Green Solvents for Precision Cleaning

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Introduction

Aerospace machinery used in liquid oxygen (LOX) fuel systems must be precision cleaned to achieve a very low level of non-volatile residue (< 1 mg/0.1 m^2) to prevent explosive oxidation of contaminants. Currently Vertrel-MCA, a blend of decafluoropentane and trans-dichloroethylene, is used in the precision cleaning process at the Kennedy Space Center. Fluorinated compounds are persistent in the environment and according to the manufacturer's MSDS, Vertel-MCA can decompose to hydrofluoric and hydrochloric acids at high temperatures. This has now led to the development of new processes in the precision cleaning of aerospace components.

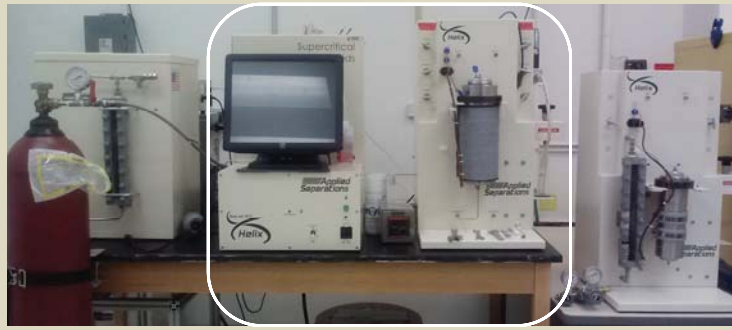

Figure 1. Helix system components. Only the center two components were used in the preliminary work which employed a stirred-batch process.

Approach

Highlighted is a cleaning process which employs supercritical CO_2 to dissolve and remove the contaminant from metal parts. A fluorinated aerospace grease, Krytox 240AC, was investigated as a model fluorinated contaminant and aluminum coupons were used as model aerospace components in preliminary investigations. A stirred-batch process [Fig. 1] was employed in which the effects of cleaning temperature, pressure, exposure time and stir rate were examined and optimized using the Taguchi method [Table 1].

Table 1. Parameters and levels tested.

	Parameter			
Level	Time, min	Temperature, ^{o}C	Pressure, psi	Impeller Speed, rpm
1	5	35	1200	0
2	30	50	2000	500
3	45	100	4000	750
4	60	150	6000	1000

Results

The Taguchi method results showed that the parameter effecting the cleaning efficiency the greatest is pressure, followed by temperature, exposure time and then impeller speed. The results were further analyzed using the Pearson product moment correlation, which showed that lower temperatures, higher pressures and shorter exposure times all resulted in improved contaminant removal. This is illustrated in the contour plots in Figure 2. Figure 3 shows the dependence of the cleaning efficiency on the CO_2 density, which was acquired from the P / T information.

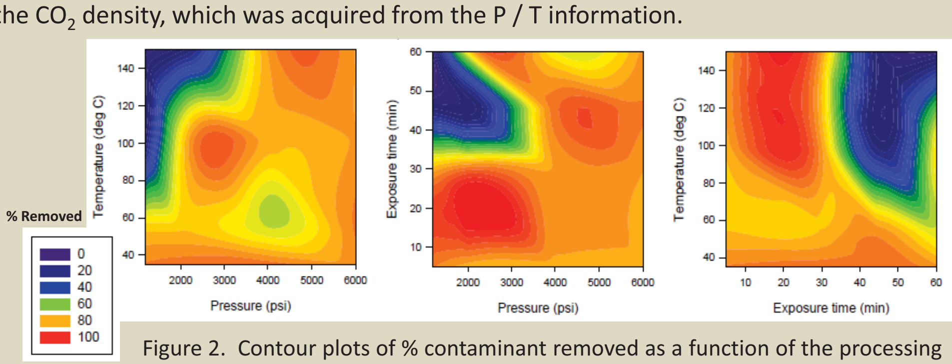

Figure 2. Contour plots of % contaminant removed as a function of the processing parameters.

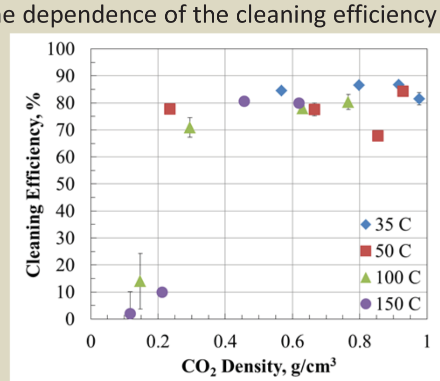

Figure 3. Cleaning efficiency as a function of CO_2 density (n=3).

Conclusions

Temperature and pressure were found to have the most significant impact on the cleaning efficiency. This preliminary work has provided a foundation for ongoing studies of cleaning using supercritical CO_2. Ongoing studies focus on the use of the CO_2 recycling module, in line detection of contaminant concentration and the use of co-solvent to further improve cleaning efficiency, if needed.