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Summary of Research

"Durability, Performance, and Emission of Diesel Engines Using Carbon Fiber Piston and Liner"

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This report summarizes the research conducted by NC State University in investigating the durability, performance and emission of a carbon fiber piston and liner in our single cylinder research Diesel engine. Both the piston and liner were supplied to NC State University by NASA LaRC and manufactured by C-CAT under a separate contract to NASA LaRC. The carbon-carbon material used to manufacture the piston and liner has significantly lower thermal conductivity, coefficient of thermal expansion, and superior strength characteristics at elevated temperatures when compared to conventional piston materials such as aluminum. The results of the carbon-carbon fiber piston testing were compared to a baseline configuration, which used a conventional aluminum piston in a steel liner. The parameters measured were the brake specific fuel consumption, ignition delay, frictional horsepower, volumetric efficiency, and durability characteristics of the two pistons.

Testing was performed using a naturally aspirated Labeco Direct Injection single cylinder diesel engine. Two test cases were performed over a range of loads and speeds. The fixed test condition between the aluminum and carbon-carbon piston configurations was the brake mean effective pressure. The measured data was the fuel consumption rate, volumetric efficiency, load, speed, cylinder pressure, needle lift, and exhaust gas temperature. The cylinder pressure, and fuel consumption, exhaust gas temperature, and needle lift were recorded using a National Instruments DAQ board and a PC. All test cases used Diesel no. 2 for fuel.

Our specific conclusions from this research are as follows:

1. The Brake Specific Fuel Consumption was generally higher for the carbon-carbon system. This seems to be a result of decreased mixing, lower volumetric efficiencies, and increased friction.
2. The volumetric efficiency was consistently lower for the carbon-carbon system. This is a result of the elevated operating temperatures.
3. The ignition delay was found to be generally lower for the carbon-carbon system due to the increased temperatures during the compression stroke, which result from the insulating affect of the carbon-carbon piston.

4. The frictional horsepower was consistently higher for the carbon-carbon case. This is believed to be a result of the breakdown of lubricants at the elevated operating conditions.
5. The exhaust gas temperature was consistently higher for the carbon-carbon case. This is a result of the reduction in heat lose of the system due to the carbon-carbon piston.
6. The peak pressure was consistently lower for the carbon-carbon case. This is believed to be a result of shorter ignition delays and reduced mixing.
7. The carbon-carbon piston survived 56 hours of cumulative operation. While this is certainly insufficient for this material to be commercially viable at this stage, the benefits of this material encourage its further development.
8. The carbon-carbon liner was not as successful. Two different liners were tried and both failed at the sealing lip between the engine block and the cylinder head with little or no run time. Both the piston and liner were not designed to exploit carbon-carbon fibers advantages and mitigate its weaknesses; they were exact duplicates of the aluminum and steel counterparts. So, it is not surprising that the durability of the liner was poor.