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Influence of Catalysts and of Oil Consumption on Particulate Emissions

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INFLUENCE OF CATALYSTS AND OF OIL CONSUMPTION ON PARTICULATE EMISSIONS

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Introduction

In keeping with this workshop's spirit of topicality this contribution introduces some work in progress which involves the application of a wide range of measurement techniques (slide 1) related to the characterisation and origin of particulate emissions from vehicles.

The background (slide 2) to this activity is the increasing relevance of the relative contributions of fuels, lubes, aftertreatment systems and individual transient elements in duty cycles to help set effective regulations and develop technologies to meet them in the context of the drive towards lower emissions.

In a current project described later (slide 5) a wide range of measurement techniques are being deployed in combination (slide 3). These include various particulate measurement techniques relevant to number, mass and obscuration reflecting the project's combined requirements for scientific understanding and for applicability to in-service test procedures. A new method for monitoring the contribution of lube oil to emissions has also been deployed.

Real time measurement of oil-sourced emissions

We monitor oil-sourced emissions via atomic absorption spectroscopic detection of marker elements in the raw exhaust (slide 4). The results reported here involve measurements of Zn present in the lube oil although doped additions can be used if the fuel/oil combination under test so demands.

The technique's fast time resolution means that oil consumption can be related to transient events. Slide 7, which monitors 3 separate runs over the same section of a standard test cycle on our LD chassis dynamometer, demonstrates the technique's reproducibility in monitoring transient events whereas slide 8 demonstrates the reproducibility of the integrated measurements over different sections of the NEDC.

The technique is also sufficiently sensitive to resolve what appear to be fluctuations in emissions due to engine management effects (slide 9).

To date we have applied this technique to LD gasoline and Diesel vehicles and to HD Diesel engines with the greatest sensitivity being demonstrated in the gasoline-fuelled examples.

It is now well established that particulate emissions can be correlated with elements of transient cycles, particularly when dealing with total particle flux or, as in the case of slide 10, a specific size classification. Therefore the combination of these techniques now offers the possibility of correlating particulate emissions with oil consumption for individual transient events.

Application to a study of oil burning in catalyst-fitted cars

The above techniques have been used in a current study on behalf of the UK Department of the Environment Transport and the Regions (DETR) in support of Inspection & Maintenance (I/M) policy. This project (slide 5) is aimed at indicating whether the detection of poorly maintained engines at annual inspections is hindered by the presence of the catalyst and whether excessive oil burning adversely affects three-way-catalyst (TWC) performance. This is not a field blessed with a comprehensive public domain literature and so some preliminary experiments on a single vehicle are being undertaken in this project to establish whether the above issues warrant further, more comprehensive, investigation in terms of the impact of I/M procedures on air quality. The project makes use of smoking induced by engine component modification and catalyst degradation simulated by accelerated ageing.

This work will eventually be reported in the public domain but has not yet been completed. Some preliminary observations are recorded here in order to elicit feedback from other workers in the field and also illustrate the value of the application of new and established measurement techniques used in combination. It must be stressed that these observations are from individual experiments and do not in any way justify the drawing of general conclusions from them. Some observations are summarised in slide 6. The not unexpected observation that oil-sourced emissions were reduced by the TWC (slide 11) suggests elemental retention by the catalyst. The observation that the TWC reduced the number of particulates at high speed from the unmodified (not excessively smoking) engine should be interpreted in the light of the recurring discussion at this workshop on the origin of the high number counts often observed at high speed. The correlations between oil-sourced emissions and various particulate indicators (slide 12) are consistent with our understanding of engine operation and the physics of the various measurement techniques.

Conclusions

These studies indicate that there is plenty of scope for increasing our understanding of particulate emissions by the use of measurement techniques in combination particularly when directed at the detail of transient events.

A more general point is that a wealth of data is generated in studies involving a multiplicity of measurement techniques. However it is often the case that not all of these data are reported, particularly if at the reporting stage of a study they are not considered to have direct significance to the main conclusions although the data might be of major value to work on different but related topics. Similarly the detailed steps in determining particulate measurements (e.g. temperatures, flow rates) are seldom reported and these may have significance for the retrospective validation of new steps in our understanding of measurement processes (e.g. the current debate concerned with the origin of high particulate count rates at high speeds). Informal workshops such as this therefore provide a valuable medium for the timely dissemination of the existence of such 'hidden' data.

Acknowledgement

Thanks are due to Douglas Macmillan (Project Officer at UK DETR) for permission to report some of the results of ongoing work related to oil burning in TWC-fitted cars which we have used to illustrate the value of the application of combinations of measurement techniques.

Contents

- Use of key measurement techniques including:
  - particulates (via range of established methods)
  - real time oil consumption (new technique)
- Examples of application to an ongoing project
- Illustration of value of using measurement techniques in combination

Slide 1

Background

- Emissions regulations getting progressively tighter
- More understanding of source of emissions needed
  - to help set effective regulations (TA & I/M)
  - to help develop technologies to meet them
- Hence importance of contributions of
  - fuels, lubes, aftertreatments...
  - individual transient elements of duty cycles

Slide 2

The techniques

- Particulate
  - number via UPM, SMPS, Las-X
  - mass via Anderson Mk III, Delron LPI, reg. filter
  - smoke obscuration via Hartridge Mk III, Celesco
- Oil contribution via real time AAS

Slide 3

Real time measurement of oil-sourced emissions

- monitors marker element in raw exhaust by AAS
- real time (<200ms time resolution)
- can relate oil consumption to transient events
- applied to gasoline or diesel, engine or vehicle
- good reproducibility over transients
- can follow engine management control cycles

Slide 4

Oil burning in TWC cars

DETR project in support of I/M policy - results eventually in public domain

Includes:

- effect of excessive oil burning on efficiency and life of catalyst
- effect of catalyst on visible smoke and fine particulate
- correlation between oil burning and particulate emissions during transients

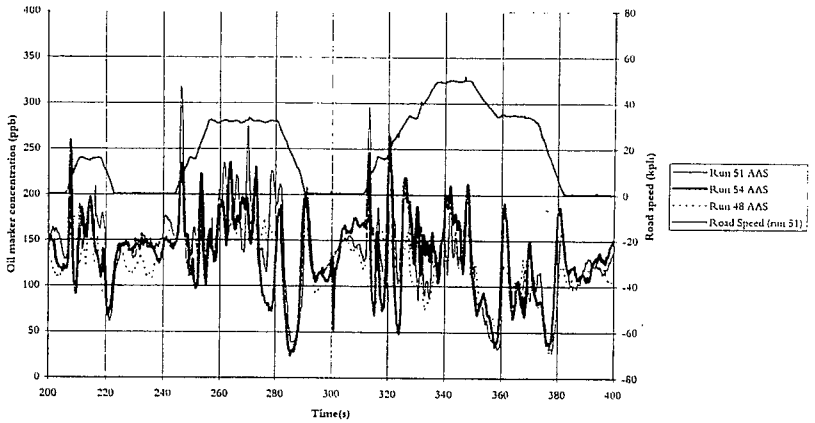
Slide 5

Some observations

- TWC reduced oil-sourced emissions (~50%)
- TWC reduced size (not number) of particles in 'smoky' vehicle
- TWC reduced number of particulates at high speed from 'clean' vehicle
- transient oil-sourced emissions correlate with smoke in certain transient events but not with particulate number flux

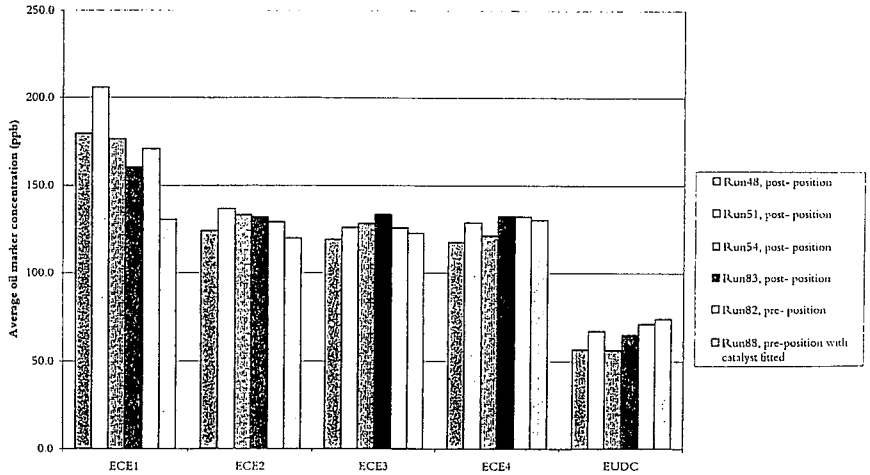
Slide 6

Reproducibility of transient oil marker emissions



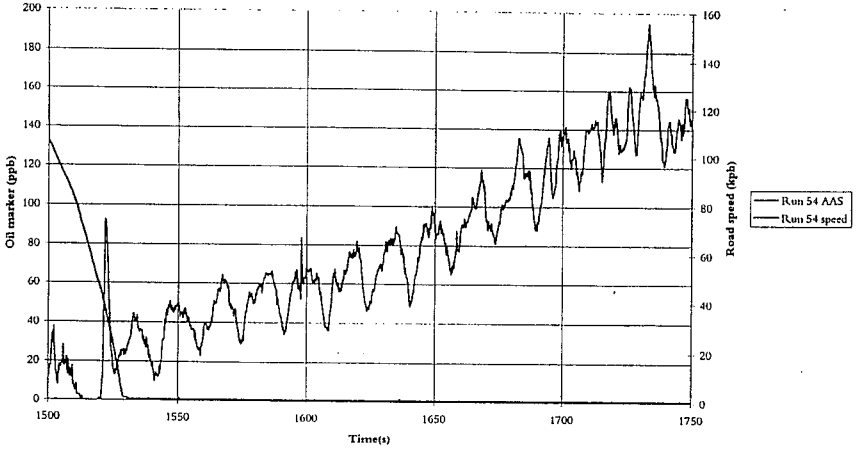
Slide 7

Average oil marker emissions from NEDC sections



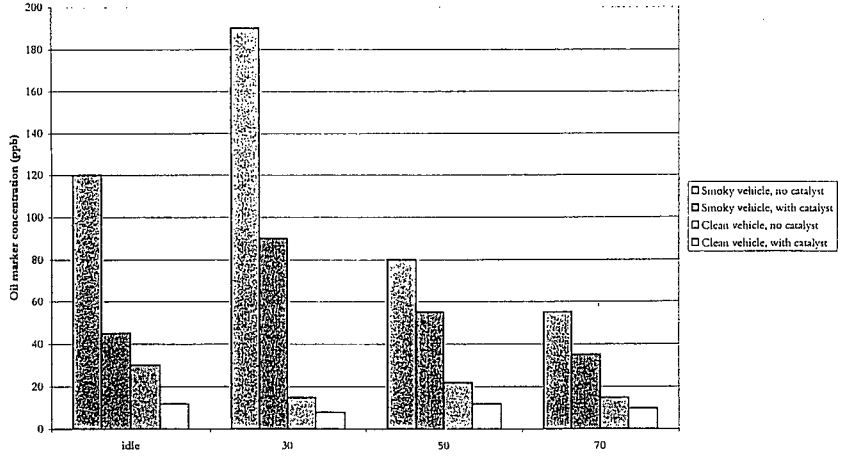
Slide 8

Idle oil marker emissions at the end of NEDC



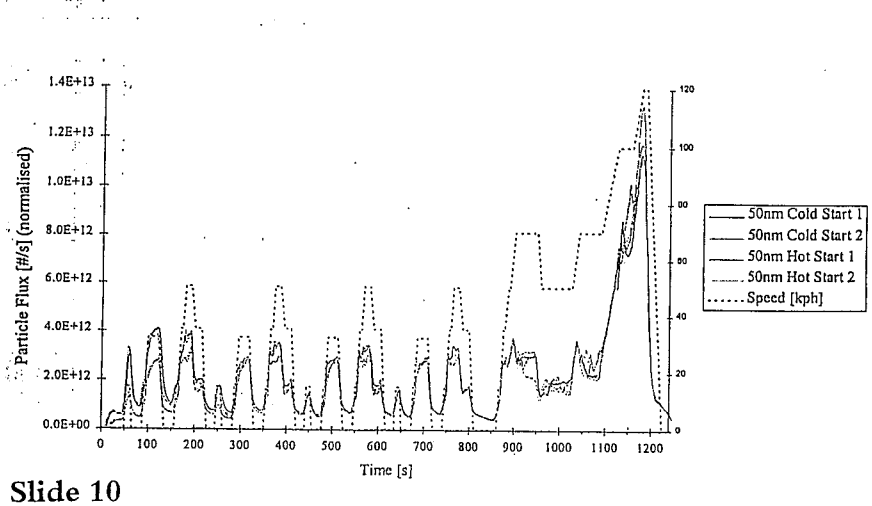
Slide 9

Steady state oil marker emissions taken from NEDC



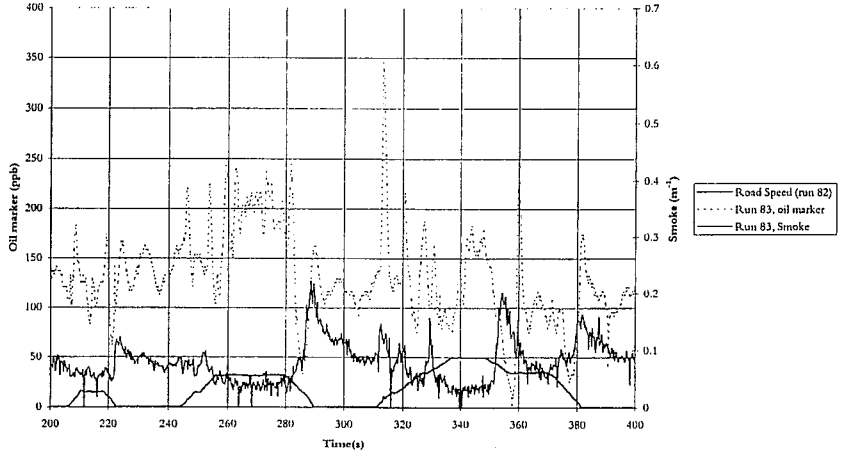
Slide 11

SMPS particle flux at 50nm during a NEDC



Slide 10

Comparison of transient oil marker emissions and smoke



Slide 12