Hydrogen-fuelled internal combustion engines: research at Ghent University

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IEA – TLM Heidelberg 13 August 2006

H_2 ICE session

Research Transport Technology group

- Alternative gaseous fuels (CNG, LPG, H_2, H_2+NG)
- Focus on hydrogen-fuelled internal combustion engines
- Started in 1991 in cooperation with, at that time, Hydrogen Systems (now part of the Hydrogenics – Stuart Energy fusion)
- Conversion of five engines on test bench, demonstration of two city buses on hydrogen and one city bus on a mixture of hydrogen and natural gas
- 'Spinoff' HydroThane NV: buses on H_2/NG mixtures
- Next to experimental work also numerical work, simulation of the power cycle of hydrogen SI engines

Demonstration (1)

- July 1994
- Greenbus - De Lijn (Flemish public transportation company)
- Partners: VCST - Hydrogen Systems NV (Belgium),
  UGent Transport Technology
- Fuel: hydrogen
- Sponsoring: Flemish Government and EU
- Engine: MAN 12l inline 6cyl
- Storage: metal hydrides

Demonstration (2)

- October 2000
- ZEMBUS (Zero Emissions Bus)
- Partners: Hydrogen Systems NV (Belgium, project coordinator), Vialle NV (the Netherlands), Trivea Technologies International SA (Luxemburg), Betronic BV (the Netherlands), Continental Energy Systems (Belgium), UGent
- Fuel: hydrogen
- Sponsoring: European Union
  Brite-Euram III - CRAFT
- Engine: DAF 8.6l inline 6cyl
- Storage: liquid

Demonstration (3)

- March 2005
- CTPT bus: Clean Technology for Public Transport
- Partners: UGent Institute of Sustainable Mobility of which our laboratory is a member and the Karel De Grote Hogeschool in Antwerp, Belgium
- Fuel: 'hydrothane'
  (20% H_2 / 80% NG)
- Sponsoring:
  the National Lottery of Belgium
- Engine: MAN 12l inline 6cyl
- Storage: compressed gas, 200 bar

Previous experimental work UGent

- Previous experience in alternative fuels: natural gas, development of liquid injection of LPG
- 1991: started work on hydrogen
  conversion of Valmet 4.4 litre inline four DI diesel to H_2 SI engine
  = proof of concept
  + initial findings led to focus of further research:
  - backfire-safe operation (cylinder pressure measurements, showing mechanism of runaway pre-ignition)
  - increase of the power output (supercharging experiments)
  - decrease of the NO_x emissions

Previous experimental work UGent

- 1995: conversion of GM 7.4 litre V8 (Chevy big block), first carburetted, mixtures H_2/CH_4, then MPI H_2
- First oil analysis of H_2 engine, showing effect of hydrogen presence in crankcase due to blowby
  Measures: crankcase scavenging
- Application of programmable motor management system and multipoint sequential injection system for H_2 (prototype injectors)
- Load control: wide open throttle, except at idling
- Experiments with supercharging

Current experimental work UGent

- CFR single cylinder, 612cc, variable compression ratio, fixed speed (600 rpm), sequential injection H2, EGR system + TWC
  - comparison of EGR to lean burn strategy
  - cylinder pressure measurements at variable IT, CR, AFR
- Audi single cylinder (prototype), 400cc, 1500-4000 rpm, dual sequential injection H2
  - research of abnormal combustion
  - cylinder pressure measurements at variable engine speeds
- Volvo 1.8 litre inline four, bi-fuel gasoline/H2, dual sequential injection of H2, variable intake cam timing
  - correlation residual gas scavenging – backfire (cam timing)
  - practical implementation of switching between fuels

Numerical work UGent

PhD “A study of the combustion in hydrogen-fuelled internal combustion engines”

PhD goal: Develop a model for the combustion of hydrogen in spark-ignition engines, to come to a simulation programme for the optimisation of these engines.

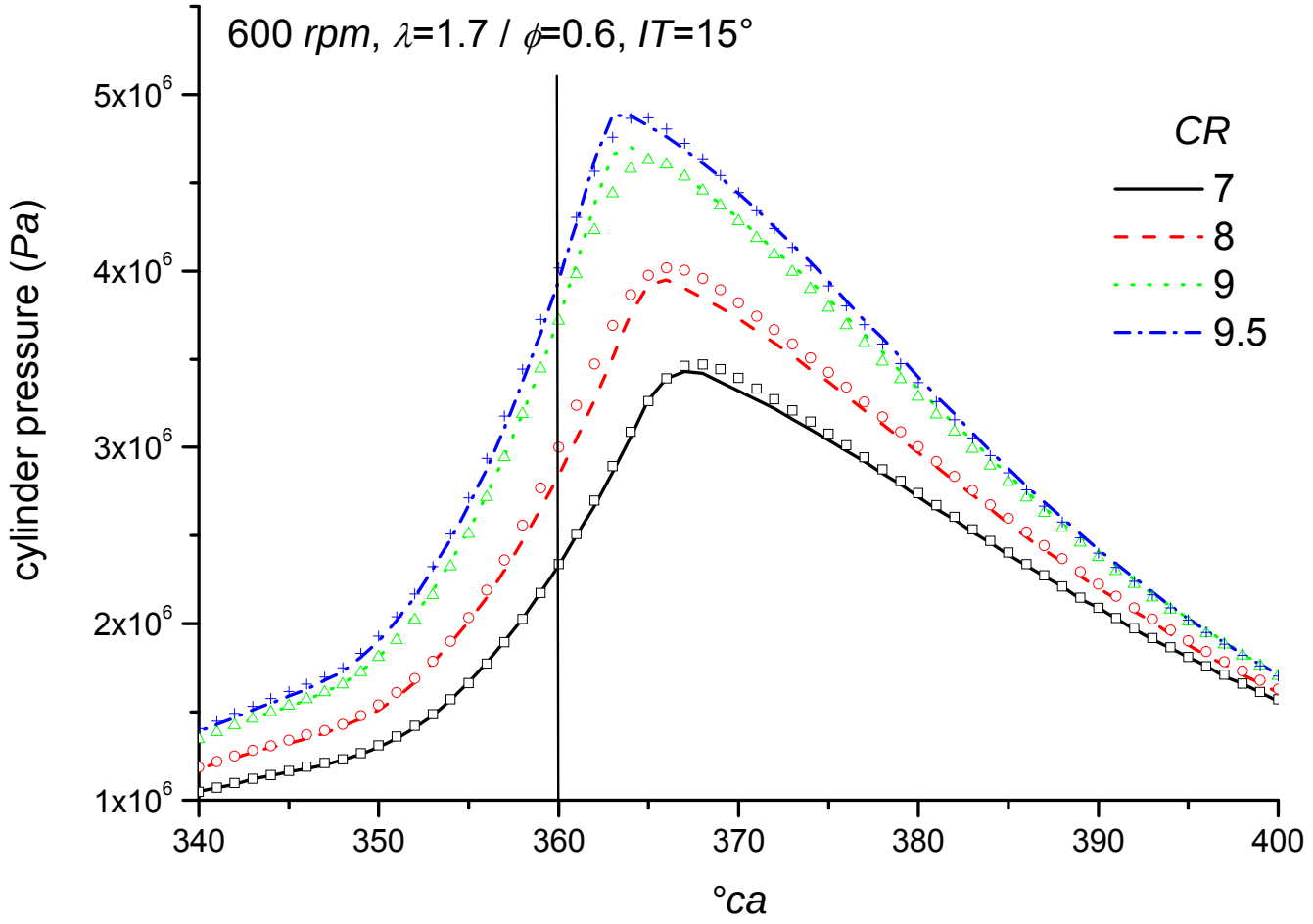
Background:

- 15 years of experience in the lab on hydrogen engines, all experimental work (engine test benches)
- wish to replace/supplement/support experiments by fast and cheap calculations
- experience in the lab on quasi-dimensional engine simulation

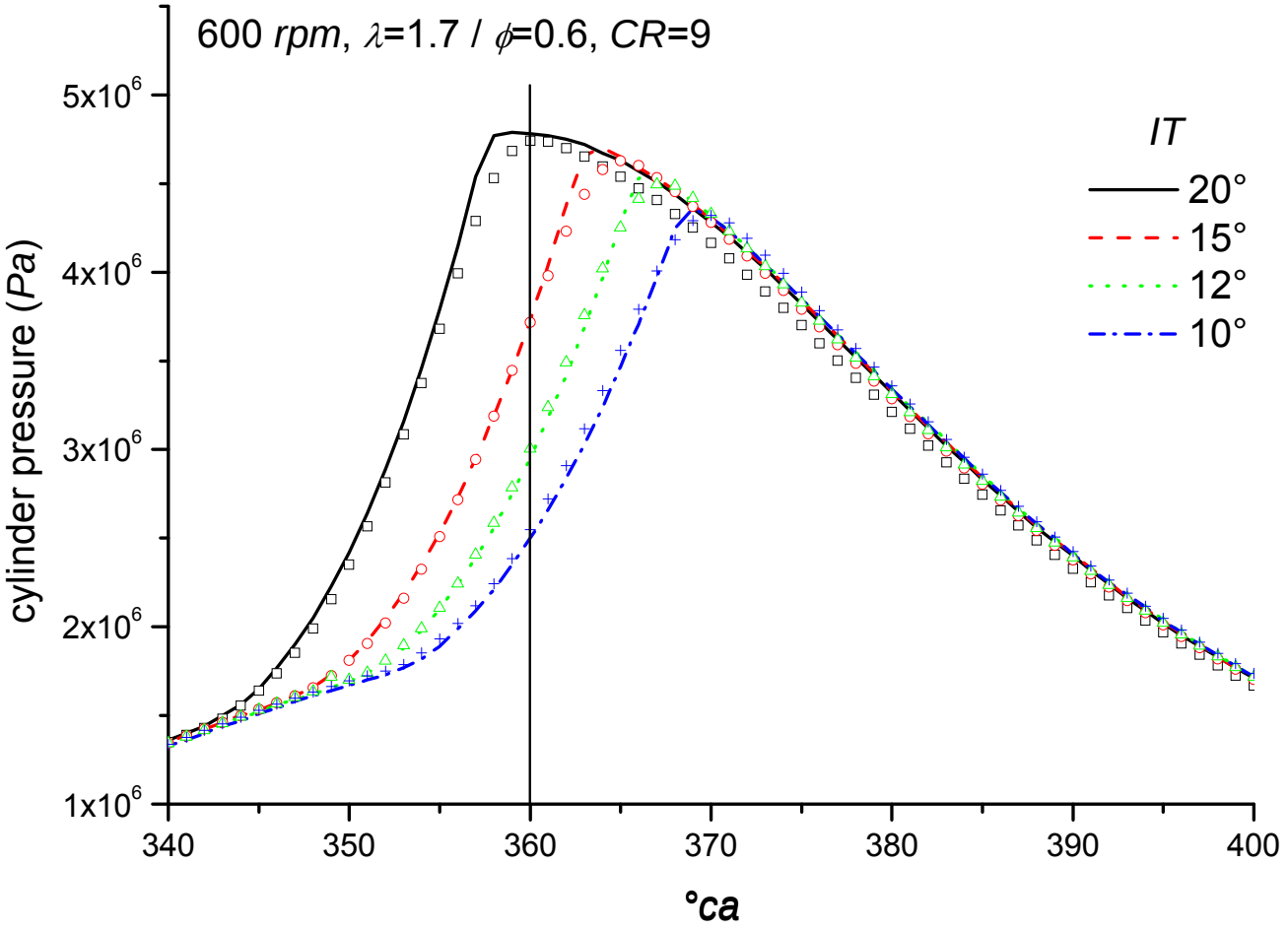
PhD contents

- Literature review of experimental and analytical research on hydrogen engines
  Summary of design features for dedicated H_2 engines
- Experiments on 3 engines: investigating conversion, engine settings, supercharging, load control strategies
- Most work on laminar burning velocities of hydrogen mixtures (building block for turbulent combustion model)
- Study of turbulent burning velocity: literature and experimental, selection of models
- Power cycle simulation: quasi-dim. class, evaluation of 6 turbulent combustion models by comparison with cylinder pressure measurements

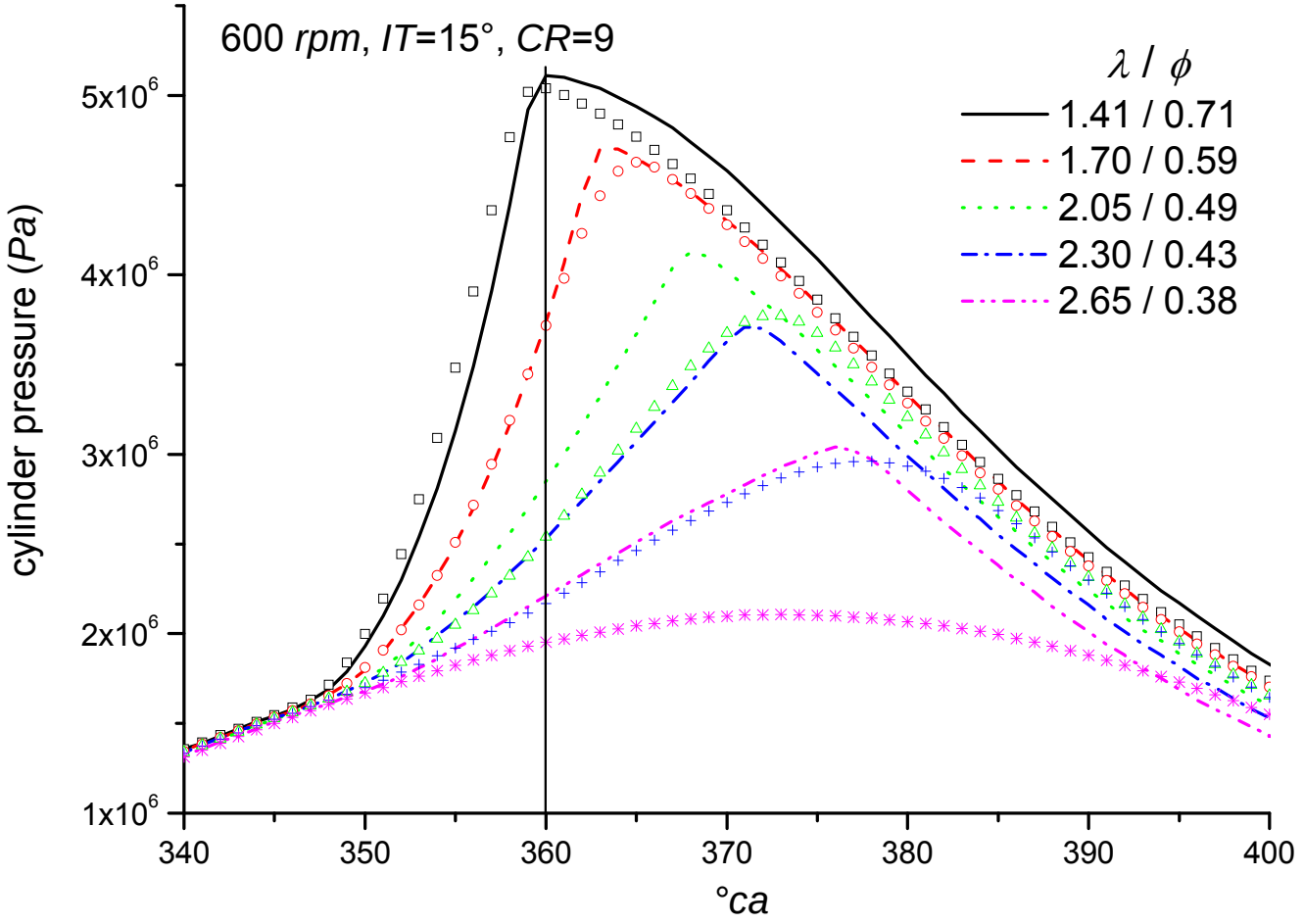
Variable compression ratio – pressure diagrams



Variable ignition timing – pressure diagrams

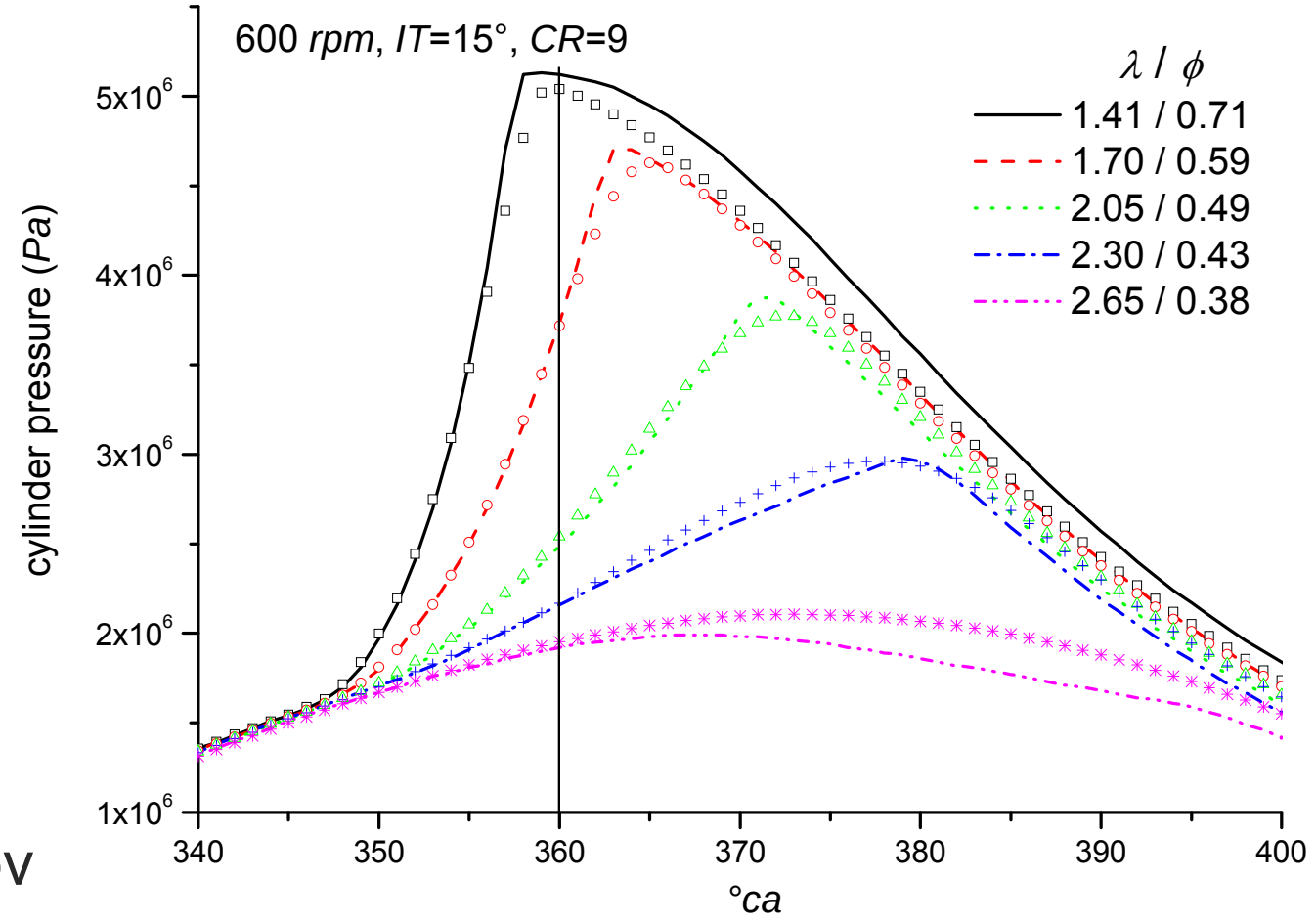


Variable equivalence ratio – pressure diagrams



Peters

Variable equivalence ratio – pressure diagrams



Lipatnikov

Research needs

Fundamental:

- Laminar and turbulent burning velocities (UGent: in cooperation with Leeds University, UK, and TU Eindhoven, NL)
- Turbulent combustion models for H_2 (UGent)
- Data on abnormal combustion, models
- Heat transfer for H_2 ICEs: data, model (UGent?)

→ coordinated effort towards a data base of burning velocities, engine combustion data (pressure, flame images, …)

Applied:

- Durability testing
- Effect of H_2 blowby on engine lubrication oil
- DI injectors

Project possibilities

- Hybrid vehicle with H_2 ICE:
  would be a first for EU (US: Ford, Texaco Ovonic)
  Currently writing up a proposal for developing a hybrid bus platform for testing H_2 ICE as well as FC
- Application of modern ICE technology for H_2: e.g. VVT
- Demonstration:
  assessing durability and every-day-use
- Commercial H_2 engine code, UGent goal:
  - Tool for optimisation of engines (fast, 0D)
  - Tool for development of new engines (3D)

See www.FloHeaCom.UGent.be/H2

(includes a link to the PhD pdf)