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European Exhaust Emission Regulation

Effects on Agricultural Mobile Machinery, Tractors and their Engines

The requirements of worldwide exhaust emission regulations are a challenge to manufacturers of both engines and machinery, since, in the new stages of exhaust emission limits, not only the engine, but also the various components for exhaust after-treatment and the conditions governing their installation play a substantial role in complying with the new exhaust emission limits. The effects occasioned by additional exhaust after-treatment, e.g. the additional installation space required for exhaust systems, will strongly affect the future development of non-road mobile machinery.

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Keywords

Exhaust emission regulations, tractors, mobile machinery, engines

In recent years, the development and sales of agricultural mobile machinery and tractors have already strongly been influenced by the requirements of the European exhaust legislation. This influence will grow massively in the future as new stages of exhaust emission limits are introduced. Additional exhaust after-treatment, increased fuel consumption, increasing noise generation, increasing temperatures, and the additional space required for the installation of exhaust systems, are already a challenge for manufacturers in the design and construction of agricultural vehicles (*Fig. 1*) in view of the coming tightening of exhaust emission limits.

EC exhaust directives for non-road mobile machinery and tractors

Directive 2004/26/EC [1;2] amending Directive 97/68/EC on exhaust emissions from engines in non-road mobile machinery was published in the Official Journal of the European Union in April 2004. The scope of this Directive includes not only agricultural machinery, but also among other things non-road mobile machinery in the domains of construction and material handling, as well as railway locomotives and inland waterway vessels.

One year later, the exhaust directive for tractors 2000/25/EC was updated by Directive 2005/13/EC [3]. Since a provision in Directive 2000/25/EC prescribes that this directive must immediately be adapted to the amendments of Directive 97/68/EC, the requirements imposed on exhaust emissions from non-road mobile machinery and tractors are identical regarding pollutant limit values, the dates of introduction of new stages of exhaust emission limits, and the test procedure. These adaptation directives supplement the existing exhaust stages I and II with stages III A, III B and IV. Exhaust emission limits will be gradually reduced in these three stages by 2014, in accordance with the engine power ranges from 19 kW to 560 kW.

Legal requirements and their technical implementation

The emission limit values for oxides of nitrogen (NO_x) and particulates (PT) were already strongly reduced in stages I and II. In stage II alone, in comparison with stage I, a reduction of up to 35% in the emission limit values for NOx and up to 60% for particulates was set. These requirements were met, as a rule, by the use of modern injection systems and turbochargers with intercooling (*Fig. 2*).

We are currently in the introductory phase of stage III A, which is to be completed by

		Stufe / Stage III B	Stufe / Stage IV
Motor / Engine	Bauraum / Installation space	→	→
	Gewicht / Mass	↗	↗
	Leistung / Power	→	→
	Kraftstoffverbrauch / Fuel consumption	↗	↗
	Wartungsaufwand / Maintenance effort	↗	↗
Kühlung / Cooling system	Motorkühlung / Engine cooling	↗	↗
	Lüfterleistung / Fan power	↗	↗
	Bauraum / Installation space	↗	↗
	Geräuschentwicklung / Sound level	↗	↗
Abgassystem / Exhaust system	Bauraum / Installation space	↗	↗
	Gewicht / Mass	↗	↗
	Wartungsaufwand / Maintenance effort	↗	↗
	Einbauflexibilität / Installation flexibility	↘	↘

Fig. 1: Trends in the changes of the engine, cooling and exhaust system, caused Stage III B and IV requirements, compared to Stage III A.

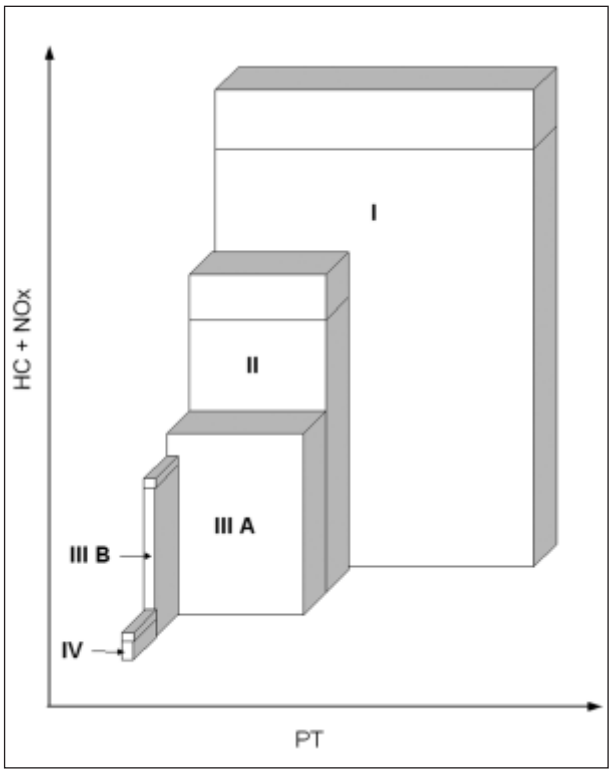

Fig. 2: Development of permissible exhaust emissions of mobile machinery and agricultural tractors

the end of 2007. Stage III A will further reduce NO_x emissions. This reduction can be achieved solely by means internal to the engine, e.g. charge air cooling, exhaust gas recirculation and increased injection pressure (*Fig. 3*).

Becoming effective from 2010, in stage III B, the particulate limit values will be lowered by up to 94% from the present stage III A. The present expectation is that complying with these emission limits will only be possible by using particulate filters. These filters are used today in non-road mobile machinery, intended for use in closed spaces or tunnel construction. The use of these filters in mobile machinery operated with low exhaust temperatures has the disadvantage that the filters have to be regularly heated up artificially to burn the particulates. When these filters are used in trucks, the particulates are burnt independently because the necessary combustion temperatures are reached in normal driving mode.

In stage IV, a further reduction by up to 88% of the emission limit values for oxides of nitrogen is required with effect from 2013. To this end, the use of NOx adsorption systems or selective catalytic reduction (SCR) systems will be necessary. In SCR systems, oxides of nitrogen are reduced to water and nitrogen by the addition of ammonia. Urea must be carried in the vehicle for this purpose, in an additional tank.

In the past, only the exhaust emissions of a new engine were considered for certification. In future, under the last amending directive, emission behaviour throughout the engine's lifetime will already be evaluated during type testing. In order to limit any deterioration in emission behaviour, durability requirements and maximum permissible deterioration factors are introduced with effect from stage III A.

It is to be ensured, moreover, that exhaust reduction systems are correctly maintained and not removed. This fact will induce the legislator to introduce OBD (on-board diagnosis), which notifies the driver about a malfunction in the system and, if necessary, intervenes in the control of the entire propulsion system.

Teamwork between engine and machinery manufacturers

The exhaust emission regulations of stages III B and IV present a challenge to manufacturers of both engines and machinery, since, in these stages of exhaust emission limits, not only the engine, but also the various components for exhaust after-treatment and the conditions governing their installation play a substantial role in complying with exhaust emission limits. The effects occasioned by additional exhaust after-treatment, such as increased fuel consumption, increasing noise generation, increasing temperatures, and the additional space required for the installation of exhaust systems, will strongly affect the future development of non-road mobile machinery.

Until now, the engine manufacturer alone has been responsible for complying with exhaust emission regulations, because the measures for achieving exhaust emission limit values have basically concentrated on the engine alone. A machinery manufacturer must comply with the guidelines of the engine manufacturer when installing the engine. Even Directive 97/68/EC is exclusively directed at the engine manufacturer, for only he can obtain an EC type approval for its exhaust emissions.

Responsibility is also to remain with the engine manufacturer in the future, so the engine manufacturer, as a system provider, will as a rule supply a matched combination of an engine plus components for exhaust after-treatment.

However, given the enormous variety of the installation conditions and operating conditions under which non-road mobile machinery is used, with some of these machines being built in a very small number of units, it is still an open question whether each engine manufacturer will be able to offer all his clients a complete tailor-made package.

Since it is the overall system, consisting of the engine and the exhaust after-treatment systems, which will be the object of EC certification, the machinery manufacturer will only to a limited extent be able to make adaptations concerning applications after having obtained the system approval.

Because of the great variety of versions of both non-road mobile machinery and engines, and the occasionally very low number of units, the amortisation of development input takes longer than is allowed for by the duration for an exhaust stage. More time is also required for development itself, and for the necessary machine tests under field conditions, which in the case of agricultural machinery can often only be carried out during a seasonally limited period.

Since stage III B will only last for three years before being replaced by stage IV, it seems now that there may be a reduction in the range of variant models of engines and machinery. Engine manufacturers will probably attempt to reduce the cost of development by using a modular system for engines and exhaust after-treatment systems.

The right fuel

A further prerequisite for reducing the emission of particulates and oxides of nitrogen is the use of low-sulphur fuels. Therefore fuels with a sulphur content of less than 10 ppm should also be available for non-road mobile machinery everywhere in the EC from 2009. For many EC Member States, the introduction of fuel in these qualities means restructuring their fuels infrastructure, since in many countries mobile machinery and tractors are still being operated on diesel fuels with a sulphur content of up to 2000 ppm.

Test procedure

Up to stage III A, total exhaust emissions are calculated using a steady-cycle test procedure (NRSC). In future, this test procedure is only to be used for calculating gaseous pollutants in stages III B and IV. This steady-cycle test will in the future be supplemented

by a dynamic test (NRTC: non-road transient cycle) to report approximately the actual operating conditions of diesel engines in non-road mobile machinery. For stages III B and IV, emissions of particulates are to be measured by the transient cycle test procedure. It is open to the manufacturer also to use this test procedure for stage III A and for gaseous pollutants in stages III B and IV.

No rule without an exception

There is an exception to every rule – and the European exhaust directive is no exception. One important exceptional provision is the rule on the sale of engines and machinery still held in store, which was already contained in the original version of Directive 97/68/EC. On the basis of this derogation, engines that correspond with the previous stages of exhaust emission limits may continue to be placed on the market for a further two years after the introduction of a new exhaust stage, if they were built before the date of introduction of the new stage. In the past, Member States themselves decided the extent to which and with what administrative procedures they granted this exception, or whether they used this regulation at all.

With the introduction of stage III A, this derogation is of obligatory application throughout the EU. For manufacturers, this means more security in planning production and sales in all EC Member States, without the administrative effort hitherto.

New additional derogations, similar to those used in the US, make it possible to place a limited number of machines on the market that correspond with the previous exhaust stage during the entire period of an exhaust stage. The number is limited to either 20% of the machinery placed on the EC market annually by the manufacturer or, alternatively, to a specified maximum number of units. This exception normally benefits machines, which are placed on the market in small numbers. In distinction to the other derogations, this one is addressed not to engine manufacturers, but to machinery manufacturers. The latter must take care of the necessary administrative procedures and compliance with the provisions.

Alignment of exhaust emission regulations between the US and Europe

In order to offer manufacturers a global market for engines and machinery, the exhaust emission regulations in Europe and the US are to be aligned with each other. In regard to dates of introduction and emission limit values, this objective has almost been achieved. Test procedures and other ancillary conditions have yet to be standardised.

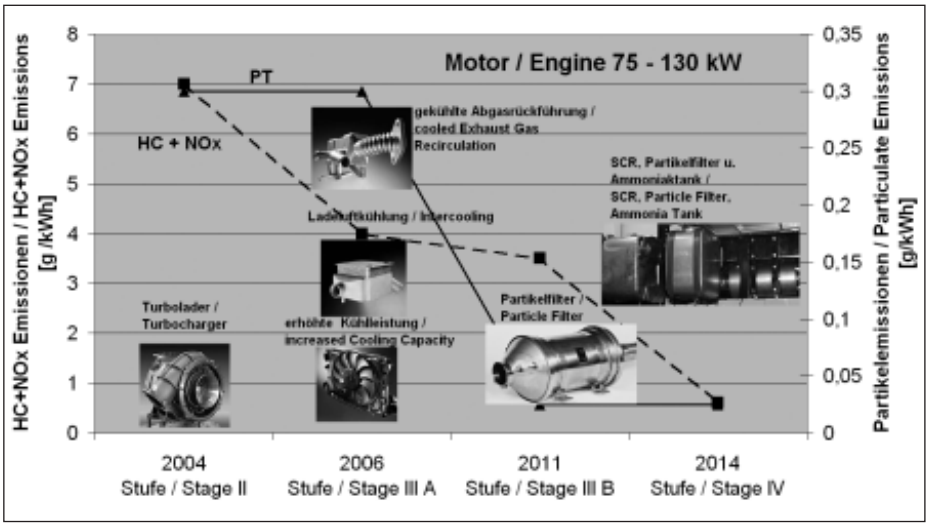

Fig. 3: Technical implementation of the exhaust emission requirements

However, the massive differences in the implementation and design of derogations and flexibility rules of exhaust emission regulations in the US and Europe are preventing full correspondence between regulations on both sides of the Atlantic. Whereas in Europe new stages of exhaust emission limits are systematically and fully implemented on the date of introduction, with few options for exception, there is a great variety of complex flexibility clauses in the US which do not enable new stages of exhaust emission limits, Tiers 1 to 4, to be implemented on specific introduction dates. Instead, implementation is spread over a long period of tome.

These flexibility rules are further supplemented with a bonus system that enables a manufacturer to collect bonus points if he keeps below the emission limit values, these then being used to compensate for the limits he exceeds or to postpone introduction dates. This flexibility system requires comprehensive control of products that are intended for different markets, so that quantity limits can be complied with even when there are natural fluctuations in the market.

"Technical Review 2007"

In accordance with Directive 2004/26/EC, the EC Commission is obliged to verify the feasibility and the cost of stages III B and IV by the end of 2007 at the latest. This "Technical Review" intends to assess all the background conditions, e.g. the availability of low-sulphur fuels in Europe and possible technologies enabling the implementation of the exhaust emission regulations. The requirements of stages III B and IV are then to be correspondingly revised, as regards postponing their dates of introduction, extending the flexibility rules, or making exceptions for particular machinery and applications, e.g. for narrow-track tractors. An extension of the scope of the exhaust directive to diesel engines, under 19 kW or above 560 kW, and the introduction of systems for monitoring exhaust emissions during operations will also be discussed.

A central point under consideration is the further alignment of exhaust emission regulations in Europe and the US.

Literature

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[3] -: Richtlinie 2005/13/EG der Kommission vom 21. Februar 2005 zur Änderung der Richtlinie 2000/25/EG des Europäischen Parlaments und des Rates über Maßnahmen zur Bekämpfung der Emission gasförmiger Schadstoffe und luftverunreinigender Partikel aus Motoren, die für den Antrieb von land- und forstwirtschaftlichen Zugmaschinen bestimmt sind, und zur Änderung von Anhang I der Richtlinie 2003/37/EG des Europäischen Parlaments und des Rates betreffend die Typgenehmigung für land- und forstwirtschaftliche Zugmaschinen. Amtsblatt der Europäischen Union L 55 vom 1. 3. 2005, S. 35