ABSTRACT

Most vehicles run at part load conditions. Spark-ignition (SI) engine uses a throttle for load control, and the partial throttle openings achieve the part-load condition. There is a power loss during the gas exchange process in the SI engine known as pumping loss. Pumping loss is severe during the SI engine's part-load condition due to throttle presence in the intake manifold. The brake specific fuel consumption (BSFC) may increase to 20% at low engine speed and load conditions due to the pumping losses. The part-load efficiency of an SI engine can be improved by removing the throttle, and the engine load is controlled by varying the intake valve events (lifts, timings, and duration). The cam operated valve actuation system controls the valve events. The valve events are fixed in terms of the crank angle. Hence, in this study, a throttle-less SI engine was developed, and the engine load was controlled by a fully-flexible variable valve actuation (VVA) system. An electro-pneumatic fully-flexible VVA system was designed and developed to control the valve events independently. The challenging task in an electro-pneumatic VVA system is to control the valve seating velocity towards the end of the backward stroke when the valve comes in contact with the valve seat. In the initial trial, different valve lifts were achieved successfully without controlling the seating velocity. However, during the forward and backward strokes, the valve seating velocity increased sharply and reached a peak of 1.28 m/s. Thus, a novel approach was proposed, and pneumatic damping was introduced towards the end of the strokes to control the valve seating velocity. The valve seating velocity decreased from 1.28 to 0.38 m/s with pneumatic damping. The VVA system can also play a significant role in the performance improvements of a gasoline direct injection (GDI) engine. A computational fluid dynamics analysis was performed to upgrade an existing port fuel injection (PFI) engine to the GDI engine. The GDI injector location was optimized in the cylinder head based on the air-fuel homogeneity index throughout the combustion chamber. A single-cylinder four-stroke conventional PFI SI research engine was modified into the camless engine. The in-house developed electro-pneumatic VVA system was integrated with the intake valve. The intake valve events were controlled independently by the VVA system. The GDI components were integrated with the PFI camless engine to modify into GDI camless engine. Thus, the developed engine can be operated into different modes, such as PFI conventional, PFI camless, and GDI camless.

The effect of intake valve opening and closing timings on performance, combustion, and emissions were investigated in the PFI camless engine during the throttled operation. The pumping loss was reduced when the intake valve was opened too early before the top dead center (TDC), and gas exchange efficiency was increased. It is due to the recirculation of high-pressure exhaust gas into the intake manifold. However, pumping loss was increased when the intake valve was opened too late after TDC. It is due to the work done by the piston against the pressure depression in the combustion chamber. At late intake valve closings, the pumping loss was decreased, and gas exchange efficiency was increased due to the backflow of high-pressure charge from the combustion chamber into the intake manifold. The performance, combustion, and the emission of a throttle-less PFI and GDI camless engine were investigated with early intake valve closing and low lift condition. The results were compared with the throttled operation of the PFI conventional engine. A significant BSFC reduction (maximum 11.2%) was achieved at low engine speed and low load conditions for the PFI camless engine compared to the PFI conventional engine. It is due to the decrease in the pressure difference between the intake manifold and the combustion chamber. Hence, pumping loss is reduced, and the net power output of the engine is increased. A further BSFC reduction (maximum 2.1%) was achieved by the GDI camless engine over the PFI camless engine. The high-pressure fuel injection improves the fuel evaporation rate, which increased the net power output of the GDI camless engine.