Hermetically Sealed Piezoceramic Actuators

The brand new piezoceramic actuators are designed to work in challenging environmental conditions.

Fig. 1
A stainless steel casing protects the piezoceramic actuator against outside influences like humidity *(source: CeramTec)*

The function of monolithic piezoceramic multilayer actuators is based on the inverse piezoelectric effect. These multilayer actuators are built up of several hundred layers of ceramic lead zirconate titanate (PZT) film, each layer measuring around 0,1 mm in thickness. To effect a 1,5- to 1,7-% change in the length of the piezoceramic actuator, electric field strengths of around 2000 V/mm are necessary. Thanks to the thin layers used, the voltages necessary can be limited to 150–200 V. Multilayer piezoceramic actuators have been used, for example, for many years in the diesel injection systems of motor vehicles. In this application they have proven effective a million times over.

Essential for long-term stability in static and quasi-static operations of piezoceramic multilayer actuators is the insulation of the ceramic to protect it against detrimental environmental effects, like, for example, water in the form of humidity. State of the art insulation is to have either a polymeric or a ceramic protective coating. During operation, the expansion and contraction of the piezostack causes the formation of microcracks in the outer coating, through which water molecules can reach the surface of the ceramic. On account of the high local field strengths of 2000 V/mm and the dipolar properties of the water molecules, leakage current results, which impairs the performance of the actuator or even destroys it. As ceramic materials are usually very brittle, especially ceramic protective coatings are prone to the formation of microcracks in dynamic operation. But even if microcracking can be avoided with the use of elastic polymer coatings, any organic coatings (epoxy or other polymers) exhibit excessive permeability for water molecules. After a certain time, water molecules find their way by means of diffusion from outside to the inside and are getting in contact with the ceramic. To provide 100 % protection against humidity or water, CeramTec has therefore developed a hermetically sealed protection for piezoceramic actuators.

A stainless steel casing (Fig. 1) functions as a 100 % diffusion barrier against water, protecting the piezoceramic actuator against outside influences like humidity. Thanks to its bellows design, the stainless steel casing exhibits low stiffness, which is necessary to allow the free expansion of the actuator when voltage is applied. Especially important for the protection of the actuator against humidity are the leadthroughs for the electric leads through the stainless steel casing. The electrical connection wires are firmly fixed into the stainless steel housing with a special glass solder developed in-house. This ensures that no moisture gets into the stainless steel casing along the wires. However, enclosing the piezoceramic actuator in a

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stainless steel casing is not sufficient to achieve the required long-term stability. The water molecules become bonded to the ceramic surface during production as a result of adsorption. This leads, even if after a relatively long time, to increased leakage current with the usual consequences. In production, water inclusion can be reduced by heating up and encasing the ceramic actuator in an inert atmosphere, this, however entails higher production costs. To provide 100 % protection against humidity with minimized added cost, CeramTec has developed a new production process. In this process the water adsorbed on the piezoceramic actuator is chemically converted in a special process AFTER hermetic sealing so as to ensure a completely water-free environment inside the stainless steel casing.

To check the long-term stability of the actuators when exposed to humidity, the leakage current for encased and non-encased actuators of otherwise identical design was measured over several thousand hours (Fig. 2). The conditions for the long-term test were 60 % rH humidity and 25 °C temperature. Voltages of 150 to 200 V were applied. After just a few hours, the non-encased actuator with a standard protective coating showed an increase in the leakage current to values above 1 mA. After this increase, safe and reliable operation is hardly possible. All the actuators available on the market that we tested demonstrated this behaviour. In contrast, the leakage current for the actuators hermetically sealed according to the CeramTec process was still well under 100 nA even after thousands of hours. The hermetically sealed piezoceramic actuators engineered in this way are designed for blocking forces of around 1–2 kN and 45 µm displacement.

The hermetic sealing of the actuators enables the realization of applications that have either not been possible at all so far or only with very considerable difficulty. For instance, for the positioning of drilling and honing tools, for which coolants and lubricants are used, piezoceramic actuators have so far not been used. The moisture would soon destroy the actuator. And in regions with very high humidity, for istance in tropical regions, long-term use of a piezoceramic actuator is now easily possible. For instance, European space satellites are launched from Kourou in French Guiana. The temperature there reaches an average of 28 °C with a humidity averaging 80 to 90 % rH. Ideal conditions therefore to destroy piezoceramic actuators as a result of ingress of moisture even before the launch. CeramTec's hermetically sealed casing can protect the piezoceramic actuators until the launch into space. But the encased actuator can be used even under water: In this case, only sufficient encapsulation of the connections is necessary. A demonstration project was set up with suitably protected clamping. Even when the encapsulated actuator is completely immersed in water, it can be operated without any problems.

Fig. 2
Water-proofed actuators – hermetically sealed *(source: CeramTec)*

For applications requiring hermetically sealed actuators with much higher blocking forces, the power module (Fig. 3) was developed. In the power module, four rows of ten piezoceramic actuators are installed together. The power module is hermetically sealed and, as for individual casings, the CeramTec process is applied to prevent residual moisture being trapped in during assembly. The power modules are designed for applications requiring very high blocking forces, the module shown here, for example, develops around 89 kN as blocking force. Different asssemblies with more or fewer actuators in the module than the four rows of ten are possible.

Fig. 3
Power module equipped with hermetically sealed actuators *(source: CeramTec)*

Thanks to the stable stainless steel casing, the piezoceramic actuator can also be used in applications with very challenging conditions. However even in normal conditions using a specially encased actuator proves to be of advantage as its installation does not demand any special care in the mechanical handling of the piezoceramic actuator.