Elastic Coil Spring Made of Technical Ceramic – Injection Moulded!

According to Wikipedia, "a spring is generally a technical component made of metal that in practical use can be deformed with sufficient elasticity. Most common is the helical spring, wire wound in helical form" (Fig. 1). This, however, is contradicted by the injection moulded ceramic helical springs made by Kläger Spritzguss GmbH based in Dornstetten/DE.

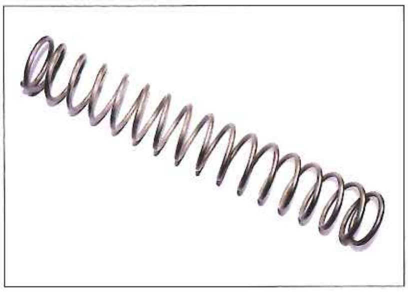

Fig. 1
Coil spring made of metal

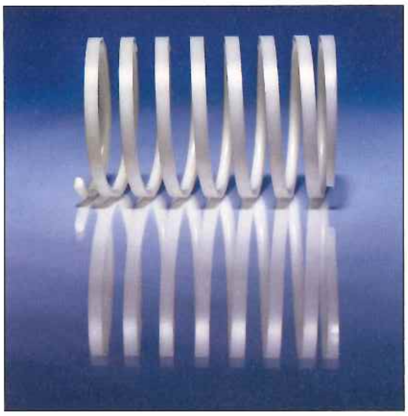

Fig. 2
Injection-moulded coil spring made of ZrO_2

Technical challenge

Ceramic is commonly associated with extremely high hardness. Ideally suited for applications in wear protection and with compression loading, at the same time it exhibits corresponding brittleness. Bending as known and possible with metals does not seem possible with this material because, if the low yield strength is exceeded, fracture is inevitable. Tensile loading is therefore only feasible under certain conditions.

What the Dornstetten-based injection moulding specialist is now doing with the ceramic spring would usually end up in a pile of broken fragments. Actually, various technical ceramics in the elastic range behave in a similar way to steel, for instance yttrium-reinforced zirconia (ZrO_2). ZrO_2 has an elasticity limit that enables a high load without permanent deformation – ergo: a reversible shape change on and after the impact of force in the elastic range.

In terms of the material, the preconditions for a ceramic spring are theoretically met. But is there a reproducible, process-stable and economically attractive production process? This was precisely the challenge that technicians at Kläger Spritzguss GmbH took on and the result is impressive: probably the first and globally only helical spring made of technical ceramic ZrO_2, fabricated by means of injection moulding (Fig. 2).

Process technology

It is well-known that the injection moulding process offers wide shaping freedom and numerous components produced by Kläger prove this impressively (Fig. 3). But is it possible to use the injection moulding process to create a compact, closed and defect-free microstructure for a sophisticated spring geometry, which can withstand such a demanding load. Process-related characteristics such as injection point, flow paths, weld lines had to be critically assessed and harmonized with the geometric complexity of the component in the tool concept. A challenge that calls for the entire interdisciplinary competence from engineering, mould making and injection moulding, all of which are found at Kläger in great depth under one roof (Fig. 4).

Fig. 3
Wide shaping freedom in injection moulding

With regard to the tool, the requirements were met with a complex slide tool. The complex and filigree interior contour is produced by means of a hydraulically moved folding core. The injection system was realized with a heated nozzle.

Keywords
injection moulding, ceramic spring, zirconia

Jens Graf
Kläger Spritzguss GmbH & Co. KG
72280 Dornstetten
Germany

E-mail: j.graf@klaeger.de
www.klaeger.de

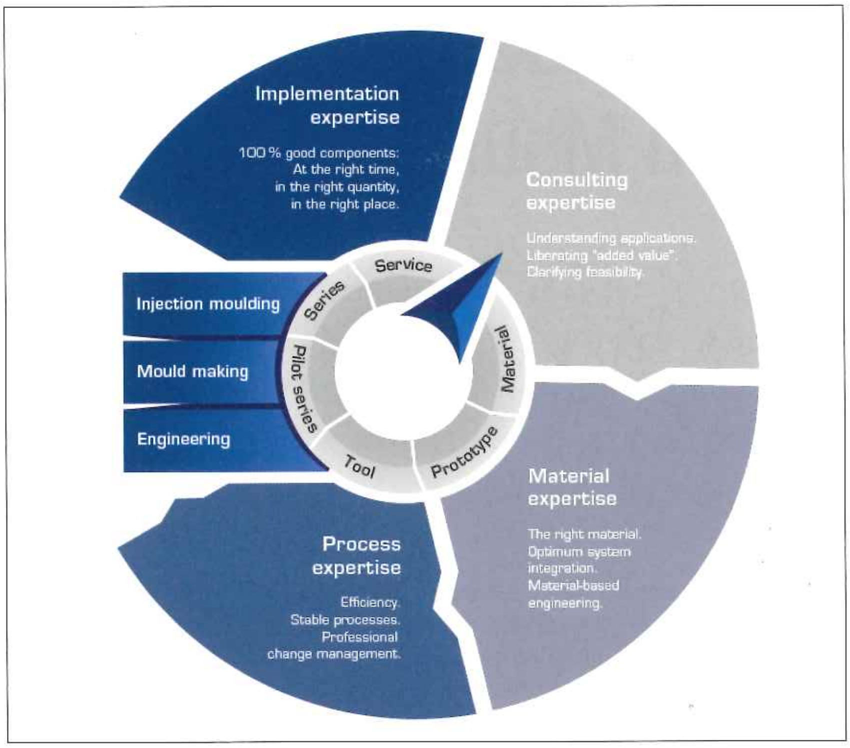

Fig. 4
Spectrum of services from one source

The realization of such a filigree component cannot be only attributed to the tool technology. A key contribution is made by the further development on the feedstock side with different binder systems. At Kläger, all binder systems currently available on the market are used in series application. In this case, diverse systems were sampled and tested, before a thermoplastic-based binder system was chosen.

Thanks to its processing parameters, this enables optimum injection and flow behaviour, which is a precondition for low-stress and consequently defect-free filling of the component (Fig. 5). Another critical moment during the shaping process is the ejection of the components from the cavity as on account of one-sided or excessively high load, hardly visible microdefects can form in the component, which after sintering can become cracks or invisibly weaken the microstructure. Both are knockout criteria for use of the ceramic as a spring. The high green component strength of the selected feedstock with simultaneous elasticity enables simple, defect-free ejection of the components from the mould.

Debinding and sintering are performed in-house in Kläger hybrid systems in atmospheric conditions (Fig. 6).

Fig. 5
Ceramic-injection moulding machine

Application of ceramic springs

Ceramic springs provide a good solution for applications in ambient conditions in which metallic materials fail, e.g. high-temperature applications or application in corrosive media. The temperature-dependent material properties limit the possible application of springs made of steel as here the application temperatures are limited to around 550 °C owing to creep. In contrast, the maximum permissible working temperature of the ceramic helical springs is 1000 °C.

The better corrosion resistance compared to steel, both at room and higher temperatures or in corrosive atmosphere and in aggressive media, proves another advantage. The good electrical insulation and the lower weight are also included in the list of advantages. Advantages that enable use as e.g. as valve springs for AGR valves, EGR valves and exhaust gas bypass valves in the exhaust gas recirculation system or also with the use of corrosive media in the chemical industry.

With this successful development, the Dornstetten-based ceramic injection moulding specialists are underlining their claim as a competent innovation partner for development projects and their fast and reliable implementation in a series-ready product.

For almost 20 years, Kläger has been involved in "ceramic injection moulding" and both the prevailing innovative spirit and interdisciplinary in-house competence over the entire value creation chain enable constant shifting of the boundaries of the technically feasible. The ongoing process improvement, cooperation with partners on the material side or research institutes form a valuable basis here.

Kläger leading in ceramic processes and plastics-injection moulding

The core expertise at Kläger is the injection moulding process. Kläger sees itself as a development partner and producer of injection moulding solutions for ceramics, plastics and metals. The SME has its own engineering, own mould-making and injection moulding production in plastics and ceramics. Its portfolio of services is rounded off with the system integration of manufactured components in complete assemblies. Customers can therefore access sound knowledge and comprehensive expertise in all relevant process steps.

In plastics injection alone, Kläger is currently processing over 300 different materials in over 2000 active articles. In ceramic injection moulding, the company is a pioneer and, measured by the components in series production, one of the current market leaders.

Numerous customers from over 15 industries depend on production of their key components at the Dornstetten company.

Whether for porous ceramic plugs or hard grinding disks in automatic coffee machines, wear-resistant nozzles for high-pressure cleaners, aesthetic, biocompatible crowns for children's milk teeth, spray systems or filigree components for electrosurgery – the injection moulding of ceramic materials offers wide shaping freedom with regard to component geometry, enabling better product performance based on improved material functionality and in many cases an additional cost advantage compared to conventional products.

Fig. 6
Debinding and sintering equipment

Tab. 1 Datasheet for ceramic springs

Geometric parameters of the realized component	
Tension-free length	L_0: 35 mm
Spring deflection (long-term use)	12 mm
Outer diameter	D: 25 mm
Thickness of the coil	d: 1,5 mm
Geometric parameters in general	
Tension-free length	L_0: max. 60 mm, min. 20 mm
Outer diameter	D: max. 50 mm, min. 15 mm
Thickness of the coil	d: max. 3 mm, min. 0,8 mm
Base material	
Material	Zirconia (ZrO_2)
Modulus of elasticity	200 GPa
Density	ca. 6 g/cm³
Hardness	1350 HV
Melting point	2680 °C
Properties of ceramic springs	
Spring force	Depending on the spring profile, max. spring force totals around 40 N
Lifetime	Long lifetime even with dynamic load
Thermal properties	High heat resistance (max. working temperature 1000 °C), high thermal dimensional stability
Mechanical properties	High mechanical strength, high dimensional stability
Chemical/biological properties	High corrosion resistance in a corrosive atmosphere or in corrosive media
Electrical/magnetic properties	Electrical insulation, non-magnetic