Potential approach on Stage V particulate control diagnostics (DPF monitoring)

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Scope of proposal

• Draft text is intended to follow request set out by QSG to provide:
  – A text proposal on PM control requirements in relation to tampering, removal and loss of function of DPF
  – A definition and/or assessment method of the extent of loss of DPF function
  – The method to inform operator and store information on malfunctions

• The following slides and accompanying text (Particulate_control_20160225) aim to provide a proposal within the above scope as an adaptation of the original text submitted by the German Ministry for Environment /TÜV NORD
Applicability

• Propose that:
  – “This section shall apply for electronically controlled engines of sub-categories subject to a PN limit according to the “Stage V” emission limits set out in Annex II of Regulation (EU) 2016/XXX fitted with a DPF and using electronic control to determine both the quantity and timing of injecting fuel or using electronic control to activate, de-activate or modulate the emission control system used to reduce particulate pollutants.”

• In order to avoid duplicative requirements applying to the same components:
  – “In cases where the NOx control system and the particulate control system share the same physical components (e.g. same substrate (SCR on filter), same exhaust temperature sensor) the requirements of this section shall not apply to any component or malfunction where, after consideration of a reasoned assessment provided by the manufacturer, the type approval authority concludes that a particulate control malfunction within the scope of this section would lead to a corresponding NOx control malfunction within the scope of [the NOx control section]”
Key definitions

• Based upon the equivalent definitions in the NOx control section:

  “Particulate Control Diagnostic system (PCD)” means a system on-board the engine which has a capability of

  (a) detecting a Particulate Control Malfunction;

  (b) identifying the likely cause of particulate control malfunctions by means of information stored in computer memory and/or communicating that information off-board.

  “Particulate Control Malfunction (PCM)” means an attempt to tamper with the diesel particulate filter (DPF) of an engine or a malfunction affecting the DPF that might be due to tampering, that is considered by this Regulation as requiring the activation of a warning once detected.

• The definition of a DPF is adopted from German Ministry for Environment /TÜV NORD proposal:

  “Diesel particulate filter” (DPF) means an exhaust after-treatment system designed to reduce emissions of particulate pollutants through a mechanical, aerodynamic, diffusional or inertial separation;
Primary failure/tampering modes

1. Removal of the DPF
   – Aside from during maintenance activities, removal of a DPF would normally only result from tampering
   – Removal could potentially be detected by disconnection of/incorrect signals from existing diagnostic systems installed by the manufacturer
   – Replacement with a substitute system that replicates the signals from the manufacturer-specified DPF and associated sensors is not readily detectable without an additional exhaust gas monitoring system and more sophisticated diagnostics

Proposal requires manufacturer to detect removal of DPF but not detection of a substitute system that mimics the DPF mechanically or electronically.

Automotive example: DPF and sensors removed and replaced with ordinary pipe
Primary failure/tampering modes

2. Restricted flow: Failure or tampering that results in an abnormally restricted exhaust flow through the DPF
   
   – This could arise due to, for example, failure to re-generate, failure to remove ash at prescribed interval, or melting of the substrate
   
   – It would normally be detected by manufacturers existing diagnostic system and if not rectified would limit engine operation without releasing additional particulate to the environment

Consistent with scope set-out by the QSG the proposal does not regulate this aspect. This will be addressed by manufacturer’s already foreseen diagnostic systems.
3. Open flow: Failure or tampering that results in the total lack of filtration in the DPF (i.e. empty can)
   
   - This could arise from the exhaust gas blowing a damaged substrate out of the DPF can or from the deliberate removal of the substrate from the DPF can
   
   - This may be detectable using available signals from sensors already foreseen by manufacturers but will in most cases require additional development/calibration/ECU functionality compared with that already foreseen by manufacturers

Proposal requires manufacturer to detect open flow (empty can) with sensors in-situ and refers to this as “Loss of function of DPF”

Automotive example: Remove DPF substrate and replace can but leave sensors in-situ
Primary failure/tampering modes

4. Partially open flow: Failure or tampering that results in the partial reduction of filtration in the DPF

– This could arise from damage to the substrate such as cracking
– The extent to which this can be detected effectively and reliably is highly limited and is the most likely to need more sophisticated diagnostics than currently foreseen
– Determination of a detection threshold that could be reached by all manufacturers would be highly challenging and require further evaluation outside of the time available for developing the corresponding delegated act

Proposal does not require manufacturer to detect partially open flow based upon above evaluation

Automotive example: Cracked DPF substrate with section missing
5. Insufficient reagent: Relevant only to DPFs that rely upon a reagent such as a fuel-borne catalyst

– This could result from failure to replenish the tank or failure of the dosing system

– Such systems have so far not been installed by non-road engine manufacturers but if they were then insufficient reagent should be detectable

– Lack of reagent would likely lead to restricted exhaust flow mode (due to lack of regeneration) which would limit engine operation without releasing additional particulate to the atmosphere

Proposal requires manufacturer to specify characteristics of reagent (if applicable) in information document but does not specify a detection requirement
Removal of DPF – Proposed approach

• “The PCD shall detect the removal of the DPF inclusive of the removal of any sensors used to monitor, activate, de-activate or modulate its operation”

• Functional requirement: Detect and activate visual warning within 60 minutes of non-idle operation or a longer period where permitted by the Type Approval Authority (as per NRMM NOx Control Diagnostic requirement)

• Type-approval demonstration requirement: Detection within engine operation over 2 runs of the appropriate bench test cycle or 3 runs where permitted by the Type Approval Authority (as per NRMM NOx Control Diagnostic requirement)
Loss of DPF function – Proposed approach

• “The PCD shall detect the removal of the DPF substrate ("empty can"). In this case the DPF housing and sensors used to monitor, activate, deactivate or modulate its operation are still present”

• Functional requirement: Detect and activate visual warning within 240 minutes of non-idle operation or a longer period where permitted by the Type Approval Authority

• Type-approval demonstration requirement: Detection within engine operation over 8 runs of the appropriate bench test cycle or 12 runs where permitted by the Type Approval Authority
Failures of the PCD system – Proposed approach

• “The PCD system shall be monitored for electrical failures and for removal or deactivation of any sensor or actuator that prevents it from diagnosing any other failures…”

• Functional requirement: Detect and activate visual warning within 60 minutes or a longer period where permitted by the Type Approval Authority

• Type-approval demonstration requirement: Detection within engine operation over 2 runs of the appropriate bench test cycle or 3 runs where permitted by the Type Approval Authority
Informing operator and storing information on malfunctions – Proposed approach

• Visual warning shall be active whenever a diagnostic trouble code (DTC) is ‘confirmed and active’ and de-activated when conditions for its activation have ceased to exist

• System to store information on operator warning system activation:
  – “The PCD system shall include a non-volatile computer memory to store incidents of engine operation with a DTC confirmed and active in a manner to ensure that the information cannot be intentionally deleted.”
  – “The PCD shall store in the non-volatile memory all incidents of engine operation with a DTC confirmed and active where the operator warning system has been active for 20 hours of engine operation, or a shorter period at the choice of the manufacturer.”
  – “It shall be possible for national inspection authorities to read these records with a scan tool.”

• A DTC may be erased by the PCD system when the failure has been remedied (self heal) or by use of a scan/maintenance tool but the above record of incidents of engine operation with the warning system active shall not be erased
Proportionate approach

The following points should be kept in mind:

• Whilst Stage V will be the first time that the exhaust emission limits have effectively required the use of DPFs at EU level the use of DPFs is not new to this sector
  – In the micro-market of Swiss construction sites DPFs have been used since 2008
  – A number of manufacturers have by choice used DPFs as the primary PM reduction method since 2011 (from Stage IIIB onwards) in tens of thousands of NRMM in the EU and equivalent third markets such as the USA

• DPF maintenance requiring operator intervention is uncommon except at very long intervals (e.g. ash removal after thousands of hours operation) in contrast to maintenance for NOx control systems that may be required on a daily basis (e.g. fill consumable reagent)

• The lack of maintenance of a DPF generally results in a limitation of engine performance without additional emissions whereas the lack of maintenance of a NOx reduction system using consumable reagent generally results in increased emissions without limitation in engine performance if there were no NOx control diagnostic system

• There is currently no known evidence of widespread tampering with DPFs on NRMM comparable with the evident after-market tampering of DPFs in the passenger car sector

• These requirements on particulate control are emerging at a very late stage in the development of the Stage V regulation after a number of manufacturers have already decided their technology and control strategies for Stage V