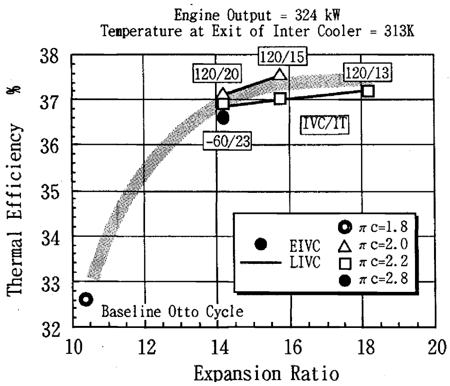
Executive Summary

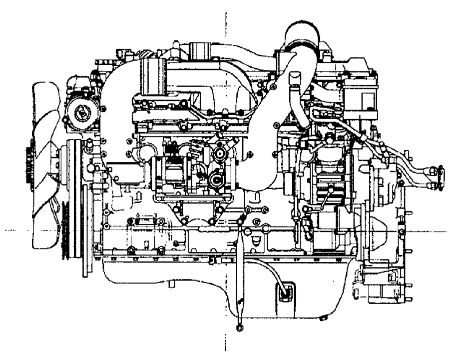
1.0 PRODUCTION MILLER-CYCLE NATURAL GAS ENGINE

Cegeneration System Achieves Acceptable Thermal Efficiency, Power [Tsukida et al.]: Engineers at Tokyo Gas Co., Ltd., and Yanmar Diesel Engine Co., Ltd., reported development results of a cogeneration system powered by an efficient natural gas engine. They have now put Miller-cycle technology into commercial application. To complete development within the limited time frame of one year, they employed the approach of late intake valve closure to increase the expansion ratio (13.3). No significant engine modifications were necessary; thus, the prototype engine could be sufficiently tested for both reliability and durability before the final production engine design was completed. A 23.15-liter natural gas engine with Miller-cycle technology achieved 36.1 percent brake thermal efficiency, and the cogeneration system produced 300 kW of electric power. The total system including the heat recovery system achieved 83.5 percent energy efficiency.

Note: Name in bracket designates references at end of this report



THE EFFECT OF EXPANSION RATIO ON BRAKE THERMAL EFFICIENCY [Tsukida et al.]



HINO CNG ENGINE [Murakami et al.]

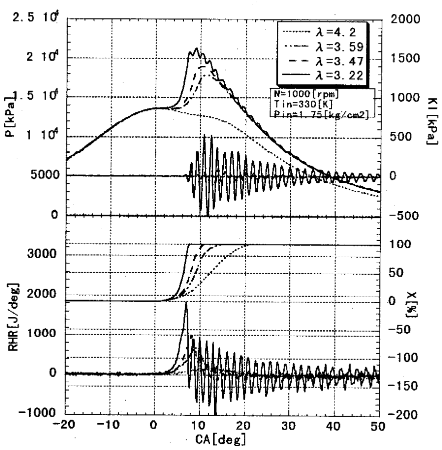
Late-intake valve closure reversed intake mixture into the intake port which was of concern for developers because some lubricant-originated deposits accumulated, but no serious problem was found during 2000 hours of operation under full load.

2.0 MEDIUM-DUTY NATURAL GAS TRUCK ENGINE

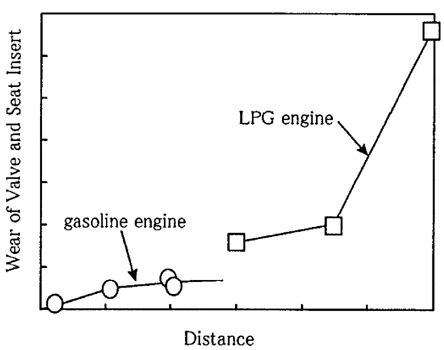
Emissions, Noise Decreased and Fuel Consumption Increased in Hino Truck [Murakami et al.]: Engineers at Hino Motors, Ltd., reported features of their latest compressed natural gas (CNG) engine developed for medium-duty truck application. A 7.961-liter production diesel engine, J08C, was converted to operate on CNG at the stoichiometric mixture. A three-way catalyst was used to reduce exhaust emissions at the tail pipe. The base engine components were modified to withstand the higher exhaust gas temperature of stoichiometric CNG operation. The cylinder head, exhaust manifold, and exhaust valve and seat insert were modified for high-temperature operation. Combustion noise reduced by natural gas operation contributed to lower vehicle noise by about 50 percent compared to the base diesel engine. The peak torque occurred at a lower speed than that of the base diesel engine. This torque characteristic was advantageous for delivery truck application. Exhaust emissions including carbon dioxide (CO_2) were significantly low compared to those of the base diesel engine. At 60 km/hour steady-state vehicle speed conditions, the natural gas engine-powered vehicle consumed 30 percent more fuel than the diesel engine-powered vehicle. Technology development to improve part-load fuel economy will be necessary.

3.0 COMPRESSION-IGNITION OF PREMIX NATURAL GAS

Premix Natural Gas Compression-Ignition Extends Lean-Limit and Produces Low NOx but High THC and CO [Kawabara et al.]: Engineers at Tokyo Gas Co., Ltd., investigated the premix compression-ignition of natural gas fuel for the feasibility of achieving reasonable power required for a cogeneration system with low exhaust emissions. A single-cylinder diesel engine was modified to operate on premix natural gas fuel. With a higher compression ratio (17) and heated intake air (~ 150°C), premix compression-



THE EFFECT OF EXCESS AIR RATIO ON COMBUSTION [Kawabata et al.]



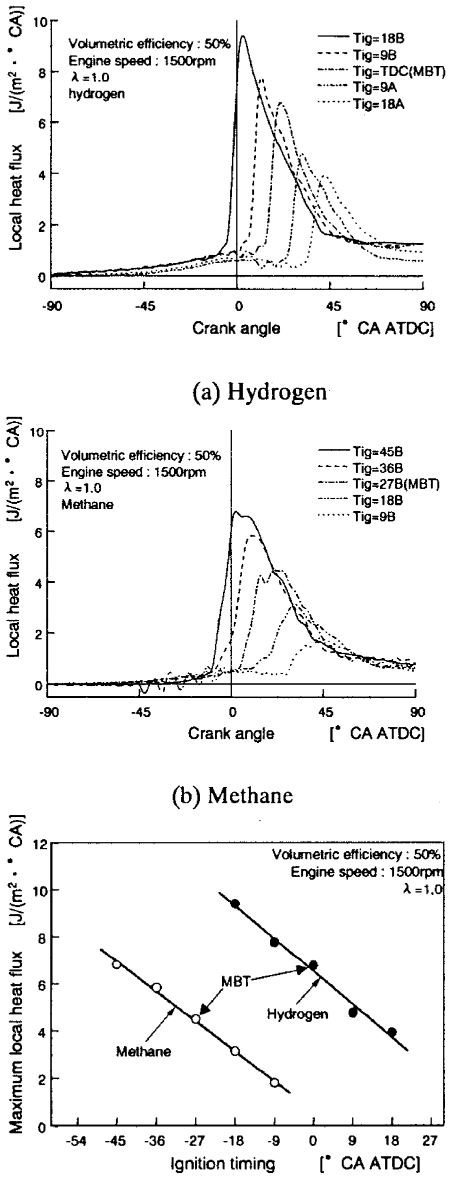
WEAR OF VALVE AND SEAT INSERT IN AN ENGINE AS A FUNCTION OF VEHICLE DRIVING DISTANCE [Maki et al.]

ignition of natural gas mixture was possible, and the engine produced indicated mean effective pressure (IMEP) of 1.0 ~ 1.2 MPa at 1000 rpm. The maximum torque was limited by combustion knock. The combustion rate was more than 10 times higher than that of a conventional, spark-ignition, natural gas engine. However, the lean-limit was significantly extended to the excess air ratio of 6.2. As a result, NOx was reduced to only a few ppm, although total hydrocarbons and CO were extremely high.

4.0 EVALUATION TECHNIQUE FOR VALVE-SEAT WEAR AND LOW- POLLUTION VALVE SEAT

Oxide Formation and Hardness Significant for Reduced Valve and Valve-Seat Wear [Maki et al.]: Engineers at Nissan Motor Co. and Fuji OOZOX investigated the wear mechanism through experiments conducted on both a test engine and a test rig. Engine tests were first conducted to characterize the wear of an intake valve made of production material in both a gasoline and a LPG engine. A test rig was used to evaluate the effects of valve seat temperature, material hardness, and contact pressure not only on seat insert wear, but also on valve wear. Based on these investigations, for gasoline engines, the oxide layer is a significant factor of the valve and seat insert wear. On the other hand, the LPG engine requires harder and stronger material for the valve and seat insert since oxide formation is difficult.

Environmentally Acceptable Material Developed for Valve Seat Insert [Ehira et al.]: Engineers at Nissan Motor Co., Ltd., and Hitachi Powdered Metals Co., Ltd. developed material for the exhaust valve seat insert for gasoline engines. A high-speed tool steel that does not contain Pb or cobalt (Co) was selected for the base metal matrix. Thus, material recycling and reduced production cost would be feasible. Two different base metals were mixed to achieve good material compatibility with valve material and low adhesive wear – Steel A, consisting of higher tungsten (W), higher carbon (C), vanadium (V), and chrome (Cr) with the remaining balance of ion; and Steel B, consisting of lower W and lower C with the remaining balance of iron. Material modifications from precipitating manganese sulfate (MnS) at the time of the sintering process and impregnating acrylic resin improved machineability and reduced the wear rate of the cutting tool. This increases productivity in the manufacturing process. Engine durability test results indicated a 30 percent reduction in the sum of valve wear and insert wear. Thus, this exhaust valve seat insert not only improved wear, but also contributed to the reduction of production costs. Additionally it is an environmentally suitable material.



THE EFFECT OF SPARK TIMING ON METHANE AND HYDROGEN COMBUSTION AT 1500 RPM AND AT THE STOICHIOMETRIC RATIO [Shudo et al.]

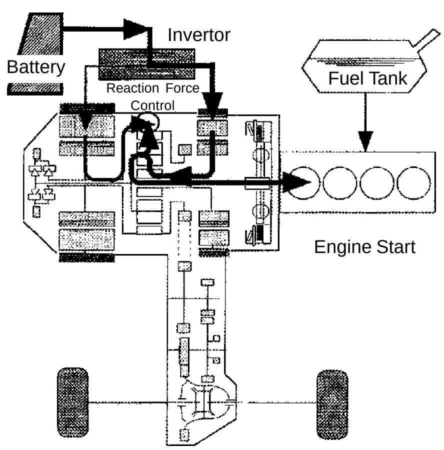
5.0 PREMIX HYDROGEN ENGINE EFFICIENCY AND HYBRID VEHICLE APPLICATION

Reduced Heat Loss Found to Improve Thermal Efficiency [Shudo et al.]: Researchers at Musashi Institute of Technology investigated the key parameters that characterize thermal efficiency of a premix hydrogen engine relative to a premix methane engine. A production, four-cylinder, automotive gasoline engine was modified to operate on either methane or hydrogen. Cylinder pressure data were analyzed to evaluate thermal efficiency and heat loss for the effects of spark timing, excess air ratio, and volumetric efficiency. As a result, the heat loss to the wall was higher than that of the methane engine. Instantaneous heat flux calculated from the measured wall temperature indicated a higher heat flux compared to that of the methane engine. Increased excess air ratio decreased heat loss. When the excess air ratio was increased, the major contributor to the improved thermal efficiency could be the reduced heat loss. Thus, technology development for improved brake thermal efficiency requires better understanding of the heat loss mechanism in the hydrogen engine.

Potential to Improve Hydrogen Engine Performance Evaluated [Nakajima et al.]: Another group of researchers at Musashi Institute of Technology and engineers at Nissan Motor Co., Ltd., investigated a hydrogen engine for series hybrid electric vehicle application. Two production engines with different bore sizes were modified to operate on premix hydrogen and tested to evaluate the effects of excess air ratio, volumetric efficiency, turbocharging, and mechanical efficiency on indicated thermal efficiency as well as on brake power. A larger bore size with fewer cylinders effectively increased indicated thermal efficiency because the surface-to-volume ratio is lower.

Since an engine used for a series hybrid electric vehicle operates under steady-state conditions at a relatively low engine speed, the valve spring constant of the valve train can be substantially reduced compared to that used for a conventional engine. Combining the lower valve spring constant with a two-ring pack piston, mechanical efficiency can be increased. Additionally, a hydrogen engine can operate on an extremely lean mixture such as the excess air ratio of 2.5. Using a turbocharger, a 1.791-liter, three-cylinder, premix hydrogen engine produced 20 kW at 2250 rpm and emitted less than 10 ppm NOx. The experimental results indicated high potential to further improve hydrogen engine performance by optimizing combustion and reducing mechanical efficiency.

6.0 TRANSAXLE DEVELOPED FOR A HYBRID ELECTRIC VEHICLE



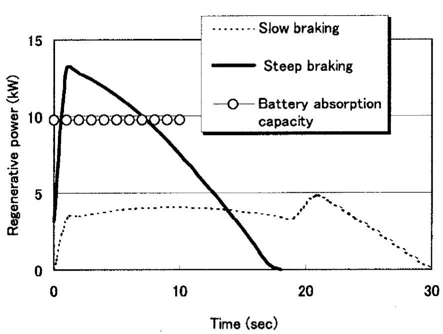
POWER TRANSMISSION AT ENGINE START AND AT ELECTRIC POWER GENERATION
[Matsui et al.]

Toyota Finds Higher Start Speed Reduces Driveshaft Torque, Noise, and Vibration [Matsui et al. and Ohshima et al.]: Engineers at Toyota Motor Corporation reported the key elements of transaxle design for Toyota's parallel-hybrid electric vehicle (HEV) called "Prius." Fuel economy is double that of a conventional passenger car which means half the CO_2 emissions. Because of the complex power management required for a parallel HEV, the transaxle design is the most important element of the HEV for comfortable driving with fuel-efficient operation. Depending on the vehicle operating conditions – city driving, hill climbing, or high-power driving – the vehicle is driven by either the engine, the electric motor, or both.

Since the engine is stopped when the HEV is either at stop or decelerating, the engine is started repeatedly from time to time. Engine startup causes noise and vibration, and reducing the engine vibration caused by engine startup is the biggest hurdle in developing a commercial HEV. A higher engine start speed rate successfully reduced the input driveshaft torque; hence the vibration decreased for a comfortable ride in the HEV. In addition, the vibration damper was designed uniquely for HEV application. A torque limiter was installed to prevent peak torque from being applied to the input driveshaft. Toyota engineers also reported the vehicle drive torque patterns under various HEV operating conditions.

7.0 THE CAPACITOR-TYPE BATTERY AND ENERGY RECOVERY

Battery-Capacitor Combination Evaluated in EV and SHEV [Ikeda et al.]: Researchers at Waseda University investigated the performance of an EV and a series hybrid electric vehicle (SHEV), both equipped with the combination of a conventional storage battery and a capacitor-type battery. Parametric analysis was conducted using a computer simulation program to evaluate the effects of the number of capacitor-type batteries and that of lithium ion batteries and also the effect of the lithium ion battery load ratio. Two different capacitor-type batteries were considered in the model. Regardless of the type of capacitor, vehicle performance did not make significant difference in terms of the driving distance and energy consumption. Consequently, the capacitor-type battery does not have a significant advantage in improving vehicle performance under city driving conditions because its storage capacity is too small. Also, a conventional battery can recover a reasonable level of energy during vehicle deceleration even without a capacitor.



BRAKING POWER AND BATTERY CHARGING POWER UNDER VEHICLE DECELERATION FROM 70 km/hour [Hayashida et al.]

Dual Brake Energy Recovery System with Battery and Capacitor Evaluated [Hayashida et al.]: Researchers at Traffic Safety Nuisance Research Institute in Tokyo tested the effect of using a capacitor-type battery in addition to a conventional storage battery on the brake energy recovery capability of an EV. When a vehicle decelerates rapidly, brake power exceeds charging power of a conventional battery. The idea is to use a capacitor and a battery alternately depending on vehicle deceleration conditions so that the recovery rate of brake energy may be increased. Hence, the vehicle has a dual brake energy recovery system. Investigation of this dual brake energy recovery system, however, indicated low efficiency of output energy from the capacitor. Internal resistance of the capacitor was high, causing the discharge current to become significantly high. Thus, the output energy was not as high as expected, although the energy recovery was improved. Therefore, the internal resistance needs to be reduced to achieve low internal loss of the capacitor.