Energy Conversion and Management 117 (2016) 548–557

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Performance, emissions and lubricant oil analysis of diesel engine running on emulsion fuel

A.K. Hasannuddin [a], J.Y. Wira [a,*], S. Sarah [a], W.M.N. Wan Syaidatul Aqma [b], A.R. Abdul Hadi [a], N. Hirofumi [c], S.A. Aizam [a], M.A.B. Aiman [a], S. Watanabe [a], M.I. Ahmad [a], M.A. Azrin [a]

[a] Vehicle System Engineering, Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Jalan Semarak, 54100 Kuala Lumpur, Malaysia
[b] School of Biosciences & Biotechnology, Faculty of Science & Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[c] Mechanical Engineering, Maizuru National College of Technology, 234 Aza Shiroya, Maizuru, Kyoto 625-8511, Japan

ARTICLE INFO

Article history:
Received 11 November 2015
Received in revised form 16 March 2016
Accepted 19 March 2016

Keywords:
Emulsion fuel
Lubricant oil
Diesel engine
Durability test

ABSTRACT

Emulsion fuel is one of the alternative fuels for diesel engines which are well-known for simultaneous reduction of Particulate Matter (PM) and Nitrogen Oxides (NO_x) emissions. However lack of studies have been conducted to investigate the effect of emulsion fuel usage for long run. Therefore, this study aims to investigate the effect of lubricant oil in diesel engine that operated using emulsion fuels for 200 h in comparison with Malaysian conventional diesel fuel (D2). Two emulsion fuels were used in the experiment comprising of water, low grade diesel fuel and surfactant; with ratio of 10:89:1 v/v% (E10) and 20:79:1 v/v% (E20). Engine tests were focused on fuel consumption, NO_x, PM, Carbon Monoxide (CO), Carbon Dioxide (CO_2), Oxygen (O_2) and exhaust temperature. Parameters for the lubricant oil analysis measured were included kinematic viscosity, Total Acid Number (TAN), ash, water content, flash point, soot, wear metals and additive elements. The findings showed the fuel consumption were up to 33.33% (including water) and lower 9.57% (without water) using emulsion. The NO_x and PM were reduced by 51% and 14% respectively by using emulsion fuel. Kinematic viscosity, TAN, ash, water content, flash point and soot for emulsion fuel were observed to be better or no changes in comparison to D2. The emulsion fuel did not cause any excessive amount of metals or degraded the additive. The average percentage of wear debris concentration reduction by emulsion fuel were 8.2%, 9.1%, 16.3% and 21.0% for Iron (Fe) Aluminum (Al), Copper (Cu) and Lead (Pb) as compared to D2 respectively.

1. Introduction

Energy is a key factor in the economic and social development for any country and the citizen. Currently, most of the energy comes from fossil sources, which are non-renewable and impose a negative effect on the environment (e.g. greenhouse gases damaging the ozone). The increasing of greenhouse gas emissions have contributed to an unstable climate and nature [1]. Unpredictable climate change is one of the most serious problems faced nowadays. In addition, the burning of fossil fuels, such as oil, gas and coal have led to 75% of the total world's energy usage [2]. At present, diesel engines are the most efficient internal combustion engines for transportation and industrial activities. This is due to their efficient fuel-to-energy conversion rate, durability and heavy-duty application. However, diesel engines suffered from Particulate Matters (PM) and Nitrogen Oxides (NO_x) emissions [3]. Emissions from diesel engines significantly contribute to the greenhouse effect, acid rain, ozone layer destruction and the decline in human health especially respiratory problem [4]. Newer stringent emission standards have motivated researchers to invent new ideas and solutions to reduce emissions without compromising engine efficiency.

A well-known in-cylinder method for reducing the NO_x production rate is emulsion fuel [5,6]. An emulsion can be defined as a combination of two-different fluids that will not physically mix but one part will stay suspended in another [7]. The emulsion fuels droplets are relatively smaller due to micro-explosions therefore allowing a complete burning to occur. The micro-explosions would cause the smaller fuel particles to be in contact easily with the air for complete combustion and reduce the PM generation without failing the combustion efficiency [8]. In diesel engines, some of the components are involved with the wearing process, such as the piston, piston ring, cylinder liner, bearing, crankshaft, cam, tappet, and valves. Therefore, the lubricant oil quality is essential to

* Corresponding author.
E-mail address: wira@utm.my (J.Y. Wira).

http://dx.doi.org/10.1016/j.enconman.2016.03.057
0196-8904/

ensure-good operation of the engines [12]. The lubricant oil provides the mechanical strength, maintains the cleanliness of the engine, reduces the friction and wears of the moving parts, removes particles, as well as protects the engine against oxidation and corrosion [13].

Water can contaminate the lubricant from leakage through weak seals and moisture from ambient sources (including the combustion and condensation in the engines) [14]. Lubricants are also susceptible to oxidation which leads to the formation of low-molecular weight materials, such as aldehydes, ketones, acids and alcohols during the start of lubricant degradation processes [15]. As emulsion fuel application is yet to be established data on engine durability tests on emulsion fuels were still limited [9,10]. Kawasaki Heavy Industries Ltd. had conducted a pre-operation testing for their ships to run on heavy emulsion fuel in July 2010 to evaluate the level of emission and engine performance. Due to the success of the pre-operation testing, implementation was made in January 2011 and the fuel has been used until today [11]. However, there are no details study on lubricant oil parameter such as kinematic viscosity, Total Acid Number (TAN), ash, water content, flash point, soot, wear metals and additive elements. Further

Table 1
Tested fuel characteristic.

Properties	Unit	D2	E10	E20
Calorific value	MJ/kg	45.28	40.76	36.24
Cloud point	°C	18	NA	NA
Density	kg/L	0.854	0.869	0.878
Total sulfur	mass%	0.28	0.25	0.21
Viscosity	cSt	4.64	5.12	5.84
Distillation temperature, 90% recovery	°C	368	NA	NA
Flash point	°C	93	NA	NA
Pour point	°C	12	NA	NA
Cetane number	–	54.6	NA	NA
Carbon	wt%	84	75	67
Hydrogen	wt%	12.8	11.7	11.1
Sulfur	wt%	0.2	0.18	0.15
Nitrogen	wt%	<0.1	<0.1	<0.1
Oxygen	wt%	3.9	3.6	3.4

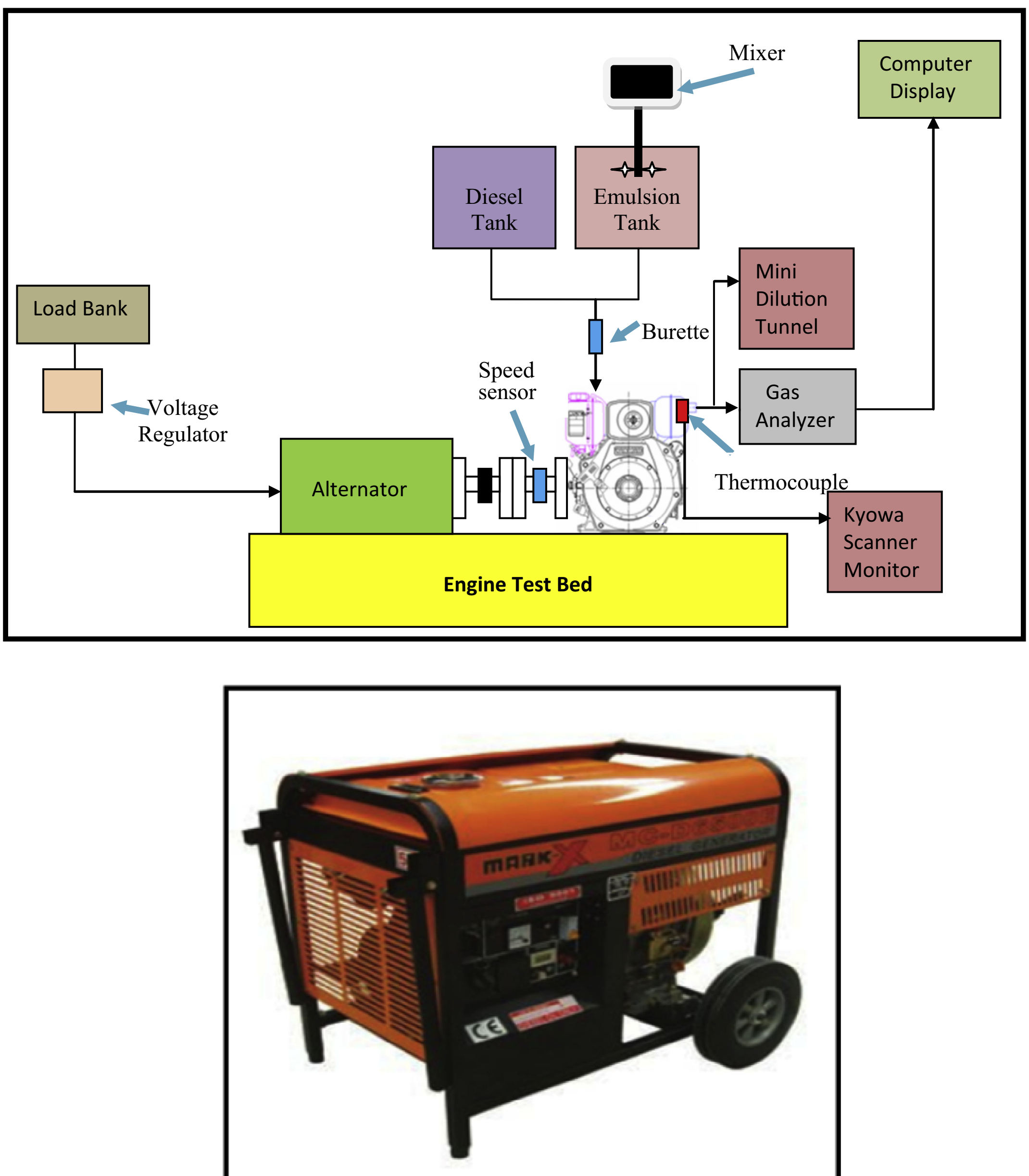

Fig. 1. Schematic diagram of the emission test setup and engine used.