

Gauging Green Sand Flowability Helps Predict Mold Quality

Due to the introduction of a new method of measurement, a sand's flowability can now be used as a direct indicator of mold quality.

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In current practice, the sand control efforts of many green sand foundries don't go much beyond maintaining a target green compression strength. Yet to consistently produce high-quality castings, a molding sand must maintain certain values within a multitude of properties.

Not only are these foundries denying themselves vital information by ignoring other mechanical properties, the value of the green strength measurement may itself be misleading. This is because the final characteristics of the finished mold are greatly influenced by sand density at the mold metal interface. Variations in density at this interface can be attributed to a sand's ability to flow freely and compact into a dense mass around a pattern under the influence of an externally applied force (jolt-squeeze, for example).

Controlling this ability of the sand to flow freely around the pattern is extremely important. The flow must overcome friction between sand and the pattern walls of narrow pockets, between patterns, or between patterns and flask walls. Sand with poor flowability tends to form void spaces at the mold-metal interface that are larger than the individual sand grain size. These voids can result in rough casting surfaces and metal penetration. This sand's poor packing densities reduce the number of contact points and clay binder bridges between the grains, resulting in low mold strength. Low packing densities can also result in shrinkage, sand erosion defects and oversized castings.

Therefore, thorough knowledge of a sand's flow characteristics is important to the metalcaster. A new method of determining a sand's flowability via stress-strain curves has been developed to help foundries quantify this important sand quality indicator.

The Problem

Sand flowability has been a topic of concern to foundrymen for decades. As many as 12 different methods have been put forth to measure it. None of these, however, has been universally adopted as a reliable indicator of flowability. These methods can be clas-

sified into three broad categories: hardness gradient, extrusion, and deformation vs. compaction methods.

Most of the instruments previously devised for these methods used mold hardness measurements to quantify flowability. The accuracy of this concept is suspect, since mold hardness numbers are affected not only by mold density, but also by bond strength. Other measurements of flowability concentrated on the ability of a prepared molding sand to extrude through an orifice or move perpendicular to the direction of compaction forces. Since this type of sand movement is rarely encountered in everyday foundry operations, these measurements are also of questionable benefit.

The search for a measurement device that would be extremely sensitive to changes in a molding sand's flowability led to the development of a method that expands and enhances the standard green sand compression strength test. This new method uses sensitive computer technology to measure the stress-strain characteristics of a standard 2x2 in. AFS cylindrical test specimen under a continuous compressive load.

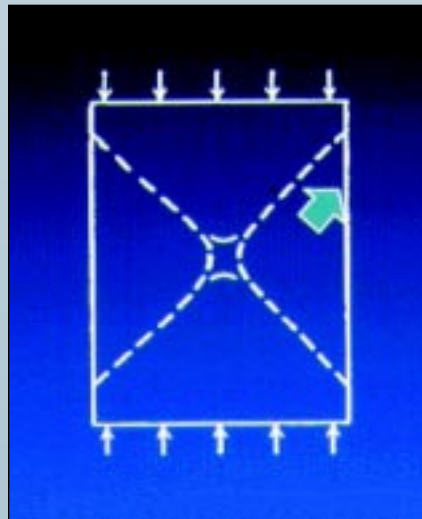


Fig. 1. This drawing depicts the typical shear or "cone" type failure of a standard cylindrical molding sand specimen under a compressive load.

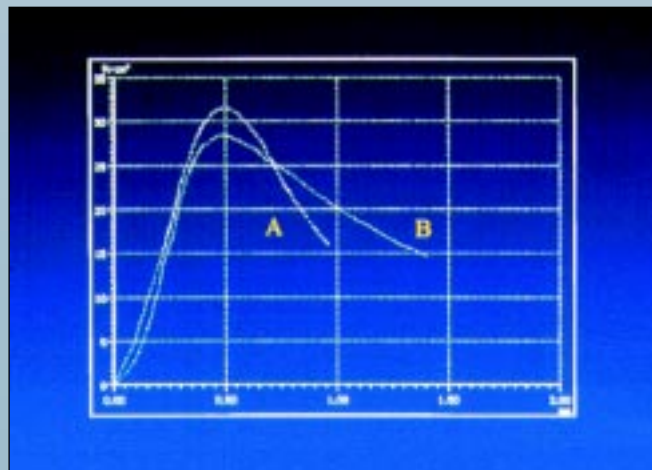


Fig. 2. This chart shows the stress-strain curves of two molding sands. The highest point on each is its maximum strength. The angle of the falling slope from that point indicates a sand's flowability. Here the sand represented by Curve A exhibits better flowability than that represented by Curve B.

Experimenting

A literature review of relative research makes it plain that sand movement under compacting forces proceeds in horizontal layers and is greatly influenced by vertical shear between the sand grains. There are also considerable frictional losses between the pattern and flask as sand moves downward toward the pattern plate. Therefore, it was determined that the essential properties that influence flowability are:

1. The shear resistance (force required to start flow or movement);
2. The ease of movement after the flow has started (resis-



Fig. 3. This instrument, comprised of a hydropneumatic press, microprocessor, keyboard, monitor, displacement transducer and electronic load cell, provides the first accurate way to quantify a sand's flowability.

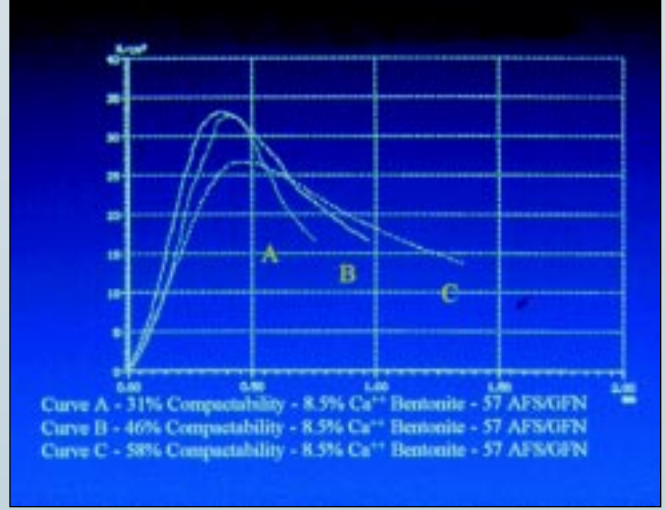


Fig. 4. This chart shows the stress-strain curves of an 8.5% calcium bentonite sand mix at three different compactibilities. Sand A, at 31%, shows the best flowability.

tance to the movement of the mass).

The strength of prepared molding sand can be measured in tension, shearing or sliding, as well as in compressive stresses. Due to the difficulty of obtaining reliable and repeatable tensile strength data, most foundries have chosen to measure compressive strength.

A brittle material such as molding sand is much weaker in tension and shear than in compression. Generally, failures in molding sands under compressive loads are essentially shear failures on planes. A shear or cone of failure is typical when applying a compressive load to a standard cylindrical molding sand specimen (Fig. 1). The inclination angle of the cone of failure is determined by the angle of internal friction, which is typically 44–49 degrees for a standard three-ram specimen.

In the case of materials made of granular components, the resistance to failure under shearing stresses is a function not only of the adhesion, but also of the frictional resistance to the sliding of the rupture surfaces. The shear stress that accompanies strain may be thought of as arising from the effort of thin parallel slices of the specimen to slide over one another.

The typical "hourglass" failure of a molding sand under a compressive load yields an excellent opportunity to measure the initial force required to start flow and the force necessary to maintain flow. When applying a compressive load to a standard specimen an instrument must accurately mea-

sure and plot the stresses and corresponding strains after the point of maximum green compression strength. From these results, it is possible to assess the sand's resistance to flow between the planes of failure.

When compressing a molding sand sample, the compressive force rapidly increases up to a point called maximum strength. After the point of maximum strength, the strength of the specimen declines. This is illustrated on the stress-strain curve (Fig. 2). This portion of the curve, referred to as the falling slope, is indicative of both the cohesion of the bonding materials and the resistance of the molding media to move under a compacting load. This falling slope gives an excellent indication of a sand's flowability.

The more fluid the sand is, with lower cohesion and internal friction, the less shearing energy is required to displace the moving plane. A very rapid deterioration of strength after maximum compres-

sive strength (a sharply falling slope) indicates that the sand has good flowability characteristics. Those with a low flowability value would exhibit a gradual falling slope on the stress-strain curve.

This concept may also be useful in measuring sand brittleness. Brittle molding sands lack plasticity and are susceptible to a variety of molding problems, including broken edges and molds. Sands that are extremely brittle should have steep falling slopes similar to sands with good flow characteristics.

A New Instrument

To determine the stresses and corresponding strain after the point of maximum strength, a computerized strength and deformation instrument was designed and constructed. The object of the instrument is to provide a method and system for testing molding sand providing stress-strain test curves. The primary components of the instrument are a hydropneumatic press (including a movable specimen supporter), microprocessor, keyboard, monitor, displacement transducer and electronic load cell (Fig. 3).

To operate the instrument, a standard AFS cylindrical sand specimen is loaded within the specimen supporter located on the moveable arm. When the testing sequence is initiated, the hydropneumatic press applies a compressive load on the sand specimen. The displacement transducer generates a strain-representative signal and the load cell generates a stress-repre-

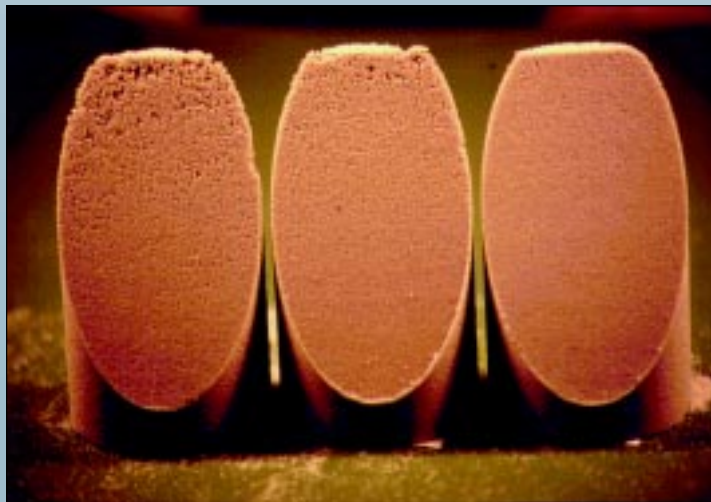


Fig. 5. This photo shows the qualitative effects of compactibility on 1-ram Rowel specimens. From left to right, they have compactibilities of 58, 46 and 31%. Note difference in quality at lesser compactibilities.

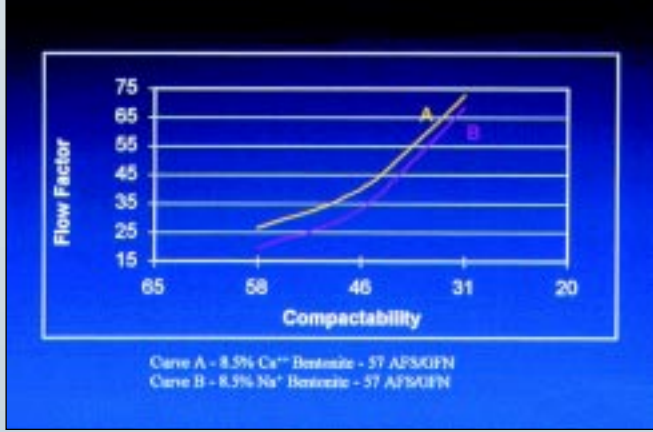


Fig. 6. This chart illustrates the effect of compactibility on clay type and flow factors. It clearly shows that the drier a sand is, the freer it flows, regardless of the type of bentonite in the mix.

sentative signal of the sand sample being tested. The signals are displayed in real time on the monitor. The computer performs calculations according to operator-determined preset values to generate a falling slope number. A sand's "flow factor" is calculated by dividing the falling slope by the compressive strength. Lower absolute flow factors indicate a higher resistance sand that opposes movement under compaction.

Using this instrument, data was generated from laboratory-controlled batches of green sand prepared in a 50 lb vertical wheel batch muller, with each batch mulled for 10 min. Batch formulas were chosen to represent molding sands expected to have high and low flow characteristics. Water was added to maintain three predetermined compactibilities: high—58%; medium—46% and low—31%. A total of 30 batches were prepared using three different silica sands.

Four green compression strength specimens were made from each batch, and were tested on the instrument described above. Compression values were averaged to represent each batch.

Results

Compactibility—A substantial decrease in flow factors was experienced with increasing compactibility percentages. Regardless of the batch formula, an increase in the water to clay ratio

resulted in lower flow factors. Figure 4 shows examples of stress-strain curves from sand batches prepared in all three compactibility categories. The curves clearly show a change in downward inclination associated with the reduction in the water to clay ratio. Figure 5 shows a qualitative example of this inclination in the pictured test specimens. Changing the compactibility of sodium bentonite mixes from 58 to 31% improved the flow factor by 345% (Fig. 6). This points out the importance of automated compactibility controls to precise sand properties.

Bentonite—Table 1 shows the data from the tests on mixes with 8.5% of both bentonites. The type and percentage of bentonite affects the flow factor at all compactibilities. Referring to Fig. 6 again, we see that the effect of bentonite type on flowability is less at low compactibilities. In other words, when dry, a sand is more free flowing, regardless of bentonite. Flow factors were lower in sand mixtures containing 8.5% sodium bentonite, compared to sands prepared with the same percentage of calcium bentonite. In all sands tested, reducing the bentonite percentage increases the flow factor. Lowering sodium bentonite percentages from 8.5% to 6% increased the flow factor 93%.

Flowability Enhancers and Cereal Additives—The addition of flowability enhancers to 8.5% sodium

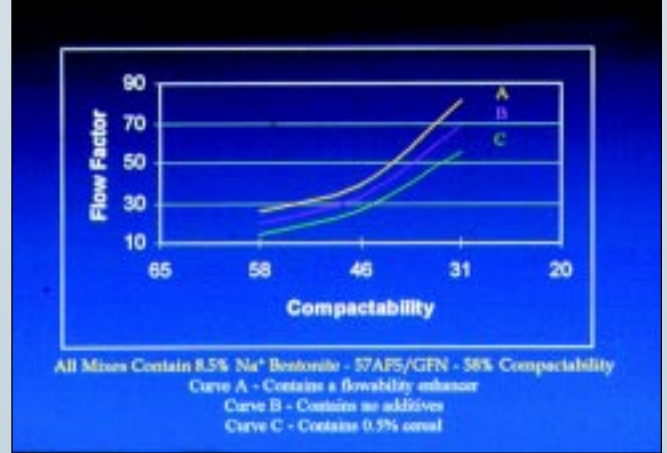


Fig. 7. From this chart, we see that flowability enhancers greatly improve the sand's flowability, while a cereal addition lowers it.

bentonite mixes resulted in increased flow factors at each compactibility level, compared to mixes without them. These enhancers increased the flow factors in the sodium bentonite mixes to nearly equal to those of the calcium bentonite at each compactibility level. Conversely, flow factors were lowered by adding 0.5% cereal to both sodium bentonite and calcium bentonite sand mixes. Figure 7 shows the effects of flowability enhancers and cereals at the various compactibility percentages.

Sand Distribution and Average Size—Of major significance was the sensitivity of the new instrument in measuring the effects of changes in sand grain size and distribution. Changing the screen distribution from a 3- to a 4-screen sand while maintaining a constant AFS Grain Fineness Number (GFN) increased the flow factors. The magnitude of this improvement was influenced by compactibility. At 58% compactibility, the increase in screen sand distribution resulted in only a small flow factor increase. Decreasing the compactibility caused flow factors to increase at a more rapid rate with the change in screen sand distribution. Increasing AFS GFN boosted the flow factor compared to coarser sands of equal compositions and compactibilities. An increase in flow factors was also experienced with an addition of 5% 330-mesh silica flour.

The development of this new method and instrument will help foundries more closely control the quality of their molds by adding the dimension of flowability to their sand quality efforts. ▼

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Table 1. Results of Tests on 8.5% Bentonite Sand Mixes

Compactibility	Falling Slope	Flow Factor	Green Compression Strength
8.5% Calcium Bentonite			
58	-505.60 psi	26.80	18.86 psi
46	-907.10 psi	40.40	22.56 psi
31	-1625.00 psi	72.86	22.30 psi
8.5% Sodium Bentonite			
58	-401.00 psi	19.89	20.16 psi
46	-794.00 psi	33.50	23.70 psi
31	-1765.00 psi	68.67	25.70 psi