Investigation of DPF Failure Modes and Identification Strategies

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INTRODUCTION

1. Recent in-use emissions data have indicated DPF failure to be a common occurrence
2. Failure of On-board Diagnostics (OBD) to detect a DPF failure
3. Could possibly result in exceeding USEPA PM standard depending on type of failure or propagation of the failure
4. DPFs are a robust after-treatment system
   - Failure could be caused by one or more engine sub system failure
   - EGR failure, regen control failure etc

OBD for DPF

1. One of the challenging diagnostic monitors in a modern heavy-duty diesel
   - Use of tailpipe PM sensors
2. Cost limitations dictate the use of simple delta pressure sensors to monitor DPF activity
   - Sufficient to monitor DPF fill rate and regen control
   - Studies have shown that current pressure sensor technology cannot identify a cracked DPF
3. Lack of representative “failure modes” to accurately model failed aftertreatment behavior
4. Assess the measuring thresholds for tailpipe PM sensors

APPROACH

1. Development of the open OBD demonstration platform
2. OB-3D: On Board Diagnostics- Development and Demonstration Platform
3. Combination of laboratory and real-world approach to develop and test, failure identification strategies
4. Collect failed after-treatment systems to assess type of failure and related emissions data
5. Use the data to develop algorithms that can detect failures based on existing sensors on vehicles
    - Develop virtual sensors

APPROACH

1. EGR Circuit Instrumentation
2. Boost Circuit Instrumentation
3. Proprietary ECU data Acquisition
4. Coolant and Oil Circuit
5. Fuel system instrumentation
6. Possible in-cylinder pressure acquisition

Engine Monitors

1. MKS FTIR 2030 HS
   - Before and After ATS
2. AVL Micro Soot Sensor
   - DPF out for regen monitors
3. TSI EEPS
   - PM Sensor Evaluation
4. PMP conditioning system
   - PN Sensor Evaluation
5. Laboratory grade electrochemical NOx Sensors (Mexa 720)

Aftertreatment System Monitors

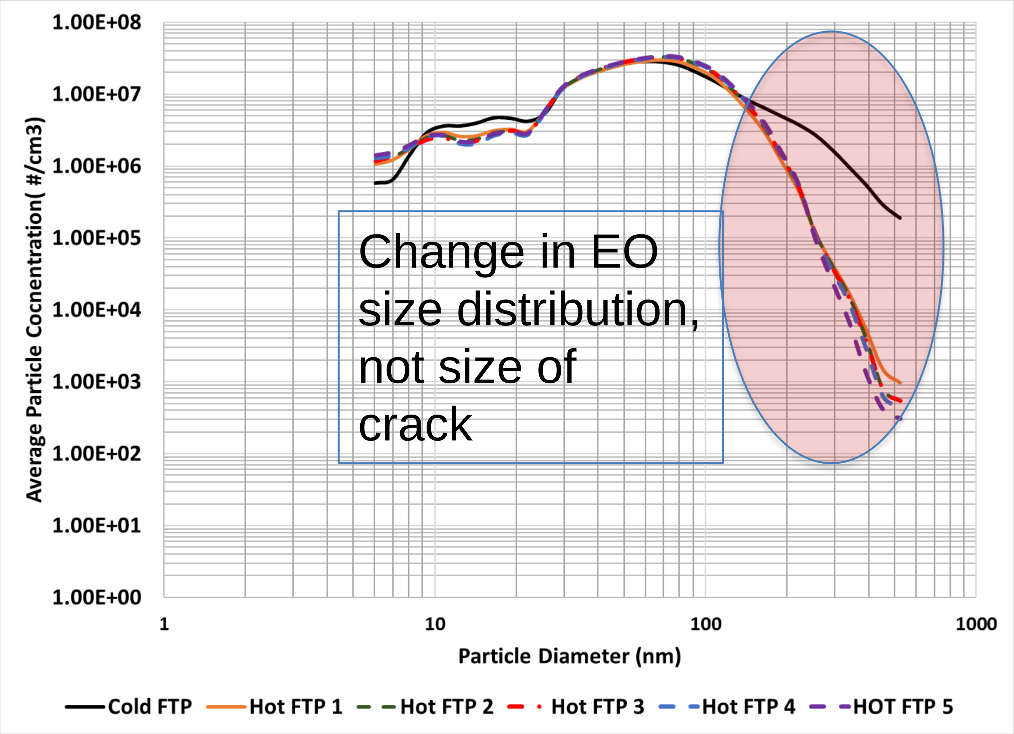
DOC + DPF + SCR+ Urea Dosing + NH3 Catalyst

1. Physical Models
2. Data driven models
   1. Neural networks
   2. Multi spine regressions
3. Sensor failure detection algorithms
   1. Probability based techniques
   2. Pattern recognition

METHODOLOGY

1. Ongoing project samples multiple failed DPF candidates
2. Test failed DPFs to assess its filtration efficiency and back pressure characteristics using controlled engine dynamometer testing
    - Analyze the type and magnitude of failure that will result in non-compliance of the engine to PM standards
3. Compare sensor based parameters such as delta pressure, temperature etc to a working DPF.
    - Analyze multiple operating conditions that could potentially indicate a failure pattern

RESULTS



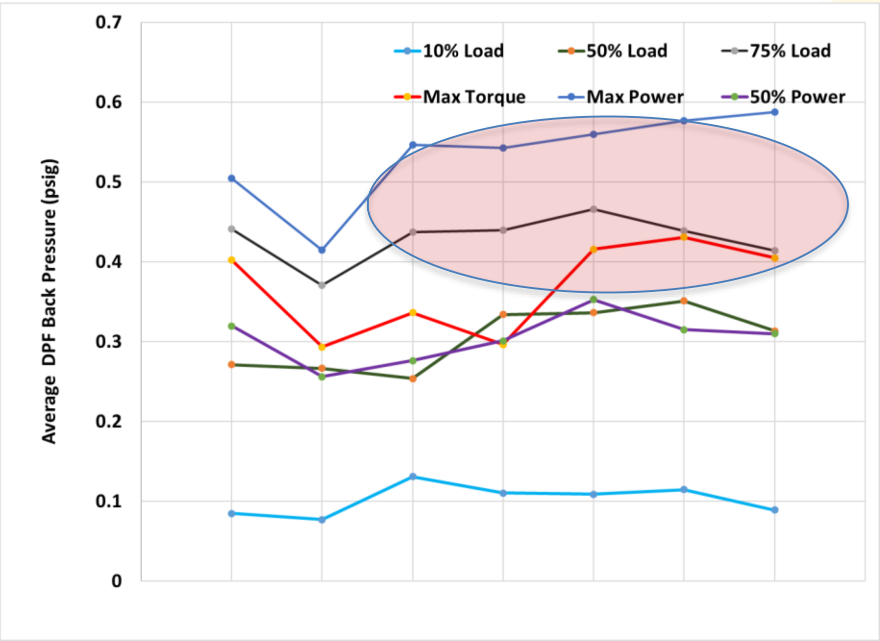
- Failed DPF with 24% filtration efficiency exceeds the USEPA mass regulation by magnitude of 10
- This test engine employed a low NOx, high EGR map with higher engine-out soot emissions
- Current technology HD diesels with SCR would potentially have lower EO soot characteristics and hence lesser deviation to PM standards during failed operations

1. With exception to particles over 100 nm there seems to be no observable difference in particle size distribution between cold and hot engine operation
2. A repeatable number and size distribution indicating a “thermally stable” crack

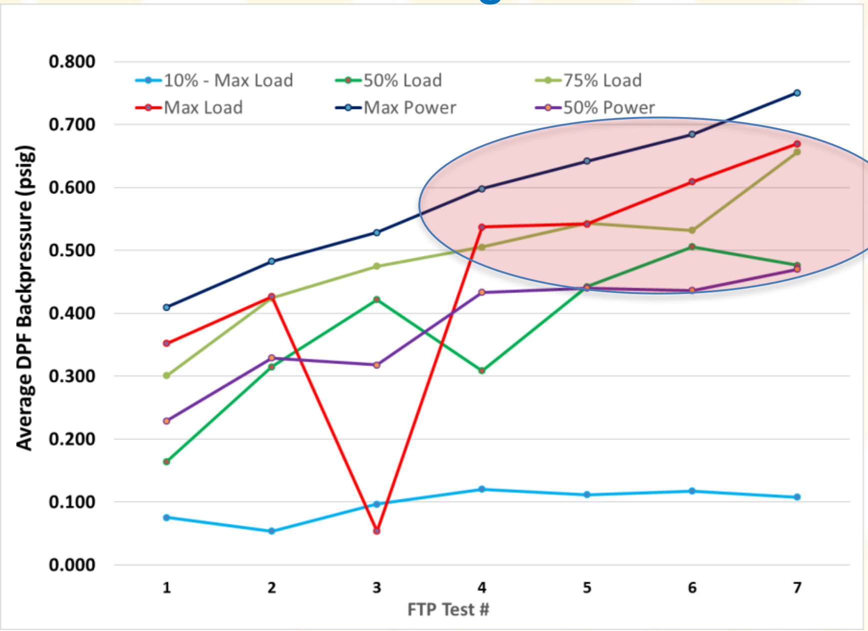
RESULTS

- First DPF sample tested in this study did exhibit a significant change in delta pressure characteristics compared to a working DPF
- Filtering the transient FTP data into discrete operating set points, yields a better analysis of the DPF delta pressure changes as opposed to instantaneous Dp traces

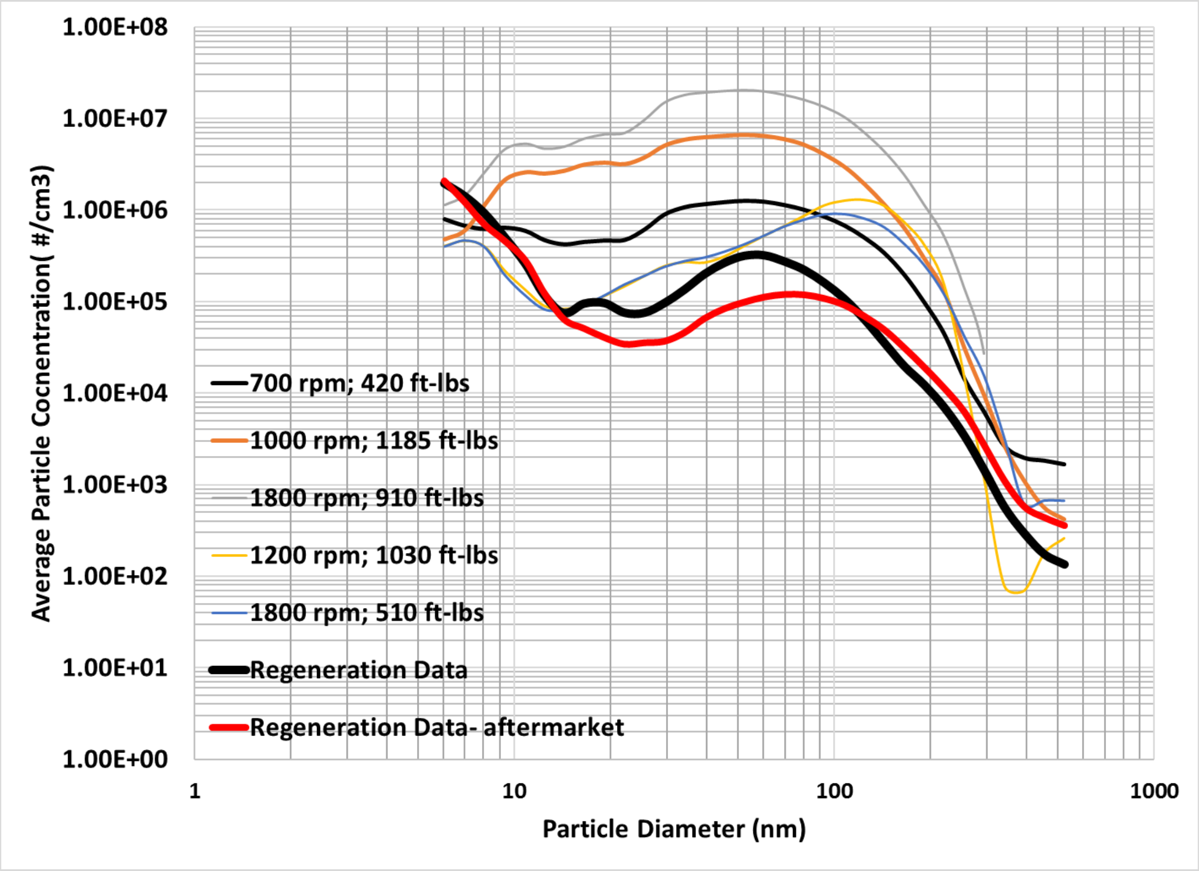
Failed DPF



Working DPF



RESULTS



- Particle emissions from a cracked DPF is over two orders of magnitude higher than during a regeneration event
- In this DPF failure case, the change in Dp change was significant compared to a working DPF
- Although Dp sensors are used as feedback for active regen control, this engine was unable to detect a failed DPF using the same sensor

CONCLUSION

- Ongoing study is testing multiple “naturally failed” DPFs to develop robust algorithms
- Establishing the relationship between the slope of Dp increase to the filtration efficiency for a working DPF vs a failed DPF could be a viable pathway to suggest a possible DPF failure
    - Chances of false positives needs to be eliminated
- Preliminary results from the 1st DPF indicate, the nature of the failure does not seem to change.
    - Remote sensing data have indicated changing PM numbers from failed DPFs as a result of opening or closing of cracks
- The use of tailpipe PM sensors could potentially help identify DPF failure issues, however a separate layer of diagnostics for the sensor needs to be developed
- The study is working towards creating controlled failed DPF samples by removing plugs and or drilling holes in-order to simulate naturally failed DPF

THANK YOU

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