Carbon pistons
for internal combustion engines

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Pistons for internal combustion engines require specialized and highly-developed materials. Due to their unique properties, **carbon materials** which have been especially developed for this application offer an alternative to metals and allow exceptional solutions as well as improved performance in automotive engineering.

The raw material

Special materials synthesized from constituents of coal tar or petroleum pitch serve as raw materials for manufacturing carbon pistons. Due to their liquid crystalline structure, these materials are called "meso-phases". Separated from the pitch and chemically as well as thermally stabilized, they are used to produce carbon materials with outstanding physical and mechanical properties.

The manufacturing process

Elementary carbon cannot be melted or sintered. Therefore, carbon products are normally manufactured by a ceramic process. In this process primary carbon powders with a high carbon content are mixed with a binder (mostly coal tar pitch). Subsequent to a shaping process of this mixture, the binder is thermally decomposed to elementary carbon ("carbonisation") at temperatures of up to 1000 °C in order to form a matrix for the primary carbons. A further heat treatment ("graphitization" at temperatures of up to 3000 °C) leads to the graphitic properties of carbon, which are advantageous for many applications.

The porosity resulting from the limited coke yield of the binder during carbonisation restricts the attainable bulk density and, consequently, the mechanical strength of the material. Conventionally, increases in bulk density can only be achieved by supplementary, time and money consuming infiltrations ("impregnations").

The raw material ("mesophase") used for manufacturing carbon pistons, though, shows a certain sinterabil-ity. Therefore, it is possible to manufacture carbon materials with high values in density and mechanical strength directly - without binder. Although the use of mesophases seems to simplify the manufacturing process by reducing the number of production steps, the process control is much more complicated, due to

- the oxidation sensitivity of the raw materials,
- the necessity of processing very fine-grained starting powders with a low density,
- the large quantity of volatile components generated during pyrolysis,
- the very high volume shrinkage during the manufacturing process.

The material properties

Due to the nature of the raw materials and the manufacturing process, mesophase materials have a very homogeneous and dense texture together with high values in bulk density and mechanical strength. They show excellent tribological properties because of their isotropic graphitic structure. Additionally, they exhibit a very high thermal and electrical conductivity and are resistant against chemical attack and oxidation. These advantages make our special mesophase materials ideal for manufacturing pistons for internal combustion engines.

The following table gives the typical physical properties of two **SCHUNK** carbon materials (**FU 4270** and **FU 2451**) which have been especially developed for the use in different engines.

	FU 4270	***FU 2451***
Bulk density / g/cm^3	1,8	1,9
Young's modulus / GPa	13	15
Bending strength / MPa	80 - 100	100 - 120
Compressive strength / MPa	150	250
Coefficient of thermal expansion / $10^{-6}K^{-1}$	5	7
Thermal conductivity / W/mK	40	60

The application

The development of modern two stroke and four stroke engines places demanding requirements on both construction and the materials used. The obvious objectives in engine development are to

- minimize fuel and oil consumption,
- reduce noise and emissions,
- maximize engine performance,
- maximize operational reliability,
- increase comfort
  - avoid vibrations
  - optimize acceleration and torque curve.

The use of **carbon pistons in internal combustion engines** contributes significantly to achieving these objectives:

- ⇒ Carbon has a density which is **30 %** lower than that of aluminum. This advantage in weight results in a considerably reduced reciprocating mass in the engine, thus leading to higher performance and reduced vibration as well as to lower fuel consumption.
- ⇒ Carbon is a **refractory material**. The mechanical strength of metals heavily decreases with rising temperature, whereas the strength of carbon increases. Even in thermally high-loaded engines, a complicated cooling of the piston is not necessary.
- ⇒ Carbon exhibits **self-lubricant** properties which increase the operational reliability of the engine and result in reduced lubricant (oil) consumption.
- ⇒ Carbon has a **low coefficient of thermal expansion**. This allows engine designs to incorporate lower cold clearances without risking piston seizure under high loading. This also implies a significant decrease in HC emissions during cold start and reduced blow-by as well as increased operational reliability.
- ⇒ Carbon shows an excellent **resistance to thermal shock**.

By using **carbon pistons** for internal combustion engines it is possible to

- ⇒ reduce piston weight by **up to 30 %**,
- ⇒ reduce HC emissions by **up to 40 %**,
- ⇒ increase engine performance by **up to 10 %**,
- ⇒ reduce oil consumption by **up to 50 %**,
- ⇒ reduce fuel consumption by **up to 5 %**,
- ⇒ reduce blow-by by **up to 50 %**, and
- ⇒ reduce CO emissions by **up to 55 %**

compared to engines equipped with aluminum pistons.

Please do not hesitate to contact us to learn more about how carbon pistons may help improve your engine design in new ways!