Variation of Natural Gas Composition

Challenges for Power Generation

Wilhelm Müller, Jens Reeh  Caterpillar
Introduction of Gas Composition

- Chemical composition of Natural Gas defined as gas quality in the DVGW-Arbeitsblatt G 260.
- Natural gas is mainly methane with a fraction of alkanes or hydrogen with a max. fraction of 12%, L and H gas acc. to G 260.
- Fractions can also be higher more than 20% in future.
- Pipeline gas is mixed from different gas fields with a certain range of variation in compositions.
- Globalisation of pipeline network and sourcing of energy like LNG and increase of shale gas within the supply chain will increase the variation of compositions.
- Sustainability direction will increase the biogas and hydrogen fraction.
LNG supply channels for Europa

Flüssigerdgas (LNG) für Europa
Mrd. m³/a

- Lieferungen 2008: 55,3 Mrd. m³
- Importe 2010: 94 Mrd. m³

davon
- Algerien: 19,38
- Ägypten: 6,37
- Qatar: 7,89
- Oman: 0,17
- Trinidad & Tobago: 5,03
- Libyen: 0,53
- Nigeria: 14,63
- Norwegen: 1,38
- Äquatorial-Guinea: 0,08

Quelle: Cedigaz
*davon 3,5 Mrd. m³/a aus Nigeria über Montoir für Enel I Italien
Comparison MN impacted by 10% hydrogen

Methane number

- Russia
- Nordsee
- Dänemark
- Libyen
- Nigeria
- Ägypten
- Bioerdgas

- H with H2 additive
- H without H2 additive
- LNG
Engine Knocking

- Knocking events by self-ignition of unburned Gas-Air-Mixture
- Knocking in the higher load range is a self accelerating process and must be immediately stopped to avoid increase of wear and tear and engine damage
- Knock resistance of NG mixtures depends on fast ignitable long chain hydrocarbons; condensate droplets stored knock initiate compounds which have to be avoided
- Methane Number is the key to define the knock resistance
- Each cylinder has its individual knock margin
Main factors impacting the gas engine operation

- Methane Number
- Gas quality, gas composition
- Air to fuel ratio
- Compression ratio
- Charging pressure
- Ignition system
- Ambient conditions (Charge air temperature / de-rating strategy)
Gas engine control system

- Monitoring & Protection
- A/F-ratio control
- Ignition Timing control
- Knock control per cyl.
- Gas Pressure control
- Speed Governor
Control strategy for power plant operation

Examples

- Grid parallel IPP operation
- Unstable grid (frequency, voltage)
- Peak shaving operation grid parallel
- Island mode (droop, load shedding, sharing operation)
- Island mode variation elec. load (e.g. cement industry)
- Etc.

Corrective action plant control system

- Power matching
- Power matching
- Power matching
- Power management
- Power management
Reliability

- Continuous knocking can damage engine parts (e.g. piston, see picture)

- Preventing engine knocking
  - Drop in methane number reduces knock margin
  - MWM TEM anti knock control system per cyl. detects cylinder knocking and acts preventing it
  - Knock control system per cyl. optimizes the engine efficiency
  - Transient velocity of methane number variation has to be limited. Within this transient time the control is very reliable

- Older field gas engines are not equipped with this technology.
Engine efficiency versus methane number

- Reduced methane number resulting in change of efficiency
  - Lower methane number leads to higher flame velocity
  - Engine control increase air ratio to adjust combustion and NOx
  - Both measures have a converse impact to the engine efficiency
  - Due to lower rating effected by the lower methane number a drop in efficiency has to be considered
Engine rating versus methane number

- Engine rating is impacted by lowering the methane number
  - Knock limit could impact engine rating (de-rating with lower MN)
  - Knock margin is different from engine to engine
  - Engine reacting on parameters changes in next working circle

![Graph showing engine rating versus methane number](image)
Measures to operate with changing methane numbers

- Limitation of methane number transient velocity for state of the art gas engines with knock control
- Older field engines without knock control requested in time information from gas supplier about impacting methane number for preventive de-rating
- In time information that temporary supply with low methane number gas is terminated, operator can switch back to previous load profile with improved engine efficiency
Sulphur content in natural gas supply

- Natural gas in the network contains contaminants from the different sources.

- Sulphur content is limited acc. to DVGW G260 (max. 30 mg/m³

  - Sulphur is transported over long distances acc. to pressure and velocity in the pipeline to the consumer
  
  - Sulphur is converted during the combustion process to SO₂

- Especially oxidation catalysts convert SO₂ with additional oxidation towards SO₃ and generate together with the water vapour sulphur acid H₂SO₄

- Increased risk due to sulphur acid corrosion in the exhaust gas system
Example corrosive attack by sulphur acid

Gas engine operated with natural gas

• The condensate contained sulphur acid with a pH of 0.3 was extreme acid dissolving chromium and nickel in the condensate
• Source for the sulphur origin couldn’t be identified afterwards
Thank You For Your Attention!