Concept and Experiences of a fast Measuring Aerosol Spectrometer for the range from 5 to 630 nm

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INTRODUCTION

Counting of nanoparticles has become an established method in the engine development and in the discussion for new emission measurement standards. The most common particle counting systems based on nucleus condensation technique (CPC) in combination with an electrostatic classifier for size differentiation (DMA) are only able to measure stable aerosol conditions and are not able to measure with scanning times [Collins 2002] as required during transient driving cycles. A well known technique of combining high quality Vienna type DMAs with highly sensitive FCE (Faraday Cup Electrometer) in a multi channel setup closes the gap to measure with high accuracy in real time. This **TR-DMPS** (Transient Differential Mobility Particle Spectrometer) is able to measure complete particle size distributions every 200 ms (5 Hz) even for fast changing aerosol compositions.

INSTRUMENT CONCEPT

Based on the proven SMPS+C system of GRIMM this technology has been incorporated into a battery of 10 Differential Mobility Analyser (Vienna type DMA cluster [Reischl 1997]), combined with high performance Faraday Cup Electrometer (FCE), assuring extremely short response times with highest time resolution. This high quality technology is nearly insensitive to internal contamination and also extreme robust. This unique concept is not matched in sensitivity and flexibility by any other commercial instrument.
Applications range from low environmental concentrations and “downstream filter measurements” to high engine emission concentrations. Air flow changes or air pressure changes can not result in errors or wrong measurements and the results can be compared to any existing SMPS system. In addition this system does not have any problems of sensitivity due to dirt in the system.

This system is an absolute and a reference system for any other particle sizer and counter system.

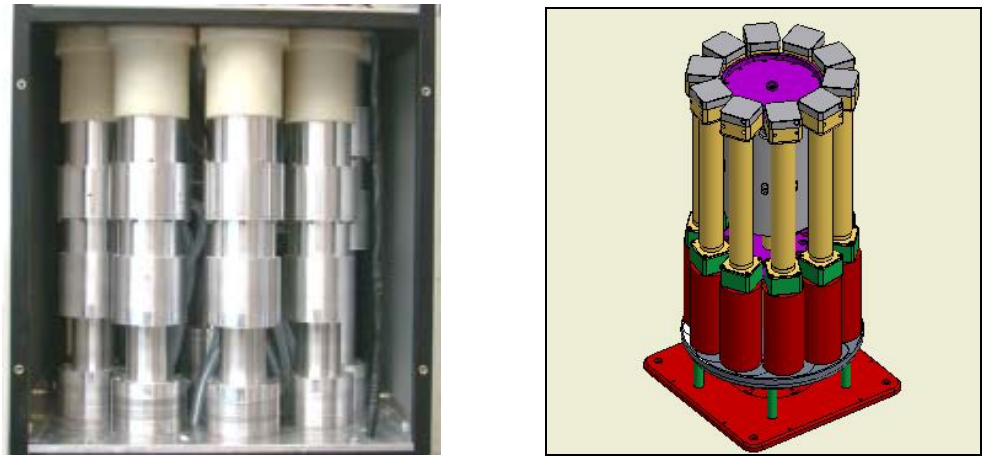

Fig. 1: Carousel (photo and schematic) of the different, separated DMA / FCE units

OPERATION

The Model 5.600 TR-DMPS uses a bipolar charger to charge the particles. The charged particles enter the 10 DMA columns where they are classified by size. From 10 DMA voltages 21 size channels can be

obtained continuously. These voltages can be altered depending on the user specifications to cover the range from 5 to 630 nm (3 selectable size ranges).
The number of particles is detected by highly sensitive faraday cup electrometers (FCE). Each FCE is separate and has a real response time on aerosol concentration changes within 20 ms and a concentration sensitivity of 0.5 fA for this response time ! The internal data acquisition reaches up to 100 Hz. The design of the FCEs avoids the use of PTFE and has an isolator integrated which is much less sensitive to mechanical, pressure or temperature stress than existing solutions.

This leads with a data reduction algorithm [Winklmayr 1990, Reischl 1996] to complete particle size distribution measurements with 5 Hz. Real-time data display is shown 5x per second and can be averaged during data collection.

For high concentration measurements from the raw engine exhaust a built in sampling and dilution unit gets representative and stable sample aerosol to the sensor.

MAINTENANCE

Due to the physical separation of the different size channels and the separated DMA/FCE-units, the system is very robust due to dirt in the DMA or FCEs. It requires less maintenance than in a classical SMPS system needed. For maintenance each DMA can be cleaned individually. The electrometers are designed for long term operation without any maintenance.

THE REFERENCE SYSTEM

Standard CPC and SMPS measurement systems are normally calibrated or referenced against DMA/ FCE-combinations. A DMA/FCE is the established reference method for validation of any other aerosol measurement system in the nanometer range. This DMA/FCE system is therefore the basic measurement method assuring highest resolution and reliability. The GRIMM TR-DMPS, built up with 10 DMA/FCE combinations is therefore an absolute measurement system assuring highest size resolution combined with highest time resolution for fast measurements. A calibration of this system is not needed. Any other measurement principle will be calibrated and validated with this unit.

RESULTS AND BENEFIT

The consistency, high time resolution and accuracy of the Model 5.600 makes this system a very powerful measurement technique in the field of motor efficiency testing, monitoring fast atmospheric changes, filter efficiency tests and various other research topics. The main merits of the TR-DMPS are in these fields:

- Changing aerosol concentrations and sizes => transient driving cycles for automotive emission measurements => environmental monitoring of fast changing aerosols like in nucleation events or on-road/drive by tests
- Changing sample air pressure => the instrument is also operating under different pressure conditions even for measurements in front of filters/traps
- Fast scans in any field (the TR-DMPS spectrometer determines a complete particle-size distribution every 200 milliseconds)
- Flexible setting and combination of the DMAs, user specific choice of particle size to be measured

A prototype of this concept has already proven its capability over years [EU-Projects: PARTICULATES, Heavy Duty Vehicles; PSICO-DEXA, Diesel Engine Emissions under Transient Conditions, 2001] in fast transient measurements even with lower emitting sources like gasoline fueled engines (fig. 2).

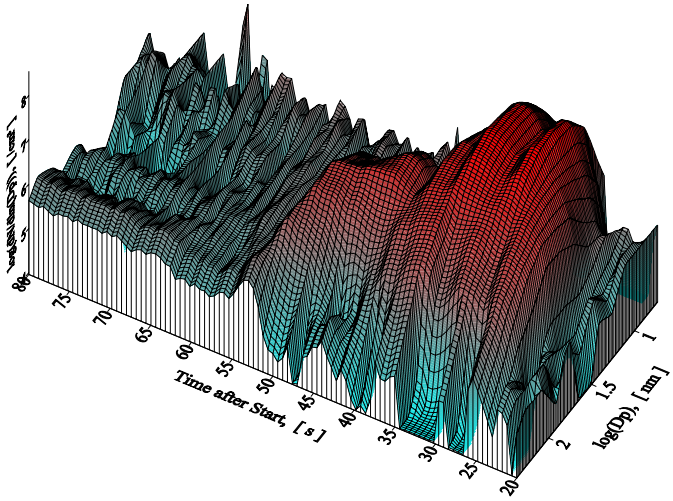

Figure 2: Example for a fast measured size distribution during a transient driving cycle (Fast Acceleration: 0-120 km/h in 30 s. Gasoline fueled engine, 3.5 l)

Higher concentrations lead to better performance and higher time sensitivity of the electrometers. The instrument in combination with the built in diluter covers a range of about 6 decades in concentration. This unit was built up for "robust" applications and a minimum of maintenance without the need of calibration of the system itself. Even cleaning of the complete system is only necessary after several driving cycles – the same frequency like normal SMPS units.

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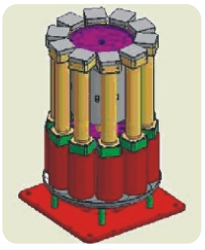
Abstract

Counting of nanoparticles has become an established method in the engine development and in the discussion for new emission measurement standards. The most common particle counting systems based on nucleus condensation technique (CPC) in combination with an electrostatic classifier for size differentiation (DMA) are only able to measure stable aerosol conditions and are not able to measure with scanning times as required during transient driving cycles.
A well known technique of combining high quality Vienna type DMAs with highly sensitive FCE (Faraday Cup Electrometer) in a multi channel setup closes the gap to measure with high accuracy in real time. Realized in the Grimm TR-DMPS (Transient Differential Mobility Particle Spectrometer) this unit is able to measure complete particle size distributions every 200 ms even for fast changing aerosol compositions.

The GRIMM TR-DMPS 5.600 with its high sensitivity is suitable for emission (automotive) and environmental applications to follow even fastest instationary aerosol processes.

Concept

Based on the proven SMPS+C system of GRIMM this technology has been incorporated into a battery of 10 Differential Mobility Analyser (Vienna type DMA cluster), combined with high performance Faraday Cup Electrometer (FCE), assuring extremely short response times with highest time resolution. This high quality technology is nearly insensitive to internal contamination and also extreme robust. This unique concept is not mached in sensitivity and flexibility by any other commercial instrument.
This system is an absolute and a reference system for any other particle sizer and counter system.
Applications range from low environ-mental concentrations and "down-stream filter measurements" to high engine emission concentrations. Air flow changes or air pressure changes can not result in errors or wrong measurements and the results can be compared to any existing SMPS system. In addition this system does not have any problems of sensitivity due to dirt in the system.



Application

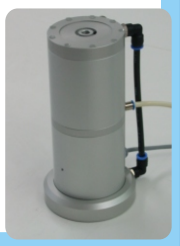
The TR-DMPS covers a wide range from standard test measurements to fundamental research from high concentrations in engine exhaust to normal environmental conditions, from dynamic behaviour in combustion processes to dynamic processes during nucleation events even in different pressure levels or altitudes.

Operation

The Model 5.600 uses a bipolar charger to charge the particles. The charged particles enter the 10 DMA columns where they are classified by size. From 10 DMA voltages 21 size channels can be obtained continu-ously. These voltages can be altered depending on the user specifications. The number of particles is detected by highly sensitive faraday cup electrometers (FCE).

FCE (Faraday Cup Electrometer)

This very short time resolution can be achieved by the highly sensitive and fast FCE-units. Each FCE is separate and has a real response time on aerosol concentration changes within 20 ms and a concentration sensitivity of 0.5 fA for this response time ! Our design of the FCEs avoids the use of PTFE and has an isolator integrated which is much less sensitive to mechanical, pressure or temperature stress than existing solutions.



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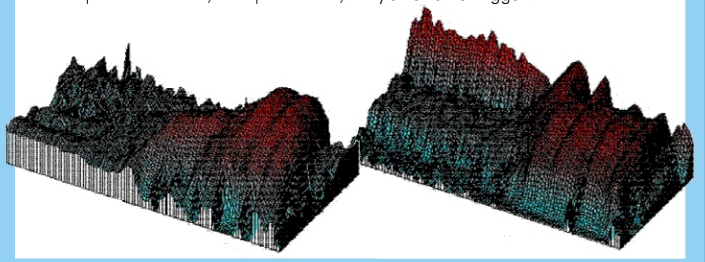
Results and Software

Data is collected from all faraday cup electrometers (FCE) at a rate of 100 Hz (100 times per second, the total response time of the extremely sensitive unit is 200 ms). This leads with a data reduction algorithm to complete particle size distribution measurements with 5 Hz. Real-time data display is shown 5x per second and can be averaged during data collection.
TR-DMPS software is user friendly but full-featured. It includes a complete data inversion algorithm and allows data to be displayed and exported in many different ways to meet a variety of needs. Naturally, also a three-dimensional representation of size distribution over time is included. The software collects data with 5x per second and can display averaged data with 0.5- to 60-second averages.
Pull-down menus and dialog boxes simplify setup and operation. Tests may be started by a few simple mouse clicks, at a specific time, or by an external trigger.



Benefit

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