The Thermal Efficiency of Wankel and Inline Piston Engines

Claim

The thermal efficiency of all car engines is the same

# Rationale

The investigation began with the claim that The thermal efficiency of all car engines is the same The thermal efficiency of an engine is defined by the equation Where is the thermal efficiency of the engine is the work performed by the engine and is the heat produced by the engine The bestselling smallcar in Australia in was the Hyundai i which can be bought with a turbocharged inline four engine Recently Mazda announced the release of a hybrid petrolelectric car which utilises a Wankel rotary engine as a gas to rangeextender Both piston engines and Wankel rotary engines are fourstroke engines based around the Otto cycle The Otto cycle is a theoretical thermodynamic cycle that consists of four stages intake compression power and exhaust During the intake stage a mixture of fuel and air are drawn into the engine In the compression stage the airfuel mixture is compressed which raises its temperature and pressure before it is ignited in the power stage rapidly increasing the pressure in the engine which does mechanical work on the piston or rotor In the final stage the exhaust gases are expelled from the engine Since and the discontinuation of the Mazda RX the Wankel engine has not been used in a car due to its lower fuelefficiency than traditional piston engines Mazda’ decision to reintroduce it suggests that the Wankel engine is more fuel efficient than an equivalent piston engine If a piston engine with similar specifications to a Wankel engine is established to have a higher thermal efficiency than the Wankel engine it would disprove the claim The latest Wankel engine used in a car is the RENESIS BMSP which has a displacement of A similar displacement cylinder inline piston engine is the Honda B which has a displacement of Thus the research question was determined as “To what extent is the RENESIS BMSP Wankel rotary engine more thermally efficient than the Honda B fourcylinder inline piston engine ”

# Research Question

# “To what extent is the RENESIS BMSP Wankel rotary engine more thermally efficient than the Honda B fourcylinder inline piston engine ” Bibliography

# Sources

The following sources were used in the investigation

# Analysis and Interpretation

Argument

Figure Theoretical Thermal Efficiency vs Compression Ratio

The B cylinder inline piston engine has a greater theoretical thermal efficiency than the BMSP Wankel Rotary Engine Connor investigated the thermal efficiency of the Otto cycle He concluded that the theoretical thermal efficiency of an engine that utilises the Otto cycle is determined by the equation where is the compression ratio of the engine and is where is the specific heat capacity of the air at a constant pressure and is the specific heat capacity of the air at a constant volume The equation was graphed with The graph depicts an exponential relationship between the compression ratio of a car’ engine and its theoretical thermal efficiency However the graph is limited because it does not consider empirical thermal efficiency which could be significantly different than the theoretical thermal efficiency due to friction impurities in fuel and an improper airtofuel ratio The compression ratios of the BMSP and the B were plotted on the curve produced The B has a compression ratio r higher than the BMSP which results in a increase in theoretical thermal efficiency This occurs because the higher compression ratio results in combustion temperatures being achieved with less fuel making the engine more thermally efficient because the same amount of work is done with a lower energy input Therefore the BMSP theoretically has a lower thermal efficiency than the B due to its reduced compression ratio

Argument

Evidence

Figure A Brake Specific Fuel Consumption Map of the Honda B

The B has a minimum brake specific consumption BSFC of kWh Stuhldreher et al benchmarked the B ’ brake specific fuel consumption and graphed it as a BSFC map Figure The map displays the BSFC of the B at different RPMs and the torque brake mean effective pressure BMEP and the power produced by the engine at the different efficiencies Stuhldreher et al found a trend for the B ’ BSFC where it will decrease to hr as its BMEP increases to if the engine speed is between and This occurs because the BSFC of an engine is the amount of power produced fuel consumed for the effective power of the engine The lower the BSFC the more efficient the engine is because the same amount of power is produced with less input energy However the graph is limited in its ability to effectively compare the B and the BMSP because the investigation was conducted using petrol with a higher Research Octan Number RON of than Turner et al’ study which used RON petrol As a result the BMSP would be less fuel efficient

Evidence

Figure The Brake Specific Fuel Consumption vs the Brake Mean Effective Pressure of the RENESIS BMSP at Various Engine Speeds

Comparatively the BMSP has a higher minimum BSFC than the B of kWh Turner et al investigated the benefits of eliminating port overlap in Wankel rotary engines recording the BMSP’ BSFC at various engine speeds Their investigation revealed that the BMSP’ efficiency will decrease in a logarithmic relationship as the BMEP increases if the engine speed is above Below the relationship is parabolic with the most efficient point occurring at a BMEP of kPA with a BSFC of kWh However the graph produced by Turner et al is limited by the low range of engine speeds investigated which increase in increments up to despite the engine being capable of running at The graph is also limited because it does not display the power produced by the engine

Using the trends described by the engine speed with the lowest BSFC for each engine a significant difference in the engine’ efficiency was revealed At the B reached a lower BSFC than the BMSP at kWh while the BMSP reached a BSFC of kWh at higher than the B which suggests that the B is significantly more efficient However the peak consumption of the engines reveals scenarios where the BMSP is more efficient When running at its least efficient running point which produces a BMEP lower than kPA the B produced a BSFC of kWh while the BMSP’ lowest efficiency point was kWh when producing a BMEP of Therefore in most circumstances the B is more thermally efficient than the BMSP

Conclusion

This report aimed to determine whether “the RENESIS BMSP Wankel rotary engine is more thermally efficient than the Honda B fourcylinder inline piston engine” It determined that the BMSP Wankel engine is less efficient than the B cylinder inline petrol engine in most situations partially due to a increase in efficiency due to the B ’ higher compression ratio than the BMSP However in situations where the engine is producing a BMEP lower than kPA the BMSP is more efficient than the B As the car engines have different thermal efficiencies the claim can be disproven Therefore the B is predominantly more efficient than the BMSP Wankel Engine however more research is required to determine the causes of the differences in efficiency

Extrapolation of Findings

The research investigation found that the BMSP has a lower peak efficiency than the B However its least efficient point was lower than the BMSP’ These findings could be extrapolated to different displacement Wankel and turbocharged inline fourcylinder engines because they would have similar designs and thermal properties However as the thermal efficiency would vary significantly if the engine type was changed the findings could not be extrapolated to include all petrol piston engines and nonWankel rotary engines

Evaluation

Despite having limitations Connor’ determination of the relationship between theoretical efficiency and compression ratio is still reliable because it was published recently suggesting that it contains uptodate data However it is only partially valid because the insight provided by the relationship fails to accurately predict the difference in the thermal efficiency of the BMSP and the B suggesting that other factors contribute to the difference in efficiency The benchmark completed by Stuhldreher et al was valid because it detailed the BSFC of the B which directly relates to its thermal efficiency It is also reliable because it was conducted by the Environmental Protection Agency and published recently in However it does have a significant limitation within its data Turner et al ’ investigation into the fuel efficiency of the BMSP is reliable even though the engine was released in because it is the most recent Wankel engine used in a production car Furthermore Turner et al ’ report is also valid because it depicts the thermal efficiency of the BMSP through its graph of the engine’ BSFC

Improvements

To address the limitations of the evidence several improvements could have been made to the investigation The first improvement would be the examination of empirical data on the effect of compression ratio on thermal efficiency in piston and Wankel engines By investigating empirical data insight into the cause of the difference between the theoretical and actual efficiency differences of each engine could have been gained

To further improve the investigation the range of engine speeds investigated for the BMSP’ BSFC could have been expanded The existing limits prevented any useful correlations between either engine’ higher performance bracket from being drawn as the extent investigated did not include the BMSP’ upper limits

Extensions

To extend this investigation its domain could have been expanded to include a broader range of engines such as the GDFTV straightfour diesel engine The GDFTV would have significantly different characteristics because it has a higher displacement and because it uses diesel which has a higher energy density than petrol

The investigation could have also researched the efficiency of rangeextender engines in plugin hybrid electric vehicles PHEVs because engines used in PHEVs would be under different loads because they act as an electric generator for the battery in the car As this is the situation which the Wankel engine would be reintroduced it could have provided valuable insight into the Wankel’ use

Bibliography