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A REVIEW ON SIX STROKE, HIGH EFFICIENCY QUASITURBINE ENGINE

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ABSTRACT

One of the most difficult challenges in engine technology today is the urgent need to increase engine thermal efficiency. This paper presents a Quasiturbine thermal management strategy in the development of High-efficiency engines for the 21st century. In the concept engine, high-octane fuels are preferred because higher engine efficiencies can be attained with these fuels. Higher efficiencies mean less fuel consumption and lower atmospheric emissions per unit of work produced by the engine. While the concept Engine only takes a step closer to the efficiency principles of Beau de Rochas (Otto), it is readily feasible and Constitutes the most efficient alternative to the ideal efficiencies awaiting the development of the Quasiturbine photo-detonation engine, in which compression pressure and rapidity of ignition are maximized.

I. INTRODUCTION

In 1862, Alphonse Beau de Rochas published his theory regarding the ideal operating cycle of the internal combustion engine. He stated that the conditions necessary for maximum efficiency were: (1) maximum cylinder volume with minimum cooling surface; (2) maximum rapidity of expansion; (3) maximum pressure of the ignited charge and (4) maximum ratio of expansion. Beau de Rochas' engine theory was first applied by Nikolaus Otto in 1876 to a four-stroke engine of Otto's own design. The four-stroke combustion cycle later became known as the "Otto cycle ". In the Otto cycle, the piston descends on the intake stroke, during which the inlet valve held in open. The valves in the cylinder head are usually of the poppet type. The fresh fuel/air charge is inducted into the cylinder by the partial vacuum created by the descent of the piston. The piston then ascends on the compression stroke with both valves closed and the charge is ignited by an electric spark as the end of the stroke is approached. The power stroke follows, with both valves still closed and gas pressure acting on piston crown because of expansion of the brunt charge. The exhaust stroke then completes the cycle with the ascending piston forcing the spent products of combustion past the open exhaust valve. The cycle then repeats itself. Each Otto cycle thereby requires four strokes of piston intake, compression, power and exhaust and two revolution of crank shaft [1]. The disadvantage of four stroke cycle is that only half as many power stroke are completed per revolution of the crankshaft as in the two stroke cycle and only half as much power would be expected from an engine of given size at given operating speed. The four-stroke cycle, however, provides more positive scavenging and charging of the cylinders with less loss of fresh charge to the exhaust then the two stroke cycle. Modern Otto cycle engine, such as the standard gasoline engine, deviate from the Beau de Rochas principles is many respects, based in large part upon practical consideration related to engine materials and the low-octane fuel used by the engine. The six stroke Quasiturbine concept engine described in this monograph is designed to overcome many of the limitations inherent in the Otto cycle and bring the engine's operating cycle closer to beau de Rochas ideal efficiency conditions. The preferred fuel for the concept engine is methanol because of its high octane rating and its ability to cool the fuel/air charge during the intake stroke.

II. CONDITIONS FOR MAXIMUM EFFICIENCY

Maximum volume/minimum cooling surface:

The first Beau de Rochas principle teaches that the engine should have a minimum cooling surface area while still allowing for maximum charge volume during intake ("volumetric charge efficiency"). Otto cycle engines generally have cooling systems. The cooling system represents an engineering compromise.

Maximum rapidity of expansion:

Rapidity of expansion in a spark-ignition engine can be achieved by increasing the engines compression ratio. A higher compression ratio brings the fuel and oxygen molecules in closer proximity during ignition and facilitates rapid expansion. In order to increase engines compression ratio, a high octane fuel is used. A higher octane fuel is a fuel that has high auto ignition temperature (470C/740k) in air [2]. Because of fuel/air mixture is heated during the engines compression stroke (especially in the thermally insulated compressor cylinder of the concept engine), it is critical to avoid premature ignition or knock during that stroke. With high octane fuels, such as methanol, premature ignition can be prevented while still increasing the engines compression ratio.

Maximum pressure of the ignited charge:

The pressure of the ignited charge is subject to several conditions: the compression pressure of fuel/air charge prior to ignition, the ratio of fuel to air in the charge itself and temperature of the combusted gases after ignition. While ideal, maximum pressure cannot be achieved in the concept engine, the concept engine does improve on Otto Cycle engine by eliminating the cooling system and by allowing high compression pressures with high-octane fuels. The Otto cycle cooling system reduces pressure both during the expansion stroke. By using thermal insulation for both the compression function and for the expansion function and by using a near stoichiometric ratio of high-octane fuel/air, the concept engine takes significant step closer to Beau de Rachas ideal cycle efficiency.

Maximum expansion:

The fourth Beau de Rachas efficiency principle teaches that the expansion volume of the combusted fuel/air charge should be maximized.

In Otto cycle engines, the compression volume and the expansion volume are equal because the cylinder volume swept by the piston is the same for both the compression stroke and for the power stroke. For maximum efficiency, the expansion volume should always exceed the compression volume. The constant-volume Atkinson cycle has the characteristic.

IV. CONSTRUCTION & WORKING

Engine components:

There are four principal engines components necessary to perform the engines three functions. The first component is a thermally-insulated, piston-type air compressor the air compressor shares a common shaft (or is linked by a belt drive) with the Quasiturbine expander. The expander provides the necessary power for compression work. The second component is Holzwarth combustion chamber, which is described in more detail below. The third component is Quasiturbine expander, which is also comprised of thermally insulating material. The fourth component is compressed fuel/air line, which delivers the fuel/air charge under pressure to the combustion chambers. The engine is a six stroke engine. The six strokes occur during each 90 degrees of shaft rotation. The six strokes are: one intake stroke, one compression stroke, two power strokes and two exhaust strokes. A special linkage, not unlike the Atkinson engine linkage, allows the compressor to complete eight strokes (four intake strokes and four compression strokes) during each360 degrees of shaft rotation, which results in one complete compression cycle over each 90 degrees.

There are eight strokes per each 360 degrees of Quasiturbine revolution as compared to one power stroke per two revolutions of the Otto cycle engine. Each of the engine components and operation are described in more detail in the following sections.

Piston-type compressor:

The concept engine is a thermally-insulated, positive-displacement, piston-type compressor. The piston crown is a “pancake” or “flat aspect” crown. The compressor shares a common shaft with the Quasiturbine expander. See, figure1. The maximum temperature in compressor is limited by the temperature tolerance of the oil free piston ring lubricant and by the auto ignition temperature of the fuel. The compressor temperature, however, can be moderated by port injection of a liquid with a high latent heat of vaporization. The liquid in this case is the methanol fuel itself. The operation of the compressor must be considered over 90 degrees of shaft rotation, which represents one complete compression cycle.

Compressed fuel/air line

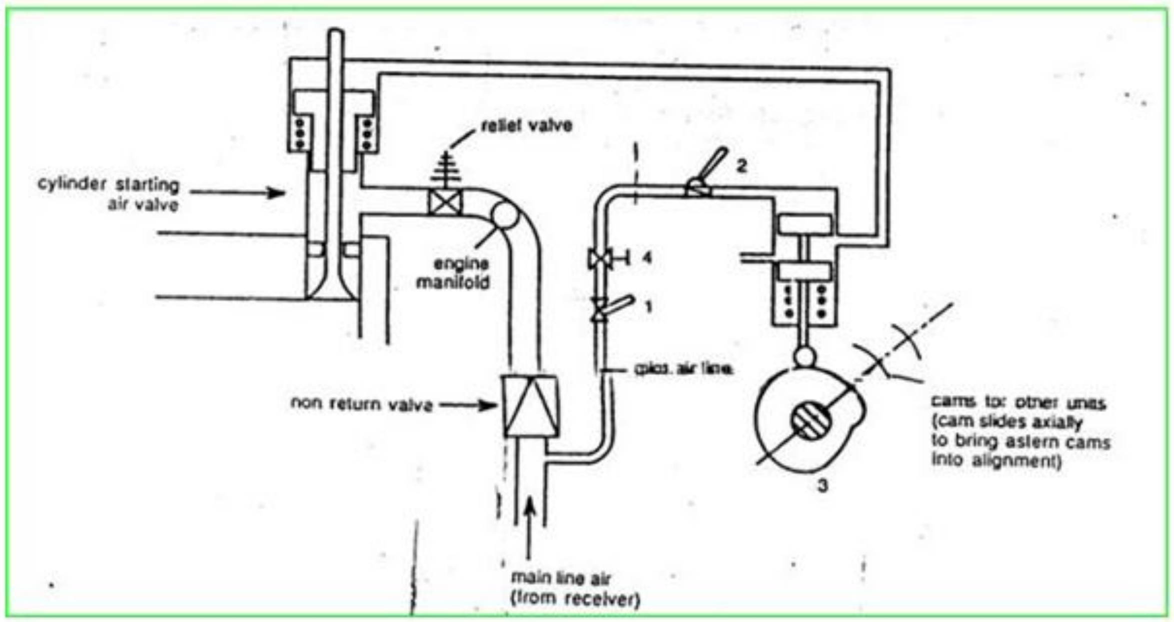

Fig 1- compressed fuel/air line.

The compressed fuel/air line interconnects the compressor with the combustion chambers of the concept engine. The compressed fuel/air line is thermally insulated. At one end of the compressed fuel/air line, there is a connection with the compressors outlet port. The compressed fuel/air charge enters the line at that point. See, figure1. At the other end of the compressed fuel/air line, the line splits into four separate “feeder” lines. Each feeder line connects with the compressed fuel/air inlet valve of one of the four combustion chambers [2, 3]. The purpose of the compressed fuel/air is to convey the compressed fuel/air charge from the compressor to the combustion chambers with a minimum of heat and pressure loss.

Holzwarth combustion chambers:

There are a total of four combustion chambers in the concept engine design. Each combustion chamber has two valves: a compressed fuel/Air inlet valve and a combusted gas outlet valve. The fuel/air charge is ignited by spark.

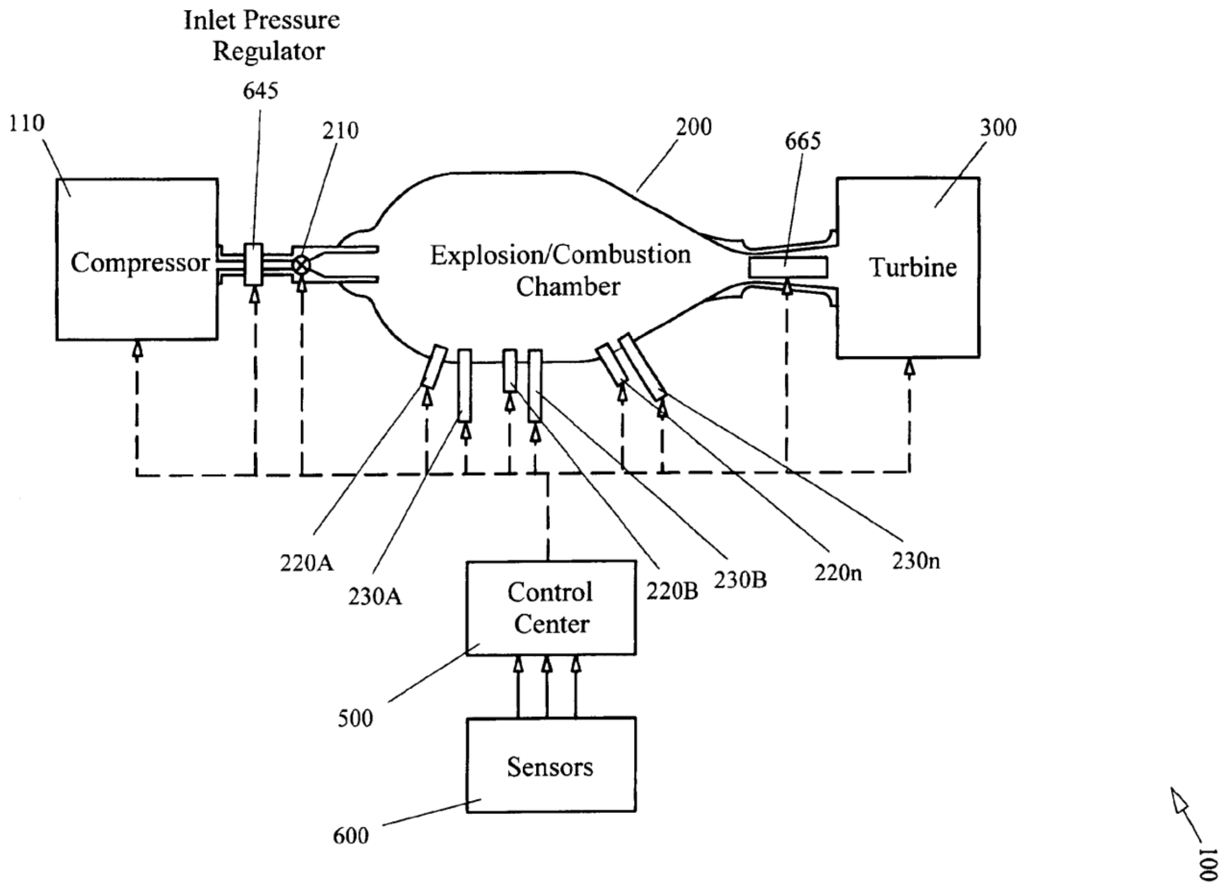

Fig 2 – Holzwarth combustion camber

The combination chamber are "Holzwarth -type” combustion chambers. In the concept engine, the fuel/air charge is first compressed in the compressor. The compressor's outlet valve opens when the pressure in the cylinder exceeds the pressure in the compressed fuel/air line. Simultaneously, the compressed fuel/air inlet valve of two of the combustion chamber open. The fresh compressed fuel/air charge is delivered to the two combustion chambers through the compressed fuel/air line. The pressure equalizes and the fresh fuel/air charge is thereby delivered to the combustion chambers. The compressor outlet valve and the combustion chambers inlet valve close at about 46°of the shaft's rotation. The two combustion chambers are thereby fully charged and ready for ignition.

The charges in the two combination chambers are spark-ignited. As combustion is completed, the combusted gas outlet valve in each of the combustion chambers opens (at about 90° of the shaft's rotation) and the high-temperature, high-pressure combusted gases are delivered to two opposed Quasiturbine's expansion chamber. Thus, combustion chamber charging occurs during the first 45° of rotation and combination chamber discharge occurs at the end of 90° of rotation. The charge/discharge cycle matches the Quasiturbine's four-chamber rotation.

The pressure and temperature of the combusted gas remaining in the combustion chamber at the end of the discharge will be equal to the pressure and temperature of the combusted gases in expansion chamber at the end of Quasiturbine power stroke, discussed below. When the combusted gas outlet valves closes (at the end of the power stroke), some of the combusted gases will remain in the chamber. The remaining combusted gases will have an "exhausted gas recirculation" effect i.e., the combustion temperature of the next, first fuel/air charge will be lowered somewhat. However, the lower combustion temperature will serve to reduce NOx formation during the combustion event.

V. QUASITURBINE EXPANDER

The Quasiturbine is a static pressure expansion engine. See Figure3. It differs from an aerodynamic pressure expansion engine, like a gas turbine, in that the pressure of the combusted gases acts directly on the rotor segments rather than first having to be converted to kinetic energy in order to activate the rotary motion by turbine blades [4]. In essence, the Quasiturbine is a direct expansion engine.

QUASITURBINE QT75SC

Fig 3- Quasiturbine expander.

The Quasiturbine operates like an inflow engine in that the combustion/ expansion area of the engine occupies a different region of the stator than the cooler exhaust area. In conventional piston engines, the same cylinder head and cylinder walls are cooled due to engine exhaust and have to be reheated by combustion. The ceramic Quasiturbine engine can operate at higher thermodynamic efficiency since the temperature of the combustion/ expansion area of the engine remains hotter and has less temperature fluctuation during operation. These characteristics make the Quasiturbine the ideal expander for the constant-volume Atkinson cycle. Like other rotary engines, there are relatively few parts to the engine itself. The Quasiturbine consists of four rotor segments, two face plates, a stator and differential.

The present engine concept would not be as efficient with a conventional turbine as the expander because a conventional turbine cannot be adapted for the thermal retention strategies discussed below.

VI. METHANOL AND EFFICIENCY

Methanol is a high-octane fuel that can be derived from natural gas (currently the most common method), coal or biomass charcoal. With respect to the concept engine, methanol's primary application would be as vehicle fuel because it can be easily dispensed at a fuel station and can be stored in the vehicles fuel tank. Methanol's energy density is about half that of gasoline, i.e., about 55,000BTUs per gallon. Methanol's auto ignition temperature in air is 470C/740K. Because of methanol's high latent heat of vaporization (1100J/g), the compression ratio can be 12:1 without premature ignition even with thermal insulation. At a 12:1 compression ratio, the theoretical thermal efficiency of the Atkinson cycle is above 60%. Because heat has been absorbed by the methanol adiabatically prior to ignition, bringing the methanol close to its auto-ignition temperature, ignition lag, which is a second problem often associated with methanol in Otto cycle engines, may be eliminated in the concept engine [5].

In a recent EPA study, methanol was used in a high compression ratio, Otto cycle engine (19.5:1 ratio). Although the engine had a cooling system, efficiencies of 43% were reported. With heat retention strategies and operation in the efficient Atkinson cycle, it is believed that the six-stroke Quasiturbine should be capable of higher thermal efficiencies. It should be noted that, despite the concept engine's lower compression ratio, its expansion ratio can equal, Or exceed, 19.5: 1 because of the separation of the compression and expansion functions. The fourth Beau de Rochas principle teaches that maximum expansion is required for high engine thermal efficiencies. By increasing the efficiency of the engine, methanol lower energy density can be compensated for and the vehicle's fuel tank need not be much larger than a comparable gasoline-powered vehicle's tank.

VII. CONCLUSION

The concept engine is intended to follow Beau de Rochas principles with methanol as the preferred fuel. In the concept engine, high- octane fuels are preferred because higher engine efficiencies can be attained with these fuels. Higher efficiencies mean less fuel consumption and lower atmospheric emissions per unit of work produced by the engine.

Unfortunately, present engine technologies are primarily the result of the century-long development of the petroleum fueled, Otto cycle engine. These engines were designed for low-octane fuels and are not well suited to high efficiency operation with high octane fuels. The six-stroke Quasiturbine concept engine is an engine, which, by design, operates most efficiently with high-octane fuels like methanol.

By separating the engine functions, the concept Quasiturbine engine permits efficient utilization of methanol by:

- Maximizing volumetric charge efficiency through the latent heat of vaporization of the methanol, which, in turn, reduces the temperature of the fuel/air charge during intake.
- Minimizing the loss of compression heat by thermally insulating the compressor.

- Minimizing the negative work associated with compression by reducing the final compression temperature of the compressed fuel/air charge.
- Maximizing the rapidity of ignition by means of high charge compression ratio and by eliminating Of the ignition lag associated with methanol.
- Maximizing the engine pressure during the power stroke by means of thermally insulating expander materials and by means of the Quasiturbine unique “static pressure” expansion characteristics.
- Maximizing the volume of the power stroke by means of the Atkinson cycle, as adapted for the Concept engine
- Maximizing the power/weight and power/volume engine ratio by means of 8 power stroke per revolution in the Quasiturbine.

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