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Ultra High Efficiency Power Generation from Victorian Coals

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The Direct Injection Carbon Engine (DICE) represents a major step towards a baseload energy technology that has low capital cost, high efficiency, low greenhouse gas emissions and provides quick stop/start/ramp times. DICE can be used with any carbon-based fuel source, including both renewable and fossil fuels, and can provide back up for intermittent energy sources, such as solar and wind, or provide peaking power to complement fixed-load power stations. DICE also has the potential to provide a synergistic fit with carbon capture technologies.

Victorian brown coal has proven to be an ideal fuel source for DICE. The DICE technology involves producing a low ash coal water slurry (a micronised refined carbon or MRC).This is injected into specially adapted large diesel engines where it burns in a manner similar to heavy fuel oil, at a significantly higher thermal efficiency than existing power stations. DICE has the potential to become an alternative power generation technology to produce low cost, low CO2 electricity from Victoria's world-class coal reserves.

This article summarises RD&D undertaken with Brown Coal Innovation Australia over the last three years towards a DICE demonstration in Victoria.

The BCIA funded research program has assessed the suitability of a range of separation technologies for controlling the amount and size of mineral particles in the MRC, strategies for controlling fuel rheology, atomisation, combustion, techno-economics, and integration of CO2 capture technologies.

Better-than-expected results have been obtained across all research areas. Highlights of the RD&D program to date include:

- Hydrothermal processing is the preferred method of preparing the fuel. Hydrothermal processes are well known to Victoria, with development dating back to the late 80s and the SECV's 24 t/day pilot plant at Mulgrave. More recent pilot scale development has been by Exergen and Ignite Energy Resources. JGC has also recently commissioned a 24 t/day pilot plant near Jakarta for upgrading Indonesian lignites. Larger hydrothermal plants are in operation in China.
- An important sub-process has been de-sanding to ensure a consistent MRC quality with respect to coarse mineral content. Good results have been achieved using inexpensive conventional coal processing spirals.
- The brown coal MRC has high energy and a viscosity low enough for injection. Atomisation of the fuel is complete in around 1ms, and ignition is also very rapid (around 5ms), providing excellent combustion under simulated engine conditions.

- Higher viscosity/solids fuel mixtures have shown better ignition properties, highlighting the need to develop improved atomisers to handle these viscous fuels. A novel air blast injection system has been developed for brown coal pastes that gives excellent atomisation of paste with low air consumption.
- MRC from Yallourn coal combusts under engine conditions to produce the same highly bimodal flyash size distribution as in pf boilers – micron size sulphate fume, and large mostly fused flyash comprising either iron-rich cenospheres or smaller fused silicates. Only quartz particles larger than 20 µm remain essentially unfused.
- Metal wear tests have shown that Victorian coal and ash create wear scars on the engine cylinder that are similar to or smaller than those produced using clean lubricant.
- Achieving high thermal efficiency with DICE will depend on optimising a range of operational factors. R&D is underway to maximise engine efficiency using fuel pre-heating, optimised fuel injection profiles, and blast atomisation of higher calorific value paste-type MRC. With successive generations of the fuel cycle, an overall thermal efficiency of around 54 per cent LHV (52 per cent HHV) is expected – which will reduce CO2 intensity by more than 50 per cent compared to current plants.
- Techno-economic analysis shows that DICE is likely to give the lowest cost of electricity for likely future gas and carbon prices. A range of carbon capture options were included in the study.

A key objective of the project is to develop an engineered proposal for a Victorian DICE demonstration that could lead to commercial deployment before 2018. Discussions have started with possible participants in the demonstration program. MAN Diesel and Turbo has taken the lead in developing a program that could lead to a production-ready low speed engine within three years. The program is being developed with joint MAN and Australian industry funding, with the opportunity for other parties to contribute.

A DICE development network is being established to support, facilitate and help integrate DICE pilot/demonstration projects internationally. The DICE development network intends to participate in shared development of DICE, by facilitating integration of the development of DICE and its associated fuel cycle (from carbon fuel resources through to delivered power), to fast track commercialisation, and to maximise the benefits that the technology provides.

More information on this network can be obtained from BCIA or myself on the email below.

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