Failure Regimes of single wet granular aggregate under Shear

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Highlights

- Shear induced fragmentation and aggregation of a single cluster aggregate.
- Failure regimes: Rigid, ductile and brittle.
- Induced stress variation with respect to various orientation of elongated cluster.
- Effects of mass, hysteresis in capillary bridge force, nature of underlying fluid and internal voidage on Stability of a single cluster under shear.

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The behaviour of a single cluster aggregate made up of sticky wet granulates inside a Couette cell under constant shear has been numerically studied with the help of a Lattice Boltzmann model. Cluster composition and ratio of shear to capillary force present in the clusters have been found to be the two important factors in determining cluster behaviour. Clusters having size below a critical value are found to exhibit rigid translational and rotational movement; above this critical value the cluster breaks. Two broad failure regimes have been identified based on the relative magnitude of shear and capillary forces. For low values of the ratio the clusters are seen to undergo ductile failure either by thinning at the middle or due to severe coiling-recoiling action. At very high force ratios the clusters cannot withstand any shear and almost immediately breaks to form debri-like structures. Failure in these clusters is found to bring down the stress levels in the fluid. Increase in mass, less hysteresis in capillary forces, shear thinning base fluid and intrinsic voidage present in the clusters are found to make cluster-aggregates more susceptible to breakage.

1. Introduction

Granular materials have their wide presence on earth, almost all raw materials for daily usage and industrial applications come in the form of solid granular material. Physical properties of dry granular material like sand dunes in the desert was studied by the scientist for a long time [1]. They could derive an essential relation between the applied shear rate and the local granular temperature, in order to predict the avalanching of dry sand. It was observed that shear and normal forces depended linearly on the shear rate in the viscous regime; as the grain-to-grain interactions increased in the 'grain-inertia' regime, the developed stresses depended on the square of the shear rate and were independent of the fluid viscosity [2-4]. Dry soil does not show any binding characteristics between the particles. A majority of empty space is occupied by air. Moisture in the air can condense in the capillary region formed between two grains even at unsaturated conditions. Thus, limiting moisture content creates a liquid bridge between any two grains touching each other, which exerts an attractive capillary force between the grains [5]. The grains start behaving like sticky particles, gains mechanical strength and now can be converted to any shape. Excessive presence of water reduces and finally helps in eliminating the binding forces. Excessive shear also leads to extension and possible rupture of capillary bridges over the sticky particles. Both of which lead the soil to start moving like a slurry flow. Liquefaction of soil has been found to be a major reason behind natural phenomena like landslides [6].

Wet granulates can also form if the particles are suspended over an underlying fluid at the liquid-air interface and capillary bridges are formed due to the presence of a secondary "sticky" liquid. In the

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