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

In this reporting period, the project focused on the investigations of FM material container-less HIPping, disc section examination and heat treatment, and full disc manufacture.

The FM container-less HIPping resulted in either full density not being reached or reaching full density but losing the FM structure. Container HIPping seems to be necessary to consolidate the FM material. The heat treatment conducted on the 6.5" disc section with a WC insert caused cracking in the WC body and along the WC and H13 boundary. Two full 6.5" disc cutters were produced but contained defects.

It is planned to produce more full disc cutters in the next quarter.

Experimental

For the container-less HIPping tests, an FM specimen after sintering at 1350°C for one hour reached the desired density (absorbing no water). This specimen was sent to ACM for container-less HIPping at 1300°C and 30 ksi. Another FM specimen was sintered at 1350°C for one hour in a vacuum furnace and followed immediately by a 50 ksi argon pressurizing at the same temperature for another hour in the same furnace.

To test disc section heat treatment, the 6.5" section with the sintered conventional WC insert was selected. This part was heat-treated in a vacuum furnace using the following procedure:

- heated at 600°C/hr from 25°C to 1020°C
- held for one hour at 1020°C for austenitizing
- argon quench from 1020°C to 25°C
- heated again at 600°C/hr from 25°C to 600°C
- held for two hours at 600°C for tempering
- furnace cooled to 25°C

In preparation for full disc manufacture, twenty WC inserts were prepared by die pressing GWC-10 powder (purchased from Alldyne Powder Technologies, 90% WC and 10% cobalt) and vacuum sintering at 1350°C for one hour (*Figure 15*). Ten inserts were then bonded together using epoxy to form a WC ring with the help of an auxiliary tool (*as shown in Figure 17*).

Results and Discussions

During this reporting period, the efforts continued on the investigations of FM material container-less HIPping, disc section examination and heat treatment, and full disc manufacture.

FM Material Container-less HIPping

An FM specimen after sintering at 1350°C for one hour reached the desired density (absorbing no water). This specimen was sent to ACM for container-less HIPping. After HIPping, this specimen was returned to MTU (Figure 1). There was no noticeable difference in appearance between before and after HIPping. The specimen was cut and polished to expose its microstructure, as shown in Figures 2 and 3. Porosity obviously remained. The remaining porosity indicated that HIPping did not help to consolidate the specimen further after sintering or that the remaining pores were still interconnected to external surfaces so that pressurized gas could not act on the specimen's external surfaces to build a pressure difference inside and outside the specimen during HIPping.

Another FM specimen was sintered at 1350°C for one hour in a vacuum furnace and followed immediately by a 50 ksi argon pressurizing at the same temperature for another hour in the same furnace. The specimen showed significant shrinkage after the sintering/low pressure HIPping, as shown in Figure 4. The specimen was cut and polished. It was surprisingly found that the FM microstructure disappeared, as seen in Figure 5. The WC grains seemed bigger than their original size and were distributed randomly as a conventional WC microstructure. This suggests that the WC particles recrystallized at the high temperature of 1350°C, which is near the melting point of the matrix cobalt. The specimen reached near full density.

Disc Sections Examination and Heat Treatment

Three 6.5" disc sections and one 17" disc section had been produced during the last reporting period. The three 6.5" sections contained a "green" FM WC insert, a hot pressed FM WC insert, and a sintered conventional WC insert, respectively. The 17" section contained a sintered conventional WC insert. These sections were cut during this reporting period to expose their structures, as shown in Figure 6. The 17" section with the conventional WC insert is shown in Figure 7. The "green" WC insert obviously shrank (Figures 8 and 12) and the hot-pressed WC insert shows a relatively coarse FM structure (Figures 9 and 13). The sintered conventional WC insert in the 6.5" disc section shows homogenous microstructure and good bonding with the H13 body as seen in Figures 10 and 11. There is a concern that the heat treatment normally required for an H13 steel may break the bonding between the WC insert and the H13 body since WC and steel have very different thermal expansion properties. To test the concern, the 6.5" section with the sintered conventional WC insert was selected and heat-treated in a vacuum furnace. This part showed cracks in the WC insert and along the boundary between the WC insert and the H13 body (Figure 14).

Full Disc Manufacture

Originally, it was planned to produce three 6.5" disc cutters: one H13 only and two with WC inserts, using the CastCon process. Twenty WC inserts were prepared (Figure 15). Figure 16 shows the insert before and after sintering. Ten inserts were then bonded together as shown in Figure 17. Two WC rings were made in this way. Three sand molds were made and two of them had the WC ring inserts positioned in their centers. H13 powder then filled the rest of the sand molds. The sand molds were encapsulated in HIP cans, made of 1/16" thick mild steel sheet. The cans were heated in furnace to remove organic binder and sealed. Unfortunately, the first can was blown badly due to the relatively high heating rate during the binder burn-out cycle (Figure 18). Heating rate was reduced when treating the remained two cans. The cans still expanded slightly as seen in Figure 19. The two cans were shipped to Bodycote, a commercial HIPping

service company for processing. The two cans were HIPped at 1120°C for four hours under 15 ksi by Bodycote. The cans showed severe distortion after HIPping but after opening the cans, the disc cutters appeared to be fine, as shown in Figures 20 and 21. Cracks can be seen on the H13 only disc cutter (Figure 22). A small degree of distortion occurred on both cutters. Dimension measurements indicated that all diameters of both cutters meet our original design requirements, but the thickness needs to be increased. The two cutters are currently being machined.

Conclusions

The two container-less HIP experiments imply that the FM material cannot achieve both full density and maintain the FM microstructure using container-less HIPping. Container HIPping may be necessary to consolidate this type of material.

As a result of the disc section examination and heat treatment, we concluded that a barrier material may be needed to coat the WC insert surface to isolate its contact with the H13 body as a buffer to reduce the thermal shock due to the thermal expansion differences. Cobalt was selected as the barrier material because of its good match with both materials and no potential to react to form a brittle intermetallic compound.

The full disc manufacturing process is still being evaluated.

Future Work

It is planned to manufacture more full 6.5" disc cutters in the next quarter.

References

No references are included in this quarterly report.

Figure 1. Container-less HIPped FM Specimen

Figure 3. Microstructure at 50 magnification of Container-less HIPped FM Specimen

Figure 4. Low Pressure Container-less HIPped FM Specimen

Figure 2. Microstructure at 400 magnification of Container-less HIPped FM Specimen

Figure 5. Microstructure of Low Pressure Container-less HIPped FM Specimen

Figure 6. Cut Disc Sections

Figure 7. Sintered Conventional WC Insert 17" Disc Section

Figure 8. "Green" FM WC Insert 6.5" Disc Section

Figure 9. Hot Pressed FM WC Insert 6.5" Disc Section

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Figure 11. Microstructure of Sintered Conventional WC Insert 6.5" Disc Section

Figure 12. Microstructure of "Green" FM WC Insert 6.5" Disc Section

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Figure 14. Heat Treated Microstructure of Sintered Conventional WC Insert 6.5" Disc Section

Figure 15. WC Insert Preparation

Figure 16. WC Insert Before (top) and After (bottom) Sintering

Figure 17. WC Insert Ring Binding

Figure 18. Blown HIP Can

Figure 19. Expanded HIP Cans

Figure 20. First Disc Cutter from Expanded HIP Can

Figure 21. Second Disc Cutter from Expanded HIP Can

Figure 22. Cracks on H13 Only Disc Cutter