EFFECTS OF THERMAL STRESSING CONDITIONS ON CARBON DEPOSITION FROM JET FUEL DECOMPOSITION

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Introduction

In advanced future aircraft, jet fuel may be exposed to temperatures as high as 540°C prior to combustion if the fuel is used as a coolant onboard [1]. At these high temperatures, the fuel will undergo decomposition reactions leading to formation of carbon deposits which will clog the tubes, increase the pressure drop in nozzles, and decrease the thermal conductivity [1,2]. Previous studies on carbon deposition gave conflicting results especially with respect to pressure effects [1-3]. The objective of this study is to investigate the effects of thermal stressing conditions on solid deposition from jet fuel on different metal surfaces.

Experimental

Thermal stressing of a commercial JP-8 fuel sample was carried out in an isothermal flow reactor at temperatures 375 to 600°C and pressures from 175 to 900 psig. The reactor is a 20-cm long, 1/4" OD glass-lined stainless steel tube. Thermal stressing procedures are described elsewhere [4]. The metal foils of stainless steel 347, superalloy Inconel 718, titanium, and aluminum were cut into 0.3x15 cm coupons and placed in the flow reactor for thermal stressing. A fuel flow rate of 4 cc/min. was used in the experiments. The total amount of carbon deposition on metal coupons was determined by LECO Multiphase Carbon Analyzer [5] and the morphology of the deposits was examined by SEM.

Results and Discussion

The carbon deposition on all metal surfaces increased steadily with the increasing temperature. Figure 1 shows that carbon deposition increased very rapidly above 550°C for all the metal surfaces, SS347, Inconel 718, titanium, and aluminum, with SS347 giving the highest deposition throughout the temperature range studied. Inconel 718 gave a relatively slow build-up of deposits at high temperatures. Figures 2 and 3 show the electron micrographs of carbon deposits on SS347 and Ti at 500°C and 500 psig. The deposit on SS347 shows plate-like structures, indicating active surface catalysis of the deposition. In contrast, the deposits on Ti appear to have amorphous structures resulting from thermal processes.

Among the metal surfaces, Inconel 718 was selected to study the effects of reaction time and pressure on solid deposition from jet fuel. Figure 4 shows the amount of deposit collected as a function of reaction time at 500°C and 500 psig. A rapid increase in deposition was observed following an induction period of approximately 3 h. SEM examination of the deposited coupons showed essentially amorphous structures at the surface. It is interesting to note that the deposition profile resembles that of an autocatalytic process. In other words, the incipient deposition on the alloy surface appears to accelerate subsequent deposit formation [5].

Figure 5 shows that the amount of carbon deposit decreased as the system pressure was increased from 200 psig to 900psig at 500°C. Marteney and Spadaccini [2] found no pressure effect on deposition rates for JP 5 fuel from 250 to 800 psig. Chin et.al. [3] also noted that the pressure had no effect on deposition rates provided that it was high enough to prevent fuel boiling. According to Watt et al. [6], however, increasing the pressure reduced both local and total deposits. This behavior was not entirely consistent, and depended on the fuel sample used. In our experiments, the JP 8 was in gas phase at the 175 psig test, while it was in a supercritical state at 500 and 900 psig. Free radical reactions are responsible for solid deposition. Thermal stressing experiments in near critical and supercritical conditions indicated that the chemistry of fuel decomposition under initial supercritical conditions is very different from that under subcritical conditions [7]. The significant pressure effects on the product composition and the apparent first-order rate constants in the near-critical region are attributed to large changes in reactant concentrations (or density) in this region [8]. High pressures in the near-critical region favor bimolecular hydrogen abstraction reactions to produce alkanes over unimolecular -scission reactions that produce olefins. Therefore, the decreased deposition with the increasing pressures near the critical region in our experiments can be related to changes in reaction mechanisms, which reduce the yields of olefins, the principal precursors to solid carbons.

Conclusions

Solid carbon deposition from jet fuel decomposition depends strongly on temperature, exposure time, pressure, and the nature of the substrate surface. In particular, surface catalytic activity of SS347 results in a large amount of deposition. The decrease in deposition on Inconel 718 with the increasing pressure is attributed to the changes in reaction mechanisms and product distribution in the near-critical region of jet fuel.

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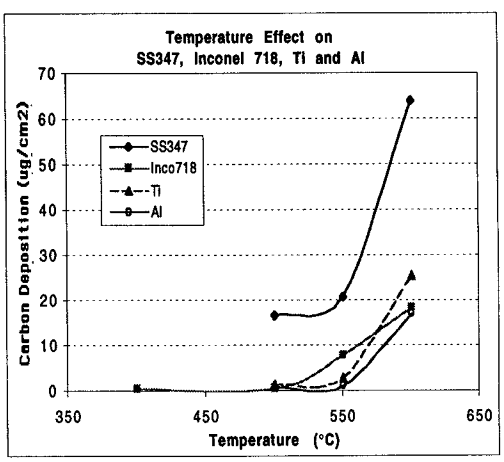

Figure 1. Effect of temperature on deposition

Figure 2. Deposit morphology on SS347.

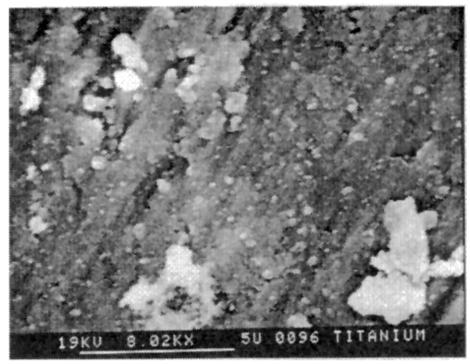

Figure 3. Deposit morphology on Ti.

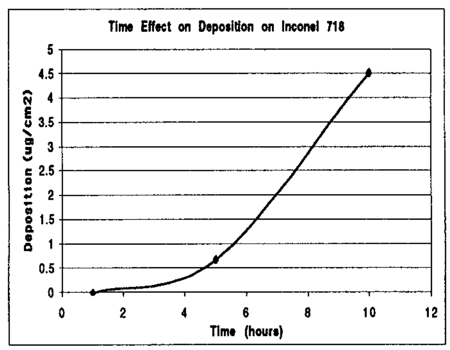

Figure 4. Effect of time on deposition

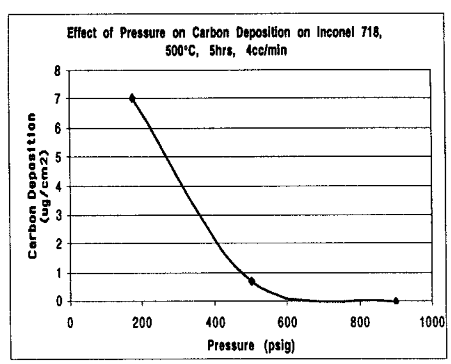

Figure 5. Effect of pressure on deposition.