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State-of-the-art Technology for Combustion Analysis Application on Test Bench and In-vehicle Calibration

Dr. A. Bertola
Kistler Instruments

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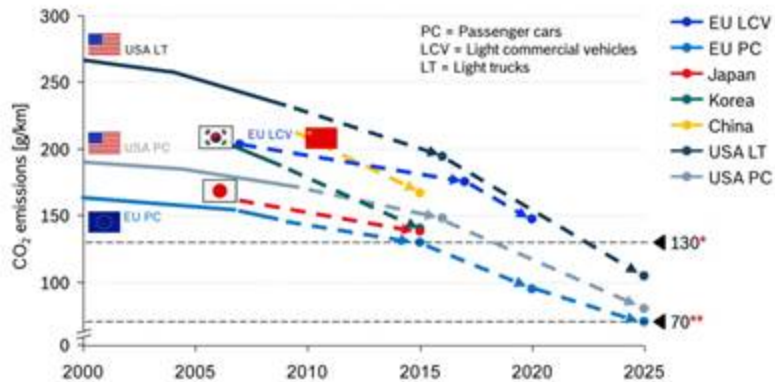
Thailand Automotive Institute
4th Floor, Bureau of Industrial Sectors Development
Building, Soi Trimit, Kluaynamthai, Rama IV Road,
Klongtoey, Bangkok 10110 Thailand
Tel: +66 2712 2414 | Fax: +66 2712 2415
Website : www.thaiauto.or.th

Outline

- Motivation
- Actual trends of combustion analysis
- Measurement layouts
- Test Bench application
- In-vehicle application
- Conclusions

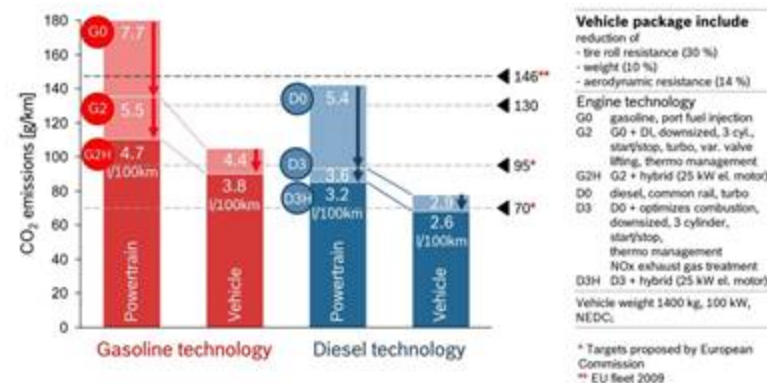
CO₂-targets only achievable via optimized combustion engines

CO₂ emission targets for newly registered light vehicles



* EU passenger cars (2015), ** EU passenger cars (proposal EU Commission for 2025)

Final CO₂ reduction by vehicle technology



Source www.bosch-press.de

Engine technology with downsizing, high IMEP, operation mode switching homogeneous-stratified, cylinder deactivation, stop-start ...

- Vehicles can become even more fuel efficient
- Lower emission regulations, advanced certification procedures
- Increased complexity for optimization, calibration
- Demand for easy-to-install, robust measuring equipment for P_{cy}l

Measurable variables



Force

Pressure

Torque

Rotation

Acceleration

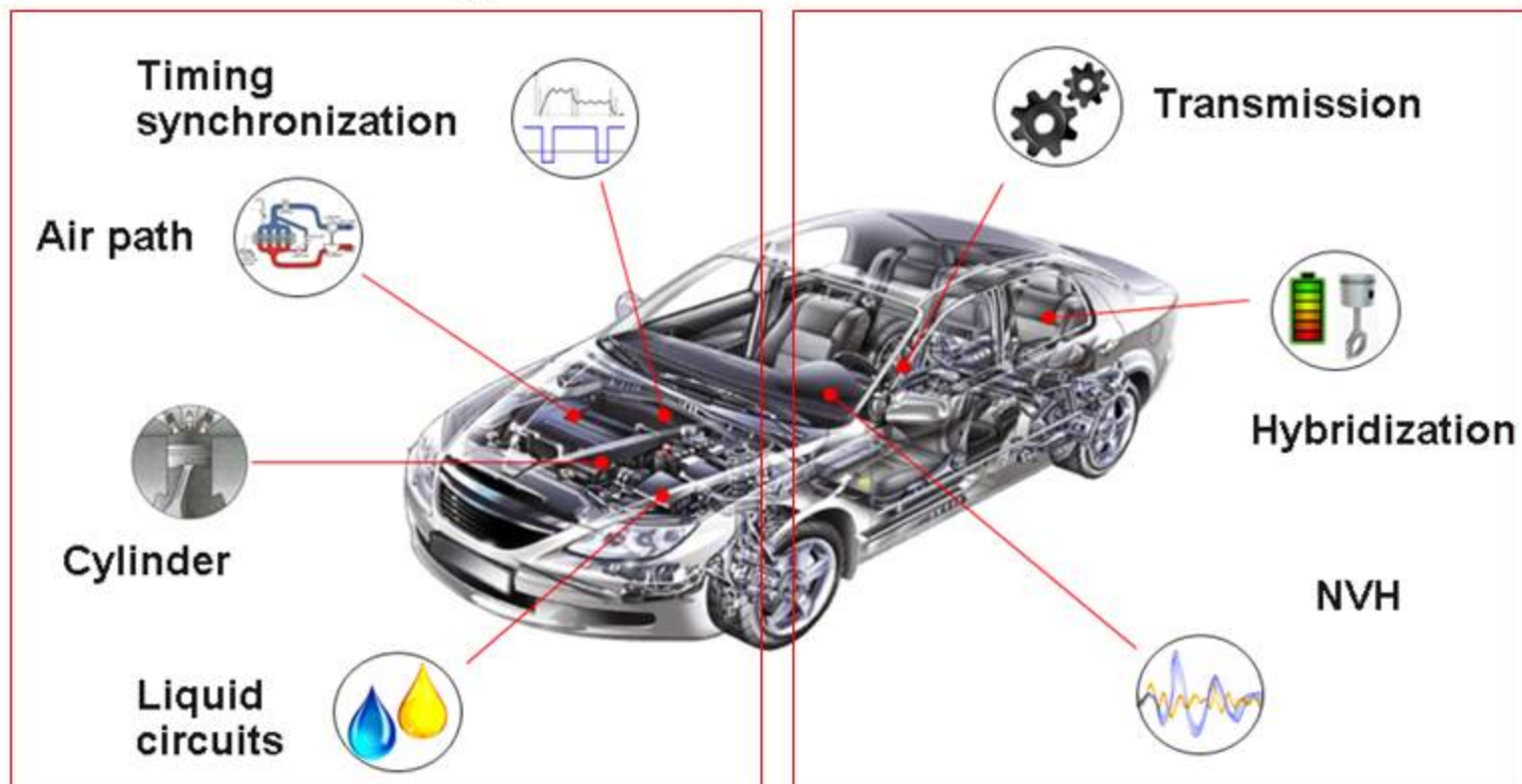
Electrical pulse

Displacement

...

Application field – challenges for OEM

Powertrain



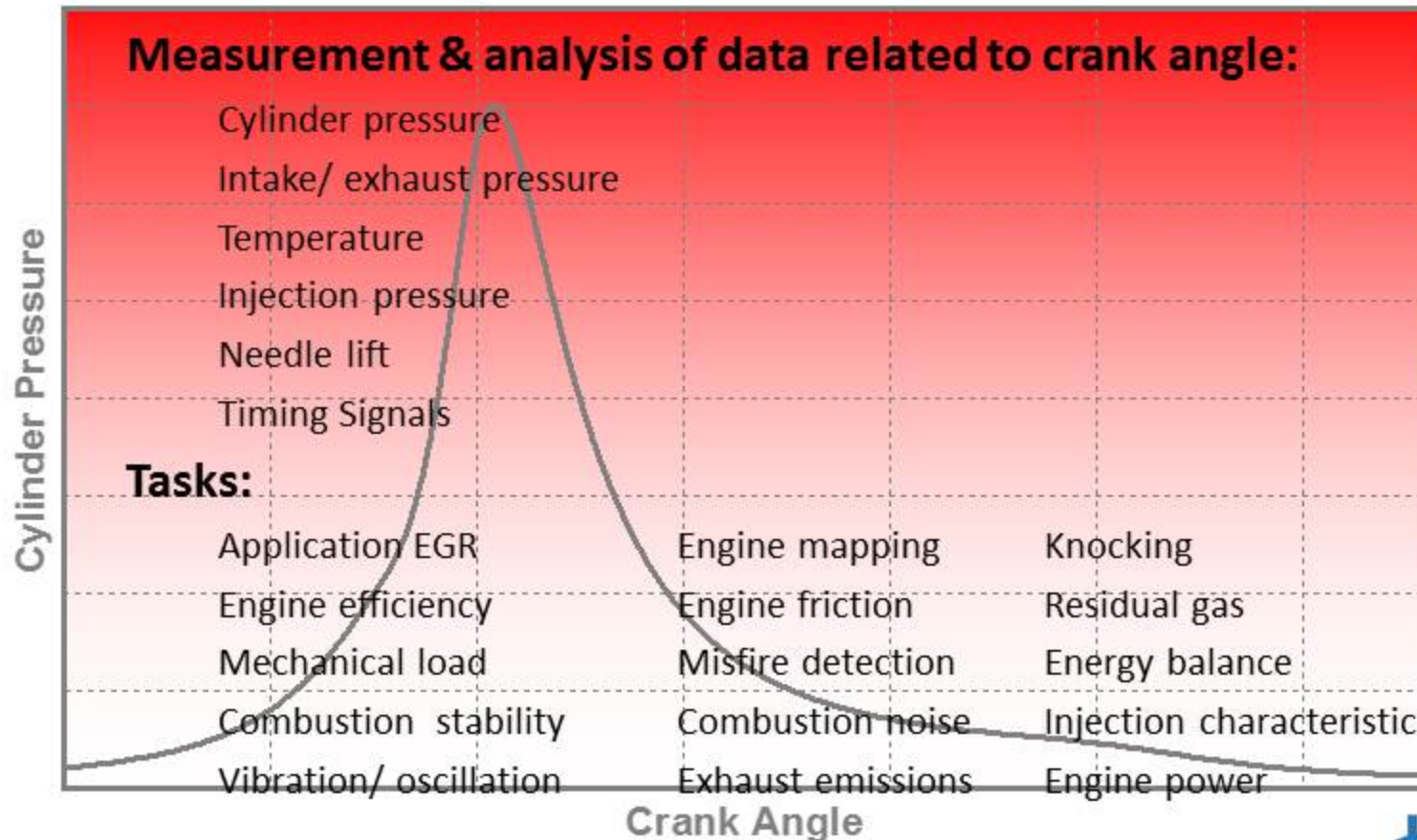
Combustion engine

Complementary
powertrain

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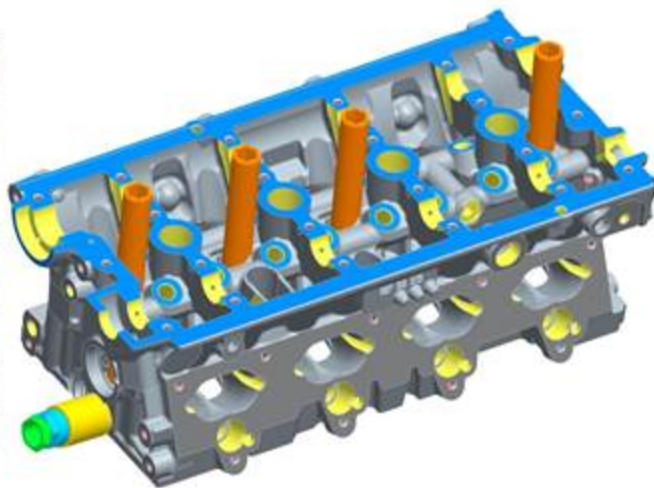
Combustion Analysis



Actual trends

- **Measurement in all cylinders**
 - Cylinder balancing, knocking
 - Gas exchange analysis
 - **Reduced space available in cylinder head**
 - Installation of measuring spark plugs/ glow plugs
 - Reduced sensor dimensions
 - **Increased peak cylinder pressures**
 - Increased pressure gradients, knocking operation
 - Higher accuracy
 - **Increased in-vehicle ECU calibration tasks**
 - ECU complexity
 - Reduced calibration tolerance
 - Engine start
 - **Electrification of power train**
 - High currents
 - Higher voltage ignition system
- > Multichannel system
-> Plug-and-play features
- > Miniaturization
- > Robustness, accuracy
- > Portable system
- > Low-noise system

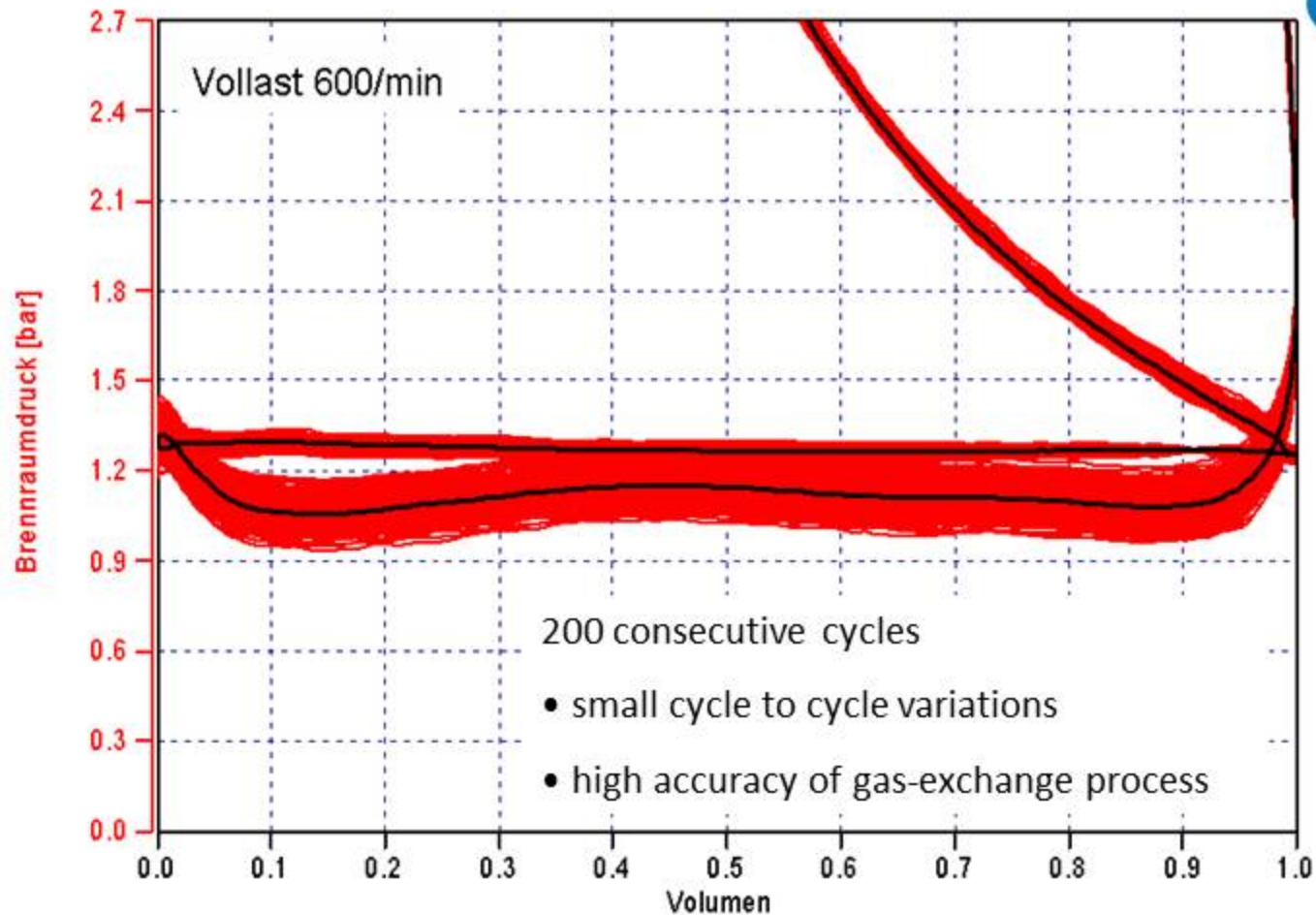
Application on test bench - R&D and engine calibration



- Plenty of space around the engine
 - Water cooling system for sensors (in-cylinder or exhaust)
 - Optical crank angle encoder
 - Laboratory electronic systems
- Cylinder head is prepared with additional bores
- Highest accuracy, reference measurements



Cylinder pressure during Gas exchange

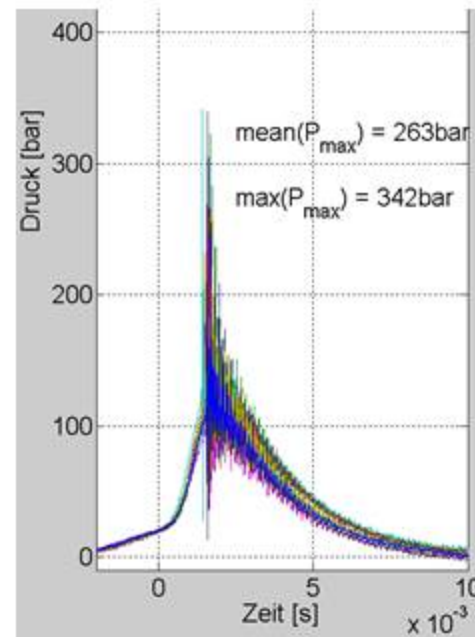
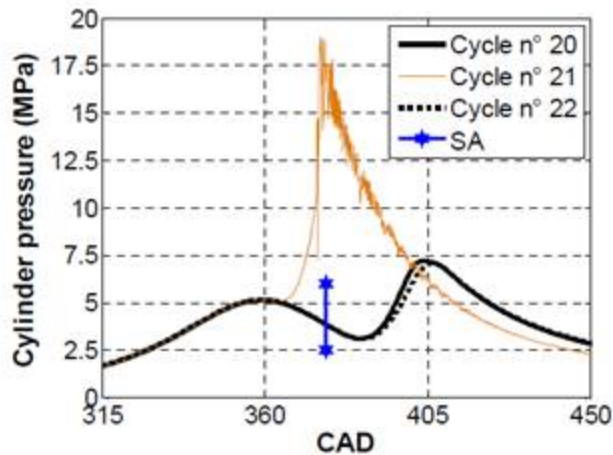


Accuracy



8mm sensor
Type 6045B

Pressure sensor resists to extreme load from abnormal cycles



Robustness



5mm sensor
Type 6054BR

Pre-ignition occurs before the spark ignition timing. The cylinder pressure in this illustration reaches 190bar whereas the normal cycles are limited to 75bar.

In-vehicle testing

Trend is to tune powertrains in driving conditions as close as possible to reality

- Measurements in real driving conditions are always transient
- Results available in real time, for every single cylinder , for every single combustion cycle

Future requirements for certification driving cycles

- Horizon 2020 / Euro 6.2
- Real driving conditions / RDE cycle
- China 5 / Beijing 6

Consequences:

- For practical reasons, need to adapt the testing equipment to on-board use (at least P_{cyl} + synchronization with crank angle)
- Users expect the same level of accuracy
- Integration of different systems

In-vehicle testing – engine ECU calibration

Source: ATZ



Source: PSA

- Extreme space constraints
- High power density
- Not invasive equipment

PSA EB2 DTS
3 cyl turbocharged
1,2L GDI
96kw (130ch)
230Nm



Test bench vs. in-vehicle testing

PR pressure sensors



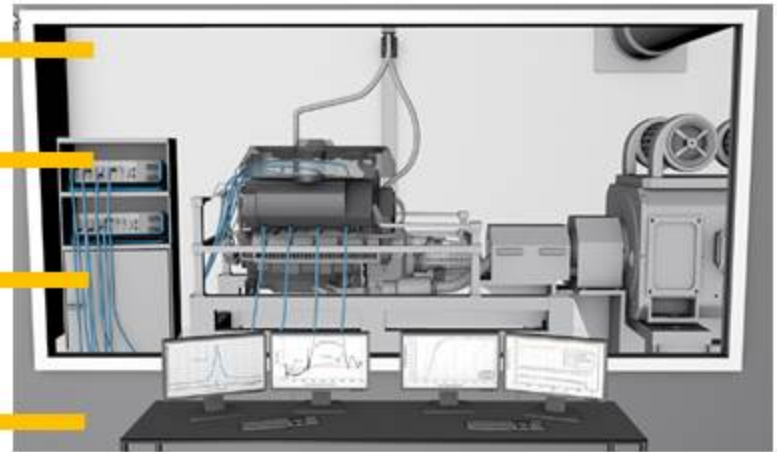
Pcyl sensors



Optical CA encoder



Current clamps



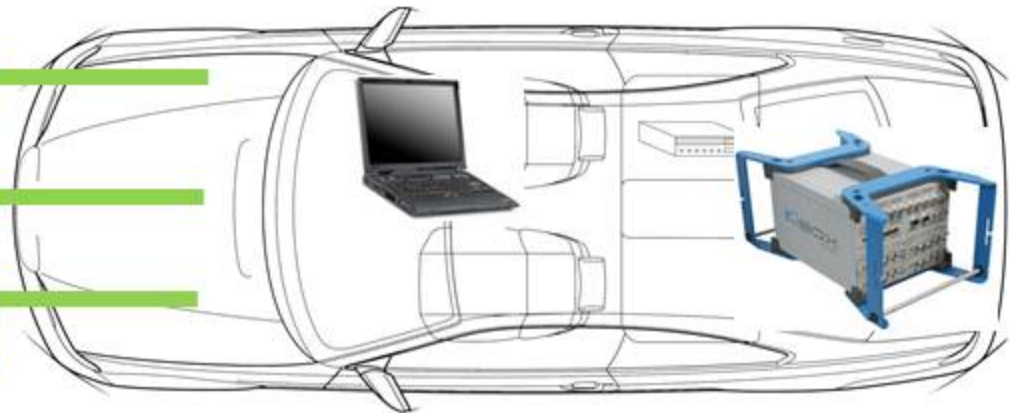
Pcyl sensors



Eng. speed sensor

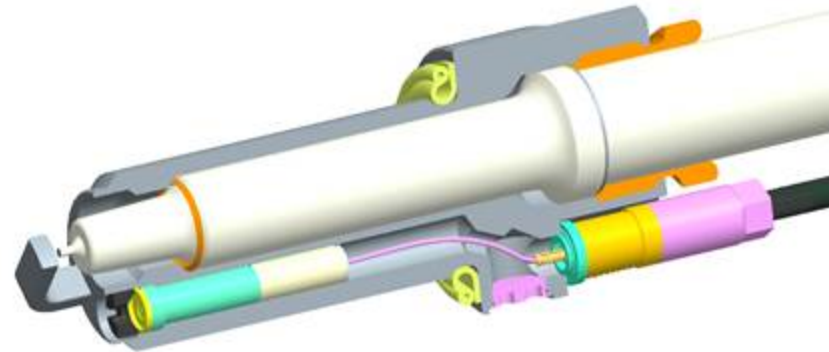


Current clamps



Spark plugs with integrated pressure transducer

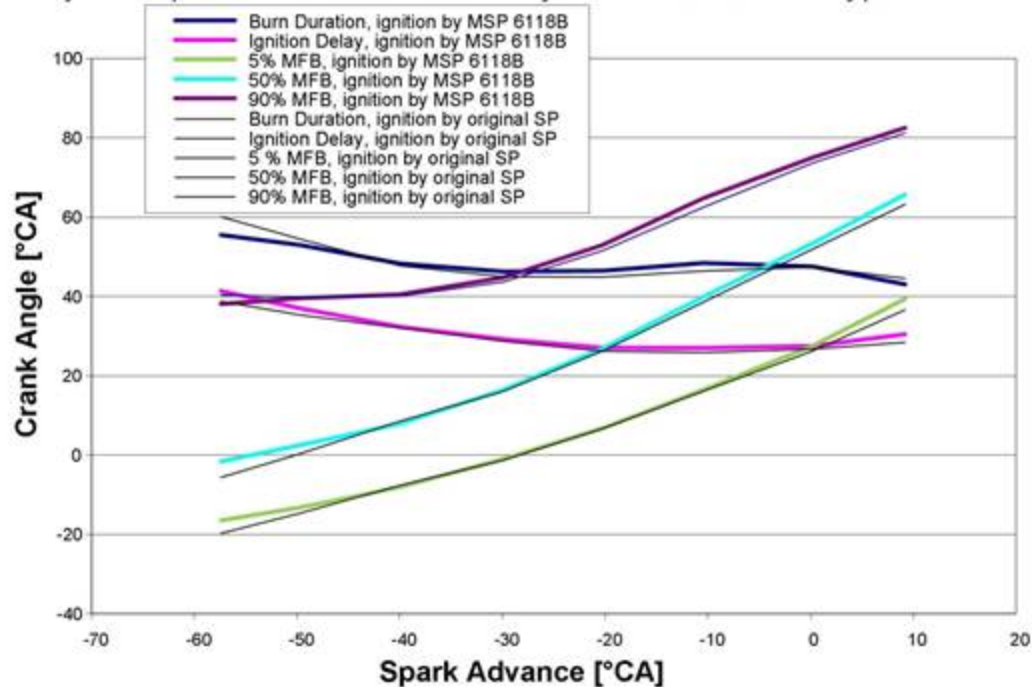
Integration



- Most simple assembly without the need for an additional drilling in the cylinder head
- Well suitable for use in downsized, TC gasoline engines
- Same geometry, heat value as original spark plug

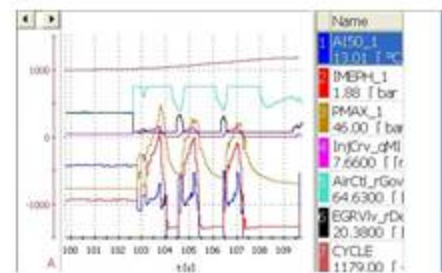
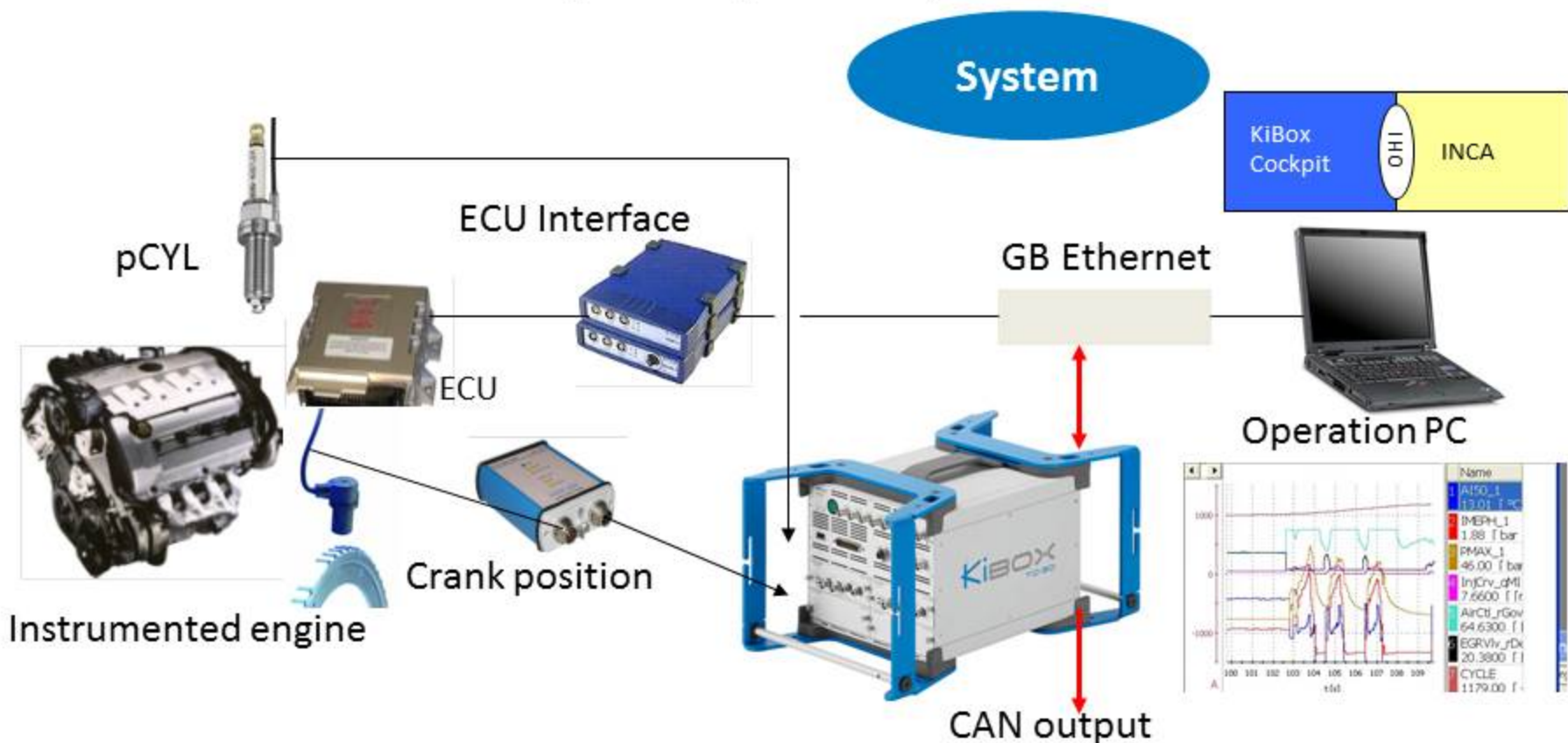
Spark plugs with integrated pressure transducer

Cylinder pressure measurement by reference sensor Type 6041B

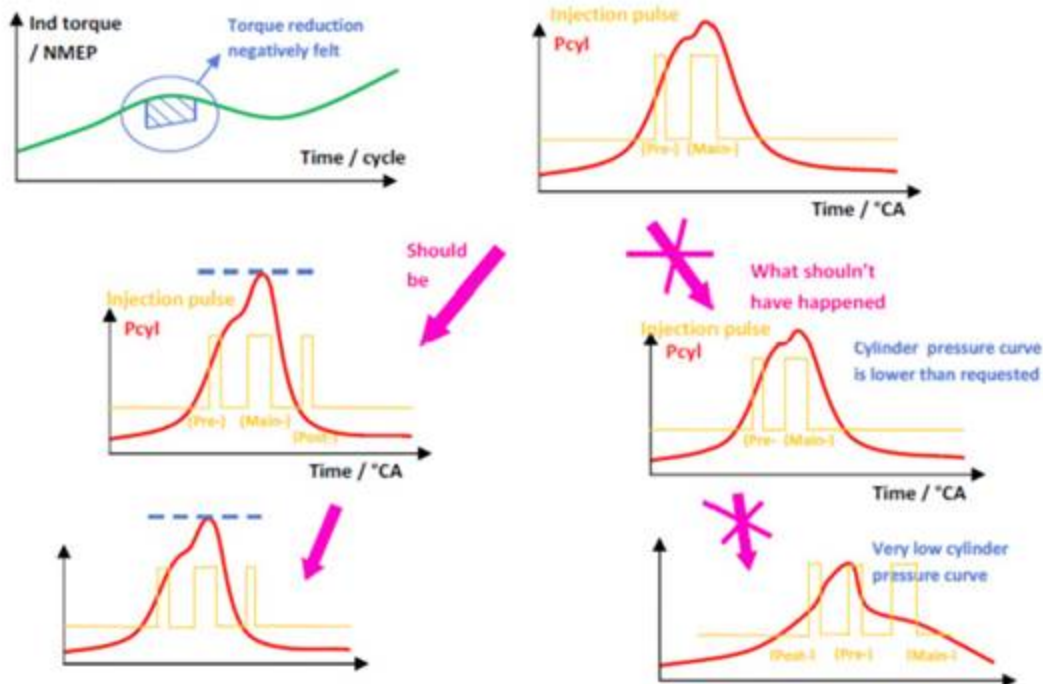


- same ignition characteristics
- same combustion characteristics
- same engine performance as with original spark plug

KiBox combustion analyzer – system layout with ETAS INCA

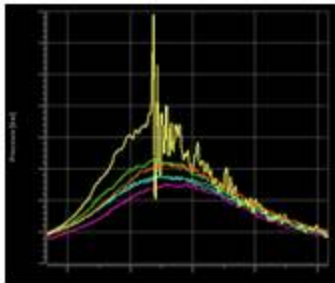


Issue analysis and ECU calibration



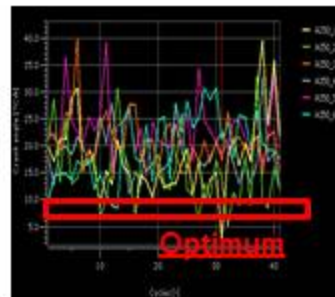
- KiBox and INCA show a strange torque reduction. A deeper analysis indicates a wrong synchronization of the multiple-injection phase.

Combustion analysis system for in-vehicle ECU calibration



- Knock Application

High-quality measurement data is available to evaluate knock level (in-cylinder pressure) which allows you to operate the engine at its optimum



- Efficiency Application

To operate the engine with location of 50% mass fraction burned at approx. 8° .. 10° CA after TDC gives you the best combustion efficiency (high power, low fuel consumption) which leads to less weight and higher performance

ECU Calibration

Indication results are transferred to ECU Calibration SW (INCA or ATI Vision or Vector CANape)



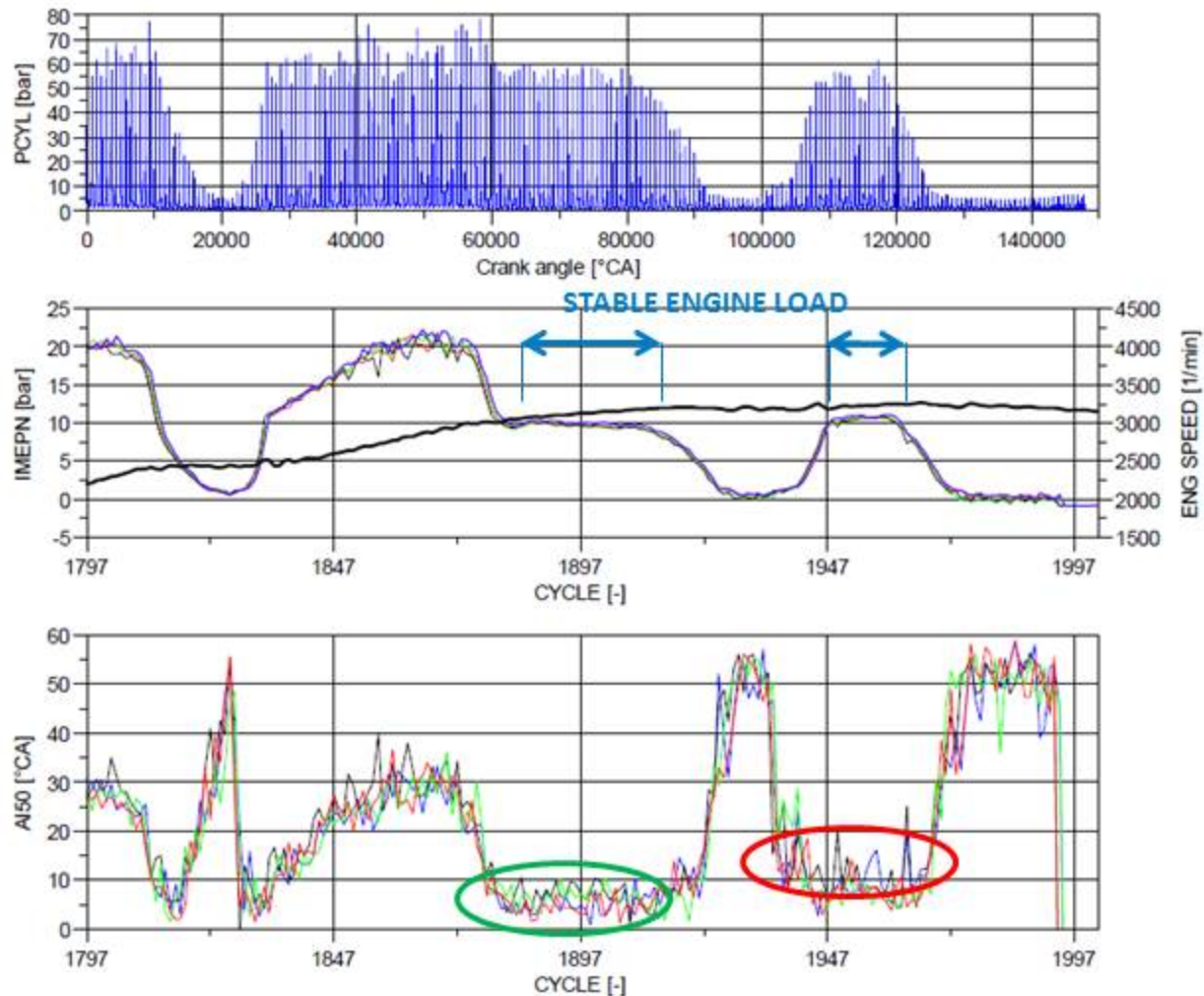
Emission test cycle on chassis dyno or on-road

Full analysis results for each combustion cycle. Data streaming with MDF4

Efficiency Application

To operate the engine with location of 50% mass fraction burned at approx. 8° .. 10° CA after TDC gives the best combustion efficiency

(high power, low fuel consumption) which leads to less weight and higher performance



Summary

- In-vehicle measurements are required for the optimization and calibration of engines for better fuel economy, lower emissions, real driving emissions
- Measurement in every cylinder is required – also in the vehicle
- The accuracy of measuring spark plugs is sufficient for application/ECU calibration measurements and benchmark testing. Can be used in modern turbocharged engines with high power density
- KiBox offers the Cranksmart technology for using the standard CPS sensor
- Real time combustion results with interface to calibration software, full synchronization with ECU data
- Accurate crank angle based data is ensured through even under most challenging conditions, including engine start, engine transients, or measurements on downsized engines under full load operation.
- Kistler provides a robust , easy-to use system solution

THANK YOU