Metal Supported Catalysts for Large-Volume Engine Applications: From Designing to Recycling

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4TH AVL LARGE ENGINE TECHDAYS 05th & 06th May 2010
- Emitec: Who we are

- Project: Boundary conditions
- „Turbulent Substrates“
- Geometric Analysis
- Application and Durability Tasks

- Recycling

Typical procedural method
Advantages of a Metalit®

- lower pressure drop
- greater effective inside surface
- by that: smaller volumes at the same efficiency
- faster light-off
- very low mechanical sensitivity e.g. against impacts (mechanical shock)
- no suspension of the matrix in a separate mantle needed
- structured foils to provide higher efficiency
Emitec’s Wide Range of Different Sizes and Shapes
Applications

Mantle Tasks

Housing Tasks
Emitec’s Urea Dosing System

- Tank Unit
- Tank Extraction
- Support Unit
- Injection
Emitec: Locations Worldwide

- Eisenach
- Lohmar
- Pune
- Taipei
- Beijing
- Osaka
- Tokyo
- Detroit
- Fountain Inn
- Birmingham
- Saigon
- Seoul
- Moscow
- Gothenburg
- Birmingham
- Moscow
- Birmingham
- Saigon
- Saigon
- Saigon
- Emitec: Who we are

- Project: Boundary conditions
  - Nonroad/Offroad Legislation
  - Large Engine's Emissions
  - Fuels and Restrictions

- „Turbulent Substrates“

- Geometric Analysis

- Application and Durability Tasks

- Recycling
EU and US Emission Legislation for Different Applications

Source: MTU
Drilling – Different Limits Depending on type of Application
Mechanical Drilling versus Electrical Drilling
Diesel Emission Trade-Off

- NOx [g/kWh]
- PM [mg/kWh]

Final Limits
Near-term Limits

DPF
SCR
Combined Systems
Standard Engine Technology
Advanced Engine Technology (EGR, Injection, Miller, etc.)

Fuel Savings
• Most preferred diesel fuel is ULSD according to EN 590
• Sulfur-contents of more than 50 ppm can deactivate DOC-coatings
• Sulfur-contents of more than 0.5% generates deposits of ammonium sulphates in SCR-systems
• Aftertreatment systems will be poisoned by exhaust gas contents of
  - Phosphor (P), Zinc (Zn), Boron (B)
  - Chlorides (-Cl)
  - Potassium (K), Sodium (Na)
  - Calcium (Ca), Magnesium (Mg)
  (regardless of source fuel or lubricant)
• DPF-systems require low ash oil
  (low-SAPS = low Sulphate-ashes, Phosphor and Sulfur)
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**SECA Sulphur Emission Control Area:**
- North Sea
- Baltic Sea
- USA (250 miles)
- Mediterranean Sea
- Australia

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**International Convention for the Prevention of Marine Pollution**

Sources: Shell, Germanischer Lloyd

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**Revised MARPOL Annex VI – 2008**

Implementation Dates for NO<sub>x</sub>, SO<sub>x</sub>, PM, Fuel-Regulations
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- Recycling
Catalytic Converters with Straight Channels
“Turbulent”, Structured Substrates for SCR-, NO\textsubscript{x}-Adsorber-Systems and Oxidation Catalysts to Improve Mass Transfer / Efficiency
Partial-Flow Deepbed-Filter: Structure of the PM-Metalit®
Function of a Ceramic Wall Flow Filter with a Single Wall-Passage
Function of the PM Metalit®

Multiple Usage of NO₂
PM-Metalit®: Length Improves Soot Reduction
ESC-Test
Soot reduction in DPF depends on:

- Soot loading (absolute amount of soot)
- NO\textsubscript{2}-concentration
- Temperature

![Graphs showing the relationship between soot reduction rate, soot loading, NO\textsubscript{2}-concentration, and temperature.]

Continuous Soot Regeneration: Thermal Management
Thermal Management Study with AVL
Control of PM-Metalit Performance and Soot Load by Engine Thermal Management

Limit 1: For a soot load above 2 g/L the temperature at DOC inlet is increased by 30K

With thermal management TM1 the soot load exceeds a value of 4.0 g/L

With thermal management TM2 (additional 30K) the soot load could be held below 3 g/L

Also the tail pipe soot emissions could be held below 0.02 g/kWh

NRTC Emissions, Cold Ambience (-10 °C), Thermal Management
Thermal Management Study with AVL
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At the same matrix volume, depending on the diameter and the mat for suspension of the matrix, the really needed space for installation of a ceramic substrate is about 5 - 10 % bigger

Differences of the Catalytic Volume
Substrate Diameter: 24”
Frontal Area: 0.233m²

2 x 12.4” = 24.8”

Brick Diameter: 12”
Matting Thickness: 0.2”
Frontal Area: 0.211m²

Same Frontal Area in a Smaller Package with Reduced Canning Effort
Same Frontal Area in a Smaller Package with Reduced Canning Effort

Brick Diameter: 12”
Matting Thickness: 0.2”
Frontal Area: 0.211m²

Substrate Diameter: 24”
Frontal Area: 0.286m² +35%
Pre-Turbine Aftertreatment?
Exhaust Aftertreatment: Pre- or Post-Turbine?

DPF-Study together with FEV
Exhaust Aftertreatment: Pre- or Post-Turbine?
Study together with FEV
Exhaust Aftertreatment: Pre- or Post-Turbine?
Study together with FEV
Example: PM-Metalit System for 1000 kW Engine
SCR-System with DPF
SCR-Systems: Urea nozzle position
Results @ Nozzle Position 1 and 2, 8 bar Injection Pressure

- **Nozzle Position 1**
  - Urea mass flow: 30 mg/s
  - Exhaust gas mass flow: 500 kg/h

- **Nozzle Position 2**
  - Urea mass flow: 100 mg/s
  - Exhaust gas mass flow: 1800 kg/h
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Loads Influencing the Lifetime of Catalyst Substrates
Thermal Loads

- Load from max. temperature: $\sigma_{T_{\text{max}}}$
- Max. temperature difference during operation cycles: $\sigma_{\Delta T}$
- Max. rate in temperature variation during heat-up and cool-down: $\sigma_{dT/dt}$
- Uniformity index of incoming flow: $\sigma_{\gamma}$

Mechanical Loads

- Max. acceleration level (pk/RMS): $\sigma_{a}$
- Frequency range of excitation regarding resonance frequencies of the whole system: $\sigma_{f}$
- Gasdynamic loads by gas pulsation: $\sigma_{\text{dyn.}}$
Dimensioning Target by Means of a Wöhler Curve

\[ \sigma_{\text{Eff.}} = \sqrt{\sigma_{T_{\text{max}}}^2 + \sigma_{\Delta T}^2 + \sigma_{dT/dt}^2 + \sigma_{\gamma}^2 + \sigma_{a}^2 + \sigma_{f}^2 + \sigma_{\text{dyn}}^2} \]

Diagram showing the relationship between load cycles and system lifetime, with a graph indicating the dimensioning process and the concept of "Overstressing."
Lastenheft

Thermische Belastung
Maximale Temperaturbelastung: $\sigma_{T_{\text{max}}}$
Maximale Temperaturdifferenz innerhalb eines Zyklus: $\sigma_{\Delta T}$
Maximale Temperaturänderungsgeschwindigkeit beim Aufheizen und Abkühlen: $\sigma_{\frac{dT}{dt}}$
Grad der Gleichverteilung des Abgases auf der Frontfläche: $\sigma_{\gamma}$

Mechanische Belastung
Maximaler Beschleunigungspegel (pk/RMS): $\sigma_{a}$
Frequenzbereich der Anregung im Hinblick auf System-Eigenfrequenzen: $\sigma_{f}$

Gasdynamische Belastung durch Gaspulsation: $\sigma_{\text{dyn.}}$

Beschichtung
Canning

Specifications

|-----------|--------------|----------|---------|----------|--------------|-------------|

Abgleich mit bekannten Belastbarkeitsprofilen

From Specification to Serial Design
FE simulation of large diameter substrates
Thermal stress analysis

Thermal shock cycle – input for Katprog
Temperature results from Katprog

Temperature loads mapped on FE model
Elastoplastic stress analysis
Elastoplastic strain analysis

Exhaust temperature
Exhaust mass flow

Time

FE simulation of large diameter substrates
Thermal stress analysis
FE Simulation of Large Diameter Substrates
Vibration Analysis – Determination of Frequency Response
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Recycling of Metallic Catalysts: Easy and Proven Process

Separation Process for Catalyst Systems with Metalits

Metal Substrate Converters ➔ Shredder ➔ Washcoat ➔ Metal ➔ Magnetic Separation ➔ Stainless Steel ➔ Substrate Foil ➔ Mechanical Separation ➔ Substrate Foil ➔ Blending and Sampling ➔ Washcoat

Recycling of Metallic Catalysts: Easy and Proven Process
Metallic substrates have a proven durability during 25 years of catalytic exhaust aftertreatment.

Large engines have to be prepared for exhaust aftertreatment – exhaust aftertreatment has to follow the new approach for large engines.

Loads coming from engine, canning and coating are superposed in the substrate and perform interactions to each other.

Analytic processing represents reality in a good way – that leads to shorter development time and reliable dimensioning.

Detailed specifications help arranging aftertreatment systems and produce best results for the customers.

Recycling of all-metal aftertreatment systems are state-of-the-art and the recovery of coating components close the material flow.

Summary
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Thank you for your attention!

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