Ceramic Replaces DLC

A sliding block made of steel coated with DLC (Diamond-Like Carbon) has been replaced with an injection-moulded Si_3N_4 component. Crucial for the ceramic sliding block with improved material properties was to set up a dedicated manufacturing process for large-volume manufacturing. This success story relates the background to the cooperation between Nidec GMP GmbH and FCT Ingenieurkeramik GmbH with statements from the two partners. NIDEC GPM GmbH has been part of the AMEC business sector of the Japanese Nidec Corporation since 2015. The combination of NGPM pump technology with NIDEC's motor technology shows great potential for the development of electrically powered pumps.

Objective

High-performance ceramic materials and their production processes are developing rapidly. For some time now, NGPM has been looking at alternative materials for the introduced tribological systems. This specific case concerns a sliding block in an axial piston pump which runs against a swash plate made of stainless steel.

This axial piston pump is integrated in an adjustable water pump and responsible for supplying the hydraulic pressure to activate the control system. The water pump is used in many currently available combustion engines. The objective was to find an alternative to a DLC (Diamond Like Carbon)-coated steel component, which would offer better performance at a lower price with full interchangeability.

Requirements for an alternative material solution are:

- High wear resistance
- Homogeneous microstructure
- No coating build-up problems
- Low weight
- High dimensional stability
- Stable process
- Lean process
- No sensitivity to any known media
- Friction reduction.

Keywords
ceramic membrane, direct gas conversion

Material selection

On the basis of these requirements, back in early 2013 the search began for alternative materials. Various materials and combinations were tested and assessed, including metals, high-filled plastics and, as intimated above, technical ceramics. In a brainstorming session, a leaning towards high-performance ceramics became evident. Basically, a rough division was made the beginning of the tests between oxide ceramics and non-oxide ceramics.

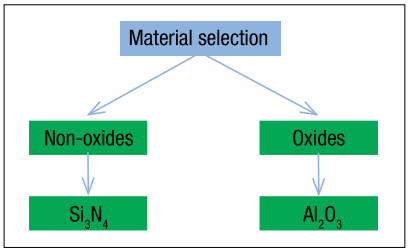

Fig. 1 Material selection

Because of its much better properties, Si_3N_4 was chosen in order to ensure suitable safety reserves for the actual component and also for the entire pump application. If you look at classical applications, it is not always possible to compare the materials with each other, not with regard to the production process nor the associated costs, but for new developments, especially in material development, the limits can be explored in this way. Naturally, it is not enough to find the optimum material, it is paramount to find a suitable process for production in line with automotive requirements. Requirements for potential suppliers are:

- High unit numbers
- Stable process
- Traceability
- Quality mechanisms
- Flexibility.

Process selection

Required was the development of a process, which without significant refinishing can achieve the tolerances in the "as-fired" state, and that in a reliable process capable of large-volume production.

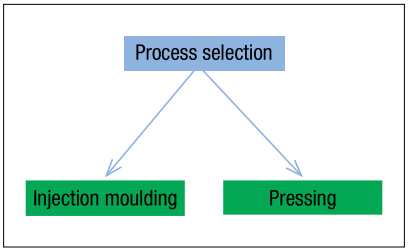

Fig. 2 Selection of shaping technology

NIDEC GPM GmbH
98673 Auengrund OT Merbelsrod
Germany
www.nidec-gpm.com

FCT Ingenieurkeramik GmbH
96528 Frankenblick, Germany
www.fcti.de

After various rounds of testing with suppliers, it was very soon evident that an injection moulding process offers more advantages for the green part in this specific application. The process proved particularly expedient with regard to the shaping freedom and contour accuracy. Handling prior to sintering was also assessed as positive with regard to process stability as, owing to the binder, this material in the green state is relatively robust for further processing.

In the geometric design of a component, on no account should a 1 : 1 switch be made from a non-ceramic to a ceramic component as ceramic-specific adaption is always necessary. But in this case, this was only needed for certain details of the injection moulded part.

As NGPM does not fabricate any ceramic components, it was necessary to find a qualified development partner who could offer subsequent series production. NGPM generally enters development partnerships very early on in order to work systematically towards an objective from the start. In this development, FCT Ingenieurkeramik GmbH based in Frankenblick acted as a strong development partner at NGPM's side.

In the first quarter of 2014, the joint development was started with prototyping of the parts, which were then subjected to different stress tests on the test rig at NGPM. Following the positive conclusion of this series of tests, NIDEC GPM decided, to order an auxiliary tool from FCTI, to test the parts on a broader basis and with contours as close as possible to the series parts.

A comprehensive testing programme was set up and ran over 16 months. The goal was to apply the NGPM standards and especially the customer requirements to the test series.

The test series essentially comprised: continuous running, fouling tests, climatic change tests, shaker tests and various functional and exposure tests. Up to this point, the parts were only tested in the pump on component level.

After this, the range of tests was extended and end-customer vehicles fitted with corresponding water pumps (with ceramic sliding block). A large number of these water pumps (with ceramic sliding block) are currently being successfully tested at different OEMs. The first series production is scheduled for early 2017.

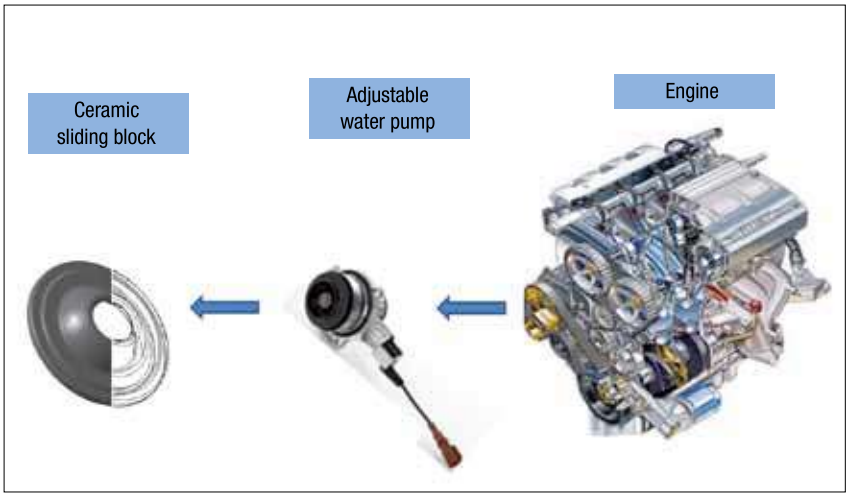

Fig. 3
Water pump with ceramic sliding block

An important factor for the successful introduction of this component are the material and process development at FCT Ingenieurkeramik GmbH.

Beginning with feedstock production through plasticizing to the debinding and sintering process, vibratory grinding and ultimately surface grinding, two and a half years of cooperation had passed. One key advantage is the availability of the complete process landscape at the supplier's operations.

Statement from FCT Ingenieurkeramik GmbH

In mid-2014 the development engineer of GMP, Toni Steiner, contacted FCT Ingenieurkeramik. He described the problem of a dome-shaped component with a sliding or sealing face, the performance of which had to be improved in spite of its DLC coating. In the scope of preliminary research into materials and possible development partners, GPM chose silicon nitride. The reason for this was mainly that the company had been impressed by the very good tribological properties of silicon nitride compared to steel based on its application in hybrid ball bearings (cage made of steel, balls made of Si_3N_4). The customer had soon decided: we want to test that! In complex processes, the small round sliding blocks were cut and ground from solid material.

Then at GPM, today part of the Japanese NIDEC Group, extensive tests were conducted on the component. The results were exceptionally promising. Following this, GPM and FCT both considered what production process might be feasible for large unit numbers and whether FCT Ingenieurkeramik could be considered at all as a partner for large-series automotive production. The decision was taken in favour of ceramic injection moulding (CIM) and against uniaxial pressing. And, although an SME, FCT was considered as potential supplier for series parts, although NIDEC regards it as prudent to look at potential elsewhere, too.

NIDEC has ordered a pre-series tool for the existing injection moulding technology. Several iteration steps finally led to the goal of being able to produce components conforming to the drawings. The following component tests at NIDEC brought resounding success: besides the material, the suitable production process had been found! At FCT Ingenieurkeramik, it was then necessary not only to accumulate the know-how needed for the large series production of injection moulded components, but also for the right sintering process to guarantee flawless reproducibility of the dome shape. With the help of a smart partner in automation, a dedicated process was set up in many months of development work. At the end of 2016, the plant was available ready for use, and it is expected that series production will be begin in the early months of 2017.