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Wear Protection in Powder Processing with SSiC and Si_3N_4 Components

Introduction

In powder processing for ceramic, metallurgical and electronic components and processes, plants that suffer no or only minimal wear are necessary. Moreover, a contamination of the products with "alien" wear particles must be prevented. This can be guaranteed with "constructional materials" that exhibit much higher hardnesses than the products processed. In addition, for many applications, provision must be made for impact stresses.

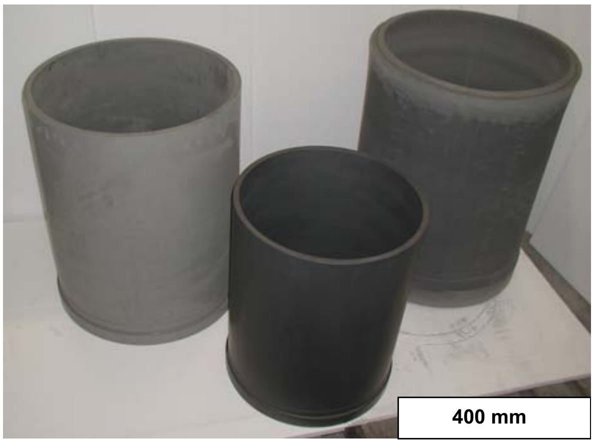

Fig. 1 (top) Mill lining made of SSiC: raw component, green-machined, sintered

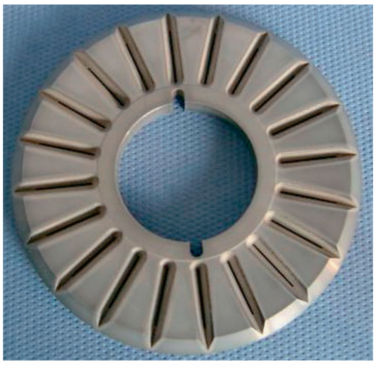

Fig. 2 (right) Filter disk made of Si_3N_4

Materials and Applications

Dense, sintered SiC and Si_3N_4 materials are very suitable as such constructional materials because, on the one hand, the extremely fine abraded particles in ceramic glazes react with water or during the sintering process to SiO_2, forming substances of a similar nature as the product that do not impair it. On the other hand, SiC and Si_3N_4 materials are very hard and extremely resistant to corrosion. Even when these are used in electronics, food technology and pharmaceuticals, there is absolutely no metallic contamination. In metal powders, the smallest traces of wear particles are reduced to Si during sintering and dissolve or they are not damaging as trace contamination because it exists or can exist as an alloying constituent. Other applications have been realized and tested in the grinding and dispersion of the following materials: soldering pastes, glazes, frits, colour pigments, food, paints, sewage sludges, white cement, etc.
In this field report, mainly applications for ceramics are described in which these materials are increasingly replacing hard metal, which is often unsuitable because of the associated discolouring contamination with heavy metals.

Wear Behaviour

The wear behaviour is determined in a range of ways. For the processes described, essentially two methods provide a possibility for performing application-specific, comparative basic analyses. These processes can be used to simulate the critical wear types.

Wear Caused by Sliding Friction

Here, wear is primarily caused by an abrasive particle sliding over the surface at a low angle of impingement. The essential material property in this case is the material hardness, or to be more exact its scratch hardness. If the particles are harder than the material used, wear is incurred, if the particles are softer they cannot damage the material and therefore have no wear effect. This type of wear occurs in applications involving the processing of suspensions. For such applications, high-density SSiC and LPSSiC exhibit better behaviour than Si_3N_4, ZrO_2 and Al_2O_3.

Impact Wear

Here wear is caused by particles impacting the surface of the component, sometimes at high speed, at an angle > 30°. Besides the material hardness, its fracture toughness and strength are crucial. A large part of the kinetic energy must be absorbed to slow down and divert the particle. On account of its combination of high hardness and fracture toughness, Si_3N_4 exhibits a more resistant behaviour than SSiC, ZrO_2 and Al_2O_3.
Besides the purely abrasive stress, a corrosive component is often superimposed in most applications.
One factor with a significant wear-reducing effect in a tribosystem is the fast removal of the frictional heat formed during the process from the system. For such applications, the very high thermal conductivity of SiC materials must be emphasized as a major advantage over ZrO_2 with its high thermal insulation.
This problem is encountered particularly during intensive grinding in attritor mills and fine dispersion on calender rolls. In recent years, particularly SSiC has proven effective for mill linings and grinding cylinders as well as for roll shells for these applications

Test conditions	
Medium	600 ml water + 600 g silica sand
Particle size	0,9...1,2 mm
Test duration	2 h
Speed	3 000 rpm
Test specimen	disk D 55,0 mm x 5 mm
Borehole	D 6 mm
Temperature	RT

	Wear rate [mm/a]
Cast iron	40...60
Stainless steel	40...60
Chill-cast iron	4...10
Hard metal	1,5...3
SSiC FCT	1
Si_3N_4 FCT	1,5
Al_2O_3	2...4
ZrO_2 PSZ	3...6
SiC/CuSnSi	2,5...4,5

Tab. 1 Hydroabrasive wear: test conditions and materials' data

Fig. 3 Grinding cone made of SSiC

Fig. 4 Agitator arms for an Eirich stirrer mill

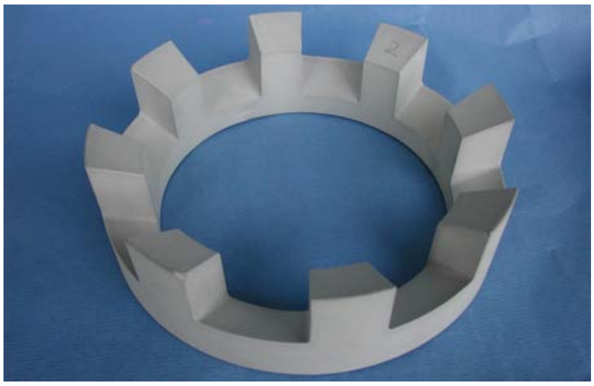

Fig. 5 Dispersion unit made of Si_3N_4 for ore dressing

Fig. 7 Propeller agitator made of Si_3N_4

and helped this technology make the breakthrough in certain sectors.
Besides components with simple geometries, very complex structures such as bored grinding cones are used as linings.
Excellent results have been achieved with SSiC roll shells for calender rolls for the very fine dispersion of pastes, glazes and paints for the foodstuffs, ceramics and electronics industries. Here besides the universal corrosion and wear resistance of the material, its extremely high thermal conductivity is a particularly important factor. If such pastes and suspensions become too warm during extremely intensive dispersion, the dispersant begins to evaporate or the product breaks down. This results in a change in the rheological properties of the suspension and consequently in its handling and process parameters. Thanks to the good heat dissipation enabled by the SSiC, very high throughput rates are possible.
For applications in which impact stresses are dominant, Si_3N_4 has been used with greater success. Its thermal conductivity is lower than that of SSiC, but it is still as good as that of high-alloy, wear- and corrosion-resistant steels and ten times higher than that of ZrO_2. With agitator arms made of Si_3N_4 (FSNI, FCT) in MAXXMill units, approximately the same service lifetimes are achieved as with agitator arms made of hard metal while twice or three times the service lifetimes of agitator arms made of MgO and Y_2O_3, partially stabilized ZrO_2 and Al_2O_3, are possible. As expected, SSiC has not proven effective in such applications on account of its higher brittleness.
Other typical applications for which Si_3N_4 can provide benefits include: rollers and jacketed pipes for roll crushers, agitator arms, grinding disks, stators, rotors, blades, sealing rings, filter plates and candles for attritor grinding plants, crusher plates for jaw crushers, scraper bars for cylinder drum dryers, propeller agitators, nozzles and other fittings. Here too the Si_3N_4 with its higher strength and fracture toughness can withstand the operating stresses of these components more effectively and work more reliably.
To make provision for the specific properties of the ceramics, very sophisticated design concepts have been developed and implemented.
The much lower coefficient of thermal expansion of SSiC and Si_3N_4 must be taken into consideration in combination with steel at temperatures up to around 350°C.

Fig. 6 Jaw plates for jaw crushers

Summary

Based on examples from trials and the field, it could be shown that the use of components made of SSiC and Si_3N_4 ceramics offers certain advantages. Despite higher prime costs and more complex design, the substantially longer service lifetimes and reduced contamination can ensure the competitive operation of plants equipped with such ceramic components. For certain processes, the operating and process costs have been lowered substantially compared to the original plant system as a result of the higher plant availability and throughput rate. Often a much better product quality is also achieved.
Components with high complexity and dimensions to around 1 000 mm have been realized here and their series production is state-of-the-art now. In precisely reproducible manufacturing processes, components with very accurate dimensions and narrow tolerances can be achieved already after sintering at FCT. Finishing is usually limited to functional surfaces, which, even in the case of metal components, require grinding to ensure the required precision. Ceramic components are therefore competitive for use in powder processing machines and plants.