Function, Flexibility and Flair – How Technical Ceramics Respond to Industrial Design Demands

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Abstract: Across the industrial world, design engineers are battling on all fronts to meet the ever-tighter demands placed on modern manufactured components, whether that be for miniaturisation, lighter weight, thermal robustness, simpler production or lower cost. Technical ceramics play a vital role in these endeavours.

Keywords: technical ceramics, alumina, recrystallised silicon carbide, silicon carbide, steatite, technical cordierite, corundum/mullite

1. Introduction

Technical ceramics are increasingly being brought into the picture when solutions are called for. Their unique mix of superior chemical, mechanical and electrical characteristics – allied to flexibility in shape, manufacture and interaction with other materials – means that the successful operation of thousands of distinct engineering, electronic, thermal and mechanical systems now relies heavily on them. The desirable characteristics of technical ceramics include:

- Thermal resistance and stability
- High hardness and mechanical strength
- Electrical insulation and conduction
- Wear and chemical resistance
- Corrosion resistance
- Low specific weight
- Low friction
- Near-net shaping
- Durability in service

Additionally, many of the technical ceramics used in component design are manufactured from raw materials that are still abundant, meaning that the feedstocks are subject neither to exorbitant pricing nor heavy commodity pressures. Due to their high resistance (including wear, chemical, thermal and corrosion resistance), they also provide a long service life – sometimes running for many hundreds more cycles than traditional materials – and make the lives of plant operators easier due to their reduced need for maintenance and repairs. These factors all impact on the bottom line.

To better illustrate the points made above, some of the recent projects that IPS Ceramics has undertaken are being discussed in this text which clearly demonstrate how different technical ceramics provide a good fit for industrial design parameters.

2. Example 1: Special sintering supports

The increased use of powdered metal (PM) and metal injection moulded (MIM) parts – as well as the production of smaller low

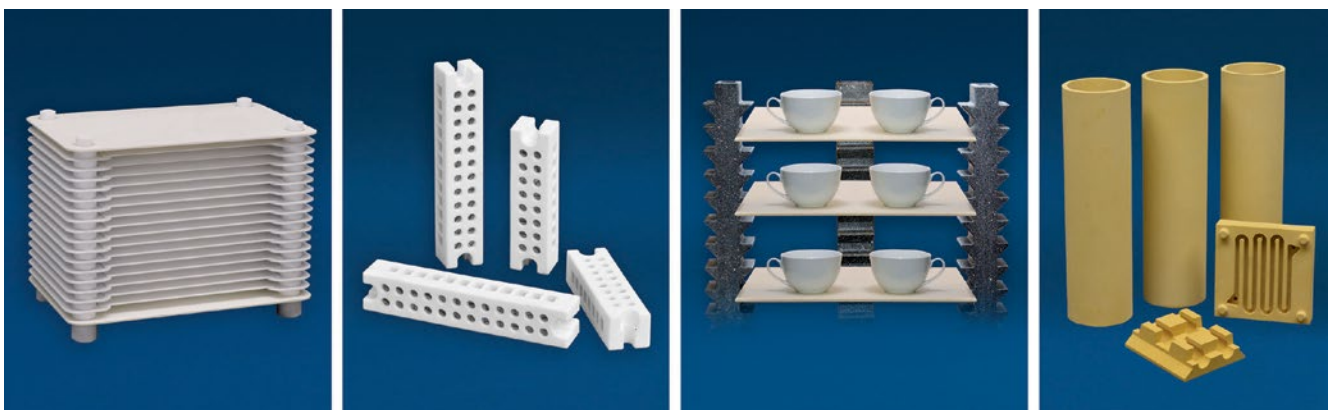

Figure 1 A range of IPS technical ceramic products, including an alumina cassette, steatite terminal blocks, silicon carbide posts and injection moulded components (© IPS)

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temperature co-fired ceramics (LTCCs), solid oxide fuel cell components and a variety of dental and medical ceramics – means that a better way of carrying these sorts of products through the furnace is required.

For these sintering operations, the company has designed a customisable cassette system which is manufactured from 95 % alumina. Alumina provides chemical and thermal stability, relatively low weight and a long life at temperatures up to 1200 °C. The cassette has low reactivity and does not contaminate other components in the system.

The cassettes have a small and compact design, with components specially machined to ensure exact tolerances and thicknesses. The modular configuration allows for a high fill density, increased flexibility and the ability to stack the cassettes on top of each other. Shelves can be removed and put back in, even when filled with product, and the feet screw onto the corner posts, locking the cassette into a single stable unit which can then be lifted and transported. Using alumina, the company has been able to create a compact and functional product ready to meet the demands of a wide range of growing industries.

3. Example 2: Safety critical considerations

Whether upgrading existing facilities or building new ones, the incorporation of fire-rated electrical enclosures is an important element of safety critical systems planning. There are many examples of these types of applications around towns, cities, ports and airports, including road tunnels, above and below ground rail, roadside and trackside applications, and major infrastructure projects. Whether in emergency lighting, fire suppression, smoke extraction or fire alarm systems, it is paramount to offer increased fire survivability for safety critical electronic circuits. Here, technical ceramics play a key role.

Fire-rated enclosures are designed for use on safety critical circuits or those carrying emergency power supplies. They will maintain insulation integrity for 120 minutes during direct exposure to fire. Within these enclosures, technical ceramics are often preferred for use as terminal blocks due to their superior heat resistance properties (even in direct heat situations). These ceramics can withstand much higher internal temperatures than poly or KRG terminals and can survive fire tests up to 842 °C, enabling fire-rated enclosures to conform to BS EN 50200. Technical ceramics are particularly popular for applications where reliability and performance are key.

Working with a leading enclosure manufacturer, the company designed both 8-way and 12-way blocks in steatite ceramic. Their configuration provides a simpler installation than individual rail mounted terminals which also require an end plate and stop clamps. The blocks are supplied complete with nickel plated stainless steel connectors and screws, providing a no-hassle, ready-to-fit component, which demonstrates the key elements of design flexibility and improved performance.

A glazed version can be offered for applications where surface contamination is a concern.

Figure 2 An alumina cassette (© IPS)

Figure 3 8-way and 12-way steatite terminal blocks (© IPS)

Figure 4 Investment casting plugs in a range of sizes and shapes (© IPS)

Figure 5 Silicon carbide posts holding slide-in batts and cups (© IPS)

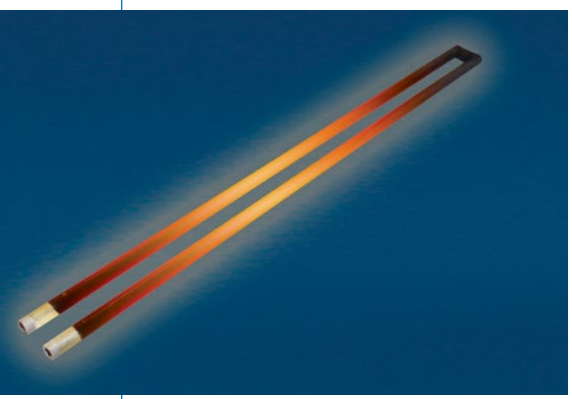

Figure 6 A silicon carbide heating element (© IPS)

Figure 7 A range of technical cordierite products (© IPS)

4. Example 3: Investment casting

Anyone involved in high specification manufacturing will appreciate the role played by investment casting (also known as lost wax and precision casting). This process is renowned for its ability to produce complex geometries with excellent tolerances and a fine surface finish and the benefits of investment casting are felt in a number of major industries, such as aerospace, power, automotive, oil and gas, and medical.

Stability, as well as high temperature resistance, is an important element of the investment casting process. With this in mind, the company has designed a range of casting plugs to ensure that pattern assembly vent holes are effectively covered and to act as a mechanical means of sealing core supports within the assembly.

The casting plugs can be manufactured in different grades of ceramic material. For standard use, a corundum/mullite mix is usually preferred. However, where a very smooth, clean finish is required, a 95 % or 99 % alumina material is available.

Casting plugs form part of the single-use ceramic shell, and so in addition to superior finish and effectiveness in operation, they need to be made available at a competitive cost. IPS Ceramics' plugs meet the brief in all respects and many well-known companies have already started using them, including one of the best known aero engine and industrial gas turbine component manufacturers, and an internationally renowned producer of nickel-chromium steel alloys.

5. Example 4: Silicon carbide takes the heat

When it comes to firing and sintering, manufacturers need to maximise the fill in any furnace or kiln if they want to minimise energy costs. A suitable kiln furniture system can allow much greater levels of kiln utilisation but can also be restricting if product lines need to change frequently.

The company has developed adjustable systems based on toothed support posts and slide-in batts. Recrystallised silicon carbide (ReSiC) is ideal for high-duty support posts operating at high temperatures. This material has very low levels of high temperature creep, meaning that the posts remain straight after many firings. These toothed posts have been supplied in lengths of nearly 2 m and have been in prolonged service at temperatures of up to 1600 °C without any distortion or breakage. The post design can be optimised so that the spacing of the teeth matches the customer's specific product line.

Furnace designers also rely on the very best heating elements in order to both develop the ideal firing configuration for their clients and to guarantee long-lasting top performance. They are crucial when it comes to improving sintering and heat treatment processes. The company has successfully introduced a new range of silicon carbide (SiC) heating elements specifically for these applications.

The SiC heating elements demonstrate many in-use advantages over metallic types. They offer superior performance and strength at temperatures above 1200 °C (where metallic elements start to fail). They are easily installed and changed, and are self-supporting, making furnace design simpler. Issues of surrounding oxidisation of the SiC elements and the increase in resistance over time have been addressed by the addition of a special protective film coating on the surface of each element's hot zone.

6. Example 5: Flair for Design

The company is known for the manufacture of cordierite products, used primarily for kiln furniture in the ceramics industries, particularly in the tableware and sanitary ware sectors. Many decades of experience have produced highly optimised designs for these applications, with a wide range of manufacturing processes (including extrusion, pressing and casting) being used to achieve the wide range of shapes needed.

Cordierite ceramics are well known for their exceptional resistance to thermal shock. They are often used for components that are subject to rapid thermal cycling and in applications where other ceramic materials would quickly crack or break. They are fired close to 1400 °C to give a material that

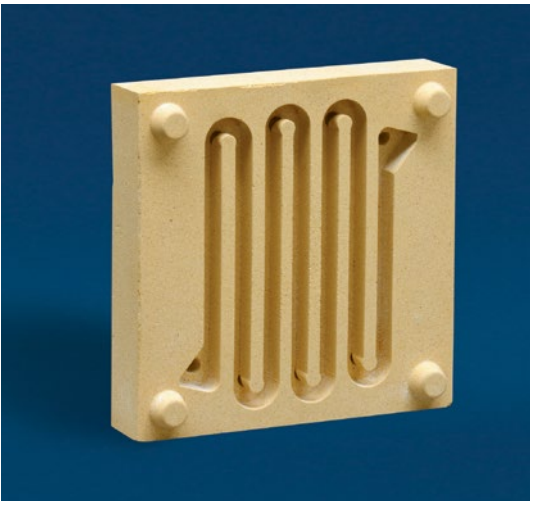

Figure 8 A technical cordierite support block with complicated design work on its front (© IPS)

is volume stable for service temperatures up to 1300 °C.

For technical applications, the company has introduced a grade of cordierite suitable for injection moulding. This allows a wide variety of complex shapes to be produced, with features such as through holes, slots and fine surface detail. A good example of this design flexibility is the manufacture of support blocks for plate heaters, which require a complex zig-zag slot arrangement to retain the wire element (see Figure 8). Such a design would be impossible to achieve through the traditional manufacturing processes.

7. Moving forward

The design of technical ceramics is constantly evolving, involving the careful matching of material properties, manufacturing processes and product geometry in order to provide the level of performance that modern applications need. IPS Ceramics is ready to assist customers with product development and looks forward to the exciting new ways that technical ceramics will be used in the future.

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