Use of Boron Nitride Coatings with Aluminum Casting Technology

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ABSTRACT --- Boron nitride is an advanced ceramic material that shows outstanding lubricating and release properties when used at high temperature in contact with aluminum and its alloys. Today boron nitride is available in the form of paints for brushing and spraying. These coatings are proven release agents in the casthouse for coating thimbles, transition plates and refractory linings of distribution troughs of DC casting machines. During cast breaks they ensure an easy release of the remaining aluminum without damaging the refractory lining. In contrast to coatings used so far (based on graphite, silicates and similar substances) boron nitride release coatings are stable in air up to 1000°C (1832°F), show excellent non-wetting behavior (the best in the field of ceramics) and very good lubrication properties even at high temperatures. These advanced characteristics make boron nitride release coatings a first choice to engineers and metallurgists.

INTRODUCTION

Coatings are used to change the properties of given substrate surfaces as required. The boron nitride coatings described here protect ceramics in a high-temperature environment and furthermore act as an release and lubricating agent in contact with aluminum. The properties of boron nitride that are important for this application are discussed and some examples of applications are given. Only paintable coatings consisting of boron nitride suspended in a carrier liquid are considered here.

PROPERTIES OF BORON NITRIDE

Boron nitride is a non-oxide ceramic material, belonging to the group of advanced ceramic substances with the chemical formula BN. This material does not occur in nature, however it is synthetically produced. For the application in foundry coatings boron nitride is used in powdered form. Figure 1 shows a scanning electron micrograph of boron nitride powder with a magnification of 3000 times. The boron nitride powder is made of plate-like particles having a size of max. 5-8µm. The center of this micrograph shows some particles with their flat side up; on the right side, boron nitride particles are shown with their edge in an upward direction.

The hexagonal modification of boron nitride crystallizes in a layer structure similar to that of graphite (Figure 2).[1] Because of this similarity in structure and its white color boron nitride is often referred to as “white graphite”. The layers of boron nitride may be shifted easily so this substance may be used as a solid lubricant.

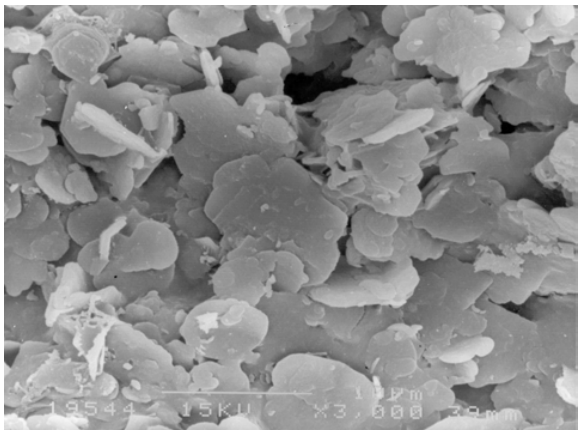

Figure 1. Scanning electron micrograph of boron nitride powder (magnification 3000-times)

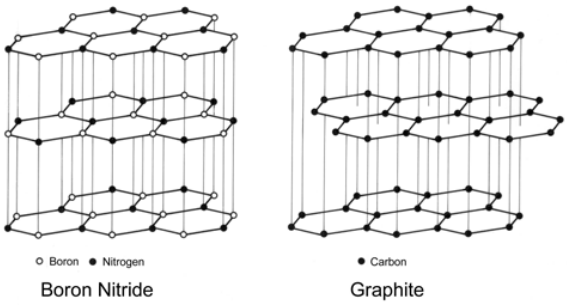

Figure 2. Crystal lattice of boron nitride and graphite[1]

The coefficient of friction for boron nitride compared with that of graphite is given in Figure 3.[2] At temperatures up to 600°C (1112°F), graphite shows a lower coefficient of friction than boron nitride. The strong increase of values between 600 … 800°C (1112 … 1472°F) is caused by the oxidation of graphite. Here, boron nitride shows advantageous values in the range of casting temperatures of aluminum. The climb in the curve of boron nitride between 800 … 1000°C (1472 … 1832°F) is caused by oxidation as well.

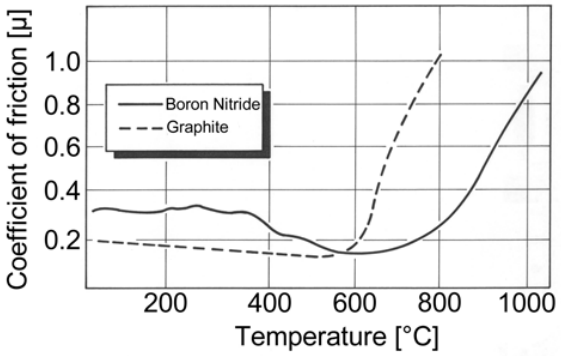

Figure 3. Comparison of friction data for boron nitride and graphite in air in dependence on the temperature.[2]

Boron nitride shows chemical inertness and corrosion resistance to molten metals combined with very good non-wettability against many metallic melts including aluminum, magnesium, and its alloys.

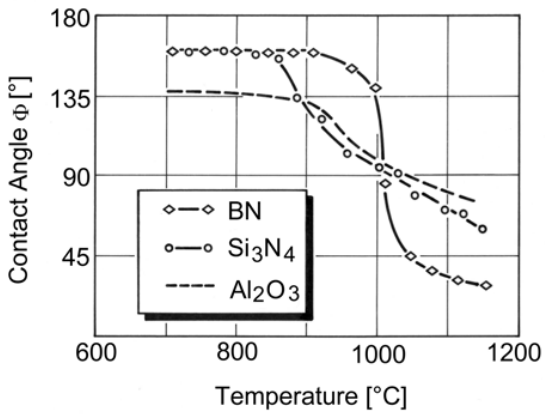

Figure 4. Contact angle data of aluminum on boron nitride (BN), silicon nitride (Si_3N_4), and alumina (Al_2O_3) in dependence on the temperature.[3]

The contact angle data for aluminum drops on BN is compared with those of Al_2O_3 and Si_3N_4 in Figure 4.[3] Up to 900°C (1652°F) boron nitride is only poorly wettable by aluminum and shows a contact angle of 160°. Between 900 ... 1000°C (1652 … 1832°F) the contact angle decreases, but is well above those of Al_2O_3 and Si_3N_4. However, in the temperature range which is interesting to aluminum casters, the wetting behavior of boron nitride is far superior to oxide ceramics like alumina and even a little better than silicon nitride. Thus boron nitride is an ideal release agent for many foundry applications.

COATINGS BASED ON BORON NITRIDE

In order to use boron nitride in foundries it is necessary to apply it in the form of coatings. These coatings are water-based suspensions like house paint. In these coatings boron nitride is blended with a refractory binder in order to ensure a good adhesion on the surface where the coating is applied.

Such boron-nitride-coatings are applied like ordinary house paints by brushing or dipping. If it is required to coat small objects, dipping can be an application method of choice as well. Spraying is also possible and is recommended for coating larger surfaces and for hot objects which are difficult to paint. For spraying, a blow cup or a spray gun operated by pressurized air can be used. Nozzle sizes of 1.5mm (0.060-inch) will give best results.

USE OF BORON NITRIDE COATINGS

Boron nitride coatings can be used to coat various objects which are in contact with molten aluminum or immersed into molten aluminum. These may be made from metal or steel, for example, ladles and thermocouple protection tubes. It is possible to coat ceramic and refractory parts as well. Due to the very good non-wetting and release properties, the melt or any remaining parts of it do not stick onto coated surfaces and can be easily removed.

Castings of billets

One major field of application of boron nitride coatings is use of DC billet casting machines. Here boron nitride coatings are used to coat and protect thimbles, transition plates and the refractory lining of troughs. Due to their superb release and parting properties, cleaning of the refractory parts is made easier. At the same time damage of the refractory substrate is prevented because it is not necessary and of course not recommended to use iron tools or any tools at all for cleaning purposes.

Application on thimbles

In conventional practice thimbles are treated using coatings based on graphite or iron oxide in order to prevent sticking of aluminum to the refractory material. However, experience shows that despite the applied coats considerable amounts of metal stick firmly to the thimbles. So force is used with tools for the subsequent cleaning of such thimbles which disintegrates the refractory surface. Tiny particles of the refractory material are separated from the thimble during this cleaning process enlarging its surface and providing even better adherence of melts in future castings. These are the initial stages of destroying the thimble and limiting the life time of these parts to about 200 … 300 casts.

In order to extend the life time of thimbles, today boron nitride coatings are used. Such coatings are applied by brush to the thimbles (made of fused silica) before the casting table is put into service for the first time. Additional coats are painted during casting breaks. This treatment enables the operator to easily remove the remaining metal without the use of any tools. In this way boron nitride coatings help to extent the life time of such thimbles dramatically. Tests carried out show that it is possible extended it to about 400 … 600 casts (Table 1). This is achieved mainly by the fact that the surface of the refractory parts is not damaged any more by mechanical influence of any tools and remains in good shape.

Table 1. Extended life time of thimbles with billet casting using boron nitride coatings

Plant	No. of casts with conventional coatings	No. of casts with boron nitride coatings	Alloy used
A	200 … 250	400 … 500	6063
B	200 … 300	500 … 600	7000
C	200 … 300	~500	3000

Application on transition plates

Transition plates (mainly made of Ca-silicate) of MaxiCast casting machines are still coated with graphite today. However, AirSlip transition plates are treated with boron nitride establishing a proven method to protect these parts and successfully replacing graphite.

Application on troughs

Standard procedure of coating troughs when casting billets is the use of coatings based on bone ash or iron oxide (red mud coatings). Bone ash is applied as powder whereas iron oxide slurries are painted yielding a coating thickness up to 1cm (0.39-inch).

Today boron nitride coatings are used in troughs lined with Ca-silicate or low-density fused silica. In this way the achievable life time is extended from about 1 year to 2 … 3 years. However such results will be obtained only by a careful application and thorough maintenance of the coated troughs. Best way to do this is to start coating a cold trough by using a concentrated coating and polishing this coating into pores of the refractory material as well as into the joints. Thus the surface is sealed in order to prevent the aluminum from infiltrating the voids of the refractory material and sticking to it. This enables the operator to clean the trough without damaging its surface. Subsequent applications of boron nitride coatings are carried out during casting breaks when the remaining metal is removed from the trough. As described earlier the use of any tools for removing the metal from the trough should be avoided in order to prevent any damage of the refractory substrate.

SUMMARY

Boron nitride coatings have an excellent thermal and chemical stability in the temperature range that is of interest to aluminum casters. It does not react with the metal melt or the refractory nor does it disintegrate. Boron nitride shows a very good non-wetting behavior, one of the best known in the fields of

ceramics. Furthermore it is an excellent high-temperature lubricant with outstanding lubrication and parting properties. Last but not least, boron nitride is of white color. Therefore, in contrast to graphite, it is a good way to keep the foundry cleaner.

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