High-Performance Ceramics for Reference Standards

Thanks to their material properties, certain high-performance ceramics are ideal for the production of reference standards for the calibration of measuring instruments. To obtain the necessary high precision, a clever combination of green machining with subsequent hard machining (grinding/polishing) is applied, enabling fabrication without cost-intensive moulding tools. This makes a cost-efficient solution possible even for small to medium unit numbers with a large number of variants of the calibration bodies.

Fig. 1
Ceramic reference standards for crowns according to DIN EN ISO 12836:2013-1, appendix B

Introduction

At first glance, a workpiece with inaccurate dimensions and a poorly fitting dental crown have nothing in common – except that it costs nerves, money and time to correct both. The actual connection between the two is the material, that is ceramic, a high-performance ceramic to be precise. On the one hand, a material with perfect properties as a reference standard for measuring instruments, on the other hand a material with high strength and biocompatibility. High-performance ceramics are materials optimized for specific applications based on the application of different starting raw materials, production methods and machining technologies. The finished components are extremely hard, wear-resistant, high-temperature resistant and insensitive to both acids and lyes. In addition comes the fact that most are also electrically insulating and boast low thermal conductivity. The best-known oxide ceramics include alumina (Al_2O_3) and zirconia (ZrO_2).

The special properties of ceramic components enable a variety of applications, which range from the chemicals industry through plant and machine engineering to medical technology. Besides the technical possibilities, cost-efficient production is a relevant consideration – for small to medium unit numbers too. Here with green part machining, a very efficient process has become established. This can be described as the CNC machining of a green part, which, for example, has been fabricated by means of cold isostatic pressing – a process in which the prepared ceramic powder is filled into an elastic rubber mould, which is matched to the final contours of the component, and is homogeneously compacted in a cold isostatic press with hydrostatic pressure up to 2500 bar. Green part machining enables a filigree component structure with high dimensional accuracy.

Keywords
calibration, reference standards, oxide ceramics, ATZ (Alumina-toughened Zirconia)

BCE Special Ceramics GmbH
68229 Mannheim
Germany

info@bce-special-ceramics.de
www.bce-special-ceramics.de

Green part machining for small series

One specialist in green part machining is BCE Special Ceramics based in Mannheim, Germany. The company develops and manufactures customized high-performance ceramics fabricated primarily from alumina or zirconia as well as their mixed oxides ATZ (Alumina-Toughened Zirconia) and ZTA (Zirconia-Toughened Alumina). For mechanical machining after cold isostatic pressing, a total of 10 CNC-controlled machines as well as a large number of NC machines are available. From the 5-axis machining centre, through high-precision circular grinders to ultrasonically assisted hard machining as well as lapping and honing, all important technologies are installed in-house.

With green part machining, ceramic components can be produced quickly to near to net shape or exactly to shape without cost-intensive, shaping tools – regrinding is therefore not necessary as with uniaxial pressing or often in the case of ceramic injection moulding process. That is of key importance for many applications, as remachining, e.g. in very fine boreholes, pockets and recesses, would not be possible. This applies especially for threads. With grinding, internal threads can only be produced to a minimum of M 5, but with the help of CNC manufacturing in the green state, it is possible to get down to M 1,2.

Other advantages compared to finish machining are a far lower energy input and higher flexibility. So, for example, changes required by the customers can be made to the component during fabrication – only the CAD/CAM data file has to be modified. In addition, there is more scope for testing materials and mixes, especially in the case of prototypes or small product runs. For, as a result of different shrinkage during sintering, the costs would increase considerably for every near-net fabrication on account of the necessary moulding tools.

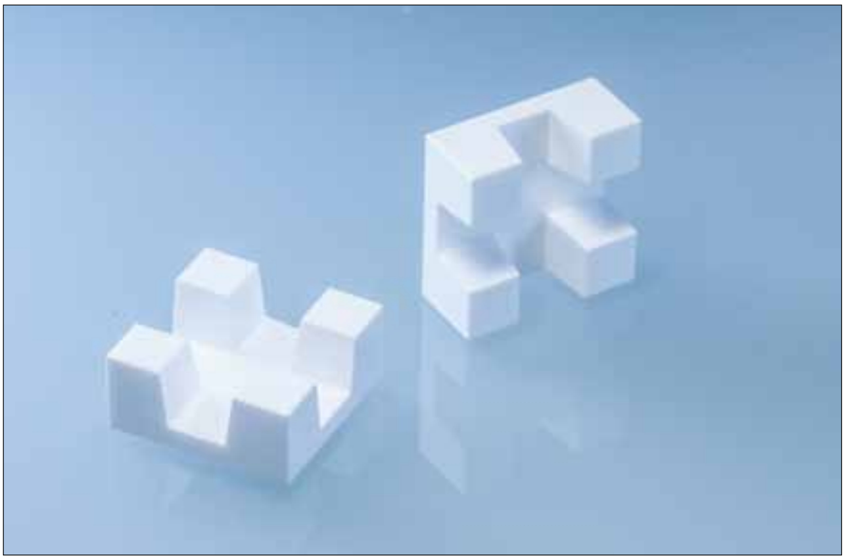

Fig. 2
Ceramic reference standards for Inlays according to DIN EN ISO 12836:2013-1, appendix A

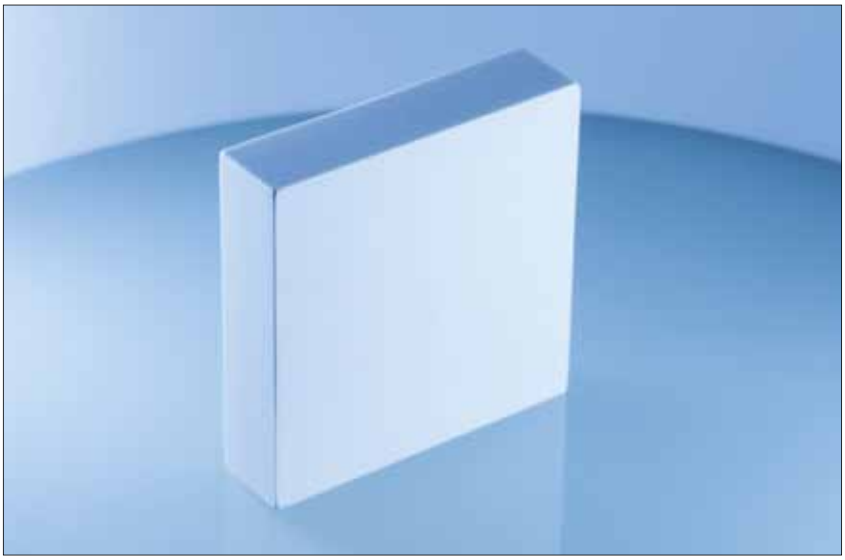

Fig. 3
Ceramic reference standard for parallels

Optimization of the microstructure

The crucial process variable during the fabrication of a ceramic component is its shrinkage during sintering. This can amount to up to 25 %, relative to the final dimensions. That means to obtain the required contours, it is necessary to add an appropriate factor to the dimensions of the green component. Another aggravating aspect is that the quality of the fired ceramic during sintering is largely dependent on the "internal structure" of the green part. Relevant here are fluctuations in the density on different size scales. This ranges from the macro-range to the distance of adjacent particles on a 20 µm scale. Deviations from a homogeneous distribution lead to uneven shrinkage, more severe fracture behaviour and the formation of agglomerates between the cavities (pores), which require a higher sintering temperature to be broken up. Therefore, besides the process of sintering and precise CNC machining, the quality of a high-performance ceramic part is therefore closely connected with high homogeneity of the green body. Precondition for this are raw materials, preparation and shaping.

Calibration of measuring instruments

The special material properties of certain high-performance ceramics make them predestined as materials for the production of reference standards for calibration of measuring instruments. The poten-

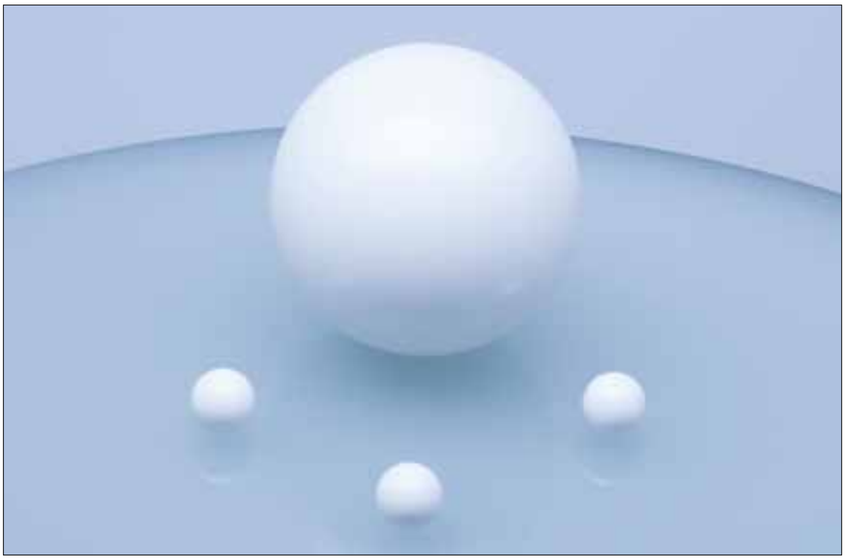

Fig. 4
Ceramic balls for measurement with optical systems

tial applications are wide – from dental scanners for the production of inlays and crowns to the coordinate measuring machines widely found in the industry.

The preparation of a tooth for an inlay or crown is done either conventionally with a "mechanical" impression and the scanning of the produced plaster model or with an intraoral camera in the mouth. With the second option, for example, a crown is cut from a ceramic blank directly after digitization at dental surgeries. To produce functional and also aesthetically flawless dental prostheses, however, a precise reproduction of clinical situation is necessary. To verify and assess the accuracy of the digital impression of a dental scanner, three different specimens are measured according to the European standard DIN EN ISO 12836. These are reference standards for inlays, which simulate the corresponding cavity (inlay cavity), second reference standards for crowns with positive geometry and calibrated truncated cones, which are used, for instance, by VMT in Mainz/DE. The calibration references should in the ideal case exhibit no deviation from the prescribed form. As such manufacturing precision without tolerance is neither cost-efficiently nor technically feasible, the bodies are, despite their high precision with approx. 5 to 20 µm deviation, are all individually calibrated by the

DKD (German Calibration Service) and only then passed on to the end-customer.

As material for the dental prosthesis itself, zirconia has proven itself suitable for heavily stressed components for many years. In yttrium-stabilized zirconia (3Y-TZP), for example, a high strength of the microstructure when exposed to tensile stress is combined with toughness, reliability and high biocompatibility. It also enables the fabrication of long-span bridges in posterior tooth regions. Optimal is also the white colour of the material, which offers excellent aesthetics compared to a ceramic-covered metal.

Roundness precision <2 µm

Also in the calibration of coordinate measurement machines (CMM), which have become a permanent fixture found in industrial production, high-precision measurement bodies made of a high-performance ceramic are used as measurement standards. Tactile or optical and therefore non-contact measurements scan the surface of workpieces and compare the measured 3D coordinates with the defined values. In this way it is possible to verify whether the geometric shape corresponds to the CAD specifications. To obtain qualified information, the measurement uncertainty of the measurement machine must be much smaller than the maximum tolerance of the workpiece. Accordingly, this gives calibration a special importance.

Whereas, on account of the reflection, "shiny" stainless steel balls are only suitable for tactile measuring CMMs and the matt variants can be used for laser scanners, ceramic balls can be used for white-light scanners, tactile CMMs and laser scanners – without a halo effect as can happen with metals. Moreover, certain zirconium mixed oxides have an advantage over alumina in that they can be measured without further surface treatment even in different light conditions. Their surface is diffusely scattered and corresponds to the VDI/VDE 2634 directive. The roundness precision of the BCE-manufactured balls, which are successfully used at AiMESS products GmbH, is <2 µm, the typical diameter at 1,5". A positive aspect of measurement standards made of ceramic compared to metals is even after being subject to an effective force (impact on the floor), there is no plastic deformation, which leads to an erroneous reference.

Conclusion

Thanks to the dialogue between users, the manufacturers of measurement systems and BCE Special Ceramics GmbH, the specific advantages of high-performance ceramics for application as calibration bodies for different measurement duties could be realized. The special properties of the ceramic combine several advantages such as a higher achievable measurement accuracy and long lifetime of the calibration bodies to the benefit of the users. The users can rely on support from the sales and application engineers of the companies AiMESS or VMT.