

Solid fuel analysis – Information about a few analysis parameters

Ash – what is that – and what does it mean for plant operation?

A fuel does not contain ash. However, the residue remaining by a standardised, total combustion of the fuel in a laboratory furnace is denominated “ash” or “ash content”. The larger the residue, the more ash is to be disposed of after thermal utilization of the fuel – and if the ash melting temperature is low, huge slagging problems may arise.

As regards the solid mineral fuels, determination of ash is carried out by ignition at 815 °C until constant weight and as regards solid biofuels, by ignition at 550 °C. The lower ignition temperature for solid biofuels is due to the fact that solid biofuels often contain large amounts of inorganic salts, which evaporate at temperatures above 600 °C. In full-scale plants the evaporated salts in gaseous phase will subsequently condense into fine particles when the flue gas temperature is lowered in the convection part.

The volatile matter – what is that – and what does it tell us?

The volatile matter is determined in the laboratory as the part of the fuel, besides water, which is submitted by heating the fuel to 900 °C without contact with air for precisely 7 minutes. The volatile matter is an empirical coal quality parameter used for estimating the reactivity of coal. As regards coal, the content of the volatile matter ranges from below 10 % in anthracite coal to about 70 % on the dry and ash free basis in brown coal.

As most solid biofuels produced from ordinary biomass, i.e. non-pyrolised or composted biomass, in general are reactive fuels there is no reason to determine the volatile matter. For most of the ordinary virgin biomasses the volatile matter content is about 80 % on the dry and ash free basis.

Based on the volatile matter content, the so-called “Fixed carbon” content may be calculated. Fixed carbon is the coke residue, besides ash, which remains by the heating to the 900 °C. That is:

Fixed carbon = 100 % - %moisture - %ash - %volatile matter.

Calorific value – but which calorific value?

The value measured in the laboratory is the *Gross calorific value at constant volume*. The gross calorific value is the highest calorific value as this value includes the heat of vaporization of the water, i.e. all water after combustion is assumed to be liquid water.

In Europe it is common practice to use the *Net calorific value at constant pressure* for characterisation and trade of fuels. The net calorific value is calculated from the gross calorific value by subtracting the heat of vaporization for both contained water (water in the fuel itself) and the water formed by combustion of the fuel (which is calculated from the content of hydrogen, H, in the fuel), i.e. all water after combustion is assumed to be water vapour. The net calorific value could also be calculated at constant volume – but please observe that this value is higher than the value at constant pressure (which generally equals actual combustion conditions).

$$q_{p,net,M} = q_{v,gr,M} - 212 \times H_M - 0,8 \times (O_M + N_M) - 24,4 \times M$$

as

$q_{p,net,M}$ is the net calorific value at constant pressure, at M weight% moisture, in J/g

$q_{v,gr,M}$ is the gross calorific value at constant volume, at M weight% moisture, in J/g

H_M is the content of hydrogen, at M weight% moisture, exclusive of hydrogen in the moisture, in weight%

O_M is the content of oxygen, at M weight% moisture, exclusive of oxygen in the moisture, in weight%

N_M is the content of nitrogen, at M weight% moisture, in weight%

M is the moisture content, in weight%

Formula 1. Calculation formula for the net calorific value, at M % moisture

To calculate the net calorific value at constant pressure is needed – apart from the gross calorific value, knowledge of the hydrogen content and to a lesser extent, knowledge as to the content of nitrogen and oxygen. For well-known fuels such as coal, wood and straw empirical formulas as e.g. Seyler's formula or typical default values may be used to lay down the hydrogen content. As regards more un-known fuels or fuels in which the hydrogen content varies significantly (such as olive residues with varying olive oil remains) it will be necessary to determine the actual content of hydrogen in order to calculate the net calorific value.

If the net calorific value is known for a moisture content then the net calorific value can be calculated for other moisture contents:

$$q_{p,net,M^*} = (q_{p,net,M} + 24,4 \times M) \times \frac{100-M^*}{100-M} - 24,4 \times M^*$$

as

q_{p,net,M^*} is the net calorific value at constant pressure, at M* weight% moisture, in J/g

$q_{p,net,M}$ is the net calorific value at constant pressure, at M weight% moisture, in J/g

Formula 2. Calculation formula for conversion of the net calorific value to other moisture contents

The SI-unit of calorific values is J/g (= kJ/kg) but calorific values often are stated in other units, e.g.:

MJ/kg = value in J/g divided by 1000

kcal/kg = value in J/g divided by 4,1868

kWh/kg = value in J/g divided by 3600

Fuel analysis parameters may be stated/reported at different sample bases. FORCE Technology e.g. reports the net calorific value on the three following bases:

- **as received basis (a.r)**, i.e. the net calorific value at the existing moisture content of the sample. This equals the energy content in the introduced fuel.

- **dry basis (d)**, i.e. the net calorific value of the dry matter of the received sample. Typical values obtained by experience for the energy content of the dry sample are used in some contracts for the settlement of accounts of shipments (together with actual determined moisture content).
- **dry ash free basis (daf)**, i.e. the net calorific value for the combustible part of the sample. The energy content on the dry ash free basis is a useful key figure as this value is at a typical level for the various types of fuels, e.g.:

32 MJ/kg for ordinary hard coal

19 MJ/kg for wood (as hard wood has the lowest value and soft wood the highest value)

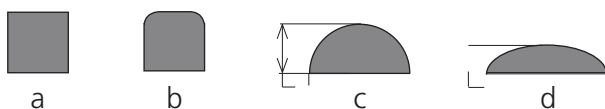
18 MJ/kg for straw and grasses

17 MJ/kg for grain.

Ash fusibility – standard methods

An indication of the melting behaviour of the fuel ash is obtainable by determining “the characteristic temperatures” cf. the standard ISO 540 as regards the solid mineral fuels and CEN/TS 15370-1 as regards the solid biofuels. The method in the two standards is identical in principle but in CEN/TS 15370-1 more restrictions are laid down (e.g. only a small cylindrical test specimen is allowed) and the ash is prepared at a lower temperature.

In the test a representative analysis sample is prepared and ashed in the laboratory. Of the ash a small test specimen is prepared which is then observed during slow heating to 1500 °C under specified conditions. During the heating process the characteristic temperatures are determined according to the profiles below.



Profiles of the characteristic temperatures

The profiles show:

- Start,
- Deformation temperature,
- Hemisphere temperature,
- Flow temperature.

The test may either be performed in reducing atmosphere (CO/CO₂) or in oxidizing atmosphere (air). In general, use of reducing atmosphere provides the lowest deformation temperatures.

Further information

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