Choosing a blender based on your material's flow properties

Knowing your material's flow properties can simplify blender selection by allowing you to predict the material's behavior in different blender types. This article focuses on three conditions required for blending efficiency — a lack of stagnant regions, differences in flow velocities, and a lack of segregation — and how to match your material properties to a blender to achieve these conditions.

Choosing the right blender for your materials can be a difficult and frustrating job. Vendors claim their blenders work efficiently, and their claims are generally true, provided the blenders are correctly chosen for your material. But if you change materials or your material formulation, or if you select a blender that's designed for materials other than the ones you’re blending, you can run into trouble. A materials specialist or calculations based on your material's flow properties can help you match your material with a blender as shown in Table I.

Three conditions must exist for a blender to operate efficiently. First, the blender must have no stagnant regions. Second, the blender must promote different flow velocities in various sections of the blender. Third, blender operation must not segregate, or demix, mixture ingredients.

Preventing stagnant regions

Stagnant regions are areas where materials can sit undisturbed and not enter the mixing process, thus preventing complete mixing from taking place. They exist in the freeboard area (the area between the material bed's surface and the top of the blender) and the area between the agitator blades and blender walls. Limited flow channels, where materials remain segregated in layers or channels during blending, can also produce stagnant regions.

The effect of stagnant regions depends on the mixture and the flow properties of its individual ingredients. For example, using a gravity-flow tube blender to mix cohesive materials results in stable rathole formation around each tube inlet and destroys blender effectiveness. But mixing freeflowing materials in this blender will not result in rathole formation.

An air blender, plow or paddle blender, or even a ribbon blender operating at a high number of revolutions per minute can blow fine particles into the air and cause them to adhere to the freeboard surfaces if the fine material is adhesive. In an air blender, vibrators or special coatings and liners can prevent material accumulation in these regions. These remedies aren’t practical for plow, paddle, or ribbon blenders, so it’s best to avoid the problem by choosing another blender for adhesive materials.

Tumble blenders rely on continual pile formation and avalanche flow in a small region on top of the material pile in the vessel to mix material. An excessively cohesive material will create thick avalanche layers with little interparticle motion. The result is stagnant regions that reduce blender effectiveness. However, a completely free-flowing material can have very thin avalanching zones and also have less-than-optimal interparticle motion. This, too, produces blender inefficiencies. A tumbler blender works best with ingredients that have similar angles of repose and only enough cohesiveness to prevent sifting.
**Promoting differences in flow velocities**

Differences in flow velocities promote mixing. Some blenders include mechanisms designed to produce different flow velocities in the material during operation. For example, the gravity mass-flow cone-in-cone blender promotes a faster velocity in the center of the vessel than on the side. This flow blending velocity profile extends up from the cone-in-cone hopper about one hopper diameter high, typically resulting in a short, squat, low-volume blender. Using a cylinder-in-cylinder retrofit inside the blender’s vertical section above the cone-in-cone hopper section extends the blending profile far up into the vertical section. This can maintain a 5-to-1 height-to-diameter velocity profile ratio, thereby allowing larger blender volumes.

Differences in flow velocities alone are not enough to promote effective mixing. For example, a ribbon blender lifts and transports only a small quantity of material during one revolution, and it tends to lift material more efficiently than it transports material from side to side. The blender’s action promotes differences in flow velocities, but it also causes poor blender operation: It blends well vertically but mixes slowly end to end. Some ribbon blender users have discovered that optimal blending is possible only when in-

**Table 1**

<table>
<thead>
<tr>
<th>Blender</th>
<th>Mixing mechanisms</th>
<th>General description</th>
<th>Flow properties as calculated by Johnson Indices</th>
<th>Sifting</th>
<th>Angle of repose</th>
<th>Fluidization</th>
<th>Air currents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumble (twin-cone V-blender)</td>
<td>The blender’s tumbling action distributes the materials along an ever-changing angle of repose surface.</td>
<td>Materials with the same angle of repose within ±2 degrees that are not cohesive or lumpy, but have sufficient cohesion to prevent sifting.</td>
<td>0.2 ≤ Arching Index ≤ 0.6 feet 0.2 ≤ Rathole Index ≤ 3 feet Flow Rate Index ≥ 100 lb/min</td>
<td>High</td>
<td>Very High</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Ribbon</td>
<td>Inside and outside ribbons convey materials in opposite directions, forcing them to intermix.</td>
<td>Moderately cohesive materials of similar particle densities, without floculating tendencies.</td>
<td>0.2 ≤ Arching Index ≤ 0.6 feet 0.2 ≤ Rathole Index ≤ 3 feet Flow Rate Index ≥ 100 lb/min</td>
<td>High</td>
<td>Moderate</td>
<td>To high depending on speed</td>
<td>Low to moderate with a dust collector</td>
</tr>
<tr>
<td>Flow or paddle (horizontal or vertical, single or multiple-shaft)</td>
<td>Materials are thrown about, providing great particle mobility, large flow velocity differences, and rapid mixing.</td>
<td>Cohesive materials or those that require liquid addition or lump breaking. Frangible materials will degrade in particle size. Fluidizable fines can be added if there are sufficient cohesive components to mix with the fines and prevent fluidization or air entrainment. With cohesive materials, it may be necessary to run the blender during discharge.</td>
<td>0.2 ≤ Arching Index ≤ 0.6 feet 0.2 ≤ Rathole Index ≤ 3 feet Flow Rate Index ≥ 100 lb/min</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Screw</td>
<td>Materials are lifted from the bottom to the top of the hopper and exchanged with materials on the way up.</td>
<td>Moderately cohesive materials that don’t contain hard lumps.</td>
<td>0.2 ≤ Arching Index ≤ 0.6 feet 0.2 ≤ Rathole Index ≤ 3 feet Flow Rate Index ≥ 100 lb/min</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Gravity-flow tube</td>
<td>Materials that are drawn from various bin levels by tubes accessible at the bottom.</td>
<td>Very free-flowing and uniformly sized materials with a low angle of slide on the bin wall surface. Cohesive materials will block the tubes.</td>
<td>Arching Index ≤ 0.2 feet 0.2 ≤ Rathole Index ≤ 3 feet Flow Rate Index ≥ 100 low uniformly sized particles</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Gravity mass-flow (cone-in-cone, cylinder-in-cylinder, or one-dimensional convergence arch breaking hopper) ¹</td>
<td>Cone-shaped or cylindrical inserts in the blender’s hopper and cylinder produce differential flow velocities, promoting mixing at the blender's discharge.</td>
<td>Low to moderately cohesive materials. A cone-in-cone must also have a fluidizable material to prevent preferential flow patterns.</td>
<td>0.2 ≤ Arching Index ≤ 1 feet 0.2 ≤ Rathole Index ≤ 1.5 feet Flow Rate Index ≥ 100 for cone-in-cone blender only</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Air</td>
<td>Materials are moved upward by air jets, causing differential movement.</td>
<td>Easy-flowing, slowly sized materials without a fluidizable component.</td>
<td>0.2 ≤ Arching Index ≤ 0.6 feet 0.2 ≤ Rathole Index ≤ 3 feet Flow Rate Index ≥ 100 lb/min</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Notes: ¹ The Johnson Indices are used to determine material flow properties. Three indices are referenced on this chart: The Arching Index provides the minimum outlet diameter (in feet) required to prevent material from arching in a monofluidic conical hopper or blender with typical impact pressures from material filling. The Rathole Index is the flat conical hopper outlet diameter (in feet) required to provide complete discharge of a cohesive material. The Flow Rate Index is the rate at which a material will exit a 1-foot-diameter outlet in a conical mass-flow hopper. For more information, contact the author.

² All equipment mentioned in this article is available in designs from various equipment manufacturers, except for the cylinder-in-cylinder retrofit and the one-dimensional convergence arch breaking hopper, which are developed patented and licensed by JR Johnson.
individual ingredients are layered in the blender, because layering, in effect, does some of the mixing job, thereby decreasing reliance on flow velocity differences.

Preventing segregation

Sometimes blender operation segregates individual ingredients during operation and discharge. For example, because a V-blender relies on continual pile formation to blend material, segregation can occur if the mixture's individual ingredients have different angles of repose or if sifting takes place. This produces a nonuniform mixture. Selecting another blender can help decrease segregation, as can retrofitting a V-blender with a device such as a one-dimensional convergence arch-breaking hopper at the V-blender outlet. This device causes flow across the blender’s entire width, which can reduce segregation to an acceptable level.

Air currents within the blender can also segregate ingredients. For example, a ribbon blender typically has several feed ports. Connecting one port to a dust collection system leads to fines accumulation below that port. Since a ribbon blender mixes poorly from one end to the other, operating a dust collection system during blending can cause segregation, reducing blender effectiveness and increasing blending times.

For a list of common blenders and descriptions of their mixing mechanisms, the materials that mix well in them, and their comparative segregation mechanisms, see Table I.

References

1. One calculation tool is the Johanson Indices, a group of eight formulas that measure material flow properties and prescribe parameters for selecting material handling equipment. More information about them can be obtained from the author.

2. All equipment mentioned in this article is available in designs from various equipment manufacturers, except for the cylinder-in-cylinder retrofit and the one-dimensional convergence arch-breaking hopper, which are devices patented and licensed by JR Johanson.

For further reading

Find more information on blenders in articles listed under “Mixing and blending” in Powder and Bulk Engineering’s comprehensive “Index to articles” (in the December 2000 issue and at www.powderbulk.com).

Lee Dudley is a consulting engineer with JR Johanson, 712 Fiero Lane, #37, San Luis Obispo, CA 93401; 805-544-3775, fax 805-549-8282 (info@jrjohanson.com). He has a degree in chemical engineering from the University of Washington, Seattle, and has been working with solids flow problems, with a special emphasis on batch and continuous mixing processes, for 25 years.