Linear Load Estimation of Medium-Speed Diesel Engines

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***Abstract*—The operating condition for medium-speed marine and power plant engines are usually described in terms of engine load and speed. Especially engine load is widely used for calculation of controller parameters and set points for both internal and external control circuits. Obtaining an external measure of the engine load can, in certain circumstances, be difficult to achieve at an acceptable cost, e.g. for marine diesel-mechanic installations. In order to eliminate the need for an external power-measurement system, a linear engine-load estimator is proposed in this paper, which utilizes the so-called Willans approximation. Despite the straightforward linear approach, a sufficient accuracy is achieved in order to be used for control of the engine. The proposed method is successfully tested on a 1 MW common-rail diesel engine, where the estimated engine load is used by the engine control system for calculation of set-points and controller parameters.**

I. INTRODUCTION

ENVIRONMENTAL regulations have in recent years increased the demands of the engine-control quality, not only for automotive applications, but also for marine and power plant installations. In order to ensure the control quality, regardless of the prevailing situation, the control circuits need to take into account the current operating condition of the engine.

The engine speed and load describe the fundamental state of the engine and are thus widely used for determining set-points and parameters in engine control circuits, such as control of engine speed, wastegate, cooling system, etc. For common-rail diesel engines, the engine load signal is particularly important for calculating the set-point of the fuel pressure, since it directly affects the NOx emission and soot generation level [7]. In addition to the internal engine-control system, the engine load is also useful for external control circuits and measurement systems, for example propeller-pitch control in marine systems and overall supervision systems.

In diesel-electric marine and power-plant installations, the engine load is usually directly obtained from the generated electric power of the generator. This requires, however, that a) a generator is present and b) that it constitutes the whole engine load. For example, for diesel-mechanic marine engine systems, where the diesel engine is mechanically connected to the propeller shaft and alternatively also to an auxiliary generator, the measured electric power of the generator cannot be used, since it does not necessarily correlate with the total engine load.

The problem of estimating the engine load is not new. Several different approaches have been developed for estimating both the instantaneous and average torque acting on the crankshaft of automotive engines. An often revisited approach is to reconstruct the oscillating torque component from the measured angular speed of the flywheel by means of a lumped-mass model of the engine [8], [5], [9] and [10]. By assuming that the crankshaft is rigid and that the engine is sufficiently decoupled from the load, the oscillating torque component applied on the flywheel can be reconstructed by means of a simple lumped-mass model comprising of one mass [11]. To obtain a measure of the net indicated torque, the fact that oscillating torque level is linear with respect to the net indicated torque, is usually used [8] and [10].

In [6] a Kalman-filter method has been suggested, where the oscillating torque component is reconstructed from the measured angular speed in the same manner as previously described. Instead of directly relating the oscillating torque component to the net indicated torque, discrete measurements of the engine-load torque are obtained by taking into account the fact that the instantaneous torque is zero when the piston is at the *top dead center* (TDC) and the *bottom dead center* (BDC). The instantaneous torque can hence be estimated as the sum of the engine-load torque and the oscillating torque component. A stochastic method has been suggested in [8] where several different basis functions are used to build cross-correlation matrices for estimating the instantaneous torque from the measured angular speed. In terms of net indicated torque contribution, a nonlinear engine torque estimator was suggested in [3], where measurements of the angular speed, air-fuel ratio and fuel injection durations and angles were utilized along with an LQ control strategy in order to address the problem as a tracking problem.

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