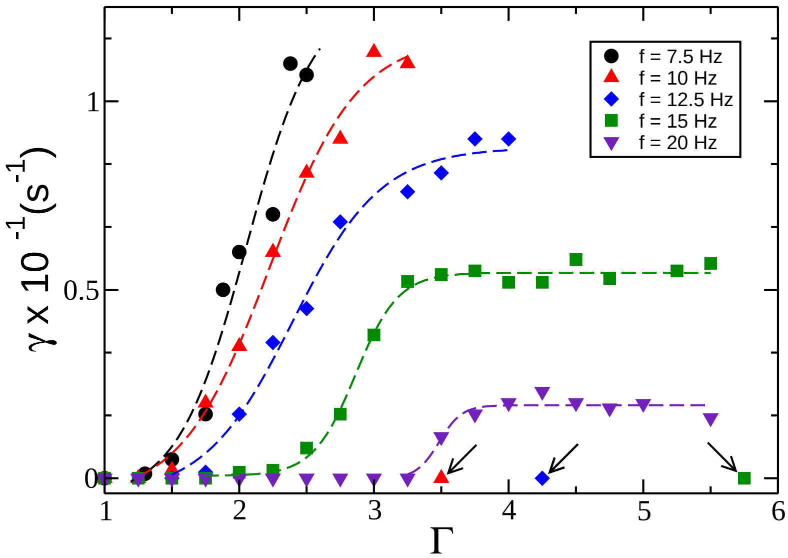

Fig. 3 Growth rate γ versus the maximum adimensional acceleration $\varGamma$. The dashed lines correspond to sigmoidal fits of each curve given by equation (1). Each point represents the average of ten similar experiments, the error bars have been omitted to ease visualization. The three arrows in the graph are pointing to the values $(\varGamma, \gamma)$ that mark an abrupt transition from nonzero γ to zero growth rate at sufficiently large $\varGamma$.

interval $\Delta\gamma$ (gives the range of growth rate from the lower asymptote to upper asymptote); (c) the inflection point $\varGamma_i$; and (d) the width $\Delta\varGamma$ of the transition region.

$$\gamma = \gamma_{max} - \left[\frac{\Delta\gamma}{1 + e^{(\varGamma - \varGamma_i)/\Delta\varGamma}}\right]. \qquad (1)$$

A plot of γ_{max} as a function of the frequency is shown in Fig. 4. This parameter is the saturation growth rate and gives an upper limit for the speed of the upward granular transport through the tube. We observe that the ability of the granular material to flow upwards is reduced as the frequency increases. For higher frequencies we can expect that the granular system approaches a liquid like behavior, and consequently, as the frequency rises it becomes more difficult for the granular bed to climb up.

For each frequency we can separate the observed behavior in Fig. 3 in three regions. One for which $\gamma = 0$ at low $\varGamma$, the second one for which $\gamma \neq 0$, for intermediate values of $\varGamma$; and a third region for which $\gamma = 0$ and $\varGamma$ is high. We can speculate that, for a given frequency, at low $\varGamma$; the granular bed behaves like a solid; at intermediate values of $\varGamma$; a mixed state occurs were the solid like state and the fluid state combine in a complex way to produce the collective upward motion of the grains in one of the branches of the container; and for sufficiently high $\varGamma$ the liquid like state dominates and the grains are unable to climb up on one of the branches of the tube.

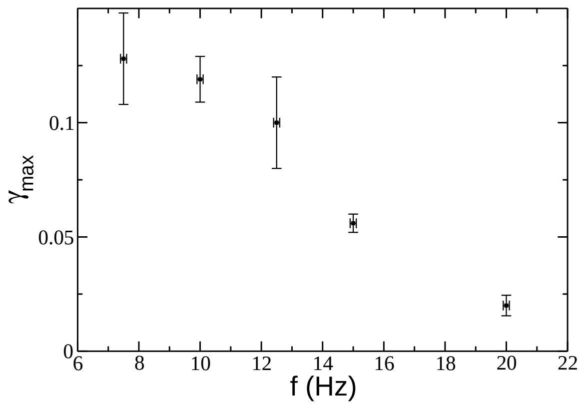

Fig. 4 Plot of the maximum growth rate γ_{max} as a function of frequency. It is clear that higher frequencies reduce the ability of the granular material to flow upwards.

We will now focus below on two types of transitions that were observed. One of them was a (seemingly continuous) transition from zero growth at the lowest amplitudes to a finite γ at higher amplitudes. The other was a “jump” in the value of γ (resembling a first order phase transition), which marked a transition from finite growth rate to no growth, when $\varGamma$ was sufficiently large. A detailed study of each transition requires further investigations. For the case of the abrupt transition, a different experimental setup capable of reaching larger amplitudes is necessary. Nevertheless, our data could give us an insight on the nature of the transition at low $\varGamma$.