Nickel Based Superalloy with Improved Weldability and Oxidation Resistance

Fourth Quarterly Report for the Period July 1999 to October 1999

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Summary

This program is part of the U.S. Department of Energy (DoE) Energy Related Inventions Program (ERIP). The purpose of ERIP is to promote and facilitate the development of energy saving technologies that may not otherwise be developed solely by commercial enterprises. The program has been highly successful in achieving its mission.

Project Aim

The aim of this project is to determine and provide technical and economic data to a commercial end user of the alloy so that a full-scale alloy qualification program can be defined and implemented. The object of this project is to define the compositional range for a new alloy that is suitable for evaluation and qualification by a commercial enterprise. Alloy properties that will need to be determined include weldability, oxidation resistance, creep strength, resistance to thermo-mechanical fatigue, microstructure stability, and cost. Test results will be used to finalize the compositional range of an alloy that will undergo a rigorous qualification process.

Project Objective

There are 4 objectives:

1. Define a compositional range for a new alloy that is suitable for evaluation by a commercial enterprise.
2. Optimize alloy properties of weldability and oxidation resistance, creep strength, thermo-mechanical fatigue, microstructure stability, and cost.
3. Evaluate experimental materials in a real manufacturing environment.
4. Develop a range of alloy compositions for final qualification process.

Summary of Project Work Plan

Task 1 - Commercial Interface

In this task the principal investigators will cultivate and maintain a technical and business relationship with an industrial end-user. This is a critical step to the development of an alloy ready for a rigorous qualification program. Continual involvement of an industrial partner will minimize risk and increase the possibility of a successful program.

Task 2 - Evaluation of Test Alloy Composition

This is the most technical part of the program. The relationship between palladium, chromium, and aluminum and alloy properties will be investigated, most notably in terms

of weldability and oxidation resistance. This task includes determining alloy compositions, obtaining alloy powders, testing, and evaluation.

Task 3 - Follow-on Alloy Definition

Two compositions will be evaluated based upon the belief that they will be suitable for a follow-on qualification program. By consulting with an industrial end-user, the compositions will be defined and designed to maximize cost/performance of the alloys. Additional alloy powders will be obtained. Follow-on compositions will undergo a series of tests with key input from an industrial end-user. Test results may be used as part of a full-scale alloy development program.

Task 4 - Development of Preliminary Full Scale Qualification Program

The industrial end-user and the principal investigators will develop a preliminary plan for full-scale qualification. The plan will address the issues necessary to obtain Federal Aviation Administration approval for use as a repair material for turbine blade tips.

Task 5 - Reporting

Reporting will be the primary method of transmitting and archiving final technical data, results, conclusions,

Description of Progress

Progress description will be detailed by Task.

Task 1

Effort to maintain working relationship with Sermatech continued during this quarter. Revised intellectual property agreements were transmitted to Sermatech for review. A trip to Sermatech was postponed so that additional oxidation data could be generated.

The University received a PTO action on its application. All claims were disallowed. However, the patent examiner report detailing the office action indicated that the cited prior art 'fails to meet all the limitations of the instant invention'. This statement provides insight into how the prior art can be overcome. The University has retained outside patent counsel to continue the prosecution of the patent and will be preparing a response. The response is due November 12, 1999. This will be reported on in the next quarterly report.¹

Task 2

Based on the review of prior work and the needs of this program a series of experimental alloys have been established and shown in Table I. As can be seen the Cr level is varied from 5 to 20 atomic percent in the Ni-Pd-Cr alloys and Al is varied from 5 to 10 atomic

percent in the Ni-Pd-Al alloys. Testing these ternaries will help us separate the effects of Pd on Cr_2O_3 and Al_2O_3 formation. This information will be used to help adjust the level of Cr and Al in a commercial alloy. Finally, the last two alloys are chosen to test merge the effect of Pd on ternaries to quaternary alloys. Other solute constituents, such as Co, Mo, and others do not complicate the analysis. During subsequent analysis it was concluded that several non-Pd bearing alloys should also be included into the experimental matrix, to help establish the effect of Pd on oxidation at low and high temperatures.

Table I Experimental Ni-Pd-X Compositions

Alloy I.D.	Atomic Percent			
	Ni	Pd	Cr	Al
5Cr	90	5	5	-
10Cr	85	5	10	-
20Cr	75	5	20	-
5Al	90	5	-	5
7Al	87.5	5	-	7.5
10Al	75	5	-	10
15Cr5Al	75	5	15	5
15Cr10Al	80	5	15	10
5Cr NoPd	95	0	5	-
20Cr NoPd	80	0	20	-
5Al NoPd	95		-	5
10Al NoPd	90		-	10
15Cr5Al NoPd	80		15	5
15Cr10Al NoPd	75		15	10

Isothermal oxidation testing was conducted at 1000°C. The complete results are shown in Figure 1. Generally the greater the mass change and rate of mass change indicates less desirable oxidation property. As expected there are significant differences in oxidation between the alloys. Low Cr and low Al alloys have much higher mass changes than alloys that contain higher levels of these elements.

As detailed in the proposal, 1000°C is a temperature in which previous Pd bearing alloys have have no performed as well as traditional alloys. The reasons for this remain unclear, but it was hypothesized that Pd altered the diffusivity of Al or Cr outward to the scale/metal interface or that Pd increased the diffusivity of oxygen into the alloy, below the scale/metal interface. The test alloys in Table I are designed to address some of these theoretical questions, but they are also designed to identify an engineering solution as well.

The data shown is significant in that the oxidation of the quaternary Ni-Cr-Al-Pd alloys is better than the ternary alloys. Further, the oxidation rate of these alloys is similar to corresponding Pd-free alloys. A comparison between the present alloys and previous Pd-

bearing and Pd-free alloys will be made in the next quarterly. For now, it is sufficient to say that, from an engineering standpoint, the data is very encouraging.

Figure 1 1000°C Isothermal Oxidation, Complete Test Data

The data shown in Figure 1 is re-plotted in Figure 2 except that the time scale has been changed so that early differences in the oxidation behavior of the test alloys can be studied. As shown, the oxidation of the two quaternary alloys is the lowest of those tested to date.

Figure 2 1000°C Isothermal Oxidation, 0-3000 Minutes

Accomplishments

Task 1

- Received response from PTO
- Continued dialogue with Sermatech

Task 2

The following accomplishments were made in Task 2:

- Over 450 hours of 1000°C isothermal oxidation testing complete
- Preliminary engineering analysis of raw data complete

Task 3

No activity on this task.

Task 4

No activity on this task.

Task 5

Reporting is current with program milestones.

Future Activities

Task 1

Continued effort to establish an IP agreement will be made with Sermatech. The investigators will assist outside patent counsel in the preparation of a response to the PTO action received during this past reporting period.

Task 2

A Comparison of current data with previous oxidation test data will be completed. Begin testing at 1200°C and perform preliminary engineering evaluation. Perform metallographic examination of 1000°C test data.

Task 3

Effort related to Task 3 will be initiated.

Task 4

No activity is planned on this task.

Task 5

Fifth quarter report will be prepared, no papers or presentations are anticipated.

Changes in Key Personnel

Primary point of contact at Sermatech has changed from Dr. B. Somers to Mr. J. Helm.

Distribution

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