DOE/PC/95211--T1

LEHIGH UNIVERSITY

BETHLEHEM, PA

ENERGY RESEARCH CENTER

Cermet Composite Thermal Spray Coatings for Erosion and Corrosion Protection in Combustion Environments of Advanced Coal-Fired Boilers

Progress Report Prepared For U.S. Department of Energy under Grant No. DE-FG22-95PC95211

Project Period: 7/14/95-12/31/96

Semi Annual Technical Report For The Period July 1995 through January 1996

by

B. F. Levin, J.N. DuPont and A.R. Marder

Energy Research Center
117 ATLSS Drive
Lehigh University
Bethlehem, PA 18015

DOE Project Officer: Sean I. Plasynski
Administered by: Cynthia Y. Mitchell

May 2, 1996

EXECUTIVE SUMMARY

Research is presently being initiated to determine the optimum ceramic/metal combination in thermally sprayed metal matrix composite coatings for erosion and corrosion resistance in new coal-fired boilers. The research will be accomplished by producing model cermet composites using powder metallurgy and electrodeposition methods in which the effect of ceramic/metal combination for the erosion and corrosion resistance will be determined. These results will provide the basis for determining the optimum hard phase constituents size and volume percent in thermal spray coatings. Thermal spray coatings will be applied by our industrial sponsor and tested in our erosion and corrosion laboratories.

During the last quarter, model Ni-Al_2O_3 powder cermet composites were produced at Idaho National Engineering Laboratory by the Hot Isostatic Pressing (HIP) technique. The composite samples contained 0, 21, 27, 37, and 45 volume percent of Al_2O_3 in a nickel matrix with an average size of alumina particles of 12 um. The increase in volume fraction of alumina in the nickel matrix from 0 to 45% led to an increase in hardness of these composites from 85 to 180 HV_{1000}. The experimental procedure and preliminary microstructural characterization of Ni-Al_2O_3 composites are presented in this progress report along with plans for the research in coming year.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

I. INTRODUCTION

Present coal-fired boiler environments remain hostile to the materials of choice since corrosion and erosion can be a serious problem in certain regions of the boiler. Recently, the Clean Air Act Amendment is forcing electric power plants to reduce NO_x emissions to the environment. To reduce NO_x emissions, new low NO_x combustors are utilized which burn fuel with a substoichiometric amount of oxygen (i.e., low oxygen partial pressure). In these low NO_x environments, H_2S gas is a major source of sulfur. Due to the sulfidation process, corrosion rates in reducing parts of boilers have increased significantly and existing boiler tube materials do not always provide adequate corrosion resistance. Combined attack due to corrosion and erosion is a concern because of the significantly increased operating costs which result in material failures.

One method to combat corrosion and erosion in coal-fired boilers is to apply coatings to the components subjected to agressive environments. Thermal spray coatings, a cermet composite comprised of hard ceramic phases of oxide and/or carbide in a metal binder, have been used with some succes as a solution to the corrosion and erosion problems in boilers. However, little is known on the effect of the volume fraction, size, and shape of the hard ceramic phase, on the erosion and corrosion resistance of the thermally sprayed coatings. It is the objective of this research to investigate thermally sprayed metal matrix composite (cermet) coatings in order to determine the optimum ceramic/metal combination that will give the best erosion and corrosion resistance in new advanced coal-fired boilers.

II. EXPERIMENTAL PROCEDURE

II.A Alloy System

Model Ni-Al_2O_3 powder cermet composites were produced at Idaho National Engineering Laboratory by the Hot Isostatic Pressing (HIP) technique. Alloys contained from 0 to 45 vol. % of hard phase (Al_2O_3) in a nickel matrix. The variation in alumina content in Ni-Al_2O_3 composites will provide a systematic change in their microstructure and mechanical properties. Therefore, the effect of hard second phase particles on mechanical properties and erosion resistance of metal-matrix composites can be analyzed.

II.B. Microstructural Characterization

The cermet alloys were cross-sectioned and mounted in cold curing, thermosetting epoxy and each sample was mechanically polished to a 0.04 um surface finish. The microstructure of the Ni-Al_2O_3 composites was characterized using Light Optical Microscopy (LOM). A LECO 2001 quantitative image analysis system was used to measure volume fractions and sizes of the hard phase (Al_2O_3). Hardness measurements were made on cross-sectioned surfaces of all composites using a Vickers indenter and 1000g load.

III. RESULTS

The composite samples contained 0, 21, 27, 37, and 45 volume percent of Al_2O_3 with an average size of alumina particles of 12 um. Microstructures of the Ni-Al_2O_3 composites with different volume fraction of hard Al_2O_3 particles (dark phase) at low and high magnifications are shown in Figures 1a-c and 2a-c, respectively. The effect of alumina volume fraction on hardness is shown in Figure 3. An increase in volume fraction of alumina in the nickel matrix from 0 to 45% led to an increase in hardness of these composites from 85 to 180 HV_{1000}. Hardness measurements show that variation in alumina volume fraction produces significant change in mechanical properties of the composites. The effect of the mechanical properties on erosion resistance will be analyzed in the following progress reports.

IV. PLANS FOR COMING YEAR:

In addition to *powder processed* Ni-Al_2O_3 composites, an *electrodeposition technique* will be used to produce cermet coatings with a nickel matrix and Al_2O_3 particles of controlled volume percent (from 0 to 40%) and size from 0.5 to 1um. Coating microstructures will be characterized using light optical microscopy, scanning electron microscopy and quantitative image analysis. Next, the powder and electrodeposited cermet alloys will be tested in our erosion simulator at different velocities. From these results we expect to determine the effect of hard phase constituents size and volume percent on the steady-state erosion rate. These results will form the basis for determining thermal spray coating hard phase constituent size and volume percent.

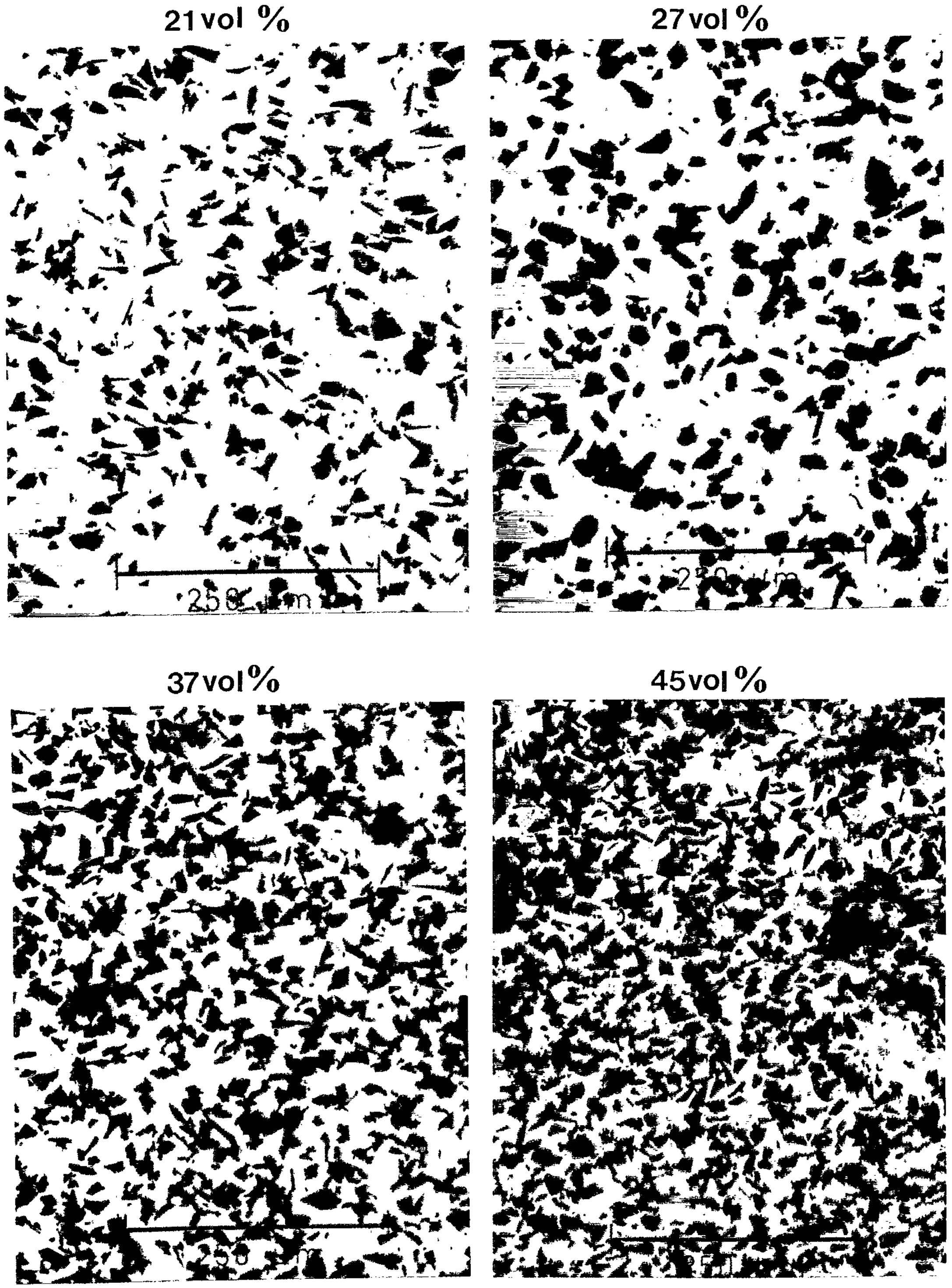

Figure 1a-c. Low magnification photomicrographs of Ni-Al2O3 composites (dark particles are Al2O3).

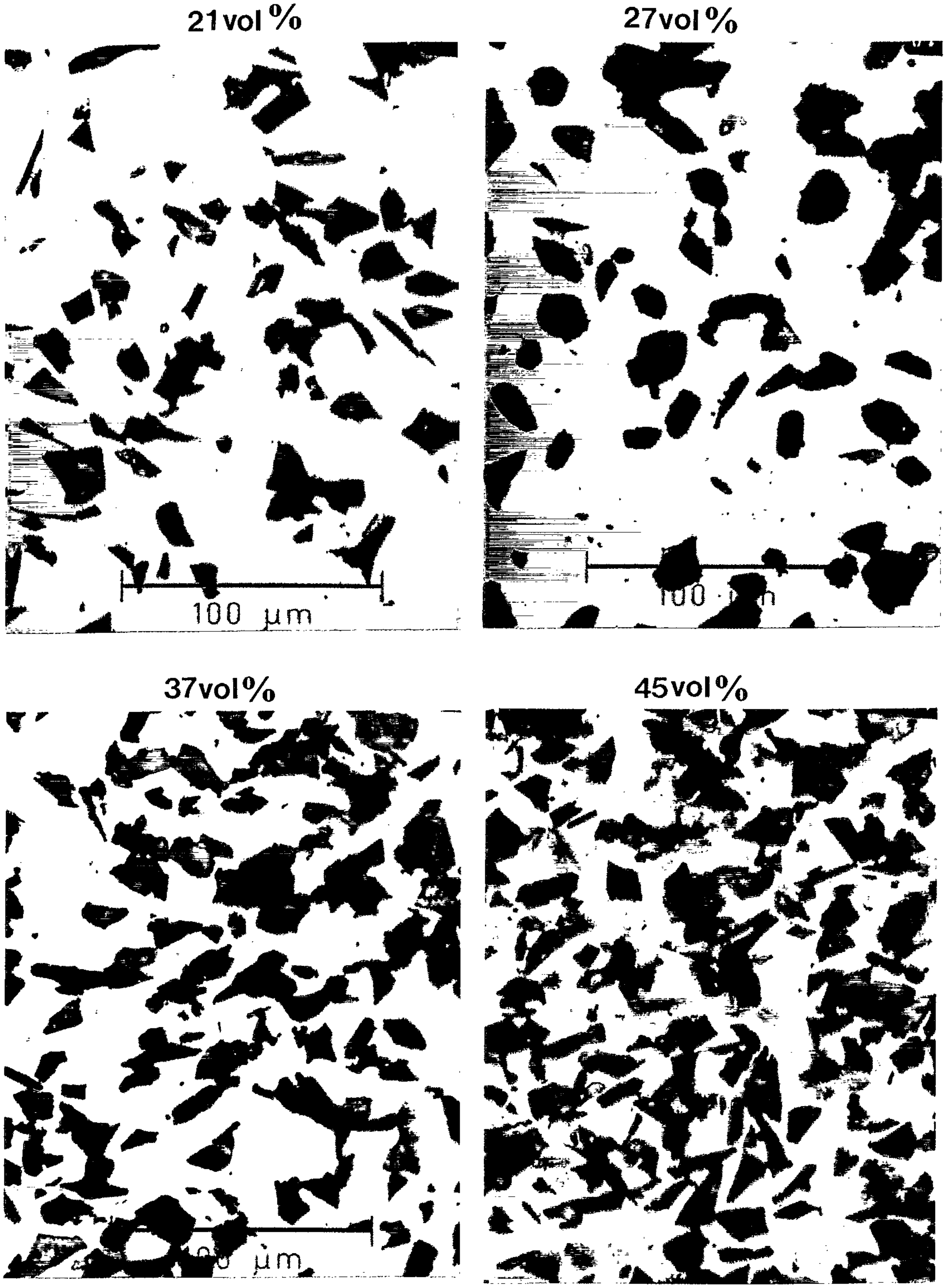

Figure 2a-c. High magnification photomicrographs of Ni-Al2O3 composites (dark particles are Al2O3).

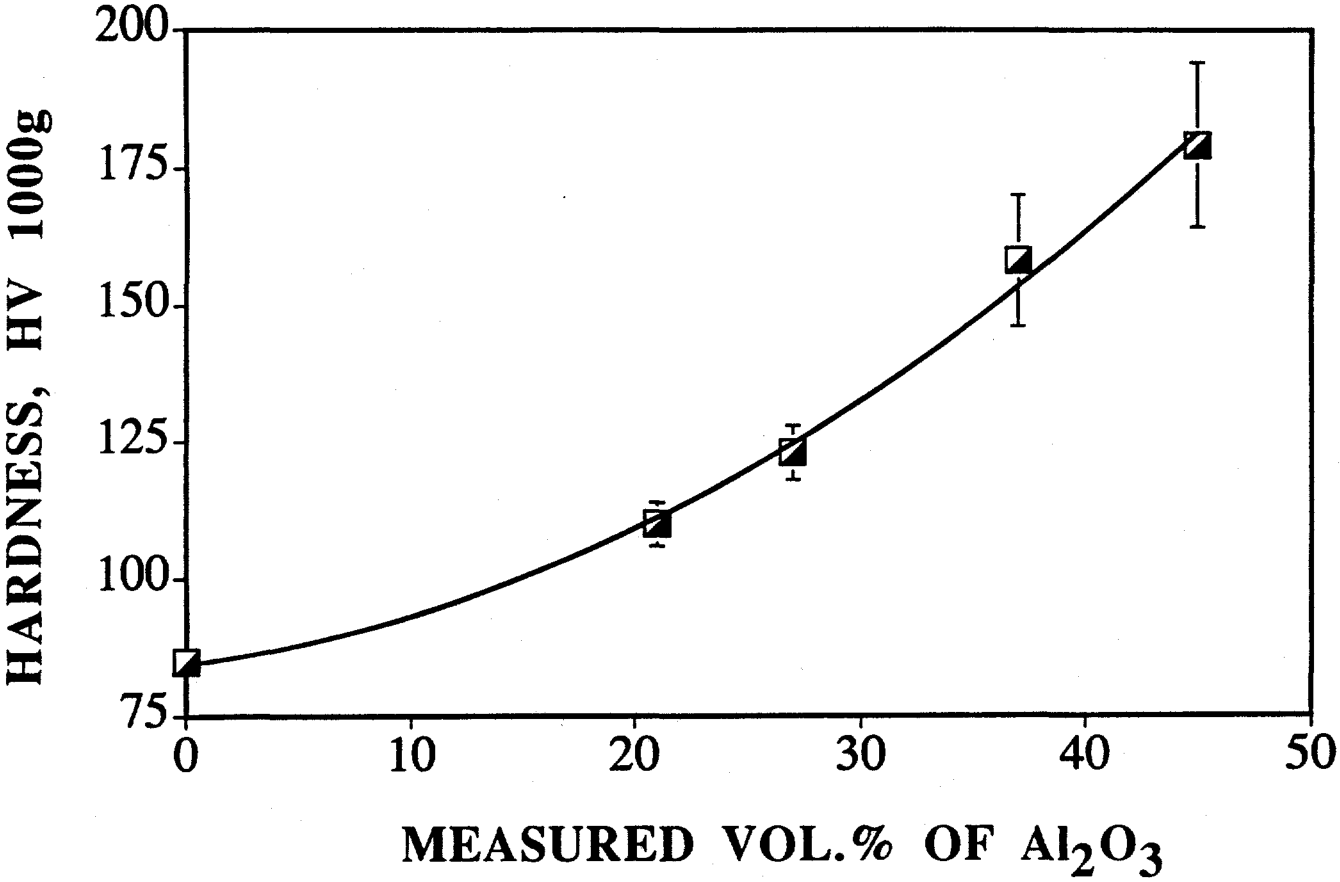

Figure 3. The effect of volume percent of Al_2O_3 particles on hardness of Ni-Al_2O_3 composites.