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BIODYSEL AS THE ALTERNATIVE FUEL FOR MARINE TRANSPORT

BIODYZELIS KAIP ALTERNATYVUS KURAS JŪRŲ TRANSPORTUI

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In the article is analyzing the possibilities and problems related with usage of biofuels, derived from renewable raw materials - vegetable oil and animal, in the maritime transport sector. It is shown that in the ship diesels can be used unprocessed vegetable oils and esterified plant and animal fatty acid products (biodiesel) without any major technical problems. Development of biofuel usage in maritime transport is mainly restricted by 20-50% higher price than oil fuel and absence of biofuels supply and bunkering infrastructure in the ports.

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Biofuel, marine transport, possibilities and problems of biofuel usage.

Introduction

Over the last 20 years the world's population has increased by 1.6 billion people, and it is projected to rise by 1.4 billion over the next 20 years. At the global level it means that the production and consumption of energy will rise [1].

The consumption of primary energy in the world in 2010, according to the data provided by British Petroleum (BP) [1], was 12002,4 Mtne, including 158,6 Mtne of energy produced from renewable energy sources (RES). It increased by 29,6% and 140% respectively, if compare to year 2000. In the EU (in the same decade) energy consumption has only increased by 1.7%, however the usage of RES has increased by 365% and in 2010 it comprised 3.86% of total energy consumption. Whereas in the world, analogical indicator is only 1.32% (Table 1).

Tab. 1. Primary energy consumption (total and made from RES) in years 2000 and 2010 (in the world and EU)
1 lentelė. Pirminės energijos suvartojimas (bendras ir iš AEI), 2000 ir 2010 metais (pasaulyje ir ES)

	Total energy			Energy from RES			Fraction of RES from total, %		Change 2010 over 2000, %
	Mtoe		Change 2010 over 2000, %	Mtoe		Change 2010 over 2000, %	2000	2010	
	2000	2010		2000	2010				
World	9262.6	12002.4	29.6	51.2	158.6	209.8	0.55	1.32	140
EU	1703.9	1732.9	1.7	14.1	66.9	374.5	0.83	3.86	365

Data shows that the world's and the EU's trends in the energy sector differ essentially: worlds energy consumption increases rapidly whereas in EU it's almost invariable. While RES share in the EU's total energy balance increases much faster than in the rest of the world. Biofuel, as one of important RES elements, is an attractive alternative for fossil fuels by ecological approach. According to BP data [1], we can see that biofuel makes up a significant part of RES.

Tab. 2. Primary energy from RES and biofuel consumption in the world and EU in 2000 and 2010.
2 lentelė. Pirminės energijos, iš atsinaujinančių energijos šaltinių ir biodegalų, suvartojimas pasaulyje ir ES 2000 metais ir iki 2010 m.

	Total RES			Biofuel			Fraction of biofuel from total RES, %		Change 2010 over 2000, %
	Mtoe		Change 2010 over 2000, %	Mtoe		Change 2010 over 2000, %	2000	2010	
	2000	2010		2000	2010				
World	51,2	158,6	209,8	9,2	59,3	544,6	18,0	37,4	107,8
EU	14,1	66,9	374,5	0,74	10,4	1305,4	5,2	15,5	198,1

We can see that fraction of biofuel in the world's RES is higher than in the EU, but the growth rate of biofuel consumption in the EU is almost twice as big as in the world. In addition, it is clear that in the EU the other types of RES are relatively much more developed than in other regions of the world, for example, wind energy utilization.

Fraction of biofuel in the total EU energy balance has grown from 0.16% in 1999 up to 3.94% in ten years (2010). But this indicator is not sufficient to comply with obligations to reach the target of 5.75% in the total EU energy (including transport sector) balance.

Eurostat statistical data shows that during the decade 1999-2009 EU-27 transport energy consumption increased by 8% from 340 to 368 Mtoe [2]. However, these statistical data does not cover the marine transport sector.

Main reason for that is the specific of the marine transportation. Marine shipping is basically a global activity and as a result of that it's energy consumption can't be restricted to any country and it's energy balance. There is no international institution that could oblige ship owners to accumulate and provide precise technical and economical data about shipping. Therefore, specific information is provided by scientists and specialists, based on fragmental, often indirect data. Because of that it's quite common that different evaluations differ and usually are provided not as absolute values, but as intervals between minimum and maximum values.

The goal of this work is to evaluate possibilities, perspectives and problems of the introduction and use of biofuels in the marine transport, emphasizing technological, ecological and economical aspects.

In this report a review of documents, directives and regulations prepared by international organizations and other competent institutions, relevant for solving questions concerning practical implementation of biofuels in the marine transport, is also presented.

Opportunities and challenges of using of biofuels in marine diesel

Chemical, technological and ecological properties of biodiesel

Biodiesel is an oxygenated alternative diesel fuel, consisting of the alkyl monoesters of fatty acids from vegetable oils and animal fats; it can be used in existing diesel engines without modifications. Its primary advantages are that it is one of the most renewable fuels currently available and it is also non-toxic and biodegradable.

Many studies has shown, that vegetable oils derived fuels have potential as alternative fuel for diesel engines [3, 4, 5].

Raw vegetable oils and their chemically modified forms could be used for running a diesel engine in different ways:

Early in the last century **raw vegetable oils** were investigated to be used for running a diesel engine [3, 6, 7]. Researches show that vegetable oil used in diesel engines can cause long-term engine deposits, ring sticking, lube oil gelling and other maintenance problems and can reduce engine life.

Micro-emulsification. To solve the problem of high viscosity of vegetable oil by explosive vaporization, micro emulsions with solvents such as methanol, ethanol and butanol have been used [8].

Transesterification. The major components of vegetable oils are triglycerides. The process of transesterification removes glycerol from the triglycerides and replaces it with radicals from the alcohol used for the conversion process [9]. These fatty monoesters (fatty acid methyl esters - FAME) have come to be known as biodiesel.

Blending. Biodiesel (fatty acid methyl esters - FAME) can be used pure or mixed in any proportion with diesel fuel. A 20% blend of biodiesel with 80% diesel fuel called B20. Higher than 20% of FAME blend levels, require special handling and fuel management [10] and may require equipment modifications such as the use of heaters or changing seals and gaskets that come in contact with the fuel to those compatible with high blends of biodiesel.

With chemmotological points of view the greatest practical value have the specific properties of a biodiesel, connected to features its element and chemical compound. They define the most essential distinctions in comparison with petroleum fuels some important motor and operational qualities of a biodiesel engine at its application in diesel engines.

In general vegetable oils are mixtures of triglycerides from various fatty acids and the composition of vegetable oils varies with the plant source. The chemical and physical properties of oils and fats and derived from them esters vary with the fatty acid profile [9]. Compared to the chemistry of diesel fuel, which contains hundreds of compounds, the chemistry of different fats and oils typically used for biodiesel are very similar [11, 12]. The oils and fats contain about 10 common types of fatty acids which have between 8 and 22 carbons, with over 90% of them being between 16 and 18 carbons. Some of these fatty acid chains are saturated, while others are monounsaturated and others are polyunsaturated.

The fatty acid compositions of the biodiesel esters (products of oils transesterification) investigated in study [13]. All the vegetable oil esters had very highly unsaturated fatty acid content, ranging from about 88% (sunflower esters) to 97% (rapeseed esters).

In Table 3 is shown general impact on the fuel properties and emissions of fatty acids types. A “perfect” biodiesel would be made only from monounsaturated fatty acids [10].

Tab. 3. Fuel Properties as a Function of Fuel Composition in Diesel Engines
3 lentelė. Kuro savybės kaip funkcija nuo degalų sudėties automobiliuose su dyzeliniais varikliais

Fatty acid	Saturated	Monounsaturated	Polyunsaturated
Cetane Number	High	Medium	Low
Cloud Point	High	Medium	Low
Stability	High	Medium	Low
NO_x Emissions	Reduction	Slight increase	Large increase

Specific gravity (density). Density of fuels is used as a precursor for a number of other fuel properties, such as heating value, viscosity and cetane number. Biodiesel has a lower density (kg/m^3) than raw feedstock oil, but has a higher specific gravity and density (kg/m^3) than conventional diesel fuel, witch exhibits a specific gravity of 0.85. The measurements [14] indicated that all the biodiesel fuels and their blends with diesel fuel had a linear specific gravity-temperature relationship which varies between 0.79 and 0.89.

Viscosity. Fuel viscosity plays an important role in the combustion of fuel. High viscosity leads to poorer atomization of the fuel spray and less accurate operation of the fuel injectors.

Depending on feedstock and the amount of oxidation, biodiesel's kinematical viscosity will vary between 4.0 and 6 cSt, while diesel fuels tend to fall in the a narrower range of 1.3 to 4.1. [10].

Surface tension. Surface tension is another fuel property that affects spray atomization, droplet size, and other important properties of the diesel spray. Only very limited data on the surface tension of neat biodiesels and blends is available. A typical value for No.2 diesel fuel is 22.5 dyne/cm at 100°C. Slightly bigger values of 25.4 dyne/cm at 100°C for rapeseed oil methylester and 34.9 dyne/cm at 60°C for neat soy methylester were reported [6].

Biodiesel low temperature flow properties. The cloud point is the temperature at which a cloud of wax crystals first appears in a liquid upon cooling. Operating at temperatures below the cloud point for a diesel fuel can result in fuel filter clogging due to the wax crystals [15]. Biodiesel fuels typically have higher cloud points, than standard diesel fuel.

The cloud point of pure biodiesel starts at -1°C to 0°C for most of the vegetable oils that are made up primarily of mono- or poly-unsaturated fatty acid chains and can go as high as 27°C or higher for oils that are highly saturated [10]. There are some efforts underway to design new additives – pour point depressants [16].

Volatility and boiling points. The boiling temperatures of the compounds in biodiesel are so high at atmospheric pressure that the compounds may decompose (crack) during the distillation test [15]. Therefore the vacuum distillation could be used for data getting.

Biodiesels, being mixtures of methyl esters, will have physical property trends analogous to those of pure methyl esters, which are dependent on fatty acid composition.

The TGA (thermogravimetric) technique has been employed to yield information on the volatility of the biodiesels since the volatility influences the ignition quality of the fuels in a compression ignition engine [13, 17, 12] (table 4).

Tab.4. Volatilisation and distillation temperatures from TGA
4 lentelė. Lakumo ir distiliacijos temperatūros TGA

Samples	Onset of volatilisation,ºC*	Distillation temperature (ºC)		
		10%	50%	90%
SME	178.2	192.9	236.1	>350
SEE	187.3	202.3	247.3	320.3
RME	192.7	206.9	251.8	293.6
REE	203.2	220.5	274.4	>350
No.1 winter DF	54.7	64.0	97.3	123.5
No.2 summer	76.8	94.1	168.3	211.4

* At 5% weight loss.

RME – rapeseed oil methyl ester; REE - rapeseed oil ethyl ester; SME-sunflower oil methyl ester; SEE- sunflower oil ethyl ester.

Atomisation characteristics. Physical fuel properties, such as viscosity, density and surface tension influence on fuel spray and fuel atomisation parameters. Experiments for the vaporisation mechanisms of a single RME and SME droplets characterisation have been conducted [18] in air at temperatures between 473 and 1020 K and at atmospheric pressure in the experimental chamber.

During the experiment [10] was noted, that droplets of vegetable oil methyl esters evaporate like mono-component liquid droplets, but with a very significant heating phase. For example, at 600 K, the heating phase represents 60% of the total vaporisation time for RME and SME. This result may be explained by the higher molecular weight (294 g/mol for RME against 142 g/mol for n-$C_{10}H_{22}$) and the higher boiling point (601 K for RME and 447 K for $C_{10}H_{22}$) of the vegetable oil methyl esters.

Biodiesel has a higher flash point (100-180°C) [6] than diesel fuel (60-80°C), because biodiesel has a high number of FAMEs which are generally not volatile. Thus, biodiesel is safer to handle at higher temperatures than diesel.

Residual methanol in the fuel is a safety issue because very small amounts of methanol reduce the flash point [11].

The cetane number (CN) is one of the prime indicators of diesel fuel quality. It is related to the ignition delay time a material experiences upon injection into the combustion chamber. Generally the shorter the ignition delay-time, the higher the CN and vice versa.

The cetane number of biodiesels in general is at the high end of the range typical of No.2 diesel fuel. In the study [6] reported cetane numbers range from 45.8 to 56.9 for soy and from 48 to 61.8 for rapeseed methylesters.

Heating value. The heat content of the diesel fuel is approximately 45 MJ/kg. The vegetable oil and their esters contained approximately 11% less heat energy on a mass basis because oxygen content. Since the densities of the biodiesel esters were 2-7% higher than those of diesel fuel, the heat energy of the biodiesels therefore was about 4-9% lower on a volume basis. The gross heat of combustion of the four pure vegetable oils and the corresponding esters changes in range 39,5-40,27 (pure oils) and 39,56-40,43 (esters relevant) [13].

Stability. A fuel is considered unstable when it undergoes chemical changes that produce undesirable consequences such as deposits, acidity, or a bad smell. There are three different types of stability:

Thermal stability addresses fuel changes that occur due to elevated temperature [19].

Oxidative stability refers to the tendency of fuels to react with oxygen at temperatures near ambient [10].

Storage stability is refers to the stability of the fuel while it is in long-term storage [10].

Experimental research of process of ageing with rapeseed methyl ester (RME) which was produced in Lithuanian manufactory was made [20]. 4 identical (2,5 l) samples of fresh RME were stored (exposed) in different conditions: closed vessel - on the daylight, in the dark, in the refrigerator; open vessel - on the daylight. Every week samples from each 4 vessels were taken to measure the following 6 parameters: induction period, acid value, iodine value, water content, density and viscosity.

In conclusion, it can be observed that rapeseed biodiesel, which is produced in Lithuanian manufactory, during 10 weeks storage period under normal conditions (in the dark) are stable enough and meet the requirements of standards.

Material Compatibility. Brass, bronze, copper, lead, tin, and zinc will oxidize diesel and biodiesel fuels and create sediments. The fuel or the fittings will tend to change colour and sediments may form, resulting in plugged fuel filters. Affected equipment should be replaced with stainless steel or aluminium. Acceptable storage tank materials include aluminium, steel, fluorinated polyethylene, fluorinated polypropylene, and Teflon [11].

Biodegradability. Vegetable oil methyl esters are reported to be non-toxic and easily biodegradable in an aquatic environment. It was determined [21] that during a 21 day period, 98% of pure rapeseed oil methyl ester (RME) and only 60% of pure fossil diesel fuel were biologically decomposed.

Currently biggest consumers of biodiesel are automotive transport, agriculture, inland recreational fishing and shipping. But intensive R&D to widen the use of biofuels, adjusting it to suit more powerful diesels are being done. Most experience in these fields is possed by world's most known engine builders Wartsila and MAN. Their powerful (Pe > 2000 kW) diesels adapted to work with biofuels are made for stationery use, but can work in ships just as well without any major alterations.

Tab.5. Stationary and marine diesel installation adapted to work by biofuel
5 lentelė. Stacionarių ir jūrinių dyzelių instaliacijos pritaikytos dirbti biokuru

Builder, year	Production	Use
Wartsila, 2002	Multi fuel diesel generator set Wartsila 6L32, Pe = 2760 kW; n = 750 min^{-1} made to work with biofuel (unconverted palm oil). Can work with HFO and with further modifications LNG.	Power station
Wartsila, 2008	Multi – fuel 7MW Wartsila 18W46 HFO /Biofuel Diesel generator made to work with MDO, HFO, WFE, Vegetable oil, Palm oil, Raseseed oil. Air pollutant concentrations, reduced to 15% O_2. NOx – 250mg/Nm^3, PM-15 mg/Nm^3; Generator efficiently 46%.	Power station
Wartsila	Two Vasa LN32 engines work with biofuel [22]	Power plant in M/V Bastø III
USA	Recreational boats work with soya biodiesel in the Great Lakes, 1998 Two research ships work with soya biodiesel on Lake Michigan, 2003	Power plant
MAN, 2005	MAN B&W 5L27/38 engines for biofuel power station in Epingen – Richen, Germany	Power station
MAN B&W, 2007	MAN B&W 18V48/60 engine for cogeneration plant at Mouseron in Belgium, a biofuel version	Power station
Earthrace, 2008	Two Cummins Mercruiser engines, both with a power output of 350 kW. Powered by 100% biodiesel from sustainable sources.	Power plant
RCCL	Gas turbines GE LM2500 works in biodiesel. RCCL started out with 5% blends and eventually fuelled the turbines with a 100 % biodiesel.	Caribbean-based cruise ships
BVEnergi, 2007	Two MAN diesel 1300 hp (975 kW) engines	Luxury yacht
2012	Three Wärtsilä 6L20 main gensets capable of running on various types of liquid bio-fuels (LBF) as well as marine diesel oil	Power plant in M/V Aura II

Fig. 1. Wartsila marine vessel " Bastø III" powered by biodiesel
1 pav. Wartsila laivas " Bastø III", dirbantis biokuru.

Tab.6. Technical data of Wartsila marine vessel " Bastø III"
6 lentelė. Wartsila laivo " Bastø III" techniniai duomenys

Vessel type:	Ro-ro/passenger Ship
Gross tonnage:	7,310 tons
Summer DWT:	3,105 tons
Length:	116 m
Beam:	20 m
Draught:	4.8 m
Engine	Vasa LN32
	Cylinder configuration: W 12V32
	Power: 6960 kW
	Speed: 750 rpm
	Fuel consumption: 183 g/kWh
	4 - stroke, non-reversible, turbocharged and intercooled diesel engine
	Cylinder bore: 320 mm
	Stroke: 400mm

Experience in the design and operation of these engines showed that there are a few technological problems that should be done, before introducing biofuels in marine transport (table 7):

Tab.7. Technological problems associated with implementation of biodiesel in marine diesels

7 lentelė. Technologinės problemos, susijusios su biodyzelino panaudojimu jūriniuose dyzeliuose

Conditions of using biofuels	Problems and solutions using VO or FAME	
	Vegetable OMS	Fat acid methyl (ethyl) esters
Pure biofuels (100%) and mixtures with other marine fuels.	Biofuel's physic - chemical changes when storing (aging). Researches of long-time storage aging and changing of fuel properties have to be done in bunkering facilities reservoirs and vessel's tanks. Biofuel's and it's mixtures effect on reservoirs and vessel storage tanks (chemical and biochemical corrosion of metal). Research for determination what concentration and type of biofuel does increase corrosion. If there are possibilities of corrosion –storage tank modification has to be done. Biofuel's and it's mixtures cold yield deterioration. Research has to be done to determine special means, differentiated according fuel type and composition of mixtures, for ensuring the fuel yield. Selective compatibility of different types of biofuels with different types of fossil fuels.	
	Without restriction complies with HFO.	Without restriction complies with MDO and MGO.
5% of biofuel	Adjusting the engine to work with biofuel. No special measures needed.	
20% of biofuel	Possible effects on engine non metal parts, corrosion of metal parts and cavitations in high pressure fuel system.	
Pure biofuels and mixtures with more that 20% of biofuel.	Engine and fuel system, vessel fuel preparation system has to be modified in order to comply with current type of biofuels and properties of fuel systems.	Might be necessary to additionally adjust fuel system and change fuel injectors to comply with greater than MGO fuel viscosity.
	Calorific value of nominal fuel supply portion decreases. Necessary to adjust high pressure fuel pump in order to compensate lower calorific value.	

Taking into account the increased security requirements for ships, there are additional specific general and organizational problems affecting usage of biofuels in marine transport required by the relevant decisions (table 8).

Tab. 8. General and organizational problems associated with implementation of biodiesel in marine diesels

8 lentelė. Bendrosios ir organizacinės problemos, susijusios su biodyzelino panaudojimu jūriniuose dyzeliuose

Problem	Solution
No standards for marine biofuels and no legitimated regulations for its use in ships.	IMO, ISO, marine classification societies and suppliers of biofuel should prepare and legislate appropriate standards and other normative documents.
No infrastructure for marine biofuels bunkering in the Baltic sea.	Special programme for biofuels bunkering network has to be developed and implemented (stationery and mobile bunkering network).
Insufficiently clear economical expediency and payback of using biofuels in ships.	Extensive analysis of current situation and perspective conjuncture of biofuels and fossil fuel markets has to be made. Differences of current and future prices of these fuels must be estimated, with respect to political decisions that influence solutions on the development of biofuels, considering ecological and economical situation.
Insufficient biofuel production amounts, not ensuring it's availability and competitiveness in the marine fuel market.	The programmes of development of the use of biofuels in marine transport must be in line with biofuels production capacities. Analysis of possible new sources for biofuels production (alga aquaculture) and technologies (Fisher Trops method for recycling of bioenergetical materials) has to be made at least for the years 2020–2030. The expediency and needs for investments to use biofuels in maritime transport should be evaluated accordingly.

Current status of biodiesel market in EU

The global transport sector in 2010 consumed about 2,2 billion tons of oil equivalents (Mtoe) [23]. About 12-16% of total transport energy consumption accounted for marine sectors. In the Baltic Sea the average fuel consumption is 5,9-6.2 Mt [24] i.e. about 1,8% of the global marine sector consumption per year.

According to the data provided by British Petroleum (BP), the energy used for transport will continue to be dominated by crude oil, but – will grow slowly. The slowing of growth in total energy in transport is related to higher oil prices. The growth of oil in transport slows even more dramatically, due to displacement of oil by biofuels. The main cause of it is EU set minimal fraction of biofuel for transport sector in 2010 had to be no less than 5,75 %, till 2020 - 20%.

It means that in marine transport sector, where currently dominated oil products, at 2020 should be using 20% of biofuel and most promising alternative fuel as marine biofuel is biodiesel.

The prices of marine fuels strongly depend on global oil crude prices which are related with reduction of hydrocarbon resources. During the last 10 years crude oil prices increased more than twice, i.e. 2.8 times from 209 US$/t in 2000, till 583 US$/t in 2010. During the same period prices of marine distillates (MDO, MGO), and rapeseed oil increased by the same number as crude oil, but the price of residual oils increased more than 3 times. As we see in table 9 biodiesel are more expensive than fossil fuels. The price for biodiesel is 1.5-2 times higher than fuel oil with the same chematological properties.

Tab. 9. Different types of marine fuel and rapeseed oil prices, US$/t
9 lentelė. Įvairių jūrinio kuro rūšių ir rapsų aliejaus kainas, US $/t

Year	Crude oil	MDO	MGO	LSFO 1% S	HSFO 3,5% S	IFO 180 cSt	IFO 380 cSt	Rapeseed oil price
US dollars per tonne, $/t								
2000	208,87	232,25	256,47	154,07	135,16	144,34	138,5	359
2005	399,64	459,08	505,04	254,28	228,49	253,33	234,5	669
2010	582,70	637,74	666,03	473,58	439,55	467,13	448,50	1012

Biodiesel prices in most cases depending on external factors such as the increase of oil prices, production capacity, subsidies, duties and the worldwide availability of biofuels, political stability of countries as main energy suppliers, stability of global economy and banking sectors.

Today, the EU is the world’s biggest producer and consumer of biodiesel. Biodiesel production and consumption is on the rise, the industry is still not running at full capacity. In 2006-2010 period, biodiesel production amounted 4.9-9,6 million tonnes, but production capacity was more than twice higher. It has been a significant rise in production between 2007 and 2008. High oil prices in the first half of 2008 made it highly attractive and economical to substitute fossil fuels by biofuels (Table 10).

Another outcome of price difference is that EU biofuel users import up to 50% of needed amounts of biofuels whereas local biofuel producers use less than 50% of their nominal production capacity. This is because imported low quality biofuel (palm oil) is cheaper but suits well for the use with darker oil fuels, used in maritime transport.

For marine transport most promising biofuel is unconverted plant oils (palm, soy, raps seed and others.). Using these biofuels cost of the fuel increases proportionally to the part of biofuel in the mixture.

Tab.10. Development of biodiesel production capacity, production volumes, consumption and other parameters in EU-27 during 2006-2011

10 lentelė. Biodyzelino gamybos pajėgumai, gamybos apimtys, suvartojimas ir kt. parametrai 2006-2011 (ES-27)

Year	2006	2007	2008	2009	2010	2011
Production capacity, kt/y	6069	10289	16000	20909	21904	22117
Production volume, kt/y	4890	5708	7755	9046	9570	8800
Biodiesel consumption, kt/y	4074	5899	8018	9667	10742	10588
Total biodiesel imports,kt*/y		9030	9242	8901	8583	9693
Crude oil price, US$/t	477,5	530,6	712,9	452,1	582,7	815,7
RME Price, US$/t	723	950	1500	800	1012	1365

*Metric tons;

Using 20% of biodiesel in fuel blend with MDO or MGO prices will exceed 20-70 US$/t. Most price rise is when residual oils is mixed with 20% of biodiesel – from 30 till 111 US$/t. It is obvious that the conditional price increase will be most sensible when base fuel oil is cheapest (fig. 2).

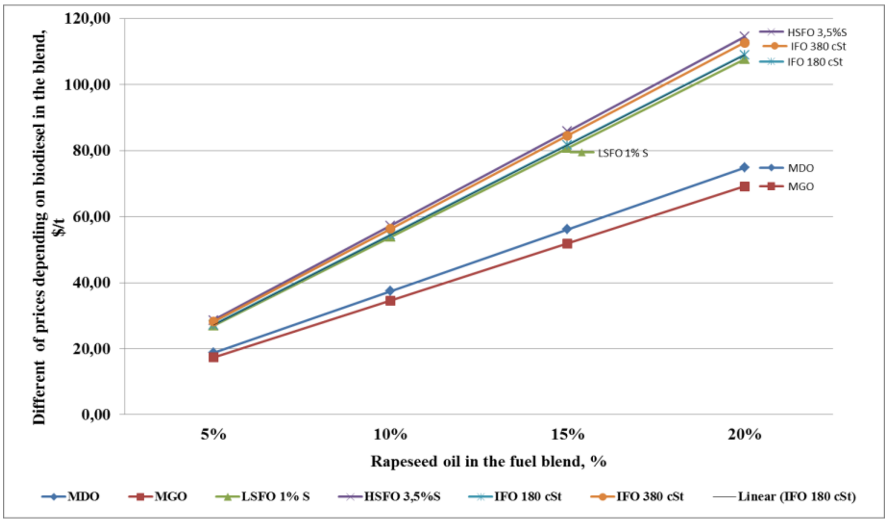

Fig. 2. Increasing of marine fuel prices depending on biodiesel in the blend , $/t

2 pav. Laivų kuro kainų padidėjimas, priklausomai nuo biodyzelino kiekio mišinyje, $/t

Calculations which had been done prospectively to year 2035 shows that changing from MDO to biodiesel fuel expenses will double until the new (second and third) generation of biofuel will be used.

Current situation in marine biofuels market could change if the base of raw materials production will be successfully expanded. That could be achieved if energetic algae growth (aquaculture) and processing technology will be mastered [25, 26].

However these forecast are not very reliable, as we can from price jump and drop in 2008 and 2009. Considering the fact that RME prices depends more on technological progress rather than on varying conjuncture of raw material prices there is a reason to believe that conjunctural price increases may not be so strong.

For all these reasons consumption of biofuel in transport sector usually doesn't exceed nominal amount set in the EU directive. This circumstance is especially important in marine transport sector where fuel consumption usually compose 30 – 40% of total ship exploitation cost.

The increasing production and availability in the market of the second-generation biofuel could improve economic reasons (reduce biofuels price) and open possibilities widespread use biofuels in marine transport sector.

Conclusions

Marine transport is a very important sector of world economy, which consumes 300 – 400 Mt of fuels that makes up 12 – 15% of total global transport consumption yearly. According to global trends marine sector is also searching for possibilities to replace part of petroleum fuels with biofuels made from renewable sources.

It`s well known that chemically converted (esterified) plant oils and animal fats by their chemotological properties are very close to diesel fuel and in little quantities mixed into diesel fuel (5%) can be used in any diesel engines with no technical alteration.

Slow and medium speed powerful marine engines can use raw biofuel (vegetable oils and animal fats) mixed with heavy fuel oil without any difficulties.

The possibilities to use biofuels in marine diesels were convincingly demonstrated in created modified industrial and marine applications that work on biofuels (MAN, Wartsila and etc.)

The main barriers for wider use of biofuels in maritime transport currently and in the near future is 20-50% higher price in comparison with fossil fuel and lack of biofuel supply and bunkering infrastructure in EU and Baltic Sea ports.

Biofuel perspectives in maritime transport can be changed radically by uptake of the next generation raw materials (algae) and the EU and IMO consistent tightening of requirements to reduce greenhouse gas emissions in the maritime transport sector.

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БИОДИЗЕЛЬ КАК АЛЬТЕРНАТИВНОЕ ТОПЛИВО ДЛЯ МОРСКОГО ТРАНСПОРТА

Аннотация

Биодизель, как альтернатива нефти в секторе транспортной энергетики, уменьшает нежелательную зависимость от невозобновляемого, постоянно дорожающего ископаемого сырья и смягчает неблагоприятные воздействия морского транспорта на окружающую среду, в первую очередь – эмиссию тепличных газов (CO_2,CH_4) и твердых частиц (ТЧ). Учитывая это, ЕС и некоторые другие страны (например, США) разработали и осуществляют национальные программы, предназначенные для расширения объемов применения биотоплив не только на сухопутном, но и на морском транспорте.

Известно, что химически конвертированные (эстерифицированные) растительные и животные жиры, по нескольким основным химотологическим и экологическим показателям не уступают, а в отдельных случаях и превосходят нефтяные топлива. Важнейшие из них – более высокое (51–56) цетановое число, меньшая возгораемость, более легкая биодеградация в природных условиях, значительно меньшая эмиссия

продуктов неполного сгорания (CO, CH, ТЧ) и естественная нейтрализация тепличных газов в процессе выращивания сырья.

Исследования также показали, что и неконвертированные растительные масла тоже имеют хорошие перспективы в морском транспорте как альтернатива тяжелому топливу (HFO), используемому на мало- и среднеоборотных судовых дизелях большой мощности.

Альтернативное топливо биологического происхождения имеет и недостатки, требующие соответствующих компенсаций. Среди них более важные: меньшая на 5-10% массовая и объемная теплотворная способность, большая вязкость, меньшая химическая стабильность в условиях длительного хранения и нежелательные термохимические конверсии в системах топливоподачи судовых дизелей.

Однако больше всего применение биотоплив на морском транспорте тормозят экономические факторы и конъюнктурные проблемы. В настоящее время и в обозримой (10–15 лет) перспективе цена биотоплива будет на 20-50% превышать цену нефтяного топлива и с трудом сможет конкурировать с ним. Сильно мешает также недостаток надежной нормативной базы для легализации использования биотоплив на морских судах и отсутствие системы снабжения и бункерования судов биотопливом.

Из-за указанных обстоятельств морские суда, способные работать на биотопливе (MAN, Wartsila) в ЕС пока следует рассматривать лишь как экспериментальные образцы, по экономическим показателям неспособные конкурировать с аналогичными судами, работающими на нефтяном топливе. Однако природоохранная политика ЕС и ММО (IMO), особенно ограничение эмиссии тепличных газов, увеличивает интерес к биотопливу и делает актуальным поиски больших возможностей внедрения его в морском транспорте.

*Биотопливо, марской транспортt,возмо*жности и проблемы использования *биотоплив.*

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BIODYZELIS KAIP ALTERNATYVUS KURAS JŪRŲ TRANSPORTUI

Reziumė

Biokuras, kaip alternatyva naftos kurui jūrų transporto sektoriaus energetikoje, mažina nepageidautiną priklausomybę nuo neatsinaujinančių, nuolat brangstančių iškastinių žaliavų ir švelnina neigiamus jūrų transporto poveikius aplinkai, visų pirma – šiltnamio dujų ir kietųjų dalelių (KD) emisiją. Atsižvelgiant į tai, ES ir kai kurios kitos šalys (pvz. JAV) parengė ir realizuoja programas, skirtas biokuro panaudojimo plėtrai ne tik sausumos, bet ir jūrų transporte.

Yra nustatyta, kad chemiškai konvertuoti (esterifikuoti) augaliniai ir gyvuliniai riebalai pagal keletą pagrindinių chemotologinių ir ekologinių rodiklių nenusileidžia, o atskirais atvejais ir pranašesni, negu naftos kuras. Svarbiausi iš jų yra aukštesnis cetano skaičius, mažesnis gaisringumas, geresnis gebėjimas biodegraduoti gamtinėje aplinkoje, žymiai mažesnė nevisiško degimo produktų (KD, CO, CH) ir žaliavų augimo stadijoje natūraliai neutralizuojama šiltnamio dujų emisija.

Tyrimai taip pat parodė, kad ir nekonvertuoti, žaliaviniai augaliniai aliejai turi geras perspektyvas jūrų transporte kaip alternatyva sunkiajam kurui (HFO), naudojamam mažų ir vidutinių apsukų didelės galios laivų dyzeliuose.

Biologinės kilmės alternatyvus kuras turi ir trūkumų, kuriuos tenka vienaip ar kitaip kompensuoti. Tarp jų svarbiausi: mažesnis 5 – 10% tūrinis bei masinis šilumingumas, didesnis klampis, mažesnis cheminis stabilumas ilgalaikio saugojimo metu ir nepageidautinos termocheminės konversijos laivų variklių kuro padavimo sistemose.

Tačiau biokuro panaudojimą laivuose daugiausia stabdo ekonominiai faktoriai ir konjunktūrinės problemos. Šiuo metu ir įžvelgiamoje 10–15 metų perspektyvoje, biokuro kaina 20–50 % viršija naftos kuro kainą ir nelengvai gali su juo konkuruoti. Labai trukdo taip pat organizaciniai ir konjunktūriniai klausimai: nėra tvirtos teisinės bazės biokuro panaudojimo įteisinimui jūrų laivuose ir nesukurta jūrinio biokuro tiekimo ir bunkeravimo sistema.

Dėl šių aplinkybių biokuro panaudojimas ES laivuose šiuo metu sutinkamas tik išskirtiniais atvejais (Wartsila, MAN) ir turi labiau eksperimento, negu praktinio pritaikymo charakterį. Tačiau ES ir IMO aplinkosaugos politika, ypač šiltnamio dujų emisijos ribojimas didina interesą šiam kurui ir skatina ieškoti daugiau galimybių įdiegti jį jūrų transporte.

Biodegalai, jūrų transportas,biodegalų naudojimo galimybės ir problemos.