A correct ‘octane number’ for LNG

“Een correct ‘octaangetal’ voor LNG

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**Background – Matching Fuels and Engines**

- **LNG growing as transportation fuel: ships, trucks, off-road**
  - >50 ships built, another 50 on order
  - Truck market developing
  - Low pollutants compared to diesel/HFO, low noise (trucks)
  - Takes advantage of worldwide availability LNG

- **Worldwide supplies of LNG vary substantially depending on the geographical origin and change of composition in the value chain (Boil-Off gas management).**
  - Vary from pure methane to >13% ethane, >3% propane, >1% butanes (i-butane and n-butane) and N₂

- **Different LNG compositions have different combustion properties:**
  - *most critical for engine performance is resistance to knock*

- **The occurrence of engine knocking leads to significant loss of performance (power reduction), potential engine shutdown and potentially extensive damage.**
Necessity of characterizing engine knock

- Engine performance designed for the knock characteristics of the fuel: power, efficiency, emissions
  → Highest knock ‘resistance’, best performance

- Must match fuel and engines → octane number of gasoline and automotive engines → methane number of LNG gases and gas engines

- Must balance best performance with widest supply of LNG (GIIGNL)
  - Range of LNG too wide → risk of knock or structurally underperforming engines
  - Range too narrow → exclude fuel compositions unnecessarily

- Currently no agreement on equivalent knock method (methane number) for LNG
Original motivation: Poor predictions by traditional methods

Measured Knock-Limited Spark Timing (KLST) in DNV GL test engine
Excellent prediction by DNV GL method

Measured Knock-Limited Spark Timing (KLST) in DNV GL test engine versus calculated PKI Methane Number (DNV GL method)

Engine used for verification:
Lean-burn high-speed medium BMEP CHP type engine (MAN)

DNV GL Method
Project outline and deliverables

- **Goal:** develop ‘algorithm’ to characterize knock resistance of LNGs for engine types used in trucks and ships, analogous to octane number

  *Impact: Engine OEMs and LNG suppliers can match fuels and engines, to give best performance, risk free*

- **Method:** extend the DNV GL method to 2 new LNG engines (1 for trucks and 1 for ships) for analysis and algorithm development
  - Modeling of cylinder processes and verification of results using engine data
  - Develop algorithms for both engine types
  - Compare 3 algorithms and analyze possible differences and their consequences for (standardization in) the market

- **Deliverables:**

  *Impact: Verified algorithms to characterize engine knock, à la the octane number, ready for use in international standards*
Progress: Selection marine and truck engine

- Based on an inventory of gas-fuelled marine engines we selected:
  - A ultra-lean-burn, medium-speed, high BMEP dual-fuel marine engine
  - Progress:
    - First set of experiments have been performed
    - Started modelling this engine

- Based on an inventory of gas-fuelled truck engines we selected:
  - stoichiometric truck engine with EGR
  - Discussions with large truck OEM to join this TKI project

- We started and will continue the discussion with ISO work groups (e.g. TC193 and WG 28/SC4) regarding standardization of the algorithm(s)
Outlook 2016

**Marine engine:**
- Modelling marine engine
- Verification of the knock model for the marine engine with measurements (Wärtsilä)
- Develop algorithm for marine engine

**Truck engine:**
- Preparations truck engine tests

**General:**
- Contacting ISO work groups for standardization of the knock algorithm(s)
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Ungraded
Appendix: Knock phenomenon

Normal combustion vs. knocking combustion

Knock is autoignition of end gas
→ competition between propagating flame front and autoignition reactions in end gas

Knocking combustion → end gas spontaneously ignites

\[ t_{\text{autoignition}} < t_{\text{combustion}} \]

DNV GL approach
→ understanding and describing (changes) in end-gas autoignition process with varying fuel gas composition