CASTBALL

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Sintered Bauxite perfomance compared with Silica Sand and Chromite Sand

Executive Sumary

Physical properties evaluation and casting trials were performed on a synthetic aggregate material directly produced from bauxite with high alumina content and compared to properties and casting performance of silica and chromite sand. This product was created by Curimbaba Group and has the name of CastBall. The following physical properties were evaluated for each sand sample; AFS-GFN, tensile profiles, specific surface area, pH, acid demand value (ADV), base permeability, bulk and tapped density, specific heat capacity, and linear expansion. Step-cone castings and Gertzman castings were poured for evaluating casting quality performance in low carbon, low alloy steel, class 35 grey iron, and 60-40-18 ductile iron. Tensile cores and cores for casting analysis were prepared using the furan no-bake, phenolic ester-cured no-bake, and phenolic urethane cold box binder systems. Physical properties were determined to be comparable to the base line sands investigated. The low thermal expansion was observed for the CastBall and was related to the absence of veining defects in the casting trials. CastBall demonstrated satisfactory casting performance in a laboratory and foundry environment. Subsequent investigation using an engineering CastBall, where tried to prevent penetration, showed improvement in metal penetration resistance. Industrial casting trial using CastBall in an uncoated core application showed acceptable results for a complex stainless steel casting when compared to zircon coated silica sand. Based on the laboratory results and industrial casting trial, CastBall aggregate presently meets casting requirements for ferrous applications with an absence of veining defects.

Introduction

Natural occurring sands mined from large deposits have been traditionally used since the dawn of metal casting. Historically, natural occurring sand with natural occurring binding agents such as clay was the primary molding medium of choice. With the advent of polymeric based binder systems, removal of these additives was a requirement to prevent interference with the chemical reactions of the sand binder. Today, practically all sands arrive at the foundry washed, free of impurities and other unwanted material. This advancement in the science of molding aggregates has lead to huge strides in producing highly complex casting designs.

As the demand of molding aggregates to meet special casting requirements increased, introduction of other sands such as chromite and zircon sand addressed issues related to casting defects to produce defect-free, high quality castings while minimizing post-processing costs for the foundry. In order to meet these requirements, several factors to meet the severe conditions induced by the particular casting alloy, particularly ferrous situations, some important properties are necessary of a molding aggregate. These factors are permeability, thermal stability, surface energy properties between the liquid metal and molding aggregate, compatibility with other molding aggregates, additives, and binding agents; screen distribution, refractoriness, heat transfer properties, changes in resin demand levels, possible thermos-chemical reactions when molding aggregate stream(s) are mixed, and thermal expansion properties.

Since the 1990's, synthetic sands have been introduced to the foundry industry to address the limited availability of specialty sands and cost associated with transporting these sands over long distances to the foundry. Derived and processed from lower cost ceramic materials, synthetic sands have been developed to meet molding and casting requirements attained from natural occurring specialty sands. The challenge of synthetic sand producers is producing a comparable molding aggregate at a substantially lower cost. Additionally, changes in resin demand levels, possible thermo-chemical reactions when molding aggregate stream are mixed, and higher permeability issues leading to casting surface changes have been a concern for the foundry in adopting these types of molding aggregates.

This case study presents the preliminary investigation of engineering a synthetic sand, in this case called CastBall, to meet the harsh thermal conditions of the casting process while developing molding properties to address metal penetration and veining defects associated with ferrous casting applications.

Physical Properties and Cores

Physical properties testing included tensile strength, density profile and scratch hardness at 30 seconds, 5 minutes, 1 hour, 4 hours and 24 hours. A KitchenAid mixer was used to prepare cores for physical testing, step come cores, and Gertzman cores.

Furan Binder System

A batch of sand (3000 grams for silica, 3500 grams for sintered bauxite and chromite) was placed in the mixer. A sulfonic type co-reactant was first added to the sand and mixed for 60 seconds after which the furfuryl alcohol resin was added and mixed for a further 60 seconds. The sand was then packed into the respective core boxes and allowed to cure while checking for work time and strip time. After strip time was reached, the cores were placed on a shelf and allowed to cure for 24 hours before testing, except in the case of tensile strength tests. A resin content of 1.5% based on sand and co-reactant content of 30% based on resin was used for all cores.

Phenolic Ester Binder System

The same procedure of Furan system, except for using potassium based ester co-reactant and using 1.75% resin.

Phenolic Urethane Cold-Box Binder System

A batch of sand (3000 grams for Silica, 3500 grams for sintered bauxite and chromite) was placed in the mixer. A resin content of 1.25% based on sand was used at a Part I: Part II ratio of 55:45. The Part I resin was first added to the sand and mixed for 60 seconds after which the Part II was added and mixed for a further 60 seconds. The sand was then removed from the mixer and blown into the cold-box tensile core pattern using a Redford Cold-Box machine. The sand was then gassed with TEA for 1 second and then purged with dry air for a further 7 seconds. Three tensile cores from the gang core box were then placed in the desiccator and the above process was repeated till a total of 15 cores were obtained.

The same sand preparation procedure was followed to prepare Gertzman and step-cone cores. After sand preparation, the mixed sand was manually packed for the step cone cores whereas the Gertzman cores were blown using the Redford Cold-Box blower. For the step-cone cores, a Gaylord Gassing Chamber was used to produce using a gassing pressure of 20 psi for 4 seconds and purging pressure of 40 psi for 30 seconds. The curing parameters for the Gertzman cores were identical to the parameters used to produces dog bone cores for tensile testing.

Sand Charactarization

The AFS-GFN, specific surface area, pH, ADV, base permeability, bulk and tapped density tests were run according to AFS standards specified in the AFS Core and Mold Handbook, 3rd Edition. A Simpson digital absolute Permmeter was used to determine base permeability. A Thwing-Albert tensile tester was used to measure the tensile strength. A high temperature dilatometer was used to run the linear expansion tests. Tests were run from room temperature to 1600°C at a rate of 15°C per minute. Samples in the dry condition were compacted into high purity alumina crucibles and placed in the dilatometer and flushed with nitrogen for approximately 15 minutes.

Specific Heat Capacity Determination

Specific heat capacity for sintered bauxite 40/100, silica 50/140, and chromite 40/100, determined by the ASTM sapphire method, was measured inside a thermo-gravimetric analysis and differential scanning calorimetry (TGA/DSC) (Mettler Toledo TGA/DSC 1 STARe System, Zurich, Switzerland). To accurately determine the heat capacity of the molding aggregates, a dynamic and isothermal hold profile was developed to minimize the thermal conductivity effects.[2] The DSC profile used was

1. Isothermal hold at 30°C for 10 minutes.
2. Dynamic heating from 30°C to 275°C at a heating rate of 20°C/min.
3. Isothermal hold at 350°C for 60 minutes.
4. Dynamic heating from 350°C to 550°C at a heating rate of 20°C/min.
5. Isothermal hold at 625°C for 60 minutes.
6. Dynamic heating from 625°C to 825°C at a heating rate of 20°C/min.

All DSC experiments were performed using a pure nitrogen flow rate of 20 mL/min.

Step Cone and Gertzman Mold Preparation

Step-cone and Gertzman molds, excluding the test cores, were prepared using silica sand using a bio-urethane no-bake binder system. A Palmer M50 continuous no-bake mixer was used for mold production at a dispensing flow rate of approximately 50 lbs. per minute of no-bake sand. The step-cone molds utilized a vertically parted cope and drag dump box measuring approximately 15” x15” x 7.5” for the cope and identical width and length dimensions for the drag dump box but with a 3" depth.

The Gertzman mold, holding four 2” by 2” sample cores, was constructed using multiple sections. The 3-inch diameter riser section was double stacked to increase the metallostatic pressure on the cores.

Melting Procedure

The composition of the metal used in the trials was consistent with the chemistry used to produce standard class low alloy steel, class 35 grey iron, and 60-40-18 ductile iron. The metal was melted in a 340 lb. high frequency coreless induction furnace utilizing a neutral refractory lining. After meltdown, the slag was removed and chemical analysis sample was taken. After the chemical analysis was verified and, if necessary, alloy additions made, the temperature of the molten metal was raised to approximately 3050°F (1676°C) in the case of steel and 2700°F in the experiments requiring of grey or ductile iron. The heats were tapped into a 350 lb. heated monolithic tilt pour ladle. The metal was then poured into the molds located on the pouring line using a target pouring temperature of 2900°F for Steel and 2600°F for grey and ductile iron. An approximate total target pour time of 10 to 12 seconds was used for the step cone molds and 30-40 pour time for the Gertzman molds, with each step-cone mold requiring approximately 32 lbs. of metal and each Gertzman mold requiring approximately 80 lbs. of metal.

Results

AFS-GFN

The average grain fineness number (GFN) obtained from a sieve analysis are shown in Table 1. the screen classification is defined as the amount of retained sand grains exceeding 10% or more retained on a screen based on the distribution provided in Table 2.

Table 1: AFS-GFN Results

Sample ID	GFN	Screen Classification
CastBall 40/50	35	2-screen
CastBall 40/100	56	4-screen
CastBall 40/70	40	3-screen
CastBall 70/140	78	3-screen
Chromite 40/100	45	4-screen
Round Grain Silica 50/140	63	4-screen

Table 2. Screen Distribution

Screen	CastBall 40/50	CastBall 40/100	CastBall 40/70	CastBall 70/140	Chromite 40/100	Silica 50/140
20	0.02	0.00	0.00	0.01	0.74	0.00
30	0.02	0.03	0.05	0.00	5.51	0.02
40	58.89	18.66	32.14	0.06	15.33	4.16
50	34.28	28.16	44.45	0.04	31.00	21.72
70	6.00	18.61	19.08	18.34	34.47	23.38
100	0.75	24.06	3.74	56.23	11.75	26.85
140	0.01	8.09	0.46	19.44	0.88	16.90
200	0.00	1.60	0.02	4.04	0.18	5.10
270	0.00	0.34	0.00	1.02	0.04	1.06
Pan	0.00	0.22	0.00	0.66	0.02	0.68

Specific Surface Area, PH, Acid Demand Value, and Base Permeability

Results are shown in Table 3. The CastBall 40/50 aggregate exhibited a surface area half of silica, indicating that could require less binder, however, not in the same percentage reduction. The binder demand for CastBall would be comparable to chromite sand. However, chromite exhibited lower surface area than CastBall 40/50. This is an unexpected result because of the sand distribution and acicular nature of chromite. Acid Demand Value (ADV) and pH for all aggregates tested were comparable, indicating minimal effect on basic or acidic type binder systems. The most notable feature of CastBall was the exceptional permeability, that characteristic could decrease gas related defects.

Table 3: Physical Properties Results

Sample ID	Surface Area	pH	ADV	Base Permeability
CastBall 40/50	76.8	7.5	1.36	370.0
Chromite 40/100	55.3	7.7	1.15	144.0
Silica 50/140	160.5	8.8	0.283	54.67

Bulk and Taped Density

The bulk and tapped density results are shown in Table 4. The data shows sintered bauxite has an intermediate density between chromite and silica sand.

Table 4: Bulk and Tapped Density

Sample ID	Bulk Density	Tapped Density
CastBall 40/50	2.017	2.197
Chromite 40/100	2.598	2.860
Silica 50/140	1.590	1.750

Linear Expansion

Linear expansion results obtained are shown in Figure 1. All samples were run as un-bonded aggregate. It can be seen that silica, as expected, goes through the alpha-beta phase transition at 1045°F (580°C) and starts undergoing a cristobalite transition at 2410°F (1300°C). Both CastBall 40/50, CastBall 40/100, and chromite display lower linear expansion when compared to round grain silica. CastBall 40/100 exhibited a lower linear expansion rate up to 1475°F (800°C) than CastBall 40/50. The expansion rate increases up to the identified sintering point. Chromite starts sintering at ~2450°F (1350°C) while CastBall 40/50 and 40/100 start sintering at 2100°F (1150°C).

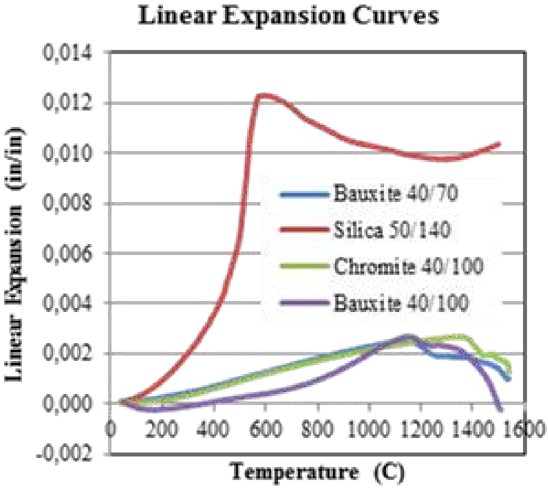


Figure 1. Linear Expansion Curves – Refered Bauxite 40/70 as CastBall 40/70 and Bauxite 40/100 as CastBall 40/100.

Specific Heat Capacity

Specific heat capacity for CastBall 40/100, determined by the ASTM sapphire method. The results are shown in Figure 2. CastBall 40/100 showed a rise in thermal heat capacity to approximately 800°C, starting at 0.75 J/g °C and increasing to roughly 1.4 J/g °C. Chromite 40/100 showed a thermal capacity range of 0.65 to 1.4 J/g °C for the temperature range investigated. In the case of silica 50/140, the specific heat capacity increased from 0.8 to 1.1 J/g °C to approximately 575°C followed by a decrease to 1.0 J/g °C at 650°C with a subsequent increase to 1.1 J/g °C at 800°C. This change in thermal heat capacity between the range of 575°C and 650°C can be attributed to the phase change of silica.

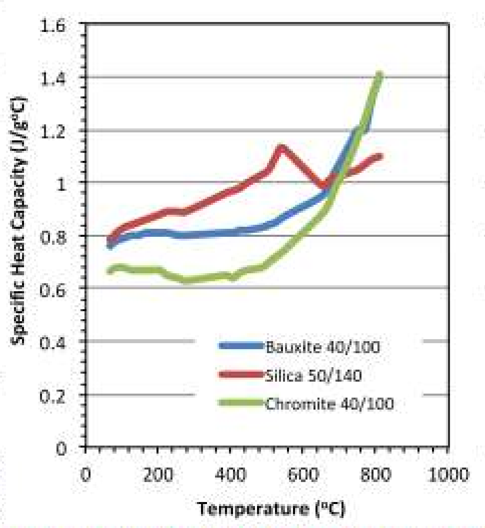
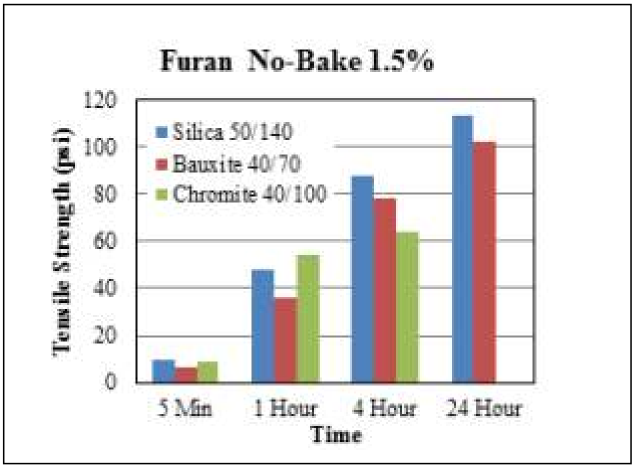
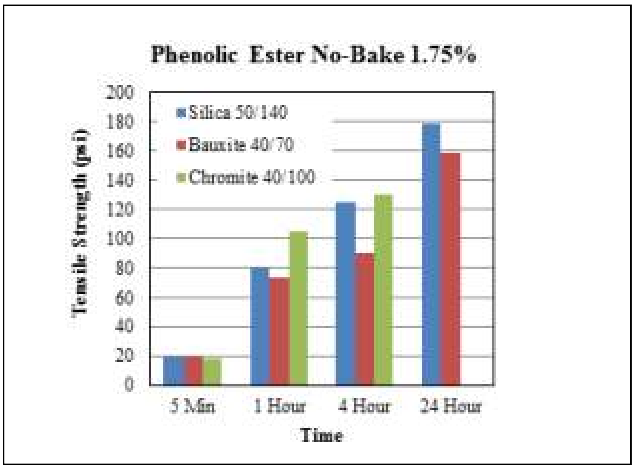


Figure 2. Specific Heat Capacity of bauxite 40/100 (CastBall 40/100), silica 50/140, and chromite 40/100.

Tensile Strength Results

The tensile strength results obtained for Furan binder system at 1.5% resin content, Phenolic Ester binder system at 1.75% resin content and Phenolic Urethane Cold-Box binder system at 1.25% resin content are shown in Figure 3, 4 and 5 respectively. The significant contributor to the higher tensile properties of silica sand for the furan binder system can be contributed to the higher surface area and broad screen distribution. CastBall 40/50 was comparable in strength, no significant detrimental effects for screen distribution or chemical nature of CastBall 40/50 was observed with the furan binder system, neither for phenolic ester cured binder system. For the phenolic urethane binder system, CastBall 40/50 had the lowest performance, however, still acceptable for foundry industry.





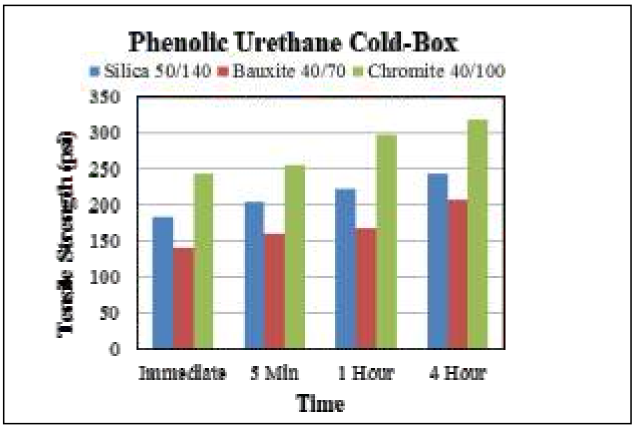


Figure 3, Figure 4, Figure 5. Tensile strength profile for Bauxite (CastBall) 40/50, silica 50/140, and chromite 40/100.

Step Cone Casting Analysis

The step-cone castings obtained were evaluated for veining, metal penetration, and overall surface quality. The evaluation method is described in Reference 3. The overall index is a sum of the veining and penetration indexes. Higher index values indicate more veining or penetration while lower index values indicate better defect resistance.

Grey Iron

Table 5 shows the casting analysis results for coated and uncoated cores produced using the phenolic ester-cured binder system poured with a class 35 iron. The best performing aggregate was the CastBall 40/50 with a graphite coating. The significant contributing factor to the overall index was penetration resistance, though the penetration resistance exhibited the second lowest penetration value. When comparing the index values for uncoated cores, penetration resistance was comparable to chromite sand. This can be contributed to the grain fineness value for bauxite and chromite. However, as expected, silica sand performed the worst for coated and uncoated based on the overall index value mainly from the high propensity to form veining defects.

The same table shows the casting analysis results for coated and uncoated cores produced using the furan binder system. Again, CastBall 40/50 performed the best in overall defect resistance with the coated and uncoated CastBall ranking in the top three best overall performing aggregate material. The major attribute was its veining resistance. This can be attributed to the low thermal expansion properties of CastBall 40/50. However, the penetration resistance was markedly reduced, attributable to low grain fineness and high permeability of CastBall.

The table also shows the casting analysis results for coated and uncoated cores produced using the phenolic urethane cold-box binder system. The overall defect index value of the CastBall aggregate performed noticeably better than silica sand but was slightly worse that chromite sand. Similar to the furan binder system, penetration resistance was the contributing factor to the overall defect ranking, reinforcing the physical properties evaluation observations of low grain fineness number and high permeability of CastBall 40/70.

It is important to add that as lower the index as better. First, through the step cone, it is analyzed every part of the cone where there is a grade for each step, where there is a higher grade when when there is lots of penetration or veining and a lower grade when there is few penetration or veining, the overall sum result the final ranking.

Table 5. Class 30 Gray Iron Step-cone Castings Analysis

Aggregate	Coating	Binder System	Penetration	Veining	Penetration Index	Veining Index	Overall Ranking
Silica 50/140	Graphite	Phenolic-Ester	35	39	3	5	5
CastBall 40/50	Graphite	Phenolic-Ester	34	4	2	3	1
Chromite 40/100	Graphite	Phenolic-Ester	44	0	6	1	4
Silica 50/140	None	Phenolic-Ester	28	62	1	6	6
CastBall 40/50	None	Phenolic-Ester	37	1	4	4	3
Chromite 40/100	None	Phenolic-Ester	37	0	5	1	2
Silica 50/140	Graphite	Furan	34	60	3	5	5
CastBall 40/50	Graphite	Furan	47	4	5	2	1
Chromite 40/100	Graphite	Furan	28	47	1	4	4
Silica 50/140	None	Furan	30	66	2	6	6
CastBall 40/50	None	Furan	54	0	6	1	3
Chromite 40/100	None	Furan	38	14	4	3	2
Silica 50/140	Graphite	Phenolic-Urethane	47	58	4	6	6
CastBall 40/50	Graphite	Phenolic-Urethane	59	1	6	3	4
Chromite 40/100	Graphite	Phenolic-Urethane	38	8	1	4	2
Silica 50/140	None	Phenolic-Urethane	42	21	2	5	5
CastBall 40/50	None	Phenolic-Urethane	51	0	5	1	3
Chromite 40/100	None	Phenolic-Urethane	45	0	3	1	1

Ductile Iron

Table 6 shows the casting analysis results for coated and uncoated cores produced using the phenolic ester-cured binder system. The best overall performing aggregate was chromite sand and worst performing was silica sand. CastBall and chromite showed no veining defects. However, the penetration performance of CastBall ranked as the lowest for coated and uncoated cores.

The same table shows the casting analysis results for coated and uncoated cores produced using the phenolic urethane cold-box binder system. Similar to the phenolic ester-cured test, CastBall and chromite sand exhibited no or minimal veining defects. The better performance of chromite sand is attributable to the finer and broader distribution of the chromite sand grains measured in the physical properties evaluation section, leading to better penetration resistance of chromite sand as observed on the table bellow.

Table 6. Class 30 Ductile Iron Step-cone Castings Analysis

Aggregate	Coating	Binder System	Penetration	Veining	Penetration Index	Veining Index	Overall Ranking
Silica 50/140	Graphite	Phenolic-Ester	43	39	3	5	5
CastBall 40/50	Graphite	Phenolic-Ester	50	0	5	1	3
Chromite 40/100	Graphite	Phenolic-Ester	29	0	1	1	1
Silica 50/140	None	Phenolic-Ester	50	80	4	6	6
CastBall 40/50	None	Phenolic-Ester	51	0	6	1	4
Chromite 40/100	None	Phenolic-Ester	35	0	2	1	2
Silica 50/140	Graphite	Phenolic-Urethane	25	41	1	5	5
CastBall 40/50	Graphite	Phenolic-Urethane	49	0	5	1	2
Chromite 40/100	Graphite	Phenolic-Urethane	43	0	3	1	1
Silica 50/140	None	Phenolic-Urethane	26	64	2	6	6
CastBall 40/50	None	Phenolic-Urethane	58	0	6	1	4
Chromite 40/100	None	Phenolic-Urethane	44	6	4	4	2

WCB Stell

Table 7 shows the casting analysis results for zircon coated and uncoated cores produced using the phenolic ester-cured binder system. Surprisingly, the best performing aggregate was silica sand with no veining defects and minimal penetration. It should be noted that results would be different than the grey and ductile iron evaluation because of the solidification behavior of steel. Steel, a skin-forming alloy, will support the growth of dendrites from the nucleation event occurring at the core surface. This will immediately cover the step cone core with a sufficient skin thickness to prevent metal penetration and veining. Grey and ductile iron solidification behavior does not nucleate from the mold wall but occurs in the liquid. As the sand temperature increases from heat flow, the non-skin forming behavior of grey and ductile iron allows the liquid to penetrate the interstitial pore space of the aggregate and, if the sand core expands and contracts to form a crack while the metal is partially or fully liquid, a vein will form.

CastBall 40/50 was observed with substantial metal penetration for coated and uncoated cores. Since metal penetration is strongly dependent on the surface tension properties between the aggregate and liquid metal, the permeability of the aggregate is very influential on the initiation and propagation of liquid metal into the aggregate. As shown in the physical properties evaluation, CastBall 40/50 had a very high permeability value. For steel castings, and as shown in Table 7, the high permeability of CastBall 40/50 permitted the steel to penetrate the sand prior to a solid skin to form.

Table 7 shows the casting analysis results for coated and uncoated cores produced using the furan binder system. Bauxite did not perform overall when compared to chromite and silica sand. This is attributable to the poor penetration resistance of CastBall.

Table 7 shows the casting analysis results for coated and uncoated cores produced using the phenolic urethane cold-box binder system. As in the case for phenolic ester-cured and furan penetration and veining evaluation, the bauxite product performed the worst. However, no veining defects were observed and the poor overall performance was attributable to the high degree of metal penetration defects observed.

Table 7. WCB Steel Step-cone Castings Analysis

Aggregate	Coating	Binder System	Penetration	Veining	Penetration Index	Veining Index	Overall Ranking
Silica 50/140	Zircon	Phenolic-Ester	0	0	1	1	1
CastBall 40/50	Zircon	Phenolic-Ester	61	0	6	1	6
Chromite 40/100	Zircon	Phenolic-Ester	15	0	3	1	3
Silica 50/140	None	Phenolic-Ester	8	0	2	1	2
CastBall 40/50	None	Phenolic-Ester	31	0	5	1	5
Chromite 40/100	None	Phenolic-Ester	19	0	4	1	4
Silica 50/140	Zircon	Furan	21	0	3	1	2
CastBall 40/50	Zircon	Furan	34	0	6	1	6
Chromite 40/100	Zircon	Furan	0	0	1	1	1
Silica 50/140	None	Furan	11	6	2	6	3
CastBall 40/50	None	Furan	27	0	4	1	4
Chromite 40/100	None	Furan	32	0	5	1	5
Silica 50/140	Zircon	Phenolic-Urethane	9	8	3	5	3
CastBall 40/50	Zircon	Phenolic-Urethane	41	0	5	1	5
Chromite 40/100	Zircon	Phenolic-Urethane	9	0	2	1	1
Silica 50/140	None	Phenolic-Urethane	6	8	1	5	2
CastBall 40/50	None	Phenolic-Urethane	61	0	6	1	6
Chromite 40/100	None	Phenolic-Urethane	29	0	4	1	4

Step Cone Casting Analysis – Part 2

Additional step cone castings were poured to evaluate three CastBall sizes that were engineered to combat metal penetration. The aggregates investigated were CastBall 40/70, CastBall 40/100, and CastBall 70/140. Screen distribution and GFN values for these aggregates are presented in Table 1 and 2. The purpose of the testing was to broaden the screen distribution and increase the GFN to decrease the high susceptibility of metal penetration observed with the CastBall 40/50. Since no veining defects were observed with the bauxite product, only metal penetration was evaluated upon sectioning the castings. Additionally, only class 30 grey iron and low carbon, low alloy steel were poured into phenolic urethane cold box cores. Table 8 presents the metal penetration evaluation for class 30 grey iron and low carbon steel, respectively.

When comparing the metal penetration index values presented in Table 5 with the penetration index values in Table 8 for a class 30 grey iron, the resistance to metal penetration improved considerably, demonstrating a broader distribution and finer GFN improves the casting performance of the bauxite product. For CastBall 40/50 product, the average penetration index was 49.3 and 57.5 for graphite coated and uncoated step cone cores, respectively. The finer GFN and broader distribution lowered the penetration index value to a range of 30 to 40 for both graphite coated and uncoated cores.

Table 8. Step-cone analysis for class 35 grey iron.

Aggregate	Coated	Penetration Index	Penetration Rank
CastBall 40/70	No	37	4
CastBall 30/150	No	42	5
CastBall 50/150	No	32	1
CastBall 40/70	Yes	32	1
CastBall 30/150	Yes	32	3
CastBall 50/150	Yes	43	6

Similar comparison between Table 7 and Table 9 for the low carbon steel was performed. It is difficult to definitively conclude a positive effect to increasing the GFN and distribution of the bauxite product based on table comparison. The penetration index for silica sand was appreciably higher in Table 9 and makes the baseline comparison difficult. However, based on the silica penetration index value differences between Table 7 and 9, if a factor of 5 is used to raise the penetration index value in Table 7 to similar values in Table 9, the adjusted penetration index value in Table 7 for CastBall 30/50 increases to roughly 200 and 300 for zircon coated and uncoated step cones, respectively. Using these adjusted values to compare to the bauxite products presented in Table 9, significant improved metal penetration resistance can be inferred from the data.

Table 9. Step-cone analysis for low carbon, low alloy steel.

Aggregate	Coated	Penetration Index	Penetration Rank
Silica	Yes	21	1
CastBall 40/70	Yes	84	8
CastBall 30/150	Yes	75	7
CastBall 50/150	Yes	52	4
Silica	No	46	3
CastBall 40/70	No	63	6
CastBall 30/150	No	45	2
CastBall 50/150	No	54	5

Gertzman Casting Analysis

Series of Gertzman test casting were performed to investigate the new synthetic aggregate CastBall 40/100. The experimental binder system used for the test cores was 1.25% phenolic urethane no-bake poured with a class 35 grey iron at 2600oF. Two Gertzman molds were poured using CastBall 40/100 and silica sand with zircon coated and uncoated test cores.

As expected, the silica sand exhibited massive metal penetration in the uncoated condition and extensive veining defects for the zircon coated cores. The CastBall 40/100 product did not exhibit any veining defects for the coated and uncoated condition. Slight metal penetration was observed for both the uncoated and zircon coated cores. Aggregate distribution contributes significantly to penetration resistance for the CastBall. CastBall 40/100 product performed equal well when compared to chromite and zircon sand.

Industrial Casting Trial

A casting trial at a steel alloy foundry was performed to advance the product from the laboratory environment to actual part production, measuring the performance the bauxite product to silica sand used by the foundry. To observe the performance of CastBall, a complex stainless steel valve body with two internal cores was selected as the test casting. The test casting was selected because the solidification pattern around the two cores produces heat saturation; giving a higher propensity to cause metal penetration, aggregate sintering, and veining. Because of this casting geometry, the foundry coats the two cores with a zircon water based coating. To increase the casting difficulty of CastBall 40/100, the two cores produced were not coated.

The stainless steel casting was poured at 2850oF and allowed to cool for approximately 4 hours before the casting went through shakeout and blast cleaning. The internal features of the stainless steel valve were observed for surface finish, comparing the zircon coated silica sand cores to the uncoated CastBall 40/100 cores. For both castings, no metal penetration or veining defects were observed. CastBall 40/100 cored area showed a slightly rougher surface than the zircon coated silica sand cored area. However, the foundry manager indicated the surface finish of CastBall 40/100 product was accepted and would be included into the finish casting lot.

Conclusions

Assessment of CastBall aggregate indicates performance is comparable to other foundry aggregates available in the foundry industry. No significant physical properties issues were observed to affect the mold making performance of the bauxite product for three different sand binder systems. Physical property evaluation showed the heat capacity property of bauxite is similar to silica sand, expansion characteristics comparable to zircon and chromite sand, and chemical properties analogous to the aggregate materials investigated. Through some modification with the screen distribution, the bauxite product subjected to laboratory and actual casting conditions performed equally well as silica sand, chromite sand, and zircon sand. The series of evaluation tests clearly illustrated CastBall can be used as synthetic sand for the foundry industry.

The major attributes of the bauxite aggregate product are:

- Aggregate material is compatible with furan, phenolic ester-cured, and phenolic urethane binder systems. Aside from the differences in screen distribution and GFN, the bauxite aggregate performed equally well as silica and chromite sand.
- The lower bulk density of CastBall when compared to chromite sand would create lighter cores and molds.
- CastBall exhibited similar expansion characteristics as chromite sand and superior expansion profile when compared to silica sand. Lower overall expansion is inherently related to absence of veining defects in ferrous applications. This was confirmed in the step-cone and Gertzman casting trails with a class 35 iron, 60-40-18 ductile iron, and low carbon, low alloy steel.
- Though initial casting trials with the CastBall 40/50 product showed susceptibility to metal penetration, subsequent testing with 40/70, 40/100, and 70/140 products showed substantial improvement to metal penetration resistance by broaden the screen distribution and increasing the grain fineness number (GFN)
- The specific heat capacity of CastBall 40/100 exhibited values of silica sand. It would be expected that the CastBall 40/100 product would solidify a casting at a slightly faster rate as silica sand but would be considered more insulating when compared to chromite sand and published data for zircon sand.

Recomendations

Based on the results and analysis of the physical properties and casting trails, the following recommendation is made. Broadening the screen distribution to engineer a molding aggregate to combat metal penetration showed promise and should continue. Each casting alloy will require slight modification of the screen distribution to address surface tension issues associated with surface finish.

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