

RAPID PROTOTYPING OF MODEL BASED CONTROL ALGORITHMS FOR DIESEL-ENGINES WITH TURBOCHARGER

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Summary A Control Prototyping system for the design of electronic control unit (ECU) functions for truck Diesel engines is presented. By this way the different steps of the control development can be optimized. As an application example, the design of a control algorithm for the charging pressure of a variable geometry turbocharger is described. The modeling process for the required dynamic nonlinear turbocharger model with variable turbine geometry (VTG) and the resulting control performance is shown in detail.

INTRODUCTION

Without appropriate tools for the design, implementation, and test of new engine control algorithms, the tight schedules in the development process of engine control systems can not be met anymore. Especially in the automotive industry, the concurrent design of engine, body and electronics requires efficient development methods. In this context the model based control design increasingly plays an important role in all steps of the development process. The Control Prototyping is used to test the new control function together with the real already existing control unit and the simulated or the real process. In contrast to the Software-in-the-Loop simulation, only a selected subset of the ECU functions is realized as a software model. Only these interesting parts are calculated on a real-time computer system in a bypass mode to the real ECU. The presented real time system for the design of engine control functions was developed in cooperation with the DaimlerChrysler AG. The presented application demonstrates as one example an efficient way to design a control algorithm for the turbine inlet guide vanes of a variable geometry turbocharger.

TURBOCHARGER MODEL

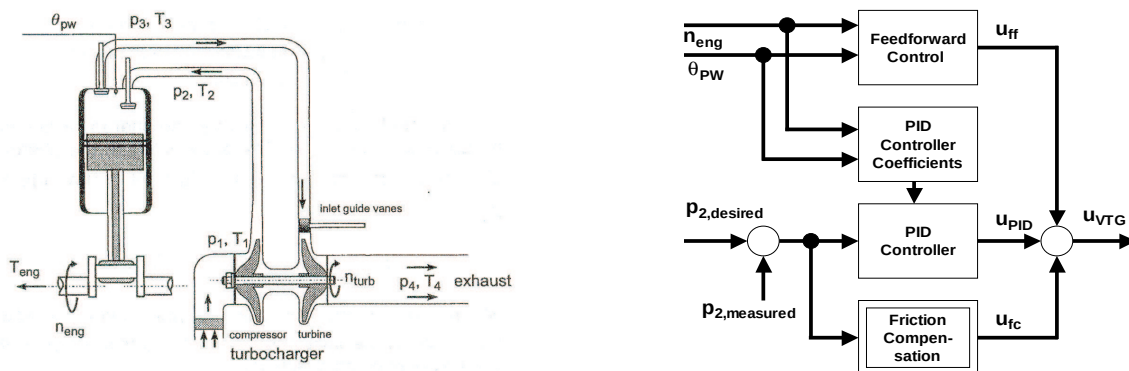


Figure 1. Basic structure of a Diesel engine with a variable turbine geometry turbocharger (VTG) and VTG controller with friction compensation

Figure 1 schematically represents the exhaust turbocharger with variable turbine geometry (VTG) (Heywood, 1988). For the charging pressure control the position of the turbine inlet guide vanes u_{VTG} is the input and the charge pressure p_2 is the output variable. The charging process has a nonlinear static input/output behavior as well as a strong dependency on the dynamics on the operating point. There are several ways to build a model of a turbocharger: (Isermann *et al.*, 1998)(Kessel *et al.*, 1998). In general, the static behavior of the turbocharger may be sufficiently described by characteristic maps (Look-up tables) of the compressor and turbine. However, if the dynamics of the turbocharger need to be considered, basic mechanical and thermodynamical modelling is required. Practical applications have shown that theoretical models are capable of reproducing the characteristic dynamic behavior of the turbocharger. The model quality, however, essentially depends on the accurate knowledge of several process parameters, which have to be laboriously derived or estimated, in most cases by analogy considerations. A further disadvantage is the considerable computational effort due to the complexity of these models. For these reasons, simple and easy identifiable input/output models suitable for real-time simulation are required for typical control engineering applications such as controller design, fault diagnosis and hardware-in-the-loop-simulations. Therefore, realtime capable Neural Networks (LOLIMOT (Nelles, 1999)) are chosen. The pulse width of injection θ_{pw} , the engine speed n_{eng} , and the control signal for the turbine inlet guide vanes u_{pwm} are chosen as inputs while the charge-air pressure p_2 is the output. The sampling time is $T_0 = 0.1s$.

CONTROL PROTOTYPING SYSTEM

In this section, the development system for the design of truck Diesel engine management systems is presented. The Control Prototyping is used to test new ECU functions together with the simulated or real process in a bypass mode to the real ECU. To fulfill the necessary real-time constraints, a powerful computer hardware is required. The used real time computer system is based on a dSPACE-system equipped with digital signal processors and a DEC Alpha processor. This system has the advantage of a high computing power and the possibility to download models realized in MATLAB/SIMULINK to the real-time hardware in an automated way. If the Control Prototyping system is used together with the real engine, the necessary sensor signal inputs for the investigated ECU-functions can be accessed via an A/D converter and a CAN-interface. Different types of Control Signals (e.g. PWM-signals, continuous signals) can be generated by the dSPACE I/O-Boards. Signal conditioning is done by a voltage level converter.

APPLICATION EXAMPLE

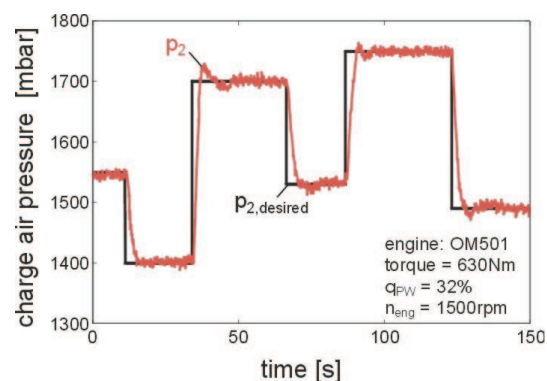
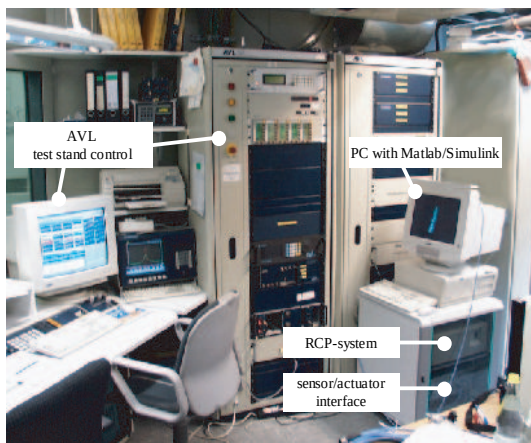


Figure 2. Dynamic engine test stand with Control Prototyping System and measured controlled charge air pressure for setpoint changes

As an application example, the development of a control algorithm for the turbine inlet guide vanes of a variable geometry turbocharger is presented. For this application, a PID controller with adaptive proportional and integral action factors and feed forward control was investigated (Figure 1). During the off-line simulation, MATLAB scripts may be used to perform a comprehensive set of automated simulation runs. The controller structure can be tested and an initial optimization of the parameters, based on the turbocharger model of section , can be done. MATLAB supports the optimization process with different tools and algorithms. After a promising controller structure is found, the Control Prototyping can be used to test the new control algorithm together with the real turbocharger and Diesel engine. Therefore a dynamic engine test stand, (Figure 2), or a real truck can be used. The VTG control algorithm is computed on the real-time hardware in a bypass mode to the already existing ECU. Important input signals of the controller, as the engine speed or the actual boost pressure can be transmitted via CAN bus. Additional sensor signals can be accessed via an A/D converter board. Figure 2 shows the charge air pressure set point ($p_{2,desired}$) and the measured charge air pressure (p_2) of an heavy truck diesel engine at the test bed. The controller output is generated by the dSPACE system, amplified and connected to the actuator for positioning the turbine inlet guide vanes. With the method of Control Prototyping this new control algorithm could be tested together with the real process in real-time, before the function was implemented in the production ECU.

CONCLUSION

Modern techniques like model based control and Control Prototyping are increasingly employed in the automotive industry to reduced the development time and cost. It has been shown, that this method can optimize the development process of ECU control functions substantially. As an application example for model based control prototyping, the development of a PID control algorithm for the turbine inlet guide vanes of a variable geometry turbocharger was demonstrated.

References

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