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Global Approach to Diesel Aftertreatment Issues in Mining Industry

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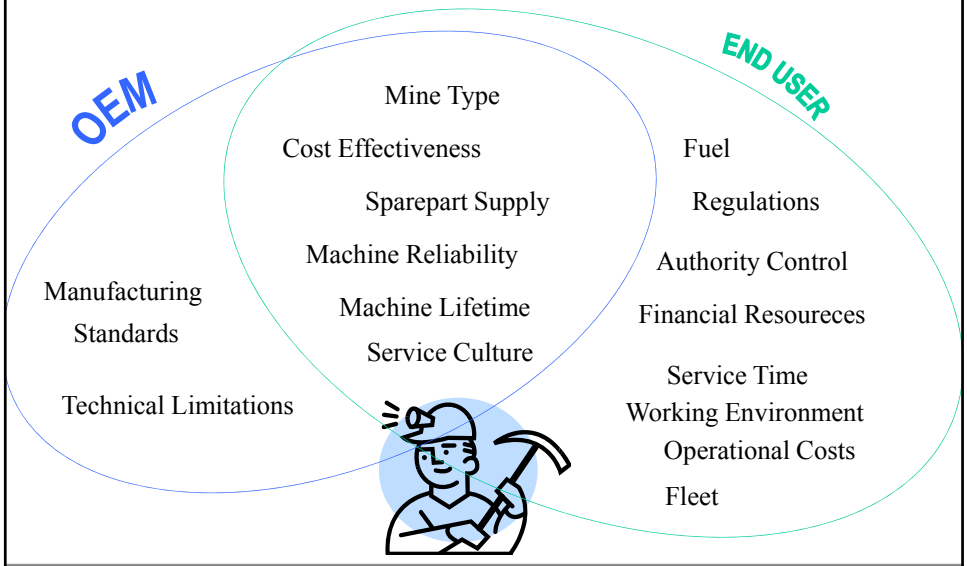
FACTS INFLUENCING THE CHOICE OF AFTERTREATMENT TECHNOLOGY



FINNKAT OEM PERSPECTIVE

- Global business
- OEMs have no control over the engine duty cycles
  - Driving cycles are transient and unpredictable
- Machinery lifetime, proof of operation
- Technical requirements
- Engine emission standards are linked to fuel sulfur, but market area includes also areas where only high sulfur fuel is available
  - Reliable engine operation have to be ensured in all markets
- More power ≈ more efficiency.
  - End user might modify engine settings.
  - tampering proof systems, both engine settings and aftertreatment systems

FINNKAT END USER PERSPECTIVE

- Service culture
  - when something fails and machine does not run any more
  - based on running hours
  - measurement-based maintenance
- Fuel quality
  - biodiesel
  - <15ppm S, >3000ppm S
- Operating conditions
  - efficiency is measured as engine running hours -> lot of idling
  - different machinery (loader / dumper / drilling machine) all have different **duty cycles**
  - different exhaust gas temperature / different engine brands
  - existing fleet / new engines

END USER PERSPECTIVE

- Regulations and limits
  - only engine out emissions
  - DPM exposure limits
  - other gaseous components exposure limits
- Environmental
  - metal / non-metal mines
  - coal mines

AVAILABLE SOLUTIONS FOR DIFFERENT EMISSION REQUIREMENTS

DOC

- Minimum requirement in mining industry
- – low PM reduction
- \+ maintenance free

FTF Flow Through Filter

- Techically mix between DOC and DPF
- – Not as efficient as DPF
- \+ maintenance free
- \+ sulfur tolerant
- \+ medium space requirement

AVAILABLE SOLUTIONS FOR DIFFERENT EMISSION REQUIREMENTS

DPF

- – Typically wall-flow filter, >98% PM filtration rate
- – maintenance requirements
- – fuel requirements, possible fuel penalty
- – operating conditions
- \+ Best solution for maximum PM reduction

LIMITATIONS FOR STATE OF ART PRODUCTS

- Proper service is not possible
  - no specific maintenance workshop
  - only light is on your helmet
  - no cranes or lifts
  - visibility <20m (high humidity, dust, diesel smoke etc.)
- Misfueling with high sulfur fuel or 10-20h at "cold" driving cycle can lead to seriuos regeneration problems due to increased soot loading and improper regeneration
- Driving force is still missing in some market areas

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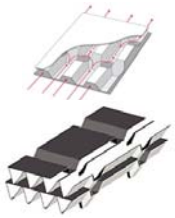
FTF TECHNOLOGY

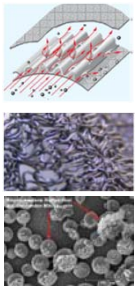
Flow Through Filters

- Structures metal foils
- knitted wire ”filters”



PM reductions 30-60% (total PM)

- Puff of black smoke is possible
- FTF is not real filter with over 95% PM filtration under all running conditions
- PM reduction is depending on duty cycle and engine out emissions



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FTF TECHNOLOGY

Open system

- Soot loading capasity limited
- Back pressure does not exceed maximum, designed for max 100-150mbar.

Regeneration

- Engine out NO2
- partly continuously due to NO2 formation in the catalyst. NO2 from exhaust system lower than engine out NO2 due to soot oxidation
- thermal regeneration if temperature high enough
- No active action needed

FTF TECHNOLOGY

- Intergration to machinery
- Catalyst coating – mining sector
  - Highly selective towards soot oxidation
  - NO oxidation to NO2 is not preferred
  - Balance is possible!
- Robust system for various operating conditions
- FTF is very robust against poor maintenance practices and can recover its usefulness eventually, even after it is misfueled. The FTF also contains no sensors or electronics or any warning lights to be monitored in order to maintain proper operation of the FTF.

FTF – FIELD EXPERIENCE

- nearly 1000pcs. FTF systems installed in underground / tunneling sector
- <1% warranty claims
- Proper working with various fuels and operating conditions
- Back pressure levels are within engine manufacturers specifications
- NO2 levels after FTF not exceed engine out levels

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NO_2 ISSUE

- Steady state and transient cycle of same engine could give totally different NO2 engine out emissions
  - Steady state driving **NO2 5%** of total-NOx
  - Transient driving **NO2 32%** of total-NOx as average over test cycle. NO2 peaks 45-60% of total NOx.
  - Realistic measurement of FTF aftertreatment system on transient operation. Also soot regeneration will happen more likely
  - Test engine 12 liters on-road certified engine, 285kW

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FTF IN WORST CASE SCENARIOS

- Operating temperature <220ºC for several hours
  - PM reduction efficiency decreased with temperature decrease
  - Slight back pressure increase (~10-40mbar)
  - Soot build up is oxidized and partly released when higher operating temperatures occur
  - >60% of soot is oxidized within 2-3 minutes when exposed to higher exhaust gas temperatures
- Works also with low NOx/PM ratio and relatively high engine out PM emissions

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FUTURE CHALLENGES

- US Tier 4 Interim / EU Stage III B most probably needs exhaust gas filtration (among other possible aftertreatment methods).
- DPF will be future. When – depends on fuel qualities
- Robustness of aftertreatment systems to withstand mining environment
- Emission certification test cycle will changed from steady state to transient test cycle – how this will change engine out NO2 emissions?
- Engine out NO/NO2 ratio is expected to change for higher NO2.
- Use of Urea-SCR in underground mining? Safety and health considerations.
- World wide harmonization of emission regulations
- Large areas of the world are still without proper emission regulation, mining, non-road or even on-road regulations.