汽车动力系统控制---机遇与挑战

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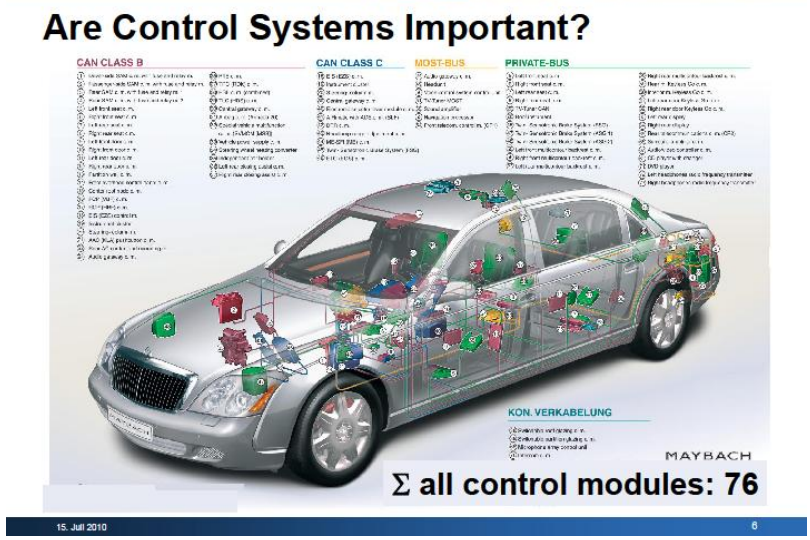
東京・日本

Photo Provided by TOYOTA

Contents

- Road Vehicles and Control, and MBD
- Challenges in Engine Control
- How to approach from academic community
  ––SICE Benchmark
  ––SICE–JSAE Benchmark

Control and Vehicles： ECU(CPU)>100



Lino Guzzella, IFAC Symp. ACC 2010

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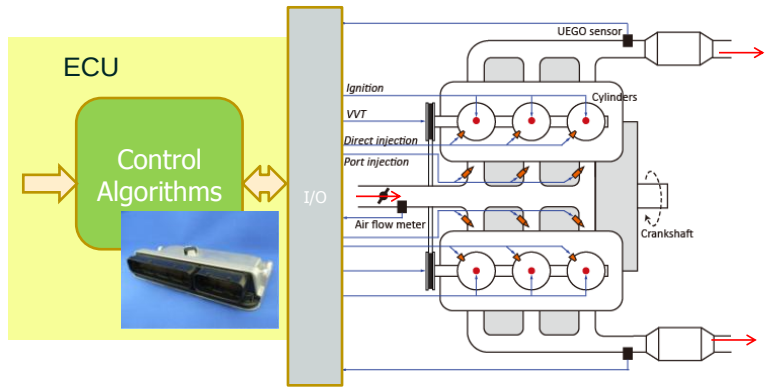
Example: ECU and Engine



Sensor： Temp., Pressure. Flow rate, O2
Actuator： Injector, Ignition, Throttle , VVT……
Coordination： xHEV, Powertrain–Vehicle–Route Control Loop

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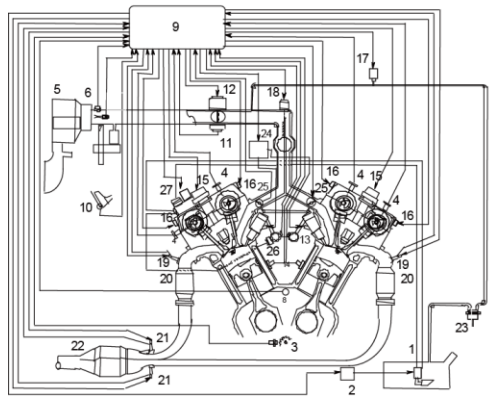
V6 Engine (200 Wires)



1.燃料ポンプ
2.燃料ポンプレジスター
3.クランク角度センサー
4.カム角度センサー
5.空気クリーナ
6.吸気温度センサー
7.エアーフローメータ
8.水温度センサー
9.32ビットECU
(Electronic Control Unit)
10.アクセルペタル位置センサー
11.Tスロットル開度センサー
12.スロットルコントローラ
13.インジェクタ
14.ノックセンサー
15.電子点火
16.オイル制御弁
(VVT -i制御用)
17.VSV
(EVAP, プラグ制御I)
18.ロータリソリノイドバルブ
(アコースティック制御インダクションシステム)
19.空燃比センサー
20.三元触媒変換器
21.酸素センサー
22. 三元触媒変換器
23.炭罐チャコール
24. EDU(Electric Driver Unit)
25.SCV(Swirl Control Valve)
26.燃料圧力センサー
27.高圧燃料ポンプ

トヨタ自動車提供

申、大畠 「自動車エンジンのモデリングと制御」、コロナー社、2011

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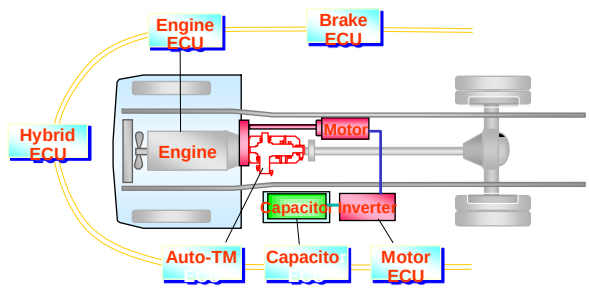
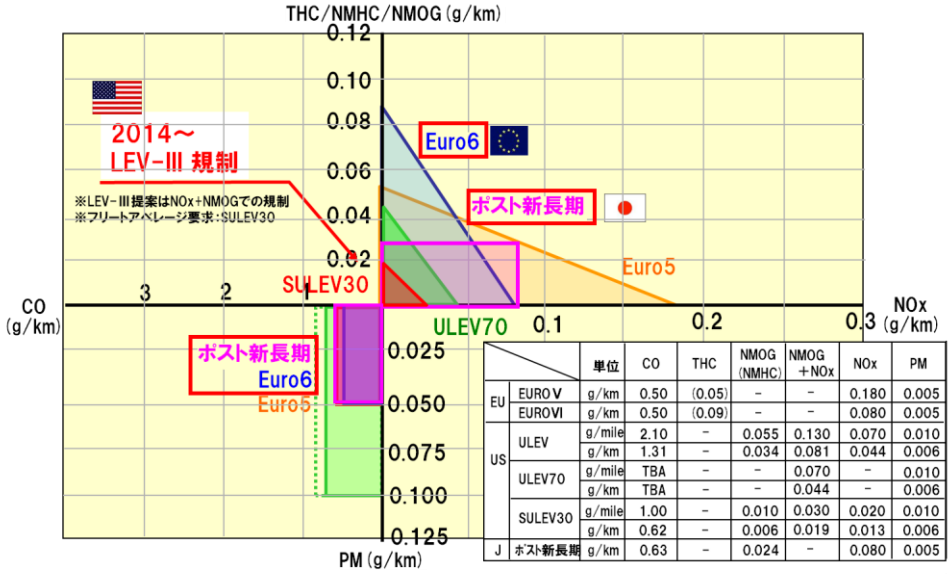
Hybrid Powertrain



HEV
- IC Engine + Electric Machine
- Multi-Actuator System
- Even-based switching

世界各国排放标准

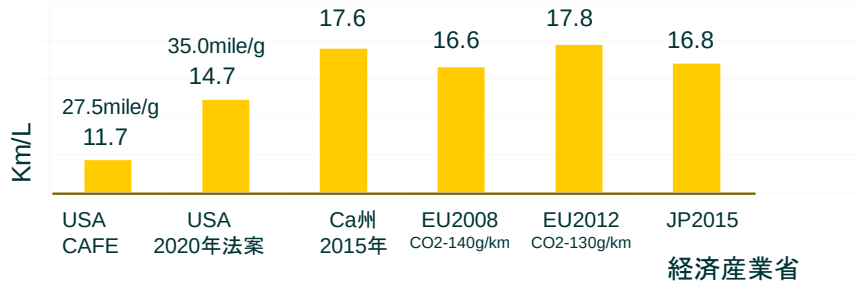


		単位	CO	THC	NMOG (NMHC)	NMOG +NOx	NOx	PM
EU	EUROV	g/km	0.50	(0.05)	–	–	0.180	0.005
	EUROVI	g/km	0.50	(0.09)	–	–	0.080	0.005
US	ULEV	g/mile	2.10	–	0.055	0.130	0.070	0.010
		g/km	1.31	–	0.034	0.081	0.044	0.006
	ULEV70	g/mile	TBA	–	–	0.070	–	0.010
		g/km	TBA	–	–	0.044	–	0.006
	SULEV30	g/mile	1.00	–	0.010	0.030	0.020	0.010
		g/km	0.62	–	0.006	0.019	0.013	0.006
J	ポスト新長期	g/km	0.63	–	0.024	–	0.080	0.005

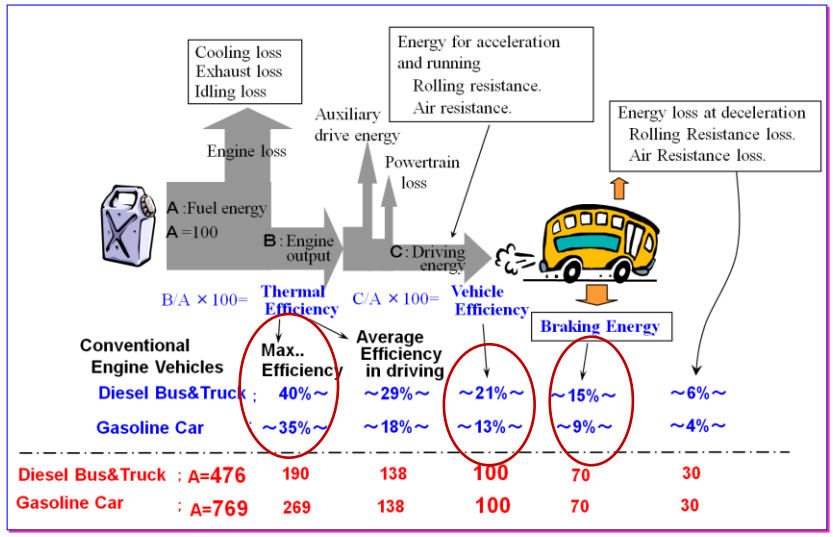
耗油指标

2015年度燃費目標値

自動車種別	2004年度実績	2015年度推定値	改善率
乗用車	13.6 (km/L)	16.8 (km/L)	23.50%
小型バス	8.3 (km/L)	8.9 (km/L)	7.20 %
小型貨物車	13.5 (km/L)	15.2 (km/L)	12.60%



汽车的能源转换效率



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排放原因

- 空燃比：缸内混合气体中的空气与油的质量比

$$\lambda = \frac{\text{空气}\ m_{air}[kg]}{\text{油}\ m_g[kg]}$$

- 排気特性：

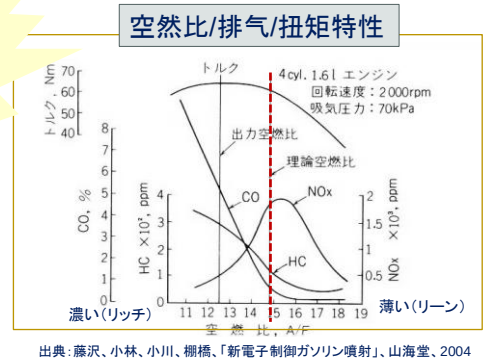
CO 氧不住，碳不
不完全氧化

HC 碳不完
氧

Nox 高
燃烧

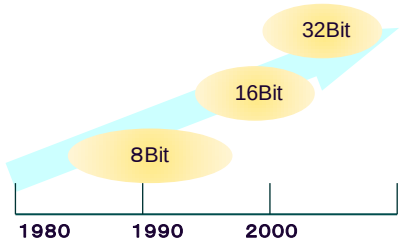
理想空然比

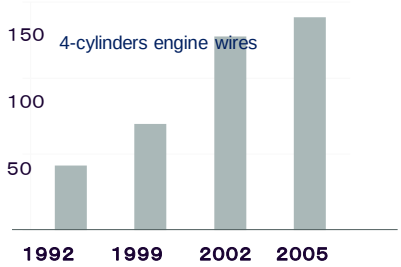
空然比/排气/扭矩特性



出典：藤沢、小林、小川、棚橋、「新電子制御ガソリン噴射」、山海堂、2004

软硬件环境





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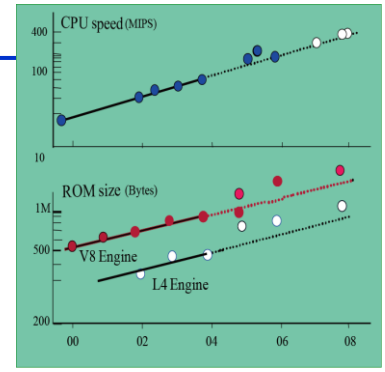
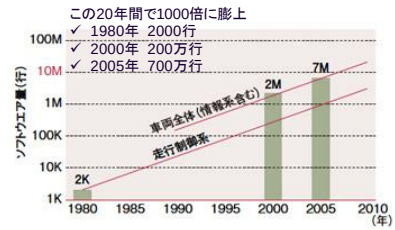
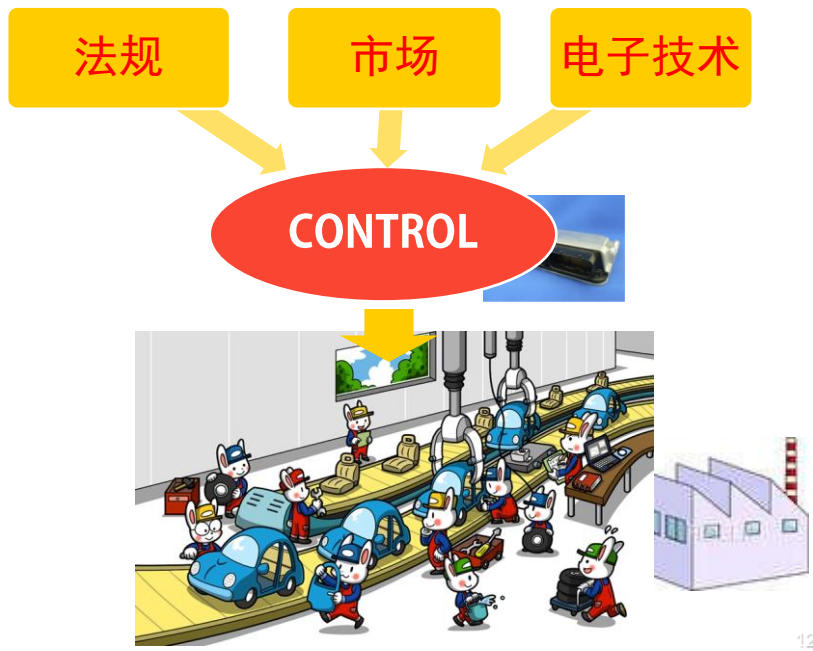


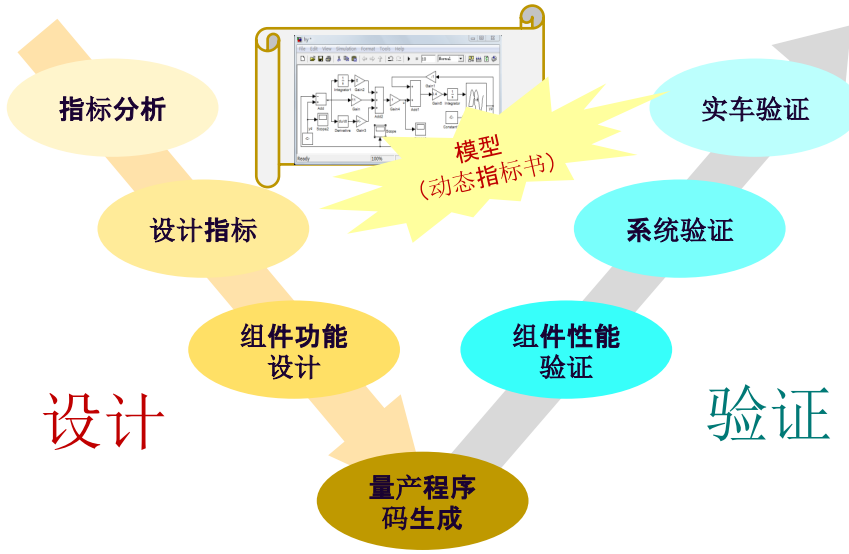
ECU処理能力　By Ohata



日経Automotive Technology 2007年11月号より



V字形开发过程与 MBD



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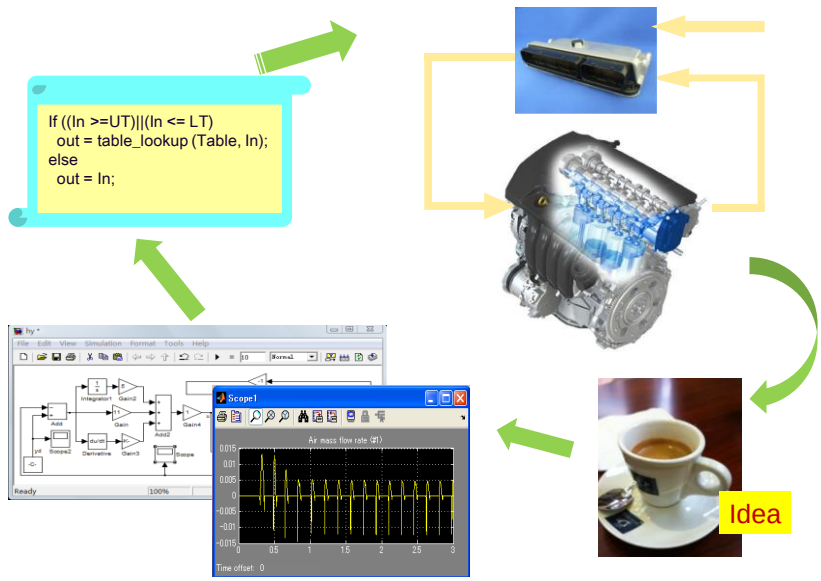
开发环



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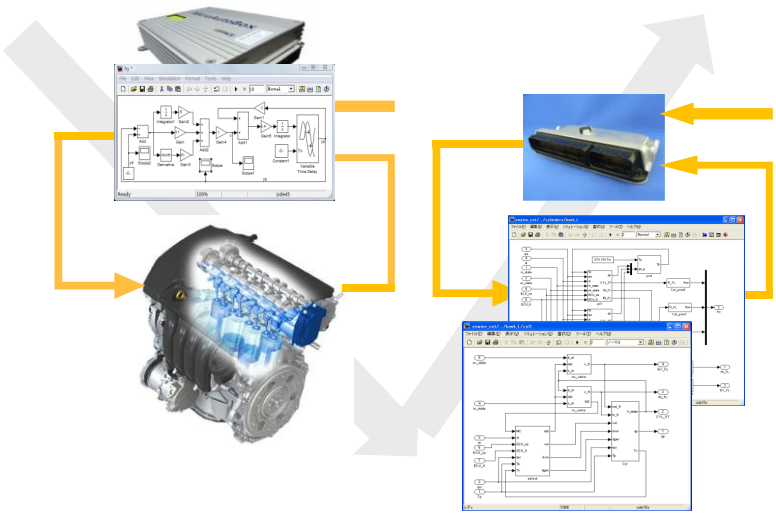
RPCとHILs



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Challenges in Engine Modeling and Control

- Transient Dynamics
- Individual Cylinder Actuation
- Coordinative control with alternative….

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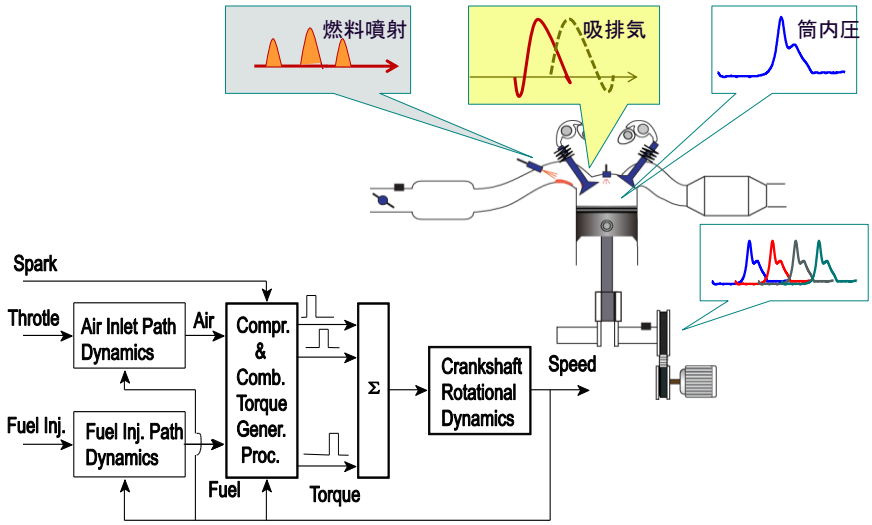
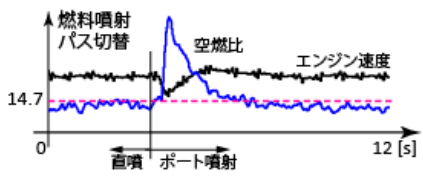
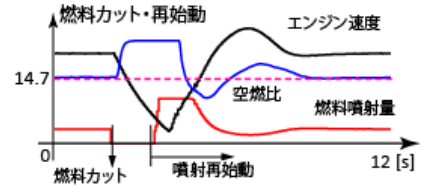
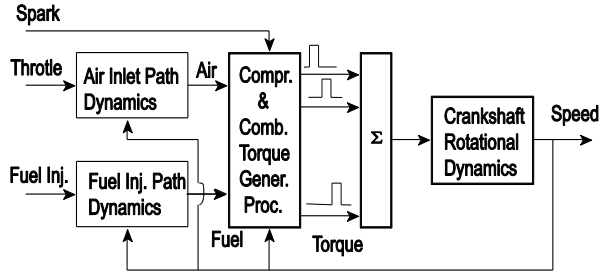
Physics



Challenge I: *Transient Behavior*

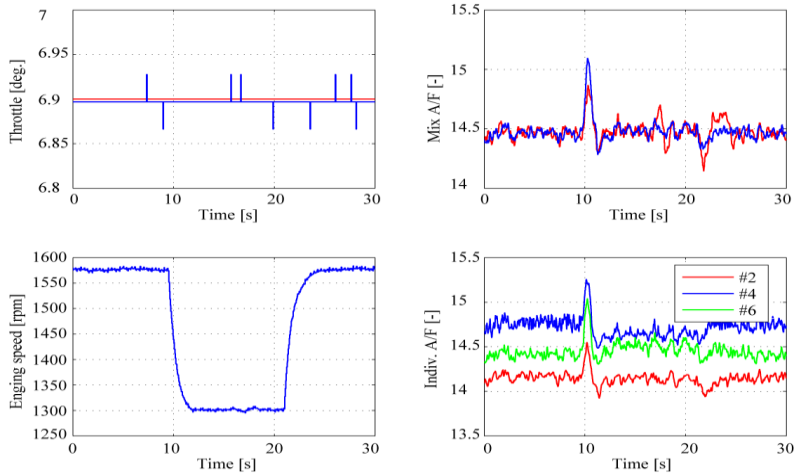






Challenge II: *Cylinder-to-Cylinder Imbalance*

☆ 全気筒一律噴射量（負荷変更時の応答）



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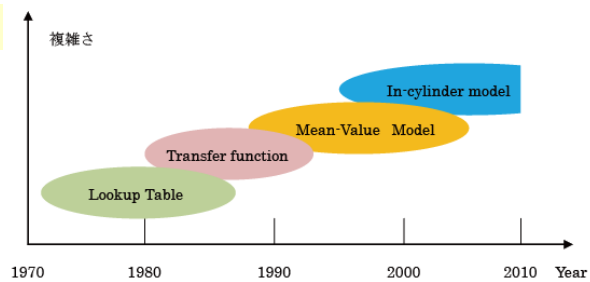
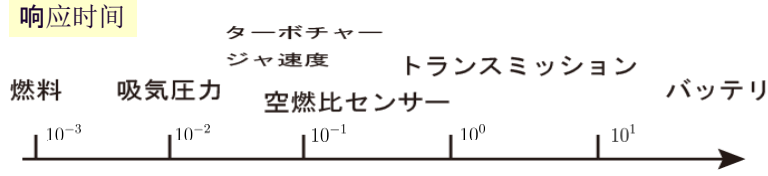
Dynamic Model

模型変迁



响应时间



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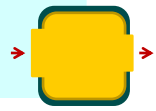
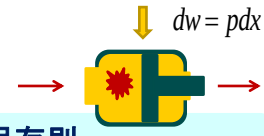
物理法則

■理想気体方程式

$$pV = mRT$$





■ エネルギ保存則

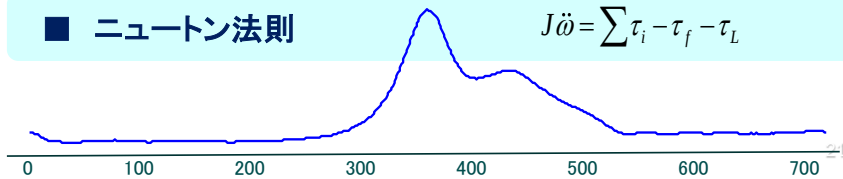
$$du = dq - dw$$

■ 流量

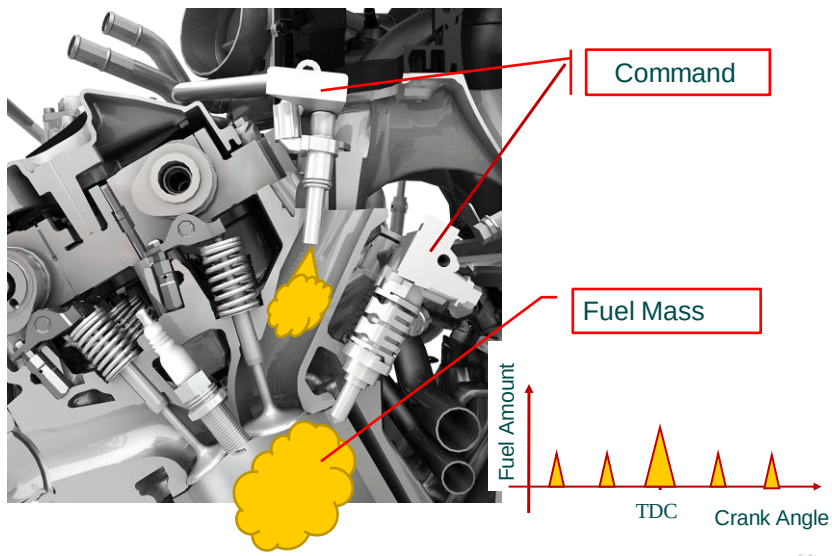
$$\dot{m} = \frac{Ap_0}{\sqrt{RT_0}}\left(\frac{p}{p_0}\right)^{\frac{1}{\kappa}}\sqrt{\frac{2\kappa}{\kappa-1}\left(1-\left(\frac{p}{p_0}\right)^{\frac{\kappa-1}{\kappa}}\right)}$$

■ ニュートン法則

$$J\ddot{\omega} = \sum \tau_i - \tau_f - \tau_L$$



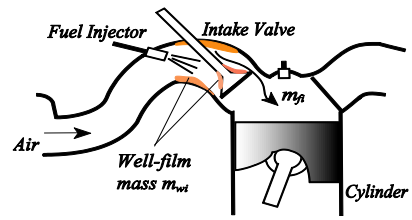
燃料噴射系



Well-Wetting Dynamics

Statistic Model

$$\begin{cases} \dot{m}_{fn} = -\tau m_{fn} + \varepsilon u_f \\ m_f = \tau m_{fn} + (1-\varepsilon) u_f \end{cases}$$



Air Charge

$$m_a = \int \dot{m}_{cv} dt$$

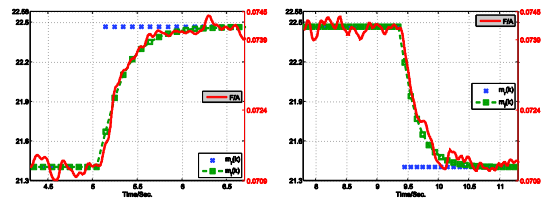


Fig.8 Experimental validation for identified wall-wetting model

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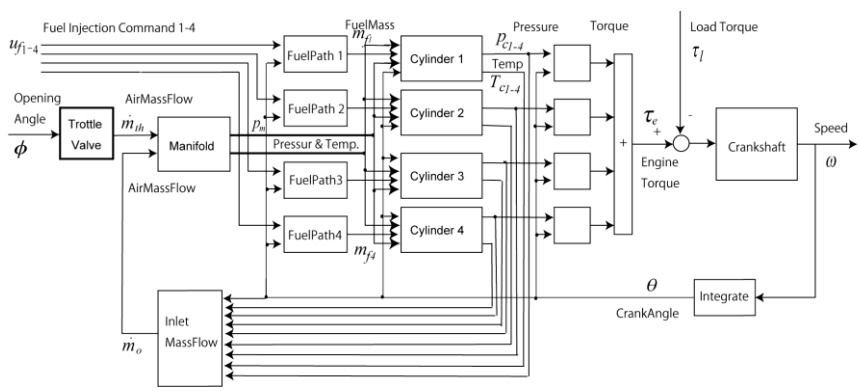
Block Diagram



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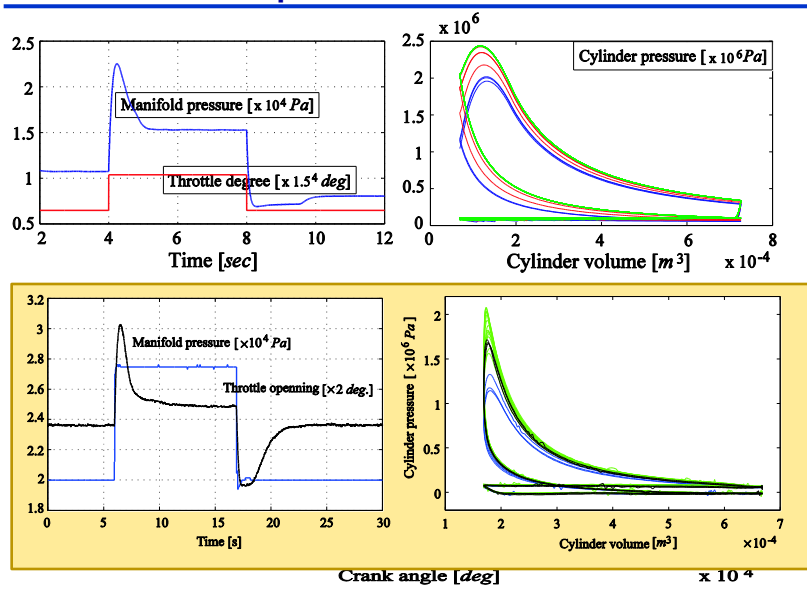
Simulation and Experiments



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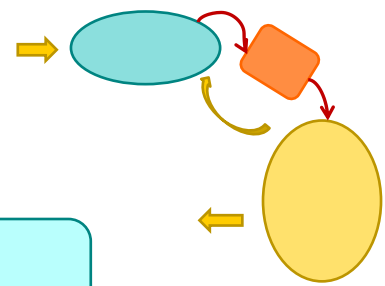
Control-Oriented Model: Mean-Value Model

Torque Generation

$$\tau_e = \frac{a\rho_a T_a V_c \eta}{4\pi T_m p_a} p_m(t-t_d) f_s(\cdot) f_\lambda(\cdot), \qquad f_s(\cdot) = \left[\cos(u_s - \mathrm{MBT})\right]^{2.875}$$

Mechanical Dynamics

$$J\dot{\omega} = \tau_e - D\omega - \tau_{load}$$



Mean-value model

$$\begin{cases} \dot{\omega} = -D\omega + c_1 p_m(t-t_d) - T_l \\ \dot{p}_m = c_2 u_t - c_3 p_m \omega \end{cases}$$

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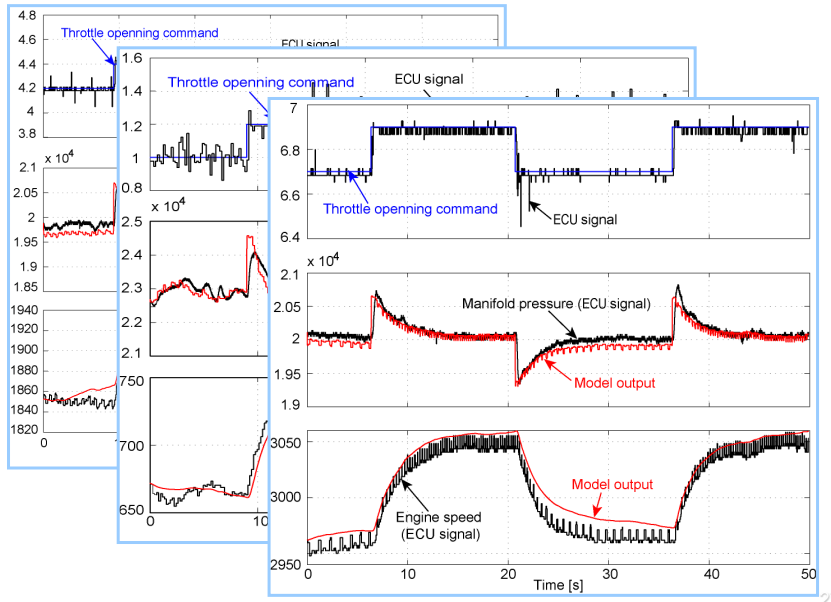
Model Validation



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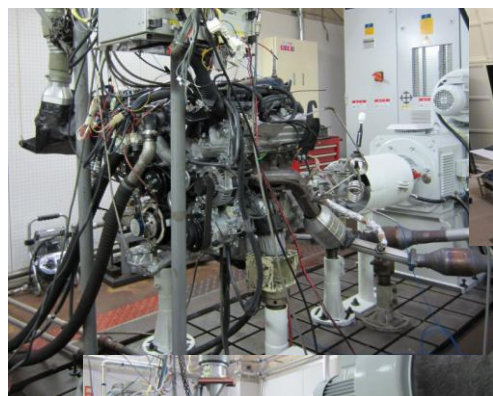
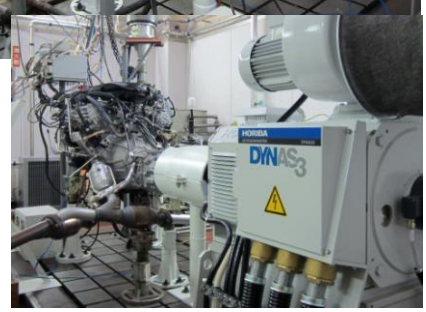
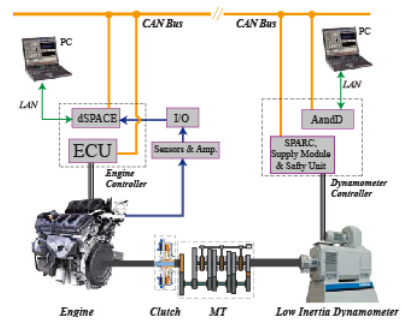
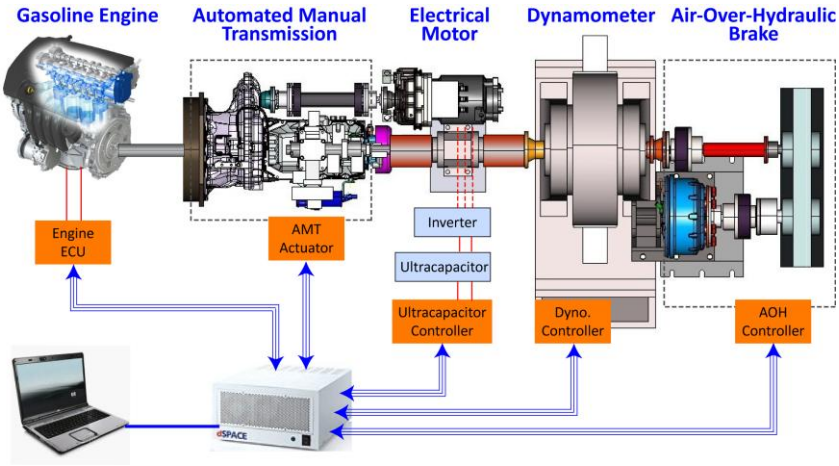






SHEN Lab., Sophia Engine Test Bench
Supported by TOYOTA

HVE Driveline Control Test Bench



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HOW TO

理解社会民生需求，与产业界联手提炼经典问题，从SCIENCE角度提供可能的求解途径

- SICE Benchmark Problem
  Starting Speed Control
  …….Nonlinear, Hybrid system, time-varying
- IFAC TC7.1 Benchmark Problem
  Throttle Angle Control
  ……. Nonlinear, Backlash
- SICE-JSAE Benchmark Problem
  / Engine Modeling
  / HEV Energy Management
  / Vehicle dynamics Control

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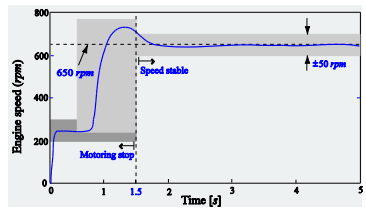
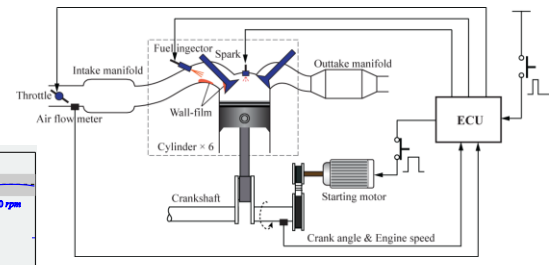
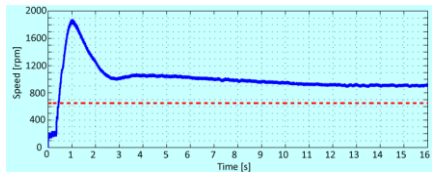
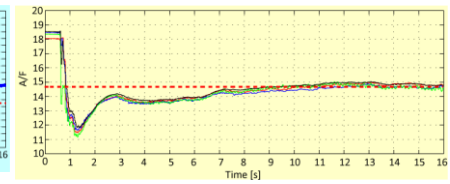
SICE Benchmark Problem: Starting Speed Control





13-inputs 1-output system





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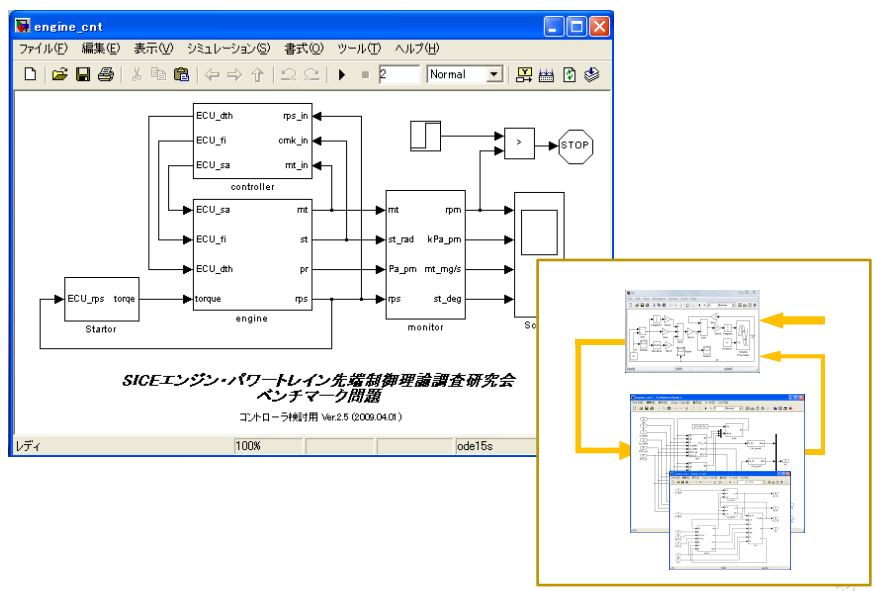
SICE Benchmark



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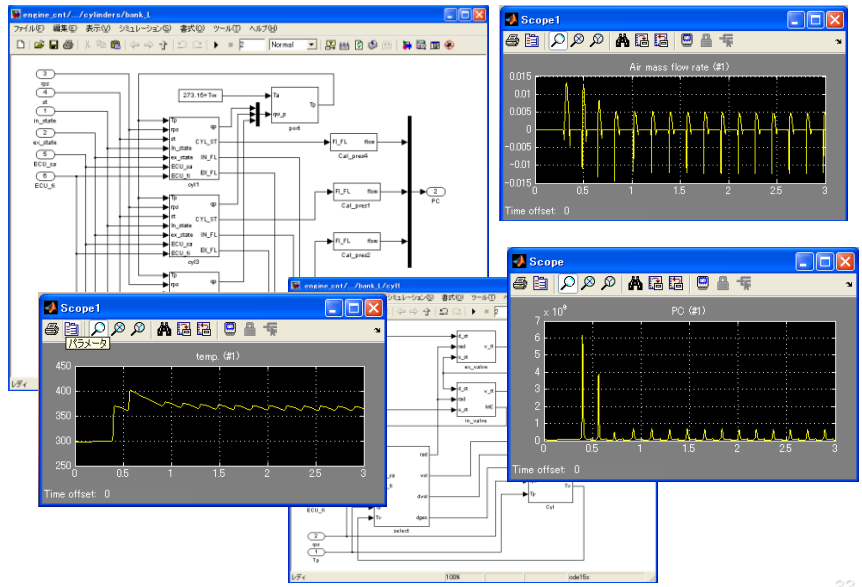
In-Cylinder Model



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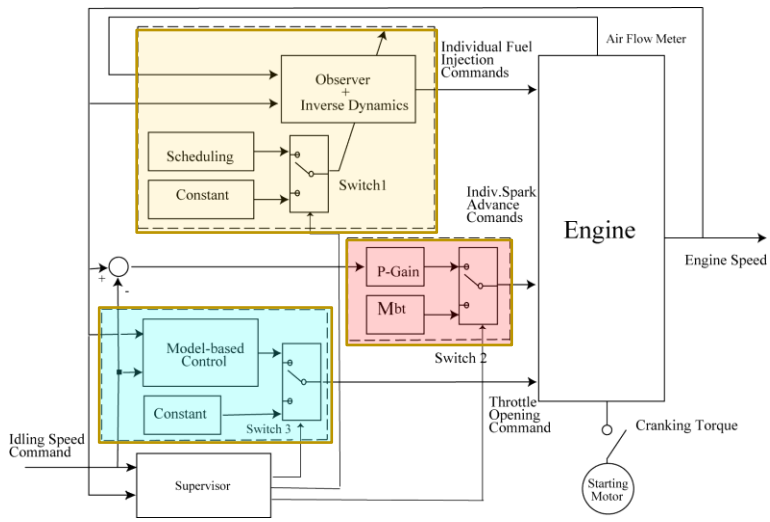
MBC



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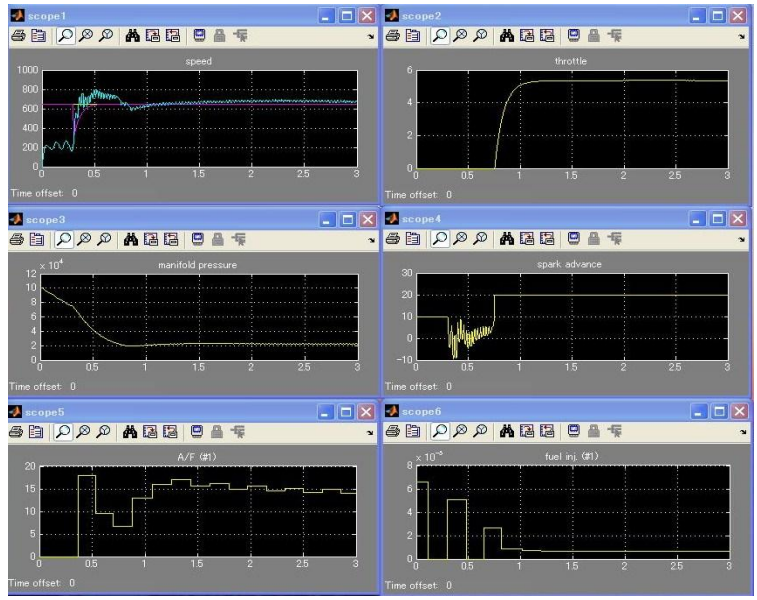
Simulation



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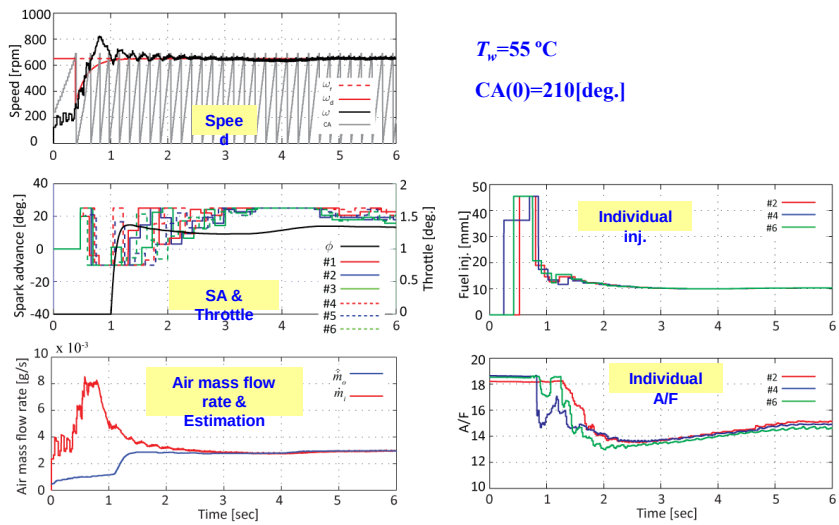
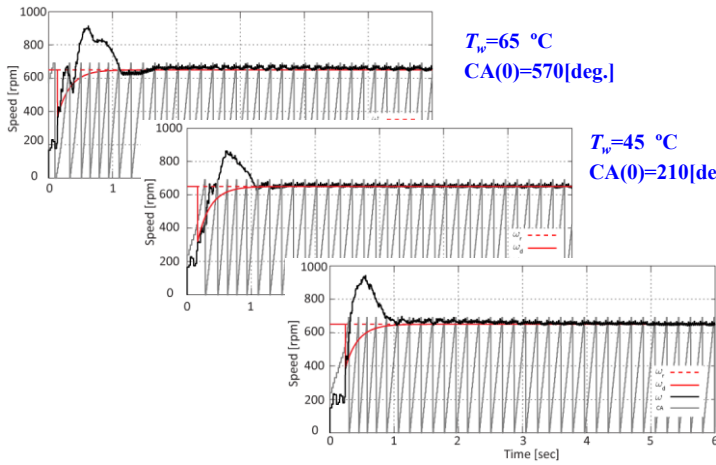
実験結果



T_w=55 ºC

CA(0)=210[deg.]

実験結果



T_w=65 ℃
CA(0)=570[deg.]

T_w=45 ℃
CA(0)=210[deg.]

T_w=75 ℃
CA(0)=210[deg.]

- WCICA 2012 Beijing
- IFAC AAC 2013Tokyo

谢谢！

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