Modeling Activities to Support After-Treatment System Design for Future Eu 7 HD/ BS VII Vehicles

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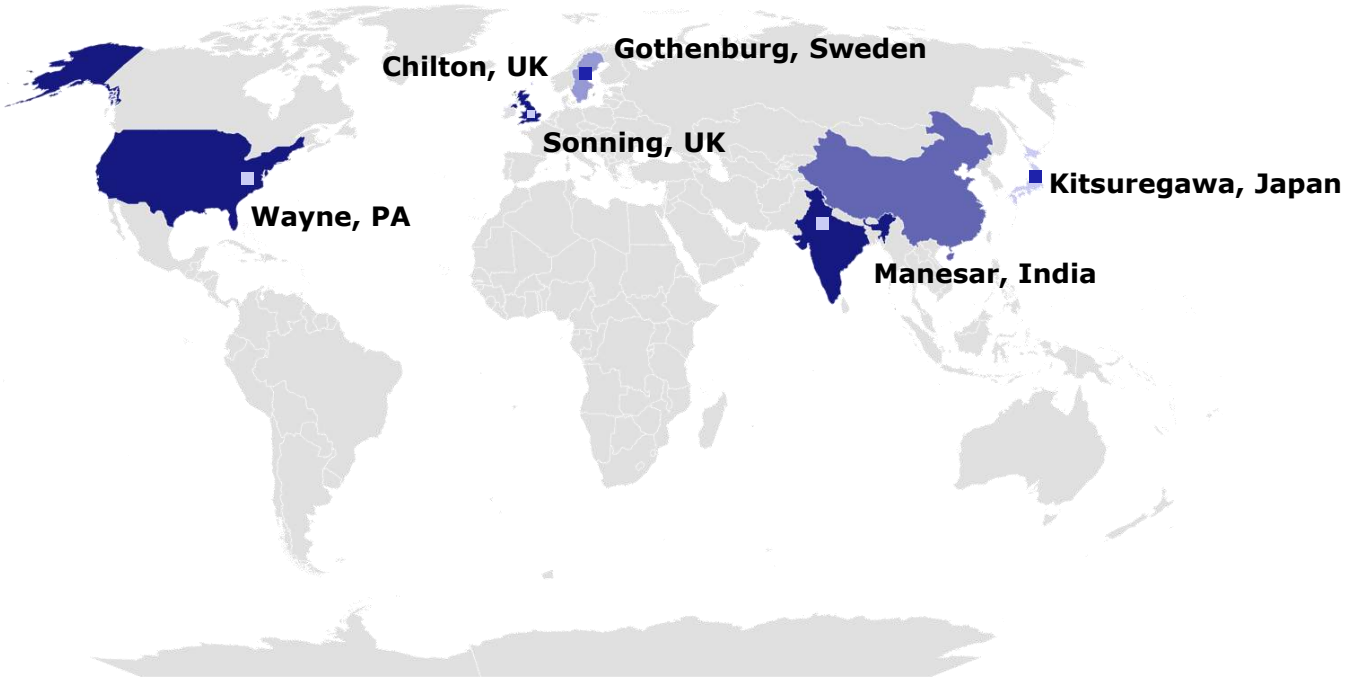
Modeling at JM – Global Locations

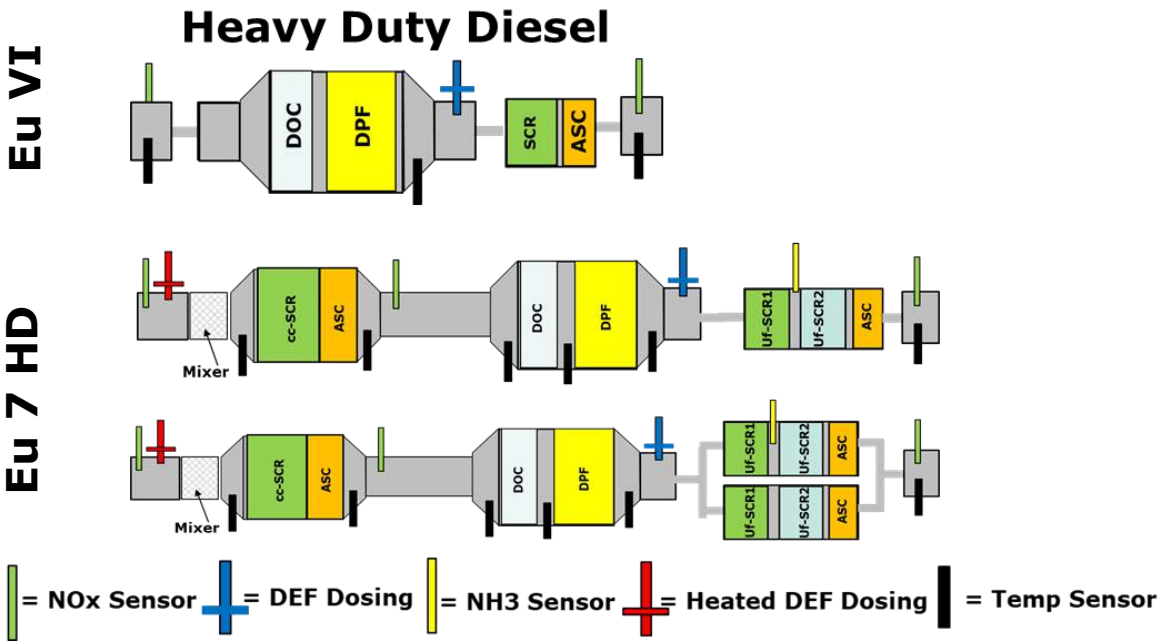


- 30+ years of experience of successfully using modeling tools for customer support
- High fidelity kinetics models validated against engine data
- Models are available on common software platforms including Matlab/Simulink

CO/HC Removal	PM Removal	NOx Removal	NH_3 Removal	CO/HC/NOx Removal
DOC	DPF	SCR	ASC	TWC
	CSF	LNT		
	GPF	PNA		
	SCRF®			

PGM Loading **WC Loading**	**Catalyst Size** **Catalyst Aging**
Feed Gas **Temperature**	**S Poisoning** **And more …**

Introduction and Overview of Eu 7 HD



Emissions	WHSC (CI) and WHTC (CI and PI)	*Real Driving Emissions (RDE)*	*Eu VI- (Weighted WHTC)*
NOx *mg/kWh*	200	260	460
PM *mg/kWh*	8	-	10
PN *#/kWh*	6×10^{11} PN_{10}	9×10^{11} PN_{10}	6×10^{11} PN_{23}
CO *mg/kWh*	1500	1950	4000
NMOG *mg/kWh*	80	105	160
NH_3 *mg/kWh*	60	85	10 ppm
CH_4 *mg/kWh*	500	650	500
N_2O *mg/kWh*	200	260	-

CI-Compression ignition, PI-Pressure ignition, PM-Particulate mass, PN_{23}-Particulate number under 23 nm size, PN_{10}-Particulate number under 10 nm size

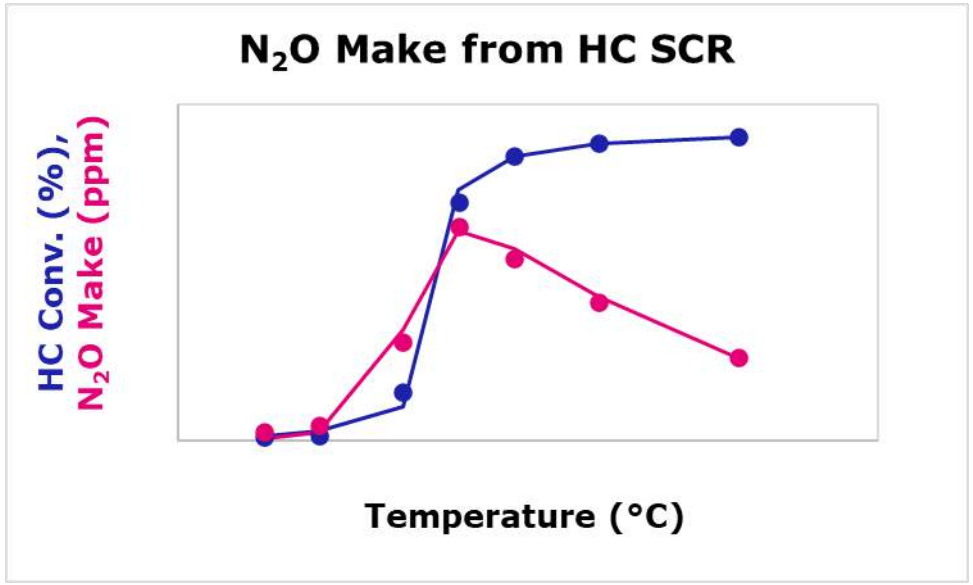
Challenges with Euro 7 HD

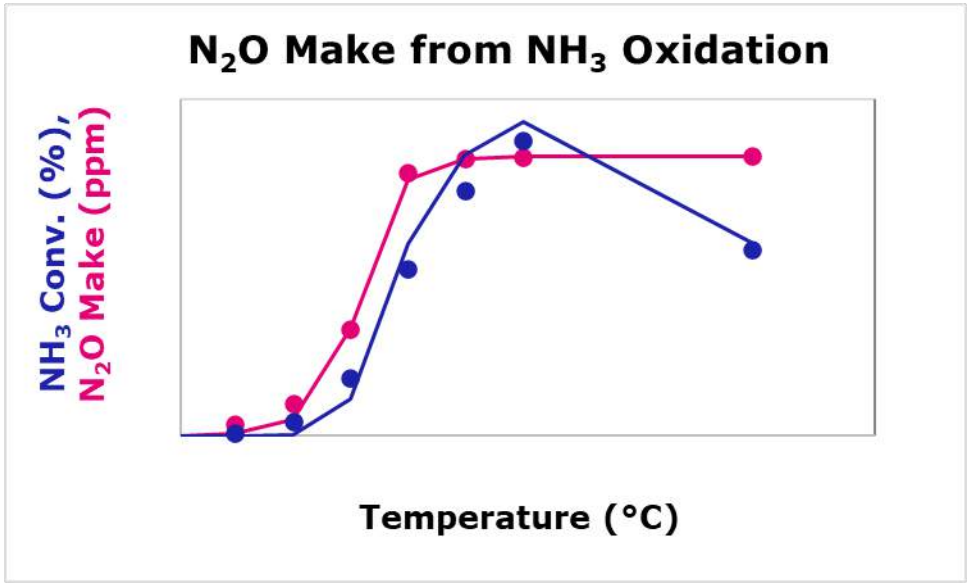
- ✓ **Addition of N_2O**
- ✓ Strict emissions limits
- ✓ Stringent limits of PM/PN
- ✓ Stronger push toward dual dosing
- ✓ Poisoning of catalysts

Technological Advancement of JM Catalysts: N_2O Make in DOC

Steady State Modes

- Data —— Model



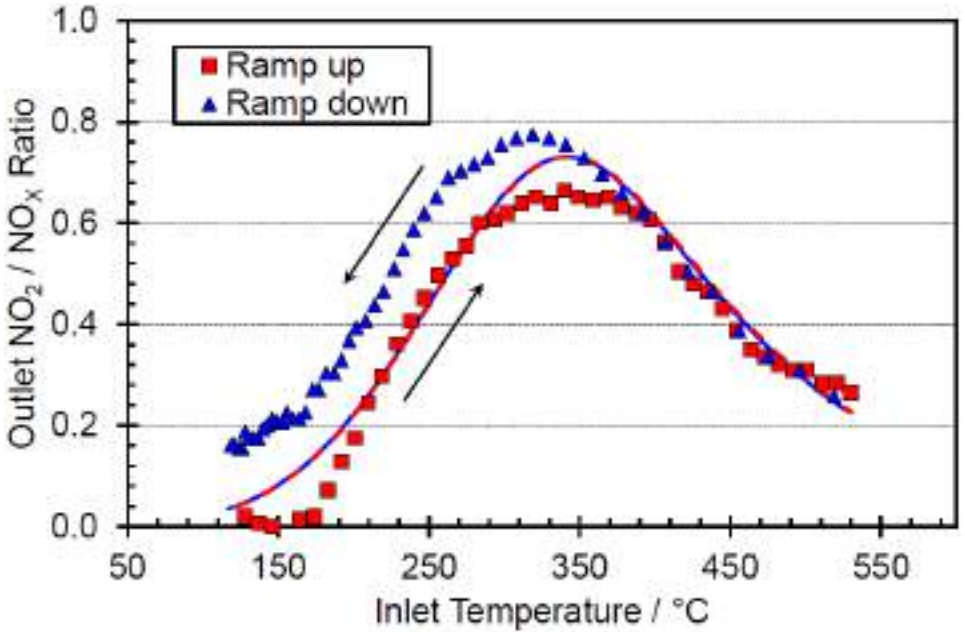


- ✓ **Incorporated NH_3 oxidation reactions in the DOC Model**
- ✓ **Model captures the HCs, NH_3 and N_2O make in DOC, which helps to tackle future Eu 7 HD norms more effectively**

Technological Advancement of JM Catalysts: NO Predictions in DOC

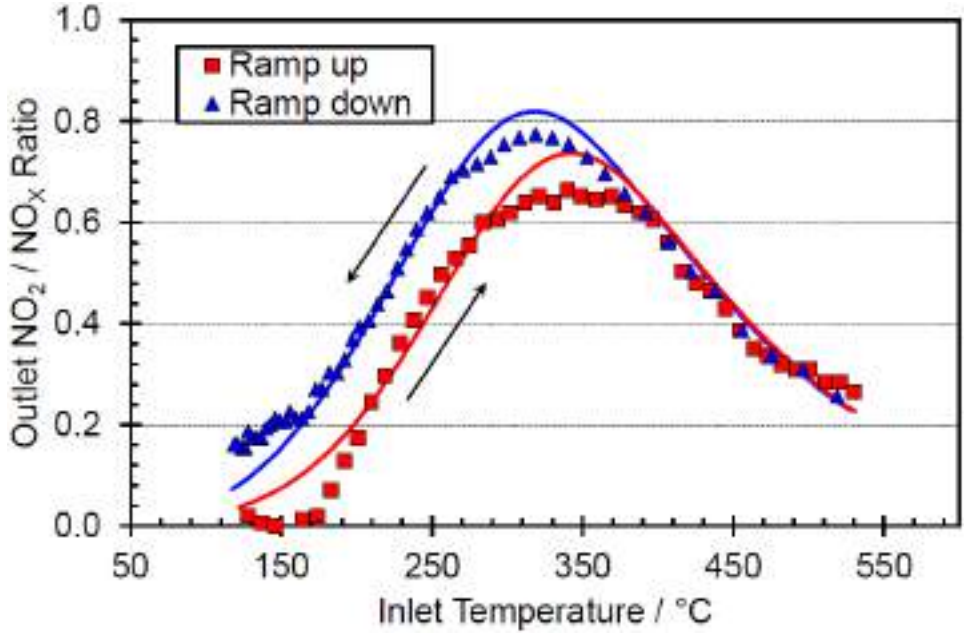
An Oxide Layer is Formed on Surface of Catalysts Which Affects the Activity

Traditional NO oxidation



NO Hysteresis

Including Oxide Effect



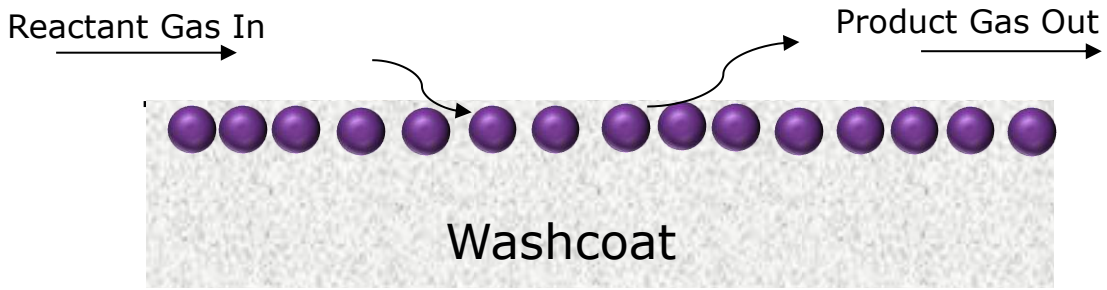
NO prediction is improved significantly on considering the oxide effects in the reaction mechanism

Ref: SAE Int. J. Engines 5(3):2012

Technological Advancement of JM Catalysts: Washcoat Diffusion

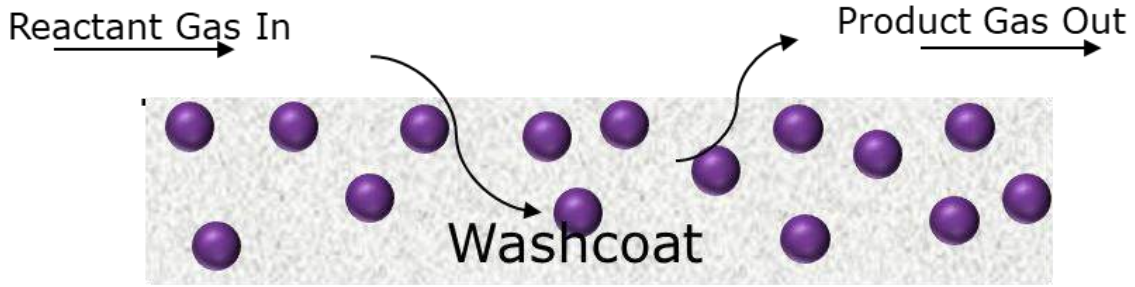
Limitation of Current Model Framework at High Flow Conditions

Kinetic Model – External Mass Transport Only



Note: In 1D kinetic model, all the catalyst active site present on the surface

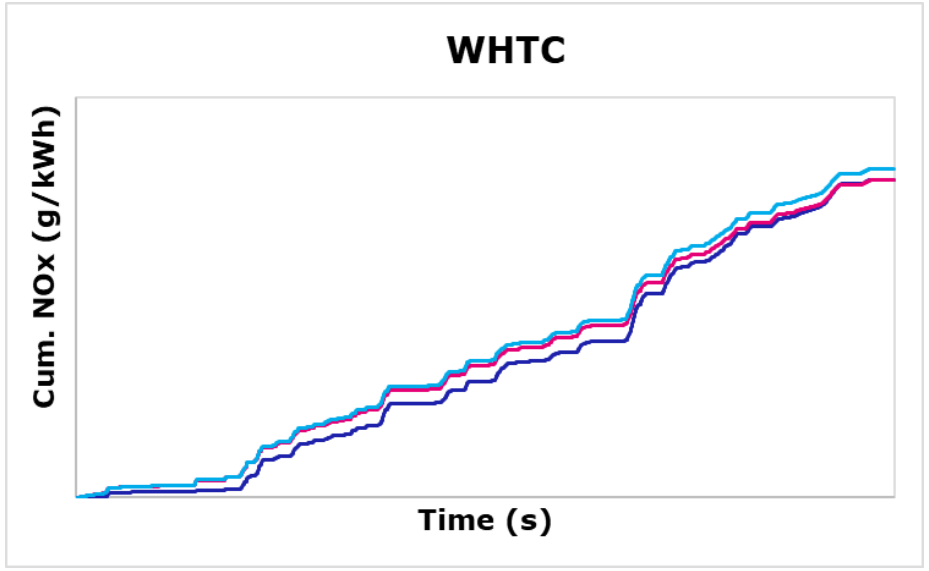
WC Diffusion Model – External + Internal Transport

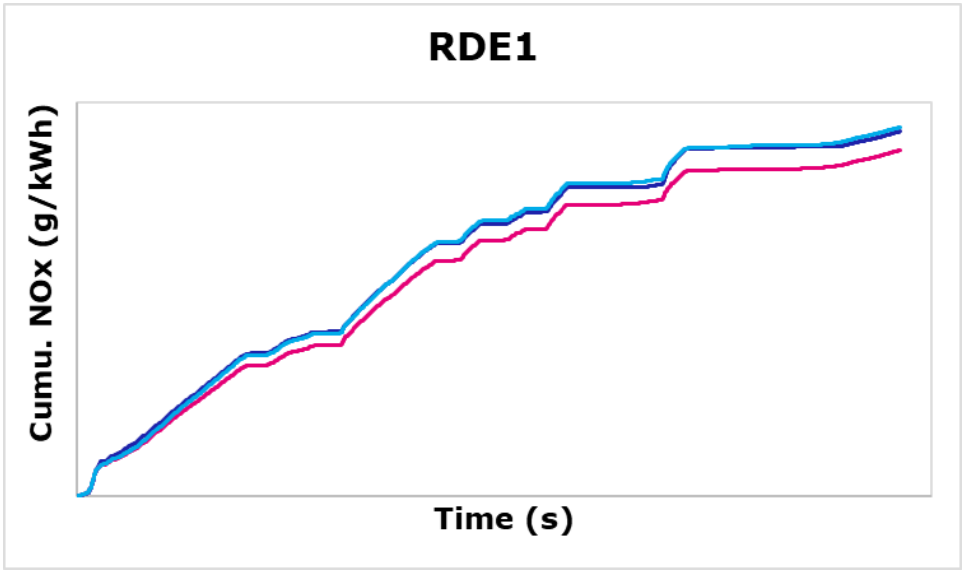


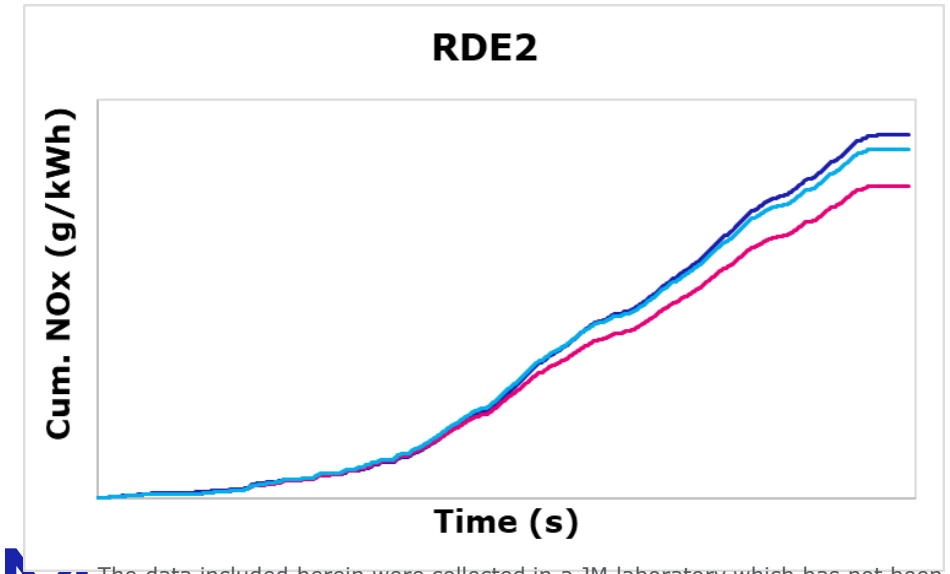
Note: In 1D+1D model, reactant gas must diffuse inside the washcoat to interact with active site

Technological Advancement of JM Catalysts: Washcoat Diffusion

NOx Prediction: Washcoat Diffusion Improves Model Predictions





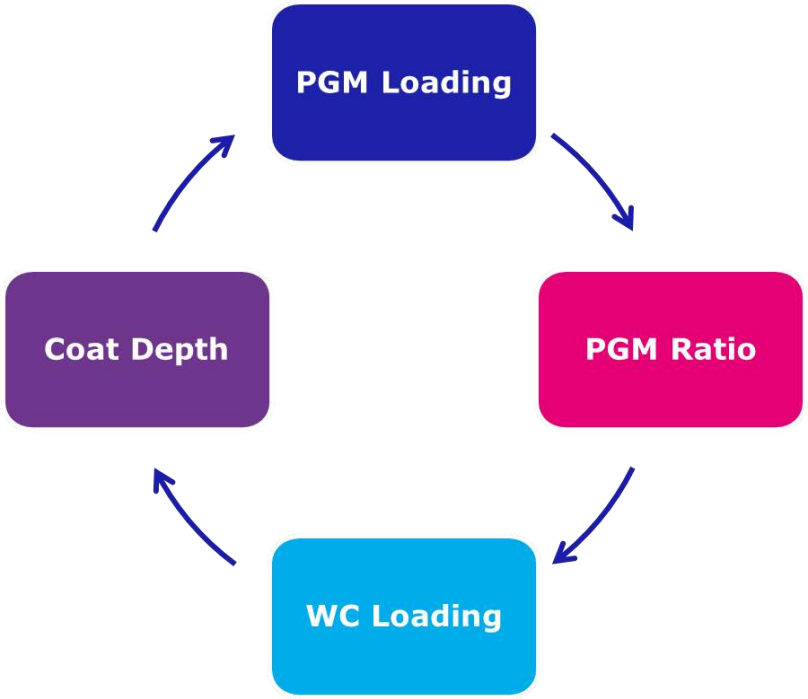


Data — Model (w/o diffusion) — Model (w/ diffusion)

Cycles	SCR NOx Conversion (%)	
	|Data – Model| (w/o diffusion)	|Data – Model| (w/ diffusion)
WHTC	**0.5**	**0.4**
RDE1	**1.2**	**0.2**
RDE2	**3.3**	**0.7**

Technological Advancement of JM Catalysts: Product Design

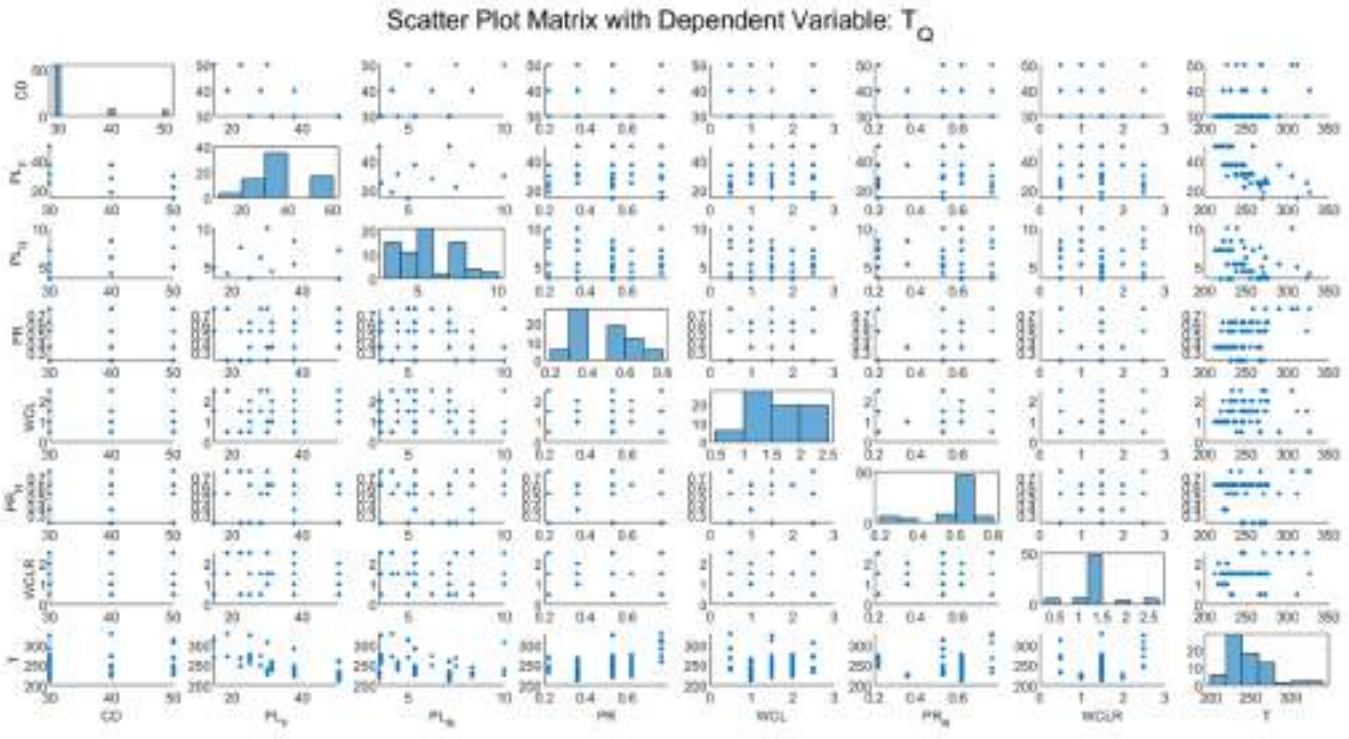
DOC Designs Based on Simulation Results



Proposed

FZ PGM	RZ PGM
FZ Pt:Pd	RZ Pt:Pd
FZ WC Loading	RZ WC Loading
FZ Coat Depth	RZ Coat Depth

Regression Analysis for Tunable Parameters



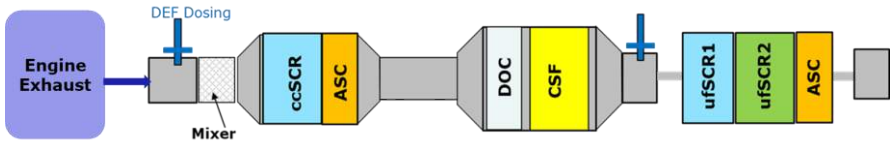
Model can be used for product design optimization

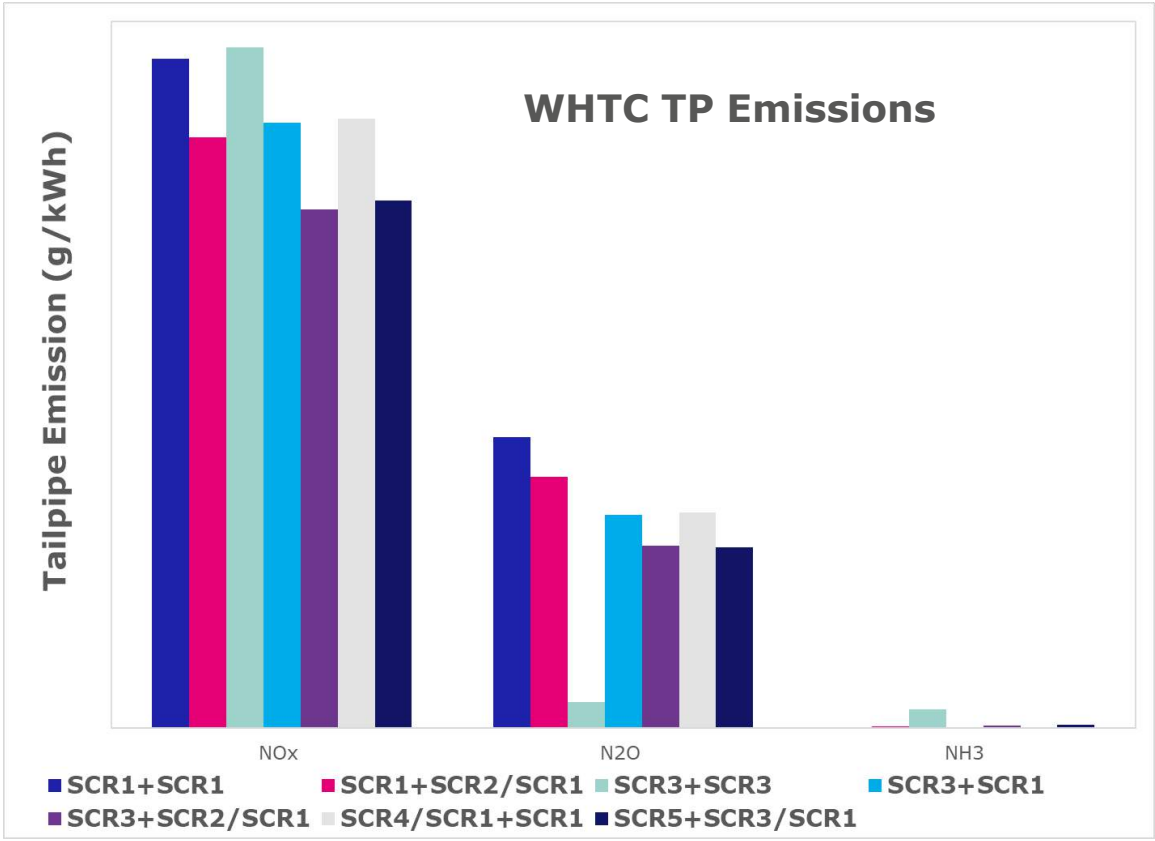
Example of Simulation Led Design of System Architecture

System Architecture Design for Eu 7 HD

- To perform this testing physically would require:
  - Manufacturing 13 bricks
  - Running 28 engine tests
  - Complete program would require 84 tests as alternative dosing options were also simulated

- If only the best 2 options from simulations need to be tested this reduces to
  - Manufacturing 8 bricks
  - Running 8 engine tests
  - Include dosing strategy optimisation





Summary

JM invested significant resources to build kinetic model library for emission catalysts

Models are useful to design system prototypes, resulting in significant cost and time savings for OEMs

Models are also useful for post design verifications and optimizations

Models are being updated to facilitate system design for future Eu 7 HD / BS VII Vehicles

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