Lab Fouling Test Unit Correlation to Delayed Coker Furnace Fouling

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Introduction

Fouling, the accumulation of unwanted carbon based deposits on the surface of process piping, is studied using an autoclave based Fouling Test Unit (FTU).

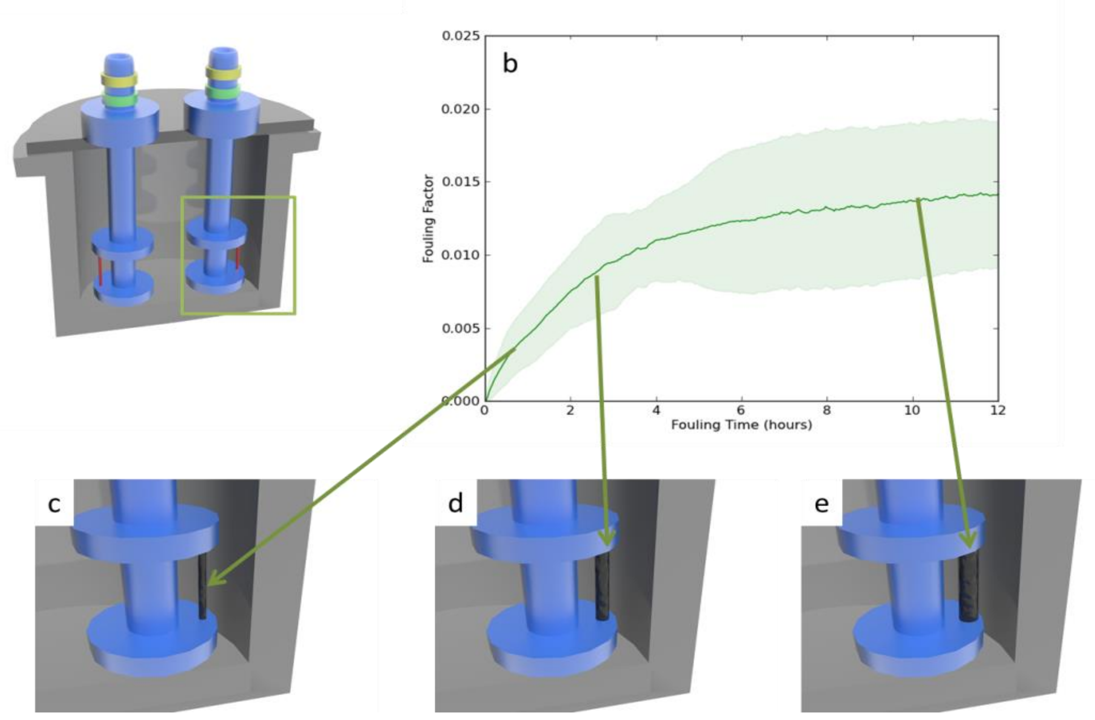
Fouling build-up reduces heat transfer from the metal surface to the process fluid. The FTU measures this heat transfer and correlates it to the rate fouling build-up in situ during testing.

Tests were conducted using Vacuum Tower Bottoms (VTB) samples and comparisons were made between deposits on the wire in the laboratory FTU and in a delayed coker in the field using Scanning Electron Microscopy (SEM).

The effect of blending with Paraflex oil and addition of Antifoulant chemicals was analysed using the FTU demonstrating the high resolution and clear results from the technique.

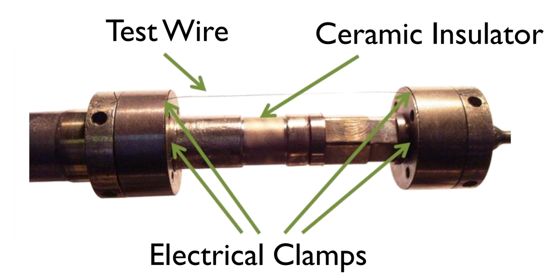
Experimental Conditions & Goals

1. Employ the FTU to simulate plant conditions and investigate the key variables for controlling fouling in heat exchanger applications.
2. Explore the effect of chemical additives and feed mixtures on rate of fouling at high temperatures and pressures.
3. Identify and optimize fouling mitigating chemical additives.

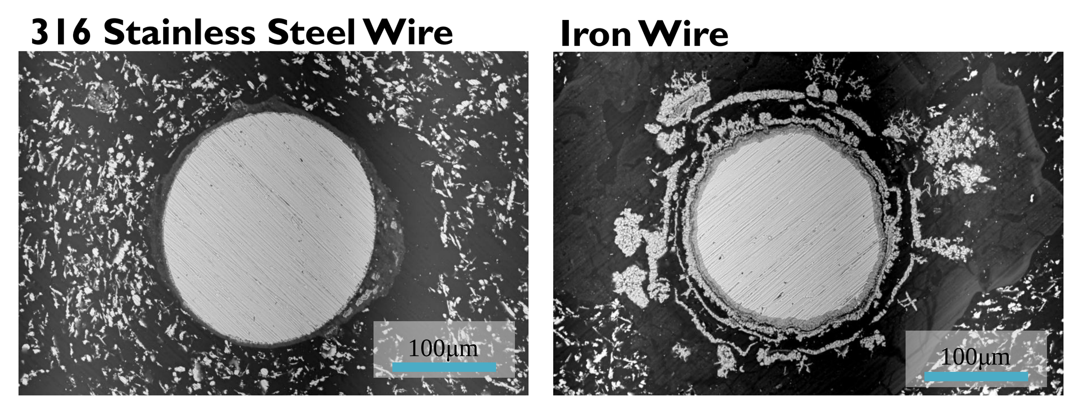


FTU testing uses a heated wire to provide a hot metal surface in a heated and stirred autoclave reactor. As fouling forms on the heated wire the measured fouling factor increases providing a precision continious measurement of the fouling build-up process. Temperature of the process fluid is kept at 500 ^{0}F while the heated wire is kept at 950 ^{0}F. Autoclave stirring is designed to provide a uniform flow field across the wire durring testing. The autoclave is held under a pressurized head of nitrogen at 200psi. Each run includes an initial slow heating rate used to calibrate the test wires and fit their resistance vs. temperature measurements to an ex-situ obtained calibration up to 1000 ^{0}F.

Fouling Testing

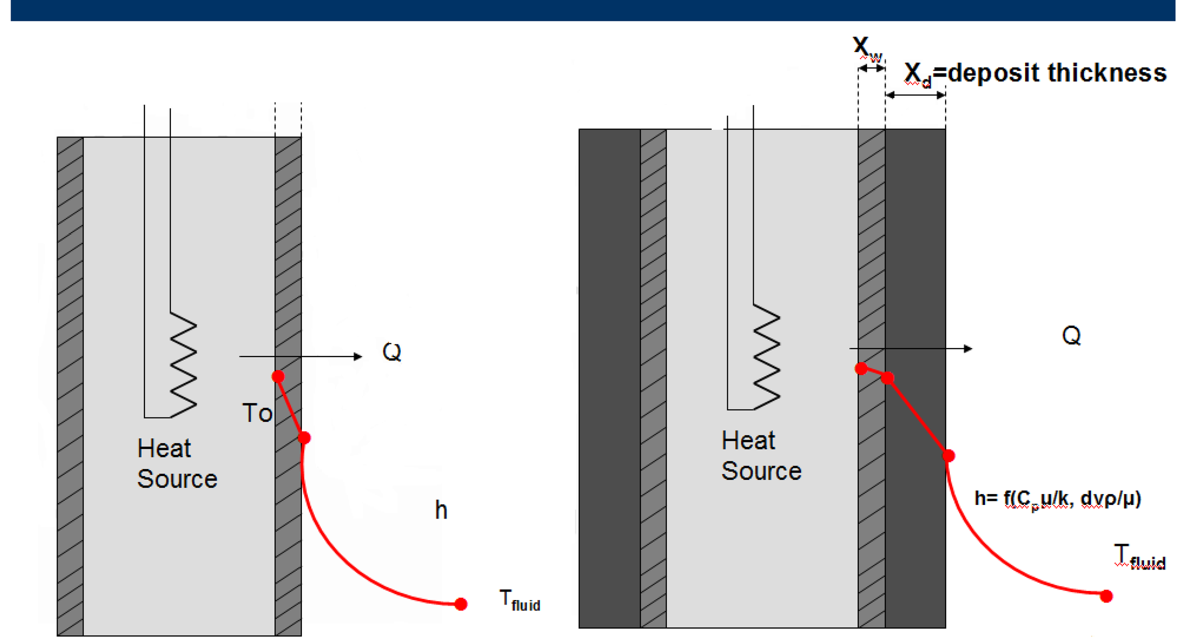


The test wire is held firmly between two electrically isolated clamps that are connected with a four wire electrical connection. A fresh section of clean wire is mounted before each run and after each run the wire is removed from the clamps for analysis.



After the fouling test is completed the wires are washed with xylene, dried, and mounted in conductive epoxy. They are then cross sectioned and polished using metallographic techniques. Above are SEM images of the cross sectioned wires with thick fouling deposits surrounding them.

Heat Transfer Theory



$Q_c = U_c A_c \Delta T_c$

r_1=pipewall resistance $= X_w/K_w$

r_2=fluid film resistance $=1/h$

$R_{total} = 1/r_1 + 1/r_2$

$1/U_c = (X_w/K_w + 1/h)$

$Q_f = U_f A_f \Delta T_f$

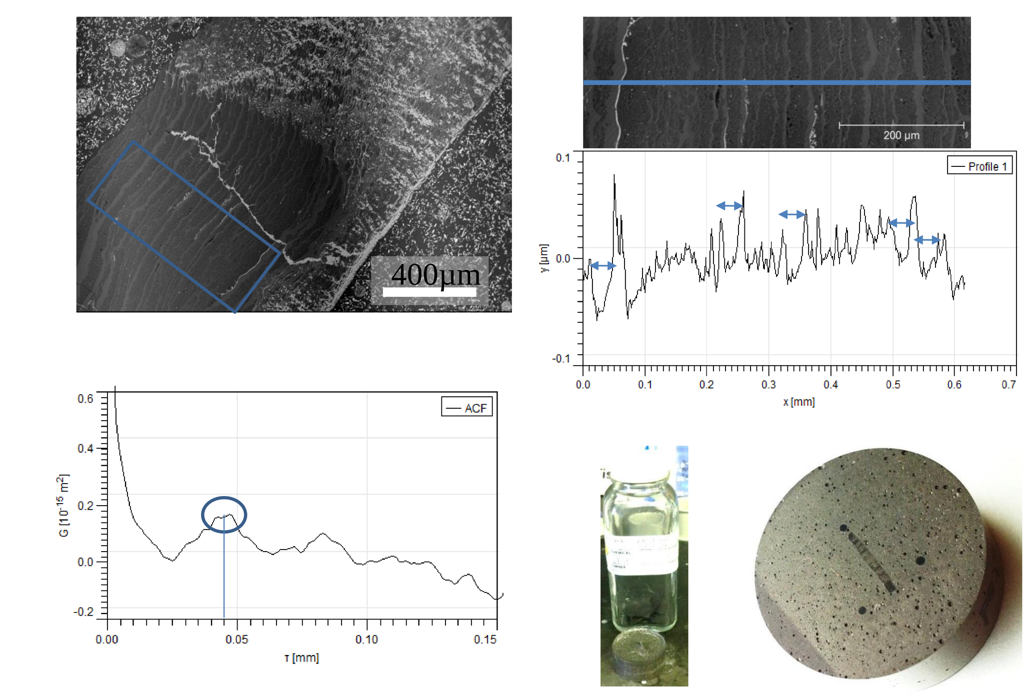
$1/U_f = (X_w/K_w + 1/h + X_d/K_d)$

$1/Uc$

$FF = 1/U_f - 1/U_c$

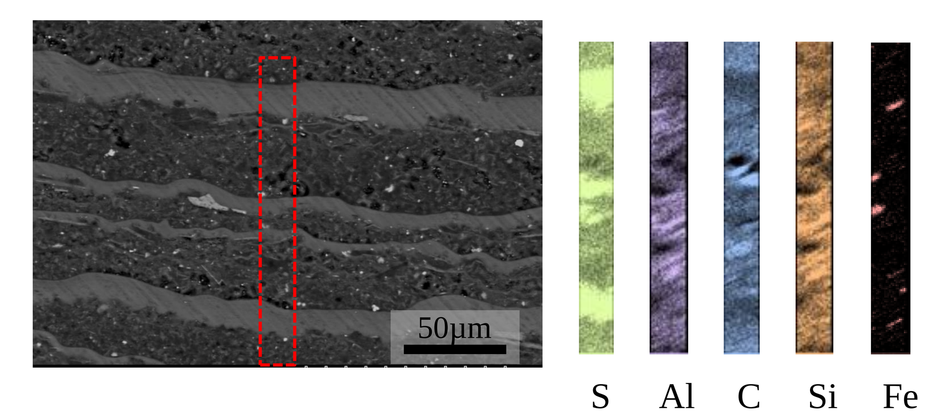
By measuring the initial temperature of the wire, the initial heat flux from the wire and then monitoring the heatflux from the wire as the temperature of the wire is held constant the Fouling Factor of the deposited coke layer is measured.

Delayed Coker Furnace Samples



Deposits removed during pigging of a Delayed Coker Furnace were mounted in conductive epoxy and analysed using SEM. A line scan of backscattered electron intensity with position was used to quantify the tree-ring spacing. Using an autocorrelation function a period of approximately 450μm was extracted from the image.

Tree Ring Morphology

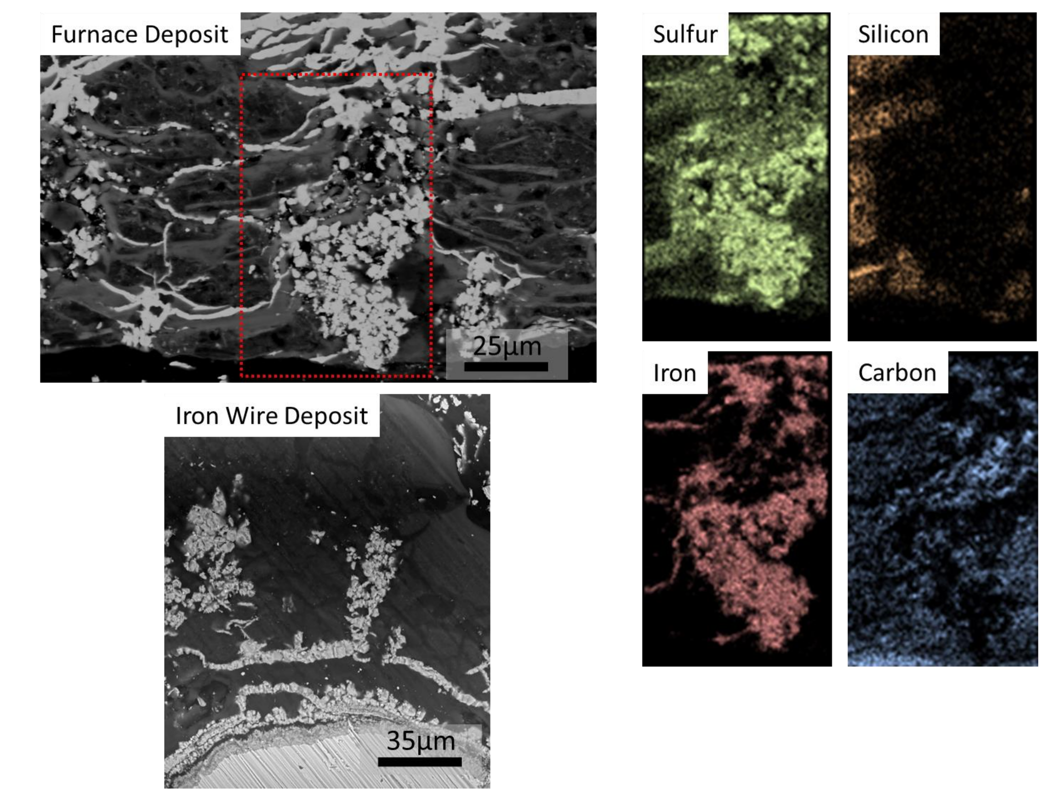


Energy Dispersive Xray Spectroscopy was used to identify elements in the tree ring structure. A strong variation in sulfur content is evident over the width of several layers. Iron is evident in the deposit and always correlates with a strong sulfur signal.

The field unit that the foulant samples were obtained from ran for a period of approximately 6months before being cleaned. By counting the tree rings observed in the deposit and assuming that the feed variation was somewhat constant through this period it was calculated that large variations in the feed composition occur on a 1-2 week period resulting in the variation in sulfur and iron content in the deposited fouling. There is a significant variation in layer thickness over the full thickness of the deposit suggesting that processing conditions over the deposit formation lifetime effected the fouling rate significantly.

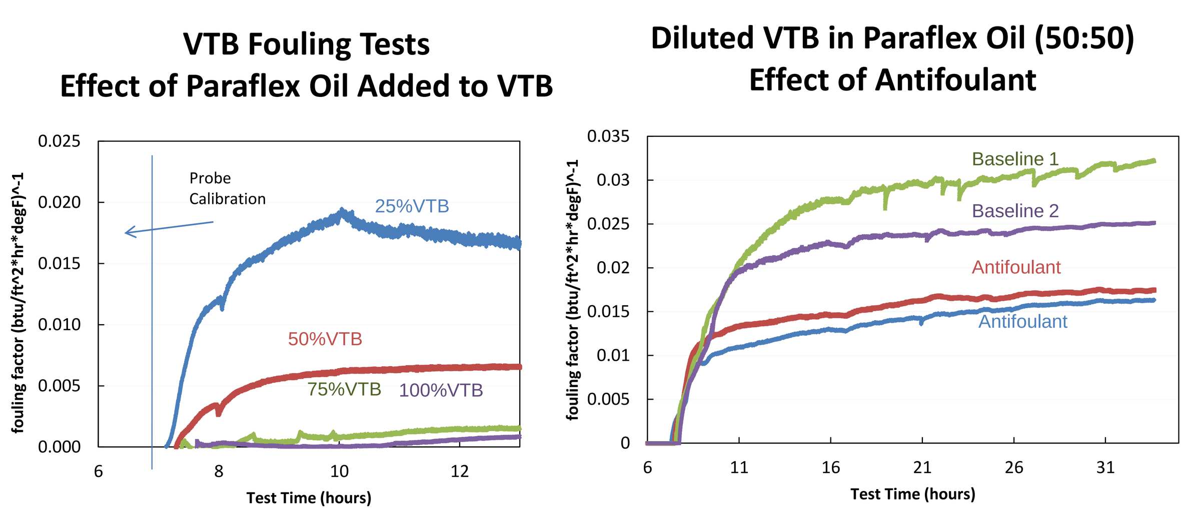
There is potential to correlate the layers to furnace operating condition history to map out what conditions led to the fastest fouling buildup in the furnace.

Sulfide Plume Correlation



Sulfide plume morphology, expected to be the product of expanding gas created through cracking reactions at the metal surface, are clearly evident in both the foulant on FTU test wires and in furnace pigging chips. The plumes consist of a high concentration of iron sulfide and expand as they move away from the metal surface.

Demonstrated Control of Fouling



The Coking rates were reduced by 50% with a chemical additive in FTU tests in VTB feedstock, raising the possibility of a corresponding reduction in the plant assuming a good correlation exists between lab and plant fouling results.

The fouling rate was found to strongly correlate with the ratio of VTB feedstock to Paraflex Oil with the addition of Paraflex oil resulting in a significant increase in fouling rate.

Conclusions

1. **The sulfide plume morphology exists in both furnace and FTU wire foulant deposits**
2. **Furnace deposits have a characteristic "Tree ring" morphology caused by varying concentrations of iron sulfide in the deposit.**
3. **Fouling rates can be controlled through Antifoulant additives and blending with Paraflex Oil.**