Influence of GMBOND® Coated Olivine Core Sands on Olivine Green Sand Molding Properties

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SUMMARY

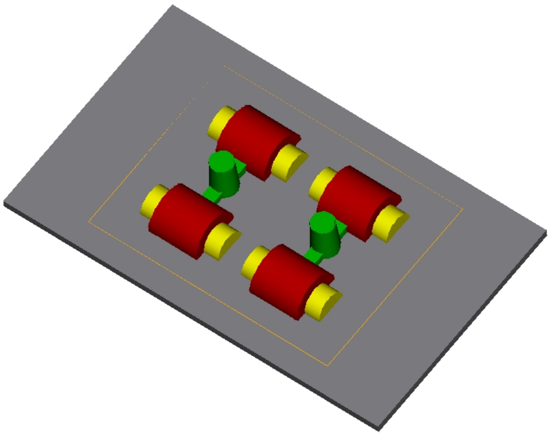
An applied research study was undertaken to assess the influence of GMBOND® coated, olivine sand cores on olivine green sand molding properties. Green sand molds were made to evaluate the green sand properties as used GMBOND® cores were continually introduced into the molding system. Aluminum castings were poured to observe the casting quality after each cycle diluted with the GMBOND® coated cores. The research work showed an increase in water capacity but stabilized toward the end of the experiment as the amount of returned olivine core sand increased. The green sand properties exhibited an initial decrease but stabilized as the olivine green sand matured with the addition of GMBOND® coated cores. The changes in the green sand properties from the addition of decomposed and composed GMBOND® binder do not appear to have any adverse effect on casting quality. The cored surface using GMBOND® coated olivine sand cores exhibited excellent surface finish with excellent shakeout characteristics. The research work demonstrated the potential of producing olivine cores using the protein based GMBOND® to extend the life of olivine green sand for aluminum casting operations. Using olivine sand cores coated with the GMBOND® binder reduces periodic disposal of green sand to re-condition an olivine green sand molding system.

EXPERIMENTAL PLAN

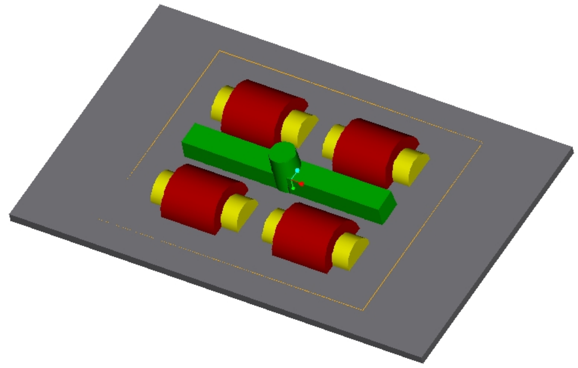
The experimental procedure, similar to that used by Iyer, Johnson, and Granlund in assessing the influence of phenolic ester and phenolic urethane core sands on green sand molding properties, was incorporated into the research study. The testing procedures and experimental casting was modified to determine the influence of GMBOND® coated olivine cores cycled back into an olivine green sand mixture. The main objective of the study was to pour aluminum castings to evaluate the green sand properties and observe the casting quality after each cycle using GMBOND® coated cores. The amount of core sand added was roughly 2-3% of the sand system, which correlates well with typical aluminum foundry practices. The experimental conditions were more severe than what would be expected in a typical aluminum foundry since core butts, which are typically removed during shakeout, were included into the recycling of the olivine green sand. Ten cycles were performed with two molds per cycle.

PATTERN AND CASTING USED

The pattern, illustrated in figure 1, used for the applied research study was a group of four cylindrical castings, 2 inches (5.08 cm) in ID and 3.25 inches (8.26 cm) OD and 3.25 inches (8.26 cm) long. For each casting, the center core was 2 inches (5.08 cm) in diameter and 5.25 inches (13.34 cm) long. Molds were made on a jolt squeeze machine at the University of Northern Iowa Metal Casting Center using a 12-inch (30.48 cm) by 16-inch (40.64 cm) slip flask. The total metal poured per mold was approximately 10 pounds (4.5 kg) of A356 alloy poured at a temperature range of 1350°F – 1400°F (732°C – 760°C). The average weight of the sand mold was 105 pounds (48 kg), giving a sand-to-metal ratio of approximately 11 to 1. Two molds were prepared for each heat. After preparing each mold, the mold hardness was measured and consistently averaged 80 or higher.



(a)



(b)

Figure 1. (a) Cope side and (b) drag side of experimental pattern. During molding, the sprue was manually cut during molding. The rectangle surrounding the casting and gating configuration is the flask dimension of 12" x 16".

PROTEIN BASED GMBONDCORE PREPARATION

For each cycle, approximately 5.5 lbs. (2500 grams) of olivine (GFN 100) sand pre-coated with 1.5% GMBOND® was weighed and placed in a Hobart mixer. 0.165 lbs. (75 grams), or 3.0% total sand weight, of tap water was added to the pre-coated sand during mixing. The pre-coated sand and water was mixed for approximately 60 seconds. A dwell time of 5 minutes was used to allow complete absorption of the water. After the dwell, the sand was mixed for 30 more seconds and then transferred to the core station. The sand was placed into the blow tube magazine and cores were made. Cores were blown at 60-psi (4.21 kg/cm^2) pressure at a core box temperature of 250^{o}F (120^{o}C). For each core, the activation time was 60 seconds followed by dry air purging at 40 psi (2.81 kg/cm^2) for 90 seconds. Typical tensile strength for the 1.5% GMBOND® coated olivine sand fell in the range of 160 – 170 psi (1103 – 1172 kPa). These tensile strengths compare favorably with silica sand coated with an aluminum-designed phenolic urethane binder.

GREEN SAND PREPARATION

On the onset of the project, an olivine green sand mixture was conditioned to develop a mature green sand system. This was accomplished by preparing a 250-lb. (113.4 kg) batch of green sand in a Simpson vertical wheel muller. 230 lbs. (104.3 kg) of olivine (GFN 100) sand was added to the muller and approximately 7.5 lbs. (3.4 kg) of water was added during mulling. After mulling, 15 lbs. (6.8 kg) of blended bentonite clay (90 % southern bentonite and 10% western bentonite) was introduced into the muller. The green sand mixture was mulled for approximately 8 minutes. The green sand mixture was allowed to dry overnight. The following day, water was added to the green sand to develop compactability between 40-45. This compactability target range was used throughout the remainder of the experiment. Green sand molds were made without cores. A356 aluminum castings were poured and removed the following day. This procedure was repeated four times before GMBOND® olivine cores were inserted into the green sand molds.

For each casting cycle, the green sand was placed into the muller and water was added until a compactability of 40-45 was obtained. Approximately one-half of the sand was removed from the muller and transferred to the jolt squeeze molding machine. While the first mold was being prepared, the muller was covered to prevent moisture loss. As the mold was being prepared, the compactability, moisture, permeability, and green compression data was collected and recorded. The GMBOND® coated sand cores were weighed individually before setting them into the mold. After the cores were placed in the mold, the cope was positioned and the mold weighed. The remaining green sand was then transferred to the molding area for the preparation of the second mold. Again, the compactability, moisture, permeability, and green compression data was collected and recorded. Cores were weighed before mold closure and transfer to the pouring area.

After each heat, the mold was allowed to cool until the next day. The mold was emptied into a wheel barrel to retain all green sand and core material. Core butts were removed from the casting and placed into a bucket. Because of the excellent collapsibility of the GMBOND® binder, all other core material was immediately retained in the green sand mixture. Before placing the green sand mixture back into the muller for the next casting cycle, the core butts were ground up using a metal file. This material was then added to the green sand mixture. All of the sand (molding sand, decomposed core sand, and ground core butts) was returned to the muller and dry mulled for two minutes to obtain a uniform blend. Water was then added to the target compactability range to start the next casting cycle. During water addition, a small bentonite addition was made to account for the addition of the core material. This was determined by the total weight of the cores (a total of eight for each cycle) that was added from the previous casting cycle.

DISCUSSION OF RESULTS

Table 1 shows the molding properties collected for each casting cycle designated by heat number. In the table, the first heat represents the starting molding properties without any contamination from GMBOND® coated cores. The data presented in Table 1 represents the average of the molding properties for the two molds made during the heat cycle. In the table, the available clay was determined where the green strength intersects the percent moisture from a sand control chart. Using the green strength and compactability data, the percent effective clay was determined from the sand control chart. Once the available and effective clay was determined, the mulling efficiency was calculated by dividing the effective clay with the available clay.

Table 1. Molding Properties for Olivine Green Sand Mixtures

Mold Properties	**Heat 1**	**Heat 2**	**Heat 3**	**Heat 4**	**Heat 5**	**Heat 6**	**Heat 7**	**Heat 8**	**Heat 9**	**Heat 10**
Moisture (%)	2.12	2.14	2.19	2.23	2.32	2.20	2.39	2.42	2.32	2.43
Compactability	43	41	43	43	42	41	41	43	41	43
Permeability	47	51	50	55	58	54	54	53	49	53
Green Compression (psi)	33.5	30.0	30.5	27.0	26.5	28.5	26.5	26.0	28.5	27.0
Percent Volatile (%)	0.52	0.86	1.14	1.17	0.96	1.16	1.16	1.52	1.04	1.50
MB Clay (%)	6.3	6.4	6.3	6.3	6.2	6.3	6.0	6.2	6.0	6.0
Total Core Weight (gm)	3616	3625	3445	3644	3635	3628	3574	3558	3593	3658
Available Clay (%)	6.31	5.96	6.15	5.80	5.92	5.95	5.99	6.00	6.10	6.10
Effective Clay (%)	5.84	5.13	5.32	4.74	4.61	4.93	4.60	4.57	4.92	4.76
Mulling Efficiency (%)	93	86	87	82	78	83	77	76	81	78

Figure 2 shows that the moisture required to maintain a compactability of 42 $\pm$ 1 slightly increased from approximately 2.1% to 2.4%. The moisture appears to plateau around heat 7 and stays relatively constant thereafter. The data indicates that the GMBOND® binder absorbs some moisture from the green sand but stabilizes after several cycles. Even after stabilizing at 2.4% moisture, the percent moisture remained within typical aluminum molding practice for an olivine green sand system. The figure indicates that the sand system is maturing with the addition of GMBOND® cores.

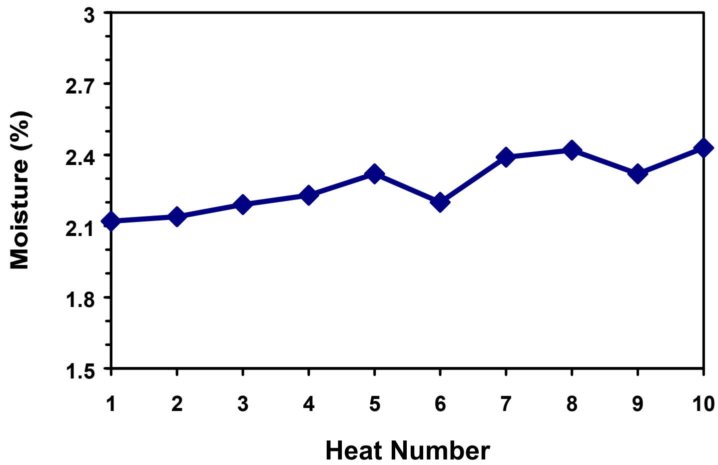


Figure 2. Moisture vs. Heat Number.

Figure 3 shows the green compression properties versus heat number as the green sand mixture becomes contaminated with GMBOND® binder. The pre-conditioned olivine green sand mixture started at a green compression of 33.5 psi. This represents a typical green compression value for the bentonite blend used and compactability value. A noticeable drop in green compression was observed during the initial cycling of GMBOND® cores. However, the green compression properties stabilized relatively rapidly and remained within a range of 26-28 psi for the remaining casting cycles. Though this drop in green compression appears to be detrimental, the green compression range developed toward the end of the casting cycles remains within acceptable production standards.

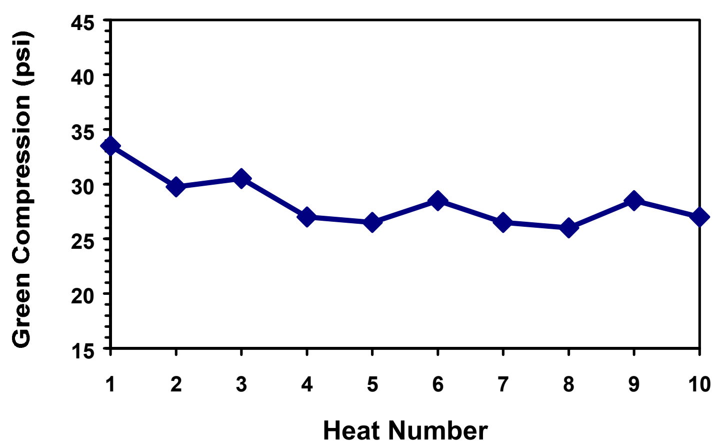


Figure 3. Green Compression vs. Heat Number.

Figure 4 shows the active clay was maintained around 6% during all casting cycles. The figure also shows the effective clay decreases during the first three castings but stabilizes in the range of 4.5% - 5.0%. The trend was also observed with green compression, indicating GMBOND® binder has an influence on the green sand system but stabilizes over a short period of time. Figure 5 illustrates this point. Compactability was plotted in this figure to show no variation in compactability. Again, the green sand system stabilizes after a few casting cycles to a mulling efficiency range between 76% - 82%. This supports that the dilution of GMBOND® coated cores have an initial effect on green sand properties but readjusts and matures to account for the contamination of the binder.

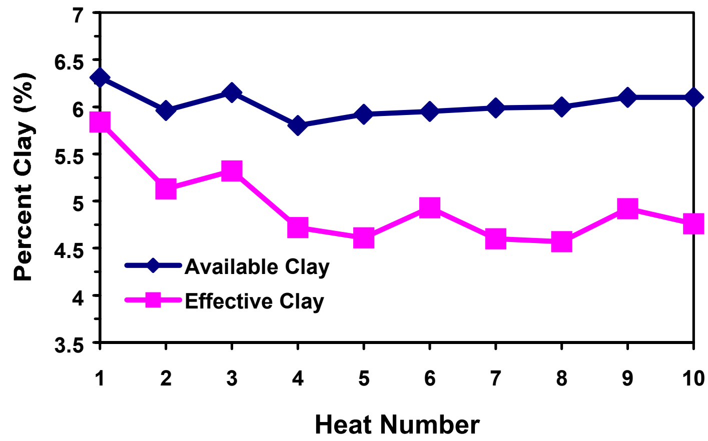


Figure 4. Available Clay vs. Heat Number and Active Clay vs. Heat Number.

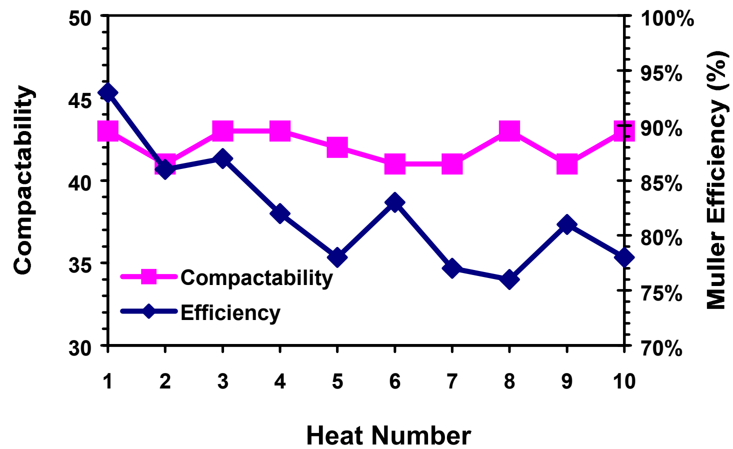


Figure 5. Mulling Efficiency vs. Heat Number. Compactability data was included to indicate that the decrease in mulling efficiency was not related to compactability.

The amount of volatile material, or the amount of decomposed and composed binder, was shown to increase during the first three casting cycles but stabilizes for the duration of the experiment. The range of contamination range from 1.2% - 1.5% as shown in figure 6. Interestingly, the amount of volatile material stabilizes as observed with green compression and mulling efficiency. The data suggests that the amount of core sand returned to the system equal the amount loss within the green sand mixture.

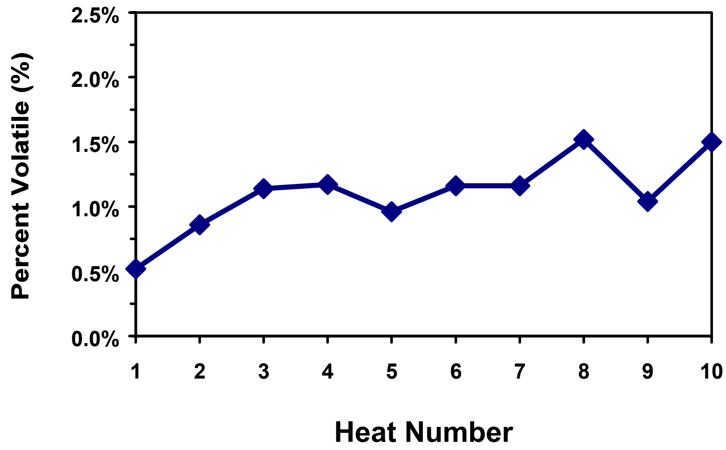


Figure 6. Volatile Material vs. Heat Number.

One important aspect of the research study was to observe any changes to casting quality. The core sand surfaces of the aluminum castings showed no defects and excellent surface finish. GMBOND® binder exhibited excellent shakeout characteristics. For each casting, the core material was easily removed by lightly tapping the castings approximately three to five times with a ball-peen hammer. No other secondary core cleaning operations were required to observe the inside casting surface. On the molding sand surfaces, very little differences could be noted among the various casting cycles.

CONCLUSIONS

The research study assessing the effect of GMBOND® coated olivine cores with an olivine green sand system showed no significant detrimental effect on green sand properties. Molding properties decreased during the first three cycles of the casting experiments but stabilized by the fourth cycle. Moisture showed an increase but began to level toward the end of the experiment. The data collected indicates the green sand system diluted with GMBOND® cores begins to mature relatively rapidly.

The changes in the green sand properties from the addition of decomposed and composed GMBOND® binder do not appear to have an adverse effect of casting quality. The cored surface using GMBOND® coated olivine sand cores exhibited excellent surface finish. Upon extraction of the casting from the mold, the core exhibited excellent shakeout characteristic requiring minimal effort. No surface degradation was observed on the mold side of the casting.

The research work demonstrated the feasibility of producing olivine cores using the GMBOND® to extend the life of olivine green sand for aluminum casting operations. The GMBOND® binder eliminates silica sand dilution of olivine green sand and the associated degradation of green sand properties from silica sand buildup. The use of olivine sand cores coated with the GMBOND® binder reduces periodic disposal of green sand to re-condition the molding system. Additionally, the GMBOND® binder reduces the risk of silicoses for foundry workers and exposure to hazardous air pollutants associated with organic binder processes.

REFERENCES

Iyer, S.R., Johnson, C.K., and Granlund, M.J., "Influence of Phenolic Ester and Phenolic Urethane Bonded Core Sands on Green Sand Molding Properties and Their Effect on Casting Quality", AFS Transactions, vol. 97, pp 617-626 (1989)