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TESTS OF DIESEL DRIVES CARRIED OUT AT KOMAG

KIERUNKI BADAŃ NAPĘDÓW SPALINOWYCH PROWADZONE W ITG KOMAG

A b s t r a c t:

The directions of KOMAG's investigations into diesel drives used in workings at risk of explosion are described. Two groups of research problems, i.e. the impact of a flameproof inlet--outlet system on the engine's operational parameters as well as identifying the phenomena in the engine regarding the emission of toxic substances with tests on improvement in the quality of exhaust gases, were specified.

Keywords: mining industry, diesel engine, ATEX, quality of exhaust gases

S t r e s z c z e n i e:

W artykule opisano kierunki prowadzonych badań w ITG KOMAG dotyczące napędów spalinowych eksploatowanych w wyrobiskach zagrożonych atmosferą wybuchową. W badaniach tych wyszczególniono dwie grupy problemów badawczych ,tj.: wpływu ognioszczelnego układu dolotowo-wylotowego na parametry pracy silnika oraz identyfikacja zjawisk zachodzących w silniku w aspekcie emisji substancji toksycznych wraz z badaniami pozwalającymi poprawić jakość spalin.

Słowa kluczowe: górnictwo, silnik spalinowy, ATEX, jakość spalin

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1. Introduction

In the mining industry, diesel engines are commonly used to drive the machines designed for operation on the surface as well as the locomotives and drivetrains used underground. Using this type of drive safely in underground mine necessitates meeting the requirements associated with the hazard of ignition of flammable dust and/or gases, and with the emission of hazardous substances in the exhaust gases to the workings' atmosphere. The regulations determine composition of air in workings as regards maximum concentration of such substances as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and hydrogen sulphide (H_2S) [9]. The maximum temperature of the surface of objects placed in the atmosphere potentially threatened by coal dust and methane ignition hazard are also determined. Thus, because of the hazards and the permissible concentration of each harmful substance in the atmosphere, operating a diesel drive cannot create the risk of ignition of flammable dust and/or gases present in its operational area, and it cannot worsen air quality. With this in mind, designing a machine with a diesel drive should include systems aimed at ensuring its safe operation. A testing facility enabling complex testing and assessment of impact of diesel engine protecting systems on engine operation has been designed at KOMAG. It is also possible to carry out research work aimed at testing the new systems designed for cooperation with diesel engines, e.g. systems improving the quality of exhaust gases. An overview of the work conducted over the last few years, focusing on the improvement and optimization of diesel drives designed for operation in underground mines, is presented.

2. Tests of diesel drives with reference to the impact of a flameproof inlet-outlet system on engine operation

The hazards resulting from the use of diesel drives in a potentially explosive atmosphere can be reduced by special protections, especially in the diesel engine itself. Protection of engine compartments against contact with atmosphere, in such way that in the case of failure and generation of flame or sparks the ignition of potentially explosive atmosphere is impossible, is the key issue. Moreover, any surface that has contact with external atmosphere cannot reach a temperature above 150ºC, i.e. the limit value associated with the possibility of coal dust ignition. A flameproof inlet-outlet system, protecting against propagation of flame or sparks from engine internal compartments to the outside, is one of the components of diesel drives designed for operation in areas threatened by methane and/or coal dust explosions. Its design affects the flow of air and exhaust gases, which can result in the change of engine's operational parameters.

Because of the lack of information about the operation of diesel engines fitted with flame-proof inlet-outlet systems, comprehensive tests aimed at determining its operational parameters were carried out [3, 4]. A general view of the testing facility is presented in Fig 1.

The design of the testing facility and the methodology for testing the engine are described in [2]. The characteristics of an engine cooperating with a simplified inlet-outlet system and with a flameproof inlet-outlet system designed at KOMAG were prepared based on test results. A comparison of the characteristics obtained enabled us to assess the impact of the flameproof inlet-outlet system used on diesel engine performance. Examples of characteristics are presented in Fig. 2 and 3.

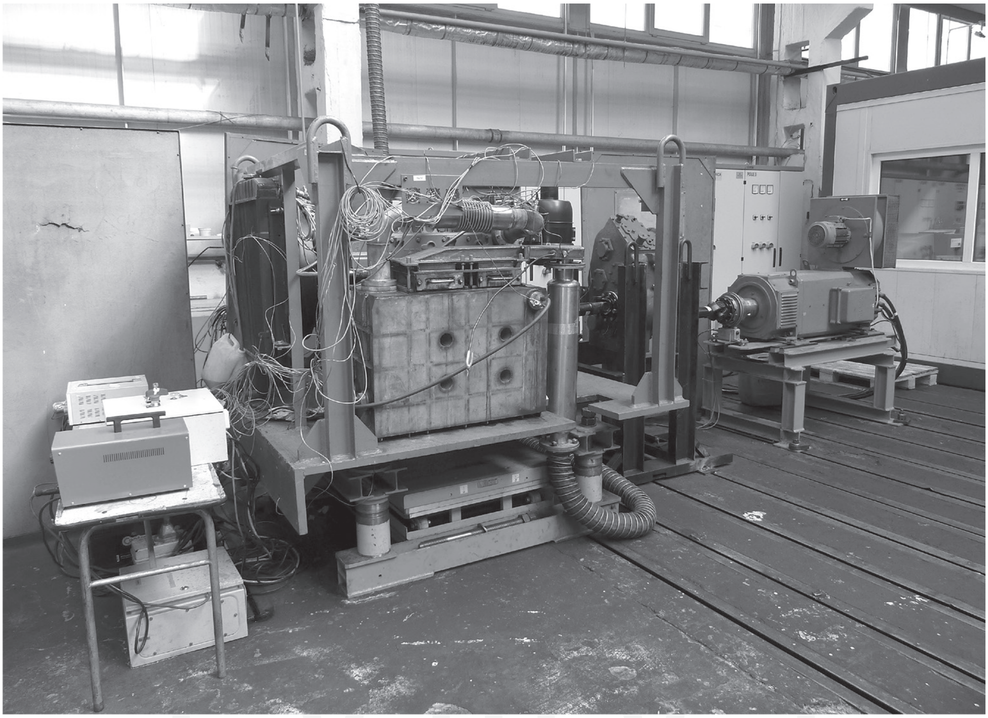

Fig. 1. General view of stand for testing the diesel drives [3]

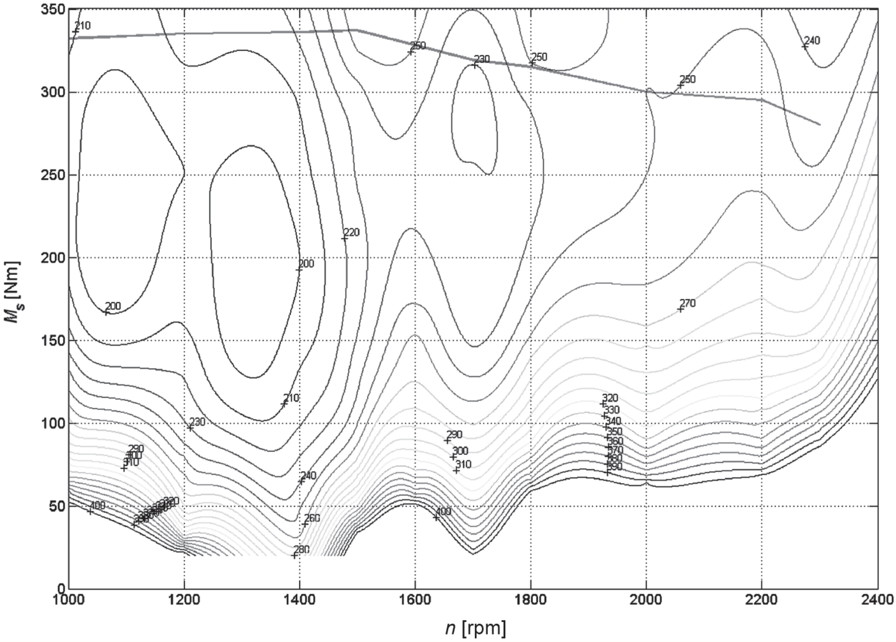

Fig. 2. Versatile characteristics of engine with flameproof inlet-outlet system [2]

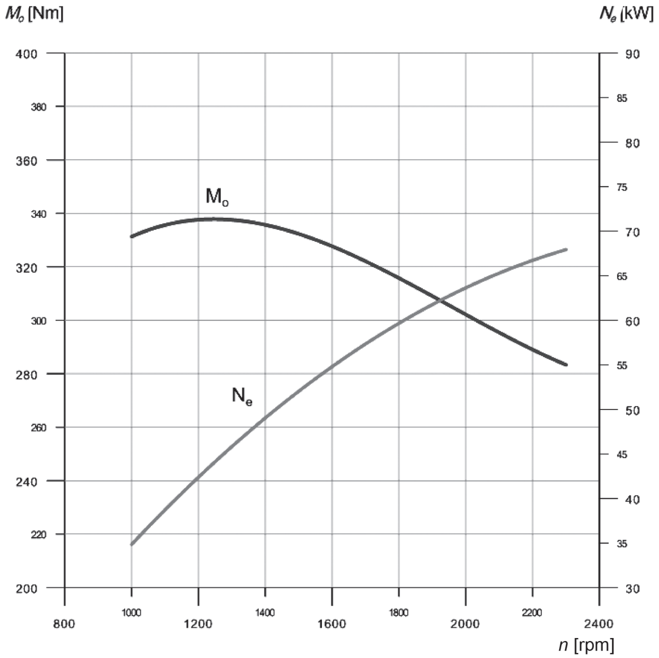

Fig. 3. External characteristics of diesel engine [4]

Unique data as regards operational parameters of diesel engine with a flameproof inlet-outlet system were obtained as a result of stand tests. Further work improving the design of the diesel drive, which is used among others in the Lds-100K-EMA mine underground diesel locomotive, was conducted on their basis. Simulation tests of the inlet-outlet system were carried out and the impact of the system's design on resistance of flow of air and exhaust gases was determined on the basis of test results [2]. The results of stand tests were also used for optimization of design of outlet system. Simulation tests are presented in Fig 4.

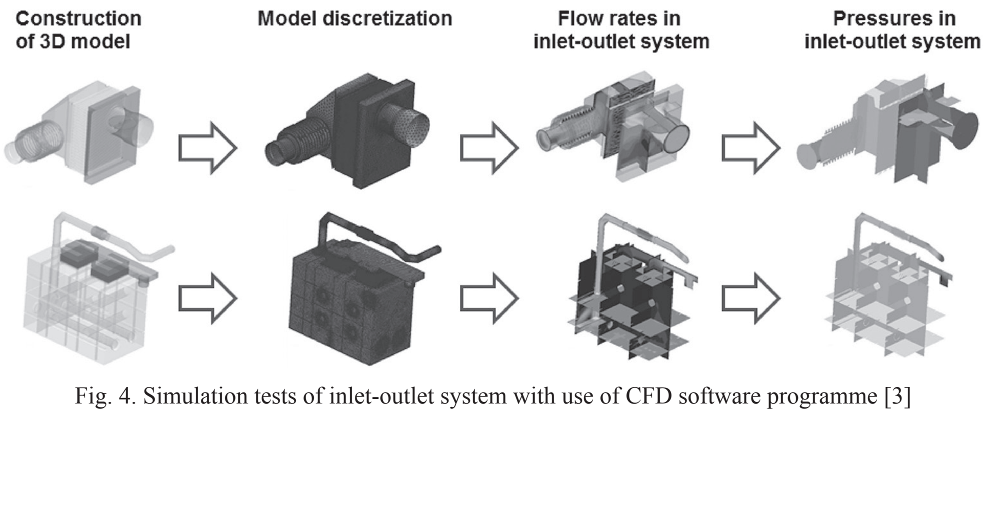

Fig. 4. Simulation tests of inlet-outlet system with use of CFD software programme [3]

An example of a diagram presenting the pressure drop in each component of outlet system is presented in Fig. 5.

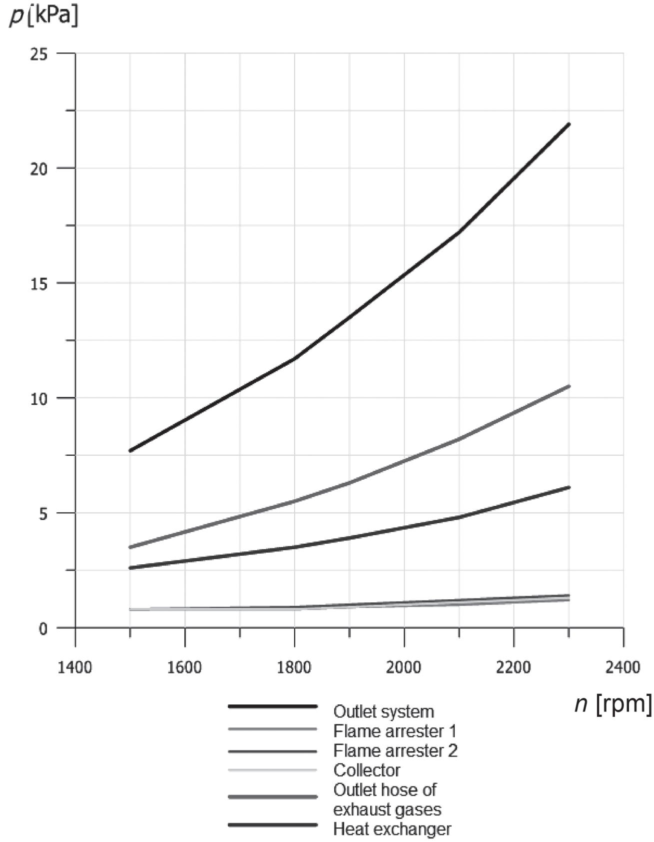

Fig. 5. Flow resistance in each component of the outlet system [3]

Changes in the design of the outlet system, minimizing the flow resistance of exhaust gases, were made as a result of optimization work. Moreover, simulation tests using the results of the stand tests enabled the adaptation of the hydrokinetic gear used in the drive of the Lds-100 locomotive to the diesel engine to be assessed. Further work on stand tests of diesel drive will cover an analysis of the cooperation between diesel engine and hydrokinetic gear, which will enable the model of the driving system to be improved.

3. Tests of diesel drives in the aspect of emission of toxic substances

The processes in an engine's combustion chamber are complex and take place in a very short time. According to theoretical assumptions, H_2O and CO_2 should be the products of hydrocarbon combustion (1).

$$C_m H_n + \left(m + \frac{n}{4} \right) O_2 \Rightarrow m CO_2 + \frac{n}{2} H_2O \tag{1}$$

In fact, the composition of exhaust gases is more complex. According to the composition of exhaust gases presented in Fig. 6, harmful substances represent only 1% of their volume. They include carbon monoxide, hydrocarbons (including the especially harmful polycyclic aromatic hydrocarbons), solid particles and heavy metals, which have a significant impact on the environment, and in the case of machines operating in the workings of underground mines – on the health of mining teams.

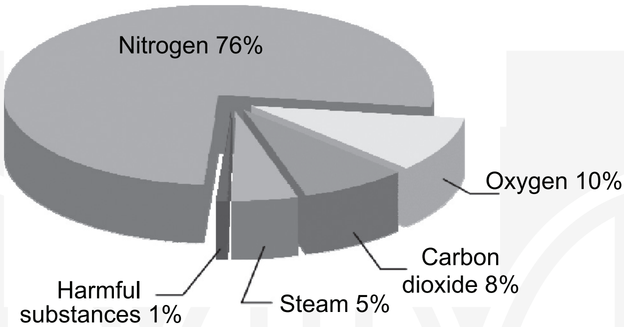

Fig. 6. Sample composition of exhaust gases from self-ignition engines [6]

Tests aiming at identifying the phenomena in the engine in terms of emission of toxic substances have also been carried out within KOMAG's research work on diesel engine designed for operation in underground workings where there is a risk of explosion, to develop methods for reducing the content of toxic substances in exhaust gases.

Within this research work on improving the quality of exhaust gases, the testing facility for diesel drives was extended by a system for processing the exhaust gases (after-treatment system) installed in the outlet system Fig. 7. This was preceded by an analysis of the known methods for converting toxic substances regarding their application in diesel drives operating in a potentially explosive atmosphere. The method of improving the parameters of exhaust gases can be successfully applied in surface machines with no need to change the engine's design.

Testing of the diesel drive which is used in the Lds-100K-EMA underground locomotives and SKZ-81 drivetrain was carried out. The state-of-the-art, turbocharged diesel engine with direct injection was used in this drive. The tests were carried out in eleven stages in the test cycle. Each stage was characterized by operational parameters of engine such as rotary speed and torque. The results of the tests in terms of determining the quality of exhaust gases enabled the conclusion to be drawn that the emission of nitrogen oxides is the most significant hazard (emission of hydrocarbons and carbon monoxide was low). Emission of carbon monoxide was the main problem in the case of diesel drives used in the previous decade, e.g. the SW400 manufactured by Andoria. This problem was less significant in the

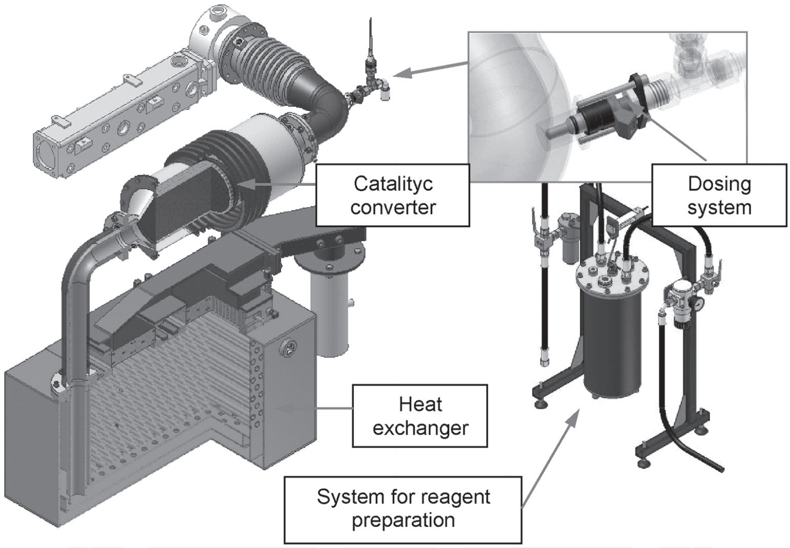

Fig. 7. Systems for processing the exhaust gases in the outlet system [5]

newer D916 engine manufactured by Deutz MWM. These engines were normally aspirated engines with a pre-combustion chamber. The requirements of the ATEX Directive should also be taken into account in the case of drives operating in workings at risk of explosion [8]. The systems for protecting against excessive temperature on the surface can affect the conversion of toxic substances included in exhaust gases. Selective catalytic reduction (SCR) systems were used in the system presented in Fig. 7 [1, 7]. The efficiency of the SCR system was tested at each stage of the test cycle in relation to the operational parameters of the diesel engine and temperature in selected points of the outlet system. The results obtained enabled the impact of temperature protection of external surfaces on the efficiency of the system for conversion of toxic substances to be determined. It was observed that a deposit is prone to settle on the internal surface of the outlet channel, between the reactant injector and the catalytic reactor, which had a negative impact on the level of NO_x conversion. Further work as regards systems for exhaust gases processing will be focused on optimizing the reactant dosing system and design of the outlet channel for exhaust gases in terms of reactions of thermolysis and the hydrolysis of the fed reactant.

4. Summary

The main problem is the absence of any possibility to use the technical solutions applied in the surface machines increasing the economy and ecological effectiveness of such drives in the mine drives, which should meet the requirements of the ATEX Directive. The KOMAG Institute of Mining Technology realizes work on diesel drives designed for operation in workings at risk of explosion. There are the following main directions in the tests carried out at the Division of Roadway Systems:

– tests of diesel drives in terms of the impact of a flameproof inlet-outlet system on the operational parameters of the engine,
– tests of diesel drives in terms of emission of toxic substances.

The tests that have been conducted on the impact of the flameproof inlet-outlet system on the operational parameters of the engine have so far provided information about the flow resistance of air and exhaust gases, and the simulation tests enabled the design of the system to be optimized, minimizing the flow resistance of the medium. The test results enable the fuel consumption to be reduced and the engine efficiency to be increased. The results of the test regarding the ecological aspects of diesel engines operation confirmed the necessity of using the system for conversion of nitrogen oxides in drives that are used underground. The tests carried out using the SCR system gave information about the impact of the mine outlet system on the functionality of the SCR system.

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