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Original Article

Power Techniques for Improving Green Sand System Performance

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Abstract *- The production of green sand systems in iron foundries can be improved by controlling batch-to-batch mulling energy instead of controlling the mulling time. In this study, sand data from 4 foundries were evaluated before and after the transition from conventional mull-to-time (MTT) to mull-to-energy stable power mulling strategies (MTESP). Unnecessary over-mulling was eliminated with MTESP strategies, which significantly brought down the time by 75%, thus increasing the mulling output. In the process, sand properties were not adversely impacted. However, in terms of scrap, there was a 50% reduction in sand-related scrap after MTESP implementation. This paper evaluates green sand system changes during production foundry transitions from MTT strategies to MTESP strategies to significantly reduce the time, power and cost of mulling. In addition, control strategies to identify the point of stable power during mulling have been evaluated.*

Keywords *- Greensand, Mulling Energy, Sand properties, Molding systems, Foundry.*

1. Introduction

Green sand moulding systems for metal casting consist of high-quality silica sand, with 10% bentonite clay (as the binder), 2 to 5% water and about 5% sea coal [1][3]. The type of metal being cast and the size of castings determines which additives and what gradation of sand is used in the green sand system [2]. Control of the raw materials and control of the sand mulling (mixing) operation is necessary to reduce sand variations that impact casting quality and reduce casting defects from sand-related cases[4]. A basic understanding of the green sand system's materials and the equipment required to prepare and maintain constant performance are extremely important to assure quality castings[6]. Mulling consistency is one of the most important aspects of green sand control[7]. A thorough understanding of the mulling cycle sequence must be maintained to help minimize cycle time and help maintain consistent sand properties[3][5]. In most foundries, each green sand batch is mulled to a constant time. Foundries using mulling time control show the following problems: 1. Long mulling time so that all batches have sufficient mulling. 2. Different mulling energy for each batch. (e.g., Smaller muller batch sizes are over-mulled, and larger batch sizes are under-mulled.)

2. Literature Review

Control of green sand systems comprises both careful controlling of green sand additions during sand preparations and controlling sand mulling[7]. Variations in the sand mulling cycle can cause variations in the performance of mulled green sand, even with tight control of bond and water additions.[2] In the current scenario, the extent of mulling in green sand preparation in most foundries is usually between 40-100 seconds depending on the equipment used and the sand demand[15][17]. After this constant mull time is reached, the sand is discharged and sent to the moulding line[8][9][29]. Mulling's complex interaction with important green sand property development can be observed in the complex sand system, control performance measures developed by green sand researchers and green sand system operators[11][12]. Factors influencing mulled green sand performance are observed in Table 1. The amount of mulling varies with the percentage of undeveloped clay and the percentage of water[13].

Table 1. Green sand properties and calculated mulling performance indicators used by foundries

Measured Properties
Test Moisture (%TM)
Green Compressive Strength (GCS)
Methylene Blue (%MB)
Calculated properties
%ME=%EC/%AC –or- %ME=%CGS/%MGS
Effective Clay or Working Bond (%EC, WkB) = %EC= (15.29×GCS)/(132.1-%TC)
Compacted Green strength (%CGS) = %CGS=[(GCS+9.56-0.0971×%TC)/(11.25-0.1×%TC)] ×100
Available Clay or Available Bond (%AC, %AB) = %AC= 0.105×GCS+(1.316×%TM)
Moisture Green Strength (%MGS) = %MGS=(4.52×10^(1/2.5887-1.155×log(%TM)-0.5635×log(GCS)))+4.075)/6

Green sand strength is a function of electrostatic force, surface tension and friction, so sand characteristics such as fines, wettability of sand grains, grain geometry and other factors play a role in how a sand's strength develops during mulling[14][16]. Muller efficiency is the ratio of the green sand working bond to available clay or compacted green strength to moisture green strength[18]. It is evident that batch-to-batch variation in percent water addition, percent new bond formation and condition and temperature of sand all play a role in determining the required minimum mulling time for each batch.1[20][21][28]

3. Mull to Energy Stable Power Trials

The batch-to-batch variations in incoming sand mean each muller batch requires a different mulling time to develop full properties[22][23]. To obtain consistent clay activation, the mulling time for each cycle needs to be adjusted based on the characteristics of the sand in the muller. Variation in mulling energy from batch to batch leads to sand performance variability.5 However, if the mulling time can be adjusted during each mulling cycle to allow each muller batch to be mulled with a constant amount of mulling energy rather than a constant mulling time, much of the bath-to-batch variation due to mulling itself can be minimized[24]. This concept was referred to as mull-to-energy stable power (MTESP) muller control rather than conventional mull-to-time (MTT) mulling[25]. This MTESP concept was tested at 3 different foundries, and Trials were conducted over a period of time to obtain the ability of MTESP muller control to provide consistent sand properties and low casting scrap rates due to sand defects[26][27]. Calculating muller power for time gives a picture of the total energy needed to mull a batch of sand. Fig. 1 shows a typical energy curve for a mulling cycle. The shape of the mulling energy curve was similar for the foundries even though mulling equipment and mulling batch size varied.1The graphs show that after initial mulling, the amount of energy added to each batch stabilizes. In all mulling runs across foundries, the mulling time required to achieve stability varied from batch to batch. This dynamic muller energy control strategy reduced average mull time by 30% in most foundries. The foundries analyzed in this paper had converted from mull to time to mull to energy. Monitoring mull energy is also important for detecting mullers or sand systems changes. A key to the success of mull-to-energy strategies is to robustly identify when the mulling power signal stabilizes at its asymptotic level. Detecting this key mulling time when the power signal stabilizes is referred to as the Mull-to-Energy Stable Power time or MTESP time.

4. Procedure

At each of the participating foundries, the procedures were followed:

- Collect baseline data for a constant mulling time before MTESP control was implemented.
- Install a power meter and an MTESP control system.
- Run the sand system to observe sand performance.
- Observing the performance of sand and scrap data.

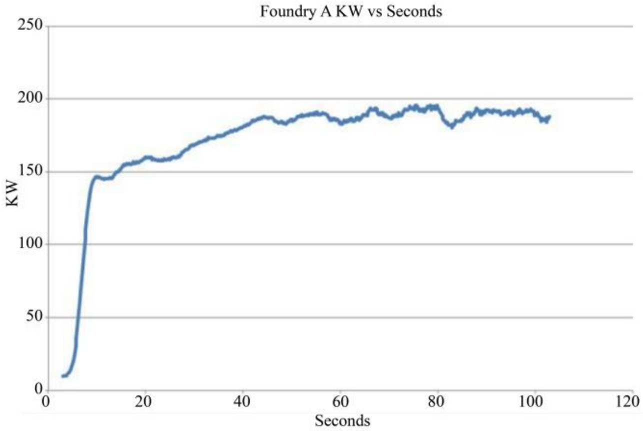

Fig. 1 Foundry A KW vs Seconds

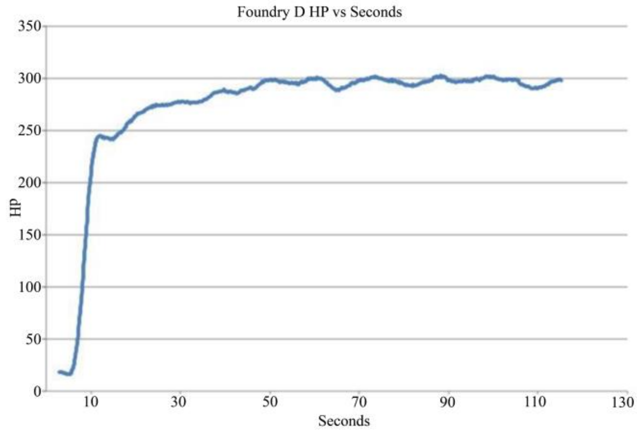

Fig. 2 Tracking Energy During a mulling cycle at Foundry A & D

5. Identifying the Mull to Energy-Stable Power Time

A sample power curve collected from foundries using MTESP is shown in Fig.2. The power curves from all foundries had similar patterns. It can be seen that approximately after 60 seconds, the power level becomes stable and fixates around constant mulling energy with an increase in mulling time. Mulling is complete when additional mulling does not further develop strength during mixing and an energy asymptote is reached. Any mulling beyond this time to reach the asymptote is unnecessary.

Hence, it becomes necessary to identify the time to asymptote dynamically and stop the process to save energy and time over the mulling of sand.

6. Observation: Mull to Energy- Stable Power Measurement

During the mulling process, as the initial water is added, the sand starts building strength continuously until the first energy drop occurs, as seen in the figure.

This energy drop indicates the 1st asymptote. Once the components are mixed, the mixture loses its significance and starts to dehydrate after the asymptotic point. Excess mixing in the dehydration phase wears out the muller, causing fracturing sand grains, which must be avoided.

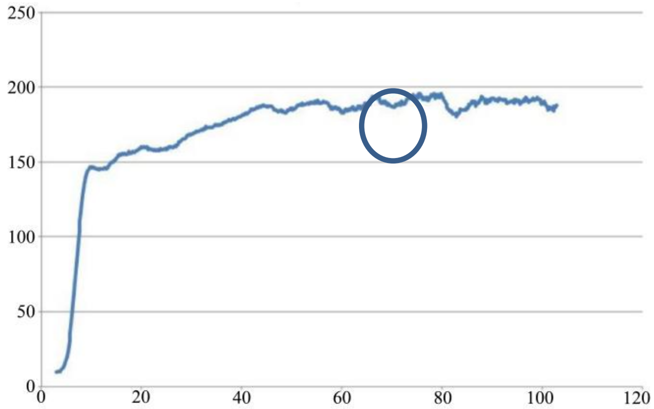

Fig. 3 Initial energy curve drop indicating that the energy asymptote is reached

Previous experiments have verified clay delamination and damaged clay due to dehydration1. For a high-production iron foundry, clay savings alone from avoiding over-mulling has the potential to save 2000-3000 tons of clay per year. Three foundries had implemented MTESP to determine the overall lengths compared to constant mulling time. Analysis of a large database of sand properties, sand system performance and sand-related casting scrap has been used to quantify the lengths achieved from MTESP implementation at different iron foundries.

7. Results and Discussion

Key characteristics of the 4 foundries studied are shown in Table 2:

The key impacts of MTESP at each foundry depend on the initial operating characteristics of the foundry sand systems prior to MTESP implementation. In all foundries, improvements in sand system performance accompanying decreases in sand system operating costs were observed. Specific sand system performance and sand system operating characteristics are performed in detail for foundries A, B and C. These data summaries are based on Aug 2014 – Dec 2015 and data points over a data collection ranging in the same period.

Table 2. Foundry characteristics and key MTESP impacts

Location	A	B	C	D
Data collection period (prior baseline and MTSE control)	1.5 years	1.5 years	1.5 years	1.5 years
General benefits of MTESP implementation as reported by the foundry.	Reduced energy by 11%; increased sand mulling capacity	Significant improvements in scrap or sand quality. Reductions in average mulling cycle time from 100 seconds to 80 seconds.	Overall improvement in muller efficiency and % moisture with increased sand strength.	Overall reduction in energy consumption and sand retained scrap costing.

Table 3. Summary before and after MTESP implementation -Foundry D

Foundry D	Mean Before MTE	Mean After MTE	% Change Mean	P Value*	StdDev B4	StdDev After	% Change Std Dev	P Value**
Avg. mulling time (sec)								
Muller Efficiency (%)	69.54	68.55	-1.4%	0	4.55	3.67	-19%	0
Green Strength (N/m^2)	29.67	28.83	-2.8%	0	3.28	2.53	-23%	0
Compactability (%)	37.99	38.69	1.8%	0	2.31	2.77	**20%**	0
Density (lb/m^3)	159.0	159.8	0.5%	0	1.45	1.21	-17%	0
Permeability (N/A^2)	82.38	81.95	-0.5%	0.337	5.99	5.38	-10%	0.567
Split Tensile (N/m^2)	5.428	5.234	-3.6%	0	0.524	0.425	-19%	0
% Moisture	2.888	2.923	1.2%	0	0.16	0.139	-13%	0
M B Clay	9.937	9.831	-1.1%	0	0.465	0.423	-9%	0
Dry Compression (N/m^2)	54.9	58.13	5.9%	0.006	12.9	7.79	-40%	0.047
Available Bond (N/m^2)	6.92	6.88	-0.6%	0.07	0.391	0.329	-16%	0.005
Working Bond (N/m^2)	4.82	4.725	-2.1%	0	0.515	0.403	-22%	0
Moisture/Clay*100 (%)	29.1	29.75	2.2%	0	1.67	1.42	-15%	0
Bond Added	79.9	80.5	0.8%	0.399	16.5	21.7	**32%**	0

7.1. Observations for Successful Implementation of Mull to Energy-Stable Power Technique

MTESP implementation should be preceded by an effort to remove sand system operating variability from other sources of variation related to the sand batches brought to the muller. This includes:

- Muller batch weight control varies +/- 10% or less.
- Proper water/ clay control
  Correct sequence of new sand, water and clay additions during mulling.
- Full documentation of baseline sand system performance.

7.2. MTESP Automatic Compensation for Clay Variations

MTESP mulling control automatically compensates for clay variations in each mulling batch. Because foundry clay distribution and activation are key mulling results, the natural variations in clays must be compensated for during mulling. The mulling time required to reach the asymptote in each batch can effectively measure clay activation. Variations in a way no standard clay tests can measure, sub-standard (different from actuating) clays are automatically mulled for longer times with MTESP control. The Mull to Energy-Stable power system effectively tracks the mullability of the clay and even compensates for it. Clays with low mullabilty do not build strength as fast, requiring longer mulling times that can be automatically achieved by MTESP control before these inferior clay problems can be corrected, thus eliminating a potential large cause of casting scrap. MTESP control not only compensates for clay and other variations for each mulling cycle, but analysis of mulling trends over time can also give an early indication of other mulling issues to be corrected in MTESP mulling times. This includes any tracking of muller wear and muller adjustments that must be controlled for effective mulling.

7.3. MTESP Energy Savings

A clear example of mulling energy saving using MTE-Stable power is shown in Fig. 4 for Foundry-D. The average energy consumption for using conventional mulling time control (baseline)is scaled to 100%. The average mulling consumption drastically reduced to 75% on switching to MTESP because of the significant reduction in average mulling time per batch.

7.4. Reduction in Scrap

Significant reductions in sand-related scrap have been observed as a result of MTESP implementation. The initial 6 months scrap average in this figure is scaled to 100%. There was a 50% decrease in sand-related scrap after MTESP implementation.

7.5. Sand System Control Stability

Variations in mulling when using conventional time control can effectively mask other sand system control problems. Shifting to MTESP mulling control removes mulling variations that can illuminate other sand system variability that needs to be corrected. This is shown in Fig. 5. Sand system controls actions by the foundry during the baseline period resulting in wide variations in sand compactibility (Aug 2014- Jan 2015). However, compatibility was much easier to control after MTESP implementation, driving other improvements in sand system stability.

8. Conclusion

The use of Mull-to-energy Stable Power (MTESP) strategies for improving green sand control in production foundries has been described. These sand system mulling control improvements drive batch reductions in sand-related casting scrap and significant reductions in mulling times. These mulling cycle time reductions result in significant cost savings by reducing both mulling energy consumption and muller maintenance and wear.

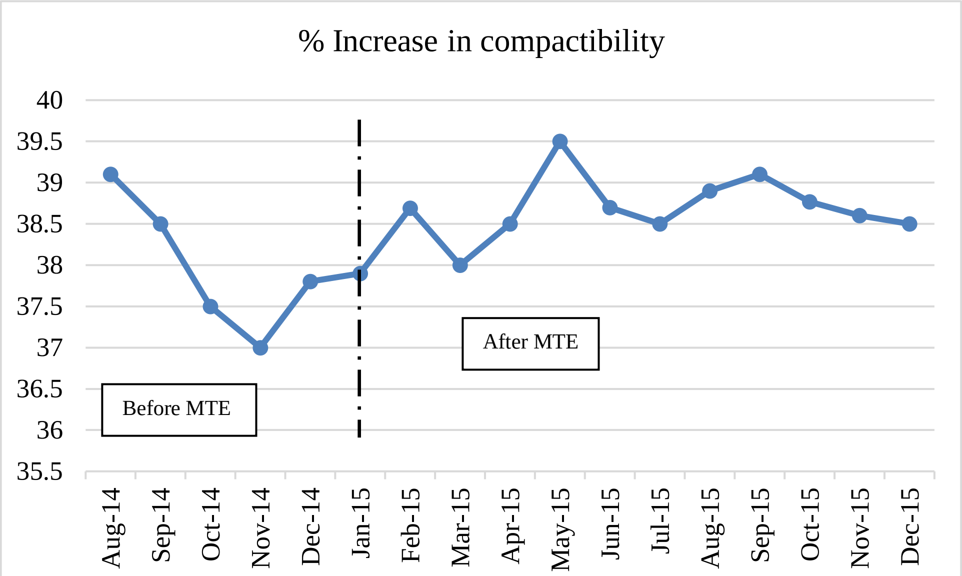

Fig. 4 Compactibility control before and after implementing MTESP- Foundry D

Limitations

The strategy is implemented only in a handful of foundries currently, which gives scope to expand the same technique to be used by foundries nationally. Identification of incoming clay quality from industries still remains a question to qualify them for future use in foundries.

Future work

The MTESP implementation to date has been at foundries using batch mullers. Similar MTESP strategies are expected to be developed and implemented in foundries using continuous mullers. Furthermore, instrumental mulling performed in small laboratory mullers may lead to the development of simple testing methods that may be used to qualify incoming clays used by foundries.

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