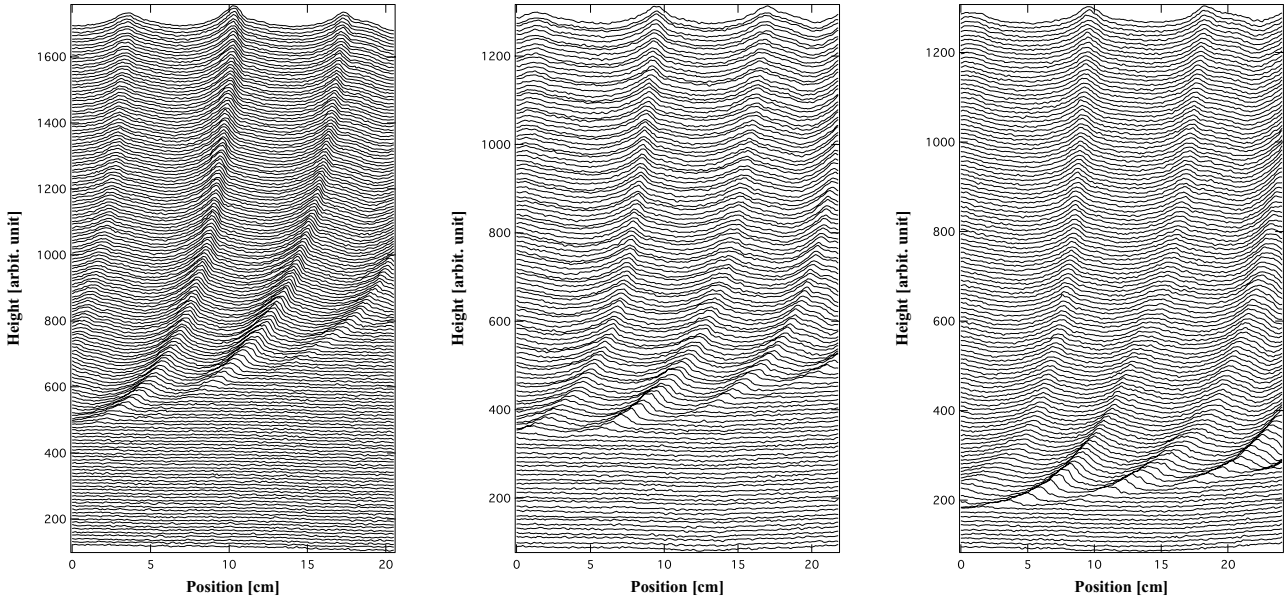


Fig. 3. Onset of sand ripples.



(a) Ω =14 rpm (b) Ω =15 rpm (c) Ω =16 rpm

Fig. 4. Time sequence of sand ripple for (a) $\Omega = 14$ rpm, (b) $\Omega = 15$ rpm, and (c) $\Omega = 16$ rpm. In each figure, the abscissa is the position in the circumferential direction, whereas the ordinate is the height of the granular surface. The data are given at every 15 seconds, whose baselines are shifted by the amount proportional to the elapsed time.

$\bar{D} = 67.5$ cm) with 12 cm height, which are placed at a concentric position with their generators vertically. The upper surface of the annular region is covered by an annular acrylic resin plate, which can rotate at a prescribed angular velocity Ω. Thus our test section consists of outer and inner fixed side walls with separation distance $W = 11.0 \pm 0.3$ cm, a fixed bottom wall and a sliding upper wall whose vertical position H is chosen between 5 and 10 cm. Tap water at room temperature was used as a working fluid, and glass beads of mean diameter $d = 0.06$ cm were placed uniformly on the bottom of the annular region up to a specified height $h = 3.0$ cm. The fluid flow is generated by rotating the upper annular plate at an angular velocity $\Omega = 16$ rpm, which gives a typical velocity $V = 20$ cm/s at the central position of the channel. The detailed velocity profiles are given in our previous paper (Hori *et al.*, 2007). As is reported, the vertical velocity distribution in the bulk is nearly constant, and only a very thin boundary layer of the order of a grain size is present near the granular surface. On the other hand, the horizontal velocity distribution shows almost linear increase toward outer boundary reflecting solid rotation of the annular plate, which imposes shear layers of the order of less than one tenth of channel width near the side boundaries. A digital camera equipped with an automatic recording system was set along the rotating axis at such a distance from the channel that the deformation of the surface of the granular material over the *entire* test section can be observed with sufficient resolution.