TITLE: **A Novel Low-Temperature Diffusion Aluminide Coating for Ultrasupercritical Coal-Fired Boiler Applications**

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OBJECTIVES

Conventional aluminizing processes by pack cementation or chemical vapor deposition are typically carried out at elevated temperatures (1000-1150°C). Thermochemical treatment of ferritic/martensitic steels at these temperatures could severely degrade their mechanical properties such as high-temperature strength and creep resistance. However, when the aluminizing temperature is lowered, brittle Al-rich intermetallic phases, such as Fe_2Al_5 and $FeAl_3$, tend to form in the coating layer, which could adversely affect the mechanical behavior of the entire coating system, particularly the resistance to fatigue cracking. The objective of this research is to develop a low-temperature (≤ 700°C) aluminide coating with reduced brittleness and improved performance via pack cementation for protection of ultrasupercritical boiler internal tubing.

ACCOMPLISHMENTS TO DATE

Our previous thermodynamic calculations on packs containing NH_4Cl activator and Al-Cr binary masteralloys indicate that the partial pressure of metal halide vapors depends on both the pack composition and aluminizing temperature. More importantly, the calculation results suggest that it is thermodynamically feasible to tailor the Al activity in the pack cementation process by controlling the Al content in the masteralloy.

Initial coating development was carried out at 650°C using pure Al as the masteralloy to obtain some *baseline* coatings. The effect of activator and masteralloy on coating formation was investigated by varying the amount of activator and Al masteralloy. The results show that a continuous coating (30-60 μm) with mainly Fe_2Al_5 phase can be deposited via pack cementation at temperatures as low as 650°C. With increased amounts of activator and masteralloy, the coating thickness was increased significantly. However, the coating thickness was not uniform where thicker coatings were formed near the specimen edges/corners. Also, cracks were observed in the brittle Fe_2Al_5 coatings.

An additional surface treatment was introduced prior to the pack aluminization to speed up coating growth and improve coating uniformity through increasing the dislocation density near the specimen surface. The aluminide coatings formed at 650°C with and without grit blasting treatment were compared. However, no significant effect was found for the grit-blasting surface treatment, where the coating thickness remained similar to that formed on the specimen ground with #600 SiC paper.

In order to reduce the Al content in the coating and achieve better surface quality, a non-contact pack-specimen arrangement was used to prevent powder embedment in the coating, where the specimens were separated from the powder mixture by either porous alumina paper or alumina foam disks. Compared to the contact arrangement, where typical weight gains of ~12 mg/cm^2 were obtained after 6h aluminization at 650°C, a significant variation in the weight change was noticed for the non-contact arrangement, ranging from 5.2 to -4.6 mg/cm^2 (the negative weight change indicating a weight loss). An Fe_2Al_5 coating of 20-30 μm thick was formed near the corners of the specimen, while thinner and non-uniform coatings (< 10 μm) with lower Al content (mainly FeAl phase) were found in the center area of the specimen. The weight loss during the aluminizing process was likely due to Fe evaporation, as Fe was detected in the residues of alumina paper/foam attached to the specimen surface after aluminization.

FUTURE WORK

- Synthesize aluminide coatings with reduced Al content to prevent the Fe_2Al_5 formation. A variety pack compositions with different amount and composition of masteralloys will be utilized to adjust the Al content in resulting aluminide coatings.
- Initiate oxidation testing on the low-temperature coatings in water-vapor environment and compare their oxidation performance with the aluminide coatings fabricated at high aluminizing temperatures.

LIST OF PAPER PUBLISHED, CONFERENCE PRESENTATIONS, STUDENTS SUPPORTED UNDER THIS GRANT

- **Publications:**

  Conference Proceeding: *Y. Zhang, Y. Q. Wang, and B. A. Pint, "Evaluation of Iron Aluminide Coatings for Oxidation Protection in Water Vapor Environment", NACE International, Corrosion 2007.*

- **Presentations:**

  Y. Zhang, Y. Q. Wang, and B. A. Pint, "Evaluation of Iron Aluminide Coatings for Oxidation Protection in Water Vapor Environment", NACE International, Corrosion 2007.

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