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Future Energy System

Distributed cycle-to-cycle closed loop combustion control in internal combustion engines

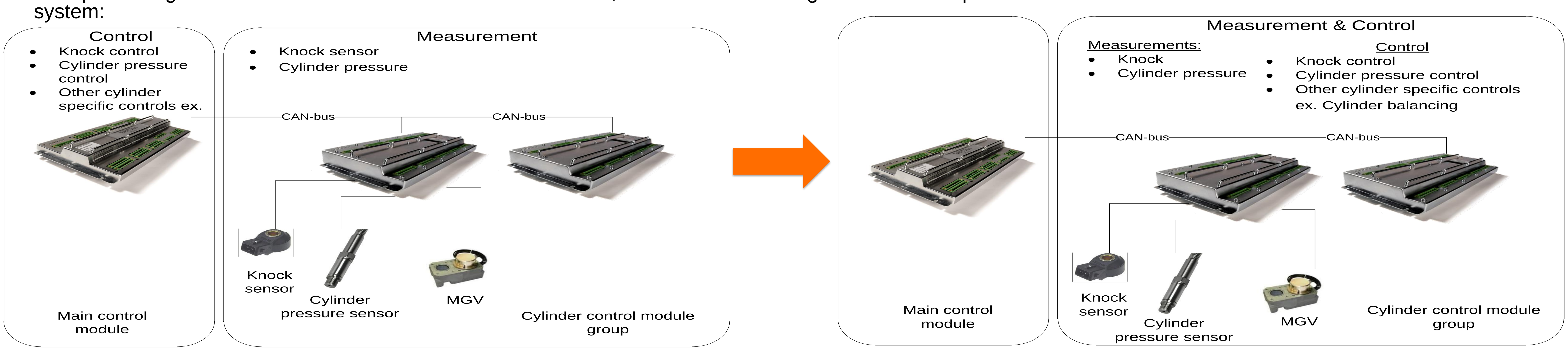
Improved combustion control, with better safety margins against abnormal combustion, by new distributed control principle and improved cylinder pressure measurement accuracy

Abstract: With the rigorous requirements on engine emission and performance, high precision cylinder pressure based cylinder-wise combustion control systems have revealed enormous potential for engine diagnosis and engine control. Moreover, for lean burn premixed engines, this can broaden the optimum operating range between abnormal combustion with either knock or misfiring. Therefore, the research of new distributed control concept and cylinder pressure measurement accuracy are important for improving future internal combustion engines lifetime performance.

Distributed cycle-to-cycle control algorithm

Matias Palmujoki (Wärtsilä Finland Oy)

For optimal engine control in situations of abnormal combustion, distributed control algorithm is developed based on current state of the art centralized to distributed control system:



New Features

- Control functions are prioritized
- Communication delays for critical controls are completely omitted
- Distribution of computation capacity and memory
- Distribution of control algorithms

Conclusion: This new algorithm is tested on a Wärtsilä 6 cylinder spark ignited gas engine. Engine test shows that, control of critical parameters in case of abnormal combustion was on an improved level; and an increase in cycle to cycle control accuracy by 24…55%. This new distributed cycle-to-cycle control algorithm is an essential development in reduction of cycle to cycle variations in gas engine.

Cylinder pressure and crank angle measurement accuracies analysis

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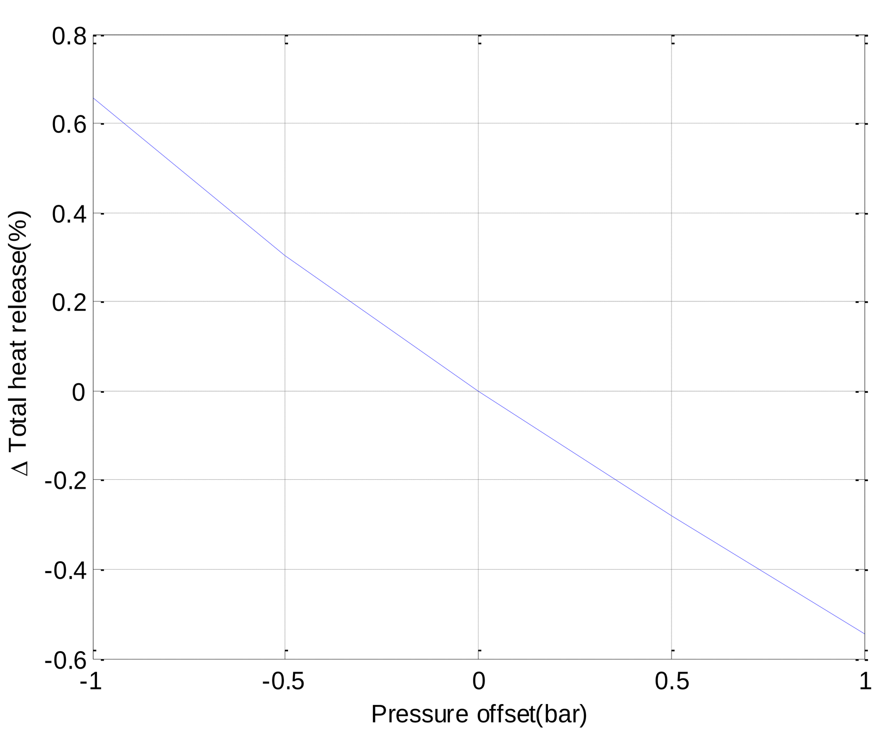
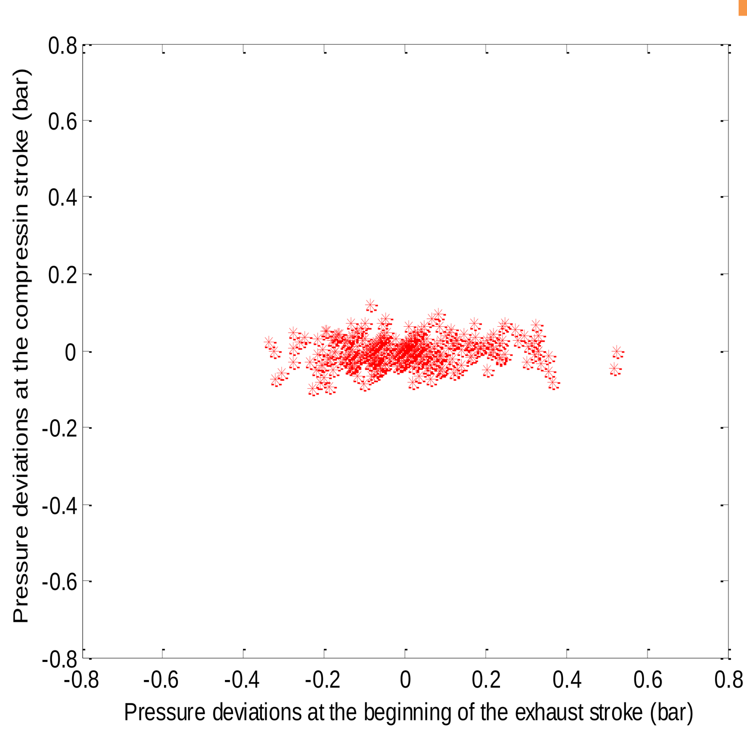
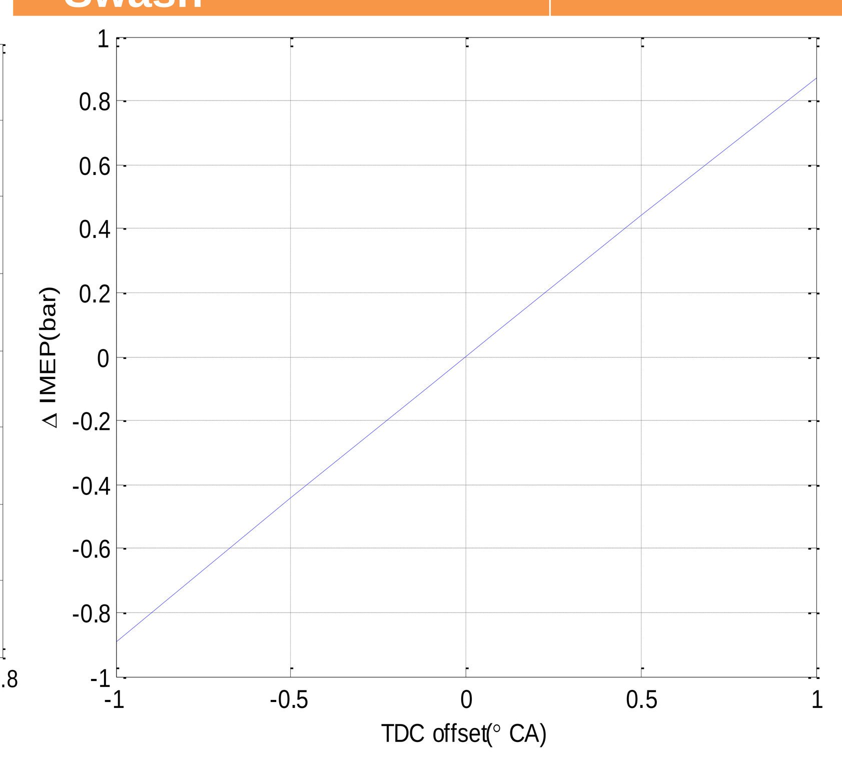
The uncertainties of components in cylinder pressure measurement system and crank angle position measurement system are analyzed individually and the impact on calculated input values for controls are estimated. Piezoelectric pressure transducer and inductive crank angle measurement sensor are used for large bore four stroke marine and power plant production engines.

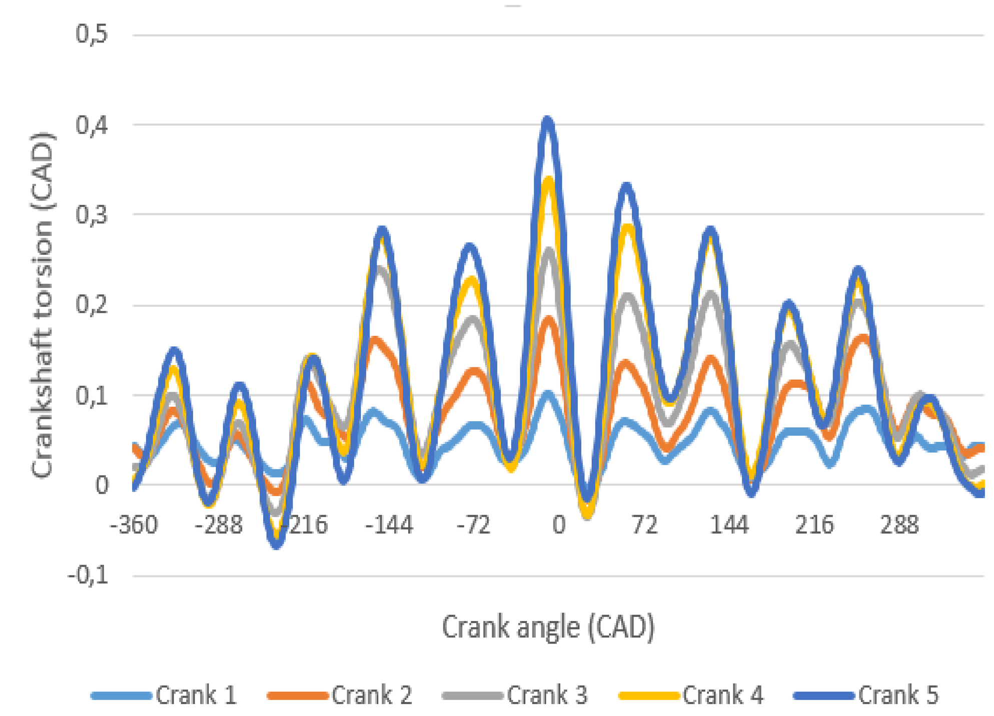
Thermal shock, signal drift and sensitivity variation	Installation: location and mounting method	Membrane vibration; Pressure changing rate

Mechanical Imperfection; Installation : Eccentricity and Swash	Operational relative displacement: torsional vibration, shaft movement and shaft bending, engine block vibration	Cylinder volume deformation; Time delay









Level of Confidence	Converge Factor	Cylinder Pressure Expanded Uncertainty [%]	Cylinder Pressure Expanded Uncertainty [bar]	Crank Angle Position Expanded Uncertainty [CAD]
68,27%	1	0,90	2,25	0,14
95,45%	2	1,80	4,51	0,29
99,73%	3	2,71	6,76	0,43

Conclusion: Crankshaft torsional vibrations has the most significant impact on cylinder pressure measurement accuracy and the algorithms used for combustion feedback in the cycle-to-cycle controls. Their absolute impact on IMEP and CA50 are 0.9% and 1 degree respectively. To improve the performance of future power plant and ship engines these inaccuracies should be taken into account.

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Conclusion

This new distributed cycle-to-cycle control algorithm is an essential development in reduction of cycle to cycle variations in gas engine. To provide the optimal cylinder pressure input to controller and algorithm, pressure and crank angle measurement uncertainties are significant and thus need to be considered for future combustion control research.