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Particulate matter emissions in real operating conditions from non-road vehicle engines after retrofitting

The dissertation concerns the evaluation of particulate matter emissions from retrofitted engines of non-road vehicles measured in real operating conditions. The content is divided into three main parts: creation of guidelines, production of the filter and verification tests. The first chapter described what the NRMM group of vehicles is and what are the forecasts for their numerical increase in the following years. It was found that statistically the average machine in operation is of a considerable age, and despite the increasing restrictions in subsequent emission norms for toxic exhaust components, this average age will continue to increase. Then, the harmful exhaust components contained in exhaust gases and their impact on human health and life as well as methods of reducing them have been described. The main focus was on particulate matter, the emission of which is currently the main problem faced by CI engines. Modern solutions used in engines to prevent the formation of toxic exhaust components and reducing the amount of harmful compounds already produced were described.

The next chapter provided a description of the exhaust emission tests from two NRMM type machines and the recording of their operating points using modern PEMS equipment. The obtained results clearly indicated an excessive PM and PN emission for both machines in real operating conditions when compared to the limit values outlined in the type approval standards. Moreover, it was found that the real conditions only reflect the points included in the static approval test cycle to a very small extent. Based on these observations, it was decided to modify the static test cycle, which helped it better reflect the real operating points of the engines during the machines operation. The test was then performed and the results used to verify the effectiveness of the proposed solution.

The next chapter was an approximation of the current and future regulations regarding the exhaust emissions of non-road machines in Europe, as well as presenting the divisions made due to the differences between the engines parameters and the tasks and types of work for which they are intended. Examples of retrofitting done around the world as a way to reduce exhaust emissions by retrofitting older engines with modern exhaust aftertreatment systems have also been discussed.

The aim of the study is to evaluate the exhaust emission of particulate matter after retrofitting the exhaust system of machines from the NRMM category. The test was performed again with the use of mobile particulate emission analyzers in terms of particle mass, number and dimensional distribution of diameters, along with toxic gaseous exhaust compounds and an exhaust mass flowmeter.

The measured exhaust gas compositions and their mass flow rate were used to create the geometry of the carrier of a newly developed filter intended to be retrofitted, combining the advantages of the two most popular types of filter carriers – open flow and wall flow. The requirements and limitations of the filter carrier structure were assessed by simulating the exhaust gas flow with the real, previously measured composition in the ANSYS simulated environment. The task of the established carrier geometry was to increase the efficiency of capturing and oxidizing of solid particles and minimizing the exhaust flow resistance. The filters with geometry calculated this way were then manufactured by a company producing metal carriers for exhaust aftertreatment systems, which enabled testing of their actual effectiveness. Seven filters were produced based on the established designs to enable the

adaptation of the developed solution to various engine displacement volumes and diameters of the machine exhaust systems.

The verification process for the effect of filters on the content and properties of particles in the exhaust gases was initially carried out on an engine dynamometer, and then in real non-road mobile machines under static conditions. In addition, a comparison of the PM and PN emissions from a machine with a factory fitted diesel particulate filter was made. The dissertation contains detailed results of the relative specific exhaust emissions of solid particles and gaseous compounds (HC and CO) at individual engine operating points. The exhaust emissions analysis, as well as the effectiveness comparison of the two tested machines exhaust systems and a reference to the factory solution, all made it possible to establish conclusions about the operation of the new designed system. The conclusions showed that placing a metal-carrier particle filter in the exhaust system significantly contributed to reducing the exhaust emissions. The obtained efficiency was notably higher than that of similar filter designs with an open flow structure. The final chapter contains a summary of the work carried out, conclusions and directions for further research, because the research performed does not fully exhaust the subject matter.

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