Technical Ceramics and its Application – CUMI Perspective

The usage of sintered technical ceramics has been one of the proven solutions in wear, corrosion resistance, thermal/thermal shock resistance, electrical insulation, dielectrics and ballistic applications.

Materials are usually classified in three broad classes; metals & alloys, ceramics & polymers. Every class of materials exhibits a unique set of properties. Ceramics are inorganic materials either crystalline or amorphous in nature. Among the class of materials, ceramics displayed a wide range of properties because of its diversified bonding, lattice-structure and microstructure, relationship. It is a stone-age material which evolved over time as Technical ceramics and finds its usage in various structural and functional applications for development and progress of economy.

Technical ceramics are oxides (e.g. alumina, zirconia, titanates), non-oxides (e.g. carbides, nitrides, oxy-nitrides) and composites which are often made with synthetic raw materials with controlled specifications, manufactured under a controlled process to deliver products for appropriate structural and functional applications.

Product portfolio of CUMI – Industrial Ceramics Division

CUMI IC-division operating in design and development, manufacture and supply of advanced sintered ceramic products for critical and demanding applications.

It is broadly classified into three segments namely

- Wear resistant ceramics
- Engineered ceramics
- Metallized ceramics

Keywords
metallized ceramics, reaction bonded silicon carbide (RbSiC) ceramics, alumina, zirconia and aluminiumtitanate ceramics

Calcined alumina is used as a major raw material for the production of high-alumina technical grade of ceramics for structural application. The performance of high alumina sintered products are determined by the alumina grade used, quality and composition of sintering additives/aids and the sintering process. The degree of sintering to manufacture a defect-free products are related to the whole chain of the manufacturing process such as extent of uniform mixing and milling, uniformity in preparation of the deflocculated slip for spray-drying, quality of spray-drying for the production of ceramic granules for the subsequent forming process, uniformity in sintering etc. CUMI – IC manufactures technical ceramics products by various forming processes such as isostatic pressing, extrusion, ceramic injection moulding (CIM), slip casting other than the conventional uni-axial pressing.

The selection of the right quality of alumina with uniform crystal size, particle size, α-alumina content, low alkali content ad reactivity and compatible sintering aids related to applications are the critical to quality. CUMI uses the best classes of selective calcined alumina and compatible different kind of sintering additives to manufacture 90 % to 99,8 % high alumina sintered products for diversified applications. It uses a very high optimum temperature sintering process to develop the right kind of microstructure with the help of various tunnel and batch kilns or vacuum sintering processes in conjunction with on-line process control.

CUMI-IC also has partially/fully stabilized zirconia, reaction sintered aluminiumtitanate, reaction bonded SiC products. The applications include wear-resistant, corrosion-resistant, thermal resistant, thermal shock-resistant, electrical insulation and ballistic application for diversified industries. CUMI-IC has a unique technology of ceramic to metal seals for manufacturing various metallized ceramic products for electrical and dielectric applications.

Wear Resistant Ceramics

Wear ceramic products are used in mineral and ore processing, power generation/distribution, cement, coal-processing, steel, non-ferrous, fluid-handling industries. CUMI-IC manufactures high-end sintered alumina (various application specific composition ranging from 90 % to 99,8 % alumina).

There are five grades of products namely; CUMITUFF 90, CUMITUFF 92, CUMITUFF CSP, CUMITUFF 96 and CUMITUFF 995 which are being used for wear and corrosion application depending upon the customer's expectation and application demands.

High alumina (> 90 % Al_2O_3) sintered structural-grade of ceramics manifests a superior wear resistance due to high hardness value because of its hexagonal close-packed crystal structure. It also possesses a high specific strength (per unit mass), moderate fracture toughness, high tem-

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Tab. 1
Products, features and its applications

Formulation	Salient features	Products and its applications
Cumituff 90/ 92	Excellent wear resistance	Standard and pre-engineered Tiles, small/ dimple tiles, iso-pressed components, lined equipment, rubberized ceramics
Cumituff CSP	Excellent wear and corrosion resistance	
Cumituff 96	Premium wear and corrosion resistance	
Cumituff 94	Excellent mechanical and di-electric strength, metallized ceramics	Metallized cylinders for vacuum interrupters and metallized devices for electrical applications
Cumituff 95	Excellent corrosion resistance	Igniters and water pump seals
Cumituff 98	Good ballistic performance	Monolithic armor plates for personnel protection, inserts for vehicle armor
Cumituff 995	Excellent wear, corrosion resistance and outstanding ballistic performance	Mechanical seal parts and inserts for personal and vehicle armor
Cumituff 998	Excellent thermal and corrosion resistance	Lab-ware, ferrules, furnace parts and components
Cumituff YSZ/ MgSZ	Excellent impact, wear and corrosion resistant tough ceramics	Battery tooling, wire drawing dies, mud-pump liners, step cone pulleys
Fully Stabilized Zirconia	Excellent thermal shock resistance, Oxygen conductivity	Oxygen sensor applications
975 M/ 995 M	Excellent di-electric strength, metallized ceramics	Metallized devices for X-ray tubes, night vision cameras and microwave
CUMITHERM	Excellent thermal shock resistance, Non-wettability to molten non-ferrous metal and insulating ceramics	Dosing tube, riser tube, sprue bushes, tapping plugs and plates, spout and other non-ferrous melts, holding and conveying parts
RbSiC	Excellent wear, mechanical, thermal and corrosion resistance	Thrust bearings, mechanical seals and shrink fitted components for chemical pump industry

perature resistance and an exceptional impact resistance property next to zirconia among oxide ceramics. Sintered alumina ceramics also exhibits a very good corrosion resistance property in most of the acidic and alkaline environment because of its chemical inertness due to amphoteric in nature. Therefore, sintered high alumina (> 90 % Al_2O_3) ceramic-based components are the most diversified used materials due to its excellent mechanical properties, wear and corrosion resistance and good manufacturing ability of even complex and large shapes and therefore a value-for-money for the customer as far as the cost to performance is concerned.

The microstructures (Fig. 1) of CUMI products are close-packed and uniform resulting one of the best and performance

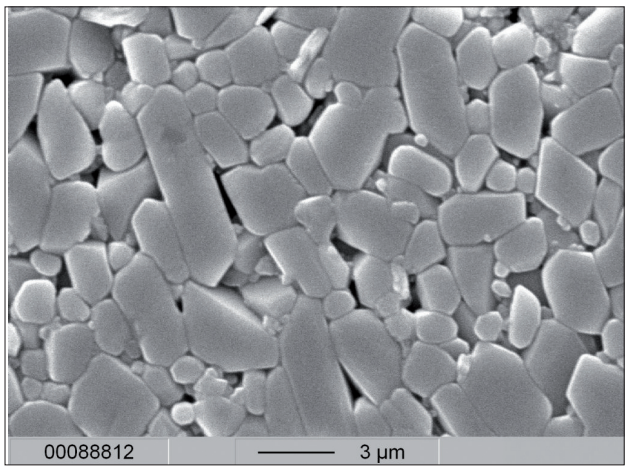

Fig. 1
SEM of etched CUMITUFF 92

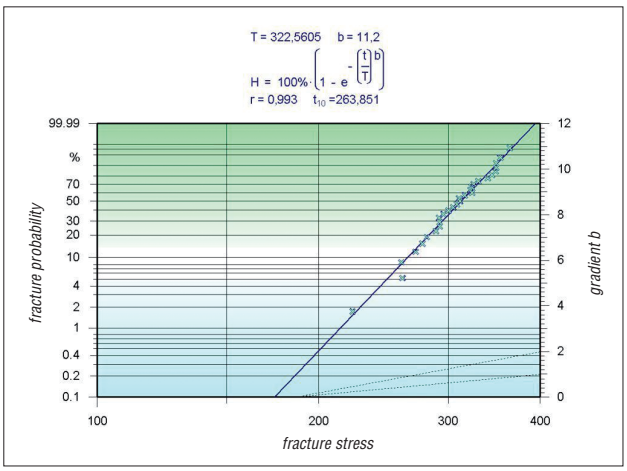

Fig. 2
Weibull Modulus of CUMITUFF 92

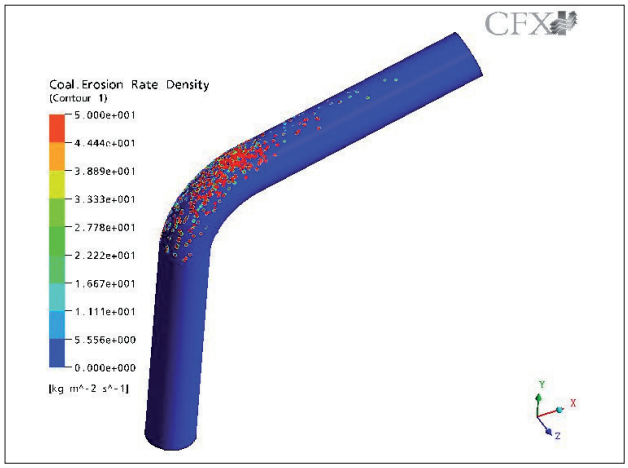

Fig. 3
CFD-analysis of wear-pattern in bends

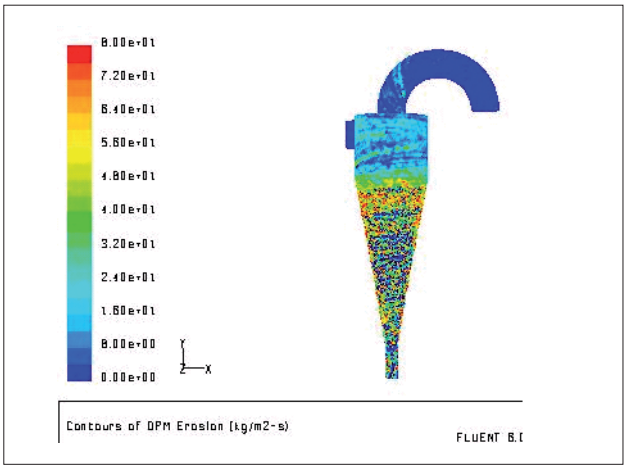

Fig. 4
CFD-analysis of wear-pattern in Cyclone

consistency, which are evident from the high Weibull Modulus value (Fig. 2).

Wear Model and Simulation

The following erosion models have been proposed [1] for non-ductile material like high-alumina ceramics for different process conditions.

Gas/Particle "low" concentration

$$E \propto V_p^{2,8}\, d_p^{0,66}\, \rho_p^{1,3}\, K_{IC}^{-1,33}\, H^{-0,25} \sin^2\alpha \quad (1)$$

Gas/Particle "high" concentration

$$E \propto V_p^{2,8}\, d_p^{0,66}\, \rho_p^{1,3}\, \rho_t K_{IC}^{-1,33}\, H^{-0,25} \sin^2\alpha \quad (2)$$

Slurry/particle "high" concentration

$$E \propto (v\rho_p f)^{-0,3551} (\sin\alpha)^{1,623} \quad (3)$$

E: Erosion Rate (gm/s)
V_p: velocity of the particle (m/s)
v: slurry velocity (m/s)
d_p: dia of particle (cm)
ρ_p: density of particle (g/cm³)
ρ_t: density of target (g/cm³)
K_{IC}: fracture toughness of target (MPa.√m)
H: Vickers micro-hardness (kg/mm²)
f: particle volume fraction
α: angle of impingement (deg)

It takes long time to understand the performance of ceramic under trial in a given sets of condition, therefore it is required to develop the method of simulation of performance under such conditions to predict the same quickly. CUMI is working to develop the method of simulating the wear performance for given set of parameters by CFD [2]. The proposed wear model (eq. 1, 2 and 3) was used as inputs for the simulation of wear in CFD model. The "CFX"-software was used for simulation wear-patterns of bends (Fig. 3) and "Fluent" was used for simulation of wear-patterns of cyclone (Fig. 4). The Eulerian-Lagrangian approach was fused for pneumatic conveying of coal particles in bends and Eulerian-Eulerian approach was used for slurries in cyclone.

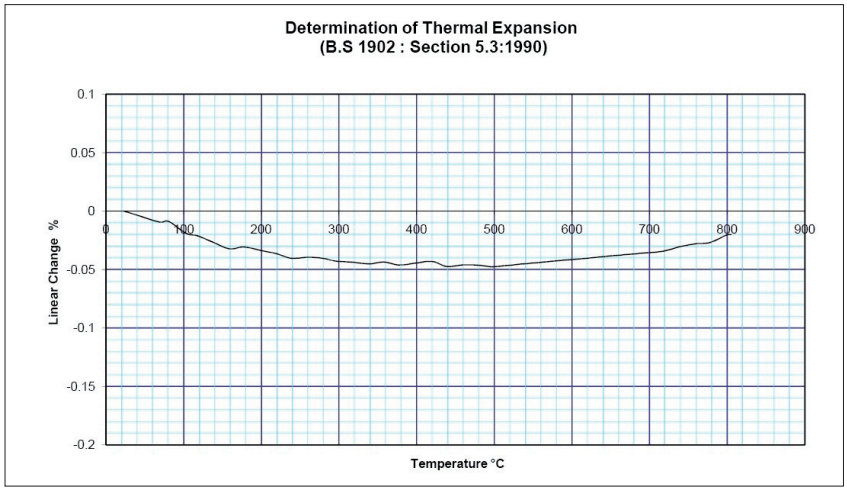

Fig. 5
Typical Thermal Expansion Curve of CUMITHERM

Engineered ceramics

Alumina Ceramics

CUMI – IC manufactures customized high purity alumina ceramics for wear protection, corrosion protection, electrical resistance and ballistic protection. The products can be used in diverse applications such as fluid handling equipment, power distribution industry, defence (personnel and vehicle armor) applications. High-alumina technical ceramics also finds applications as various wear resistant nozzle, machine components, applications in paper industry as well as in textile industry because of its high wear resistance and corrosion/contamination-free in nature.

Aluminiumtitanate (CUMITHERM) ceramics

CUMI – IC manufacture and supply a reaction-sintered aluminiumtitanate (CUMITHERM), which is ideally suited for cast houses and foundries for non-ferrous (NF) metal handling applications. It has extraordinary properties high thermal shock resistance due to near-zero expansion coefficient (Fig. 5), low thermal conductivity and non-wettability to most NF-molten metal. These properties are achieved by reaction sintering of high-purity alumina

and titania in a precision reaction-sintering process to engineer a unique micro-structure. The aluminium titanate phase has been sufficiently stabilized with the help of certain additives to prevent the decomposition of otherwise unstable aluminium titanate at high temperature. CUMI – IC supplies dosing tubes for HPDC, metal pouring tubes/nozzles, sprue bushes, connectors, metal tapping plate/plug with reaction sintered aluminium titanate products.

Zirconia ceramics

Zirconia and zirconia-toughened alumina find their applications wherein fracture toughness is one of the key requirements other than wear and corrosion resistance in applications such as battery-tooling industry, extrusion dies, pump seal and parts for petrochemical industries. MgPSZ is a preferred ceramic material for pump seal and parts applications in petrochemical industries. Other than structural applications CUMI-IC also makes fully stabilized zirconia sleeves for oxygen sensor applications.

Reaction bonded silicon carbide (RbSiC) ceramics

Sintered technical ceramics also finds various usages other than bulk wear applications. CUMI – IC supplies various products like rotating impellers, pistons and plungers, thrust bearing, mechanical seals based on 99,5 % alumina or reaction-bonded SiC (RbSiC) for pump industry in chemical applications. Shrink-fitted RbSiC components also find various applications in pump industry. CUMI RbSiC products have lower content of free-silica (~ 9 – 10 %) and finer SiC-grain structure (Fig. 6), which results in improving the mechanical, thermal and corrosion resistance properties. One of the large markets for ceramics is automotive water pump seals. Tungsten carbide seals cannot withstand certain corrosion resistant additives used to protect aluminium engine blocks therefore alumina and SiC-based superior automotive water pump seals are being used because of their wear and corrosion resistance.

Metallized ceramics

CUMI - IC has state-of-the-art technology for making hermetically sealed metallized ceramics. CUMI manufactures metallized ceramics with 94 % alumina, 97,5 % alumina and 99,5 % alumina products. Such zero-porosity sintered high-purity alumina ceramics has very good mechanical as well as good dielectric strength and hence electrical insulation properties. It has high thermal conductivity, very good volume resistivity and low di-electric loss value.

Metallized ceramics with 94 %-alumina are used in vacuum interrupters. The microstructure of sintered alumina has been engineered for making it suitable for subsequent metallization. The metallized layer are often consists of Mo-Mn coating with Ni-plating to make it compatible for subsequent brazing process. The Mo-Mn layer with high pull strength value makes it suitable for high temperature brazed assemblies. In many cases, special high-temperature impervious glazes are applied on metallized ceramics for prevention of surface flashovers.

High alumina metallized ceramics products include vacuum interrupters, feed-through insulators, X-ray tubes, power switches, power grid tubes and other various devices for electrical insulation application.

At CUMI metallized ceramics are brazed onto special alloys. High pure vacuum-grade brazed materials like copper-silver, copper, gold-nickel are used for brazing.

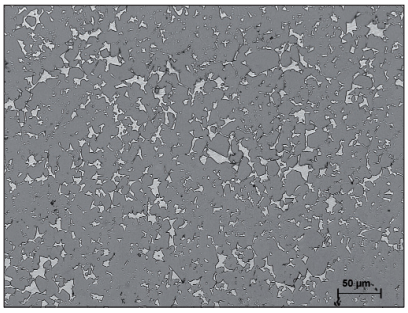

Fig. 6
Typical Optical Photograph of RbSiC, 200X

These brazed assemblies are used in high voltage feed-through, vacuum feed-through applications.

Conclusion

The usage of sintered technical ceramics has been one of the proven solutions in wear, corrosion resistance, thermal/thermal shock resistance, electrical insulation, dielectrics and ballistic applications. However, it has the limitation in the application where high fracture toughness, impact resistance and failure predictability are in demand. Therefore, the search of ceramics/composites with high fracture toughness in combination with high hardness at the competitive cost is on the way to open up a new horizon for the user industry. Research is also on for various smart ceramics such as self-healed glass and ceramics devoid of catastrophic failure to improve its reliability for structural application.

Thus, technical-grade of ceramics has been playing and would continue to play a progressively important role in various structural and functional applications because of its diversified engineered properties and tailored microstructure.

Reference:

[1] K. R. Gopi, R. Nagarajan, S. S. Rao, S. Mandal, “Erosion model on alumina ceramics: A retrospection, validation & refinement”, Wear, 264 (2008) [3-4], pp 211-218

[2] Report – Joint Research Programme on “Erosion model and CFD-analysis of wear patterns for gas/liquid-laden particle flow for certain applications” between Carborundum Universal Limited & IIT-Madras (2006).