A new method for the detection of the CPS (Cam Profile Switching) state of Spark Ignition automotive engines is proposed and implemented. The method is based on the evaluation of the amplitude and the phase of the component of the intake manifold pressure signal with the period of 720° CA (Crank Angle) degrees. The method allows the detection of the CPS Bank failure even at high rotational speeds.

8.1 Introduction

A new Cam Profile Switching (CPS) technology for Spark Ignition automotive engines has a significant effect on fuel consumption, drivability and exhaust emissions. New legislative requirements for the exhaust emissions demand the ability to conduct a continuous monitoring of the state of CPS. This, in turn, necessitates the development of the diagnostic method for identification of the system failure since the valve lift event can not be directly measured. The CPS mechanism for six cylinder engines has two cylinder groups (Banks) which in turn have two separate oil-driven systems. The cylinder groups are coupled according to the firing sequence. The CPS has two states: low and high cam profiles. The shifting event is controlled by the pressure in the oil Banks.

A couple of methods allow the detection of the CPS state according to the literature. The first one is based on the difference in the air charge inducted in the cylinders for different lifts. The inducted air charge measured by Manifold Air Flow (MAF) sensor is compared with the air charge model based on the measured position of the throttle flap, intake manifold pressure and engine speed. The failure of the CPS mechanism is detected by the error between measured and modeled air charge [31]. The method is based on the difference in the volumetric efficiency for different CPS states. The difference in the volumetric efficiency for different CPS states is due to the air pushback effect at low engine speeds and the difference in valve effective areas at high engine speeds. This difference is also influenced by the IVVT (Intake Variable Valve
The detection method described above is not able to detect a failure of a single Bank since the difference in the volumetric efficiency is small for this case. This method is also unable to detect an individual cylinder failure.

Another method is based on the combustion state monitoring using fluctuations of the engine speed. The method is based on the fact that the combustion state changes considerably during shifting [79]. The invention uses the technique of the combustion state monitoring via irregularities of the engine speed. Irregularities are associated with the CPS state. The method allows the cylinder individual failure detection. However, the method described in [79] does not allow the detection at high rotational speeds. At high rotational speeds (over 3500 rpm) the high resolution engine speed signal has fluctuations, which occur as a consequence of the combustion events contaminated with the time interval errors, low frequency oscillations from the powertrain and high frequency oscillations due to the crankshaft torsion. The CPS state information can not be recovered at high rotational speeds in the presence of the disturbances described above.

Cylinder groups (Banks) are coupled according to the firing sequence of the engine. The firing sequence for six cylinder prototyping engine is 1-5-3-6-2-4. The Bank "A" includes cylinders 2, 4 and 1 while the Bank "B" includes cylinders 5, 3 and 6. As a consequence of the failure of a single oil Bank the component whose period is 720 CA degrees appears in the intake manifold pressure signal. The method proposed in this Chapter associates the CPS state with the amplitude and the phase of this component of the intake manifold pressure signal and allows the CPS failure detection both at low and high rotational speeds. The method is implemented and tested on a Volvo S80 passenger car equipped with six cylinder prototype engine with the CPS mechanism.

8.2 The CPS State Detection Algorithm

A failure of the CPS mechanism in a single cylinder produces oscillations of the period of 720 CA degrees in the intake manifold pressure signal. The amplitude of the oscillations is amplified in the case of the failure of a single Bank due to the ignition synchronized coupling of the CPS cylinder groups. The amplitude of the component of the pressure signal whose period is 720 CA degrees is used in this Chapter for the detection of the CPS Bank failure. The phase of the mentioned above component indicates which Bank is failed. Figure 8.1 and Figure 8.2 show the harmonic contents of the intake manifold pressure signal at 1000 rpm and 4000 rpm for healthy and failed systems. Amplitudes are plotted as a function of a harmonic number of a periodic signal with the period of 720 CA degrees. The harmonic number is defined as an integer which is equal to the ratio of two periods, \( n_h = \frac{T_20^\circ}{T_h} \), where \( T_h \) is the period of the harmonic. Measurements were conducted during normal