

Online Engine Speed based Altitude Adaptation of Air Charge and Limp Home for Two-Wheelers

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ABSTRACT

Cost reduction of engine management systems (EMS) for two-wheeler applications is the key to utilize their potentials compared to carburetor bikes regarding emissions, fuel economy and system robustness. In order to reduce the costs of a system with port fuel injection (PFI) Bosch is developing an EMS without a manifold air pressure (MAP) sensor. The pressure sensor is usually used to compensate for different influences on the air mass, which cannot be detected via the throttle position sensor (TPS) and mean engine speed. Such influences are different leakage rates of the throttle body and changing ambient conditions like air pressure.

Bosch has shown in the past that a virtual sensor relying on model based evaluation of engine speed can be used for a detection of leakage air mass in idling to improve the pre-control of the air-fuel ratio. This provides a functionality which so far was only possible with an intake pressure sensor. In this paper the air mass calculated from the model based engine speed evaluation is used to adapt the influence of ambient pressure changes e.g. because of different altitudes.

Furthermore, the usability of the engine speed based air mass for the realization of a limp home mode in case of a malfunction of the throttle position sensor is evaluated. Therefore, a demonstrator bike is equipped with an additional switch to bring in certain TPS errors which will be detected by the EMS.

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INTRODUCTION

This Paper will specify the engine control strategies described in last year's SETC paper "Online Engine Speed Based Adaptation of Air Charge for Two-Wheelers" [1]. Altitude adaptation and limp home will be realized with the same engine speed based feature which was used before to adapt leakage air in idling. In order to match the requirement of a cost reduced two-wheeler system the features are shown on a typical single cylinder 110cc air cooled commuter bike.

The number of units of 2-wheeler systems with displacement volumes smaller than 250ccm is rising rapidly worldwide. Increased requirements according to emissions legislation cannot be met with conventional carburetor systems. One of the benefits of an engine management system with port fuel injection is the more precise control of the air-fuel ratio which enhances starting reliability [2] and allows an effective exhaust after-treatment via 3-way-catalyst. As shown in [Figure 1](#) intelligent engine control functions are essential to create a robust and cost effective 2-wheeler system with reduced maintenance effort.

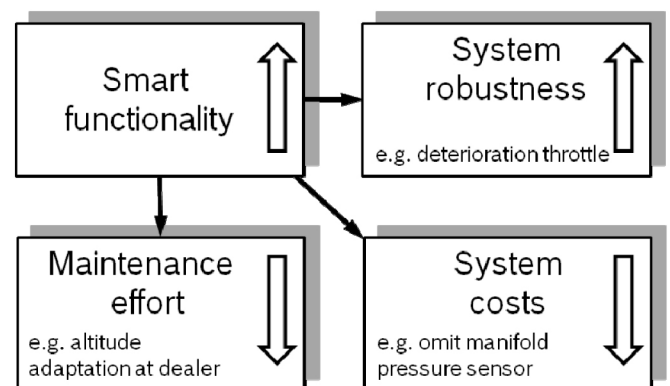


Figure 1. Benefits of intelligent engine control functions

Based on the investigations described by Seuling et al. [3] the air mass inside of the combustion chamber after inlet valve closing is estimated via a model based evaluation of the engine speed signal. In the work presented in this paper the engine speed signal is captured via a series production trigger wheel and an inductive sensor. The evaluation is also done by a series production Motronic M17.8.42 from Bosch. In

comparison to [1] the used demonstrator bike in this paper is more representative for the huge segment of commuter bikes. The two major challenges of this system configuration are the trigger wheel with only 12-3 teeth (compared to 36-2 teeth in [1]) and the air cooling of the engine which will result in higher temperature variations during operation which influence the captured air mass. An additional challenge for engine speed based functions is always the presence of tooth errors due to geometric tolerances of the trigger wheel, mounting tolerances and tolerances in the sensing and processing of the tooth edges. Therefore a compensation of this tooth error influence was developed to reduce bike to bike tolerances of the calculated features. In order to prove the ability of the developed functionality to work under series production conditions, it is tested on three different bikes of the same type with different tooth errors.

DESCRIPTION OF ENGINE SPEED EVALUATION

The key to retracting additional information about the operating conditions of the engine from the engine speed signal is taking into account the engine kinematics as described by Hamedovic [4]. Figure 2 shows the transient characteristic of the engine speed signal over one working cycle for two different bikes at two different load points, defined by different relative air charges. As a reference signal the high resolute signal from an additional sensor (resolution 0.1°ca) is added as well. It is obvious that the engine speed signal from the series production trigger wheel shows deviations from the reference signal for certain teeth. Especially for bike B, where bigger deviations occur.

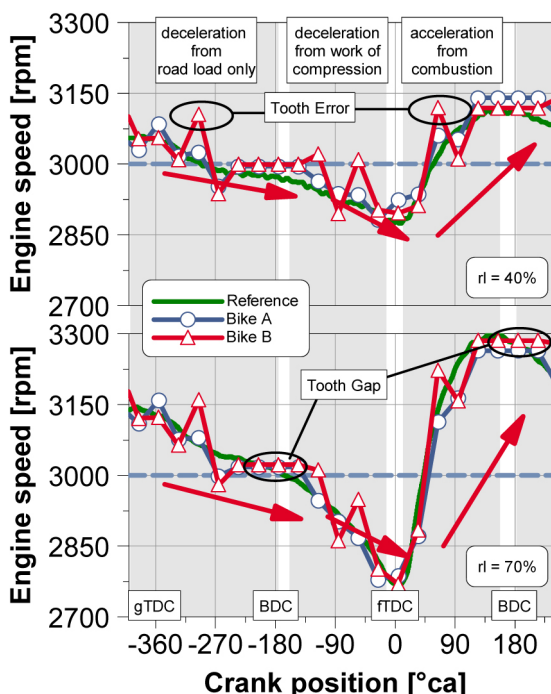


Figure 2. Periodical fluctuations of the engine speed signal and tooth error influence over one working cycle

The fact that these deviations are reproducible from cycle to cycle, for different engine loads and even speeds and repeat for each tooth after one complete revolution is an evidence for them being caused by incremental tooth errors. These errors have to be compensated in order to ensure a good correlation of $ACFn$ and the real measured air mass for different bikes. Three major phases can be identified in the engine speed signal. First during gas exchange the influence of gas forces on the piston can be neglected, therefore the crank shaft is only decelerated by engine and crank train friction and the external road load. The second phase starts after the intake stroke when the intake valves are closed. Here the engine is decelerating even more because of the compression of the charge inside of the cylinder. The third phase shows the acceleration of the crank shaft because of the gas pressure inside the combustion chamber after TDC as a result of the combustion process. Comparing the upper and lower part of Figure 2 a change of the characteristic because of higher road load, work of compression and higher indicated mean effective pressure is visible which will be used for the feature calculations.

The estimation of the air mass inside of the combustion chamber is based on the calculation of the work of compression from the tooth times of the engine speed signal. The functional approach is shown in Figure 3. After collecting the tooth times and taking into account the crankshaft dynamics the incremental errors are compensated and the raw feature ($ACFn_{raw}$) is calculated. This feature is mapped to match the actual air mass under norm conditions and finally in order to achieve good results under different ambient and driving conditions a temperature correction depending on engine temperature (t_{mot}) is applied.

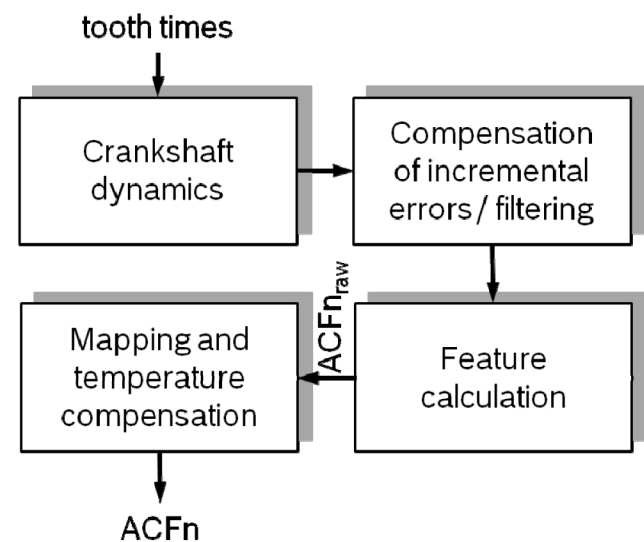


Figure 3. Calculation of engine speed based feature for air mass

EXPERIMENTAL SETUP

As described above, the used demonstrator bike is equipped with a typical 110cc air cooled two valve engine. It is equipped with a four gear step through transmission and a centrifugal

clutch. As shown in Figure 4 the EMS does not contain an intake pressure or temperature sensor so the primary load detection is performed via the evaluation of the throttle position sensor and the mean engine speed (α/n -system). Throttle leakage air and thereby engine speed in idling can only be changed manually by changing the idle screw position. The EMS is equipped with an unheated two point oxygen-sensor. The engine speed signal is collected by an inductive sensor and the 12-3 trigger wheel.

For reference purposes only the bike is equipped with an additional wide band oxygen-sensor and a high resolution engine speed sensor with 0.1°ca resolution from Heidenhain GmbH. In Combination with a spark-plug pressure sensor the in-cylinder pressure can be measured and a calculation of different combustion parameters like the combustion phasing or the indicated mean effective pressure are possible.

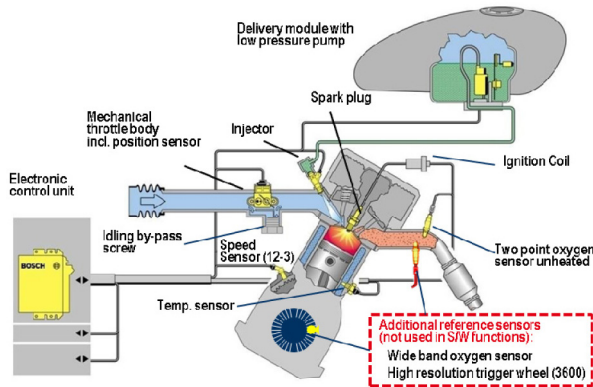


Figure 4. System configuration of demonstrator bike

In order to vary the engine temperature of the air-cooled engine at constant operating conditions, defined by engine speed and air mass, fans with continuously controllable rotor speeds are used. These allow varying the engine temperature depending on the operating point between 50 and 150°C . Higher engine temperatures could be achieved but will not be measured to protect the engine from damage. Additional temperatures like the cylinder head temperature, oil temperature and intake air temperature are collected via several thermocouples.

Figure 5 shows the examined operating points for the calibration of ACFn for altitude adaptation. Because of the centrifugal clutch of the demonstrator a systematic variation of the measured air mass (α) on a dyno test bench is only possible at engine speeds (n_{mot}) equal to or higher than 3000rpm. The engine speed is varied up to the maximum engine speed of 9000rpm. The air mass is changed via the throttle angle position from minimal values of around 8 to 10% (throttle valve completely closed or at higher engine speed no stable combustion was achieved below these values) up to full load conditions. In order to calibrate the temperature compensation functionality the engine temperature was varied between 60°C and 150°C . As can be seen from the depicted

operating points the higher engine temperatures will reduce the captured air mass within the combustion chamber at completely closed throttle as well as under full load conditions.

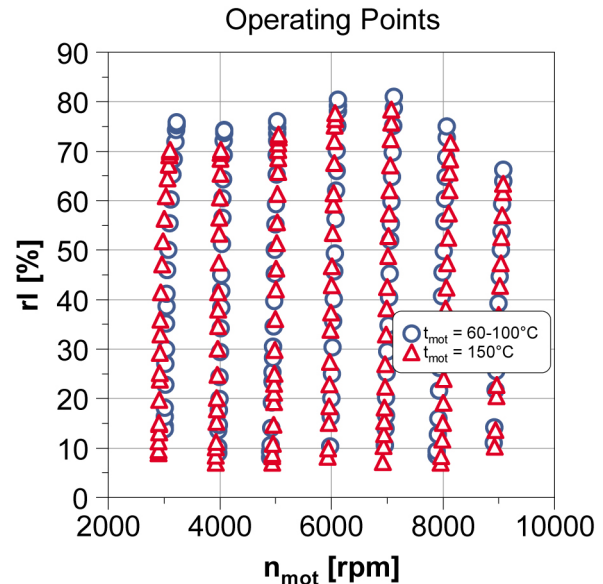


Figure 5. Examined operating points and temperatures

TOOTH ERROR COMPENSATION

As described before tooth errors are influencing the derived engine speed feature in a major way. This behavior can be reconstructed from Figure 6. Here the dependency of the unmapped feature from the reference air mass is shown.

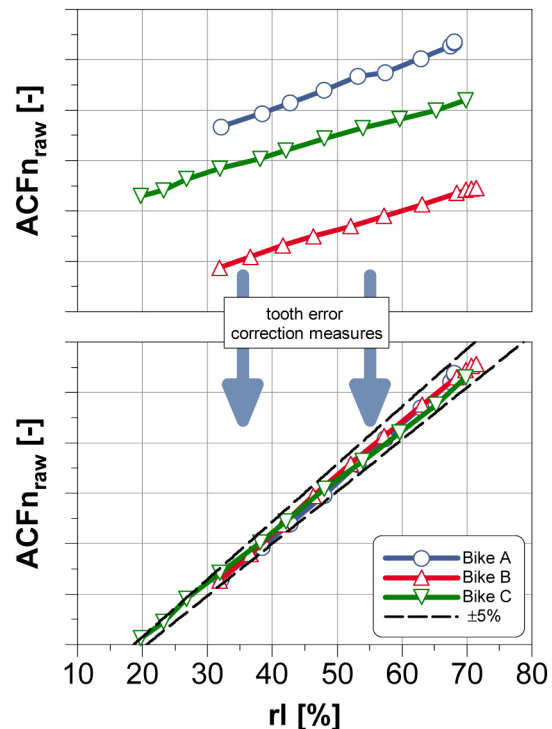


Figure 6. Quality of feature correlation with and without tooth error correction methods