# 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 and 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 their diversified bonding, lattice-structure and microstructure relationship. They are a stone-age material which evolved over time as technical ceramics and find their 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 is 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 aluminium titanate 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 is 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 product is 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 ceramic products by various forming processes such as isostatic pressing, extrusion, ceramic injection moulding (CIM), and slip casting – other than the conventional uni-axial pressing.

The selection of the right quality of alumina with uniform crystal size, particle size, $\alpha$-alumina content, low alkali content, its reactivity and compatible sintering aids related to applications are the critical aspects regarding quality. CUMI uses the best classes of selective calcined alumina and compatible with different kind of sintering additives to manufacture 90 – 99,8 % high alumina sintered products for diversified applications. It applies the optimum sintering process in order 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 aluminium titanate, and reaction-bonded SiC products. The applications include wear-resistant, corrosion-resistant, thermal resistant, thermal shock-resistant, electrical insulation and ballistic applications 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 compositions ranging from 90–99,8 % 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 ceramics manifest a superior wear resistance due to high hardness values because of their hexagonal close-packed crystal structure. They also have high specific strength (per unit mass), moderate fracture toughness, high

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*Tab. 1*
*Products, features and their applications*

| Formulation | Salient Features | Products and Their 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 dielectric 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 dielectric 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 |

temperature resistance and an exceptional impact resistance property next to zirconia among oxide ceramics. Sintered alumina ceramics also exhibit a very good corrosion resistance property in most of the acidic and alkaline environments because of their chemical inertness. Therefore, sintered high alumina (>90 % $Al_2O_3$) ceramic-based components are the most diversified used materials due to their excellent mechanical properties, wear and corrosion resistance and good manufacturing ability of even complex and large shapes. Therefore they are a value-for-money for the customers as far as the costs to performance are concerned. The microstructure (Fig. 1) of CUMI products is close-packed and uniform resulting one of the best performance consistency, which is evident from the high Weibull modulus values (Fig. 2).

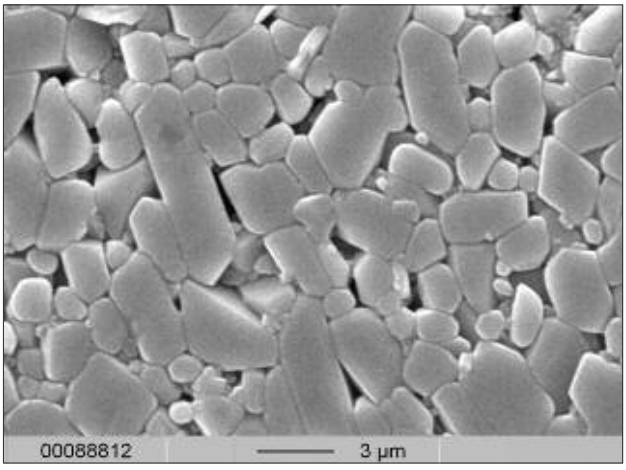


*Fig. 1*
*SEM of etched CUMITUFF 92*

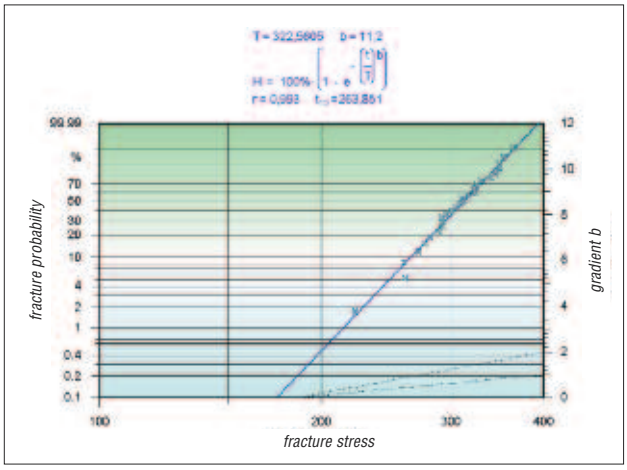


*Fig. 2*
*Weibull modulus of CUMITUFF 92*

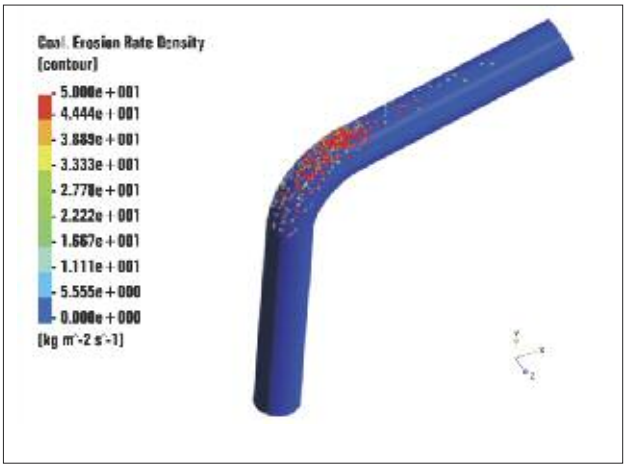


*Fig. 3*
*CFD-analysis of wear-pattern in bends*

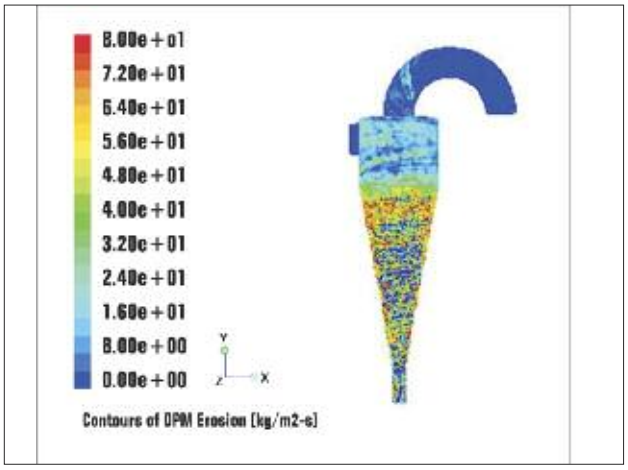


*Fig. 4*
*CFD-analysis of wear-pattern in a cyclone*

**Wear model and simulation**

The following erosion models have been proposed [1] for non-ductile materials 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

$$E \propto V_p^{2,8}\, d_p^{0,66}\, \rho_p^{1,3}\, \rho_t K_{IC}^{-1,33}\, H^{v0,25} \sin^2\alpha \quad (2)$$

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 particles (m/s)
v: slurry velocity (m/s)
$d_p$: diameter of particles (cm)
$\rho_p$: density of particles (g/cm³)
$\rho_t$: density of the target (g/cm³)
$K_{IC}$: fracture toughness of the target (MPa.√m)
H: Vickers micro-hardness (kg/mm²)
f: particles volume fraction
$\alpha$: angle of impingement (°).

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

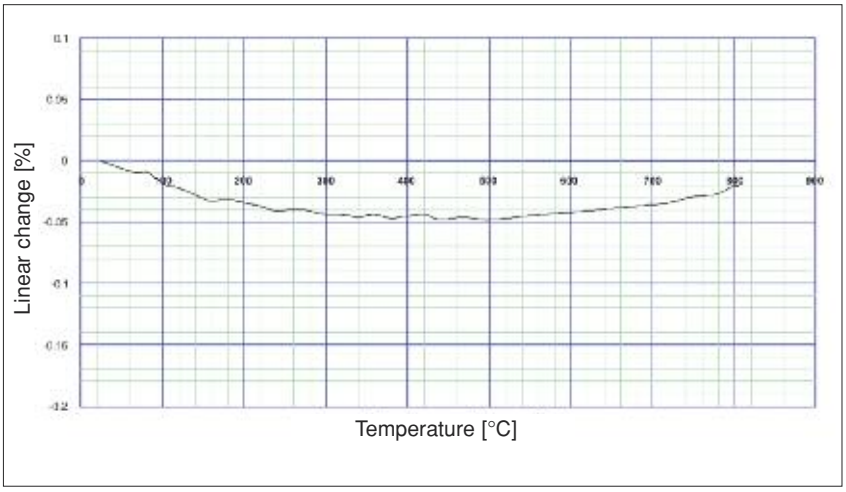


*Fig. 5*
*Typical thermal expansion curve of CUMITHERM*

**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, and defence (personnel and vehicle armor) applications. High-alumina technical ceramics also find application as various wear resistant nozzles, machine components, applications in paper industry as well as in textile industry because of their high wear resistance and corrosion/contamination-free in nature.

***Aluminium titanate (CUMITHERM) ceramics***

CUMI-IC manufactures and supplies reaction-sintered aluminium titanate (CUMITHERM), which is ideally suited for cast houses and foundries for non-ferrous (NF) metal handling applications. It has extraordinary properties like high thermal shock resistance due to near-zero expansion coefficient (Fig. 5), low thermal conductivity and non-wettability to most NF-molten metals. These properties are achieved by reaction sintering of high-purity alumina and titania in a precision reaction-sintering process to engineer

unique microstructure. 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 seals and parts for petrochemical industries. MgPSZ is a preferred ceramic material for pump seals 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 find 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 %, 97,5 % and 99,5 % alumina products respectively. Such zero-porosity sintered high-purity alumina ceramics have very good mechanical as well as good dielectric strength and hence electrical insulation properties. They have high thermal conductivity, very good volume resistivity and low dielectric loss values.

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 often consists of a 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 ceramic 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 braze materials like copper-silver, copper, gold-nickel are used for brazing. These brazed assemblies are used in high voltage feed-through, and vacuum feed-through applications.

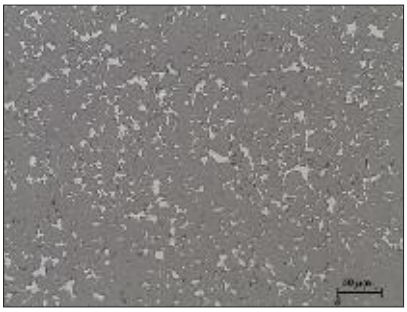

*Fig. 6*
*Typical optical microstructure of RbSiC (200×)*

**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 competitive costs is on the way to open up a new horizon for the user industries. Research is also on for various smart ceramics such as self-healed glass and ceramics devoid of catastrophic failure to improve their reliability for structural application.

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

**Reference:**

[1] Gopi, K.R. et al: Erosion model on alumina ceramics: A retrospection, validation & refinement. Wear 264 (2008) [3–4] 211–218

[2] Report of the 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 and IIT-Madras (2006)