An Overview of the Aerocam Engines NorEaster Power System

A Coaxial Counter-Rotating Power System for Small, Lightweight Rotary-Wing Aircraft

The traditional technology for helicopters and other vertical takeoff and landing (VTOL) aircraft, utilizes a rotor system consisting of a single large lifting rotor, and a smaller tail rotor to provide offsetting torque for the lifting rotor. Customarily, a turbine with a gear reduction and transmission system powers such helicopters, both for scaling turbine speed to rotor speed, and for driving the tail rotor. While such systems are functional for larger VTOL aircraft, their benefits diminish as aircraft size decreases, because the key aeronautical performance metrics of brake specific fuel consumption (BSFC) and power/weight ratio scale poorly with size. These metrics directly influence an air vehicle's ability to attain greater payload capacity, range, and/or performance. Internal combustion (IC) engines, which perform better at such smaller scales, typically still require a heavy transmission to allow the high engine speeds where peak horsepower is developed. Aerocam Engines has a novel alternative VTOL aircraft power system, called the "NorEaster" Power System (the NorEaster) that dispenses with these problems via an innovative variation of a radial aircraft engine featuring a simple cam-drive mechanism. This permits balanced, counter-rotating lifting rotors (eliminating the tail rotor), and provides superior power/weight ratios and BSFC for smaller VTOL aircraft, enabling economical and reliable 500-2000 lb.-class VTOL helicopters. The NorEaster satisfies a major need in this most important and unfilled market space. Very few power systems tailored to small, unmanned helicopter requirements are available in the marketplace. Aerocam Engines has a patented, unitized power system for light rotary-wing aircraft, in particular small, unmanned helicopters and drones that will be the smoothest and most efficient on the market. The NorEaster combines a fully mass-balanced internal combustion engine and transmission into an integrated, simple, quiet and lightweight package. By incorporating coaxial counter-rotation, it provides increased forward speed capability and eliminates the need for a tail rotor assembly (and its associated complexity). Employing a very high efficiency direct injection HCCI engine technology, it will be both gasoline and heavy-fuel powered. Small-scale proof-of-concept engines have been developed and tested, and the company is now getting ready to demonstrate a second-generation engine in more realistic operating conditions, and to scale power delivery demonstrations to meet customer needs.

Traditional Design: Failure Points and Problems

- Tail Rotor: Dangerous, vulnerable, adds weight, robs power, limits speed
- Transmissions: Unreliable, high manufacturing cost, high maintenance, complicated
- Turbine Engine: Not scalable, inefficient, high RPM, narrow output band

The NorEaster Design: Features, Functions, and Benefits

- Counter Rotation: Eliminates tail rotor, main rotors are shorter for safer flying, may employ a pusher prop for greater speed
- Speed Reduction: Saves weight of added gearbox, allows peak horsepower, adds reliability while reducing maintenance
- Force Balanced Design: Reduces stress on engine and airframe for maximum weight reduction and reliability
- Customizable Piston Path: Allows optimized power output while reducing fuel consumption, asymmetrical path gives cam synchronization as a by-product
- Cam Synchronization without Gearing: A patented feature that locks the cams in proper counter-rotation without the need for intermediate gearing
- Direct injection HCCI Engine: Operates without knock at very high compression ratios, allows any type fuel to be used, cooler, quieter exhaust compared to gas or diesel engines.

Technical Discussion

A conventional crankshaft-connecting rod engine, whether two or four cycle, has three basic moving parts per cylinder: crankshaft (crank), connecting rod (conrod), and piston. The conrod introduces a strong second harmonic (and smaller fourth, sixth, and other even harmonics) into all the inertial functions: force, torque, and moment. These harmonics can cause vibration in engines with small numbers of cylinders or odd cylinder configurations. The transverse component of wrist-pin force introduces side force on the piston skirt against the cylinder wall due to the conrod's angularity, which can cause increased friction and wear. The NorEaster cam engine has only two basic moving parts per cylinder: cam and piston-rod assembly. The piston-rod assembly is in pure translation, thus it introduces no additional harmonics, and it also adds no transverse force between piston and cylinder. If the cam function used is simple harmonic motion, then there will be only a primary harmonic component in all the inertial functions. They will be pure sinusoids. With properly arranged (opposed) pistons in a multi-cylinder arrangement, this results in zero inertial shaking force and torque. If the pistons are all coplanar, as is true in the NorEaster engine, then there is also zero inertial shaking moment. In either engine, there will still be higher harmonics of the gas force and gas torque functions. However, the NorEaster is capable of perfect harmonic balance of all moving components.

A major advantage of the NorEaster cam arrangement is its allowance of simultaneous counter-rotating output. Pairs of rollers on either side of each piston rod drive two concentric cams on concentric shafts such that the downward motion of the piston drives one cam clockwise and the other counter clockwise.

Having multiple lobes on the cam is another advantage, giving an inherent gear reduction ratio between piston speed and output shaft rotational speed. The power system is essentially an integrated power source and speed reduction unit that does not need an external gearbox. For example, with a four-lobe cam, piston speed will be four times that of the output shafts. This feature is particularly well suited to the requirements of a slow-turning helicopter rotor and the need for pistons to travel at higher speeds for power generation. With a four-lobe cam driving rotors at 1000 rpm, the pistons will be operating at an effective 4000 rpm, thus being in a better range for thermodynamic efficiency and power output. A crank engine has piston displacement, velocity, and acceleration functions that are completely defined by its bore, stroke, and conrod length. The NorEaster cam engine, on the other hand, can tailor these piston functions with variation in the cam profile. The simplest arrangement is a symmetrical, simple-harmonic-motion rise and fall. This mimics a Scotch-yoke mechanism, which is, in effect, a crank engine with an infinitely long conrod. These both have pure harmonic motion with no higher harmonics. If desired, the NorEaster piston motion can be made asymmetric (i.e., a piston's downward velocity can be slower than it's upward velocity) and can be tailored to take maximum advantage of minimum-volume combustion, dynamics of the intake or exhaust systems, or other desired parameters. The velocity profile of the piston on either the up or down stroke can be varied within broad limits using sophisticated motion functions.

A byproduct of this asymmetric piston motion is that it locks the two cams together in proper counter-rotation without the need for intermediate gearing, thus reducing housing size, weight, drag, and cost. Aerocam Engines holds three patents on this important development.

TECHNICAL BACKGROUND

Current UAVs typically do not have high payload capacity. Those that are VTOL tend to be small and unable to lift large loads. Conventional helicopters have high payload capacity but must be manned. The power systems on turbine powered helicopters are not well suited to small airframes. They are typically powered by heavy fuel turbines that turn at high speed (20,000 to 30,000 rpm) and require large heavy transmissions to reduce that speed to the hundreds of rpm required at the rotor. There is a significant size and payload gap between the small, electric motor powered, quadcopter drone, and the smallest commercial, turbine-powered helicopter. Smaller IC engine powered helicopters have payload capacities from 200–950 pounds but require a pilot.

Aerocam Engines has a patented, built, and tested novel compact internal combustion engine/ transmission system for application to VTOL UAVs in the size gap described above. Several prototype engines have been built and successfully run. The "NorEaster" power system provides coaxial counter-rotation on concentric shafts using pistons and cylinders mounted in a radial configuration on a “cam case” that replaces the crankcase of a conventional internal combustion engine. Inside the cam case are two multi-lobed cams that turn in opposite directions when piston force imparts motion to the cam followers. The cylinder arrangement and lack of oscillating connecting rods creates an engine that is completely balanced.

The two rotors are driven in opposite directions at a speed that is a fraction of the effective speed of the pistons. That fraction is 1 over the number of cam lobes. As an example, with four-lobe cams and a rotor speed of 1000 rpm, the piston velocities are the same as if they were connected to a crankshaft turning 4000 rpm. This, in effect, provides an automatic low-friction reduction in output speed without any gearing. It also puts the rotor at its optimum speed while simultaneously running the piston in its best power range.

The NorEaster engine can be configured with two, four, six, or eight cylinders in a single plane. Only gasoline prototypes have so far been built and run.