Conversion, Simulation, and Engine Testing on a Single Cylinder Port-fuel Injected (PFI) Atkinson Cycle Engine Based on an Otto Cycle Engine

Engr. Jose Luis L. Villalon[1]

[1] 1 Concepcion St. ABA Homes Subd., Brgy. Dalig, Antipolo City, Rizal, Philippines

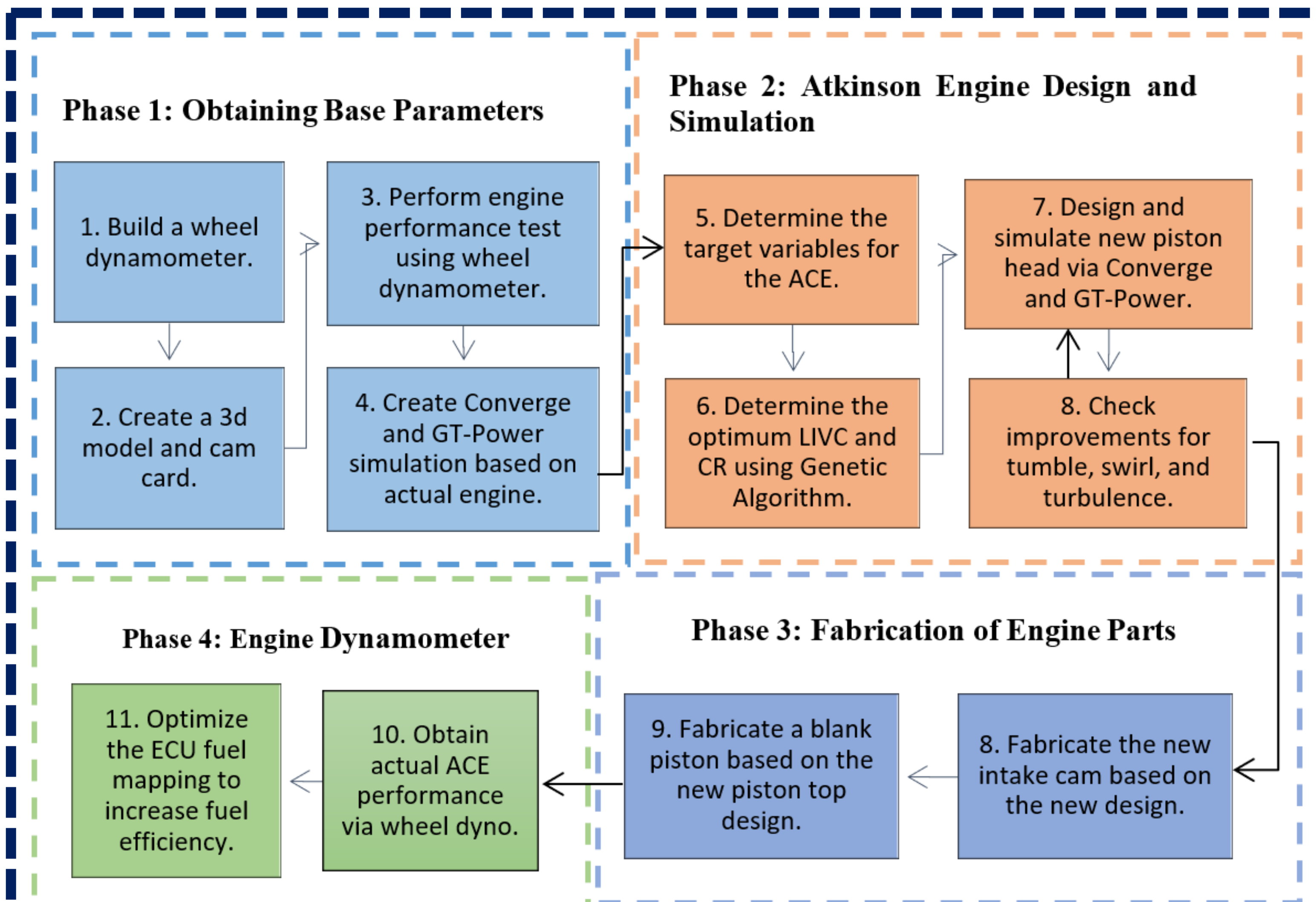
[a]jllvillalon@mymail.mapua.edu.ph

ABSTRACT

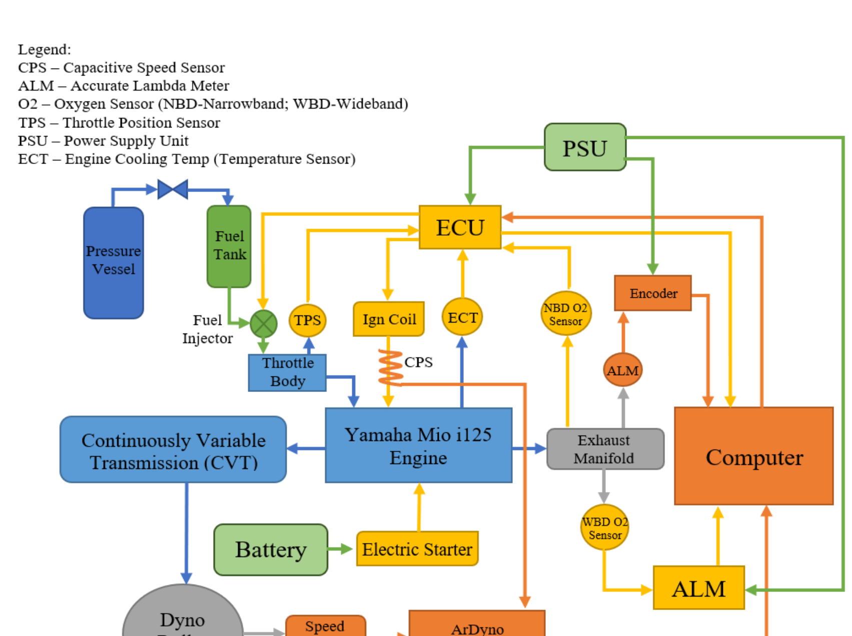
This research aimed to convert a single-cylinder Otto cycle engine (OCE) that will accomplish an Atkinson cycle effect by modifying the intake cam timing, via late intake valve closing (LIVC), and compression ratio. A wheel dynamometer was built to analyze the engine's baseline performance and behavior. The engine modification underwent a two-part CFD-1D simulation with a Genetic Algorithm (GA) optimization strategy to obtain baseline performance and design improvements. It was found that the engine modification with the optimized fuel mapping significantly which reduced the average BSFC by 36.07% at 3000rpm range, 8.58% decrease at 5000rpm range, and 14.9% decrease at 8000rpm range. The corresponding engine power resulted in a 68.93% increase at the 3000rpm range, 1.76% decrease at the 5000rpm range, and 3.49% decrease at the 8000rpm range.

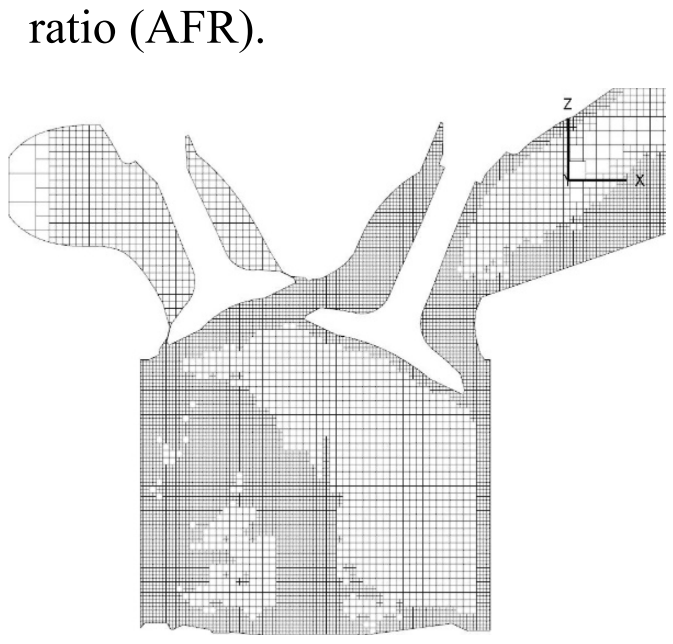
Keywords: Atkinson, LIVC, Genetic Algorithm, Converge, GT-Power, BSFC

METHODOLOGY



An actual wheel dyno was built to test the engine performance which was performed at different crank speeds (e.g., 3000rpm, 5000rpm, and 8000rpm). The dyno used an Arduino and the SimpleDyno to read, calculate, and display the brake power and brake torque. A separate Accurate Lambda Meter (ALM) was added in the setup to monitor the air-fuel ratio (AFR).





Converge was chosen for this study to produce accurate simulation results. The PISO algorithm predicted the pressure-velocity values, RANS k-epsilon RNG was used for the turbulence model, and G-equation was used for the combustion model.

Furthermore, the GT-Power was coupled with Converge to match the theoretical engine performance and to perform the design optimization of the cam timings.

INTRODUCTION

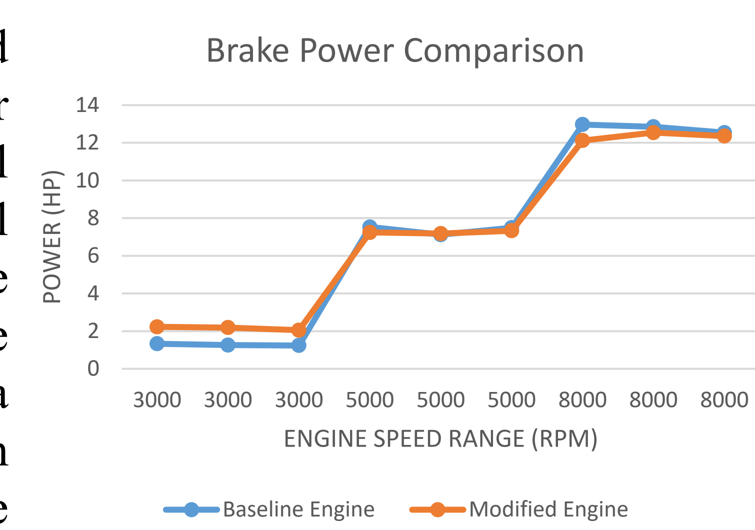
In 1882, a British engineer named James Atkinson introduced the Atkinson Cycle Engine (ACE). The principle behind his invention was to derive the Otto cycle by the relatively increasing the expansion stroke than the compression stroke. One novel concept in accomplishing the Atkinson Cycle Effect is through a planetary gear train installed in a crankshaft mechanism by Kawamoto et al. Then, Honda motors was able to develop an ACE, called the EXLink, wherein a trigonal link and an eccentric shaft is utilized to manipulate the piston movement.

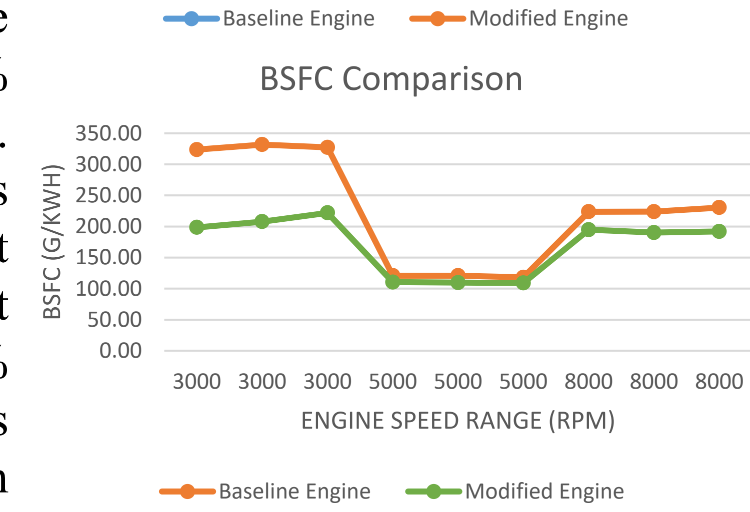
This research aims to provide a methodical strategy to convert outdated OCEs into reusable ACEs in single cylinder configurations. Powered Two-wheelers (PTW), such as tricycle engines, and other forms of downsized portable power units may also be developed with the use of this research.

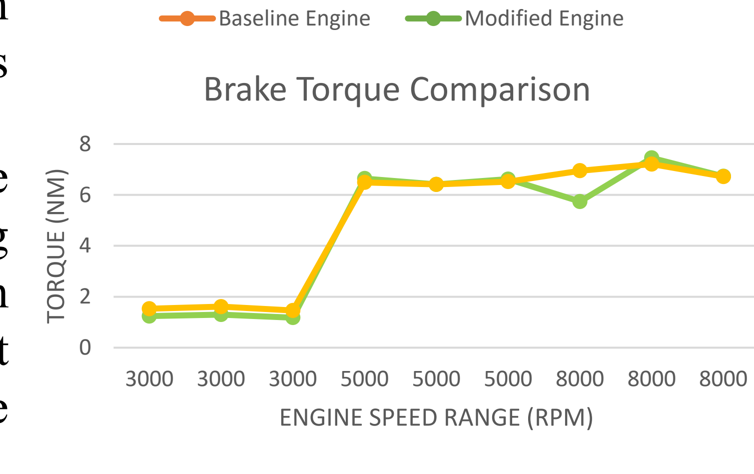
RESULTS AND DISCUSSIONS

A final engine test was performed by optimizing the fuel mapping, for the ACE, to maximize fuel efficiency with minimal performance losses. The brake power comparison of the baseline vs. modified engines resulted to a 68.93% increase at the 3000rpm range, 1.76% decrease at the 5000rpm range, and 3.49% decrease at the 8000rpm range. However, the BSFC comparisons resulted to a 36.07% decrease at 3000rpm range, 8.58% decrease at 5000rpm range, and 14.9% decrease at 8000rpm range. This shows that the optimum BSFC with respect to engine speed is achievable in the 5000rpm range.

It was also observed that the optimization of the fuel mapping provided a significant advantage in improving fuel economy without the excessive decline in brake power and brake torque.







CONCLUSIONS

According to the GA optimization, the new intake valve closing was delayed by 40 CA˚, while the maximum valve lift was increased by 0.4mm. Furthermore, it was found that the optimum operating range of the modified Atkinson Cycle Engine was 5000rpm since the BSFC was lowest in this operating range, averaging at 109.71g/kWh. To be specific, the BSFC was reduced by 8.58%, while the engine power resulted in a 1.76% decrease at the 5000rpm range.

Additionally, it was proven that the strategies, provided in this research, were able to modify a single cylinder from OCE into ACE. This research may develop and reuse outdated OCEs, with minimal parts needed.

It was notable that an engine dynamometer should be developed, using the same electronics from the research, to accurately measure the brake engine performance without the mechanical losses.