Pneumatic Hybrid Drive Concepts

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Abstract: Nowadays the environmental protection is getting more important. The EU’s policy of environmental protection controls the emission of internal combustion engines by laws. In order to meet the requirements, the car manufacturers design more efficient engines and apply installations utilizing the waste of energy. Energy recovery systems ERSs for automotive applications are defined as the techniques to recover the energy of the vehicle that otherwise would have been wasted. ERSs is commonly an electric device requiring battery. The development of (ERSs) is aimed at mechanic or hydraulic operation methods without the need of surplus battery. In this paper we clarify the basic principal of the (ERSs) based on compressed air.

Keywords: Energy recovery system (ERS); Kinetic energy recovery system (KERS); Internal combustion engine (ICE); Waste-energy recycling; Hybrid pneumatic engine;

1. INTRODUCTION

Energy recovery systems (ERSs) for automotive applications are defined as the techniques to recover the energy of the vehicle that otherwise would have been wasted. The recovered energy can be stored and then used when necessary, reducing the need for further energy source or fuel, and therefore improving the overall efficiency of the vehicle. ERSs may be applied in a vast range of technologies within powertrains for automotive industry. [1] In an Internal Combustion Engine (ICEs) the chemical energy from gasoline can be transformed into mechanical energy. Although the (ICEs) can generate and release power, in real operations the engine needs to be accelerated or decelerated to cope with the demands of variable speeds and road conditions. As a result, the engine cannot be maintained in an optimum running condition, thereby causing an incomplete combustion of mixed gas and generating toxic exhaust-emissions of CO and HC resulting air pollution and a waste of energy. [2] It is only ERSs that potentially offer short and medium term solutions to the problem of vehicle growth by the piece and the associated emissions.[1]

ERSs are currently found in some vehicle models, regardless of the type of powertrain.Manufacturers such as BMW [3], Toyota [5], Renault [4], Nissan[6] already integrated ERSs in their internal combustion engine vehicles (ICEVs) [1].

In the present review article, ERSs are firstly classified according to the source of energy to be recovered: (i) energy from exhaust gases, (ii) energy from vertical oscillations of the body and (iii) energy from vehicle inertia as shown in Fig. 1. Following the first classification, the techniques are further sub-classified according to type of energy recovered, storage and technology. [1]

This article deals only with two types of technology:

1.1 Thermal energy recovery systems (TERs)

In (ICEs )about 70–80% of the energy from the combustion of the fuel cannot be converted to mechanical energy, instead being directed to other parts of the engine in the form of heat or emitted as exhaust.[2] TERs recover a part of this heat so the energy can be stored and reused. In TERs, the energy recovery may be achieved by two technologies using (i) thermoelectric generator and (ii) Rankine cycle.[1]

1.2 Energy recovery from vehicle inertia

The most common source of energy recovery is the inertia of the vehicle due to its speed. When deceleration is needed, a force has to be applied to overcome the inertia of the vehicle. This is normally done by the braking system, which reduces the speed of the vehicle by converting part of its KE into waste heat in the brakes. However, a fraction of that KE can be recuperated and stored. This stored energy may be used again, normally under acceleration, thus reducing high demands on the engine and consequently lowering fuel consumption. ERSs based on vehicle inertia are termed as kinetic energy recovery systems (KERSs). As these systems recover the energy mainly during braking events, the process of energy recovery is termed regenerative braking (RB).[1]

2. PNEUMATIC HYBRID SYSTEMS

In 1999, Schechter [7] proposed the idea of an air hybrid engine for the first time. The idea evolved from the notion that the internal combustion engine can be run as a compressor and an air motor by changing the valve timings. [8] And then there have newer ideas, concepts. In this article, four promising concepts will be presented and compared.

2.1 Concept 1

The hybrid pneumatic power system is shown schematically in Fig. 2. As compared with the hybrid power engine currently available, the biggest difference of the system lies in that pneumatic motor replaces the electric motor. Rather than the combination of a gasoline engine and an air compressor, this invention has adopted an internal-combustion engine to match the air compressor, thereby compressing the air into an air cylinder for the regulation of the pressure and the storage of energy. Then, the compressed air will flow through a
Throttle valve, regulate the airflow and activate the pneumatic motor to generate the power according to the opening angle of the throttle valve. Next, the compressed air will flow through a cylinder manifold, where the compressed air will mix with the high-temperature waste gas of the internal-combustion engine, with the aim of absorbing waste heat from the internal-combustion engine. This system will not only improve efficiently the thermal efficiency of engine by recycling its waste heat, but also reduce the exhaust emissions of engine. [9]

The waste energy can be recycled and utilized to decrease the pollution and fuel consumption. All these are what the “green” engine desires. In this system, the air compressor would exert a stable load on the internal-combustion engine after it is ignited. This enables the engine to work in an optimized state of low fuel-consumption and low pollution. [10]

The exhaust gas of the internal-combustion engine can be merged with the compressed air to increase the pressure and temperature, and eventually lead to a higher work output, which can be converted into effective mechanical energy and enhance the thermal efficiency of the internal-combustion engine. [10]

This system features good scalability. Flywheel energy-storing devices and braking energy recycling devices can be installed to offset the shortcomings of low energy density to enhance the overall efficiencies of the systems. [10]
2.2 Concept 2

In this conception, four-stroke IC engine was used. By modifying the engine design, the four-stroke IC engine was modified to a two-stroke air engine and a special valve control was used. [11]

Conventional IC engines use the cam mechanism for driving the outlet valve and controlling the timing sequence of the air flowing in and out of the engine. The cam structure controls the intake and exhaust valves on the basis of a sinusoidal kinematic relation; the valves complete each cycle by opening and closing gradually, a disadvantage because this slow valve response substantially reduces the engine output power. Therefore, a new rotary intake and exhaust system was designed to replace the cam-based valve control mechanism. In the rotary design, the intake and exhaust valves open and close instantly when the cylinder block channel is connected to the intake and exhaust channel (Fig. 3). This system controls the intake and exhaust timing sequences by adjusting the relative angles of the intake and exhaust binary blocks, thus yielding the optimal output power curve. Additionally, the intake valve closing and sealing in a conventional cam system is controlled by the pre-tension of the spring. When the intake engine operates at a high intake pressure, this spring tension is insufficient, resulting in air leakage at the inlet valve. By contrast, the rotary intake and exhaust system operates at high inlet pressures without air leakage.[11]

The rotary system overcomes the problem of leakage associated with high supply pressures. As a result of the new Rotary intake and exhaust system maximal output power can be increased. [11]

2.3 Concept 3

The double-tank regenerative system is comprised of two storage tanks, one small in size, low pressure tank (LP) and one high pressure tank (HP), as shown in Fig. 4. Based on this figure, the four steps of a cycle are defined as follows: [8]

Step 1: In this step, the intake valve opens and the cylinder is filled with atmospheric pressure. [8]

Step 2: While the piston is still in the vicinity of the BDC, the intake valve closes and the charging valve between the low pressure tank and the cylinder opens and, consequently, the cylinder is charged with the pressurized air from the LP tank. Thus, the cylinder pressure increases to higher than atmospheric pressure. The charging valve closes after the cylinder pressure equals the LP tank pressure to avoid sending the pressurized air back to the LP tank. [8]

Step 3: In this step, gas in the cylinder is compressed adiabatically and the charging valve between the cylinder and high pressure tank opens allowing the HP tank to be charged adiabatically. It closes when the piston is in the vicinity of the TDC. [8]

Step 4: While the piston is still in the vicinity of the TDC and the pressure in the cylinder is still high enough, the charging valve between the cylinder and low pressure tank opens to charge the LP tank with the remaining of the pressurized air in the cylinder. The charging valve closes when the piston starts going down and the cylinder pressure starts to drop. [8]

The proposed compression strategy [8]

The proposed compression algorithm can be utilized in an air hybrid vehicle to increase the efficiency of energy recovery by the compression braking system. Compared to the double-stage regenerative braking, the double-tank system doubles the air flow rate because only one cylinder is needed to implement the proposed concept and thus, all the cylinders can be connected directly to the main tank. The proposed compression algorithm can be applied not only in air hybrid vehicle compression braking system, but also in any other applications, where higher pressure with higher air mass flow rate is demanded such as typical reciprocating compressors. Double-tank compressors are expected to have the same working pressure and outlet flow rate as double-stage compressors, but with a weight of almost half of a double-stage one. [8]2.4 Concept 4

The concept allows recuperating some of the energy that is otherwise lost when braking and the elimination of the most inefficient engine operating point is possible. Moreover, it is an ideally complements for a downsized or supercharged engine. Since the air is provided to the cylinder by a fully variable charge valve, the torque can be raised from idling to full load, from one engine cycle to the next i.e. in the shortest possible time. The hardware configuration necessary for a directly connected HPE includes an additional valve in the cylinder head, which is connected to the pressure...
REFERENCES


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