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Torsional system parameter identification of internal combustion engines under normal operation

Fredrik Östman *, Hannu T. Toivonen

Department of Information Technologies, Åbo Akademi University, FIN-20520 Åbo, Finland

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ABSTRACT

For internal combustion engines, lumped-mass models of the crankshaft system are frequently used for torque estimation in control and diagnostic applications, such as cylinder balancing and misfire detection. Due to inherent model uncertainties and changing system dynamics it may be necessary to adapt the model parameters from time to time in order to preserve the required model accuracy. In this paper a frequency-domain method for on-line identification of the parameters describing the torsional dynamics of internal combustion engines is presented. In the proposed method, the engine is excited by adjusting the cylinder-wise injected fuel amounts, and the measured responses in torsional vibration frequency components are used for parameter estimation. As the fuel-injection adjustments can be determined in such a way that the net indicated torque is unaffected, the identification can be performed on-line without disturbing normal engine operation. The procedure can be applied to estimate the torsional stiffness and damping parameters of the flexible coupling connecting the engine and the load. In addition, the gains which describe how the cylinder-wise fuel injections affect the amplitudes of relevant torsional vibratory frequency components are obtained. The parameter identification method is successfully evaluated in full-scale engine tests on a 6.6 MW six-cylinder medium-speed common-rail diesel engine.

1. Introduction

The monitoring of fuel combustion processes in internal combustion engines has in recent years become increasingly important due to a continuous demand of lower fuel consumption and increasingly stringent emission legislation. One of the most efficient and straightforward ways to monitor the fuel combustions is to measure the in-cylinder pressures, which contain extensive information about the fuel combustion process and can easily be used for balancing the cylinder-wise torques and detecting misfire [1]. Measuring the cylinder pressures has recently become more feasible for Otto engines using clean fuels such as petroleum and gas. In contrast, for diesel engines operating on heavy-fuel oil, cylinder pressure measurements are still not a practical and cost efficient solution. This is mainly due to the high combustion temperature and cylinder pressure as well as the formation of deposits on the pressure sensor. Therefore, there is a need for alternative fuel-combustion monitoring techniques that use indirect measurements of the cylinder-wise fuel combustion performances.

A frequently applied approach for combustion monitoring is to use angular speed measurements of the crankshaft to determine the cylinder-wise torque contributions of the engine [2–6]. For high-speed engines where the engine is dynamically decoupled from the load and where the crankshaft is sufficiently rigid, the cylinder-wise oscillating gas-torque

* Corresponding author. Tel.: +358 10 709 4333; fax: +358 6 317 1906.
E-mail address: fredrik.ostman@wartsila.com (F. Östman).

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