VISUAL COMBUSTION STUDIES FOR ENVIRONMENTALLY-FRIENDLY MARINE DIESEL AND GAS ENGINES

ディノ マティアス イムホフ

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氏　　名：　Dino Matthias Imhof

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環境対応型舶用ディーゼル及びガスエンジンのための燃焼可視化研究

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論　文　内　容　の　要　旨

More than 90 % of world-wide cargo transportation is carried out by ships. Nowadays, a contradictory circumstance like tough exhaust emission regulations for ocean-going ships by IMO (International Maritime Organization under UN) and deterioration in quality of marine fuel force some challenges, the development of new emission reduction technologies as well as countermeasures for low quality fuels, in the side of marine industry. Furthermore, a change to another fuel, such as Liquefied Natural Gas (LNG), is conceivable. Hence, the development of adequate and efficient marine gas engines is required.

This paper describes fresh studies to promote the above-mentioned development applying the visual technologies of combustion proceeding in marine diesel and gas engine combustion chamber. This paper has six chapters.

Chapter 1 is “Introduction” and refers to the above-mentioned background of this study in more detail.

Chapter 2 is “Objectives and issues” and explains the purpose of this study being related to the background referred in Chapter 1.

Chapter 3 is “Experimental apparatus and technologies”. The author has designed a world largest class RCEM (Rapid Compression and Expansion Machine) that holds under 20 MPa cylinder pressure for this study. This RCEM has 200 mm wide windows at the both side of combustion chamber and single spray combustion can be observed with high-speed visualization. Furthermore, installing a 240 mm dia. round shaped window in the cylinder-head, multiple sprays combustion in the swirling air flow simulating real engines can be visualized.

RCEM is equipped with EFIs, Electronically-controlled Fuel Injection systems for not only diesel fuel injection (with injection pressure of 160 MPa) but also natural gas high pressure injection (GI) with 15-50 MPa.

Characteristics of diesel spray combustion, natural gas pre-mixed lean-burn and GI combustion are analyzed using not only direct photography but also several kinds of optical techniques, for example, “two-color method” to measure the combustion temperature distribution, “shadowgraph” to visualize non-luminous flame of the natural gas lean-burn, and “BDL, back diffused laser technique” to visualize soot particles formed in the flame.

Combustion analysis is also made by “rate of heat release” calculated from the measured cylinder pressure data. After the one shot burning of the fuel, all the combustion gas is sent from RCEM to a gas analyzer and harmful emissions like NOx, CO, and THC are measured.

Chapter 4 is “Experimental results on diesel engine combustion”. The author has tried to improve the poor combustion of “LCO, Light Cycle Oil” that represents the high aromatic fuel. The first trial is LCO-water emulsion that improves the long after-burning of LCO, however lengthens the ignition delay extremely. The second trial is “pilot injection” of small amount of LCO, that is injected earlier and ignites the LCO main spray. As a result, combination of these two ways leads to the mild and clean combustion of LCO.

The author has also tried to visualize the diesel spray combustion under the “EGR, Exhaust gas Re-circulation” atmosphere. EGR will be applied to clear the IMO Tier 3 NOx regulation, but deterioration of combustion under such a low oxygen air has not been verified till now.

Chapter 5 is “Experimental results on dual fuel type gas engine combustion”. At first, the author has tried to visualize the abnormal combustion that occurs in the lean-burn type gas engine, and has found the specific phenomena that existence of lubricating oil for piston-cylinder lubrication could be an origin of the abnormal combustion. It means that the lubricating oil particle that has entered into the combustion chamber ignites earlier than the pilot injection and causes “too-early pre ignition” of natural gas mixture.

As the second stage, the author has tried to visualize the GI combustion, and a big difference of combustion pattern between the above-mentioned lean-burn and GI is made clear. Abnormal combustion seen in the lean-burn would not occur by GI combustion. However, as GI combustion emits much higher NOx than the lean-burn, some measures like EGR is necessary when it must clear the Tier 3 NOx regulation. The GI combustion under EGR is also visualized and the way to reduce NOx with smaller EGR% is discussed.

Above-mentioned results are concluded in Chapter 6.