Bruker Elemental Application Spotlight – G4 ICARUS C HF

Carbon Determination for the Control of Carburization in Heat Treatment Processes - September 2011

Hardening/Carburization

Tough core and a hard case are the target properties of components made of case hardened steel. That combination of wear resistance and fatigue strength in the surface and impact strength in the core zone is achieved by carburizing the surface layer of the component, which is subsequently quenched and tempered.

Components produced that way with optimized properties between core and case include gear components of all kind, camshafts, cardan joints, driving pinions, link components, axles and arbors.

Applications include:

- **Transportation:** Case hardened components are needed in any engine driven vehicle, whether it is a car, a truck or even an ocean vessel.
- **Energy generation:** Gear wheels and components in large dimensions have to withstand both stress and wear in equipment such as hydroelectric power stations, wind turbine generators, propeller drives of drilling rigs or steam turbine gears of power stations.
- **General mechanical engineering:** forging presses, steel rolling equipment, machine tools; drivelines of mining equipment and heavy duty transmissions; earth moving equipment and heavy duty construction cranes. The combination of wear resistance and fatigue strength is always a key characteristic of the case hardened steels used for these applications.

Source: Internet

In contrary to steel hardening by tempering, quenching and annealing, where the bulk material gets hardened, surface hardening technology hardens only the surface of the steel.

In the **carburization** process for surface hardening of low carbon steels the material is treated in a carbon rich gas which is generated in a gas generator from methane, ethane or propane and consists mainly of CO, H_2 and N_2.

The steel is heated at temperatures of 850°C to 980°C in a special tempering or annealing furnace or kiln where carbon atoms from the continuously controlled gas atmosphere diffuse into the surface layer of the work piece.

The carburization depth is depending on the temperature, the gas atmosphere and the treatment time. Quenching and tempering following the carburization produces a high carbon martensitic structure near the surface, with great hardness and wear resistance, while the core retains its original strength and toughness properties.

Carburization Test Foils / Shim Stock Method

In gas carburizing, the steel is heated in contact with carbon monoxide and/or a hydrocarbon which is readily decomposed at carburizing temperature. The hydrocarbon may be methane, propane or natural gas. In the carburization process carbon is transferred into iron by the following reactions:

$CO \rightarrow CO_{ad} + O_{ad}$

$CO + H_2 \leftrightarrows H_2O + C$ (dissolved)

$2\,CO \leftrightarrows CO_2 + C$ (dissolved)

$CH_4 \leftrightarrows 2\,H_2 + C$ (dissolved)

$C_3H_8 \leftrightarrows 4\,H_2 + 3\,C$ (dissolved)

The liberated carbon is readily dissolved by the austenite phase and diffuses into the surface layer of the steel. Carburizing steels for case hardening usually have base-carbon contents of about 0.2%, with the carbon content of the carburized layer generally being controlled at between 0.8 and 1% C.

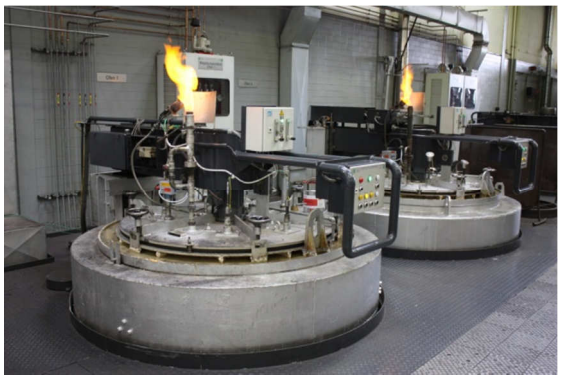
Carburizing has the following effects on the properties of the steel work piece:

Change in material properties

Work material properties	Effects of carburizing
Mechanical	• Increased surface hardness • Increased wear resistance • Increased fatigue/tensile strengths
Physical	• Grain Growth may occur • Change in volume may occur
Chemical	• Increased surface carbon content

Case hardening depth of carburized steel is a function of carburizing time and the available carbon potential at the surface. Therefore the composition of the carbon-bearing atmosphere must be very closely controlled to avoid deleterious side effects.

Direct furnace atmosphere analysis methods (shim stock, carbon gradient bars, etc.) can help to ensure getting a complete picture of the variations taking place in the carbon profile.



For shim stock analysis, clean test coupons made of 0.1 – 0.4 mm thick very low carbon annealed sheet (free of oil, grease, or dirt) are placed into the furnace, thus exposed to the carburization atmosphere for a sufficient dwell time to allow saturation to the limit of carbon in austenite for the temperature selected.

The test foils are pulled from the furnace after adequate dwell time and quickly water quenched or slowly cooled down for a sufficient time (30 to 90 min, depending on the furnace temperature) in an inert gas flow.

One of the evaluation methods for the carbon uptake is the weight-gain method where the difference in the shim weight before and after exposure to the furnace atmosphere is determined to calculate the carbon potential.

Combustion Method

The preferred test method for carbon determination in test foils is the combustion method in a high-frequency furnace in oxygen with infrared detection. This kind of carbon analysis directly determines the maximum carbon potential of the furnace atmosphere up to the theoretical limit of carbon saturation in austenite.

G4 ICARUS HF

For rapid and precise carbon and sulfur measurements the **G4** ICARUS HF, using the combustion method with high frequency induction furnace and infrared detection proves highly effective especially with metallic materials and also with inorganic materials like cement, clays and many others.

The solid sample, placed in a ceramic crucible together with accelerator material, is combusted in the high-frequency furnace in an oxygen stream. The carbon and sulfur components in the sample are oxidized to release CO_2 and SO_2 respectively. These measuring components are swept by the carrier gas O_2 to the solid-state NDIR detector system of maximum selectivity and stability.

The analyzer is equipped with two measuring ranges for both, CO_2 and SO_2 with automatic base line compensation (Automatic Level Control - ALC) and automatic optimum range selection. The calibration of the analyzer is made by means of certified reference material.

The innovative design of the combustion area with the gas outlet positioned directly on top of the ceramic crucible (**pat. pend.**) for assisted removal of the formed metal oxide particles leads to drastically reduced contamination of the quartz combustion tube by dust and slag. The integrated system pressure control and electronic flow regulation enable a fully automatic leak test which can be invoked via the software.

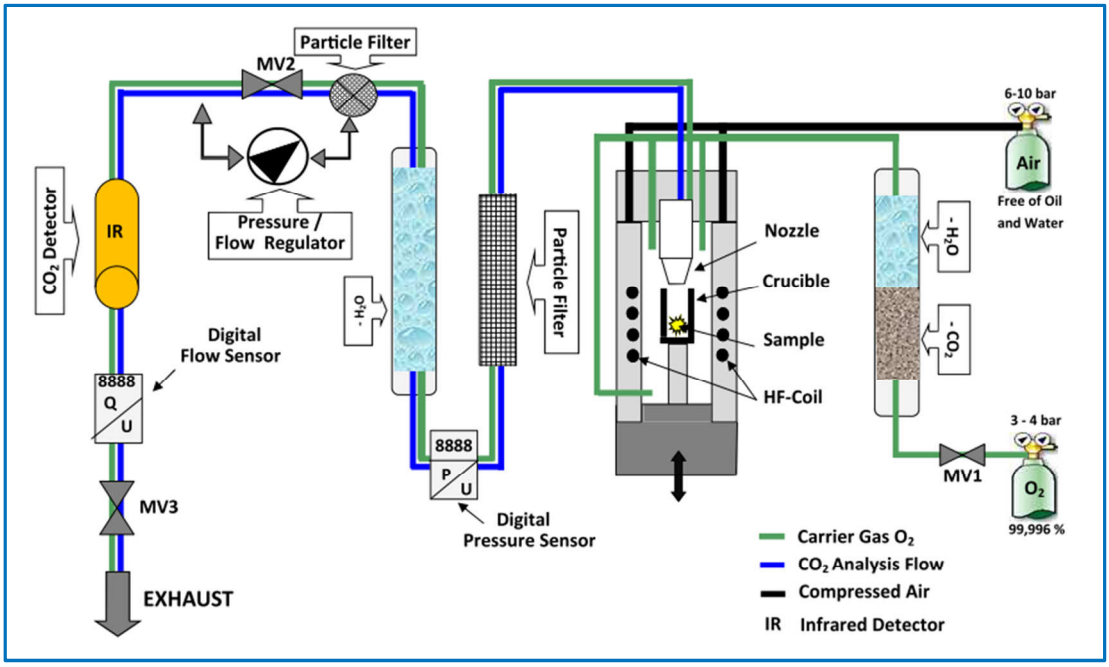
During the analysis, all detector signals are displayed on-line on the graphic screen. The analysis results together with the analog detector signals and the complete set of parameters are displayed on the color monitor and can also be printed out for documentation.

For the application of carbon measurement in carburization foils, the G4 ICARUS HF analyzer is equipped with one NDIR detector for CO_2. The measuring range is optimized for the carbon concentration range of the base foils (about 0.1% C) and the charged material after the carburization test (up to about 1.5% C).

The analyser is characterized by the following benefits and special features:

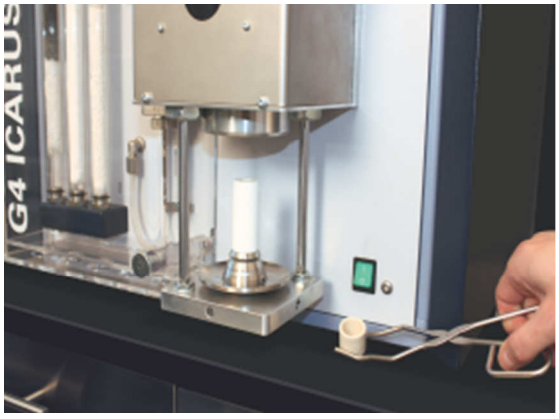
- Advanced high frequency induction furnace technology
  ⇒ High power for optimal combustion; long life oscillator tube (**3 years warranty**)
- Innovative design of the combustion area
  ⇒ Tremendous reduction of contaminations in the furnace chamber by dust or splatters; thus longer lifetime of quartz tube, much longer cleaning intervals
- Direct view into combustion zone through gauge glass
  ⇒ Visual following of the combustion process and observance of degree of contamination
- Optimized gas flow system
  ⇒ Drastically reduced analysis times, low gas consumption, no gas flow in stand-by
- Electronic pressure and flow monitoring with additional green/red display on front panel
  ⇒ Enables fault indication and a fully automatic leak check
- Selective solid-state NDIR detector for CO_2 (**3 years warranty**)
  ⇒ Automatic base line compensation
- One-4-all software
  ⇒ Easy operation; user-friendly operator interface with same layout for all Bruker Elemental gas analyzers

Gas Flow



The gas flow system of the **G4** ICARUS HF has been significantly simplified which leads to significantly shorter analysis times and a considerably higher sample throughput. Additionally, a fast purge mode for flushing the system at the beginning of an analysis is implemented to reduce the analysis cycle time.

Before starting the analysis, the weight of the test foil is transferred from the balance, and sample code and comment, if appropriate, are entered.



Then the crucible with the sample and accelerator is positioned on the crucible carrier of the analyzer, and the analysis is started.

System pressure and gas flow are continuously controlled and displayed on the screen and digitally at the front panel of the analyzer.

Thus, a constant analysis gas flow through the non-dispersive solid-state infrared detector is ensured, in which the CO_2, resulting from the combustion process, is selectively detected.

After the analysis, the result is automatically displayed on the screen. For saving gas, no oxygen is flowing when the furnace is open or in the standby mode of the analyzer.

Specifications

Measuring range*):	0.05 - 6 % Carbon
*) Can be extended by reducing the sample weight	
Sample weight:	0.5 – 1.0 g
Analysis time:	about 40 s
*) Depending on sample weight	
Resolution:	0.1 ppm
Reproducibility:	± 0.005 %
Carrier gas:	Oxygen, 99.5%
Compressed air:	min. 5 bar
Power supply:	230 V, 2.7 kVA
Dimensions/weight:	56 x 60 x 48 cm, 60 kg
	22 x 24 x 19 in, 88.2 lbs

Markets and Users

Sliding and rotating parts need to have hard surfaces. These parts are usually machined with low carbon steel as they are easy to machine. Their surface is then hardened by *carburizing.*

Case hardening increases:

- Surface hardness
- Wear resistance
- Fatigue/tensile strengths

Case hardened parts are used, for example, in:

- Valves and fittings
- Engines, gearboxes
- Printing machinery
- Railway technology
- Energy and reactor technology
- Aircraft industry
- Domestic appliances
- Hydraulic and pneumatic industry
- Textile machinery
- Heavy equipment machinery
- Hydroelectric power stations
- Wind turbine generator
- Steam turbine gears of power stations

Potential users (exemplary):

- **Automotive industry, manufacturer of automotive parts (gears, engine parts, etc.)**
- **Heat treatment/hardening shops (contractors)**
- **Foundries with carburization or nitrocarburization shop**
- **Machine manufacturing**
- **Tool manufacturing**

Source: Internet

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