12.10.3. Ceramics

Ceramics have gained great importance in the last decade. After successful development of particular characteristics, which allowed manufacturers to apply this material to valve trims as well, ceramics have become more and more acceptable. In addition to precise production of these parts the following features are particularly important in order to meet the demands of a suitable trim material:

- Sufficient bending strength and ductility,
- High hardness and wear resistance,
- High corrosion resistance,
- Resistance against temperature cycling,
- Satisfactory sliding features.

These characteristics were not available in the beginning (e.g. in the case of aluminum oxide = Al_2O_3) and there were setbacks. With the later success achieved with the application of silicon nitride (Si_3N_4), a considerably longer service life was reached (e.g. in coal hydrogenation). Meanwhile there are numerous specific ceramics available which cannot be mentioned in detail here. In most cases a special high pressure procedure is used to give the ceramic parts a raw shape. After a sintering process at high temperatures and at a specific gas pressure, the ceramic parts are finished by grinding. The application of ceramic materials as trims always demands - as for hard alloys - a special trim construction which takes the material characteristics into consideration. Tensile stress, bending stress and above all notch effects are to be avoided without exceptions. This requires compromises and basically limits the application of ceramic materials to the following:

- Severe wear by inevitable abrasion, e.g. in flue gas desulfuring, since “lime slurry” is exceptionally abrasive and destroys metallic trims quickly.
- Simple trim design is absolutely essential. Complicated solutions, such as multi-hole plugs, are impossible.

With the fixing of such ceramic trims, rolling, shrinking or wedging of ceramic parts are normally applicable. Attention must be given, however, to the different thermal expansion coefficients (Figure 12.10.3.-1).

The plug made out of ceramic material, consists of cylindrical and conical sections which are easy to produce by grinding. Since ceramic material can stand high compressive forces, the ceramic plug part can be rolled-in without problems. The cone on the upper ceramic part prevents the plug from breaking away from the metallic support which in turn connects to the valve stem.

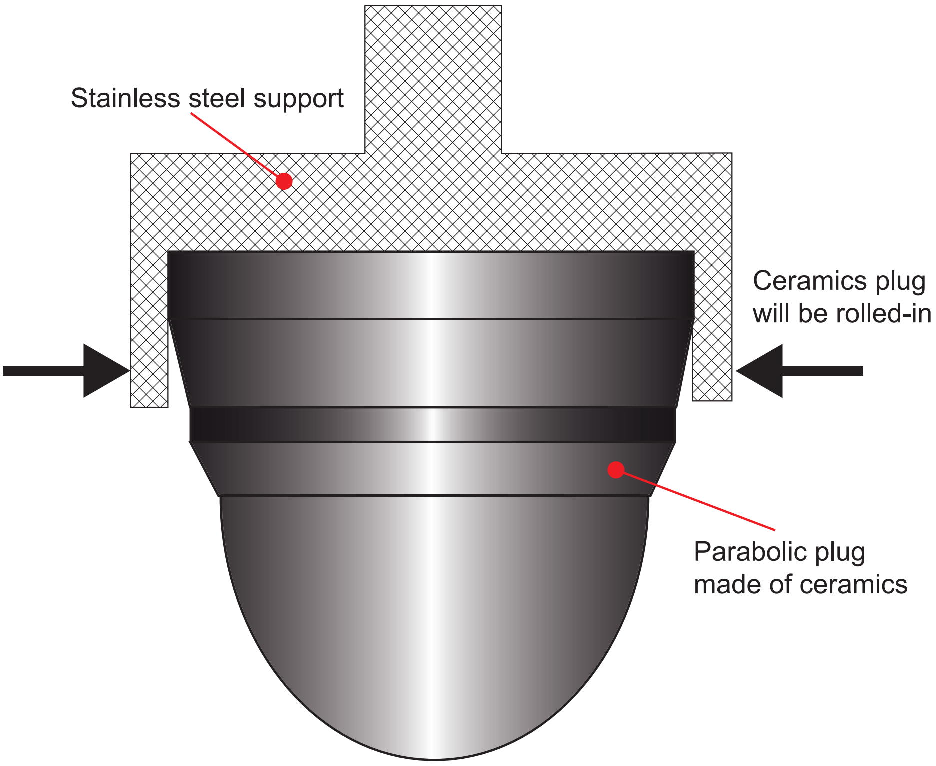

Figure 12.10.3.-1: Rolled-in ceramics plug (schematic)

In industrial plants, pneumatic and electric control valves control different media, often under unfavorable flow conditions. In flashing service and with aggressive fluids containing solid matter, the valve trim, i.e. seat and plug, as well as the valve body are subject to erosive and abrasive wear.

In some applications, valve trims made of cast iron or PTFE are worn out within only a few days and valve trims of stellited or forged titanium within a few weeks. Valve trims made of low-wear ceramic, however, shows almost no signs of wear after one year in service.

Depending on the valve design and the particular properties of the ceramic material used, the following advantages can be attained:

- Seat and plug made of **H**ot **P**ressed **S**ilicon **N**itride (HPSN)
- Constant high flexural strength and resistance to abrasive wear
- Corrosion resistance
- Service life 200 times longer compared to valve trims made of austenitic steel used under highly erosive and abrasive conditions
- Longer service life of angle valve bodies thanks to the flow¬to-close direction of flow and an additional anti-wear sleeve of **S**ilicon **C**arbide (SiC)

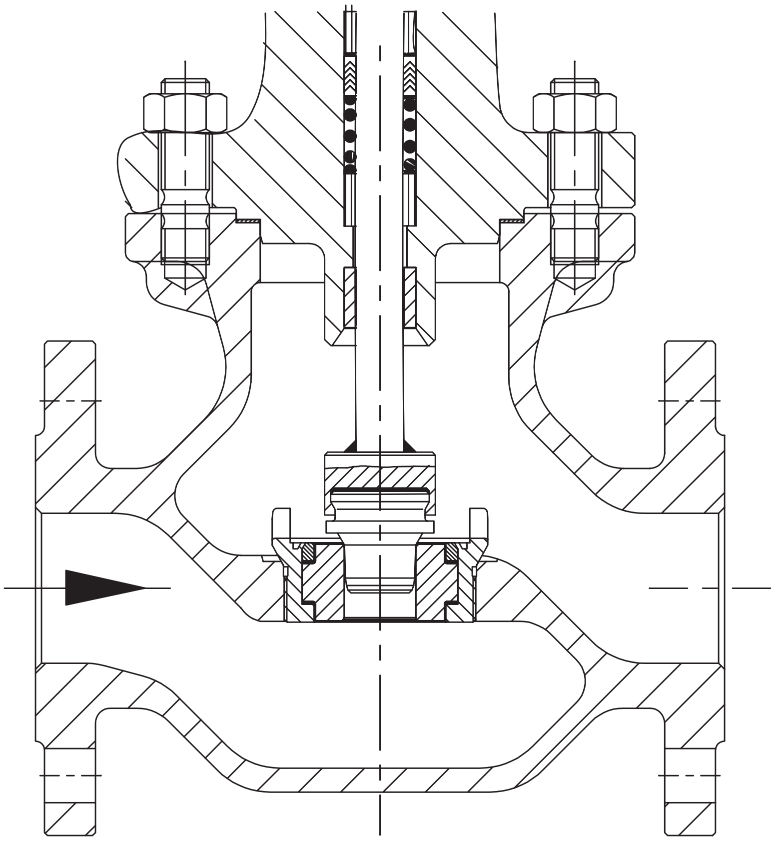

Figure 12.10.3.-2: SAMSON Type 3251-1 with ceramic trim

Material		HPSN (Si_3N_4)	SiC
Flexural strength (4-point)	N/mm^2	600 to 800	> 350
Tensile strength	N/mm^2	300 to 500	> 180
Compressive strength	N/mm^2	2500	> 1200
Young's Modulus	kN/mm^2	310 to 320	> 330
Hardness HV 10	N/mm^2	> 16000	> 21000
Thermal expansion (α)	$10^{-6}/°C$	3.2	4.3
Corrosion resistance		Better than all metal valve materials	

Table 12.10.3.-3: Properties of ceramic materials

Hot Pressed Silicon Nitride (HPSN)

HPSN was developed in the 1960s and 1970s with the aim of allowing engineers to utilise some of the outstanding properties of Si_3N_4. HPSN is made by adding a flux (usually magnesia) to a fine Si_3N_4 powder and then pressing the powder in a graphite die typically at 1800 °C and 40 MPa of pressure. The resultant body is fully dense with excellent mechanical properties (see Table 12.10.3.-3).

Silicon Carbide (SiC)

Silicon carbide is ultra hard and have a high thermal conductivity. This has led to silicon carbide being used in bearing and rotary seal applications where the increased hardness and conductivity improves seal and bearing performance.

The outstanding corrosion resistance of SiC, particularly in acids, makes it an ideal candidate for valve and valve trim applications. SiC is used in demanding applications such as slurry flashing, HF acid (Hydrofluoric acid) handling and rare earth processing. Check valve components can handle environments other ceramic materials cannot survive.

Silicon Carbide is derived from powder or grain, produced from carbon reduction of silica. It is produced as either fine powder or a large bonded mass, which is then crushed. To purify (remove silica) it is washed with hydrofluoric acid.

There are three main ways to fabricate the commercial product. The first method is to mix silicon carbide powder with another material such as glass or metal, this is then treated to allow the second phase to bond.

Another method is to mix the powder with carbon or silicon metal powder, which is then reaction bonded.

Finally silicon carbide powder can be condensed and sintered through the addition of boron carbide or other sintering aid. It should be noted that each method is suited to different applications.

Properties for HPSN and SiC

- High thermal conductivity
- Low thermal expansion coefficient
- Outstanding thermal shock resistance
- Extreme hardness
- Semiconductor
- Refractive index greater than a diamond

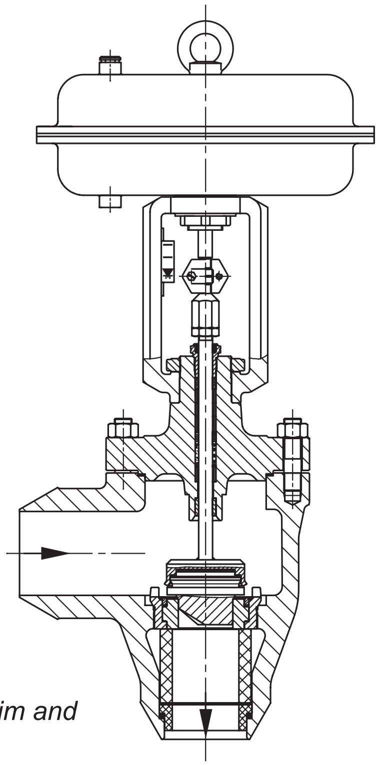

Figure 12.10.3.-4: SAMSON Type 3256-1 with ceramic trim and ceramic anti-wear sleeve