LIETUVOS AUTOMOBILIŲ INŽINIERIŲ SĄJUNGA LAIS LIETUVOS GELEŽINKELIAI

19-osios jaunųjų mokslininkų konferencijos „Mokslas – Lietuvos ateitis“ teminės konferencijos
TRANSPORTO INŽINERIJA IR VADYBA,
vykusios 2016 m. gegužės 6 d. Vilniuje, straipsnių rinkinys

Proceedings of the 19th Conference for Junior Researchers 'Science – Future of Lithuania'
TRANSPORT ENGINEERING AND MANAGEMENT, 6 May 2016, Vilnius, Lithuania

Сборник статей 19-й конференции молодых ученых «Наука – будущее Литвы»
ИНЖЕНЕРИЯ ТРАНСПОРТА И ОРГАНИЗАЦИЯ ПЕРЕВОЗОК, 6 мая 2016 г., Вильнюс, Литва

REDUCTION OF HARMFULNESS OF VEHICLE EMISSIONS TO THE ATMOSPHERE

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Abstract. The problem of atmosphere contamination due to exhaust gases released from transportations of different types, is discussed in the paper. Various mitigating measures and techniques in this relation were investigated. A gases treatment technique including operation of neutral gases generator was of our attention. It is suggested to apply improved by us technique of fuels and lubricants drying. The proposed improvement makes it possible to clear exhaust gases from CO_x and NO_x when vehicle operation, as well as to make up efficient fuel dehydration and to improve its ecological properties.

Keywords: atmosphere, exhaust-gasses, transport, neutral gas, environment.

Introduction

Current research deals with ecological problems. Ecological state of the planet in general is an open actual question nowadays. Due to scientific and technical revolution, humanity suffer from excessive contamination of environment, especially air, water and lands. In particular, transport is a significant treat for the atmosphere due to gas emissions and ozone holes.

Solving of ecological safety problems in Ukraine is closely related with assessment and reducing of unfavorable transportation effects on atmospheric air. In this regard it becomes necessary to solve actual ecological problems with the help of the whole majority of transportation, productional, intellectual and social activities involving state and branch systems of ecological management.

Transportation complex including vehicle, marine, aquatic, railway and aviation transport, is one of the most significant contaminators of atmospheric air. It affects environment, mainly, as the source of atmospheric emissions of toxicants with exhaust gases of transport engines and harmful substances from stationary sources, as well as surface water objects contamination, formation of solid wastes and transportation noise effects.

Transport, as usual, is not unique contaminator. Electrical power industry, heat power industry, industry in general, agriculture and households, are considered as significant contaminators as well. That is why, contamination due to transportation constitute only from 15 % up to half of total contamination subject to transportation kind and contamination mode.

Exhaust gases contamination is a global problem. Number of vehicles increases every day in geometric progression all over the world. Worsening environment condition, population immunity disorders, many other diseases – all these consequences are just certain effects of internal combustion engines.

Analysis of references concerning investigated topic and problem formulation

It is well-known that transportation complex is one of the most widespread sources of environment contamination. During vehicle operation, harmful substances are released into air with exhaust gases, evaporations from fuel systems, as well as when vehicles fueling. Road relief, driving mode and vehicle speed effect carbon oxides emissions. Atmospheric emissions due to railway, air or water transport are less by order of magnitude compared to vehicle transport. However, they should be improved to reduce negative effects for environment.

It is known fact that internal combustion engines emitting exhaust gases and fuel vaporizations, are the sources of air basin contamination when vehicle operation. Exhaust gases contain about 280 components of complete and incomplete petroleum fuel combustion products, as well as inorganic compounds of certain fuel substances.

Data represented by authors (Danilevych *et al.* 2005) showed that if vehicle moves with the speed of 80–90 km/h, the same amount of oxygen is transformed into carbonate acid, as due to 300–350 persons. Annual exhaust of one vehicle contains 800 kg of dangerous Carbon mon-

http://jmk.transportas.vgtu.lt
eISSN 2029-7149
eISBN 978-609-457-937-0

oxide, 40 kg of Nitrogen oxides and more than 200 kg of different hydrocarbons. However, it is known as well, that limit accessible concentration of carbon monoxide concentration in the air should not exceed 1 mg/m.

Motor transport emissions constitutes about 39 % of hydrocarbon emissions in industrial countries. Motor cars are the main emitters of Carbon monoxide (CO). This is a toxic substance having negative effects on human health. In addition, Nitrogen oxides NO and N_2O are released into atmosphere. Nitrogen dioxide affects both human beings and plants.

Ozone in the top atmospheric layers, is the natural component (ozone layer), it protects Earth from the dangerous space radiation. In bottom layers ozone behaves as a contaminator, it affects human health, nature, natural and artificial building materials. Forming of surface ozone air is the indirect contamination effect due to motor transport. It occurs as a result of photochemical reactions, in which Nitrogen oxides and hydrocarbons take part (Franchuk *et al.* 2010).

Authors of issue (Arkhipova *et al.* 2009) generalized the main reasons of air contamination due to motor transport: bad technical service of vehicles; low quality of operated fuel; lead admixtures in the gasoline; bad system of transport currents management; small part of ecologically safe operated transportations.

Authors of issue (Arkhipova *et al.* 2009) also presented facts, which show that air contamination is a serious threat for population health, it affects life quality as well. Impact of toxic substances contaminating air, causes such diseases: cancer, leukemia, asthma, endocrine, respiratory diseases, allergy, cardiovascular diseases, liver and gall bladder disorders, sense organs disturbances.

Nowadays the main measures to reduce negative effects of motor transport on atmospheric air include: replacement of motor fuel with gaseous one; operation of alternative fuels, for example liquefied petroleum gas, natural gas, ethanol, methanol and methane; application of addition agents to improve technological and ecological properties of the fuel; rational organizing of shipping operations and traffic; roads improvement; more accurate selection of rolling stock and its structure; optimal routing of vehicle shipping operations; organization and regulating of traffic; rational vehicle driving; improvement of internal combustion engines and permanent support of them in good technical conditions.

Railway transport affects environment of all the climatic zones and geographical zones of Ukraine. However, if compared with motor transport, it affects atmospheric air in a less degree (http://Eco-logylife.ru). First of all, it is due to that train is the most optimal transportation if energy consumption and energy loos per work unit are considered. But railway transport should help to solve serious problems of reduce and prevention of negative effects on environment.

As it is known, diesel locomotive is the prime mover with diesel engine power unit. Internal combustion engines are heat engines in which chemical energy of the fuel is transformed into heat energy and then – into mechanical work. The main contaminators the of atmosphere are exhaust gases of locomotive diesel engines. They contain *Carbon monoxide, Nitrogen oxide and dioxide*, various hydrocarbons, Sulphur anhydride, soot. The content of Sulphur anhydride depends on sulphur amount in diesel fuel, and the content of other admixtures – on combustion mode, as well as on mode of engine boost and loading.

Thus, although trains affect environment, but if compared to vehicles, the impact is much more less, because more work is done per unit of energy obtained due to combusted fuel unit.

Reduction of hazardous substances releases from locomotive internal combustion engines may be reached due to the following techniques: liquid flame neutralization; ejection flaming (i. e. flaming of exhaust gases); application of catalysts; air delivery into exhaust header (optimizes fuel combustion and increases power); application of anti-smoke filters, etc.

Decrease of harmful substances emitted from the locomotive internal combustion engines as well be achieved by application of additive agents to fuels: methanol, hydrogen, liquefied gas and emulsions (they enhance fuel efficiency, significantly reduce NO_x content (in 27–38 %) and smoke aerosols content (in 40–76 %) in exhaust gases).

In general, reduction of harmful emissions amount in exhaust gases is possible due to improvement of fuel burning technology in internal combustion engine, as well as of locomotive motion and all the railway elements.

As boat internal combustion engine fuel, primarily following petroleum products are operated: gasoline, solar oil, motor fuel, etc. Abroad, in countries, where no oil is available, products of coal refining are operated as well: benzene, coal-tar pitches. Liquid fuels include: carbon, hydrogen, oxygen, nitrogen, sulfur. The most significant of them are carbon and hydrogen.

CO, CO_2, C_xH_y gases are heavier than air and they are accumulated above the surface of water environment. CO and gaseous hydrocarbon emissions of boat heat engines take part in oxidative reactions resulting in CO_2 formation, which causes greenhouse effect in atmosphere.

Analysis of issue ("Aviation building of engines", 2010. No 5) helped to discover that aircrafts contaminate bottom layers of the atmosphere with exhaust gases from aviation engines nearby airports, as well as top atmospheric layers at economic height. Gases constitute 87 % of all the civil aviation emissions including emissions from specific vehicles and stationary sources.

It is mentioned in issue (Franchuk *et al.* 2007) that aircrafts, as well as helicopters, affect environment primarily because of installed gas turbine engines. Secondly, gas turbine engines require aviation fuel with chemical composition of better quality, particularly with less amount of sulfur and mechanic admixtures compared to vehicle fuel. Thirdly, the main part of exhaust gases is released by aircrafts directly into air at relatively high altitude, high speed and turbulent flow, and only small part – nearby airports and settlements. Total emissions of toxic substances by aircrafts may be approximately estimated as the volume of fuel consumed by aviation, which is about 4 % from the total fuel consumption by all the

transportations. Thus, part of contamination due to air transportation outside airport area is relatively low, however there are no exact data.

According to (Franchuk *et al.* 2007), the most significant environment contamination occurs within airport area when aircraft landing and takeoff, as well as when engines heating. It is assessed that when 300 landings and takeoffs of transcontinental airliners occur per day, about 3.7 tones of Carbon monoxide, 2 tones of hydrocarbon compounds and 1.7 tone of Nitrogen oxides are released into atmosphere. In these conditions contaminants are released into atmosphere not uniformly, but in accordance with airport schedule. During engines operation at landing and takeoff, the maximal amount of Carbon monoxide and hydrocarbon compounds is released, in case of flight – the maximal amount of Nitrogen oxides is released. Jet liner requires from 50 to 100 tones of oxygen for transatlantic flight. However, the most dangerous is that when flight in bottom stratospheric layers, engines of supersonic aircrafts emit Nitrogen oxides resulting in oxidation of ozone, which is the protective shield against ultraviolet radiation.

Authors in (Makdonal'd *et al.* 2007) mentioned that there are actual methods of the fuel ecological properties improvement due to its quality improvement. Ecological indexes of the fuel may be improved by reduce of content of sulfur, aromatic hydrocarbons (particularly benzene), actual gums, olefins and lead. Specific addition agents may be applied as well (among the national ones – Agidol-1). After series of experiments authors arrived at a conclusion that if ubiquitous operation of Jet A fuel in Ukraine to achieve rational use of the oil product, no changes of the fuel ecological properties will occur without redesign of combustion chambers.

It is well-known that considered problem of ecological indexes of aviation engine emissions should be solved in three directions: chemical, design and economic. Chemical direction is based on improvement of hydrocarbon composition of the fuel and addition of certain addition agents and additives. Essence of design direction is the improvement of the fuel combustion process in combustion chamber. Economic one is based on lowering the fuel consumption due to decrease of takeoff weight, aircraft resistance, increase of the engine frequency, decreasing of echeloning, as well as effective aircraft operation within airport.

Carried out analysis of literature showed that transportations with internal combustion engines effect atmospheric air contamination. Nowadays many techniques to reduce harmful exhaust gases emission are proposed. However, all known ones only reduce emissions into atmosphere, and do not prevent them, and with the consideration of rapid development of transportation every year, the problem of atmospheric air protection from vehicle exhaust gases still remains actual and not solved.

Aim and tasks of research

The aim of the work was to analyze the problem of atmospheric contamination due to motor transportations and to improve the technique of vehicle exhaust gases treatment.

Results and discussions

The problem of reduce of harmful transportation emissions into atmosphere today is an open and actual problem in all the countries of the world. The current paper deals with improvement of technique, from one side proposed to vehicle exhaust gases treatment, from another side to dehydrate and deoxygenate fuels.

It is well-known that dry fuel storage in the fuel tanks of vehicles, fueling station reservoirs and vessels is practically impossible, because every capacity should have access to the atmosphere to prevent collapse or destroying the surface if pressure increase or decrease due to temperature oscillations. However access to the atmosphere leads to permanent contact with the humid air. If moisture intake into vehicle fuel tank, fuel is hydrated leading to damage of physical and chemical, operation properties. Solving the problem of fuel and oil hydration is possible only if wide implementation of innovative fuel storage technologies aimed for reduction of harmful substances release into atmosphere, as well as for hydration prevention. To dehydrate the fuel, various techniques are applied, based on chemical, physical and chemical, physical processes. One of a popular fuel dehydration techniques is the mass exchange (Mikulenok 2002.). Few charts based on the technique are known. First one is the fuel drying by air blowing through it, however it was not of popularity, because it leads to significant losses of light fuel fractions rejected together with air, it also leads to fuel contamination with atmospheric dust and fuel oxygenation. It results in additional expenses for fuel treatment and quality improvement as well. Second chart is the air blowing through above fuel space of reservoir, vessel, fuel storage capacity. This chart has the same disadvantages as previous one. Another well-known mass exchange chart is the fuel drying due to freezing, however it did not became popular, because it is ineffective, expensive and durational.

To solve problems of the fuels and lubricants hydration and oxygenation, authors (Belyanskiy *et al.* 1998, Drovnin 2001) proposed drying chart. Researches were able to solve a set of following problems due to designed chart of fuel drying by neutral gas: fuels and olives dehydration; guarding of physical and chemical, operation properties of fuels and lubricants; reducing oxidative processes; fire safety insurance.

In our opinion, discussed adventures of this fuel drying system are important and actual today, as development of all leading countries is directed to the implementation of more efficient and ecological technologies. Described above chart of the fuel drying and dehydration with the help of neutral gas has one working unit (neutral gas generator), which requires permanent electric current supply and it is not safe from the point of view of impact on environment and staff, it partially reduces total efficiency of proposed technique. This neutral gas generator makes it possible to obtain gaseous mixture of the follow-

ing composition: 76–78 % N_2, 20–22.5 % CO_2, 1.5–0.4 % CO, 0.25–0.5 % H_2.

In the paper it is proposed to improve the actual chart of fuels and lubricants dehydration and deoxygenation by the replacement of neutral gas generator with catalysts for treatment of exhaust gases of internal combustion engine to get the relatively neutral gas. Moreover, we propose improved chart, first of all, to use for vehicle exhaust gases treatment. In this case we obtain not only improved fuel operation properties, but we treat vehicle exhaust gases and reduce harmful emissions into atmosphere in this way.

Discussed above catalysts are developed by research group of National Aviation University headed by O. I. Zaporozhets and they are designed for treatment of exhaust gases from internal combustion engines from harmful emissions including Carbon monoxide (Report on research work. No 951-DB00, 2001). There are analogous catalysts designed in our country and abroad (Loboyko *et al*. 2010; Orlyk *et al*. 2011; Rashidzadeh *et al.* 2000) and they may be implemented in proposed chart.

Catalysts discussed in (Report on research work. No 951-DB00, 2001), are produced from slimes, which are the wastes of metallurgy, electronic and machinery industry. These wastes contain oxides of Cupper, Iron, Chrome, Nickel, Manganese, Cobalt and other metals. Considered oxides are in fine-grained condition in slime. By addition of inorganic admixtures to them during specific processing, considered catalysts may be obtained.

The key fact to achieve our goal is that these catalysts make it possible to treat vehicle exhaust gases from CO_2 up to 6–0 % and in such a way to obtain relatively neutral gas, saturated with Nitrogen oxides, CO and H_2.

To solve assigned tasks, following chart of fuel drying by neutral gas in conditions of motor engineering operation, is proposed (Fig. 1).

To better understand the process and essence, vehicle is considered as transportation example. However, it is clear that proposed technique is easily realized in railway, as well as in marine and river transportations with the internal combustion engines. It is logically to assume that considered technique may be implemented in aviation transportations as well.

Proposed technique is based on issues (Trofimov 2013; Trofimov *et al.* 2015).

Exhaust gases from the vehicle 1 from the vehicle pipe 2 are delivered into catalyst unit 3, where they are treated from CO_2. Then gas mixture passes through counter 5. In the outlet we obtain wet N_2, which is dried when passing through moisture separator 7. Then gas is delivered to gas collector 10, after which fuel is bubbled in the tank of vehicle. On the top of the tank, sensor 18 is installed, to control the chemical composition of above fuel space. If N_2 is detected, it sends command for shifting of valve 19, which is connected with two pipes (for air output 20 and for gas mixture output 21). After mixture passing through pipe 21, it is delivered into gasholder 11, where condensation occurs resulting in wet gas N_2 and condensate of water with fuel. This condensate is collected in settling tank 13, and wet gas N_2 with the help of compressor 15 is delivered to reuse.

This chart may be used in more simple efficient mode: after moisture separator 7 just to deliver N_2 to gas collector 10 for fuel bubbling in tank. However, in this case breather 22 should be installed on the top of the fuel tank, or fuel tank should have small drainage hole. Then N_2, as excessive gas, will be released from top of the tank to the atmosphere through breather 22. In this case compressor 15, gasholder 11, settling tank 13 and pipe 21 are not required, but we have less effect.

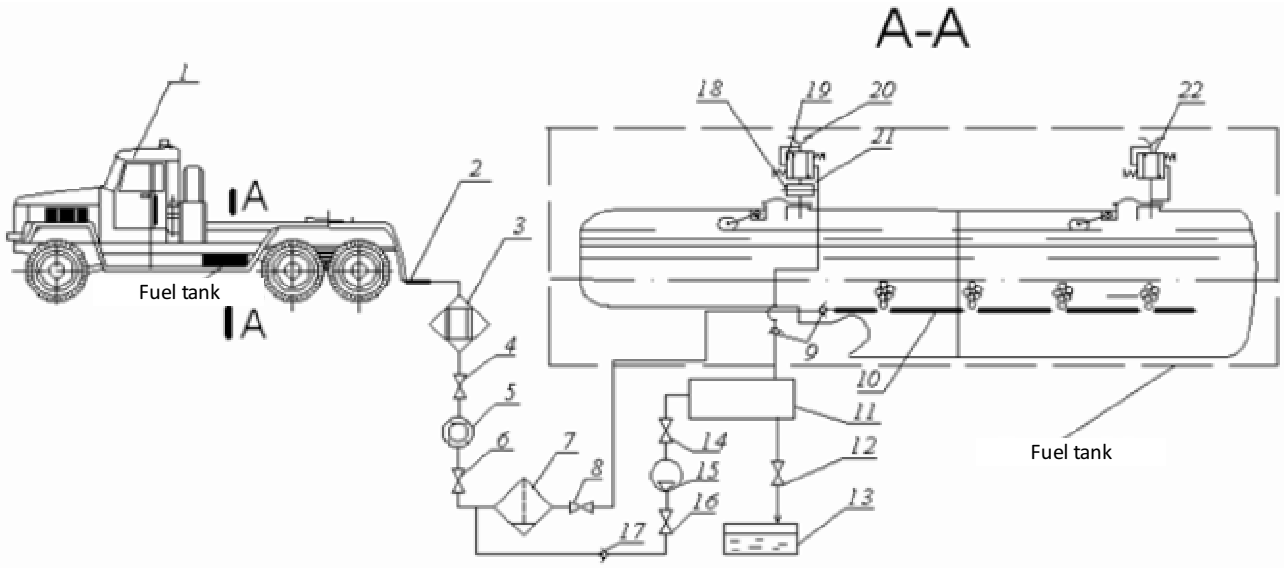

Fig. 1. Principal chart of fuels and lubricants drying with the help of neutral gas:
1 – truck; 2 - exhaust pipe; 3 – catalyst unit; 4, 6, 8, 12, 14, 16 – faucets; 5 – counter; 7 – moisture separator; 9, 17 – reverse valve; 10 – gas collector; 11 – gasholder; 13 – settling tank; 15 – compressor; 18 – sensor; 19 – shift valve; 20 – air output pipe; 21 – gas mixture output pipe; 22 – breather

Conclusions

To treat exhaust gases of vehicles, improved technique of fuels and lubricants drying is proposed to use. The adventure of proposed technique, if compared to popular ones, are that neutral gas generator is excluded from the common chart, it is replaced with catalysts for intake exhaust gases treatment. A significant adventure is that improved technique is proposed to be applied in vehicles when their operation, as well as to reduce the content of Carbon monoxide, Carbon dioxide and Nitrogen oxides in exhaust gases.

Improved technique makes it possible to solve a set of the following problems: fuel dehydration, guarding physical and chemical, operation properties of fuels, reducing oxidative processes, ensurance fire safety when operation, reducing oil product evaporation losses, reducing losses of neutral gas, environment protection. Improved technique meets modern technical and ecological requirements, necessary equipment and operation of it are of low cost.

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