Comments and Report on the

<Nanobubble Modified Diesel Vehicle Emission Gas and Fuel Efficiency Performance Test >

Dec. 24. 2024.

FAWOO NANOTECH

Contents

1. Comments on the <Nanobubble Modified Diesel Vehicle Emission Gas and Fuel Efficiency Performance Test Report>

Dec. 24, 2024.   Fawoo Nanotech: Seokji Park, Ph.D.

a. Test Results

		HC(g/km)	CO(g/km)	NOx(g/km)	CO^2(g/km)	Fuel Efficiency (km/ℓ)
Base	#1	0.02	0.44	0.11	183.1	14.6
	#2	0.01	0.22	0.02	185.1	14.5
	average	0.02	0.33	0.06	184.1	14.6
Modified Diesel	#1	0.00	0.01	0.04	184.2	14.6
	#2	0.00	0.02	0.00	184.6	14.6
	average	0.00	0.02	0.02	184.4	14.6
% effect		-80.8%	-95.2%	-68.2%	0.2%	0.1%

b. <Comments>

(1) Emission gas: The average Lambda control shown through this exhaust gas test was approximately 3.5% higher (lean) than the base fuel when using reformed fuel. In particular, in the driving section where HC and CO were generated a lot (40 km/h cruise driving), the air-fuel ratio of the reformed fuel was lean, showing a dramatic reduction effect in HC, CO, etc.

In addition, there may be a problem with NOx removal when the air-fuel ratio is lean, but in the case of nanobubble diesel, the NOx removal effect was also significantly improved, which can be seen as the effect of oxygen inflow due to the supply effect of nanobubbles.

Therefore, the original emission standard EURO6 (CO 0.5, NOx 0.08, HC <0.1, particulate matter 0.0045) vehicle satisfies the EURO 7 (effective July 2025) standard (CO 0.5, NOx 0.06, HC 0.1, particulate matter 0.002).

(2) Fuel efficiency: The effect on fuel efficiency is not visible, so there is no significant difference in total fuel efficiency. Looking at the results of the fuel consumption rate analysis according to RPM, it shows that when nanobubble diesel is used, fuel efficiency is improved under high-speed, low-load conditions.

This is because the visible fuel efficiency effect cannot be compared to the fuel efficiency due to the recent improvement in engine performance of small diesel passenger cars, but it is expected that the effect will be visible in commercial cases such as large commercial diesel vehicles, agricultural vehicles, fishing boats, and boilers.

2. Report on the emission evaluation test of nanobubble modified diesel vehicles: Inha Technical College EMISSION LABORATORY

SUBMISSION

To. Fawoo Nanotech Co., Ltd.

This report is submitted as a test result report on the exhaust gas and fuel efficiency performance of “Nanobubble Modified Diesel Fuel” commissioned by Fawoo Nanotech Co., Ltd.,

Dec. 24. 2014,

Testing Manager: Prof. JongWoo Kim, Ph.D.
Department of Automotive Engineering
Faculty of Transportation Mechanical Engineering
Inha Technical College

1. Test Details

- Test Purpose

A chassis dynamometer test was conducted to evaluate the emission and fuel efficiency improvement effects of diesel fuel modified to contain oxygen using nanotubes developed by Fawoo Nanotech Co., Ltd.

- Testing day: 2024. 12. 19
- Testing lab.: Inha Technical College Emission Gas Testing Lab
- Test Vehicle : Corando 1.6 Diesel (EURO-6), 100k km aged
- Test Mode : KD 147 Mode hot start
- Test Equipment
  1) Chassis Dynamometer
  2) MAHA MET6.3 and CGA 4500 Emission Gas Analyzer
  3) OBD-2 Scan tool
- Test Methodology
  1) KD147 test in initial condition*
  2) Inject modified diesel fuel after fuel exchange/exhaust
  3) KD147 test after break-in*

*Analyzed as continuous data with guaranteed repeatability

Table 1. key Specifications of Test Vehicle

	Corando 1.6D 2WD
Engine Type	inline 4 cylinder
Fuel	Diesel
Engine Displacement	1,597cc
Max Power	136ps
Max Torque	33 kgf·m
Emission Rating	EURO-6

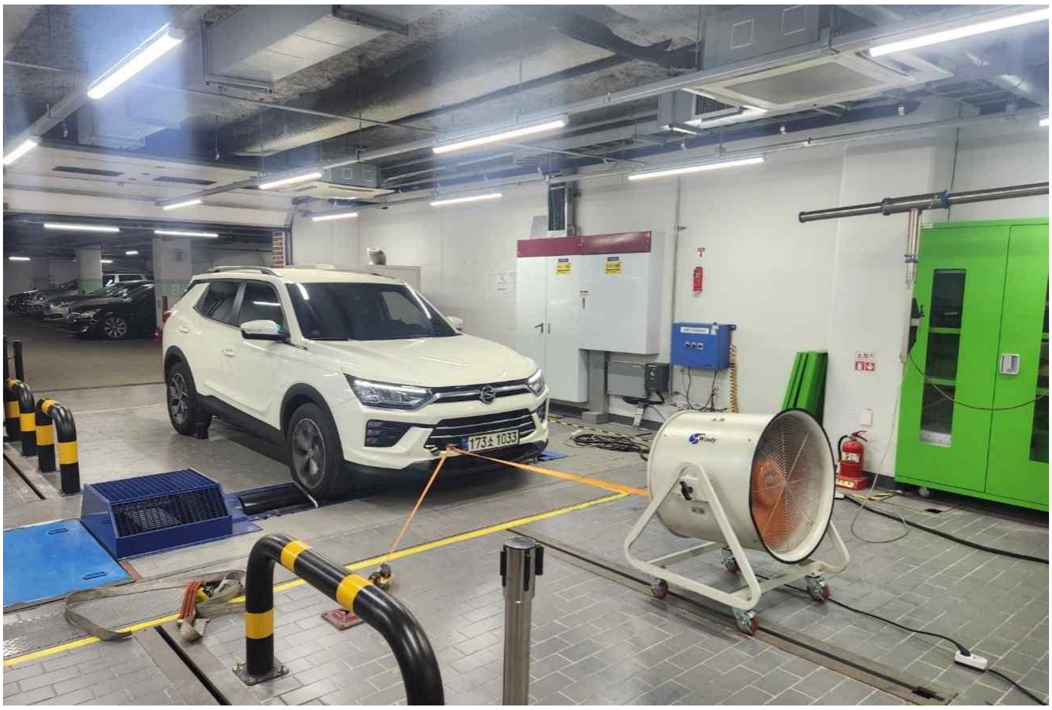


Fig 1: Test scene

2. Test Results

2-1 Emission/Fuel Efficiency

		HC (g/km)	CO (g/km)	NOx (g/km)	CO2 (g/km)	Fuel efficiency (km/l)
Base	#1	0.02	0.44	0.11	183.1	14.6
	#2	0.01	0.22	0.02	185.1	14.5
	average	0.02	0.33	0.06	184.1	14.6
Modified Diesel	#1	0.00	0.01	0.04	184.2	14.6
	#2	0.00	0.02	0.00	184.6	14.6
	average	0.00	0.02	0.02	184.4	14.6
% effect		-80.8%	-95.2%	-68.2%	0.2%	0.1%

3. Conclusions

1. Results of emission/fuel efficiency tests of diesel fuel modified using nanotubes,
   1) When using modified diesel fuel, the emission of legally regulated substances was reduced by 81% for HC, 95% for CO, and 68% for NOx compared to the base.
   2) In the case of smoke, it was not generated from the base itself or the modified fuel.
   3) The total change in fuel efficiency was 0.1%, showing no effect.

4. Discussions and Comments

1. The average Lambda control shown through this exhaust gas test was approximately 3.5% higher (lean) overall when using reformed fuel than the base fuel. In particular, the fuel efficiency of the reformed fuel was shown to be lean in the driving section (40 km/h cruise driving) where a lot of HC and CO were generated. This is presumed to be related to the oxygen inflow content due to the nanobubble effect, and thus the exhaust gas is presumed to be reduced (see Attachment #6).

   - In the case of NOx, it was shown to improve in all sections except for high-speed driving conditions.

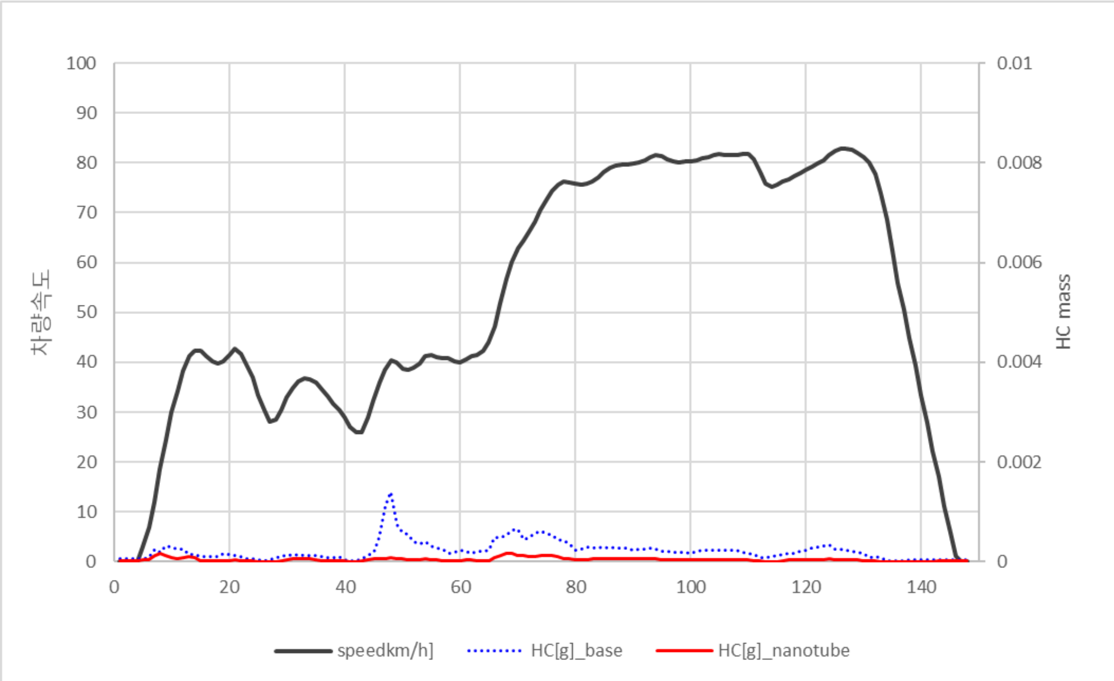
2. Although there was no significant difference in total fuel efficiency, the fuel consumption analysis results showed that when using reformed fuel, there was a tendency for improvement compared to base fuel in high-speed, low-load conditions, but the fuel consumption rate was higher in medium-speed, medium-load conditions (see Attachment #5).

3. In order to more accurately determine the exhaust gas/fuel efficiency effect of the reforming effect through nanobubbles, it is thought that it is necessary to expand the target vehicle model and conduct additional verification in the future. In addition, it is judged that it is necessary to identify the relationship between exhaust gas and fuel efficiency according to the oxygen content ratio of the fuel during the reforming process.

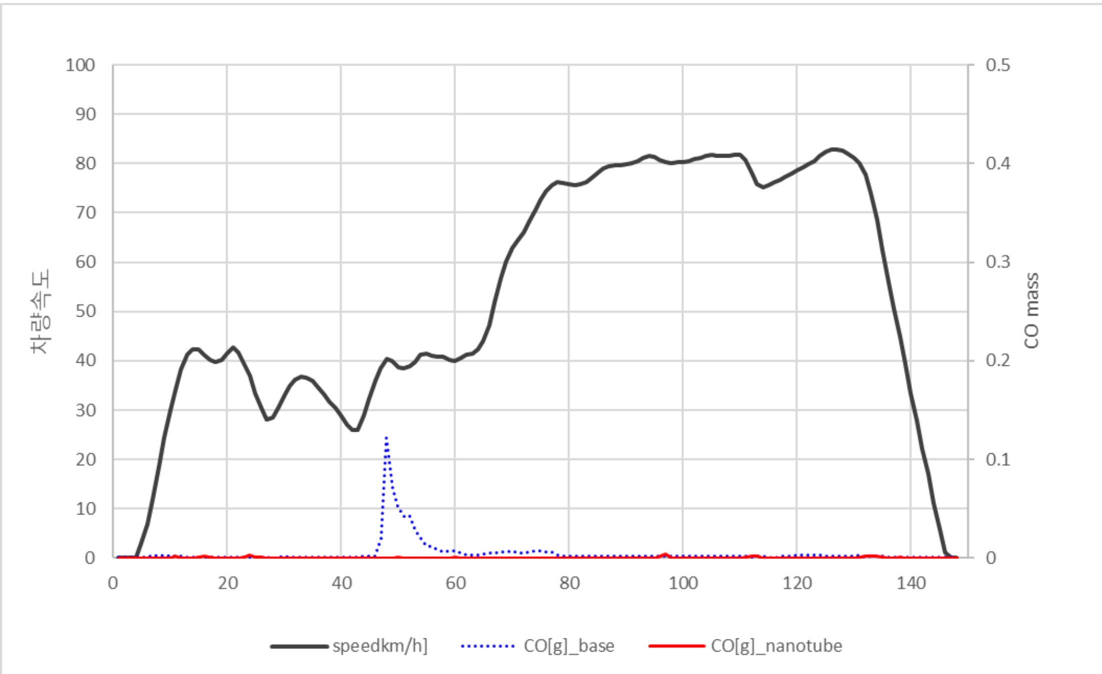
4. Since it is judged that the smoke reduction effect will be large when the fuel oxygen is included through nanobubbles, it is necessary to measure it in a vehicle without a diesel particulate filter (DPF) to determine the smoke reduction effect.

5. Attachments

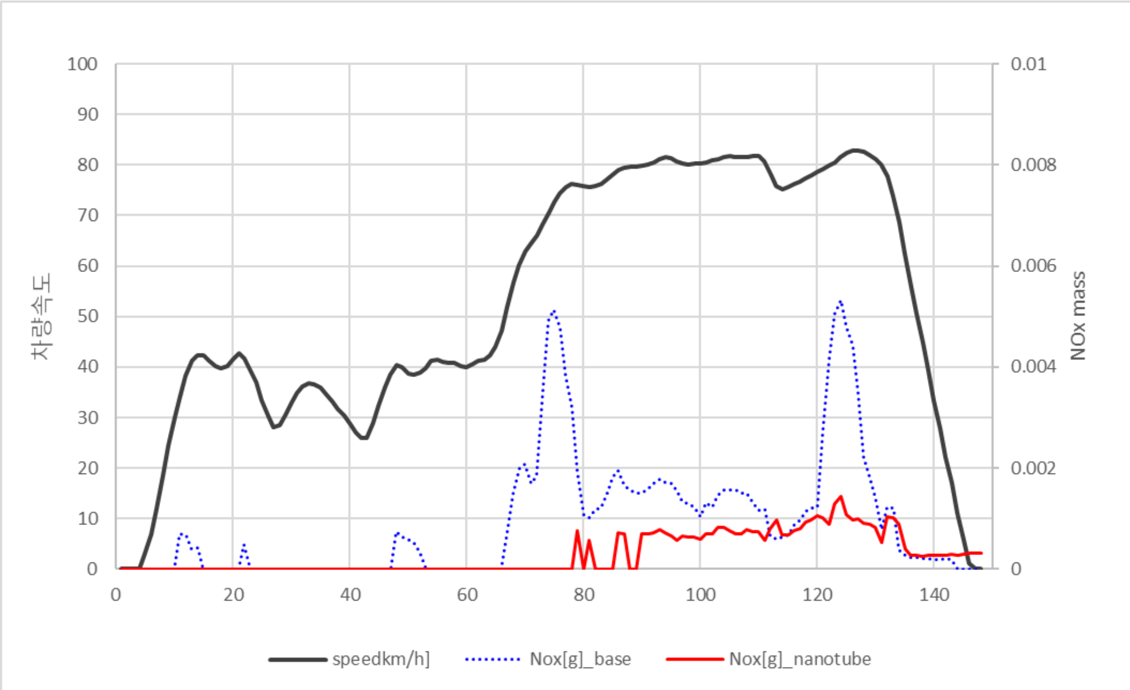
1) Attachment #1 HC Emission comparison



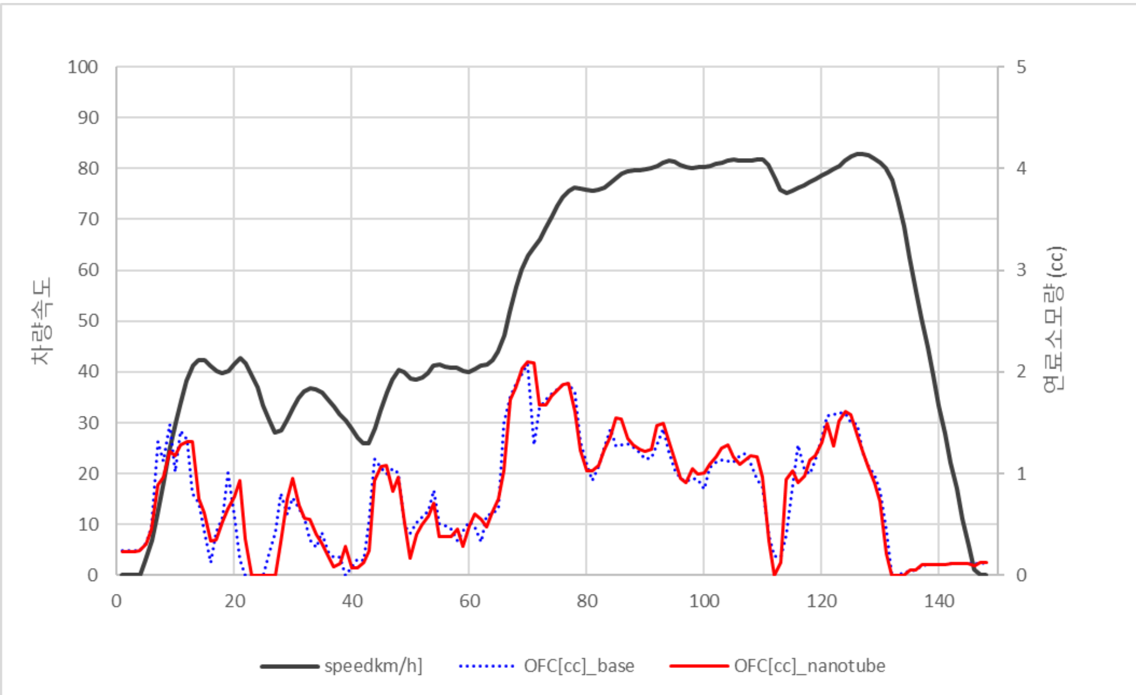
2) Attachment #2 CO Emission comparison



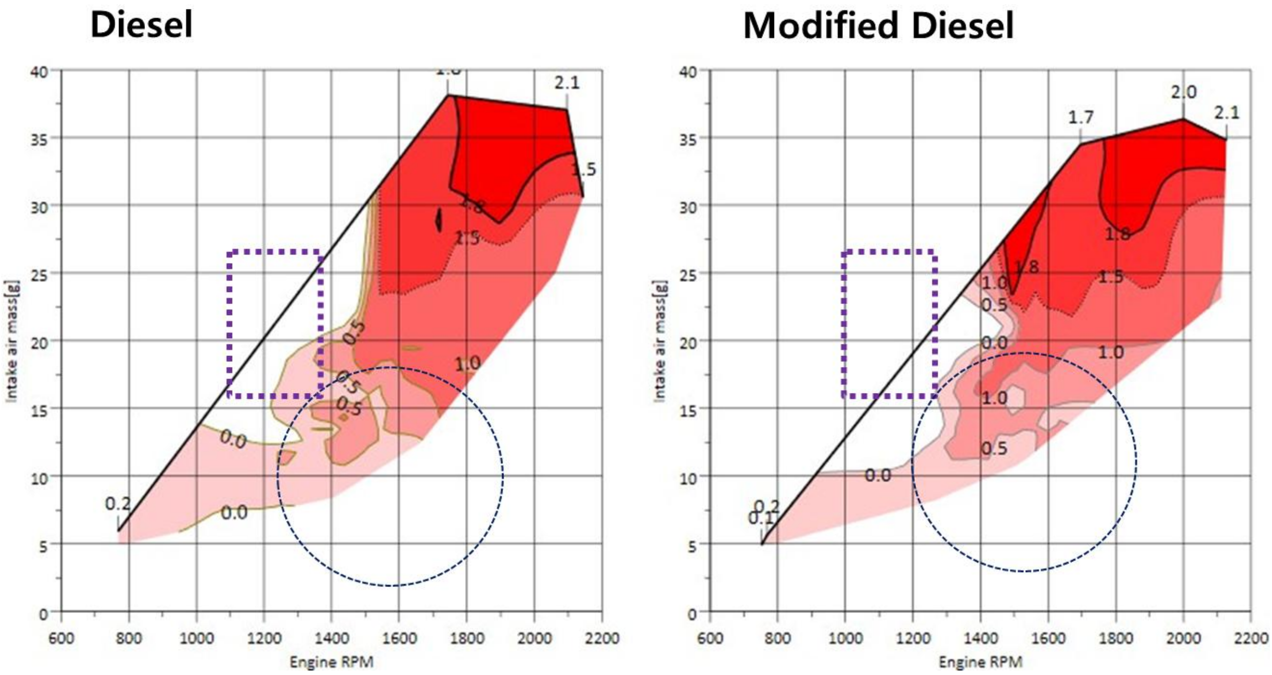
3) Attachment #3 NOx Emission comparison



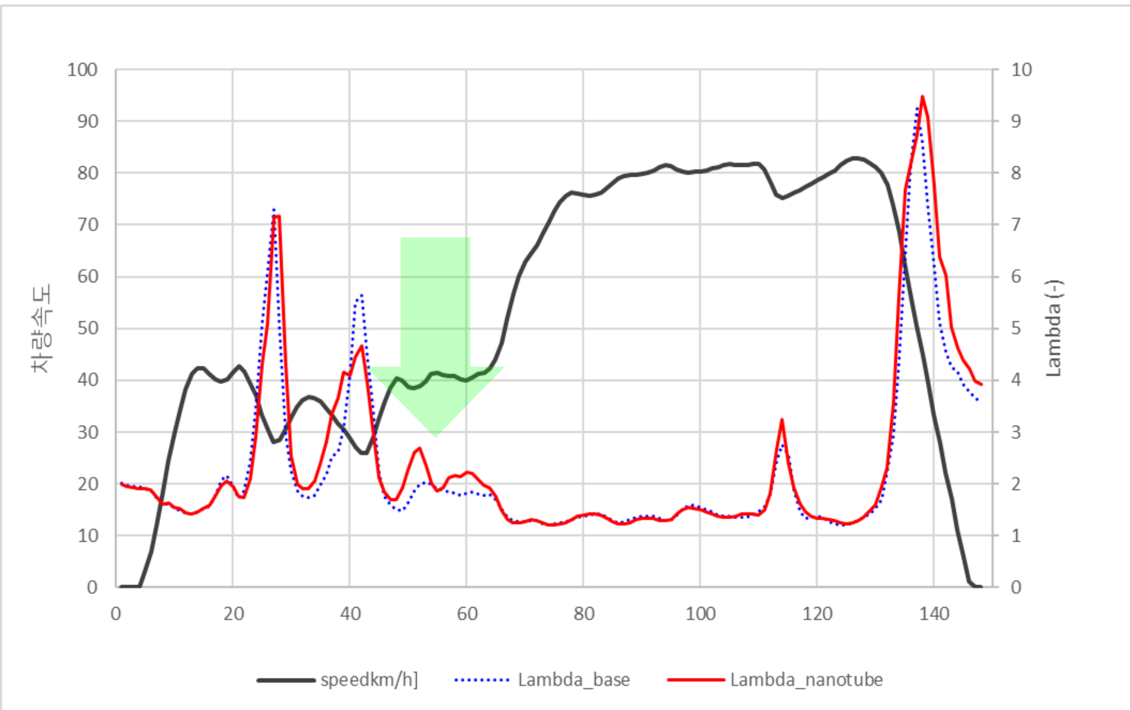
4) Attachment #4 Fuel consumption comparison



5) Attachment #5 Speed, load vs. fuel consumption CONTOUR MAP



6) Attachment #6 Lambda status comparison



6. Survey report of research papers on Combustion efficiency and effectiveness of oil when mixed with nanobubble>

No.	Reference	Nanobubble		efficiency	effects	Characteristics
		gas type	size/density			
1	Development of a new material for generating high-performance nanobubbles using radiation and development of nanobubble-fused automotive fuel oil using the same (Korea Atomic Energy Research Institute, 2015)	Oxygen	size: 93~165nm density: 1.3 ~ 3.8E+8/ml	fuel efficiency: 8% improvement	THC:67% reduction CO: 20% reduction CO_2: 8% reduction	- Fuel efficiency and exhaust gas tests using actual vehicles - Oxygen nanobubble suitability assessment (Petroleum Quality Management Institute)
2	Effect of nanobubbles mixed into diesel fuel on spray characteristics	Oxygen	size: 276nm density: 0.65E+8/ml	-Confirmed improvement in combustion efficiency and fuel efficiency compared to existing diesel fuel	-Promotes atomization of fuel particles compared to diesel fuel -Fast spray development process and increases spray area	- Spray characteristics test through nozzle - Diameter and number of nanobubbles determined using dynamic light scattering technique
3	Combustion characteristics of hydrogen nanobubble mixed fuel	Hydrogen	size: 149nm density: 11.35E+8/ml	Fuel efficiency: 7.42% improvement	-	-Sirius G4CP, Hyundai
4	Nano Gas Bubbles Dissolve in Gasoline Fuel and Its Influence on Engine Combustion Performance	Oxygen	- Micro bubble	-Dissolved gases improve engine combustion performance to reduce harmful gas emissions levels.	CO_2: 2.9%reduction NOx: 5.2%reduction	- 10% nanobubble oxygen content in benzene - Fuel enhancement technology that dissolves oxygen nanobubbles in gasoline fuel in a fluid flow
5	Effect of nano air-bubbles mixed into gas oil on common-rail diesel engine	air	size: 100~200nm density: 0.52 ~ 1.07E+8/ml	-Fuel efficiency: Average 3.2%, maximum 6.2%	- Confirmed reduction of exhaust smoke and NOx - Improved charging	-Engine: Remodeled Yanmar Diesel NFD150-E -The reason why nanobubble fuel can reduce fuel

				improvement	efficiency, exhaust gas temperature, smoke, and engine noise by up to approximately 1% - Stable driving possible without air mixing in the engine	consumption: This is due to the increased combustion speed caused by increased mixing ratio, increased ion concentration, and fine atomization of the spray oil.
6	Ilkyung Construction_2022/12(2)_ Improving fuel efficiency of heavy equipment with 'nano bubbles'	oxygen	Nanobubble	- Dump fuel efficiency: Up to 20% improvement - Rock cutting machine fuel efficiency: Up 7.8% improvement	-Reduction of exhaust gas emissions	Improving fuel efficiency of heavy equipment with 'nano bubbles' - Field demonstration of dump trucks and rock cutting machines - Daiko Industries: Development demonstration of nano bubble mixing device

<Conclusion and Comments>

o Test results of diesel fuel mixed with oxygen nanobubble gas

- Combustion efficiency or fuel efficiency is over 7%. In Japan, the Nikkei News reported that the efficiency of diesel dump trucks improved by 20%.

※ The Atomic Energy Research Institute conducted experiments on various cases, and since the actual vehicle was tested, this result can be expected to be the closest to reality.

- It has been confirmed that the factor for the increase in combustion efficiency is that diesel fuel mixed with nanobubbles becomes finer when sprayed [Reference 2], and this trend is expected to be strengthened as the size of nanobubbles becomes finer and the concentration increases.

※ The Atomic Energy Research Institute's research results [Reference 1] also predict that the concentration increases when nanobubbles become finer, and combustion efficiency increases accordingly.

- In the case of exhaust gas, most research results confirm the groundbreaking reduction effect of exhaust gas emissions such as carbon and NOx in the main component analysis.

Considering the characteristics of nanobubbles from Fawoo Nanotech Co., Ltd., which are an average of 100 nm and a concentration of 20E+8/ml, it is expected that the fuel efficiency of diesel and gasoline, etc. will increase and the exhaust gas reduction effect will be further improved when nanobubbles are included.

<Reference>

1. "Development of a new material for generating high-performance nanobubbles using radiation and development of nanobubble-fused automotive fuel oil using the same," Korea Atomic Energy Research Institute (Jeong In-ha et al.), January 2015
2. Park Ki-young and Lee Seong-wook (Department of Automotive Engineering, Kookmin University), "The Effect of Nanobubbles Mixed into Diesel Fuel on Spray Characteristics," 2020 Spring Conference of the Korean Society of Automotive Engineers
3. Oh Seung-hoon, Yoon Moo-sung, and Kim Jong-min (Department of Mechanical Engineering, Chung-Ang University), "Combustion Characteristics of Hydrogen Nanobubble Mixed Fuel," Korea Institute for Advancement of Technology, 2014, Engineering Professional Training Program
4. Pshtiwan M. Sharif et al., Nano Gas Bubbles Dissolve in Gasoline Fuel and Its Influence on Engine Combustion Performance, IPCME 1차 IOPConference
5. Yasuhito Nakatake et al., Effect of nano air-bubbles mixed into gas oil on common-rail diesel engine, Energy 59(2013) 233-239
6. Ilkyung Construction_2022/12(2)_Improving fuel efficiency of heavy equipment with 'nano bubbles', Nikkei Construction_2022.12 NEWS Technology (p42)