An experimental study on effect of sulfur contents in fuel oil on particulate emission emitted from marine diesel engine

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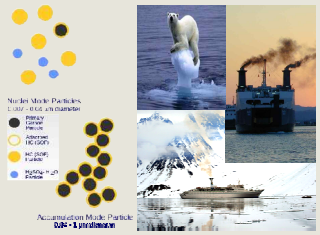
Introduction

Backgrounds

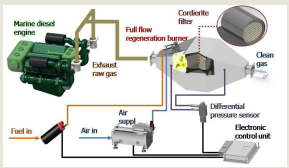
The main emissions from ships are nitrogen oxides (NOx), sulfur oxides (SOx) and particulate emission, which are restricted by international maritime organization (IMO) regulations. Among these emissions, particulate emission emitted from ships was indirectly regulated by limit for sulfur contents of fuel oil. Recently, IMO is considering to adapt regulation to reduce particulate emission. This seems to be related to ice melting in arctic region with establishment of northern sea route and more stringent emission regulations.



Route	Suez	NSR	Saving (%)
Rotterdam-Yokohama	12,894	8,452	34.45
Rotterdam-Shanghai	12,107	9,297	23.2
Rotterdam-Vancouver	10,262	8,032	21.67

Goal of this study

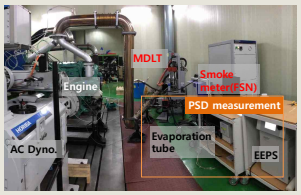
This study can give an information for developing after-treatment system and establishing of combustion strategy for emission abatement.

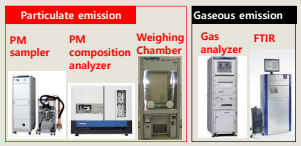


Experiment

A four stroke marine diesel engine for fishing trawler, tug boat and ferry was used for the engine bench tests. This engine equipped with intercooled turbocharger. It was coupled to an AC dynamometer(HD460, Horiba) to control engine speed and torque.

Experimental setup





Item	Specifications
Engine type	4 stroke, DI, TC
Rating output [kW/rpm]	403/1,800
Displacement [cc]	14,618
Cyl. number- bore x stroke [mm]	8 - 128 x 142
Compression ratio	14.3 : 1
Fuel consumption [Lit / h]	97

Fuel properties

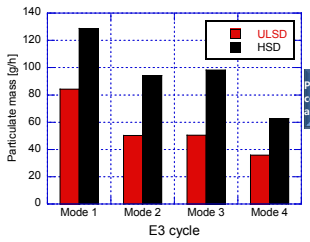
Property	Units	ULSD	HSD	Method
Cetane Index	Rating	55.0	46.7	ISO 4264
Density (@ 15℃)	kg/L	0.8280	0.8612	ISO 12185
Kin. vis. (@ 40℃)	mm²/s	2.624	3.349	ISO 3104
Ash Content	%(m/m)	0.001	0.002	ISO 6245
Sulfur	%(m/m)	<0.030	0.34	ISO 8754
Pour Point	℃	-21	-6	ISO 3016
Water Content	% (V/V)	0.00	0.00	ISO 3733

Experimental conditions

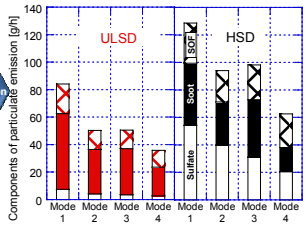
Test cycle				
Cycle	E3 cycle			
Power [%]	100	75	50	25
Speed [%]	100	91	80	63
Weighting Factor	0.2	0.5	0.15	0.15
4V158TIH				
Power [kW]	403	302	202	101
Speed [rpm]	1,800	1,638	1,440	1,134
Torque [N·m]	2,139	1,763	1,337	849
Mode	1	2	3	4

Experimental results

Particle mass concentration



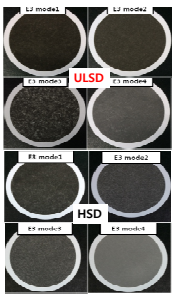
PM composition analysis

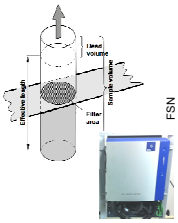


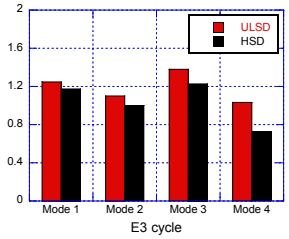
✓ Particle mass concentration for HSD was higher than that for ULSD under all operating conditions.

✓Sulfate composition for HSD had significantly higher portion than that for ULSD.

Filter smoke number

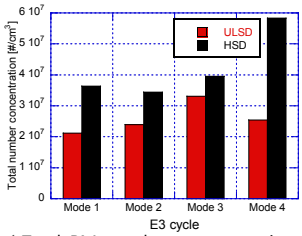


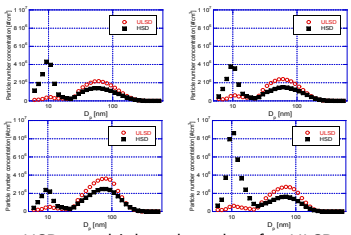




✓ FSN for HSD was slightly lower than that for ULSD. This result was inconsistency of PM mass and number concentration.

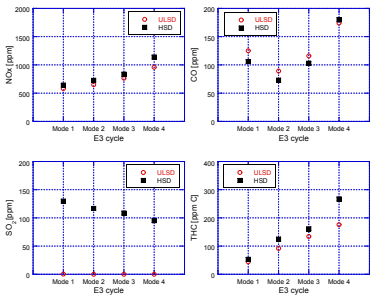
Particle number concentration





✓ Total PM number concentration for HSD was higher than that for ULSD. In case of high sulfur diesel fuel, nucleation mode particles(<50 nm) was significantly higher than accumulation mode particles.

Gaseous emission



In case of SO_2 emission,

✓ The significant difference of SOx emission measured by FTIR represented with fuel sulfur contents.

✓ The emission for HSD decreased with decrease of engine power(Mode 1 → 4) and this caused by the decrease of fuel consumption rate.

Summary

✓ PM mass concentration for high sulfur diesel was higher than that for ultra low sulfur diesel. Also, total PM number concentration for HSD was higher than that for ULSD. On the other hand, filter smoke number with fuel sulfur content was contrary to the tendency of other concentrations.

✓ Conclusively, comprehensive analysis of PM with various sulfur contents of fuel or alternative fuel is necessary for better characterization due to a possibility of inconsistency result with measurement method.

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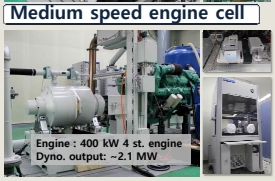
Low speed engine cell

High speed engine cell

Medium speed engine cell



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