A R C H I V E S O F M E T A L L U R G Y A N D M A T E R I A L S
Volume 53 2008 Issue 2

M. JAFARI*

THE RULE OF HIGH ALUMINA ADVANCE ENGINEERING CERAMICS AS WEAR RESISTANCE MATERIALS

ROLA ZASTOSOWANIA CERAMIKI O WYSOKIEJ ZAWARTOŚCI TLENKU GLINU JAKO MATERIAŁU ODPORNEGO NA ZUŻYWANIE

Progressing of technology and production in iron industries especially steel, iron oxide processing and coal in Iran causes to increase costs for preventing corrosion of equipments in those industries. There are different materials such as hard metals and polymers to protect wearing problems. One of the most hardest and economic materials that can be used for protection of equipments from corrosion is high alumina ceramic parts. By establishment of a factory to produce high alumina ceramics in Iran and installing these ceramic parts in one of iron oxide processing plan, Gohar Ravesh Sirjan Co., it was possible to increase production capacity. This was occurred by extending the repairing period time and also feeding of raw materials to the processing system. Except hardness of high alumina ceramics, there are different properties that make these materials more valuable and interesting to use. In this industrial experiment, wear resistance high alumina ceramics is used with Al_2O_3 content of more than 92 wt%. In this practical study physical and chemical properties and also the life time of these kinds of ceramic materials are investigated. Also the hardness and life time of these ceramics are compared with trading hard metals.

To provide scientific data some properties of high alumina ceramic like, density, hardness, microstructure and mechanical strength were studied. For example, it was found that the hardness of high alumina ceramic is 1800 to 2000 HV with compare to hard metal which in same scale is 550 to 630; this is showing that the wear resistance of high alumina ceramic is almost four times more than hard metals. In practice depend on place of application; the life time of ceramic can be increased more than eight times. Ceramics also have some limitation to use such as low toughness and installation methods.

Keywords: High alumina ceramic, Wear resistance, Hardness

Rozwój technologii przemysłowej produkcji żelaza, zwłaszcza stali, przeróbka rud żelaza oraz węgla w Iranie powoduje wzrost nakładów na zapobieganie korozji urządzeń wykorzystywanych w tych branżach. Aktualnie na rynku dostępnych jest wiele materiałów pełniących rolę ochronną – antykorozyjną, np.: spieki węglików i polimery. Ze względu na wytrzymałość oraz optymalną jakość najlepszym materiałem, który może być użyty do ochrony urządzeń przed korozją są materiały ceramiczne o wysokiej zawartości tlenku glinu.

Dzięki powstaniu w Iranie fabryki produkującej elementy ceramiczne o wysokiej zawartości tlenku glinu i wykorzystaniu ich w Gohar Ravesh Sirjan Co., w procesie przeróbki rud żelaza, uzyskano wysoki wzrost wydajności produkcji. Osiągnięto to dzięki zmniejszeniu awaryjności urządzeń oraz użyciu niewzbogaconych materiałów w procesie produkcji.

Materiały ceramiczne o dużej zawartości Al_2O_3 cechują się wysoką twardością, ale posiadają też inne korzystne właściwości. W celu określenia niektórych własności ceramiki o wysokiej zawartości tlenku glinu przeprowadzono testy. Zbadano m.in.: gęstość, twardość, mikrostrukturę oraz mechaniczną wytrzymałość. W czasie badań stwierdzono, że twardość ceramiki mieści się w granicach od 1800 do 2000 HV. Porównując uzyskane wyniki z zakresem wytrzymałości twardych stopów metali (550 do 630 HV), można stwierdzić, że ceramika o wysokiej zawartości Al_2O_3 jest prawie cztery razy twardsza. W rzeczywistości trwałość materiałów ceramicznych może być nawet osiem razy większa. Związane jest to z rodzajem urządzenia, do którego są wykorzystywane. Materiały ceramiczne mają jednak pewne ograniczenia w zastosowaniu do niektórych urządzeń – cechują się niską odpornością na obciążenia dynamiczne.

1. Introduction

During past twenty years the ceramic as a wear resistance material become more and more important in Iran. Valuable properties of ceramics such as hardness, resistance to high temperature and low density with compare to metals causes to increase attention to this materials. Apart from hardness, a high breaking strength has proved

* ISLAMIC AZAD UNIVERSITY, NAJAF ABAD BRANCH ESFAHAN IRAN

to be a significant parameter for a good abrasive behavior. From wide range of ceramic materials that could be used as hard substances, high alumina ceramic is one of idea materials. Aluminum oxides base ceramics an acceptable and abundant substance for this purpose. In this study the various properties of aluminum oxide ceramic parts, physical and chemical properties and microstructure are investigated. Also application of these parts as a liner and installation method is demonstrated.

Ceramic materials are gaining increase significance in industry. The main reasons are their outstanding properties which are, in many aspects, not achieved by other materials. Outstanding properties of ceramic material are:

- Stability of shape
- Hardness and mechanical strength
- High wear resistance
- High corrosion resistance, against chemical and environmental influences
- Resistance against high temperatures

Comparison wear resistance of different materials, metals, polymers and ceramics is shown in Fig-1 [2], as it can be seen the hardness of high alumina ceramic is much higher than the other materials.

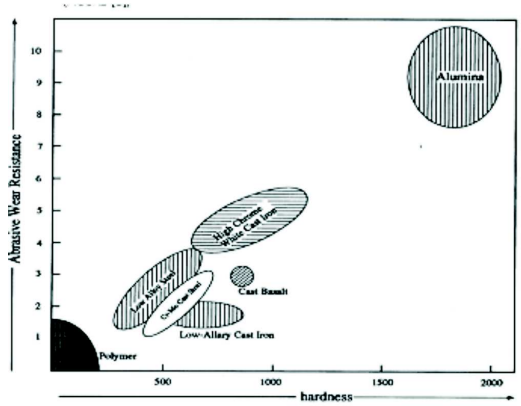

Fig. 1. Comparison result of different wear resistance materials [1]

There is some distinct difference between ceramics, metals and polymers that can be explain as follow [2]:

The structures of ceramic materials are always heterogeneous. They are formed crystals with particle size from 1 to 10 μm, held together by bond phase. A certain residual porosity remains due to the sintering process. The bond phase has different mechanical and chemical properties to the basis material.

Due to the lack of plasticity, tension peaks are not able to be compensated by plastic deformation. For ceramic materials, ion and atom bonds dominate and the adhesion tendency is lower than for metallic bonding.

Corrosion and wear of components definitely control the lifetime of machines or plan and influence the costs in manufacturing of products. One of the main reason to use high alumina ceramics as part of materials that can be used as wear resistance parts, is wear cost of materials, life time and repairing period. For those reasons high alumina ceramics with special properties are used in one of the iron oxide plans in Iran.

2. Experimental work

A factory for manufacturing of high alumina ceramic balls and liners with capacity of 1000 t/y with name of Ardakan Industrial Ceramic Co. (AIC) was established at 1996 in Iran. By improving the physical and wear resistance properties, the capacity of this factory was increased to 7000t/y. We are not at liberty to divulge our base data but we are presenting properties and comparison results of our experimental work.

The composition of high alumina ceramic that is made in this study is shown in Table 1. The special grade of alpha alumina with purity of 99.8 wt% was supplied by Alcan Co. The microstructure of this alumina is shown in fig. 2, as it can be seen the crystal size of this alumina is about 1 to 5 μm.

TABLE 1
Typical composition of high alumina ceramic

textbfRaw Material	**Amount wt%**
Al_2O_3	**92**
SiO_2	**3.0**
Fe_2O_3	**0.2**
Alkaline Oxides	**4.5**

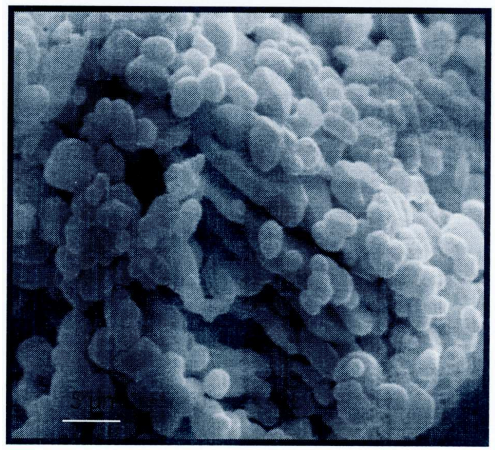

Fig. 2. Microstructure of high purity α-alumina

After making the right composition with mixing the alumina and the additives, the particle size of raw materials was reduced to less than 3 μm by wet milling and then slurry spray dried. The granules were shaped by

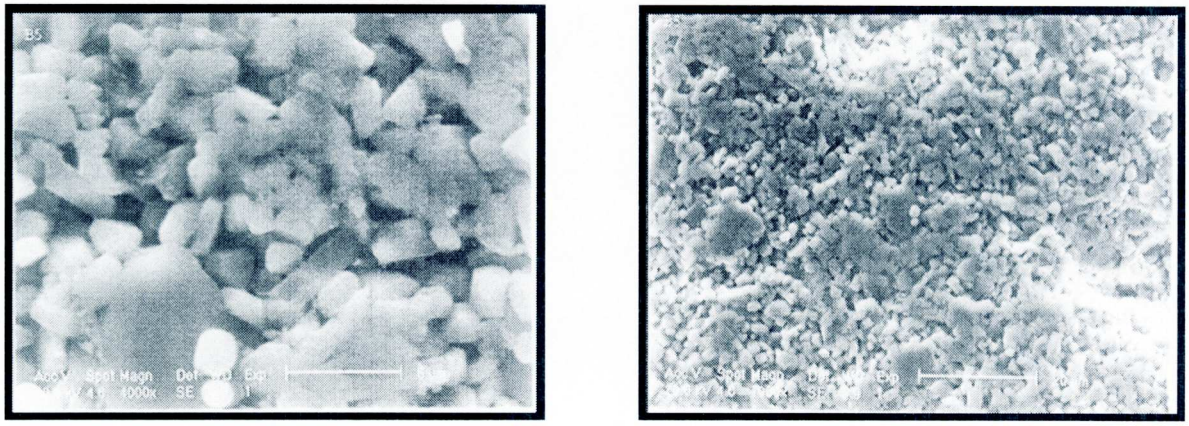

Fig. 3. Microstructure of fired high alumina ceramic parts

isostatic and hydrolic presses to form balls and liners. The shaped parts fired in shuttle kiln to the temperature of about 1600°C for soaking time of about 4 hrs. The scanning electron microscopy of ceramic parts is shown in fig 3. In this high alumina microstructures there are different phases as follow:

– Corundum phase with 1 to 10 μm crystal size as a main phase
– Mullite, spinel and glass phases as binding agent

Result and discussion

The properties of fired high alumina ceramic parts made in AIC and hard metals that is supplied from market (Hardox 400 and 600) are shown in Table 2.

TABLE 2
Physical properties of fired high alumina ceramics

Properties	High alumina ceramics	Hard metals
Bulk Density (g/cm^3)	3.68	7.8
Hardness HV (0.2)	1800 to 2000	550 to 630
Porosity (%)	0.0	0.0
Compressive Strength (MPa)	$\Rightarrow$ 25000	—-

As it can be seen the density of hard metals is twice of ceramic and the hardness is one third to one forth. By having these data the different parts of ceramic and

Fig. 4. Installed ceramic parts in Sijan Ghol Ghohar Co

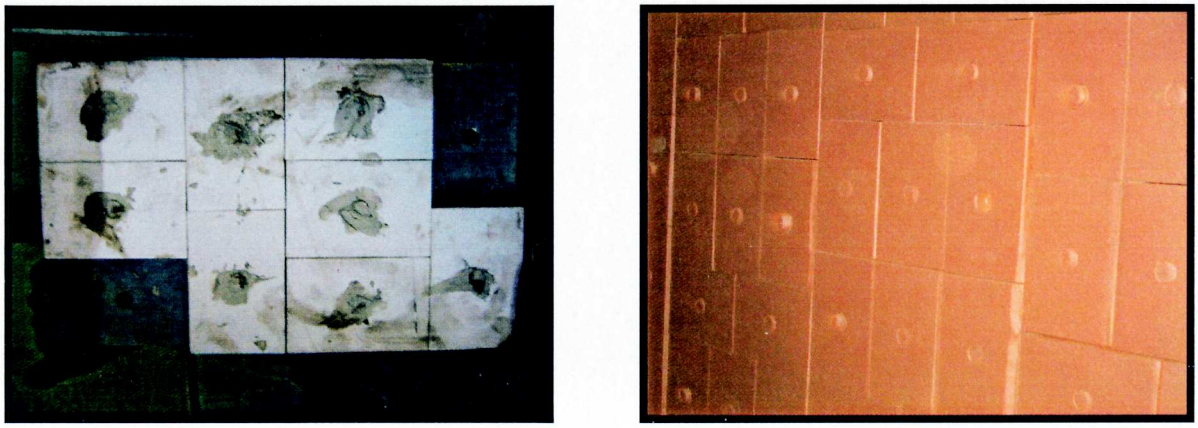

Fig. 5. Installed high alumina ceramic parts before (a) and after (b) 6 weeks work

hard metals were installed in one of the factories who is producing 6.000.000 tons of magnetite irons oxide per year (Sijan Ghol Ghohar Co.). The installed ceramic parts are shown in fig 4; these parts are installed in classifier and cyclone. Also the installation parts before and after wear are also shown in fig 5.

Since the density of high alumina ceramic parts is half of the hard metals that is 3.68 g/cm^3 with compare to 7.8 g/cm^3, therefore the weight of resistant ceramic parts is almost half of the metal. This also causes to reduce the cost per kilograms of ceramic with compare to hard metals. In experimental work is was demonstrated that it is possible to extend the life time of wear resistance materials up to eight times by using high alumina ceramic parts.

The installation of the ceramics can be down by welding them on the steel plate and also by special adhesive. This is shown in fig 5 a.

3. Summary

The life time of high alumina ceramic materials according to their used can be extended up to eight times more than trading hard metals. Also the weight of ceramics is almost half of the metals; therefore it is possible to reduce the cost of factories that have wear problems. In this experimental work the high alumina ceramic can be excellent alternative for hard metals if they installed in proper way.

Acknowledgements

The author is grateful to Mr. B. Fotohi, Mr. J. Zarea for their technical support.

REFERENCES

[1] H a n s H o p p e r t, Alumina ceramic – A wear resistant material for mineral processing, Powder handling and processing, **7**, Nov. 1 & 2 Jun. 1995.

[2] A. G. E v a n s, D. B. M a r s h a l, Fundamentals of Friction and wear of Materals; ASMC, edited by D. A. Rignery, 1981.

Received: 3 April 2008.