Master Thesis in Marine Technology – 2016
Diesel Engine Controller Design for the Hybrid Power Lab

Ketil Land

Supervisors 1: Associate Professor Eilif Pedersen
Supervisors 2: Researcher Nicolas Lefebvre

NTNU
Norwegian University of Science and Technology

Problem

Currently, the Perkins diesel generator in the Hybrid Power Lab does not offer sufficient power and dynamic load capability. The reason for these limitations is assumed to be the current Engine Control Unit (ECU) installed on the engine.

Objective

1. Design and install a new ECU that controls the engine speed for the Perkins engine in the Hybrid Power Lab.
2. Test the new ECU with variable engine speed and zero generator load.

Introduction

No data is available for the current ECU control algorithm and no data are available for the quantity of fuel injected by the fuel injectors. Therefore a reverse engineering method is used to mirror the current ECU behavior into the new developed ECU.

The engine fuel system is of Hydraulic Electric Unit Injector (HEUI) type from Caterpillar [1] as shown in figure 1. It consists of a low pressure fuel pump, a high pressure rail oil pump, rail oil pressure sensor, rail oil pressure regulating valve, camshaft speed pickup, ECU and one HEUI for each cylinder. The HEUI combines a high pressure injection unit and an injector nozzle in one unit and is hydraulically powered by high pressure oil supplied by a high pressure rail oil pump attached to the engine. An electrically controlled valve on the injector allows high pressure rail oil to

Reverse Engineering

Reverse engineering is the method chosen for the design of the new ECU. Therefore a number of engine tests with the old ECU is performed to collect data to mirror the old ECU behavior into the new ECU. The two main control parameters for controlling engine speed are presented here; rail oil pressure and injection duration.

The current drawn by the injectors consist of three phases [2], see figure 2; phase one is a sharp increase in the current from 0 to 6.7 [A] in 0.5 [ms] referred to as the attack phase. In phase two the current is kept at 6.7 [A] for 1.2 [ms], this is the holding phase, before the current is dropped to 4.3 [A] in phase three, the withstand phase 1.3 [ms]. Thus the longest injection duration is 3.0 [ms]. Figure 3 shows how the current varies for different injection durations. Figure 4 show how the injection duration varies with generator load and engine speed. Rail oil pressure controls rate of fuel injected and is shown in figure 5 as a function of generator load and engine speed.

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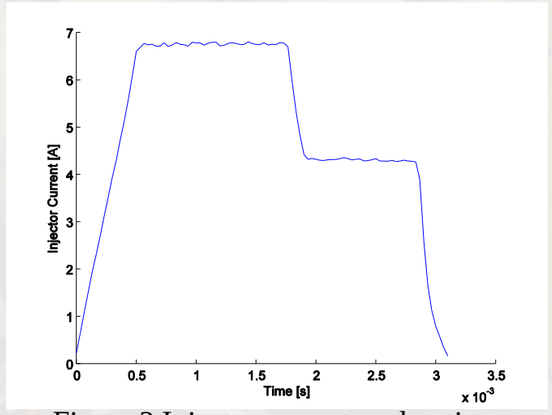

Figure 2 Injector current vs duration.

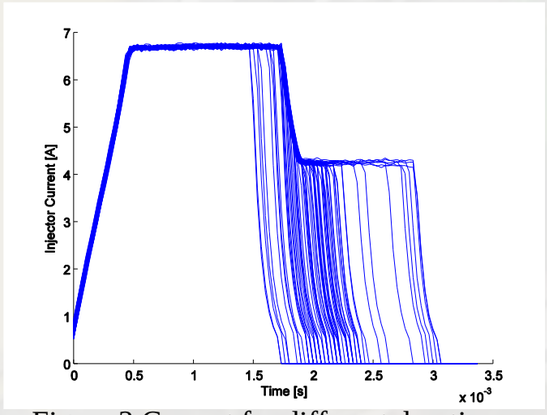

Figure 3 Current for different durations.

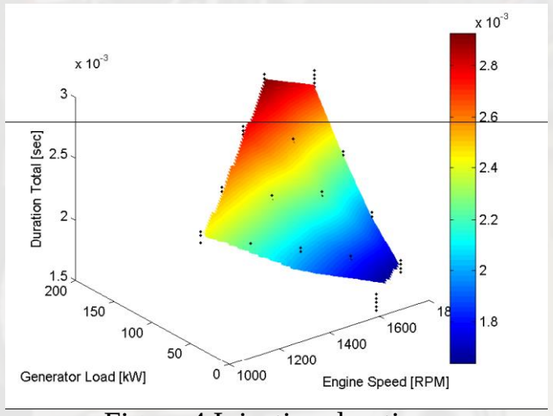

Figure 4 Injection durations.

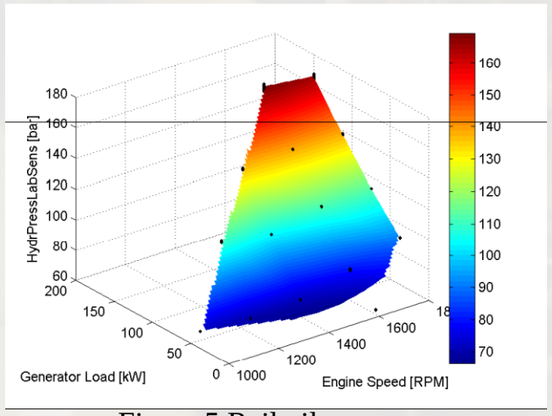

Figure 5 Rail oil pressure.

stroke a valve piston in the injector. This piston is connected to a piston in a fuel chamber. The piston area for the hydraulic oil side is larger than for the fuel side, the ratio can be ~6 [1]. This gives an increase in the fuel pressure in the fuel chamber when the hydraulic oil piston strokes, in accordance with Pascal's law. When the fuel pressure force is higher than the spring force the injector nozzle will open. By adjusting the hydraulic oil pressure and controlling the electric oil valve in the injector, both injection rate and time is controlled. To determine crankshaft position and speed the ECU uses the camshaft speed pickup sensor. This is used in the injection control algorithm to open the HEUI.

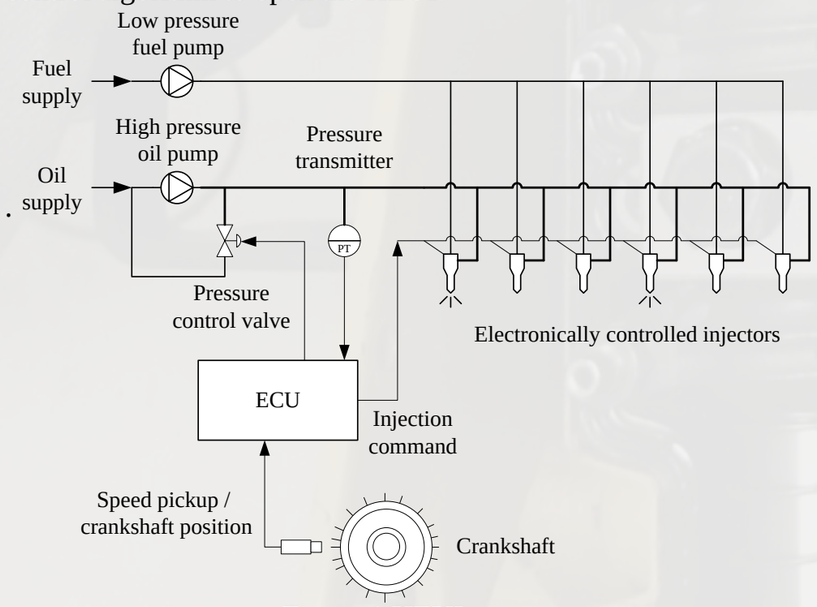

Figure 1 HEUI system

References

[1] Caterpillar (2006). "*System Operation Testing and Ajusting 3126B and 3126E Truck Engine*", Caterpillar.

[2] Sybele (2009). "*Use of Inductive Injectors Driver IMS06*", Sybele by Skynam.

Acknowledgements

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Engine Testing

A new ECU algorithm is developed in Labview CompactRIO with inputs from the reverse engineering data. The new ECU is tested with the engine running. Figure 6 shows the resulting current drawn by the injector with the algorithm developed, (6.7 [A] = 1.34 [V]). A pulse width modulation (PWM) algorithm is used. Yellow line is current and cyan is the PWM signal. The shape of the current resembles the result from reverse engineering, figure 2 and 3. Current spikes due to the PWM is seen. Theses are not in figure 2 and 3 and the reason is a different filtering time for the measuring tool used for reverse engineering.

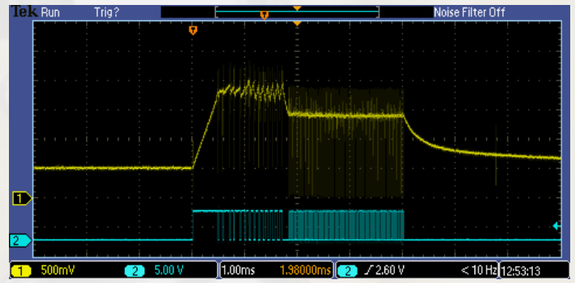

Figure 6 Injector current wtih new ECU.

During engine testing it was experimented with different injection durations and start of injection. A to retarded injection (late injection) resulted in white/greyish smoke escaping the exhaust stack, see picture 1. The smoke had a strong smell of unburnt hydrocarbons. When studying the cylinder pressure it is seen that ignition is very late. This is shown in figure 7 where the ignition occurs around 380 [deg] which is 20 [deg] after top dead center, with a cylinder pressure of approx. 12 [bar], blue line. Red line is the injector current. Ideally the ignition shall be an extension of the highest compression pressure in the cylinder. By advancing start of injection and decreasing duration the white smoke disappeared.

Picture 1 White/greyish smoke.

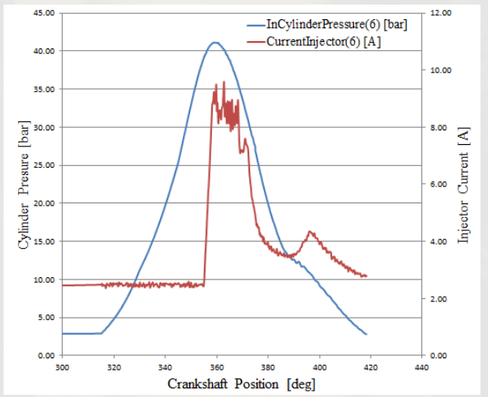

Figure 7 Late ignition.

Conclusion

A new ECU is developed that controls the engine speed by regualting rail oil pressure, start of injection and injection duration. Rail oil pressure and injection duration are closely related and a long injection duration requires a high rail pressure, so that the hydraulic pressure force opens the injector needle earlier for fuel injection. Different injection parameters is tested and a to retarded injection resulted in white/greyish smoke with a strong smell of unburnt hydrocarbons escaping the exhaust stack. The engine is running smoothly with the retarded injection.