Molding sand must be controlled to produce world-class castings competitively. One of the most fundamental tasks of sand control is monitoring sand temper. However, poor control of temper remains the leading cause of casting defects. If temper isn’t controlled properly, what results are defective, dimensionally inaccurate or scrap castings.

While the concept of compactibility control has been around since the late 1960s, many foundries with automated mold lines are still using controls that are inconsistent with the fundamental principles of compactibility control.

A Lesson in Sand Temper

Moisture is a measure of the water in the sand. Water must be added to the sand until the sand is tempered, or until it reaches a low bulk density through activation of bond. Moisture levels that are insufficient or in excess of what is required to activate the bond must be avoided.

Compactibility is a measure of sand temper that is inversely related to bulk density. It is a mechanical property related to the percentage decrease in height that the sand will compact at the molding machine. With automated molding systems, compactibility must be held constant.

Some may ask, “Why not simply determine how much moisture is required to obtain a target compactibility level and then hold the moisture addition constant at this level?” This is the old

<table>
<thead>
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<th>Table 1. System Sands Included in Fig. 1.</th>
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<td><strong>Sand Type</strong></td>
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<tr>
<td>1. Synthetic malleable facing sand, automatic jolt-squeeze molding, high thermal stress, facing sand prepared from return system sand plus about 1% new silica sand and about 2% sodium bentonite and little pitch</td>
</tr>
<tr>
<td>2. Synthetic malleable facing sand, automatic jolt-squeeze molding, medium thermal stress, facing sand prepared from return system sand plus about 1.5% sodium bentonite and 1% seacoal. New sand introduced via cores only</td>
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<tr>
<td>3. Synthetic malleable facing sand, automatic jolt-squeeze molding, medium thermal stress, facing sand prepared from return system sand plus about 1.5% sodium bentonite and 1% seacoal. New sand introduced via cores only</td>
</tr>
<tr>
<td>4. Synthetic malleable facing sand, automatic jolt-squeeze molding, medium thermal stress, facing sand prepared from return sand plus about 1.5% sodium bentonite and 1% seacoal, bentonite and seacoal of different origin that 1, 2 and 3. New sand introduced via cores only</td>
</tr>
<tr>
<td>5. Semisynthetic gray iron unit sand for medium-sized castings, prepared from return sand of several sand systems with additions of new, silica sand, sodium bentonite and seacoal, hand-operated jolt-squeeze molding machines</td>
</tr>
</tbody>
</table>

Fig. 1. This chart shows the compactibility-moisture relationships of three test mixtures (T) of silica sand with increasing southern bentonite content (S, 7.5 and 10%) and five system sands with increasing water requirement.
concept of moisture control, which has proven to be impractical. The problem with moisture control arises from the fact that the sand composition changes, the amount of moisture needed to produce the target compactibility changes. For example, the more bond, seacoal and other carbonaceous additives, the more moisture the sand requires to reach its temper point.

Figure 1 and Table 1 are part of the report that introduced the compactibility test in 1969. Figure 1 shows curves of compactibility vs. moisture for several samples of molding sand (Table 1). Note that each of the sands requires a different amount of moisture to maintain a given level of compactibility.

The difference in moisture requirement at the desired compactibility level is due to differences in the amounts of moisture-absorbing materials in the sands: Sand 5 has the greatest amount of moisture-absorbing materials, therefore requiring the most moisture (about 2.5%) to maintain 45% compactibility. Sand 75 has the least amount of moisture-absorbing materials and requires only about 1.8% moisture to maintain 45% compactibility.

If moisture is held constant at any particular level, compactibility will vary with sand composition. Figure 2 shows three sands with different compositions. Sand 1 has a low amount of clay, carbonaceous materials and other moisture-absorbing materials and requires only 2.8% moisture to produce 40% compactibility. Sand 3 has a relatively high amount of moisture-absorbing materials and requires 5.1% moisture to produce 40% compactibility.

If 3.4% water were added to Sands 1 and 3; Sand 1 would have a high compactibility due to excess water, and Sand 3 would have a low compactibility due to insufficient water. Sand 1 will require far less moisture than Sand 3 to produce a target compactibility of 40%. Moisture can be used as a control because the amount of moisture required to achieve a desired compactibility is not known unless the sand composition is known.

It is necessary to know the amount of bond and other moisture-absorbing materials in the sand to predict the proper amount of moisture. This information, however, isn't known on a real-time basis at foundry mixers. Sand composition can be determined through laboratory testing, which provides an important means of recording and monitoring changes in the system. Laboratory testing, however, isn't timely enough to be used as a real-time control.

**Moisture vs. Compactibility**

Moisture control involves holding the water addition constant. It isn't suitable for controlling molding sand because as the sand composition varies, so does its moisture requirement.

True compactibility control differs from moisture control in that the compactibility of a sample of sand is measured, and moisture addition to that same sand is adjusted to obtain the target compactibility level.

**Inaccurate Tests**

Unfortunately, many foundry officials today believe they're using the compactibility test, but are actually controlling sand based upon the constant moisture principle (Fig. 3). Constant moisture involves measuring incoming sand temperature and moisture, and attempting to predict the water addition necessary to bring the compactibility to a particular level (steps B-C in Fig. 3). After a prediction is made, the water is added, the sand mixed and then discharged (Steps D-E in Fig. 3).

Proper moisture addition can't be predicted based on temperature and moisture because it depends on sand composition. In this example, another factor is entered into the prediction. After the water is added, the compactibility of the sand produced by the prediction is measured on the sand coming out of the mixer (Steps F-G in Fig. 3). This provides feedback on whether the amount of moisture predicted was correct.

If the compactibility isn't on target, the out-of-specification sand is sent to molding, and the feedback from the out-of-specification sand is used to make an adjustment to the last moisture prediction (step G1 in Fig. 3). The new calculated moisture addition is then used as a prediction for controlling the water addition for the next sand.

Compactibility is being measured in the process but true compactibility control isn't being exercised. The water addition is controlled by attempting to determine a specific water addition that provides the desired compactibility, and then holding this moisture level constant. This is actually control based on a principle of constant moisture.

A constant moisture approach will work on a few systems, but only if the sand composition is consistent. If it is inconsistent, the proper water addition prediction cannot be reached because the target constantly changes.

For example, consider Sands 3 and 4 in Fig. 1, which are similar except for the clay and sand ratio. Assume a target compactibility of 40%. If the sand in the mixer had the composition of Sand 3, the moisture prediction for 40% compactibility would eventually (through feedback) be adjusted to 3.8%, which would be the proper amount for this sand.

A problem could arise if a change occurred in the sand composition that raised the level of the moisture-absorbing materials going into the mixer, such as an increase in clay content for a job with deep draw pockets. If the clay level were to increase and the sand composition changed to that of Sand 4 and 3.8% moisture were maintained, the compactibility of the sand coming out of the mixer would drop to 24%.

This would be detected as the sand is discharged from the mixer and sent to the molding stations dry. If molds were produced with that sand, they could produce dry sand defects such as inclusions, eosions, cuts and washes.

If the sand composition remained similar to Sand 4...
for any length of time, the moisture prediction would eventually be raised to 4.8%, which would then be correct to produce 40% compactibility, and the system would be on target again.

Once adjusted and on the new target of 4.8%, the system will remain on target until the sand composition changes again. When the sand composition changes again (for example, if there has been a large influx of core sand that dilutes the return sand or if the bonding system was plugged and less bond was added to the system), there would be less moisture-absorbing materials in the sand.

If the composition then resembled Sand 3 and 4.8% moisture were added, the compactibility would increase to 55%. This would be detected when the sand exited the mixer or in the mold area where the wet sand produced during the period of adjustment was found to be nonflowable and difficult to compact. If molds were produced from the sand prepared during the period of adjustment, the castings would be subject to core sand-related defects such as swells, supervoids on vertical faces, roughness and gas-related defects such as blow and pinholes.

As previously mentioned, the constant moisture approach works only if the sand composition of the system is consistent. The system would need to have a near constant sand-to-metal ratio, degree of core sand dilution, fines and oxides level. The amount of spill sand, unpuered molds and all variables affecting sand composition and moisture requirement would have to be kept under close control.

Every time the sand composition changes, there will be an adjustment period until compactibility is back on target. During each adjustment period (every time path G1 in Fig. 3 is followed), out-of-specification sand will be sent to the molding stations, which in turn could lead to scrap castings and rework.

**Compactibility Control**

On a real-time basis, a better method of sand control is the principle of compactibility control (Fig. 4). In this approach, the compactibility of the sand in the mixer is continuously measured. The water additions are then raised or lowered accordingly on that batch of sand to produce the target compactibility. The sand is not discharged until the compactibility is on target.

In true compactibility, the water addition isn't targeted for any previous value and it isn't assumed that the composition of the sand going into the mixer will remain constant. It assumes the sand composition will change, so a certain amount of moisture is added, the compactibility that develops is measured, and the water addition is adjusted as required by the composition of the sand currently in the mixer. The sand isn't discharged until the compactibility is on target. The water addition for each batch of sand is tailored to the moisture requirement for that batch. This approach is consistent with true compactibility control.

The difference in operating principles between constant moisture and true compactibility control leads to different results in production. With constant moisture, the system is set up to detect out-of-specification compactibilities on prepared sand and to make adjustments for correcting the next sand being prepared, assuming that the next sand has the same composition. If constant moisture is used, it has to be accepted that sands produced during each "adjustment" phase and sent to molding will be out-of-specification.

The true compactibility method is more applicable to foundries, where sand composition isn't necessarily constant. Its operating principle dictates that the compactibility of the sand in the mixer is measured as the water addition is adjusted. Even if the sand composition changes, the compactibility produced will continually be on target because it is adjusted according to the moisture requirement for that sand.

If the amount of moisture-absorbing materials in the sand change due to changes in the amount of core dilution, unpuered molds, plugged bond systems or other factors, no sands that are out-of-specification in regard to compactibility will be sent to molding.

**Control for the '90s**

It has been 21 years since the concept of compactibility control was first developed and found superior to moisture control. There is no excuse for foundries to still control the water addition by measuring compactibility but applying the old concept of moisture control.

As casting buyers are demanding higher quality, tighter tolerances and lower costs, sand control is more important than ever. With the cost of scrap and rework, foundry can afford to use a backward approach that risk production of out-of-specification sand compactibilities. To produce world-class, net shape, competitive castings, it is essential that sand temper be controlled using the modern concept of true compactibility control.

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**Fig. 3.** This is the sequence followed for the constant moisture principle, which foundry officials often mistake for compactibility.

**Fig. 4.** With sand control's growing importance, foundries need to follow this true compactibility control approach for controlling sand temper.