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Research Paper

Energy efficiency in fishing: Are magnetic devices useful for use in fishing vessels?

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HIGHLIGHTS

- Three magnetic devices were studied to see their validity for marine diesel engines.
- Engine performances were monitored, *with* and *without* the use of magnetic devices.
- Tests were carried out on a test bench and complemented by sea trials. Fuel consumption was monitored continuously under commercial fishing activity.
- Magnetic devices provided less fuel efficiency than anticipated by the manufacturers.

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ABSTRACT

Sustainability is one of the main challenges of commercial fishing. Fuel represents almost 40% of the total cost of a fishing vessel. The increase in the price of fuel over the last decade, together with the volatility and fluctuation in the price for a barrel of crude oil, makes fuel costs one of the main concerns of ship-owners. As a response, different initiatives have been undertaken, with the aim to reduce such fuel dependency. The present contribution presents the feasibility study of the use of different magnetic devices for fuel treatment, in order to improve the energy efficiency of fishing vessels and reduce exhaust emissions. According to manufacturers, fuel treatment devices provide three effects: reduction in fuel consumption; reduction in exhaust gas emissions; and improvement of engine performance by reducing maintenance costs. Three independent magnetic devices have been mounted and tested on three different 4 stroke compression ignition diesel engines. The first device was tested in an engine located on a test bench; it was operated under controlled laboratory conditions. The second, installed on board a trawler fishing vessel operating in the Mediterranean Sea; and the third, on board a representative vessel of the trolling fishing fleet operating in the Bay of Biscay and Atlantic Ocean. In all cases, the potential fuel-saving (~2%) and exhaust gas emissions (~0.6%) reduction was lower than expected by manufacturers. The aim of this contribution is to provide ship-owners with scientific knowledge to make informed decisions, when investing in energy-saving technologies.

1. Introduction

Commercial fishing is presently facing economic, social and environmental challenges, which are forcing the fishing sector to evolve towards an energy-efficient, low emission and sustainable activity. There are different technologies on the market to reduce fuel consumption and exhaust emissions of fishing [1,2]. Some require the direct input of the user to act on fuel consumption i.e. slow steaming [3]; others provide saving without any user's input, such as the use a low drag gear, e.g. use of pelagic otter boards [4,5], or low drag net materials [6]. Within the latter group, fuel conditioning devices have become of great interest as a possible and viable solution to increase the overall efficiency of the propulsion system of a fishing vessel, by acting on the main engine [7,8].

The use of magnetic devices in engines is well-known and has been studied already. The influence of magnetism on the combustion of fuels has been known since 1846, when Faraday noticed that a flame, burning under the influence of a magnetic field, was brighter

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than in the absence of the same field. However, the first attempts started before the World War II, as part of the armament strategy to eliminate smoke waft; as a beneficial side effect, a reduction of fuel consumption was noted [9]. During the last decade, many studies have been undertaken to verify the effects of magnetism on fuel consumption. There are recent examples of the benefits of fuel conditioners such as: magnetic [10–14] and air [15,16] energisers for internal combustion engines; or fuel additives in coal-fired power station. Likewise, studies on the effect of magnetic field on fuel viscosity have been carried out [17].

According to descriptions and specification sheets from manufacturers, a magnetic fuel device provides three effects: (1) reduces the fuel consumption; (2) reduces exhaust gas emissions, i.e. CO, CO_2, NO_x, SO_2, and black carbon; and (3) improves engine performance, by reducing its maintenance cost and increasing the life span of the lube oil. Magnetising fuel consists of aligning the hydrocarbon molecules; this, which provokes the de-clustering of such molecules, by forming smaller associates with higher specific surface for the reaction with oxygen. Such an approach leads to: improvement in the combustion, such as more complete and rapid combustion and burns more rapidly; and an increase in the mechanical efficiency of an internal combustion engine, thus decreasing the fuel consumption. Although the reduction of CO_2 equivalent emissions can be directly associated to the fuel consumption by a conversion factor (3.206 tn CO_2/tn diesel) [18], when the combustion procedure is improved, the emissions of carbon particles, CO, CO_2 and hydrocarbons are expected to decrease [10].

Magnetic devices have become popular lately in the fishing sector, due to their low purchasing cost and the potential energy-savings that can be obtained (according to the manufacturers). However, the results have yet to be proven empirically.

Ship-owners have begun to approach research institutions to investigate the benefits of some energy-saving devices, in order to decide whether to invest in such technologies or not [19]. All of the queries seek a common goal: proven evidence. On the basis of this requirement, AZTI (Spain) and CNR-ISMAR (Italy) have been contacted by numerous fishing ship-owners and magnetic devices manufacturers in recent years enquiring about the validity of such devices. To address this problem, highlight real potentials of such technology, and assist the fishing industry to decarbonising its fleet in an efficient manner, this contribution shows the results of the three independent research studies that assess the performance of three magnetic devices to provide such proven evidence: one installed in an engine, located in a laboratory; and two in engines of commercial fishing vessels. Likewise, it proposes a methodology to assess the gains in the use of such devices, for fishing vessels in operation. Despite tests carried out under controlled conditions in a laboratory are the most precise approach to test and describe benefits and constrains of a technology, testing it in real conditions on board commercial fishing vessels provides qualitative information to definitely assess their suitability from a technical and economical perspective. Hence, results obtained from commercial fishing vessels are seen as indications that complement the more rigorous results obtained in the test-bench.

2. Materials and methods

2.1. Estimation of fuel consumption

The performances of three independent magnetic devices were studied in order to assess the suitability of their use in medium-speed marine diesel engine. Device n° 1 was installed in a land-based engine test bench. In contrast, device n° 2 was installed in Vessel 1, which is representative of the trawler fleet operating in the Mediterranean Sea; and device n° 3 was installed in Vessel 2, a typical trolling vessel operating in the Bay of Biscay. The main characteristics of the magnetic devices, engine details and fuel monitoring are reported in Table 1; Fig. 1 shows their location in the vessels.

The first device was installed on an engine test bench at the School of Nautical and Naval Machines, Spain. The test bench is assisted of a compression ignition (CI) engine, PERKINS P60P1 (60 kVA at 1.500 rpm), coupled to an alternator (genset). Tests were undertaken *with* and *without* the magnetic device installed. The engine was submitted to 7 operational conditions ("operation points") and its performance was noted. The electrical demand was related to three resistance and air fans, for heating (7–14 kW). The theoretical operation points were elected according to the electrical load, i.e. 0.0 kW, 7.0 kW, 14.0 kW, 21.0 kW, 28.0 kW, 35.0 kW and 42.0 kW. Engine performance was monitored continuously by a DEWE 2600 high-frequency acquisition system. The protocol and further details are presented elsewhere [21]. Monitoring commenced only when monitored parameters where stabilised. At each operational point, fuel consumption (l/h), engine speed (rpm), and power consumption (kW) among other parameters (such as engine performance

Table 1
Details of the magnetic devices, engine details and engine monitoring used on the research study.

Detail	Device n° 1	Device n° 2	Device n° 3
Magnetic device	Confidential	Droptek	Confidential
Expected saving[a]	10–15%	5%	5–10%[b]
Source of magnetic field	Electric coils	Electromagnets	Magnets
Powered by	24 V_{DC}	24 V_{DC}	No power supply is needed.
Location of engine	Test bench (Spain)	Vessel 1 (Italy)	Vessel 2 (Spain)
Engine made	Perkins	Mitsubishi	Cummins
Engine power (kW)	48	478	493
Engine speed (rpm)	1500	1600	1800
N° cylinders	4	6	12
Installation location (see Fig. 1)	In series in the fuel circuit, at the fuel inlet, before the injection pump.	In the nearest point to the engine, before the inlet pump.	In series in the fuel circuit, at the fuel inlet, before the injection pump.
Fuel monitoring system	Mass consumption measure by high precision load cell connected to DEWE 2600	CorFu-m system[c]	GESTOIL[d]
Methodology used for fuel monitoring.	Seven operational conditions. Performance monitored for 30 minutes at each condition	Continuous monitoring	Continuous monitoring and sea trials
Indicator used for comparison	g/kW_e·h	l/h	l/h
Emission monitoring	TESTO 350XL MARITIME	TESTO s.p.a	–
Maintenance checked	No	Yes	No

[a] Expected saving values according to the manufacturers.
[b] Effect is noticed after a minimum of one month engine operation.
[c] Further explained in Sala et al. [20].
[d] Further explained in Basurko et al. [3].