Rotapower Engine Competitive Advantages

COMPETITIVE ADVANTAGES

The Rotapower® rotary engine combines the attributes of both the two and four-stroke piston engines in a low cost design, solving the problems of fuel consumption and emissions that have limited the use of rotary engines. Historically, the charged cooled rotor rotary engine had a low cost but unimpressive fuel consumption and emissions (OMC and Fichtel-Sachs approach) or high cost with acceptable fuel consumption and emissions (Curtiss-Wright, John Deere, and RPI approach). Mazda rotary engines operated between these two extremes without a clearly defined set of attributes. The Rotapower® engine has retained the simple low cost approach of the original OMC design and, through patented and proprietary technology, has been able to lower fuel consumption and emissions and extend life by an order of magnitude.

In the automotive market, previous rotary engines (Mazda and NSU) have had somewhat poorer fuel consumption than four-stroke piston competitors. Despite their lower weight, emissions, and cost, this limitation caused the automotive companies to be unwilling to re-tool their engine and chassis plants to use these engines. In addition, the existing emissions from recreational and small commercial engines were not a major concern. The following developments now make the Rotapower® engine a highly competitive alternative powerplant.

- The Company's patented rotor cooling and porting arrangement has reduced both emissions and fuel consumption while also lengthening engine life by lowering thermal stresses within the engine. This technology together with lower internal energy losses by using roller bearings and charge rotor cooling has made the Rotapower® engine's fuel consumption competitive with the four-stroke piston engine.
- Pollution is now becoming such a dominant issue that two-stroke engines are disappearing completely worldwide while four-stroke piston engines must significantly reduce their exhaust emissions.
- The low levels of CO, HC, and low NOx emissions from the Rotapower® engine makes it possible to require minimum after treatment of the exhaust.

COMPARISON WITH A TWO-STROKE ENGINE

Recent advances have potentially improved the fuel consumption and emissions characteristics of two-stroke engines by utilizing a sophisticated fuel injection system. Those systems are expensive, offsetting the cost advantage the two-stroke has historically enjoyed (estimated by CARB responses to add at least 35% to engine cost). The two-stroke will remain handicapped by high vibration, high fuel consumption, noise, and emissions. The only Wankel rotary type engine of a similar design to the Rotapower® engine that was put into volume production, was the OMC rotary. A major design goal in the OMC development was to be cost-competitive with the two-stroke engine it was designed to replace. OMC achieved this goal with their rotary engine which proved to be far more reliable than the two-stroke engine it replaced.

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The Rotapower® engine equivalent of a two-stroke engine:

- Produces more power for a given weight and size:
- Two-stroke engines are capable of producing approximately one horsepower per pound of engine weight while the Rotapower® engine has produced over two horsepower per pound of engine weight.
- Produces much lower emissions:
- In recent tests observed by CARB, the Rotapower® engine produced 3 g/hp-hr of combined HC and NOx emissions. This compares with over 300 g/hp-hr for carbureted two-stroke engines and 40 g/hp-hr for direct injected two-strokes. While the Rotapower produced negligible amounts of particulates, the direct injected two-stroke produced large quantities of carcinogenic particulates. Measured CO emissions from the Rotapower engine were .07% of those from the two-stroke engine.
- Is free from vibration:
- The Rotapower® engine has only rotary motion (like the turbine engine) and, with perfect balance, is free from vibration.
- Has better fuel economy:
  The best commercial two-stroke engines achieve a specific fuel consumption of .6 lb/hp-hr. Tests to date have shown the Rotapower® engine using less than .45 lbs./hp-hr.
- Is quieter:
  Two-stroke engines cannot tolerate much exhaust back-pressure, hence muffling these engines is difficult without a very large muffler. The Rotapower® engine uses the four-stroke cycle, which is more tolerant of exhaust back-pressure.
- Is more reliable:
  Two-stroke engines use roller bearings, as does the Rotapower® engine. However, in the two-stroke engine very large reversing stresses are induced as a result of the reciprocating motion. Roller bearings do not tolerate reversing motion and the associated stress well.

COMPARISON WITH A FOUR-STROKE PISTON ENGINE

There has been little innovation in this category in the last 30 years. The only trend is a gradual switch from gasoline to diesel engines. Existing gasoline commercial engines are heavy relative to the power they generate. These engines are also rated for relatively low speeds. The most efficient way to gain power-to-weight advantage is by operating at higher speeds, but those conditions cause vibration and durability problems for reciprocating engines since balancing is very difficult, especially if they have four or fewer cylinders.
The Rotapower® engine is uninhibited by valves, has no reciprocating parts, and its rotor rotates at one-third of the output shaft RPM, so it thrives on higher speeds without sacrificing durability or smoothness. It is therefore particularly effective in applications where portability or compact size is important.

The Rotapower® engine equivalent of a four-stroke piston engine:

- Produces much more power for a given weight and size:

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Very few four-stroke piston engines can produce more than one-half horsepower per pound versus over two horsepower per pound of engine weight for the Rotapower® engine.

- Produces lower emissions:
  Under contract from CARB, Southwest Research Institute tested emissions produced by small four-stroke piston engines. These results were compared with emissions from the Rotapower® engine as observed by CARB and the Institute of Transportation Studies (ITS) in University of California, Davis. In this comparison the Rotapower engine produced .6% as much HC, .08% as much CO, and 9.7% as much NOx as the small four-stroke piston engines tested by SRI.
- Is cheaper to produce:
  Four stroke piston engines cost 25 to 30% more than simple two-stroke engines. OMC produced their four-stroke rotary engine, on which the Rotapower® engine is based, for the same cost as their two-stroke engines. OMC stated that, had they produced their rotary engine in similar volumes to their two-stroke engines, the cost would have been even lower.
- Is free from vibration:
  The Rotapower® engine has pure rotary motion and therefore free of vibration.
- Has similar or better fuel consumption:
  In order to preserve the exhaust valve life, small four-stroke piston engines use a rich fuel-air mixture running typically at close to .6 lb/hp-hr. The Rotapower® engine's freedom from valves allows it to run well at very lean mixtures, which in addition to lower fuel consumption, also helps lower emissions.
- Is more reliable:
  With only a very small percentage of the moving parts of a four-stroke piston engine and only rotary motion, the Rotapower® engine is inherently more reliable. Wankel rotary engines produced in the late 1960's by Ingersoll-Rand have accumulated over 34,000 working hours without an overhaul. Many OMC rotary engines operated for well over 2000 hours without an overhaul. The Rotapower® engine uses higher quality seals and bearings than the OMC engine and has been able to demonstrate a seal life of over 10,000 hours.

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