Coal –Ash Corrosion of Iron and Nickel Based Alloys

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Motivation

Cost effective power generation is of paramount importance to our economy. The variables that affect power generation efficiency and cost effectiveness include temperature, strength of components at temperature, initial capital cost of the equipment, and durability of the components. Iron-base alloys are less expensive, in general, than the nickel-base alloys. The strength at temperature and durability of iron-base alloys is lower than that of the nickel-base alloys. The trade-off between these two sets of alloys for a given component is not necessarily obvious. In fact, detailed sets of data with regards to the aforementioned variables are needed to make a cost-effective recommendation.

Corrosion behavior is an important variable towards determination of the durability of the components. This effort is directed towards quantification of the corrosion behavior of these two sets of alloys under two types of simulated coal-ash environment in the temperature range of 650–800°C. It is well known that thermal efficiency of the power generators increase with an increase in temperature; but so does corrosion rate. Therefore, for optimal design, knowledge of the behavior of the component(s) under various environmental conditions is necessary.

Specifically, the iron-based alloys studied include:HR3C, 310TaN, HR120, SAVE25, NF709, Modified 800, 347HFG, and HCM12A. In addition, Alloy 800H clad with Alloy 671 was also included in some of the tests. Nickel-base alloys tested include: 600, 601, 690, 617, 625, 602CA, 214, 230, 45TM, HR160 and 693.

Accomplishments

Two separate furnaces were set up for the oxidation runs. The gaseous environment in both furnaces was kept the same at 1 vol.% SO_3 in air. In one furnace, the specimens were subjected to chloride-free simulated coal-ash. The composition of the ash was (in wt): 30% each of Al_2O_3, SiO_2 and Fe_2O_3 and 5% each of sodium sulfate(Na_2SO_4) and potassium sulfate(K_2SO_4). In the other furnace, 1% NaCl was added to the aforementioned ash. The composition of the second ash was: 29.25% each of the three oxides, 5.625% each of the two sulfates and 1% NaCl.

Tests were conducted at 650, 725, and 800°C. A typical test run is made in this manner: the specimens are inserted in the furnace at room temperature; the furnace is brought to temperature in the increments of 10°C per hour. The specimens are furnace cooled after an exposure of about 168 hr. The specimens are removed from the furnace, weighed, dimensionally measured, and returned to the furnace and the cycle repeated. The test is terminated when the specimens either oxidize significantly or disintegrate. Depending upon the oxidation kinetics, occasionally, a small sliver of a given specimen may be cut for metallographic examination. Upon termination of the test, all the specimens are examined via optical and scanning electron microscopy.

Both, the iron- and nickel-base samples have been oxidized at the above noted three temperatures with the exception of 725°C run for the nickel-base alloys, which is currently in progress. This run should be completed within the next two months.

Corrosion rate is measured in two distinct ways. The first method is the traditional one, wherein the weight change is plotted against time. This procedure is not necessarily reflective of "corrosion" for some of our samples. This is becauseduring the test we found that the coal-ash forms a complex slag layer on some of the samples tested. This slag layer is not very adherent and flakes/peels off in a random manner.

Therefore, some samples in our group may show true cyclical weight change behavior due to oxidation – initial weight gain followed by weight loss as the oxide layer breaks off, followed by weight gain and again weight loss as the new oxide layer falls of while the others, especially the ones that have a pronounced "slagging" tendency, show wildly exaggerated weight gain/loss pattern. Therefore, we have chosen a different parameter to reflect true oxidation behavior. This involves measurement of scale thickness and internal penetration in the substrate alloy. In this, we measure the depth of oxide formation in a composite way. We measured both, the bulk oxide layer, if any, and penetrated oxide formed within the alloy matrix and along grain boundaries and other high diffusivity paths.

Metallographic examination of the tested specimens is being completed. Examples of typical formations are shown in Figure1. Likewise, examples of weight change versus time for various temperatures and alloys are shown in Figure 2.

Results show that corrosion rate versus temperature has a maxima around 725°C, with the rate being dependent on the alloy chemistry. Several Fe-base alloys showed acceptable rates in the sulfate-containing coal-ash environment, but NaCl in the ash led to catastrophic corrosion. Nickel-based alloy, in general, were significantly more resistant to oxidation, as compared to the iron-base alloys, for a given environment.

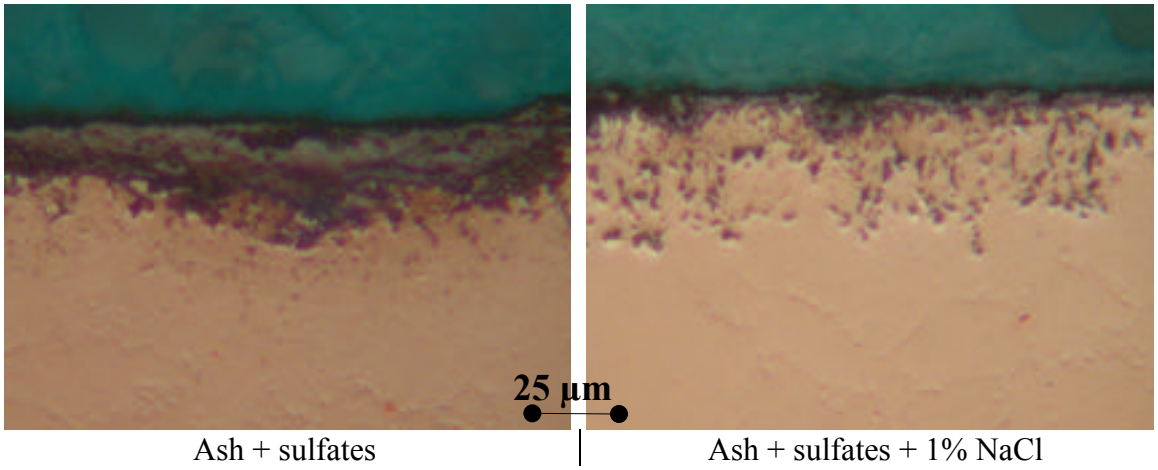

Figure 1. Scanning electron photomicrograph of Alloy 693 after 1680-h exposure in two different coal ash mixtures at 650°C.

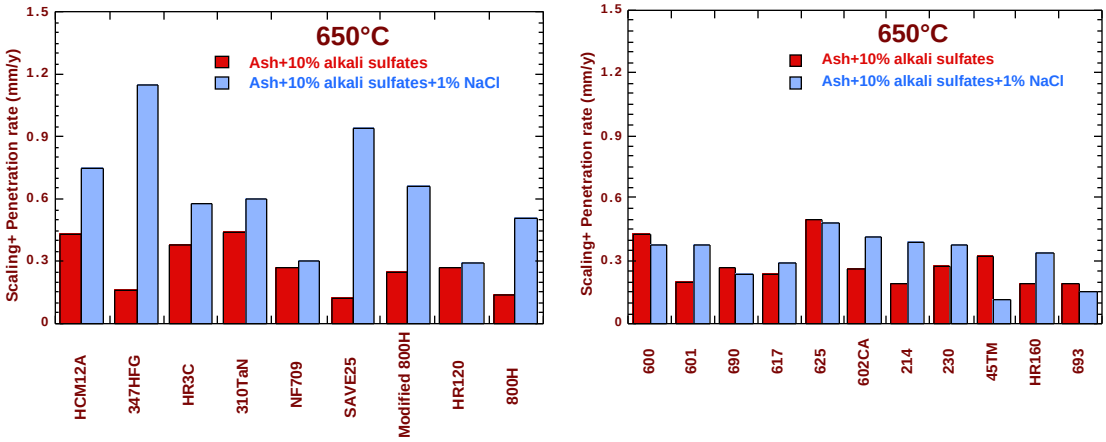

Figure 2. Scaling and Penetration Data for Fe- and Ni-base Alloys tested at 650°C in two different coal-ash Mixtures.