Summary

Introduction and Objective

Injector

- Injector Model Building

- Creation of Injection Rate Map

Combustion

- The cylinder pressure analysis

- Combustion – Calibration of DIPulse

Conclusion

More to come

- The engine block
Introduction and Objective

Improve engine part-load modeling to be able to accurately predict thermal fluxes.
Introduction and Objective

Build a predictive combustion model

- **Injection Rate Map**
  - **Inputs**
    - Start of spray timing
    - Injected mass per pulse
  - **Output**
    - Injection rate profile

- **Experimental Burn Rates**

![Graphs showing measured cylinder pressure and combustion burn rate](image-url)
Injector Model Building

Why?

- The accuracy of the measurements of the fuel flow rates is not good enough for DIPulse
- The data smoothing process could be tedious
  - Especially for the low injected quantity
- The injector model also offers possibilities for further studies of the fuel system dynamics (shot to shot variation)

Steps
Injector Model Building

Model Building Process

- Measurement of dimension and mass of all the parts (18) within the injector with a specific machine

- Put together all the parts to generate the CAD model of the injector

- Import of the CAD model in SpaceClaim to extract the fluid volumes
  - For example the volume surrounding the needle
Detailed Model Building

- The first step is to build the mechanical parts
- The second step is to build the interaction of the fluid and the mechanical parts
- The third step is to build the piping network
- The last step is to build the electric system

1 week of works

deployment of the needle
Injector Model Building

- Calibration of the injector model base on test bench
  - Calibration of the discharge coefficients
    - Z Nozzle
    - Needle Hole
- Optimization in GT

2 weeks of works
Injector Model Building

Operating Point

Energize Time vs. PRail for Mesure Point
Injector Model Building

Calibration

![Chart showing calibration points and mesure points on a grid with PRail and Energize Time axes.]
Creation of Injection Rate Map

ET 1300 us - 500 bar
Gain part Gain-1-1

ET 1100 us - 1800 bar
Gain part Gain-1-1

ET 300 us - 300 bar
Gain part Gain-1-1

ET 600 us - 1600 bar
Gain part Gain-1-1
The injection rate map was then generated automatically thanks to the injector model, through a DOE process.
Creation of Injection Rate Map

GT creates a new gtm with only the InjMultiProfileConn part and the InjectorRateMap reference object
Creation of Injection Rate Map

GT creates a new gtm with only the InjMultiProfileConn part and the InjectorRateMap reference object.
Combustion – DI Pulse

Steps

- Cylinder pressure analysis
  - Cylinder pressure matching (GT vs Test)

- Selection of the calibration points

- DOE on the DIPulse parameters (4)
Combustion – the cylinder pressure analysis

**CPOA model**

**Input**
- Air volumetric efficiency
- Residual fraction
- Compression ratio
- Cylinder wall temperatures
- Accurate injection timings and mass per pulse
- Measured instantaneous cylinder pressures
Combustion – the cylinder pressure analysis

Exemple of Burn Rate obtained with CPOA model

![Graph showing cylinder pressure and burn rate](image-url)
Combustion – the cylinder pressure analysis

Engine operating points

% of Torque Max

RPM

Point of test bench
Combustion – the cylinder pressure analysis

Point for the calibration of DIPulse

% of Torque Max

RPM

Point of test bench  Calibration
Combustion – Calibration of DIPulse

- DIPulse parameters
  - Entrainment multiplier
  - Ignition Delay multiplier
  - Premixed combustion multiplier
  - Diffusion Combustion multiplier

- DOE

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DOE Type: Latin Hypercube

# of Experiments: 2000
Combustion – Calibration of DIPulse

DOE post process and DIPulse parameters fitting with the GT-supplied Excel spreadsheet

This spreadsheet is to be used to assist in finding the optimum calibration constants for the DIPulse model following the procedure developed for V7.3 build 1 and later. Please run the model according to this procedure, then save this file to the same folder as the model. Fill in the white cells above and press the "Fit DIPulse Constants" button. For more information regarding the calibration procedure, please contact us at support@gtisoft.com.

This spreadsheet is solely for the use of licensed users of GT-SUITE and is subject to the licensing agreement with Gamma Technologies Inc. Copyright 2013.
Combustion – Calibration of DIPulse

Cylinder Pressure

Increase of the torque

Increase of the engine speed

Increase of the torque
Combustion – Calibration of DIPulse

Burn Rate

Increase of the torque

Increase of the engine speed

Crank Angle [deg]

EngBurnRate part toa

Burn Rate [1/deg]

Burn Rate - pred

Injection Rate

Start

Increase of the engine speed
Conclusion

Injection
- Even though we did not have very accurate measurement of all injector part dimension (for example hole diameter) we are able to get good result
- But to improve the quality of the result we would like to work with the injector supplier in order to get the injection rate map

Combustion
- If the analysis of pressure cylinder is accurate, the calibration of DIPulse is very quick and automatic
- The result is pretty good
  - The cylinder pressure simulate close to measure
  - The burn rate have the good shape but we still have difference due to missing input data
- We think the cylinder pressure result is enough to have a good prediction of heat fluxes (for cooling purpose)
More to come

- Calibrate several operating conditions of the engine block model in order to get the thermal behavior (fluxes and impact on water temperature).

- Integrate the block and the Fast Running engine Model (including DIPulse) to simulate the whole driving cycle.