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MEMORANDUM TO FILE

FROM: GEORGE W. BECKMAN

TRIP REPORT
BATTELLE MEMORIAL INSTITUTE
NOVEMBER 1953

SUMMARY

1. The new hot pressing die successfully bonded a 3" x 5-1/2" composite of nickel plated uranium and aluminum.
2. A die for step pressing has been designed and is now in process of fabrication. It will be finished by mid-December.
3. Copper and magnesium additions to the AlSi bath lower the dipping temperature but increase the formation of intermetallic compound with associate loss of ductility.

Optimum dipping rate for continuous AlSi coatings has been established at

4. The successful extrusion of aluminum over a 1/4 inch diameter cylindrical core indicates the possibilities of this method.
5. 7-1/2% ZrU is non-sensitive to oxygen content under crevice corrosion test conditions in boiling demineralized water.

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JR. Cohen 9/28/88
J. Smith 9/28/88 Date

MASTER

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6. A method has been developed by which progressive deterioration of bond layer in boiling water can be non-destructively followed by resistivity measurements.

Preliminary results from using this technique bear out previous findings that the copper bond is not as corrosion resistant as nickel or AlSi.

7. Two non-destructive methods have been developed by which thickness of electroplated nickel on uranium can be measured.

DISCUSSION

Pressure Bonding

Scale-up of pressure clad samples from 1"x1" to 3"x5-1/2" has been successfully accomplished using the picture frame technique. Core thickness was 0.175", cover plates 0.032". Cores were electroplated with nickel to a thickness of 0.0003". Pressing conditions were [REDACTED] psi at [REDACTED] for [REDACTED] under full load. A partial load of approximately 1,000 psi was applied throughout the heating cycle for about 15 minutes to displace entrapped air between the bonding surfaces.

The resulting bonds were excellent in that they could not be pulled apart without tearing the aluminum cover plates. Reduction of pack and core were measured by hand micrometer on samples pressed without nickel barrier layer to facilitate the post press stripping operation. No reduction of the core could be measured in this manner. The cover plates were plastically deformed 0.004" per side, or approximately 12%. More scale-up work is contemplated to verify these results.

Work leading to a better understanding of the corrosion mechanism has been continued. It has been observed that all samples pressure bonded with barrier layers of Ni, Cu, Ni and Cu, or AlSi failed in corrosion tests by separation of clad and core. Current effort is towards determining if the corrosion behavior of these systems is caused by different rates of attack or by a difference in length of incubation period before attack begins. Should the rate of attack be shown to be the same, the choice of nickel over copper as a barrier layer may not be a valid one in light of the superior bonding characteristics of the latter. Metallographic evaluation of corrosion specimens is expected by mid-December.

The pressure bonding group is also concerned with measuring tensile strength of U-Ni-Al bonds. The purpose of this work is to establish the minimum and optimum pressing conditions with respect to tensile strength. Earlier attempts with the pressing of two aluminum rods (1/4 inch diameter) and an intermediate wafer of nickel plated uranium were unsuccessful due to local upsetting of the softer aluminum which jammed the die. This difficulty will be met by using uranium rods and an aluminum wafer. In addition, a new die has been completed. It is only one-half as long as its predecessor and it is tapered to aid in retraction of the specimen. Tensile testing of bonds is scheduled after the corrosion evaluation is completed.

Three samples from National Research Corporation were submitted for evaluation at BMI. They were coated with approximately 0.0007" of chromium by a vapor deposition technique. BMI will clad the samples with aluminum by hot pressing and corrosion test the bonded composites. Chemical analysis and thickness measurements of the coating will also be undertaken.

A stem pressing program has recently been initiated at BMI. This project is intended to supplement the work being done at the plant. To date a die has been designed and is currently being fabricated. The female part of the die is a one piece channel 3/4" long, heated its entire length by Cal-rod units. The ram is 4" long and is formed so as to exert a side pressure to prevent seizing in the die. It is estimated that the die will be finished by mid-December.

Roll Cladding

The scale-up of roll clad samples to 3"x18" is underway. Three cores have been nickel plated and three picture frames are ready for rolling as soon as a minor repair has been made to the rolling mill. BMI will use an uncovered steel frame outside the aluminum picture frame for edge and end restraint.

A series of tests on 2"x3" samples are projected for the study of a post anneal on bond strength.

When extruded sheath is available it is intended to study end problems.

Al-Si Dipped Coatings

The remaining objective of the dipped coating program is that of finding an addition agent for the bath which will materially reduce intermetallic compound formation with an associated increase in coating ductility. This can be accomplished by reducing either the rate or extent of diffusion by addition agents which lower the bath temperature or form effective diffusor barriers.

[REDACTED]

Previous results with a hypoeutectic bath showed an increase in intermetallic compound formation. It was also observed that the eutectic bath produced a structure containing primary aluminum dendrites. In an effort to decrease the intermetallic compound formation, and at the same time reduce the primary aluminum dendrites found in the coatings from the eutectic bath, a 14% hypereutectic bath was tried. It was observed that the quantity of intermetallic compound was approximately equal to that formed in an eutectic bath. Furthermore, the structure still contains approximately the same volume of primary aluminum dendrites.

[REDACTED]

DIPPING RATE AND CONTINUITY OF COATING

Dipping Rate
In./Sec.

Number of Samples	
Completely coated	Incompletely coated

2
2
9
1
1
0
0

0
0
0
2
1
2
2

It is also reported that oven drying prior to dipping is not critical. Satisfactory results were obtained with slow dipping at [REDACTED] without the drying operation.

[REDACTED]

Extrusion Cladding

Early attempts to extrude aluminum over a cylindrical core were unsuccessful. Radial forces in the upset aluminum billet caused seizing of the core subjecting it to tensile stresses above its ultimate strength. Recent experiments with a protective steel mandrel between core and billet have made extrusion possible. While the results to date are preliminary in nature, they do indicate that the process is feasible.

All tests have been run with a flat face die at [REDACTED] at an extrusion rate of 3-1/2"/min. Cores are 1/4" diameter nickel plated steel or uranium. Results are evaluated by X-ray inspection, metallography and peeling tests for bond strength.

To date, 1/16" sheathing has been uniformly bonded to nickel plated uranium cores, and a 0.030" coating has been applied to nickel plated steel cores. An attempt to cover uranium with a 0.030" sheath was unsuccessful due to bending of the uranium, which is not as strong as steel at [REDACTED].

Samples have been successfully bonded on front and back respectively but never on the same sample. A study on influence of die to mandrel distance will be undertaken as a first step towards solving both the bending and the end problems.

Visual examination of X-rays of the bonded composite indicate a uniformly coated sample. A stripping test performed on a 3/16" thick clad sample tore pieces of aluminum indicating a good bond. Metallography shows diffusion between pack components.

Corrosion

Additional corrosion information is available on the 5% Zr alloy. To reconfirm previous results a number of tests have been run to pin down the H₂ to O₂ concentration effect with the 5% alloy. In an environment of 25:1 ratio the alloy has held up for 3 weeks and is still okay. A similar sample exposed to 35:1 ratio environment failed in one week.

The 5% Zr alloy was known from previous experience to be O₂ sensitive in crevice corrosion attack. The 10% alloy, however, proved to be non-sensitive in this respect. It has now been discovered by testing samples in half percent increments from 5 to 10% that the 7-1/2% alloy is not sensitive to oxygen content. This latter alloy has successfully withstood 5 weeks in H₂ saturated water and is still in good condition. (Note that one week or less was sufficient to cause sensitive materials to fail.)

The corrosion group has also been working toward the development of a non-destructive method by which crevice corrosion attack could be followed. A resistance measurement seems to show good promise. A series of tests were run on 1" square sandwiches bonded with AlSi, Ni, and Cu respectively. A plot of resistance versus time shows a parabolic function. In the initial tests the one AlSi sample measured failed in 24 hours; Cu failed in 96 hours, and the resistance of the Ni continued unchanged at 96 hours. The premature failure of AlSi is considered to be the result of a poor bonding job. The uneven coating of AlSi obviously did not permit a continuous bond. New samples will be measured. Calibration will be effected by testing samples with varying contact areas of aluminum, as well as by metallographic evaluation of the standard sample.

Non-Destructive Testing

Two non-destructive methods for measuring nickel plating thickness have been developed at BMI, an X-ray and an eddy current technique respectively. Both methods have been shown to be feasible and calibration and determination of sensitivity is now underway. The application of X-rays and eddy current techniques to measuring sheath thickness is also being surveyed.

GWB/g