Innovative Coating Solutions

CG^2 NANOFUEL OVERVIEW

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CG^2 NANOFUEL OVERVIEW

1. Summary

The CG^2 NanoFuel technology consists of surfactant that in preliminary lab tests allows the mixing, without phase separation, of gasoline and distilled water in proportions ranging between 5% to 95% water. This surfactant is basically an emulsifier which combines the water into the gasoline as nano-sized droplets. The resulting CG^2 NanoFuel is monodispersed (a few nanometers in size) and demonstrated stability (as visually assessed) for over a year. The octane index could not be measured directly as it was over 100 but a mixture of 25% CG^2 NanoFuel – 75% n-heptane yielded a measured index of 91 which was then extrapolated to well over 200 for pure CG^2 NanoFuel. Preliminary corrosion studies showed that no appreciable corrosion was induced in steel.

2. Background

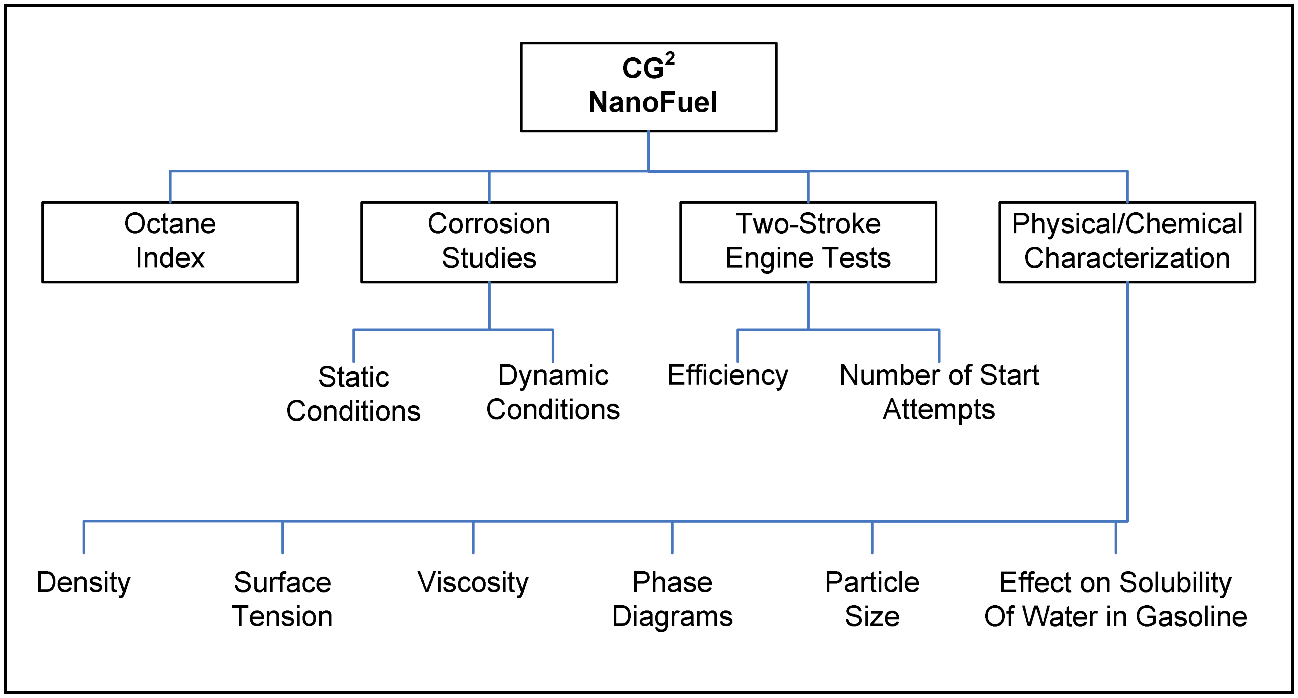
The CG^2 NanoFuel technology was initially developed as part of a PhD thesis. The goals of the thesis were to:

- **(a)** produce a novel substance that could act as a surfactant to support a gasoline-water system where nanodroplets of water would be mixed with commercial gasoline;
- **(b)** study the thermodynamics of the resulting mixture; and
- **(c)** assess the initial feasibility of using such a mixture as a fuel.

Our company has acquired this technology and we are now working to find partners with whom to validate and commercialize it.

3. Experiments Performed

The following chart summarizes the lab tests that were performed:



4. Preparation and Tests Conditions

The CG^2 NanoFuel was prepared with distilled water (with further development, it may be possible to use regular water), the surfactant and two different grades of commercial gasoline. The following table summarizes the test conditions, applicable standards and the equipment used:

Test	Test Conditions	Standards	Equipment
Octane Index	25℃ / 585 mm of Hg	ASTM-D2699 (RON) & ASTM-D2700 (MON). The statistical confidence level reported was 95.45. A 25% volume of the CG^2 NanoFuel was mixed with 75% volume of n-heptane.	CFR engine.

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Test	Test Conditions	Standards	Equipment
Corrosion	25℃ / 585 mm of Hg	Not Applicable	Satura ted calomel electrode coupled to a Luggin probe. The counter-electrode was a pure platinum wire.
Two-Stroke Engine Tests for Efficiency and Start Attempts	25℃ / 613 mm of Hg	92 octane and 87 octane gasolines were used as reference.	Two-stroke engine: 27.2 cm^3 cylinder capacity; 34 mm in diameter; ISO 8893 power level of 0.75 kW; idle speed of 2,800 rpm and full throttle at 9,500 rpm.
Density	25℃ / 613 mm of Hg	Compared to distilled water	Picnometer with thermometer, analytical balance and thermostat.
Surface Tension	25℃ / 613 mm of Hg	Compared to distilled water	Tensiometer
Viscosity	25℃ / 613 mm of Hg	Compared to distilled water	Ostwald viscosimeter, thermostat.
Phase Diagrams	613 mm of Hg at 4, 25 and 40 ℃	Not Applicable	Not Applicable
Particle Size	25℃ / 585 mm of Hg	Not Applicable	Ma lvern Autosizer 4800 equipped with an Innova Coherent 90K laser (647.1 nm).
Effect on Solubility of Water in Gasoline	613 mm of Hg at 4, 25 and 40 ℃	Not Applicable	Glass test tubes, Erlenmeyer containers, magnetic stirrers.

5. <u>Selected Test Results</u>

(a) Octane Index

The testing facility was not able to directly measure the octane index of pure CG^2 NanoFuel but using a mix with n-heptane and extrapolating implied an octane of approximately 270 for pure CG^2 NanoFuel.

(b) Corrosion Studies

The CG² NanoFuel demonstrated values of the I_{corr} (corrosion current density) that remained practically constant for various proportions of water. This would imply that the rate of corrosion is not affected by the presence of the water. Further details are available on the tests that were done.

(c) Two-Stroke Engine Tests

The purpose of these tests was to determine how the CG² NanoFuel would perform in an unmodified, off-the-shelf engine. The following tables summarize the test results at various proportions of water, based on regular and premium gasoline:

(i) The coding in the "Fuel" column is interpreted as follows: M 87 octane gasoline and P is 92 octane gasoline; 1 through 6 correspond to the water content (approximately 5, 10, 15, 20, 25, and 30%, respectively), 4C means that the CG² NanoFuel was prepared at 4 °C;

(ii) The "Working Time" column compares how long the engine ran with CG² NanoFuel against the baseline gasoline; and

(iii) The "Attempts to Start" column notes how many start attempts were necessary to get the engine running.

CG² NanoFuel Using Regular Gasoline

Fuel	Volume (ml)	Working Time (min)	Attempts to Start
Regular	*100*	*≈16*	*7*
M1-4C	100	≈15.5	7
M2-4C	100	≈15	11
M3-4C	100	≈15	9
M4-4C	100	≈14	15
M5-4C	100	≈14	15
M6-4C	100	≈13	17

CG² NanoFuel Using Premium Gasoline

Fuel	Volume (ml)	Working Time (min)	Attempts to Start
Premium	*100*	*≈15*	*11*
P1-4C	100	≈15	8
P2-4C	100	≈13	13
P3-4C	100	≈15	11
P4-4C	100	≈15	11
P5-4C	100	≈13	14
P6-4C	100	≈13.5	12

The results imply that the engine can run without difficulty using the CG² NanoFuel. The running time decreases somewhat as the proportion of water goes up which means that a higher volume of our mixture would be needed for the same running time. However, at certain percentages, the decrease in running time appears to be positively offset by the reduced amount of gasoline. For example, the M3-4C sample (15% water i.e. 15% less gasoline) has a reduced running time of approximately 6.25% (from 16 minutes to 15 minutes).

On the surface, this may appear as a claim of being able to "burn" water which is thermodynamically not valid. Our theory is that the water is helping the fuel to burn more efficiently. This would also be in keeping with considerable research which has taken place to boost engine efficiencies by the addition of water to gasoline. More experimentation is required to validate this theory.

6. Opportunities and Development Requirements

The following is a preliminary list of opportunities for this technology and the associated key development requirements. The ranking represents the speed with which we feel each opportunity could be realized, beginning with the fastest:

(a) Automobile Gasoline

The octane improvements that we achieved may be of limited use since both the gasoline supply chain and the auto industry are geared towards current octane ratings.

However, the real opportunity may be to reduce or replace some of the additives in use today, to realize commercial or environmental benefits. For example, the ability to reduce or eliminate MTBE would be of significant environmental benefit as many jurisdictions are keen on finding alternative additives. There is also the possibility to use this technology with ethanol.

To achieve commercial success, our technology will have to demonstrate that it provides the required functionality, is compatible with today's gasoline supply chain and automotive engines, reduces environmental and health impacts, and is cost effective. For discussion purposes, the following is a preliminary list of key development steps to realize success:

(i) Redo basic testing to verify the results.

(ii) Perform initial environmental testing to establish the potential benefits and risks of the technology.

(iii) Identify and execute additional development e.g. use of our technology in cold temperatures, with different gasoline blends, and so forth. This would include performing expanded testing for functionality as well as the implications of its use, such as corrosion in engines, fuel transportation systems, and storage infrastructure. Other additional development may involve stability, the use of non-distilled water, etc.

(iv) Perform detailed environmental testing. Other than a qualitative assessment that showed the engine exhaust did not have any additional smells or residues, we have not performed such testing.

(v) Establish requirements for refining, transportation and storage in commercial quantities.

(vi) Assess cost effectiveness, capital investment requirements, and marketing implications. The goal would be to have the CG^{2} NanoFuel cost the same or less than current gasoline given that a proportion of the mix will be water. Naturally, this cost needs to account for development and deployment expenses but these costs should be relatively low on a per-unit basis.

(b) Diesel / Jet Fuel

We believe that our technology could be reformulated to work with diesel and jet fuel to improve efficiency and/or to reduce pollutants such as NOx, using existing engines and infrastructure and at competitive cost. Given increasing concerns about the contributions of diesel and jet exhausts to climate change and air quality, even small improvements could have significant market potential.

(c) Aviation Gasoline

Due to differences in engine design and requirements, aviation gasoline (avgas) still contains lead, the abolition of which would have significant environmental benefits. In addition, avgas is produced in small volumes relative to auto gasoline and jet fuel, thus it is difficult to realize economies of scale for refining, transportation and storage. Being able to reduce or eliminate this “parallel” supply chain could yield considerable cost benefits.

The development steps here would be a follow on to those outlined for automobile gasoline, taking into account the special needs of aircraft engines and the operating requirements.

(d) Oil Extraction

Another area where this technology may have a role is in oil extraction, particularly for the oil sands. It may be possible to modify the surfactant to liquefy crude oil, perhaps significantly reducing the energy needed. This will require a development effort as the technology, in its current state, is not designed for crude oil extraction. We are in the process of estimating what might be involved in such a development.