Efficiency of A Vehicle in Traffic: Kinetic Energy Approach

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ABSTRACT

The land transportation contribute large amount of CO₂ emission due to the low conversion efficiency in transport vehicle. Normally, the energy conversion efficiency in road vehicle was presented in term of amount of fuel per distance within specific condition where it could not be comparable in practice especially in logistic sector that the variation of load factor and dynamic traffic condition were impacted. In this study, the alternative efficiency indicator was proposed with applying kinetic energy concept to formulate road-vehicle efficiency factor (REF) which include dynamic behavior and weight of vehicle.

Furthermore, the experimental were taken place in Pahonyothin Rd. (Bangkok, Thailand) including urban and highway with various traffic congestion level. Therefore, the road-vehicle efficiency factor were manipulated and shown that the factor could be low as 2% in severe traffic congestion while it could be more than 10%in free flow. Ultimately, this methodology included the weight of vehicle and dynamic behavior of vehicle in manipulation so the problem in efficiency for logistic fleet could be solved.

INTRODUCTION

The motor vehicle is a primary machine on land transportation which consumes fossil fuel as main energy which contributes approximately 90% of oil consumption. In addition, the fuel efficiency in motor vehicle is relatively low in comparison with other types of transportation and contributed large amount of CO₂ emission. To reduce both CO₂ emission and rate of fuel economy, the demand side management (DSM) is the potential interest solutions because it is no need for further modifications on motor vehicle. For instance, the fuel economy on motor vehicle can be improved by both driver behavior and traffic management.

In fact, the motor vehicle is regulated with emission and fuel economy standard that is tested on controlled condition road-load chassis dynamometer with standard driving pattern. However, the test was mentioned that not represent the real driving condition since the pattern is not very aggressive acceleration, consequently, the rate of fuel consumption on the datasheet were relatively better than operating condition, and the on-road measurements has been proposed[1]. The real-time fuel consumption and emission on motor vehicle under dynamic condition were examined. In addition, A Alessandrini[2] proposed the applications of OBD (on-board diagnosis system) combination with GPS (global positioning system) in standard vehicle to estimate analysis actual energy and emission. As the results, the methodology can be use to acquire the usage cycle of vehicle, the driver behavior or providing new homologation. In previous study[3], the real-time fuel consumption rate estimation technique from in vehicle diagnosis system, using parameter mass-air-flow (MAF) and vehicle speed sensor (VSS) , had been proposed and proofed for reliability. Furthermore, the driving conditions which were driver behavior and traffic condition indicated the deviation in fuel consumption about 30% between the worse and the best. Moreover, the study in traffic condition was done in Thitipatanapong, et.al [4] that the fuel consumption was mainly effected by vehicle average trip speed and vehicle weight. However, the roadside conditions, vehicle power and aerodynamic were not affected the fuel consumption in traffic. However, the VDI only interpreted the behavior that causes neither more fuel consumption nor the exact amount of fuel usage. Therefore, the fuel consumption of vehicles in traffic is function of acceleration in both magnitude and quantity. In addition, the detail analysis on the driver behavior was manipulate [5] as VDI (vehicle dynamic index) which related to the fuel consumption in same road with different driver.
Later, C.A. Prieto [6] was proposed the concept of positive kinetic energy (PKE) to solve the variation in fuel consumption that effected by driver behavior and traffic congestion level. The analysis indicated good relationship between PKE and fuel consumption rate. Generally, the rate of fuel economy is also dominated by the driving condition and vehicle weight. In this study, the novel road-vehicle efficiency analysis was proposed to rate the vehicle, load factor and driver under Bangkok traffic congestion level.

**KINETIC ENERGY APPROACH**

From road testing experience, the large fraction of energy is consumed during vehicle acceleration but it consumes small amount of fuel usage during cruising speed. Therefore, the positive kinetic energy of vehicle (PKE) in (eq.1) was taken to account and compared with fuel energy (FE) in (eq.2) as Road-Vehicle Efficiency Factor (REF) in (eq.3). For the fuel energy (FE), the real time fuel consumption were examined and manipulated by K. Tanmee, *et. al.* [7]

\[
PKE = \sum_0^i \frac{1}{2} m \cdot (v_{i+1}^2 - v_i^2) \quad \text{(eq1)}
\]

\[
FE = \sum \left[ \frac{MAF}{\lambda \cdot AFR} \cdot HHV \right] \quad \text{(eq2)}
\]

\[
REF = \frac{PKE}{FE} \times 100 \% \quad \text{(eq3)}
\]

Where \( m \) was mass of vehicle, \( v \) was velocity of vehicle, \( MAF \) was mass-air-flow into combustion chamber, \( AFR \) was theoretical air-to-fuel ratio of usage fuel, \( \lambda \) was actual combustion ratio and \( HHV \) was higher heating value of usage fuel.

**EXPERIMENTAL VEHICLE**

The compact sport utility vehicle(SUV) with the spark-ignition gasoline engine was selected which was Ford Escape 3.0-l XLT with automatic transmission as illustrated in Figure 1 and Table 1. During experiment the weight of a vehicle including load was assumed constantly at 1,700 kg.

**STUDY ROUTE**

The Prayathai road and Pahonyothin road outbound was selected in this study, the experiment was divided into 4 sectors to covers practical road conditions as listed in Table 2 and figure 2.

**Table 1 The vehicle specification**

<table>
<thead>
<tr>
<th>Model</th>
<th>Ford Escape 3.0 XLT, Model year 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel type</td>
<td>petrol (gasoline)</td>
</tr>
<tr>
<td>Fuel system</td>
<td>indirect injection</td>
</tr>
<tr>
<td>Charge system</td>
<td>naturally aspirated</td>
</tr>
<tr>
<td>Valves per cylinder</td>
<td>4</td>
</tr>
<tr>
<td>Additional features</td>
<td>sequential multi-port fuel injection EEC-V DOHC</td>
</tr>
<tr>
<td>Emission control</td>
<td>3-way cat, Lambda-Sensor</td>
</tr>
<tr>
<td>Cylinders alignment</td>
<td>V 6</td>
</tr>
<tr>
<td>Displacement</td>
<td>2967 cc</td>
</tr>
<tr>
<td>Power net</td>
<td>145 kW at 6,000 rpm</td>
</tr>
<tr>
<td>Torque</td>
<td>265 Nm at 4,700 rpm</td>
</tr>
<tr>
<td>Transmission</td>
<td>4-speed automatic with overdrive</td>
</tr>
<tr>
<td>Vehicle weight</td>
<td>1520 kg</td>
</tr>
</tbody>
</table>

![Figure 1 An experimental vehicle](image1)

![Table 1 The vehicle specification](table1)
Figure 2 Experimental routes

Table 2 the routes descriptions

<table>
<thead>
<tr>
<th>Sector</th>
<th>From (A)</th>
<th>To (B)</th>
<th>Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Inner-Urban</td>
<td>Chulalongkorn Univ.</td>
<td>Victory Monument</td>
<td>4.0</td>
</tr>
<tr>
<td>(ii) Urban</td>
<td>Victory Monument</td>
<td>Fifth constitution monument (Laksi)</td>
<td>13.5</td>
</tr>
<tr>
<td>(iii) Sub-urban</td>
<td>Fifth constitution monument (Laksi)</td>
<td>National Memorial</td>
<td>10.5</td>
</tr>
<tr>
<td>(iv) Highway</td>
<td>National Memorial</td>
<td>Thammasat Univ. (Rangsit)</td>
<td>19.0</td>
</tr>
</tbody>
</table>
In addition, to cover congestion level, the experiment also conducted with 3 different periods: peak hours started at 17:00pm, intermediate hours started at 21:30pm and free-flow hours started at 00:00am. Moreover, there were 3 difference types of ethanol blended fuel. Ultimately, there were totally 36 (4x3x3) sectors-periods including both infrastructures and congestion level to analyses.

RESULTS

The fuel consumption rate was manipulated and presented in Figure 3 (above) as re-illustrated with average trip speed (as congestion level indicator)[7]. The results showed the relation trend between congestion level and fuel consumption. However, the trends were not included different type of fuels, driver behavior or vehicle weight which really impact to the vehicle in logistic industry.

Alternatively, the concept of energy efficiency had employed to compare the energy input from fuel energy with energy output to the vehicle (as kinetic energy) as illustrated in Figure 5(below).

At severe congestion level, the efficiency could be low as 2% while, in free flow condition, more than 10% could be achieve. In congested traffic, a vehicle was on many small accelerating and braking with fluctuated engine output. For the free flow traffic, there was a few large accelerating with mostly constant engine output.

For the fuel blend, in traffic congestion were no difference on REF while at free flow traffic the E85 blend trended to deviate in less efficiency.

It is obvious that, at severe congestion, REF reflexes less conversion efficiency from fuel energy (FE) as related to high fuel consumption rate. It can be seen that the road-vehicle efficiency factor could be represented with account the dynamic behavior, weight of vehicle and fuel type could be comparable.

CONCLUSION

In this study, the alternative analysis in road-vehicle-traffic efficiency had been proposed. Moreover, the novel manipulation includes vehicle weight, type of fuel and dynamic behavior had been analyzed, so it could be applied to compare the efficiency in logistic fleets with different vehicle, load factor or traffic condition. Furthermore, the weight differences analysis should be carrying out in the future.

Figure 3 (above) fuel consumption rate,(below) road efficiency factor
REFERENCES


6. C.A. Prieto, “Use of GPS trajectories to Estimate Fuel Consumption” Young European Arena of Research, 2010


CONTACT

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