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Mini Review

Free-Piston Engine (FPE) Technology with Different Applications

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Introduction

The free-piston engine (FPE) is a linear engine in which the requirement for a crankshaft system is eliminated and the piston assembly has a free and linear motion[1]. First proposed around 1930, FPEs were in use in the period 1930-1960 as air compressors and gas generators and provided some advantages over present-time conventional combustion engines and gas turbine systems[2]. They are known to have a greater thermal efficiency (40-50%) than an equivalent and more conventional reciprocating engine (30-40%)[3]. A driving force behind the interest in free-piston engine generators is the automotive industry's increasing interest in hybrid-electric vehicle technology. Much work has been undertaken by number of research groups worldwide, including the authors' group, to explore the operation characteristics of FPEs[4,5].After initial investigations and development of free-piston related products during the early to mid-20th century, recent advances in control and real time actuation systems have enabled the technology to become a viable alternative to reciprocating technologies, and as such, research is now being carried out by number of groups worldwide [3,6-9]. Modern applications of the FPE concept have been proposed for the generation of electric and hydraulic power, typically in hybrid electric vehicles[10-15]. Known FPE applications include electric generators, hydraulic pumps and air compressors[2], which are summarised in the Table 1 below.

Table 1: FPE applications.

Load Type	Resisting Force Profile	Characteristics
Air compressor	Similar with that of a bounce chamber filled with gas during compression phase; Approximate to constant force when discharge valves open	Original FPE load devices; Stepped compressor pistons can be applied, giving a compact multi-stage compressor; Without supercharge, a large compressor cylinder is required, resulting in oversized configuration; Variable stroke may lead to poor volumetric efficiency of the air compressor
Electric generator	Proportional to the translator speed	Relatively compact in size; Generally high efficiency; Magnets or back iron in the mover may lead to high moving mass
Hydraulic pump	Approximate to constant due to the constant discharge pressure	Typically works against a high discharge pressure; Combined with the incompressible working fluid, this allows a small unit with very low moving mass; Generally high efficiency and high operational flexibility

For FPEs, the elimination of the crank mechanism significantly reduces the number of moving parts and therefore the complexity of the engine[16]. This gives a number of advantages: reduced frictional losses due to the mechanical simplicity and the elimination of the piston side force in crankshaft engines; reduced heat transfer losses and NOx generation due to faster power stroke expansion; potentially lower maintenance cost and higher reliability due to a compact and simple design; and multi-fuel/combustion mode possibility due to combustion optimization flexibility that resulted from the variable compression ratio [17].

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