Phase I Project Summary

PSI-6292

Firm: Physical Sciences Inc.
Contract Number: NNX11CF17P
Project Title: High Performing PFPE Nanofluid Lubricants

Identification and Significance of Innovation: (Limit 200 words or 2,000 characters whichever is less)

Future success of long-duration, planetary space exploration requires lubricants that can perform effectively over extended lifetimes with minimal or no maintenance in aerospace systems. These systems include rovers and machinery used in constructing the lunar habitat, bearings in gyroscopes on board satellites, and attitude control systems. Lubricants that are intended for space-use must have a low vapor pressure, be chemically stable, function over a wide temperature range, exhibit low friction coefficients, produce small wear effects, and limit corrosion processes.

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)

The specific objectives were the following: 1) Prepare novel additives, 2) Demonstrate that the additives are thermally stable between ± 65^{o}C, 3) Show a 50% reduction in friction and wear at a steel surface upon addition of the particles to PFPE, 4) Demonstrate no change in viscosity of PFPE upon formulation with an additive, and 5) Show no agglomeration of the additives within PFPE, and that the additives would have settling times > 5 years.

In Task 1, “Management and Reporting”, PSI was to provide reports and other communications with NASA. In Task 2,“Nanoparticle Synthesis”, PSI was to synthesize nanoparticles and quantify reaction yields. In Task 3, “Nanoparticle Characterization, PSI was to determine purity, particle size, particle morphology, gravimetric surface area, and thermal stability of the nanoparticles. In Task 4, “Tribological Measurements”, Nye Lubricants Inc. was to measure tribological properties at a steel surface using the proposed nanofluids. In Task 5, “Rheological Investigations”, PSI was to determine viscosity the nanofluid lubricants and neat PFPE base fluid. In Task 6, “Settling Time Estimation, PSI was to determine colloidal particle size in the PFPE base fluid and then estimate settling times of the nanoparticles.

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)

PSI developed nanofluid technology whereby stable, colloidal suspensions of additives were present in perfluoropolyalkylether (PFPE) base fluids as lubricants. The additives were sheared within minute scratches and grooves while separating surface asperities. Specifically, nanoparticles were prepared at ~ 25 nm – 50 nm diameter and their surfaces chemically treated. Elemental analysis by use of combustion chemistry and ESCA were used to characterize the material composition. Each synthetic reaction was shown to be repeatable, and many reactions to be scalable at the gram level. The presence of the additive in PFPE increased the viscosity less than 20% between 0^{o}C and 100^{o}C. The dispersions are essentially Newtonian from 50 s^{-1} to 5000 s^{-1}; there is a slight shear rate dependence. Use of the additives had 1) no significant influence on the load carrying capability, 2) dramatic decrease in wear, and 3) slight increase in coefficient of friction at steel substrates. Several of the additives were shown to be thermally stable up to ~ 275^{o}C. This decomposition temperature exceeds that typically present when using PFPE liquid and grease lubricants, and does not limit use of the nanoparticles as additives. Based upon these results, use of the nanoparticles as additives in PFPE is highly promising.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)

The proposed lubricants and formulations will have direct applications to NASA aerospace systems that require minimal/no maintenance over extended periods of time. These systems include rovers, machinery used in constructing the lunar habitat, and attitude control systems. The compounds will provide lower volatility, decreased wear effects, and better tribological characteristics than those of standard liquid lubricants that are currently used, particularly at lower temperatures.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)

The proposed lubricants and formulations have applications in terrestrial machinery. They will substantially increase performance, and reduce maintenance costs and frequencies of industrial transportation and construction systems. The compounds will also be valuable in gyroscope bearings on board satellites.

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