**Scientific Journals**
**Maritime University of Szczecin**

**Zeszyty Naukowe**
**Akademia Morska w Szczecinie**

**2013, 36(108) z. 2 pp. 51–55**
**ISSN 1733-8670**

**2013, 36(108) z. 2 s. 51–55**

# The influence of oil waste homogenizing on its morphology to improve burning conditions in marine auxiliary boilers

**Robert Jasiewicz**

Maritime University of Szczecin, Faculty of Mechanical Engineering, Institute of Ship Power Plant Operation
70-500 Szczecin, ul. Wały Chrobrego 1–2, e-mail: r.jasiewicz@am.szczecin.pl

**Key words:** oil waste, oil waste morphology, homogenization, homogenizing devices, burning oil waste, auxiliary boilers

**Abstract**
The article presents analysis of the influence of selected methods alongside with devices applied to process oil waste from engine power room plants on the changes in oil waste morphology in order to improve burning conditions in auxiliary boilers. Study results facilitated the choice of the most favourable method, in view of environmental protection, of preparing oil waste to burn so that the waste is transformed into fuel for auxiliary boilers on the ship. Burning oil waste entails changes in its morphology, therefore, measurements of toxic emissions of CO and NOx have been conducted for each of the different processing methods.

## Introduction

The processes of preparing fuels to burn in marine engines and boilers, as well as the maintenance of lube oils, result in increasing oil waste as the use of worse-quality fuels grow.

For ship crews the amount of oil waste poses an utilization problem which includes possible ways of its cumulating, cleansing and disposing of; being an obvious environmental threat.

Every year seas and oceans absorb as much as 1.8 mln cubic meters of oil waste from natural and human-driven sources, of which 34% comes from tankers' spillage or other leakage from ship operation [1].

One of the ways to dispose of oil waste recommended by Marpol Convention 73/78 is to burn the waste in marine boilers [2] thus reducing environmental pollution and simultaneously recycling the waste's chemical energy for the ship itself with visible and measurable benefits such as the reduction of fuel consumption by the marine fired boiler.

Due to a high content of water drops and asphaltene-resinous compounds in oil waste (even a few hundred micrometers in size), combustion speed is lower and more variable than with fluid flammable particles [3].

In order to use oil waste as a fuel it is essential to prepare the waste and achieve relevant morphology ensuring proper pulverizing and burning [4, 5].

## Oil waste morphology

The waste has variable physical-chemical properties and morphology (high content of water in relation to normative fuels and asphaltene-resinous compounds of different dispersion and diameters of over 100 μm). For the purpose of this research the definition of "morphology" has been coined as a composition of asphaltene-resinous compounds insoluble in n-heptane and the size of water drops contained in oil waste.

Figure 1 shows oil waste morphology from different sources collected in a waste container on a reception vessel.

This morphology is characterized by a high content of asphaltene-resinous compounds of 1–40 nm diameters and water drops of 5–60 μm in diameters. Depending on oil waste sources both contents vary heavily. To improve the morphology, oil waste needs to undergo the processes of gravitational sedimentation, shredding and homogenization.

According to literature data and confirmed by research results, to facilitate the burning process,

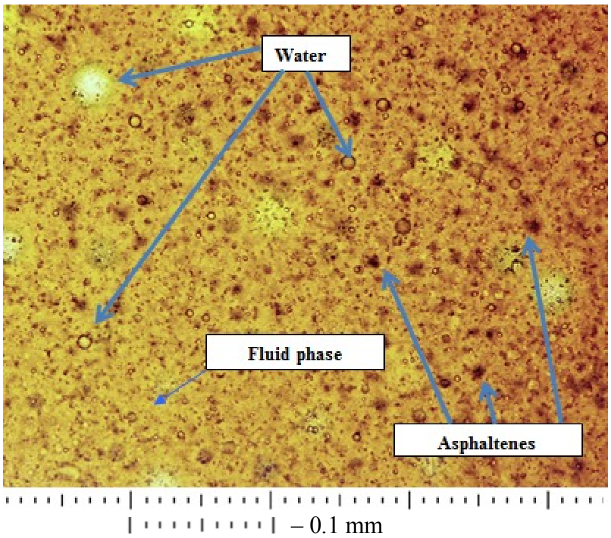


Fig. 1. Oil waste morphology

the sizes of asphaltene-resinous compounds need to be reduced to 30 µm [6, 7, 8]. Also the water content must be processed to achieve emulsion – as a result of shredding and homogenizing (by means of homogenizing devices) of oil waste. This emulsion should contain a mixture of water drops of up to 20 µm in diameter evenly spread throughout the fuel volume [4, 7, 8, 9].

Resulting from the process of waste preparation is intense evaporation, better mixing of fuel with oxygen and acceleration of burning. The fuel is then burnt completely.

## The work station

In order to do the research, fuel installation has been devised and modernised, which capacitates oil waste burning in an auxiliary fired boiler at a real vessel. The vessel is designed to receive oil waste from ships and burn it in PA-21 furnace-fire-tube boiler that creates saturated vapour of 1.4 MPa pressure, and nominal capacity of 6.5 t/h. Using the energy from the oil waste, the boiler produces vapour for its own maintenance and heating of fuel tanks and vessels.

Figure 2 shows the diagram of a research station after modification.

To improve the burning process of oil waste in boilers, taking into consideration varying physical-chemical properties and a large amount of water in the oil waste, a homogenizing device has been installed in the feed fuel system in the boiler called a static homogenizer (constructed at the Maritime University of Szczecin) along with a homogenizing shredder pump of 1000 l/h efficiency Aalborg 1333/2 W.O. Both devices can operate in series and single arrangement.

Oil waste has been subjected to the following processes of preparation for burning:

1. Gravitational sedimentation.
2. Dynamic homogenization – homogenizing shredder pump.
3. Static homogenization – static homogenizer.
4. Series arrangement of homogenizing shredder pump and static homogenizer.

## A morphology analysis of oil waste

To determine the impact of homogenization on morphology changes two analyses have been made – one of the particle size distribution of insoluble particles in n-heptane by means of laser diffraction and another – of size and amount of water drops by

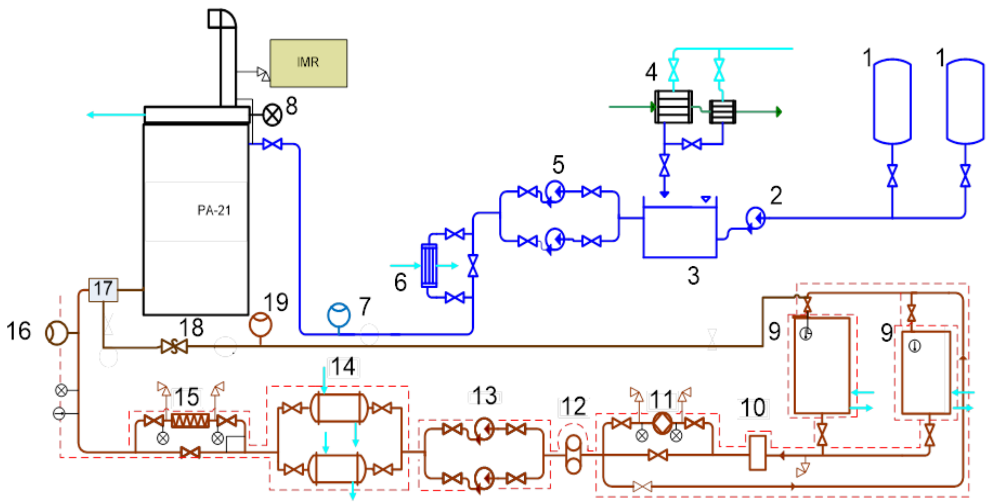


Fig. 2. Diagram of a research station; 1 – feed water tanks, 2 – hotwell feed water pump, 3 – hotwell, 4 – relief condenser, 5 – feed water pumps, 6 – feed water steam heater, 7 – water flow meter, 8 – manometer, 9 – fuel tanks, 10 – slotted filter, 11- homogenizing shredder pump, 12 – net filter, 13 – fuel pumps, 14 – steam fuel heaters,15 – static homogeniser 16 – fuel flow meter at burner inlet, 17 – burner, 18 – overflow valve, 19 – fuel flow meter at burner overflow

means of microscopic picture analysis for different preparation methods.

The table 1 shows selected physical-chemical properties of oil waste used in experimental research.

Table 1. Selected physical-chemical properties of oil waste used in experimental research

| Designation | Units | Oil waste 1 |
|---|---|---|
| Water content | [%] (m/m) | 38 |
| Sulphur content | [mg/kg] | 8540 |
| Ash content | [%] (m/m) | 1.4 |
| Calorific value ($Q^a i$) | [MJ/kg] | 24.6 |
| Density at 15°C | [kg/m$^3$] | 937.3 |
| Kinematic viscosity at 100°C | [mm$^2$/s] | 6.7 |
| Organic fraction composition: | | |
| Saturated hydrocarbons | [%] (m/m) | 48.4 |
| Aromatic hydrocarbons | [%] (m/m) | 32.7 |
| Resins | [%] (m/m) | 14.9 |
| Asphaltenes insoluble in n-hexane | [%] (m/m) | 4 |

The analysis of physical-chemical properties of oil waste proved that the waste comes from various sources and has a wide range of physical-chemical properties such as: viscosity, density, water content and sulphur content. Oil waste is a mixture of fuel of different properties, huge water amount and a lot of solid impurities.

The table 2 shows the equivalent diameters of the particle size distribution for respective processes of preparing oil waste to burn in boiler for oil waste 1.

Table 2. The equivalent diameters of the particle size distribution for respective processes of preparing oil waste to burn in boiler for oil waste 1

| 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 |

Based on the data from table 2, figure 3 displays the distribution of asphaltene-resinous compounds in order to compare morphology changes which underwent gravitational sedimentation, as well as homogenization by means of a static homogenizer and a homogenizing shredder pump operating alone or in series arrangement.

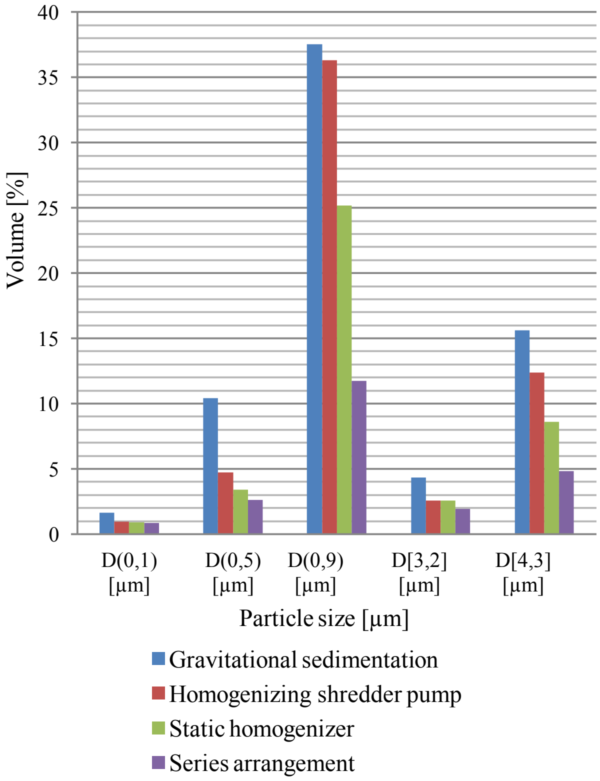


Fig. 3. The particle size distribution for respective processes of preparing oil waste to burn in boiler for oil waste 1

Analysing the research results of oil waste preparation on its morphology changes a claim can be made that comparing gravitational sedimentation process with homogenization devices in series arrangement, the diameter D(0.1) has diminished from 1.619 µm to 0.832 µm. Median diameter D(0.5) has also got into smaller particles from 10.432 µm to 2.627 µm within series arrangement operating of the homogenizing shredder pump and the static homogenizer.D(0.9) has been reduced from 37.550 µm to 11.740 µm. D(3.2) Sauter's diameter has become 1.909 µm (from previously 4.359 µm), and eventually the volume mean diameter D(4.3) from 15.619 µm has been reduced to 4.834 µm.

The table 3 shows number of water droplets for respective processes of preparing oil waste to burn in boiler for oil waste 1.

Table 3. Number of water droplets for respective processes of preparing oil waste to burn in boiler

| Dimension range [um] | Gravitational sedimentation | Homogenizing shredder pump | Static homogenizer | Series arrangement |
|---|---|---|---|---|
| | Numer of droplets | | | |
| 5 < 15 | 11 250 | 16 750 | 28 547 | 45 894 |
| 15 < 25 | 12 743 | 21 743 | 15 890 | 10 456 |
| 25 < 50 | 1534 | 1050 | 579 | 139 |
| 50 < 100 | 980 | 221 | 45 | 12 |
| > 100 | 157 | 38 | 16 | 0 |

Figure 4 shows changes in distribution of water droplets in determined sizes depending on processing methods.

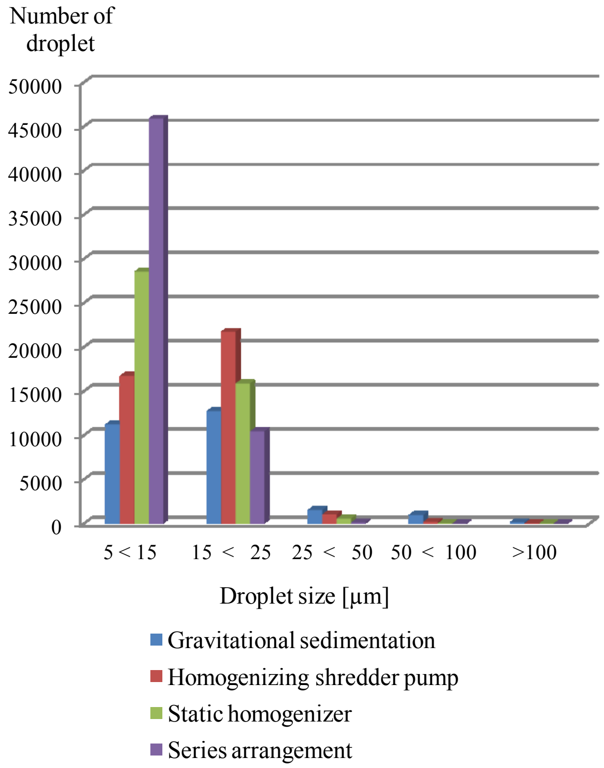


Fig. 4. Distribution of water droplets in determined sizes depending on processing methods

After the process of sedimentation the oil waste has been rid of water to a diameter of over 100 µm. A large number of droplets have been observed within 15 µm to 25 µm. Another large number of water droplets have been noticed within 25 µm to 100 µm. As a result of the homogenizing shredder pump the number of droplets has been reduced within 25 µm to 50 µm. Meanwhile, within 50 µm to 100 µm the large number of water drops would suggest insufficient effectiveness of this method.

When homogenization method was used by means of a static homogenizer the number of drops of over 100 µm in size have been reduced and similar phenomenon concerned the range of 25–50 µm.

However, apparently the best results have been achieved when the series arrangement of homogenization devices was used. The water drops have been reduced in size of over 100 µm and the preferable number of drops within 5–15 µm has been successfully increased.

## Experiment verification based on composition analysis of selected burning products

To verify this experiment CO and NOx measurements have been selected depending on relative boiler load and the preparation method to pulverize and burn the oil waste. First, CO content in exhaust fumes has been measured, depending on boiler load in 4 ways of oil waste processing.

Figure 5 shows the resulting emissions of CO in the different processing methods.

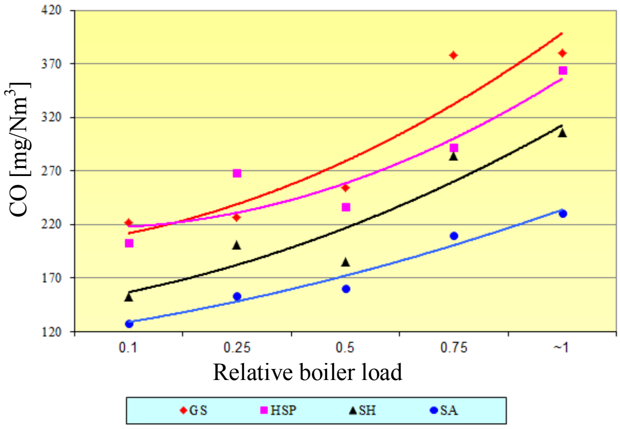


Fig. 5. Emissions of CO at burning oil waste; GS – gravitational sedimentation, HSP – homogenizing shredder pump, SH – static homogenizer, SA – series arrangement

Based on the experiment it has been proved that the most significant reduction in CO emissions at burning is achieved through the use of gravitational sedimentation along with series arrangement of the shredding pump and the static homogenizer as the means of preparing oil waste to burn.

In figure 6 NOx emissions have been presented from fumes, depending on boiler load and respective methods of oil waste preparation to burn.

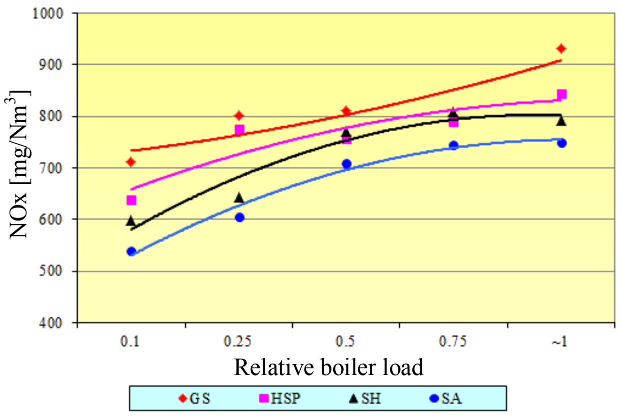


Fig. 6. Emissions of NOx at burning oil waste; GS – gravitational sedimentation, HSP – homogenizing shredder pump, SH – static homogenizer, SA – series arrangement

Again, based on the research it has been proved that the most significant reduction in NOx emissions at burning is achieved through the use of gravitational sedimentation along with series arrangement of the shredding pump and the static homogenizer as the means of preparing oil waste to burn. Verification research about NOx emissions seem to confirm the claim that the change in oil waste morphology does influence the improvement of combustion conditions.

## Conclusions

- Oil waste homogenization impacts its morphology change.
- Change in morphology facilitates burning conditions in boilers.
- Oil waste after the process of homogenization by means of a static homogenizer is more homogeneous in comparison with the use of shredder pump.
- Series arrangement use in oil waste preparation has the most significant influence on the morphology change, rather than the use of single devices.
- Series arrangement causes shredding of large asphaltene-resinous particles to 30 μm (best size), water drops to below 20 μm (best sizes) and assures their even spread in the fuel.
- The use of gravitational sedimentation along with the homogenizing shredder pump ant the static homogenizer as the method for morphology change in oil waste preparation to burn, has a huge influence on reducing toxic emissions at burning.

## References


1. FARRINGTON J.W., MCDOWELL J.E.: Mixing Oil and WaterTracking the sources and impacts of oil pollution in the marine environment. Oceanus Magazine, Vol. 42, No. 3, 2004.
2. MARPOL Consolidated edition 2011. IMO, Londyn 2011.
3. RAJEWSKI P., BALCERSKI A.: Możliwość wykorzystania energii zawartej w odpadach ropopochodnych poprzez ich spalanie w okrętowych kotłach pomocniczych. Zeszyty Naukowe Politechniki Gdańskiej, Mechanika LXIII, Gdańsk 1996.
4. JAWOROWSKI J., RAJEWSKI P., ZAPAŚNIK T.: Spalanie odpadów ropopochodnych w komorze spalania w laboratorium WSM i kotle LX. Mat. V Symp. Paliw Płynnych i Produktów Smarowych w Gospodarce Morskiej, Kołobrzeg 1983. Instytut Morski, Gdańsk 1983.
5. KARCZ H. i inni: Wpływ składu mieszaniny olejowo-wodnej na proces spalania i koszty eksploatacyjne kotła energetycznego. Ciepłownictwo, Ogrzewnictwo, Wentylacja 9, 2007.
6. JASIEWICZ R., BEHRENDT C.: The influence of selected methods of preparing oil waste to burn in ship's fired boilers by means of homogenizing devices on the oil waste structure change. Conference Environmental protection into the future. Częstochowa 2007.
7. JAWOROWSKI J.: Badania wybranych metod przygotowania paliw okrętowych. Rozprawa doktorska, Politechnika Wrocławska, Wrocław 1980.
8. RAJEWSKI P.: Badania możliwości wykorzystania okrętowych odpadów ropopochodnych jako paliwa w kotłach pomocniczych. Praca doktorska, Politechnika Gdańska, Gdańsk 1994.
9. DIBOFORI-ORJI A.N.: Critical processes involved in formulation of water-in-oil fuel emulsions, combustion efficiency of the emulsified fuels and their possible environmental impacts. Research Journal of Applied Sciences, Engineering and Technology 3(8), 2011, 701–706.