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THE METHODS OF PREPARING PETROLEUM - DERIVED WASTE TO BURN IN MARINE BOILERS

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Abstract

The paper presents a valuation of the potential use of petroleum - derived waste of various physical and chemical properties as well as morphology as fuel for oil - fired ship boilers. In order to use, as boiler fuel, petroleum - derived waste from various sources at a ship, it is necessary to prepare the waste ensuring that its morphology will enable proper combustion and atomization. Petroleum - derived waste has been a subject of treatment process on a real object.

The morphology was changed by means of a process of gravitational sedimentation, and static and dynamic homogenization. Then, the changes of the fluid structure were analyzed for individual treatment methods and for serial connection of homogenizers (static and dynamic). In order to determine how waste sedimentation and homogenization process conditions affect its morphology, the physical and chemical properties of same were measured. The application of the joint above mentioned methods for waste treatment resulted in the improvement of the atomization and combustion processes in the boilers, petroleum – derived waste utilization due to which the energy included therein may be recovered. Another result is the mitigation of environment pollution and the reduction of standard fuel consumption.

Key words: *petroleum - derived waste, morphology, homogenization, physical and chemical properties*

INTRODUCTION

The pursuit of cost reductions in shipping has caused the development of ship engines adjusted to burning fuel waste of inferior physical – chemical composition. The fuels, owning to their higher viscosity, density, and more mineral and catalytic contaminations must be subjected to a proper preparation process in order to be burnt in ship engines. The petroleum - derived waste is as a result of technological processes, operating of engine rooms and cleansing among others of marine fuel oils and lubricating oils.

The waste is a large operational problem for ship crews, in particular, with the regards to the methods of storage, treatment, utilization. The petroleum - derived waste is also a threat to the environment.

MARPOL 73/78 Convention is the basic legal act concerned with the problem of pollution of seas by the shipsand determine technical guidelines and recommendations related with i.e. the management of petroleum pollutants. According to the applicable recommendations of MARPOL Convention 73/78 the methods for waste oil management are as follows:

- storing generated waste oil in dedicated tanks on ships, its dehydration and discharge ashore in ports or specialised receiving units,
- waste oil utilisation in ship incinerators,
- energetic utilization in marine boilers (*MARPOL, 2011; Szczepanek, Kamiński, 2013*).

One of the ways to dispose of petroleum - derived waste recommended by MARPOL Convention 73/78 is to burn the waste in marine boilers. This method creates an opportunity to manage the waste and to mitigate environment pollution as well as use its chemical energy for own use, leaving a favorable effect in the form of the reduction of fuel consumption by an oil-fired boiler.

In order to use, as boiler fuel, petroleum - derived waste it is necessary to prepare the waste ensuring that its morphology will enable proper combustion and atomization.

The petroleum - derived waste morphology shall be defined as a structure consisting of a continuous phase, solid particles in the form of asphaltene and resin conglomerates and water. The petroleum - derived waste contains a lot of water and asphaltenes and resinous agglomerates dimensions, therefore the burning velocity of the petroleum - derived waste is slower and changeable in proportion to fluid flammable particles (*Jasiewicz, 2013; Rajewski, Balcerski, 1996*). The burning process of petroleum - derived waste can be improved by homogenization and size reduction of asphaltene- resinous particles with water, which result in smaller particles of 5 – 30 μm and their uniform diffusion throughout the fuel volume . Such a preparation of oil waste creates emulsion boosts burning process thanks to greater evaporation and better mixing with air (*Behrendt, Jasiewicz, 2015; Rajewski, Balcerski, 1996*).

MATERIALS AND METHODS

In order to determine how waste sedimentation and homogenization process conditions affect its morphology, the physical and chemical properties of same were measured. Carried out also a dimensional analysis of the distribution of both the asphaltene and resin particles. For that purpose an analysis of the particle size distribution of insoluble particles in n-heptane has been made by means of laser diffraction using Mastersizer 2000 (Malvern Instruments) analyser. by laser diffraction method and water droplets diameter by microscopic image analysis. All the research was carried out in the Fuel Research, Hydraulic Fluids and Environmental Protection Centre of the Maritime University of Szczecin.

RESULTS AND DISCUSSION

The petroleum - derived waste can be described as a compound structure of 3 elements: fuel, water and proper waste. Depending on the source, oil waste is a mixture of various fuels and oils of different physical-chemical properties, high water intensity and a great amount of impurities. Dispersed phase is composed of poliparticle hydrocarbons of a high ratio C:H, huge agglomerates of asphaltene – resinous (100 – 200 μm in diameter), tar, paraffin, coke and ash particles (from the final refining process), also inorganic impurities, such as: sand, rust particles, sludge and thick – drop water or water from a separate phase (*Behrendt, Jasiewicz, 2015; Jasiewicz, 2013; Rajewski, Balcerski, 1996*).

Table 1 contains selected physical-chemical properties of examples petroleum - derived waste.

Tab. 1. Selected physical-chemical properties of examples petroleum - derived waste

Physico-chemical properties	**Unit**	**Petroleum - derived waste number**					
		1	2	3	4	5	6
Density at 15^0C	kg/m^3	950	895	970	875	901	921
Kinematic viscosity at 50 ^{0}C	mm^2/s	53.6	15	89	7	11.2	28,7
Water content	% mass	18	5	2,4	0.5	10.8	16
Flash point	^{0}C	103	75	120	73	94	112

The analysis of physical-chemical properties of selected petroleum - derived waste proved that the waste comes from various sources and has a wide range of physical – chemical properties such as: density, viscosity, water content and flash point. Consequently, in the tank there is a mixture of fuel of different properties, huge water amount and a lot of solid impurities. Figure 1 presents the selected microscope photographs of the waste oil morphology from various sources, marked with sample numbers according to table 1.

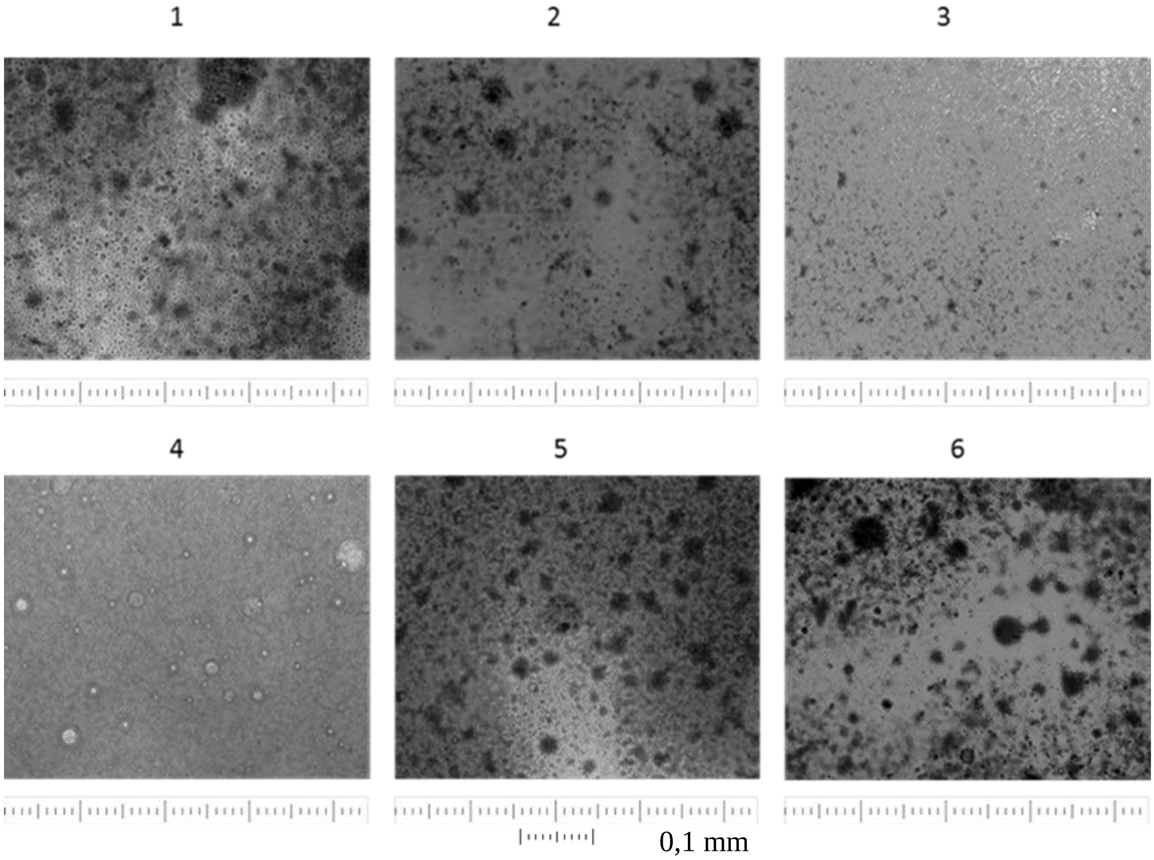

Fig.1. The petroleum - derived waste morphology from various sources, [own elaboration]

After the analysis of the asphaltene-resinous partitions for particular waste it was observed that the waste contained the largest number of pollution partitions of the diameter in the range from 63 μm to 300 μm. The analysis of the petroleum - derived waste microscope photographs presented in figure 1 shows that the water drop distribution is in the range from 10 μm to 400 μm. The water volume and the dispersion degree is variable along with following receipts of waste from different sources.

The experimental research is aimed at defining the impact of the previously mentioned homogenizing devices on the oil waste structure, particularly on the uniformity of the structure, and on the size – reducing of solid impurities in the form of asphaltene – resinous, and on the possibility of producing fuel – water emulsion. For that purpose an analysis of the particle size distribution of insoluble particles in n-heptane has been made by means of laser diffraction using Mastersizer 2000 (Malvern Instruments) analyser.

The analysis comprises four stages of the oil waste preparation for burning process:

- particle size distribution from the petroleum - derived waste sample accumulated in the oil waste tank (gravitational sedimentation),
- particle size distribution from the petroleum - derived waste sample subjected to homogenization process using the homogenising shredder pump (dynamic homogenizer),
- particle size distribution from the oil waste sample subjected to homogenization process using static homogeniser,
- particle size distribution from the oil waste sample subjected to homogenization process using homogenising shredder pump and static homogeniser working in serial system.

The measuring range of device goes from 0,02 to 2000 μm. Due to the application of Fraunhofer and Mie theories in the results analysis, the device complies with ISO 13320 norm pertaining to the analysis of particle size by means of laser diffraction method (*Malvern Instruments Ltd., 2007*). The figure 2,3,4,5 shows the distribution of size of particles insoluble in n-heptane for example of petroleum - derived waste sample for respective processes of preparing oil waste to burn in boiler on a vessel.

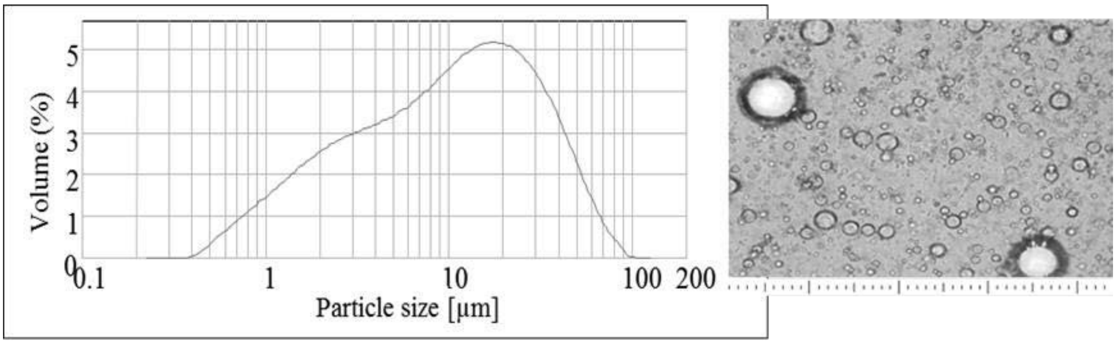

Fig.2. Particle size distribution from petroleum - derived waste sample accumulated in the oil waste tank (gravitational sedimentation)

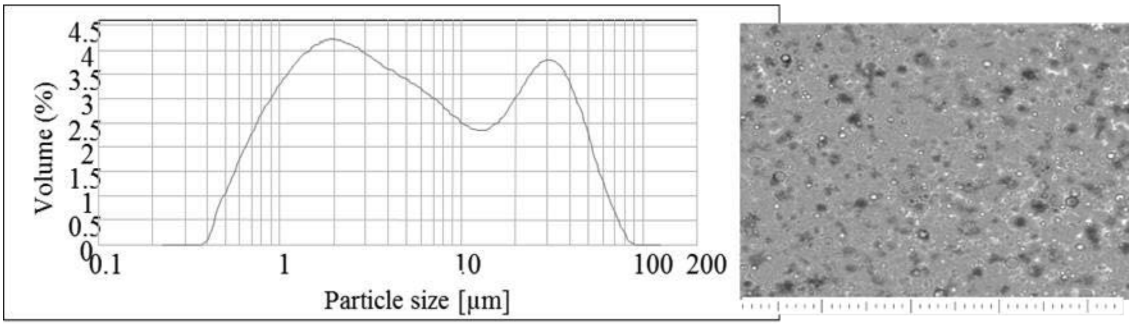

Fig.3. Particle size distribution from petroleum - derived waste sample subjected to homogenization process using homogenising shredder pump

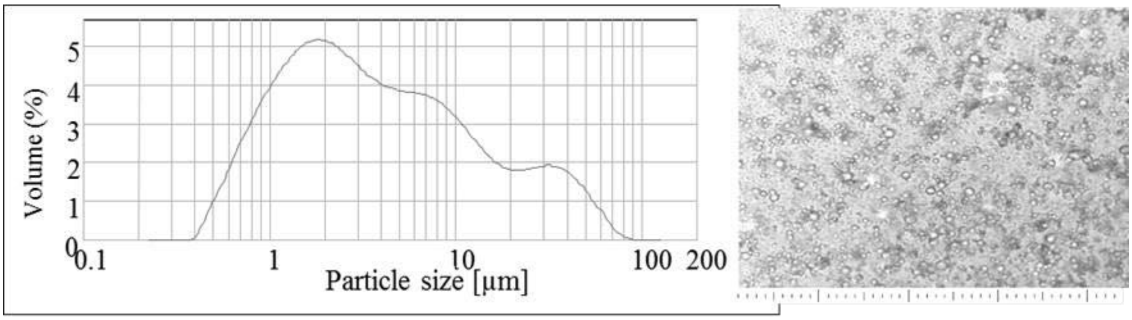

Fig.4. Particle size distribution from petroleum - derived waste sample subjected to homogenization process using static homogeniser

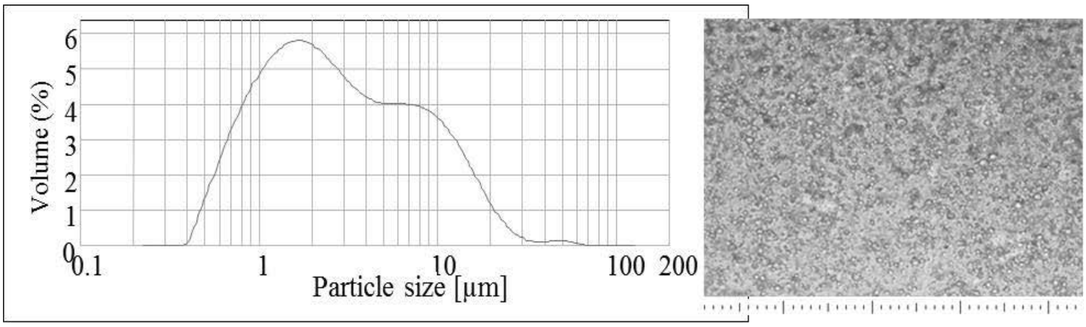

Fig.5. Particle size distribution from petroleum - derived waste sample subjected to homogenization process using homogenising shredder pump and static homogeniser working in a serial system

The application of series arrangement (homogenising shredder pump and static homogeniser) in the petroleum - derived waste preparation process for burning, has the highest impact on the structural change of the waste compared to a single device use.

The table 2 shows the statistics parameters of the particle size distribution for respective processes of preparing of sample petroleum - derived waste to burn in boiler. The statistics of the distribution are calculated from the results using the derived diameters D [m,n] - an internationally agreed method of defining the mean and other moments of particle size, whenD(v, 0.5) is the size in microns at which 50% of the sample is smaller and 50% is larger. This value is also known as the Mass Median Diameter (MMD), D(v, 0.1) is the size of particle below which 10% of the sample lies, D(v, 0.9) gives a size of particle below which 90% of the sample lies, D[3,2] is the surface area mean diameter. This is also known as the Sauter mean (*Horiba Scientific, 2012*; *Malvern Instruments Ltd., 2007*).

Tab.2. The statistics parameters of the particle size distribution for respective processes of preparing petroleum - derived waste sample to burn in boiler

Parameter	Gravitational sedimentation	Homogenizing shredder pump	Static homogenizer	Series arrangement
D(0.1) [µm]	1.619	0.962	0.925	0.832
D(0.5) [µm]	10.432	4.708	3.414	2.627
D(0.9) [µm]	37.550	36.306	25.169	11.740
D[3.2] [µm]	4.359	2.566	2.554	1.909
D[4.3] [µm]	15.619	12.378	8.590	4.834

The figure 2 and table 2 shows the changes of the petroleum - derived waste morphology when subjected to homogenizing devices operating alone or in line. The statistics parameters of the particle size distribution changes, table 2 shows size - reducing of asphaltene – resinous conglomerates for respective processes of preparing petroleum - derived waste to burn in boiler. The series arrangement brings about crushing of asphaltene – resinous conglomerates to 2 -11 µm dimensions and produces fuel – water emulsion, thus improving the burning process in the boiler.

As a result of comparing those process, one can conclude that the combination of gravitational sedimentation, the homogenising shredder pump and static homogeniser provides the best homogeneous structure of petroleum - derived waste.

CONCLUSIONS

The petroleum - derived waste comes from various sources and has a wide range of physical–chemical properties such as: density, viscosity, water content. The morphology of petroleum - derived waste from different sources is variable. In order to use, as boiler fuel, the petroleum - derived waste from various sources at a ship, it is necessary to prepare the waste ensuring that its morphology will enable proper combustion and atomization. The petroleum - derived waste homogenization by using homogenizing equipment, impacts its morphology change.

The application of series arrangement (homogenising shredder pump and static homogeniser) in the oil waste preparation process for burning, has the highest impact on the morphology change of the waste compared to a single device use. The petroleum - derived waste which underwent homogenization by means of static homogenizer are more homogeneous than the homogenising shredder pump. The application of series arrangement homogenising shredder pump and static homogeniser with the gravitational sedimentation in the oil waste preparation process for burning, has the highest impact on the morphology change of the waste compared to a single device use.

This method creates an opportunity to manage the waste and to mitigate environment pollution as well as use its chemical energy for own use, leaving a favorable effect in the form of the reduction of fuel consumption by an oil-fired boiler.

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