ANALYSIS OF CARBON DEPOSITION ON SUPERALLOY SURFACES BY COMBINED XPS-AES, AFM AND SEM

Orhan Altin and Semih Eser
Laboratory for Hydrocarbon Process Chemistry
The Energy Institute, 209 Academic Projects Building
The Pennsylvania State University, University Park, PA, 16802, USA

Introduction

Large heat loads in future high-speed aircraft will expose jet fuels to temperatures as high as 540°C [1]. At such high temperatures, the conventional fuels would decompose and produce detrimental solid deposits on metal surfaces. The extent of deposition and the structure of the solid deposit strongly depend on the metal surface composition [2-6].

The objective of this study is to investigate the effects of oxidized metal surfaces on deposition from thermal stressing of a JP-8 fuel in a flow reactor. Thermal stressing experiments were carried out in the presence of as-received and oxidized superalloy foils, Inconel 600 and Inconel 718.

Experimental

Thermal stressing of a JP-8 jet fuel was carried out in a flow reactor in the presence of Inconel 600 and 718 foils, as described previously [2]. The elemental compositions of the alloys are given in Table 1.

The alloy foils were cut into 15x0.3 cm coupons with 0.125 mm thickness, cleaned with acetone and dried. The foil coupons were oxidized in a quartz furnace in flowing UHP oxygen by heating from 100 to 900°C.

Carbon deposits were analyzed by temperature-programmed oxidation (TPO) using a LECO multi-phase carbon analyzer. The oxidized and deposited surfaces were characterized by scanning electron microscopy (SEM), atomic force microscopy (AFM), X-ray photoelectron (XPS)-Auger electron spectroscopy (AES).

Results and Discussion

The oxidation treatment of foils revealed larger grains on In 600 surface than those on In 718, as observed by SEM. The XPS data showed that the surfaces of both foils became enriched in Cr, as shown by the increased intensity of the Cr_2O_3 peak at 578 eV. The Al concentration on the surface of In 718 also increased upon oxidation.

Figure 1 shows the TPO profiles and SEM micrographs of the deposits collected on the as-received and oxidized alloy surfaces from jet fuel stressing at 500°C and 500 psig. As discussed elsewhere [3], the high temperature peaks in the profiles are attributed to structurally more ordered (less reactive) carbon deposit produced by surface catalysis. The low temperature peak corresponds to less ordered (more reactive) carbonaceous solids collected on the incipient deposit. The TPO profiles in Figure 1a show that the pre-oxidation of In 600 reduced the overall carbon deposition with a substantial reduction in the intensity of the high temperature peak. The total amounts of deposits on as-received and oxidized surfaces are 45 and 6.5 $\mu g/cm^2$, respectively. The SEM micrographs of the deposited surfaces show much less filamentous carbon formation on the pre-oxidized surface compared to the as-received surface. Both TPO data and SEM examination indicate reduced catalytic activity of the pre-oxidized surface. Increased Cr concentration on the oxidized surface as shown by XPS can explain the reduced surface activity of In 600 towards filamentous carbon formation.

Figure 1b shows that the pre-oxidation treatment had a relatively muted effect on deposition behavior of In 718. Comparing the TPO profiles for deposits on as-received surfaces, one can see that the intense high-temperature peak in the In 600 deposit, is not present in the In 718 deposit. Still, the pre-oxidation treatment reduced the overall deposition from 3.8 and 2.0 $\mu g/cm^2$. The SEM micrographs in Figure 1b show that the pre-oxidation inhibited the deposit growth on In 718 also.

In addition to SEM, AFM was used to examine the effects of deposition on polished Inc 600 surfaces (5 nm, rms). Following stressing with JP-8 at 500°C for a very short time (5 min.), the smooth polished surface of the In 600 became rougher (15 nm, rms) because of the initiation of filamentous carbon formation, lifting Ni and Fe particles from the surface.

Conclusions

The pre-oxidation of In 600 substantially reduced the catalytic activity of the superalloy for filamentous carbon deposition from jet fuel decomposition. More modest effects of oxidation were observed with In 718 because of its relatively low catalytic activity. The increased concentrations of Cr and Al species on alloy surfaces by pre-oxidation appear to be responsible for the reduced solid deposition from jet fuel decomposition.

Acknowledgments

This work was funded by the air Force Wright Laboratory/Aero Propulsion and Power Directorate, Wright Patterson AFB. We thank Mr. W.E. Harrison, III and Dr. T. Edwards of AFWL/APPD for helpful discussions and Prof. H. H. Schobert of PSU for his support.

References

1. Edwards, T., and S. Zabarnick, Ind. Eng. Chem. Res., 1993, **32**, 3117.
2. Li, J., and S. Eser, ACS Preprints, Div. Pet. Chem.1996,**41**(2), 508.
3. Altin, O., A., Venkataraman, and S. Eser, ACS Preprints, Div. Pet. Chem.1998, **43**(3), 404.
4. Trimm, D. L. , Catal. Rev. Sci. Eng., 1977, **16**, 155.
5. Audier, M. and M. Coulon, Carbon, 1985, **23**, 317.
6. Baker, R. T. K. , J. R. Alonso, J. A. Dumesic and D. J. C. Yates, J. Catal., 1982, **77**, 74.

Table 1. Bulk Composition (wt%) of Superalloys (Goodfellow, Inc.)

	Ni	Fe	Cr	Nb	Mo	Ti	Al	Cu	Mn	Si	C	S
In 718	52.5	18.5	19.0	5.13	3.05	0.9	0.5	0.15	0.18	0.18	0.04	0.0008
In 600	74.4	8.0	15.5	-	-	-	-	0.5	1.0	0.5	0.15	0.0015

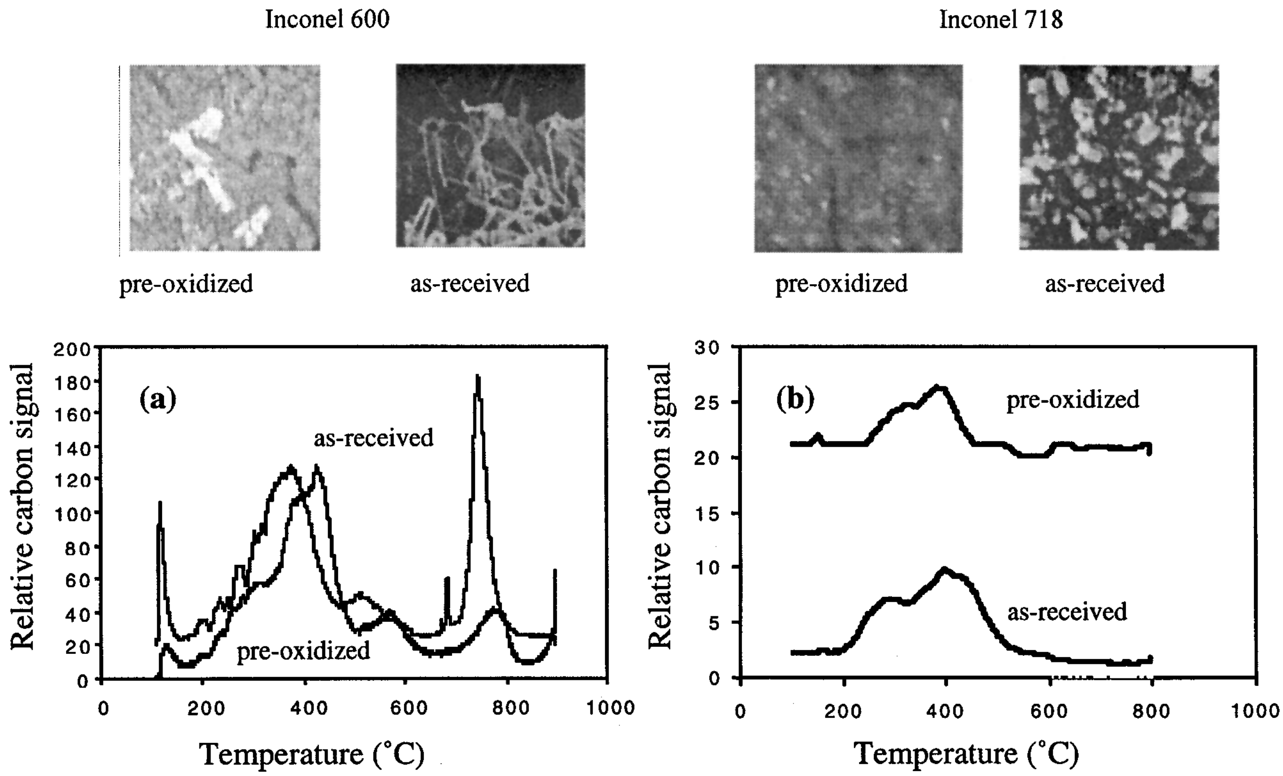

Figure 1. Temperature-programmed oxidation profiles and SEM micrographs for deposits on as-received and pre-oxidized coupons of Inconel 600 (a), and Inconel 718 (b).