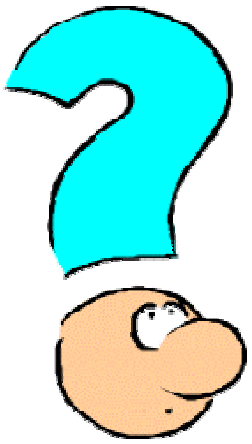
"Know Floe's Korner"



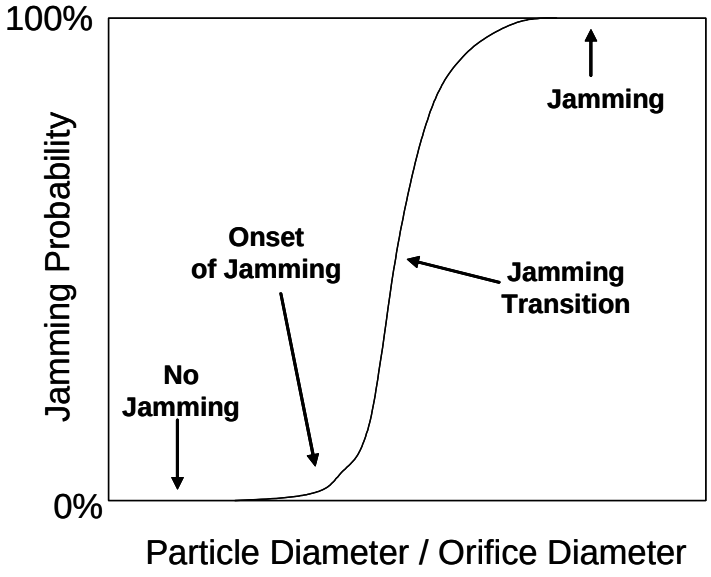
Guidelines to Prevent Particle Jamming or Structural Blockages

Lyn Bates, Ajax Equipment Co., USA
Shrikant Dhodapkar, The Dow Chemical Company, TX, USA
George Klinzing, University of Pittsburgh, PA, USA

With this article, we would like to draw your attention towards an important yet often ignored concept of mechanical jamming of particles. We hope that this article will pique the interest of the research community; thereby leading to further fundamental research.

1 Flow blockages can occur for cohesionless bulk solids when the ratio of particle diameter to discharge orifice diameter exceeds a critical value. When the particles in the flow stream converge towards the discharge outlet, **jamming** can occur if the size of the particles is large enough to sustain a stable interlocking arch. Jamming phenomenon or structural blockage can not be predicted from current theories (Jenike and others) for cohesive materials.

2 Jamming is statistical in nature. The probability of jamming to occur at the outlet depends on the random nature of packing as the particles move towards the discharge outlet. The jamming probability increases with particle size. The problem is further complicated if the bulk material has a wide particle size distribution or multi-modal size distribution and the particles are non-spherical. Various definitions and explanations of onset of jamming and jamming transitions can be found in the literature.



3 Designers of bulk solids equipment have used an **experience based approach** (rules of thumb) since experimental data tends to be scattered, and there are no usable theoretical models. The following guidelines provide a good starting point for design purposes. These suggested figures do not apply to soft, sticky, elastic or plastically deformable particles, for which special investigations should be performed. Also, note that rounded particles are less likely to adopt a stable contact relationship than those that have flat surfaces or are of elongated form.

Orifice dimension as multiple of maximum particle size

Form of flow channel	***Particle shape***	
	Round	***Irregular***
Radial non-mass flow pattern, (from static condition)	7	9
Plane non-mass flow pattern, (from static condition)	5	7
Radial mass flow pattern, (from static condition)	5	7
Plane mass flow pattern, (from static condition)	4	6
Radial non-mass flow pattern, (from dynamic condition)	6	7
Plane non-mass flow pattern, (from dynamic condition)	4	5
Radial mass flow pattern, (from dynamic condition)	5	6
Plane mass flow pattern, (from dynamic condition)	3	4

If it is important that flow stoppages do not take place, then make very generous allowances on the above guidelines, or verify the flow behaviour in representative trials.

4 Select a design for mass flow in the outlet region. If the hopper is not of mass flow design, there is a static bed of product around the discharge orifice. Invariably, some particles will overlap the opening to reduce its effective size and flow has to pass through the rough boundary surface of a static bed of particles. By contrast, mass flow takes place with slip on a smooth boundary that offers very poor support for a stable, structural arch to form. The following link to the video demonstrates reduced jamming tendency in mass flow configuration versus non-mass flow.

http://www.ajax.co.uk/model1.htm

5 Experience suggests that a slot outlet with plane flow is less prone to jamming than circular outlet with three-dimensional convergence. If the outlet is square or circular, the preceding shape can still converge in one direction only to secure the benefits of a plane flow channel.

6 Avoid use of a butterfly valve if possible, as the central blade reduces the flow cross section to two semicircles that are approximately equivalent to openings half the diameter of the valve.

7 Minimize segregation, as the accumulation of larger fractions increases the prospect of jamming. Segregation most commonly occurs during the filling of a container at a single point. Dispersing the feed stream by way of spreading the feed over an area or diverting to a multipoint feed is effective in reducing segregation.

8 Do not restrict the hopper discharge as a slow moving bed of material has less inertia to disturb an instantaneous blockage. The bulk is also in a denser state when flow is restricted because a flow stream is more dilated when moving at higher flow velocities, therefore, there is less room for slow moving particles to escape from a structural load path forming and arch as they touch in a dynamic state.

9 Mechanical vibration can be used an effective discharge aid to prevent particle jamming or structural blockage. Optimal location for application of vibration, specific energy input, amplitude and frequency will depend on the bulk material and system configuration. The effect of vibrations on jamming probability is an open area for further research.

10 Whilst research is handicapped by the numerous factors that influence particle jamming, it would be useful to fit individual contributions into a framework that distinguishes Plane Flow from Radial Flow, Mass Flow from Non-Mass Flow, Dynamic Flow from Incipient Flow, rounded particles from angular particles & so on, and include polydispersity.