

IMPROVEMENT OF WEAR COMPONENT'S PERFORMANCE BY UTILIZING ADVANCED MATERIALS AND NEW MANUFACTURING TECHNOLOGIES: CASTCON PROCESS FOR MINING APPLICATIONS

Quarterly Technical Progress Report

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Xiaodi Huang and Richard Gertsch

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Michigan Technological University
1400 Townsend Drive
Houghton, MI 49931

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Abstract

During this reporting period, we mainly focused on solving the disc distortion problem that was encountered in the last quarter. A slower heating rate during off-gassing was tested to reduce the HIPping can expansion. However, slight expansion still occurred. Two 6.5" discs were produced with many defects. One was made of H13 powder only and the other was made of H13 powder with WC inserts. It was believed that the defects were caused by the slight expansion of the HIP can during the elevated temperature off-gassing and a vacuum leak in the HIPping can.

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Executive Summary

In this reporting period, we continued efforts for full disc prototype manufacture. We modified the pattern with four steel rings bonded on the hub and cutting edge of the pattern to increase the pattern thickness. We changed the phenol binder to an oil based binder for sand molding to reduce sulfur contamination. We slowed the debinding and off-gassing heating rates to reduce the tendency of HIPping can expansion. Two 6.5" full size discs were produced using the CastCon process. One disc was made of H13 tool steel powder only and the other was made of H13 tool steel powder with WC insert in the center of the cutting edge. The HIPping cans still expanded slightly during off-gassing at an elevated temperature. The resulting two discs showed many defects and severe distortion.

It is planned in the next quarter to use a conventional furnace to conduct both debinding and off-gassing. It is expected that the new method could solve the can expansion problem.

Experimental

Two 6.5" discs were produced for the first time during the last quarter. Both cans showed distortion after HIPping. The discs, after removal from the cans, also showed distortion. We examined the cans and believed that the distortion was caused by expansion of the cans during the off-gassing process in a vacuum furnace. During debinding and off-gassing by heating, the gases in the sand mold released and were exhausted through a stem on the HIPping can. The debinding temperature went up to 1100°C in the final stage and the 1/16" thick steel of the HIPping can becomes fairly soft at that temperature. If the gas generation rate is much higher than the rate at which the gas escapes, the internal gas pressure of the can will be much higher than the outside pressure. We guessed that it was the case with our off-gassing process. The inside and outside pressure difference was greater than the strength of the can material at that temperature, resulting in can blowing or expansion. The can expansion generated a free space, which allowed the sand mold to move in the can or to crack without constraint from the can. The sand mold movement and cracking destroyed the sand mold's capability of retaining the shape of its cavity that contained the metal powder. In this quarter, we reduced the heating rates during debinding and off-gassing, and hoped to solve the can distortion problem.

We found from the last quarter that the produced discs were not thick enough on hub and cutting edges. The disc pattern was modified with four steel rings bonded on the needed surfaces to increase their thickness.

To produce 6.5" discs in this quarter, the HIPping cans were made of 1/16" thick low carbon steel sheet by cutting, rolling, bending and welding. The welding was conducted in a glove box full of argon. We used a 3/8" steel stem for gas exhaust and evacuation of the cans.

A phenol binder was used for sand molding in previous experiments. This binder needs a sulfuric acid as a catalyst to cure the binder. Sulfur came out during HIPping and may form a sulfide film on H13 powder surfaces. To reduce the sulfur contamination, we replaced the phenol binder with an oil based binder, LINO-CURE from Ashland Chemical. The sand and binder were

blended in the following ratio: 10% LINO-CURE A binder based on sand, 20% LINO-CURE C based on LINO-CURE A, 5% LINO-CURE B (catalyst) based on LINO-CURE A.

Both cans were debinded in the same way. The can was heated in a box furnace first with a hose connecting the can's stem and a vacuum pump to evacuate the can. The can was heated according the procedure described below:

- 5°C/min from 25°C to 200°C,
- hold for 5 hours at 200°C,
- 5°C/min from 200°C to 500°C,
- hold for 3 hours at 500°C, and
- furnace cooled.

After debinding, the can was heated again for off-gassing in a vacuum furnace from room temperature to 1100°C according the procedure below:

- 10°C/min from 25°C to 500°C,
- 2°C/min from 500°C to 1100°C,
- hold for 3 hours at 1100°C, and
- furnace cooled.

After the high temperature off-gassing, the can was sealed and shipped to Bodycote for HIPping. The cans were HIPped under 15 ksi at 1120°C for four hours.

Results and Discussions

Both cans expanded slightly after high temperature off-gassing although a much slower heating rate was used. After HIPping, one can cracked and another blew, as seen in Figures 1 and 2. From our past experience, the cracked can resulted from free movement of the graphite sand inside the can. A portion of the graphite sand moved over an insulation layer to contact directly with the steel can and reacted with the steel. The reaction formed a brittle iron carbide and this carbide cracked during cooling. The can blowing was due to a small vacuum leak. High-pressure gas penetrated the can during HIPping, and expanded the can upon a quick discharge of HIPping gas.

After being removed from the cans, both discs showed severe defects as seen in Figures 3 through 6. It was obvious that both sand molds cracked and the metal powder flowed into the big, thick cracks and formed the "ribs".

Conclusions

Off-gassing a larger volume and thin wall container in a vacuum furnace at an elevated temperature over softening point of the container material is not recommended. An alternative debinding and off-gassing method needs to be developed for the large, thin walled HIPping can.

Vacuum leak must be prevented.

Future Work

We plan to use a conventional furnace to carry out the debinding and off-gassing process in the next quarter.

References

No references are included in this quarterly report.



Figure 1. H13 only disc can with a big crack



Figure 2. Blown H13/WC disc can



Figure 3. H13 only disc, back, note 'ribs' where the sand mold cracked



Figure 4. H13 only disc, front, note 'ribs' where the sand mold cracked



Figure 5. H13/WC disc, front, note 'ribs' where the sand mold cracked



Figure 6. H13/WC disc, back, note 'ribs' where the sand mold cracked