profiles

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The direct injection carbon engine

Using coal to fuel diesel engines has been investigated numerous times over the last 122 years for power generation and transport applications. However, technical difficulties and unfavourable economics have resulted in the termination of previous research and development (R&D) programmes.

Coal dusts

From the 1890s to the 1950s coal dusts were used in small internal combustion engines. High mechanical efficiencies and long engine lifetimes were achieved. However, coal dusts cause severe wear and are explosive. Rudolph Diesel found that it was much easier to fire low-cost liquid petroleum fuels, which led to the development of the diesel engine as we know it.

Coal water fuels

In the 1960s laboratory research in the USA and Switzerland discovered that firing coal water fuels, made up of ~50% coal dust and ~50% water, directly into an engine is more effective than dust firing.

Cool water fuel (CWF)

US DOE

The oil-crises in the 1970s prompted the Department of Energy in the USA (US DOE) to fund a comprehensive coal-fuelled diesel engine R&D programme from 1978-2004, which led to successful full-scale demonstration of a coal-fuelled diesel engine in a train locomotive, a truck engine and a small power generation engine. The minerals in CWF were removed with physical and chemical cleaning methods. To further minimise wear an adapted diesel engine was used, which employs harder engine materials and a purpose built fuel injector.

CSIRO

More recently, higher oil and gas prices, tougher environmental and energy security drivers, coupled with advances in coal processing and diesel engine technology (such as electronic control and larger cylinders) favour the commercialisation of coal-fuelled diesel engines for power generation. The high flexibility, black-start capability and high efficiency at all loads allow maximum utilisation of intermittent renewable energy whilst keeping emissions low. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia have been investigating firing micronised refined carbons (MRC), a finer and cleaner CWF, in direct injection carbon engines (DICE). Laboratory-scale tests at CSIRO with MRC made from high- and low-rank coals have been successful. Economic analyses conducted by CSIRO, ANLEC R&D and MAN D&T show favourable economics in power generation applications, compared with diesel in distributed generation and gas in centralised generation.

Each issue of **Profiles** is based on a detailed study undertaken by IEA Clean Coal Centre, the full report of which is available separately. This particular issue of Profiles is based on the report:

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Kyle Nicol

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This report is free to organisations in member countries. £100 to organisations in non-member countries for six months after publication, and free thereafter.

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Micronised refined carbons

MRC can be made from high rank coal (HRC), low-rank coal (LRC), coal tailings, biomass and biochar. LRC and biomass can be hydrothermally treated (HTD) to increase their energy density. Ignite Energy Resources, Exergen, JGC, Xstrata Technology; Yancoal and Intertech are all producing MRC, the first three with HTD, at pilot-scale demonstration.

Direct injection carbon engines

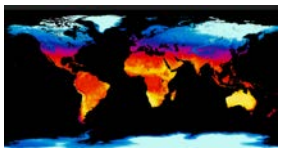
As larger cylinders are more tolerant to lower quality MRC, DICE is most applicable to 1-5 MWth cylinders, which include the large two-stroke engines used on large ships. DICE is based on technology developed by the US DOE coal-fuelled engine R&D programme.

MAN Diesel & Turbo

Using MRC produced by multiple companies, MAN Diesel & Turbo plan to operate a 1 MWe pilot-scale DICE in Japan. Assuming acceptable results from pilot-scale DICE tests and the MRC fuel cycle, DICE could proceed to large-scale and long-term demonstration which would establish the MRC specifications for the lowest life-cycle cost of MRC-DICE. The MRC fuel cycle, which includes coal beneficiation and hydrothermal treatment, also has to be demonstrated at large-scales to provide details on the MRC qualities and the associated production costs. The first commercial DICE could be built in 2025.

Wärtsilä 12RT-flex96C – currently the world's largest and most powerful diesel engine

This report reviews the previous research and development (R&D) programmes on coal-fuelled diesel engines and focuses on the recent developments of the technology in its latest form, micronised refined carbons (MRC) and the direct injection carbon engine (DICE).



Global temperature profile

There are 1.3–1.4 billion people in sub-Saharan Africa and the Indian sub-continent without access to electricity and in most cases they have coal reserves.

DICE is tolerant to high temperature, high altitude and low water environments, and could therefore play a large role in alleviating energy poverty.

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