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Alternative Solvents and Technologies for Precision Cleaning of Aerospace Components

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Introduction

Precision cleaning solvents for aerospace components and oxygen fuel systems, including currently used Vertrel-MCA, have a negative environmental legacy, high global warming potential, and have polluted cleaning sites. Thus, alternative solvents and technologies are being investigated with the aim of achieving precision contamination levels of less than 1 mg/ft^2. The technologies being evaluated are ultrasonic bath cleaning, plasma cleaning and supercritical carbon dioxide cleaning.

Experimental Approach

Swagelok parts are used as model aerospace components and contaminated with a mixture of hydrocarbon-based hydraulic fluids and fluorinated greases. The contaminant mass on the part is determined gravimetrically. After carrying out the test cleaning method, the remaining contaminant mass is determined and cleaning efficiency is calculated in terms of percent contaminant removed.

Swagelok pieces used as model aerospace components.

Alternative Organic Solvents

Process Parameters

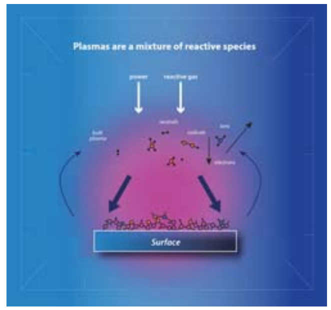
- Solvent: Isopropyl alcohol, tert-butyl acetate, ethyl acetate, ethanol, acetone, deionized water
- Ultrasound used (40 or 80 kHz frequency)

Top view and front view of solvent carts equipped with ultrasound, continuous flow, and heating options.

Plasma Cleaning

Process Parameters

- Supply gas type: Argon, hydrogen, oxygen
- Pressure: 0.1 - 0.4 mbar
- Frequency: 40 kHz
- Power: 200 W
- Exposure time: 1 - 60 min



Plasma cleaning theory (left) and system used (right).

Supercritical Carbon Dioxide Cleaning

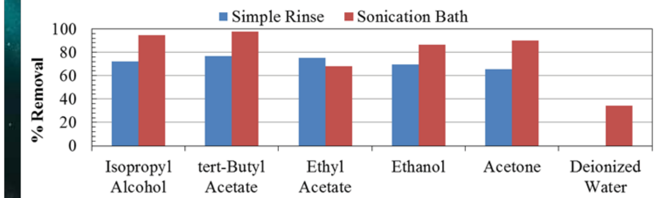
Process Parameters

- Temperature: 35, 50, 75, 100 ^oC
- Pressure: 82.8, 138, 276, 414 bar
- Exposure time: 5, 30, 45, 60 min
- Impeller speed: 0, 500, 750, 1000 rpm

Supercritical carbon dioxide cleaning system.

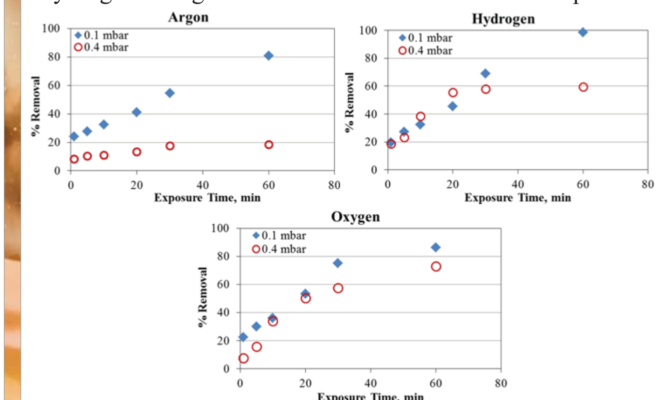
Results

Ultrasonic enhanced solvent cleaning improved cleaning efficiencies by an average of 15.5% with each solvent. Tert-butyl acetate yielded the highest cleaning efficiency using the simple rinse method and the sonication enhanced method with removals of 76.8% and 97.7%, respectively. Aqueous ultrasonic cleaning is shown to perform poorly, even compared to the simple rinse method with organic solvents, illustrating the benefit of using an organic solvent.



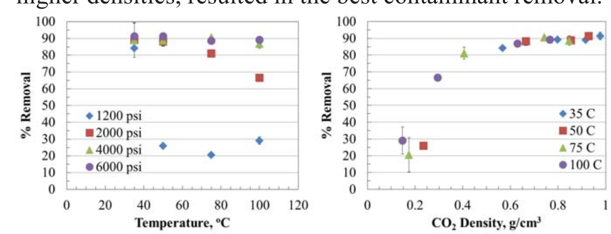
Comparison of cleaning methods using non-halogenated organic solvents.

Plasma cleaning results show that removal of contaminants is optimized using hydrogen as the supply gas, lower pressures (0.1 mbar), and longer exposure times. The maximum cleaning efficiency of 98.3% was achieved with hydrogen feed gas at 0.1 mbar after 60 minutes of exposure.



Results of plasma cleaning at 0.1 and 0.4 mbar supply gas pressure with exposure times up to 60 minutes.

Using supercritical carbon dioxide cleaning the maximum cleaning efficiency of 91.4% was achieved at 35 ^oC, 6000 psi, 60 min and 500 rpm. Temperature and pressure had the greatest effect on cleaning efficiency, while impeller speed and exposure time did not greatly affect the % removal. Lower temperatures and higher pressures, corresponding to higher densities, resulted in the best contaminant removal.



Cleaning efficiencies using supercritical carbon dioxide processing. Results express various conditions for all parameters.