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Iron & Steel Castings and Core Production Results from Finer Grades of Chromite Sand in Shell Applications

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ABSTRACT

Chromite Sands have been utilized to produce cores in foundries for many years. This investigation focuses on finer grades of chromite sand for core produced with shell technology. The specific shell cores produced result from the unique thermal characteristics of finer grades of chromite sand. The resulting castings demonstrate a high level of casting integrity.

Keywords: chromite sand, zircon sand, shell sand, cores, iron castings, steel castings

INTRODUCTION

Finer grades of chromite sands have become the cornerstone of the emerging technology allowing for improvements in casting designs and production in iron and steel. The advantages of the finer grades of chromite sand include improved grain-to-grain contact in binder systems, uniquely different thermal transfer characteristics, comparable binder requirements to other base aggregates, and others. Much of this conceptual application of finer grades of chromite sand started in the early 2000s with an investigation focused on a domestic US source of chromite sand. A 2006 *Modern Casting* article reviewed a great deal of scientific information that was generated at the University of Northern Iowa and in practical applications in the foundry industry.[1] The article, pointed out that the chromite mined in Oregon had a specific finer-grade distribution. The chromite did not require crushing and occurred as a two-sieve distribution with an 80 to 85 AFS GFN product.

The grain structure of the chromite is sub-rounded with a smooth and highly polished surface, allowing the metalcaster to use less binder to achieve the desired core and mold handling properties. The sub-rounded grain structure allows the grains to pack more tightly, reducing the opportunity for the molten metal to penetrate into the formed cores and molds, even at high ferrostatic pressures. This packing characteristic may also reduce or eliminate the need for refractory coatings. The increased grain-to-grain contact of the Oregon sand has shown a higher potential for the extraction of the metal’s temperature, affording a higher heat transfer rate and chilling capacity than other chromites or specialty sands.[1]

To understand this concept, test castings were produced at the University of Northern Iowa (UNI) to demonstrate the higher heat transfer rate and chilling capacity. The prepared molds and resulting castings are shown in Figures 1 and 2.[1] The improved heat transfer characteristics of chromite can modify and improve the surface characteristics of specialty steel or iron alloys.[1]

Figure 1. Prepared test molds and cores produced at UNI.

Figure 2. Resulting test casting produced at UNI.

This investigation highlights the importance of finer grades of chromite sand can be used to meet the requirements of iron and steel castings. Unfortunately, this geological sourcing did not become commercial for several mining and manufacturing reasons but not because of foundry applications.

RECENT PUBLICATIONS APPLIED TO UNDERSTANDING SOUTH AFRICAN CHROMITE

In the past four years, several technical papers were published and presented at AFS Metalcasting Congresses on the applications of South African chromite sands. The first *AFS Transactions* technical paper, "Prediction of Double-Skin Metal Penetration in Chromite Sand Using Process Simulation Software,"[2] and the second paper, "An Assessment of South African Chromite Sand Crushing Ratio,"[3] has a bearing on the topic of this paper.

In the prediction of double-skin metal penetration paper,[2] there are some important conclusions concerning the mineralogical chemistry of South African chromite sand that are important to understand. In the paper's conclusion, it was stated that:

"It was observed from the surface viscosity results in those progressively higher concentrations of silica within chromite sand had a strong negative correlation with sintering temperature. There was another distinct correlation that showed a decrease in overall thermal stability when contaminated chromite sand was heated to elevated temperatures, which resembled data presented by prior research."[2]

Understanding the importance of elemental silica in the base chromite sand ore is critical, the analysis of the specific South African chromite sand that is referenced in this paper was evaluated and determined to be acceptable for foundry applications which were published in the 2022 *AFS Transactions* paper by Kerns et al, concerning the application of chromite sizing for casting production.[3]

Since finer grades of South African chromite sands are the topic of this paper, it is essential to review the impact that the base chromite ores from South Africa have on the development of finer screen distribution products. Some chromite sands that are available commercially in North America are crushed or by-product versions of coarse-grain chromite sands that are commercially sold to the foundry industry. Therefore, it is important to understand the crushing tendencies of South African chromite that result in angular chromite grain shapes rather than the sub-angular grain shapes that are produced specifically for foundry applications at the mining sites in South Africa. In the paper, several evaluations were completed and visual examples of the resulting samples were presented. Figure 3 is an example of this information.[4]

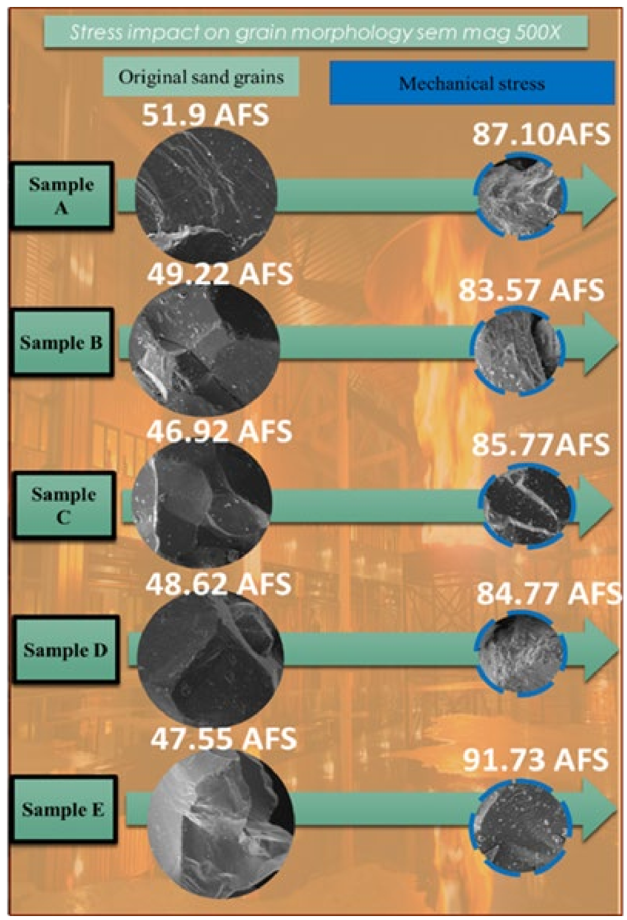

Figure 3. Grain size and morphology before and after mechanical stress application.

The practical application of this information relates to the ability of chromite sand to have the best possible grain-to-grain contact surface when a binder is applied to produce a sufficiently dense core for foundry production. An angular sand grain will not have a similar grain-to-grain contact as a subangular sand grain. This can be easily measured in the foundry testing lab as mold/core density.

SOUTH AFRICAN CHROMITE MANUFACTURED SPECIFICALLY AS FINER GRADES

In the 2022 Kerns sizing paper, specific information was shared in the manufacturing technique to produce finer grades of chromite sand at the production facility in South Africa. This designed manufacturing process has resulted in the following screen analyses of the chromite sands in Figures 4 and 5.

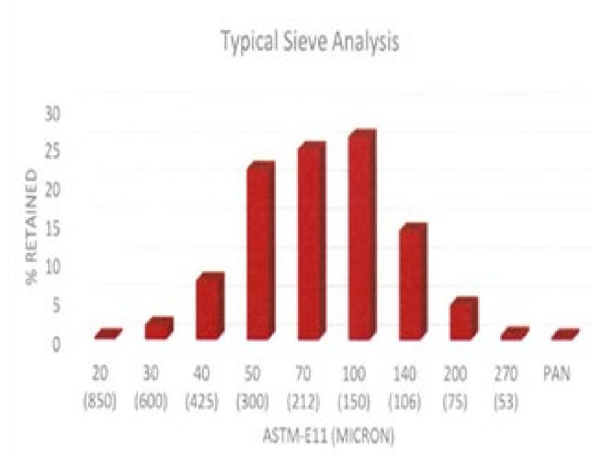

Figure 4. Typical screen analysis of Chromite 60.

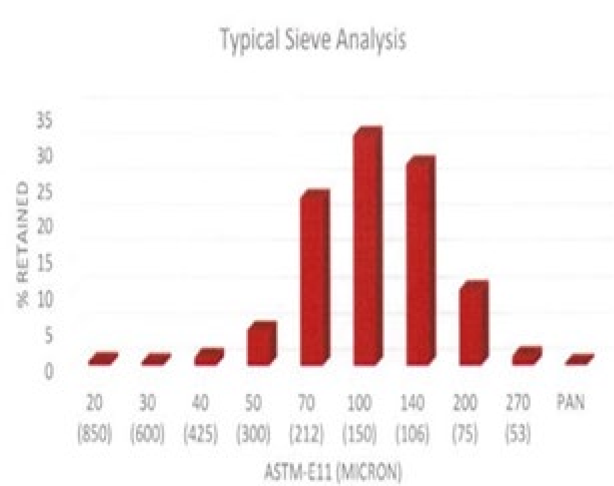

Figure 5. Typical screen analysis of Chromite 80.

SUMMARY OF THE PHYSICAL PROPERTIES OF CHROMITE SAND AS A REPLACEMENT FOR ZIRCON AND ZIRCON/SILICA SAND IN SHELL

These conclusions are taken from the Kerns, et al *AFS Transactions Paper* #23-013.[5]

- Chromite 80 is a suitable replacement for zircon and zircon/silica sand blends evaluated.
- Chromite 80 has been formulated into various shell resin products.
- Changes in resin levels are required when utilizing Chromite 80 as a replacement for zircon or zircon/silica sand blend when specific physical properties are required for casting production. However, lower specific physical properties can be desirable based on casting performance in the foundry.

INFORMATION DEVELOPED SINCE PUBLICATION OF 2023 PAPER

RESULTING CORE AND CASTING PRODUCTION CASE STUDIES

Case Study #1

This gray/ductile iron foundry historically used a blend of 15% 120 mesh zircon sand and 85% 60 mesh lake sand (Figs. 6 and 7) compared to the introduced 50% 80 mesh chromite sand and 50% 60 mesh lake sand (Figs. 8 and 9) in shell core technology.

The specific information on the core production can be found in Table 1. In addition, the only core machine setting changes were to include a doubled investment and that the cured shell sand resulted in desirable non-solid cores (Figs. 10 and 11).

Figure 6. Case Study #1 historically used a blend of 85/15 lake/zircon sand.

Figure 7. Case Study #1 historically used an 85/15 blend of lake/zircon sand.

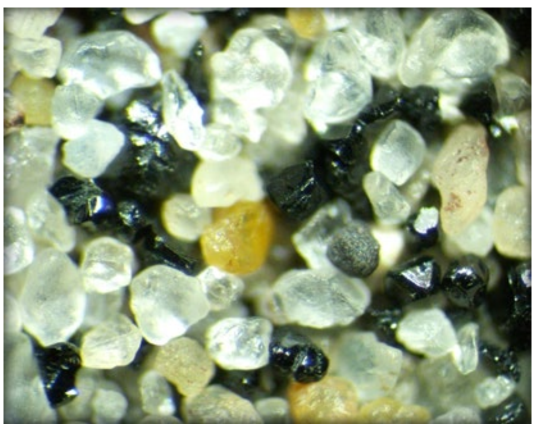

Figure 8. Case Study #1 introduced a new blend of 50% of 80 mesh chromite sand and 50% of 60 mesh lake sand.

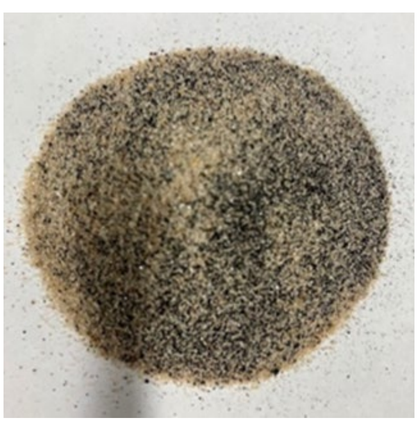

Figure 9. Case Study #1 introduced 50% of 80 mesh chromite sand and 50% of 60 mesh lake sand.

Table 1. Shell Core Material Properties

Material	Zircon // Lake Blend	Chromite // Lake Blend
Description	15% 120 Zircon/ 85% 60 Lake	50% 80 Chromite/ 50% 60 Lake Sand
RC Resin%	4.00%	4.00%
Melting Pt F	209	207
3' Hot Tensile, psi	583	550

Figure 10. Case Study #1 shell core produced from the new blend.

Figure 11. Case Study #1 shell core produced from the new sand blend.

The castings produced at this foundry have an excellent surface finish and met the customers' expectations (Figures 12 and 13). The incentive for the foundry to complete this project was the availability and the escalating cost of the zircon sand. The final blend of 50% of 80 mesh chromite sand and 50% of 60 mesh lake sand resulted in favorable casting surfaces. One additional goal moving forward is the continued improvement in costs. Therefore, the next phase will be to consider other blends, less chromite, and/or 100% chromite.

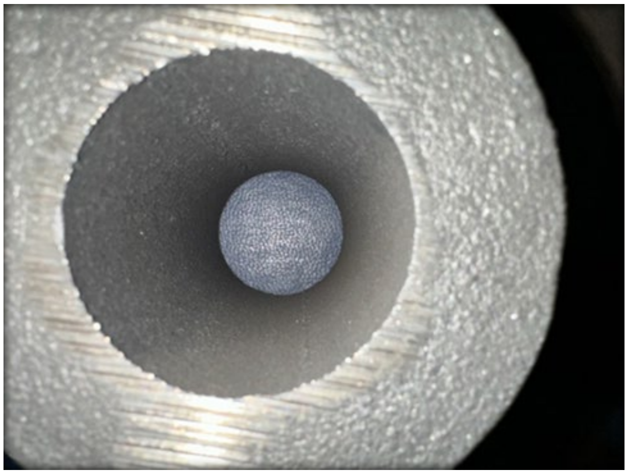

Figure 12. Close up view of an iron casting produced from Case Study #1 have an excellent surface finish and met customer expectations.

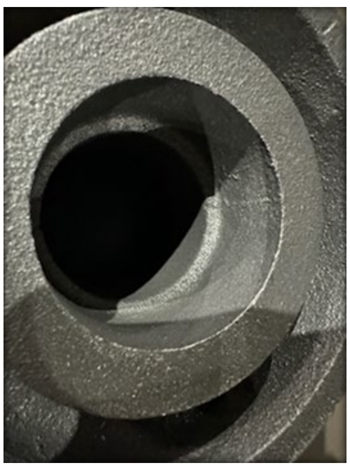

Figure 13. Overall view of an iron casting produced from Case Study #1 with an excellent surface finish.

Case Study #2

Case Study #2 involved an exotic steel alloy casting with a >3000F pour temperature that historically used 100% of 120 mesh zircon sand (Figure 14) that was replaced with 100% of 80 mesh chromite sand (Figure 15) in shell technology. A graphical comparison of the two sands is shown in Figure 16. This foundry had three successful series of core productions for this alloy.

Figure 14. Case Study #2 historically used 100% of 120 mesh zircon sand.

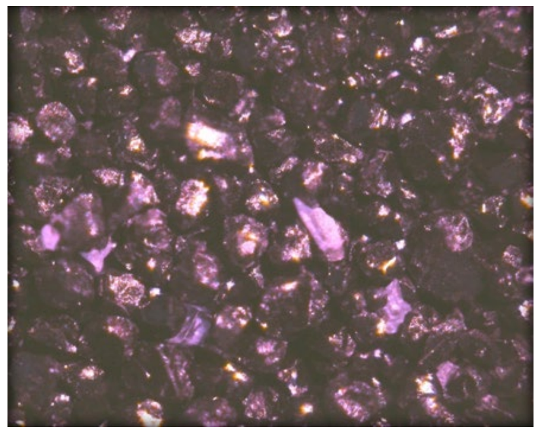

Figure 15. Case Study #2 replacement sand used 100% of 80 mesh chromite sand

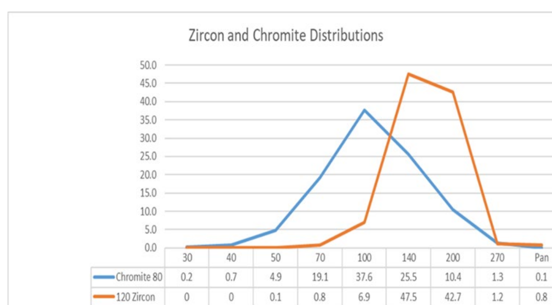

Figure 16. Graphical comparison of the two sands in Case Study #2.

SHELL CORE APPLICATION ONE

For shell core application #1, specific information on the core production is shown in Table 2. Figures 17 to 21 are photographs from the foundry comparing the two base aggregates.

In Table 2, it should be pointed out that the prepared zircon shell sand mixture contained 1.5% resin versus the chromite shell sand mixture which contained 3.25% resin. The resulting hot tensile psi was comparable at the two different resin levels and there were no gas-related issues during casting production. The foundry goal for this specific application was to reduce core breakage and improve casting definition. The foundry observed these benefits and economically resulted in a $1,944 per ton of material savings.

Table 2. Shell Core Application #1 Material Properties

Material	Zircon	Chromite
Description	100% 120 Zircon	100% 80 Chromite
RC Resin%	1.50%	3.25%
Melting Pt F	207	206
3' Hot Tensile, psi	427	458

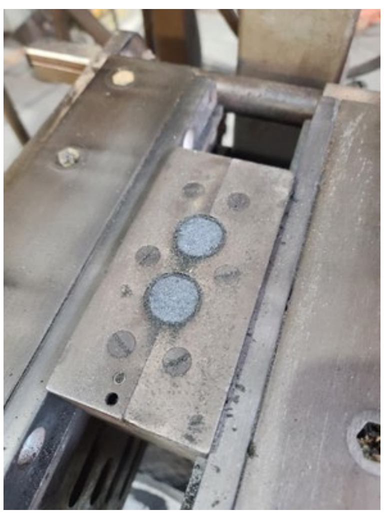

Figure 17. Tooling for Shell Core Application #1.

Figure 18. Shell Core Application #1, zircon cores are shown on the left and chromite cores on the right.

Figure 19. Bottom view of the shell cores from Shell Core Application #1, with zircon cores shown on the left and chromite cores on the right.

Figure 20. Side view of a zircon core from Shell Core Application #1.

Figure 21. Side view of a chromite core from Shell Core Application #1.

SHELL CORE APPLICATION TWO

Figures 22 to 26 are photographs from the foundry. Figures 23 and 24 compare the two base aggregates, zircon and chromite. During core production, the curing time was reduced in the chromite sand to 20 seconds from 60 seconds in the zircon sand.

The foundry goal for this specific application was to reduce core breakage and improve casting definition. The foundry observed these benefits and the weight reduction in the core was 25% lower which also increased core production volume.

Figure 22. Tooling for Shell Core Application #2.

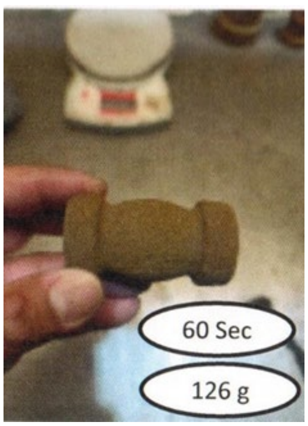

Figure 23. Zircon core production for Shell Core Application #2.

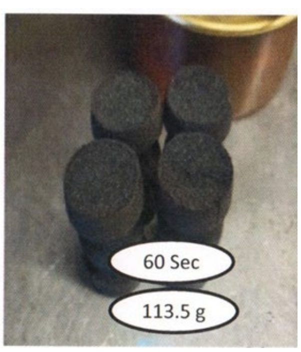

Figure 24. Chromite core production for Shell Core Application #2.

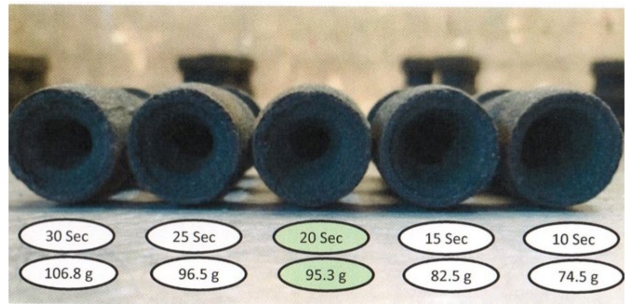

Figure 25: Chromite sand cores at various curing times for Shell Core Application #2.

Figure 26: Resulting casting for Shell Core Application #2.

SHELL CORE APPLICATION THREE

The foundry produced these cores to reduce the use of 100% zircon sand and expand the use of the 100% of 80 mesh chromite sand resulting in favorable savings. Figures 27 to 29 are photographs of an additional shell core application with 80 mesh chromite sand.

In Shell Core Application #3, the prepared zircon shell sand mixture contained 1.5% resin while the chromite shell sand mixture contained 3.25% resin. The resulting hot tensile psi was comparable at the two different resin levels and there were no gas-related issues during casting production. The foundry goal of this specific application was to reduce core breakage and improve casting definition. The foundry observed these benefits and expanded the use of 100% chromite sand.

Figure 27. Side view of a shell core with 80 mesh chromite sand for Shell Core Application #3.

Figure 28. Bottom view of a shell core from 80 mesh chromite sand for Shell Core Application #3.

Figure 29. Casting used a shell core with 80 mesh chromite sand for Shell Core Application #3.

CONCLUSIONS

1. The finer grades of chromite and chromite blends produce comparable castings to the previous aggregates applied to casting production with additional cost benefits.
2. Chromite as a specialty sand is not limited to steel foundry applications.
3. Chromite/chromite blends provide broadening applications to replace zircon when the finer grades of chromite are used.
4. With the limited availability and increasing costs of zircon sand there are proven lower-cost alternatives.
5. Finer grades of chromite sand support blending concepts with other aggregates such as silica sands
6. Finer grades of industrially produced chromite sand from South Africa are readily available.

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