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CRADA Final Report
for
CRADA No. ORNL-97-0481

Advanced Modeling and Materials in Kraft Pulp Mills

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Date Published: May 2002

Prepared by
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Managed by
UT-BATTELLE, LLC
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CONTENTS

CRADA No.: 97-0481 with Weyerhaeuser Company

Title: Advanced Modeling and Materials in Kraft Pulp Mills

Abstract

This CRADA provided technical support to the Weyerhaeuser Company on a number of issues related to the performance and/or selection of materials at a number of locations in a pulp and paper mill. The studies related primarily to components for black liquor recovery boilers, but some effort was directed toward black liquor gasifiers and rolls for paper machines.

Objective

The purpose of this CRADA was to assist Weyerhaeuser in the evaluation of materials exposed in various paper mill environments and to provide direction in the selection of alternate materials, when appropriate.

Benefits to the Funding DOE Office's Mission

DOE support for this project came through the Advanced Industrial Materials Program. This program benefitted from this project because of the significant body of information that was gained regarding material performance in recovery boilers and black liquor gasifiers. Although some of this information was initially identified as Protected CRADA Information, it will eventually be available to paper companies, boiler manufacturers and other component and material fabricators.

Technical Discussion of Work Performed by All Parties

This project addressed a number of material issues that were of concern to the Weyerhaeuser Company. Those issues included:

characterization of exposed sootblower tubes and alternate designs,

characterization of chromized tubing panels,
adaption of recovery boiler model to URNL's massively parallel computer,
characterization of ceramic coatings on large rolls,
characterization of welds in Sanicro 38 tubing by Babcock & Wilcox,
characterization of second chromized panel,
analysis of failed economizer tubes, and
characterization of black liquor gasifier refractories.

Characterization of Exposed Sootblower Tubes and Alternate Designs

Sootblower tubes are used in recovery boilers to remove the material that accumulates on the surfaces of the heat exchanger tubes located near the top of boilers. These sootblower tubes are approximately 4 inches in diameter, and they spray high pressure steam as they rotate and advance into the boiler. Different manufacturers have different sootblower designs, and there is always a significant feeling of competition between the companies. One of the conventional designs utilized a chromium plating on the steel tubes. Shortcomings of this design include the tendency for the chromium plating to flake off and leave a very rough surface that can degrade other surfaces that it contacts. In addition, the environmental issues that were associated with chromium plating are expected to cause closing of some plating facilities and significant cost increases in the others.

In response to the recognized problems with chromium plated sootblowers, Diamond Power introduced a new sootblower tube design. After ORNL signed a PIA with Diamond Power, samples were provided so that the composition and depth profile of the coatings could be determined. This information was presented to Weyerhaeuser to show the variations in layer thickness and the composition of the coating. In addition, several of these new style sootblowers were installed in the boilers at certain Weyerhaeuser mills, and some effort was directed toward monitoring their performance.

Characterization of Chromized Tubing Panels

Several years ago, Weyerhaeuser had a proposed project called "Mid-South" to build an entirely new mill in Arkansas. Because of the good experience at several Weyerhaeuser Mills with Combustion Engineering-built boilers, strong consideration was given to a boiler that utilized chromized carbon steel tubes, a material being supplied and recommended by Combustion Engineering (CE). In order to resolve some of the questions related to chromized tubes, ORNL was asked to evaluate a panel of chromized tubes that was specially prepared by CE. The analysis of this panel showed that some quality control problems were encountered in the manufacture of the panel, so CE provided a second panel, under more carefully controlled conditions, for analysis at ORNL.

Characterization of the second chromized tubing panel was conducted in the same manner as the first examination. Samples were selected in a well defined pattern from across the panel taking care to get representative samples from any air port or spout openings that were built into the panel. The samples that were selected were prepared for metallographic examination then micrographs were taking to show the depth of the chromized layer. In addition, selected samples were examined with the electron microprobe to determine the composition of the surface layers as well as to define the concentration variations through the surface layers.

Adaption of Recovery Boiler Model to ORNL's Massively Parallel Computer

A significant modeling effort has been conducted at the University of British Columbia (UBC) to describe the reaction and the flow of gases in a black liquor recovery boiler. Recovery boiler models have been developed by several organizations, but the UBC model was considered one of the most advanced. In an effort to provide a means to accelerate the calculations, an investigation was conducted to determine if the UBC code could be modified to run on the massively parallel computer available at ORNL.

An effort was also made to develop a graphical user interface that would permit the UBC code to be used as a training tool to teach recovery boiler operators the effect of boiler operating

mounted, ground, polished, etched and photographed in order to enable ORNL staff to evaluate the quality and depth of the welds. The information on penetration of the weld into the co-extruded tube as well as weld defects such as porosity, lack of fusion, etc was communicated to Weyerhaeuser in the form of presentations and letter reports.

Analysis of Failed Economizer Tubes

The Weyerhaeuser mill in New Bern, North Carolina, had a new economizer section installed in late spring a couple of years ago. To the surprise of mill personnel, several tube failures occurred in this new economizer over a period of several months. Because Weyerhaeuser personnel were not certain of the cause of these failures, ORNL was first asked to work with the economizer manufacturer to try to determine the cause of the failures. Subsequently the economizer manufacturer and Weyerhaeuser were not able to agree on the failure mechanism, so additional funding was provided to ORNL for more detailed analysis of failed tubes, analysis of flow induced vibrations and modeling of possible two phase flow in the economizer tubes. Analysis of the failed tubes involved thorough metallographic examination as well as characterization of the fracture surface with scanning electron microscopy. Microhardness measurements were made on the failed components, and laboratory studies were conducted to simulate the possible failure modes.

Finite element modeling was conducted to identify the various vibration modes that could develop in the tubes given the mechanical properties of the tube materials and the economizer design. Fluid dynamic studies were conducted to characteristic the flow in the tubes and particularly to determine if two-phase flow, reverse flow or stagnant conditions could develop in the tubes. Field studies were also conducted at the mill to gain additional information on the temperature and vibrations experienced by the tubes.

Characterization of Black Liquor Gasifier Refractories

Because of the many problems associated with black liquor recovery boilers, a number of efforts have been and/or are being conducted to develop black liquor gasifiers as eventual replacements for recovery boilers. Weyerhaeuser has taken a leading role among paper companies in the effort to develop the gasification technologies. One effort in this regard has been the installation at Weyerhaeuser's New Bern, North Carolina, mill of a black liquor gasifier. Performance of this gasifier was, at best, marginal and this was particularly emphasized by the problems with both refractory and metallic components in the gasifier. Because of the issues between Weyerhaeuser and Kvaerner Chemrec, developer of the gasifier, concerning the fault for the component degradation, ORNL was asked by Weyerhaeuser to conduct analyses of the failed refractories as well as some of the gasifier's metallic components.

The metallic components examined included the stainless steel cooled support ring that provided support for the refractory in the vicinity of the outlet for the molten salts. It was determined that sections that were much too thick and of a material with relatively poor thermal conductivity contributed to the cracking and corrosion observed on the support ring.

One solution considered for the support ring was to replace the stainless steel with carbon steel and then apply a metal spray. A visit was made to the facilities of one of the metal spray companies, and samples of several materials were provided by them for evaluation at ORNL.

Pieces of the mullitic refractory that was initially used in the gasifier were observed in the trap at the bottom of the gasifier vessel. Because these samples were immersed in water, there was a question of whether any reaction products might have been washed away. Consequently, during shutdowns, samples of the refractory were removed for more thorough examination. The performance of the mullite-based refractory was far less than desired, so after initially making repairs, it was decided to switch to a fused cast alumina refractory. To the disappointment of all involved, the cast alumina refractories also swelled and fell off the wall in significantly sized pieces. Analyses were conducted at ORNL on both types of refractories to try to determine the cause of the degradation. It was found that water-soluble corrosion products developed on both types of refractories; sodium aluminum silicate on the mullite and sodium aluminate on the alumina. Formation of these products caused significant expansion of the refractories.

Inventions

No inventions were developed during the performance of this CRADA.

Commercialization Possibilities

Several of the materials evaluated or characterized have been put into use, including the Sanicro 38 recovery boiler floor tubing and the sootblower tubes with the newly developed coating.

Plans for Future Collaborations

The documents for another CRADA have been prepared and are being processed.

Conclusions

The results of the studies conducted under this CRADA have provided a considerable amount of useful information to Weyerhaeuser, and eventually the entire forest products community, that should permit more reliable and safer operation of components including recovery boilers and black liquor gasifiers.

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