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In-use emission measurements on combustion engines used in mobile machinery

With the introduction of the in-use measurement in the European and American market engine manufacturers for nonroad mobile machinery (NRMM) are responsible for the emissions from their engines about “useful life” and “in-use”. Here TÜV Hessen sees a strong justification for the development and offer of a PEMS process for in-use measurement, to render the necessary certificates.

Keywords
In-use emission measurement, PEMS (portable emission measurement system), NRMM (nonroad mobile machinery), US EPA Tier 4, EU Stage 4

Abstract
Landtechnik 67 (2012), no. 5, pp. 366–369, 5 figures, 1 table, 4 references

End of 2012, the adoption of the emission guidelines for NRMM (nonroad mobile machinery) at the European Commission in Brussels is expected, which will take effect in 2014 and the so-called PEMS measurements (portable emission measurement system) should include. The emission certificates must be carried out during the operation of the machine under real working conditions. The guideline is to consider this as “in-service conformity” [ISC], and should be into force as 2016, starting with the gaseous emissions [1]. In the U.S. market will already with U.S. EPA Tier 4i (2011) and Tier 4 (2014) issue certificates called for “in-use compliance” [IUC] for NRMM.

The high degree of diversification of mobile machines, their work applications and thus their different engine torque-speed profiles (load spectrum) implies that there is not a typical load spectrum in NRMM and thus no standard emissions can be expected. To obtain further experience regarding various load spectra and emissions, as part of the NRMM EU pilot project PEMS TÜV Hessen led through a joint project with the company AVL Germany GmbH, DEUTZ AG and FENDT/AGCO Corporation. The results will be presented to the European Commission n Brussels and made available.

Project

The focus of the project were on the application of the equipment on a mobile machine, and the implementation of real, different agricultural applications, to investigate different load spectra with stationary or transient engine behavior. Even part-load and high-load regarding emissions were evaluated. Compared to EURO 6 for commercial vehicles, especially the application of the equipment on the different machines, and the logistics of the machines are on the field a challenge, the most flexible adaptation of the measurement was for the construction of a variable intake adapter priority.

There the mobile emission measurement technology AVL MOVE PEMS was used (AVL GAS PEMS 493, AVL PM PEMS 494, SEMTECH EFM 4 “exhaust gas mass flow sensor” including heated exhaust pipe (5 m), and AVL MOVE System Control including CAN access “engine & vehicle” and power supply, GPS acquisition, humidity, pressure and temperature sensing).

The entire data collection was as AVL i-file and was evaluated with AVL CONCERTO. The vehicle used was a tractor of FENDT/AGCO GmbH type 720 Vario (7.9 t) with the engine Deutz TCD 6.1 L6 (150 kW), SCR. The mobile measuring equipment was placed in “heavy-duty-cases” to prevent vibration, shock and dirt. The power supply was performed using a 2 kW

Fig. 1

Application of PEMS

Fig. 2

Application of PEMS on the vehicle (Fendt 720 Vario) (Photo: Mathies)

generator (230 V), and an auxiliary battery element and is thus the vehicle autarkic. The auxiliary battery element in combination with the generator ensured that the power and heat the measurement technique can be realized (**Figure 1** and **2**).

Emission measurements in real agricultural applications

For the EU as part of the pilot program NRMM the requirements for "in-use" issue certificates will defined by the so-called work based window method (WBW) oriented to the requirements for commercial vehicles EURO 6 [2]. Taking into account the boundary conditions of the draft [1] – the working window, the average performance and the 90 % percentile value - various real modes were carried out for several hours with continuous emission monitoring. This is a use for mowing (~ 18,000 s) as use for plowing (~ 13,000 s), and a transport mode (~ 7.500 s). When plowing is especially in the 2nd part of the measurement to detect a quasi-static load spectrum of the engine (**Figure 3**). The average utilization rate in this part of the measurement is about 90 % of maximum engine power (~ 35 % mowing & transport mode ~ 60 % [3]). The entire measurement included the plow setting, a change of the plow, several stop phases for the system check and plowing itself.

Evaluations

The work applications were evaluated in each case by the U.S. American NTE Method (not to exeed) and by the European WBW-method based on EURO 6 for Commercial Vehicles (WBW-evaluation: EMROAD [4]). The evaluation was conducted based on the emission limits of U.S. EPA Tier4i, respectively EU Stage 3b, since this is the emission level of the engine. In comparison to the U.S. American NTE method, the WBW method the entire engine map is considered for emission analysis. The analysis by WBW method is presented based on the NOx emissions in plowing (**Figure 4**), starting with the period from 7,000 to 10,500 s (see **Figure 3**). The picture shows all valid work windows and measuring time, and the NOx limit. Clearly be seen that in the evaluated period of actual plowing the high-load phases (engine power: ~ 70 to 90 %) dominate, along with correspondingly low NOx emissions (neutralized representation: x-axis is cut). The evaluation of the total plowing time 0–13,000 s with transient load spectrum, as well as holding and cool down phases generates higher NOx emissions at lower loads (**Figure 5**). The comparison shows that expertise

Fig. 3

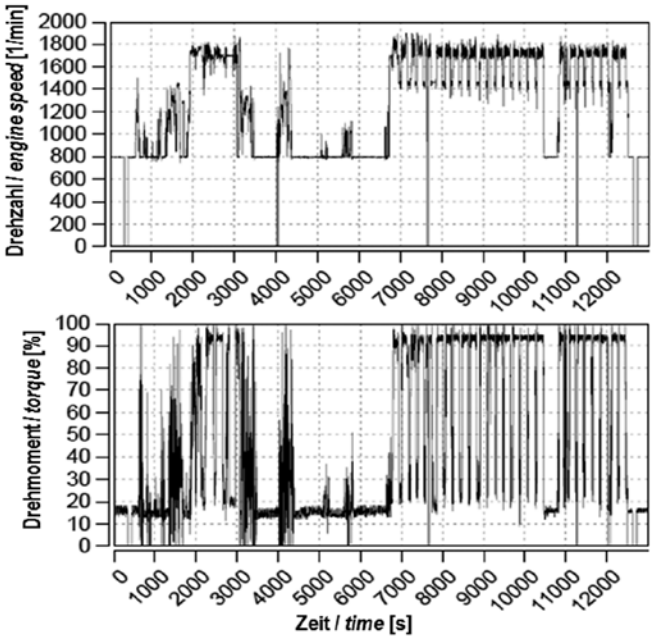
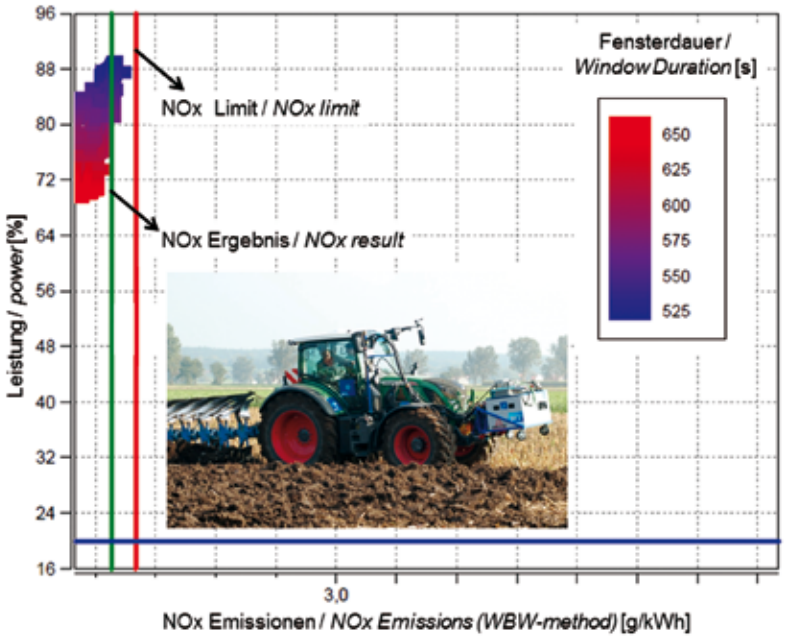


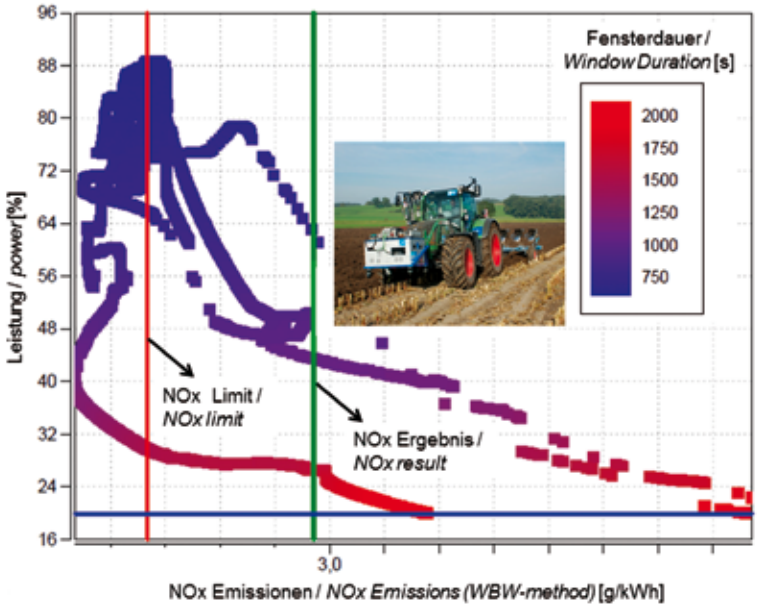
Fig. 3: Load collective while plowing

Fig. 4



Evaluation of plowing – Period, WBW method

Fig. 5



Evaluation of plowing, WBW method (Photo: Mathies)

in the selection and application of the work of the implementation of the "in-use" measurement is needed. The analysis by the NTE method are decribed in [3].

Table 1 shows the conformity factors listed which as a ratio between the "in-use" emissions [g/kWh] and the emissions limit [g/kWh] are. For NRMM in the EU limit conformity factor of 2 is expected. The results are irrelevant insofar as that exist for stage IIIB no "in-use" requirements. But for the further development of the NRMM PEMS procedure they are insightful and valuable.

Conclusions

Engine manufacturers for NRMM for American and European market in the future must to demonstrate compliance with the emission limits, taking into account the conformity factors about useful life. The strong diversification of mobile machines enforces the coming „in-use" testing revealed increased organizational effort with machine manufacturers and operators must be integrated into this process. This PEMS measurements require a high level of understanding of guidelines and legislation, engine, exhaust aftertreatment, load spectra and resulting

Table 1

Measurement results

	PM	HC	NOx	CO
Arbeitsart/*Kind of work*				
Max. Konformitätsfaktor *Limit conformity factor*	2,0	2,0	2,0	2,0
Mähen/*Mowing*				
Konformitätsfaktor *Conformity factor*	1,18	0,05	0,98	0,030
Transport/*Transportation*				
Konformitätsfaktor *Conformity factor*	1,86	0,18	0,90	0,001
Pflügen/*Plowing*				
Konformitätsfaktor *Conformity factor*	0,72	0,09	1,46	0,061
Pflügen/*Plowing (7 000-10 000 s)*				
Konformitätsfaktor *Conformity factor*	1,90	0,05	0,94	0,006

emissions, logistics of machines in use, application and safe handling of the measuring technique. The TÜV Hessen has the necessary knowledge to perform successfully „in-use" measurements and also offers this accordingly.

Literature

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[4] EMROAD ©; Version 5.1 – Build 9 (2012): Software Tool for evaluation of PEMS measurement data; European Commission; DG JRC Institute for Environment and Sustainability; Transport and Air Quality Unit; Ispra; Italy

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Acknowledgements:

TÜV Hessen expressly thanks with its project partners, the DEUTZ AG, the FENDT/AGCO GmbH and AVL GmbH, Germany for the very good and purposeful cooperation in this very successful community project.