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Research Paper

MICROSTUCTURE AND MICROHARDNESS OF CHILL CAST AL-B_4C COMPOSITES

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The mechanical properties of composite materials are strongly dependent on micro structural parameters of the system. The evolution of microstructure depends largely on the cooling rate during phase change. Though the microstructure evolution depends on many process parameters, the final structure is decided by the cooling conditions during solidification. The mold material has a decided effect on the structure formation. The use of end chills during casting not only favors directional solidification but also accelerates solidification. Faster cooling rates give rise to finer structures and improved mechanical properties. In this work an attempt is made to vary the cooling rate of AL-B_4C, composite cast using stainless steel, cast iron and copper chills. The microstructure and micro hardness of the chill cast specimens are analyzed and reported. It is observed that the chill material has a significant influence on the microstructure and hardness of the cast specimens. Finer structure and better hardness were observed with the specimens cast using copper chills, whereas, cast iron and stainless steel chills gave rise to coarse structure with reduced hardness.

Keywords: End chill, Cooling rate, Directional solidification, Microstructure

INTRODUCTION

A composite material is made by combining two or more materials to give a unique combination of properties. The development of Metal Matrix Composites (MMCs) is of growing interest to scientific and industrial communities, due to their attractive physical and mechanical properties. Particularly, particulate reinforced aluminum MMCs have attracted considerable attention, because of lightweight, high strength, high specific modulus, low coefficient of thermal expansion and good wear resistance. Sic, Al_2O_3, Tic and B_4C are common ceramic reinforcements in Al MMCs. Aluminum Matrix Composites (AMCs) are attractive materials for structural applications in aircraft, automotive and military industries. High strength to weight ratio,

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environmental resistance, high stiffness and good wear resistance are characteristics that have spurred more research to develop their applications by further improvement in the properties.

B_4C is an extremely promising material for a variety of applications. This is due to its lower density (2.51 g/cm^3) compared to Sic (3.21 g/cm^3), diamond (3.51 g/cm^3) and Al_2O_3 (3.92 g/cm^3) . It also has very high stiffness (445 Gpa) and high hardness (3700 Hv). The high hardness of boron carbide is attributed to the presence of B and C which forms covalently bonded solid. Al6061 is widely used in numerous engineering applications including transport and construction where superior mechanical properties such as tensile, strength, hardness, etc., are essentially required.

Metal molds generally offer greater chilling effect on the solidifying mass due to higher heat diffusivity. The influence of higher cooling rates is normally responsible for the superior properties of chilled castings. The use of chills favors refinement of microstructure and steepens the temperature gradient, making solidification directional.

Thus, the present study was conducted to know the effect of different chill material on the solidification behavior of Al-B_4C composite.

OBJECTIVE OF THE PRESENT WORK

The present investigation was carried out with the following objectives.

- To prepare Al-B_4C composite by stir casting method.
- To use copper, stainless steel and cast iron as end chills to vary the cooling rate.
- To evaluate the microstructure and micro hardness of the chill cast specimens.
- To correlate microstructure to micro hardness of the composite.

EXPERIMENTAL DETAILS

Materials Used

MATRIX: The matrix material for the present study was Al6061. Table 1 gives the chemical composition of Al6061.

Table 1: Chemical Composition of Al6061 by wt%

Elements	Si	Fe	Cu	Mn	Ni	Pb	Zn	Ti	Sn	Mg	Cr	Al
Composition (Wt%)	0.4	0.7	0.2	0.1	0.05	0.2	0.1	0.15	0.001	0.8	0.2	remainder

Reinforcement: Boron carbide (B_4C) was chosen as reinforcement owing to its high hardness and low coefficient of thermal expansion. Boron carbide is highly wear resistant and also has good mechanical properties including high temperature strength and thermal shock resistance.Table 2 shows the properties of Boron carbide.

Chills: Copper, stainless steel and cast iron metallic chills with dimension $125 \times 125 \times 25$ mm were used to prepare the composites. Table 3 shows thermo physical properties of the chill materials used for the present study.

Composite Preparation

A cylindrical sand mold is prepared using sodium silicate and carbon dioxide. High

Table 2: Properties of Boron Carbide

Density	Hardness	Size	Weight %	Young's Modulus	Melting Point
2.51 gm/cc	350 BHN	105 μm	8	540 Gpa	2880 °C

Table 3: Thermo Physical Properties of the Chill Materials

Chill Material	Density kg/m^3	Thermal Conductivity W/m K	Specific Heat J/kg K
Copper	8.80	380	151
Steel	7.61	52	55
Cast Iron	7.80	40	47.5

refractory silica sand is used for the preparation of the mold. After the mold is properly dried and hardened, mold coating (DYCOTE) is applied to the mold and dried again to remove any moisture present. The molds are placed on the chills (stainless steel, copper, cast iron). Core fix is used to seal the gap between the sand mold and the chill plate to avoid the leakage of molten metal during pouring. The whole assembly is dried in oven to remove any moisture present during the various stages of mold preparation. The mold assembly is taken out of the oven and cooled to room temperature before pouring the molten metal. The prepared molds along with bottom chill plates ready for pouring are as shown in Figure 1.

Aluminum (Al6061) is melted in the resistance furnace and heated up to 750 °C. Boron carbide is wrapped in aluminum foil and heated to 200 °C and poured into the crucible containing aluminum at 750 °C. The mixture is thoroughly stirred to ensure uniform distribution

Figure 1: Coated Sand Molds with Bottom Chill Plates

(a) Copper (b) Stainless Steel (c) Cast Iron of B_4C in the melt. The composite mixture is poured into the molds at a uniform pouring rate. The melt solidifies in the molds at different rates due to different rate of heat extraction from different end chill material.

Microstructure and Hardness Testing

The specimens prepared from the cast composites were polished and etched as per the standard metallographic procedure. The microstructures of etched specimens were observed using optical microscope.

The hardness was measured at different locations along the vertical length of the specimen using Vickers hardness tester at a load of 50 gm for 10 s.

RESULTS AND DISCUSSION

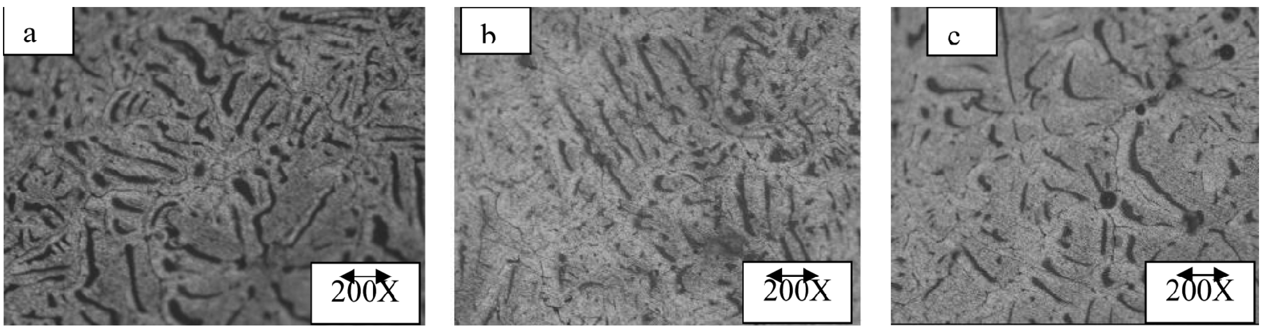
Evaluation of Microstructure

Figure 2 shows the microstructures of the cast components using copper, stainless steel and cast iron chills. The structures indicate that the chill material has a decided effect on the grain size and also on the distribution of boron carbide in the matrix alloy. Fine grained structure is obtained with the use of copper chill where as the stainless steel and cast iron chills give rise to coarse grain structures. This is because of the higher rate of heat extraction and faster cooling rate in case of copper chill. Also, boron carbide distribution is more uniform in the castings obtained using copper chill. Whereas, the boron carbide tends to agglomerate in the matrix in the castings obtained using stainless steel and cast iron chills.

Evaluation of Micro Hardness

Figure 3 shows the micro hardness of the cast specimens using different chill materials. In each one of these graphs it is observed that the micro hardness increases with the increase in distance from the chill end, reaches a peak value and then decreases. The graphs also indicate that the hardness is maximum with the use of copper chill and minimum with the use of cast iron chill. The stainless steel chill gives rise to moderate hardness values. This is attributed to the fact that the copper chill gives rise to finer structure and cast iron chill gives rise to coarser structure. It is known fact that the fine grained structures have higher hardness than the coarse grained structures.

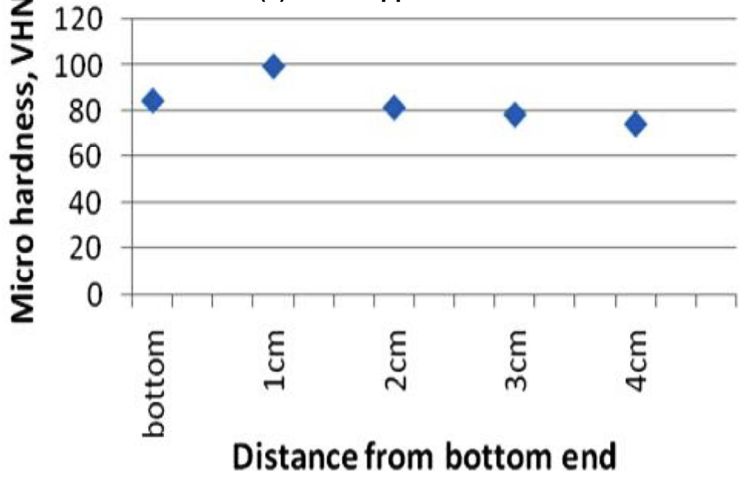
Figure 2: Micrograph of Cast Composites with Different Chill Material



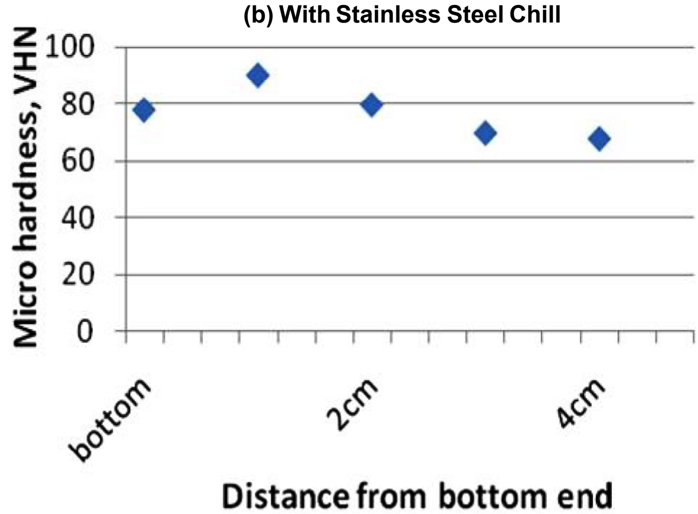
(a) Copper (b) Stainless Steel (c) Cast Iron

Figure 3: Micro Hardness of Cast Composites

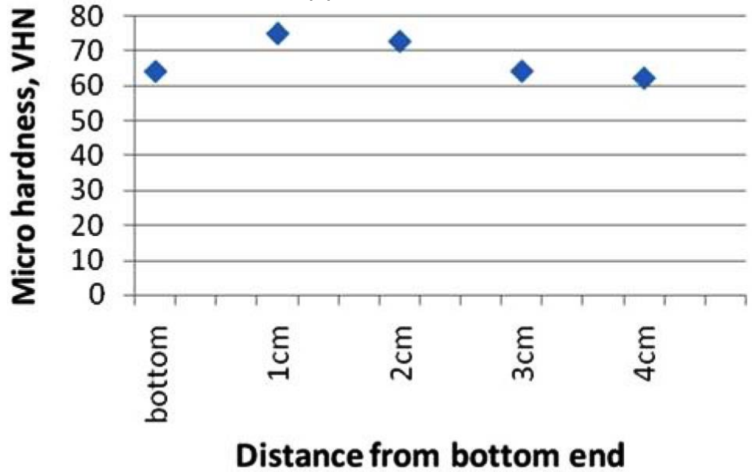
(a) With Copper Chill



(b) With Stainless Steel Chill



(c) With Cast Iron Chill



CONCLUSION

Aluminum matrix boron carbide reinforced composites were successfully cast by conventional stir casting route using different end chill materials. From the analysis of the cast specimens the following conclusions can be drawn.

- The chilling effect is maximum in case of copper chill. The chilling effect successively reduces with stainless steel and cast iron chills.
- Fine grain structure is obtained with the use of copper chill, whereas, the grain size successively increases with the use of stainless steel and cast iron chills.
- Hardness of the cast specimens increases with the increase in distance from the chill end, reaches a maximum at about 1 cm from the chill end and then decreases for all the three cases studied.
- The hardness is observed to be maximum with the use of copper chill whereas, it successively decreases with the use of stainless steel and cast iron chill.
- Therefore, the chilling effect has a decided effect on microstructure and micro hardness of the cast components.

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