Consumption calculation of vehicles using OBD data

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CTL introduction

• The Centre for Transport and Logistics of the university of Rome “La Sapienza” was funded by the Italian Ministry in 2003 as a national centre of excellence

• It follows a multi-disciplinary approach, involving Mechanics and energy, Information science, Telecommunications

• Mission
  – Bridging the gap between research and applications, between universities and industries

• Main research themes
  – Transport, Safety, Freight and Logistics
  – ICT applications for transport
  – Vehicles energy and emissions monitoring
Contents

Method and models to calculate instantaneous power and consumption
• On-board tool
• Available onboard sensors
• Power calculation
• Consumption calculation
• Accuracy of the models
The Onboard Unit

![Diagram of the Onboard Unit with labeled components like CAN bus, GPS, WiFi, GSM/UMTS, Onboard Unit, and ABS unit.]

![Image of the Onboard Unit hardware with a display screen showing real-time data with parameters such as Speed, Load, RPM, etc.]

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Available sensors on-board

- Vehicle speed
- Rpm
- Accelerator pedal
- Engine Load%
- Intake Airflow
- Air/fuel Ratio
- Coolant Temperature
- Catalyst Temperature
- .............
OBD Parameters: Calculated Engine Load

\[
Engine\_Load = \frac{Current\_AirFlow}{Max\_Airflow(Rpm)} \cdot \frac{Baro}{29.92} \cdot \sqrt{\frac{298}{T_{amb} + 273}}
\]

- Reaches 1 at full open throttle for any altitude, temperature and pressure or rpm for both naturally aspirated and boosted engines;
- Indicated percent of peak available torque;
- Linearly correlated with engine vacuum;
- Often used to schedule power enrichment.
- Compression ignition engines (Diesels) shall support this parameter using fuel flow in place of airflow.
Power: calculation

- Linearity, for each Rpm between Power and
  - engine Load (for Spark Ignition vehicles) or
  - Engine Load*Intake Airflow (for Diesel)
- Two curves needed: WOT curve and at idle (P=0)
Power: correlation for Diesel Vehicles

Fiat Bravo diesel 1.6 Multijet

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Power: correlation for Spark Ignition Vehicles

![Graph showing power correlation for Spark Ignition Vehicles. The graph plots power [kW] against engine load % for different RPM values: 1860 Rpm, 6000 Rpm, 4120 Rpm, 5010 Rpm, 2310 Rpm, 3250 Rpm, 1380 Rpm, and 6400 Rpm. Each RPM has a line with an R² value indicating the correlation coefficient.]
Consumption: Formulation

- Calculated directly from PID or
- Calculated by:
  - Airflow
    - Read from OBD
    - Calculated
  - Air/Fuel Ratio
    - Read from OBD
    - Calculated
Intake Airflow: Calculation (Spark ignition vehicles)

- Linearity correlation between airflow and engine load (or engine Load*airflow for diesel):
  - Maximum and minimum values are measured (at full load and idle) for each rpm
  - Linear interpolation at fixed Rpm between the extreme points

\[
\text{AirFlow}_{\text{actual}} = \text{AirFlow}_{\text{idle}} + \left( \frac{\text{AirFlow}_{\text{WOT}} - \text{AirFlow}_{\text{idle}}}{\text{Load}_{\text{WOT}} - \text{Load}_{\text{idle}}} \right) \cdot \left( \text{Load}_{\text{actual}} - \text{Load}_{\text{idle}} \right)
\]
Intake Airflow: Correlation (Honda Civic 2.0 SI)

![Graph showing intake airflow correlation with load and RPMs.](Image)

- R² = 0.9989
- R² = 0.9938
- R² = 0.9994
- R² = 0.9989
- R² = 0.9924
- R² = 0.9901
- R² = 0.9891
Intake airflow calculation accuracy

![Graph showing intake airflow calculation accuracy](image)

- OBD airflow STP l/min
- OBS flow Rate l/min

AirFlow l/min

Time s.

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Air/fuel ratio for spark ignition vehicles

• Measured by OBD or
• Calculated:
  – Full load: $\lambda = \lambda(rpm)$
  – Cut-off: $\lambda = \lambda_{\text{max}} (\sim \infty)$
  – Partial Loads: stoichiometric ($\sim 1$)
    (with fuel enrichment with accelerator pedal gradients).
Lambda measured (Honda Civic Hybrid)

![Graph showing lambda measurements for Honda Civic Hybrid with different sensors and commanded values over time.](image-url)
Consumption: Diesel vehicles

- Variable with:
  - engine load
  - Intake airflow

\[ FuelFlow\left(\frac{l}{h}\right) = a \cdot (Airflow \cdot Load) + b \]
Consumption: Correlation (Diesel)

Fiat Bravo
\[ y = 0.0026x - 0.417 \]
\[ R^2 = 0.9909 \]

Fiat Punto Diesel
\[ y = 0.0021x + 1.5167 \]
\[ R^2 = 0.9783 \]

Ford Focus
\[ y = 0.0021x + 0.8909 \]
\[ R^2 = 0.9966 \]

Fuel Flow l/h

AirFlow (g/s) * Load%
Calibration procedure

![Graph showing engine load and power kW at different RPM]

- **Load Idle**
- **Load 100%**
- **Power @ Idle**
- **Power @ 100%**
- **Power @ 2200 Rpm**

*Engine Load % vs. Rpm and Power kW*
## Consumption: Diesel Vehicles

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Sensors used</th>
<th>Measurement System</th>
<th>Error %</th>
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<tr>
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## Consumption: Spark Ignition Vehicles

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<th>Error %</th>
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<td>CVS</td>
<td>3.8</td>
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<td>Honda Civic Hybrid</td>
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Conclusions

- OBD data can be used as input to calculate instantaneous power and consumption of vehicles
- OBD sensors have been validated and have good accuracies to be used
- If not available on-board, airflow and air/fuel ratio can be calculated using rpm, engine Load and other parameters always available;
- Models have been validated on a dynamometer chassis with different vehicles and driving cycles.
- Consumption, for both Spark ignition and diesel Vehicles have errors always lower than 4% for the vehicles tested