Modeling of the Gas Exchange Process in Variable Cam Timing Engines

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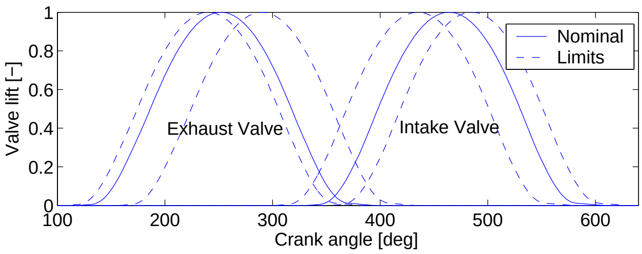
Background

Engine designers are faced with the problem of minimizing vehicles environmental impact as the regulations becomes stricter. It is evident that all possible concepts have to be exploited to their full extent to fulfill future requirements.

Setting the cam timing for an engine is a compromise. *Variable Cam Timing* (VCT) provides a solution to this compromise by allowing the *Engine Control Unit* to change the valve timing during engine operation. A typical situation is presented below.



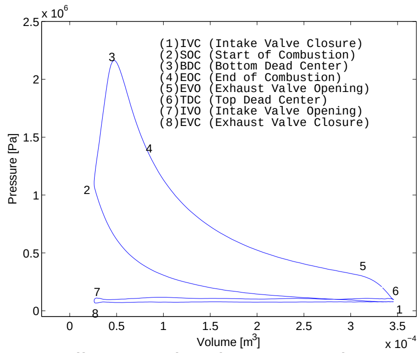
Typical valve profiles for a variable cam timing engine. In this case both intake and exhaust valve timings are adjustable.

Models that predict the residual gas fraction are important for cam timing control as the residual gas fraction is a limiting factor for stable engine operation. Also, models that predict the air charge are important as the air/fuel control strategies used for engines without variable cam timing are not easily adapted to these new degrees of freedom. Solutions exists, but they do not use the VCT concept to its full extent. Therefore residual mass fraction as well as air charge models are needed.

Modeling the Intake Process of the Variable Cam Timing Engine

Physical models have benefits over other models in that they are easily adapted to new engines. They have better reliability when used outside the region for which they are verified and they often provide insight in the systems inner workings. These are all useful properties when designing a control strategy. Therefore only physical models are being considered during the model development.

A combustion and gas exchange model is being developed using thermodynamic relations and physically motivated approximations. The model simulates the processes in the engine using a set of differential equations and is implemented in MATLAB SIMULINK. This model will be used to examine which physical effects are important when modeling the intake process. Using insights from studies of the combustion and gas exchange model, a simpler cycle model will be developed. The combustion and gas exchange model will then be used as reference model.



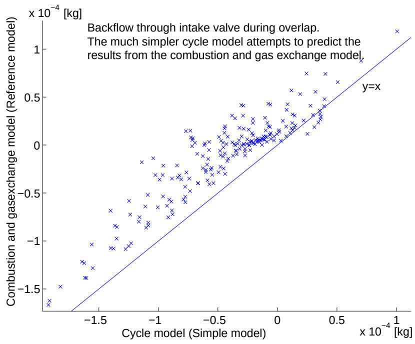
A pV-diagram showing a complete engine cycle for a typical engine.

The simpler cycle model being developed focuses on the valve overlap period (point 7-8 in the figure), because this is the only period during the engine cycle when bookkeeping is really important and because the flow during this overlap is one of the larger contributors to the difference in the intake processes for engines with and without variable cam timing.

When a model that predicts the flow during the overlap period is found, a complete cycle model will be put together using several other models covering other parts of the cycle. The set of equations given for the complete model usually have a tendency to require iterative solution methods. Using modern processors in modern *Engine Control Units*, this is not a problem.

Ongoing research

Currently there is an ongoing attempt to predict residual mass fraction and air charge using a cycle model and the concepts mentioned above. The cycle model used is based on the assumption that the valve flows stays in equilibrium during the entire overlap period. The assumption can be interpreted as that the change in valve lift is a slower process than the cylinder pressure process. Using this approach a measure of the flow during the valve overlap is found. To the left a comparison between the combustion and gas exchange model and the cycle model is shown. The straight line represents $y = x$, i.e. crosses on the straight line means that the simple cycle model were able to predict the results from the full combustion and gas exchange model. As can be seen there is a systematic error in the model, but note that the model only has physical parameters and there are no fitted parameters. Considering the low complexity of the cycle model this is a very promising result.



A comparison between backflow from simulations using the combustion and gas exchange model, and the cycle model. Note that only physical parameters are used, i.e. there are no fitted parameters.