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Comparative Analysis of Ship Lighting Systems in Terms of Economic, Environmental and Material Performance

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The uses of energy-efficient light sources on the shipboards play a significant role in the today's maritime sector. In this paper the performance of the lighting system of the bulk carrier ship named "M/V Ince Anadolu" is examined. In the case study the use of light emitting diode (LED) lamps on the shipboard instead of the existing lighting system is proposed. The existing lighting and LED lighting systems of the ship are compared in terms of economic, environmental and material performance. The results show that the energy-efficient lighting system on the shipboards decreases the operating costs, the fuel consumption and the exhaust emissions compared to the traditional lighting systems. The proposed lighting system provides a higher strength of light bulbs, required in the difficult sea conditions, due to better material specifications.

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1. Introduction

Energy efficiency has become the hot topic due to the economic and environmental factors in all sectors. The use of energy-efficient lighting systems on the shipboards can provide an important energy saving for the maritime sector.

There are numerous studies about different light systems in the literature. Uddin et al. [1] investigated power quality and effect of voltage sags on the light emitting diodes (LEDs) in terms of technical issues. Aman et al. [2] analyzed the performance of domestic lighting based on incandescent lamps (ILs), fluorescent lights (FLs), compact fluorescent lamps (CFLs) and LEDs. Gan et al. [3] examined the electrical and photometric performance of LEDs and FLs. Kim et al. [4] investigated the nonhydrolytic sol-gel condensation and oligosiloxane-based hybrid material (phenyl hybrimer) with useful properties for LED encapsulation. Woo et al. [5] examined a new nanocomposite mixture of a CdSe/CdS/ZnS red quantum dots, Sr2SiO4:Eu green phosphor and silicone resin for light conversion in a white LED.

Only a few researchers in the literature have focused on the saving potentials of the lighting system on ships. Su et al. [6] suggested the performance assessment model for energy-saving lighting equipment on ships. Mills et al. [7] investigated the technical and economic value of replacing the kerosene lanterns with LED equipment for night fishing.

In this study it is suggested to replace all existing traditional lamps on the shipboard with the LEDs. The existing lighting system and the LED system are compared with each other in terms of the energy efficiency. Fuel consumption, major exhaust emissions, energy cost, and material specification for both considered ship lighting systems are also compared.

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2. Data collection and methodology

The main goal of collecting data is to make a better assessment and to present a more reliable comparison for the use of existing and LED lighting systems. In order to make a real calculation, the real data of "M/V Ince Anadolu" bulk carrier ship is used in the analyzed. The annual average marine fuel prices of IFO 380 are taken from Bunker Index data for the year of 2015 [8]. Mean emission factors of AEs in a ship are also taken from the Entec UK Limited data, based on the bulk carrier ships at sea modes [9]. The unit energy costs of marine fuel oils are calculated according to data for the ship and the Bunker Index. This approach is considered to be realistic for the estimation of electrical energy production.

Generally, three types of the lamps have been installed in the "M/V Ince Anadolu" bulk carrier ship. These are tubular FLs, ILs, and mercury flood lights (MFLs). FLs are used for wall lights, mirror lights, berth lights, desk lamps, ceiling and corner lights and their power consumption varies between 10, 15, and 20 W. ILs are used for navigation light, signal light, pendant light, down light, spot light, wall light and for ceiling light, and their power varies between 40, 60, and 100 W. MFLs are used for gangway light, cargo light, boat deck light, and their capacity varies between 300, 400, 500, and 700 W.

3. Case study

In order to make a performance analysis, the replacement of all existing lamps (FLs, ILs, and MFLs) on the shipboard with the LEDs is considered in the case study. The existing lighting system and the LED lighting scenario are compared with each other in terms of the operational cost, energy consumption, exhaust emission and features of the lighting system materials.

TABLE I

Comparison of the light sources for the existing and alternative lighting systems

Existing lighting system				LED lighting system		
Lamp image	Lamp type	Power [W]	System power [W]	Lamp image	Lamp type	System power [W]
	FL	10	20		LED tube	6
		15	25			10
		20	30			15
	IL	40	40		LED bulb	8
		60	60			13
		100	100			20
	MFL	300	340		LED projector	120
		400	450			200
		500	550			200
		700	775			400

The LEDs which are planned to be installed instead of the existing lighting sources are selected from the literature and are shown in Table I. The LED lamps show features similar to traditional lamps in terms of lumens and are able to provide the same or better brightness on the shipboard, while their power consumption can improve the energy efficiency.

4. Results and discussion

The electrical energy consumption, fuel consumption, lighting cost and exhaust emission of existing and LED lighting systems of the ship are calculated and are given in Table II.

As it can be seen from Table II, the installed lighting capacity is 44.1 kW. The corresponding consumption of electrical energy is 214868 kWh/year, consumption of marine fuel is 49.8 ton/year, and electrical energy cost is 16505 USD/year for the existing lighting system. The CO_2, NO_x, SO_2, and PM emissions from the lighting system of ship are 134.72 ton/year, 3.42 ton/year, 2.28 ton/year, and 0.35 ton/year, respectively.

If LED lighting system is applied on the shipboard, the installed lighting capacity, electrical energy consumption, fuel consumption, and energy cost of lighting system could be 17.9 kW, 100810 kWh/year, 24.3 ton/year, and 7744 USD/year, respectively. The CO_2, NO_x, SO_2, and PM emissions from the lighting system of ship would be 63.21 ton/year, 1.60 ton/year, 1.07 ton/year, and 0.16 ton/year, respectively.

It means that if LED lighting system is applied on the shipboard, the lighting system capacity, electrical energy consumption, fuel consumption, and lighting cost can be decreased by 26.2 kW, 114058 kWh/year, 26.4 ton/year, and 8761 USD/year respectively. The CO_2, NO_x, SO_2, and PM emissions can also be reduced by 0.07 ton/year, 1.81 ton/year, 1.21 ton/year, and 0.18 ton/year, respectively.

When considering the material characteristics, ILs contain lower amounts of materials than CFLs and LEDs, except for nickel and tungsten. The CFLs have significant levels of antimony, copper, iron, lead, mercury, phosphorus, yttrium, and zinc. The LEDs have also antimony, copper, aluminum, iron, lead, phosphorus, zinc, barium, chromium, gallium, gold, and silver, according to US federal regulation (Toxicity Characteristics Leaching Procedure) and California state regulation (Total Threshold Limiting Concentrations) [10].

TABLE II

Comparison of the energy consumption, economic, and environmental factors of the lighting systems

Lighting systems	Lamp type	System power [kW]	Electrical energy consumption [kWh/year]	Fuel consumption [ton/year]	Lighting cost [USD/year]	Exhaust emissions from lighting [ton/year]			
						CO_2	NO_x	SO_2	PM
Existing lighting	FL	16.6	119 674	27.8	9 193	75.04	1.90	1.27	0.19
	IL	6.1	5 160	1.2	396	3.24	0.08	0.05	0.01
	MFL	21.3	90 034	20.9	6 916	56.45	1.43	0.95	0.14
	Total	44.1	214 868	49.8	16 505	134.72	3.42	2.28	0.35
LED lighting	LED	17.9	100 810	23.4	7 744	63.21	1.60	1.07	0.16

As it can be seen from the literature, LEDs involve materials with different properties and different products to meet various requirements of lighting. The high diffusion and transmission materials are desired for the ambient lighting. The glass globe in LEDs is manufactured from soda-lime glass and it can contain silca and a thin coating of clay in the inner surface of the glass. The plastic parts are usually made of polybutylene-terephthalate or polyethylene-terephthalate with fire retardant plastic. Their bases are commonly of nickel-plated brass. These materials would not present a significant hazard in the event of breakage of the lamps due to their insolubility and inertness [11]. The LED parts with complex geometries can be designed and manufactured with transparent polycarbonate. It provides better stability and higher purity than the standard grades. The use of highly reflecting materials increase the brightness and total reflection values up to 96%. The thermal conductive materials have an important role in the heat management in LEDs. The thermoplastic materials, which have suitable thermal conductivity can be used for solving the heating problems [12].

5. Conclusions

In this study a comparative analysis of ship lighting systems has been carried out considering economic, environmental and material performance. The real data of a bulk carrier ship is used for the analysis. This study shows that the energy-efficient light sources provide remarkable advantages in comparison with the traditional light sources of ships. The lighting system power capacity, marine fuel consumption, and lighting cost can be reduced by about 65%, 59.4%, and 53% of the existing system, respectively. The CO_2, NO_x, SO_2, and PM emissions can also be decreased by 53% by more efficient lighting.

The new technologies will also increase the strength of light bulbs in terms of material performance, required in the changeable sea conditions, compared to the traditional lighting system of the ships. Today ship owners should invest in the new technologies to meet the maritime regulations. The use of the LED lighting on the ships will contribute to the sustainability of maritime sector. In this way, a significant decreases in energy consumption, environmental pollution, and operational cost can be achieved. The significant hazard of lighting systems can also be avoided with LED lighting due to more efficient materials of the LED lamps.

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