Image Cover Sheet

CLASSIFICATION UNCLASSIFIED	**SYSTEM NUMBER** 510309

TITLE

PROGRESS IN SURFACE ENGINEERING RESEARCH AT DREA

System Number:

Patron Number:

Requester:

Notes: Paper #4 contained in Parent Sysnum #510305

DSIS Use only:

Deliver to: DK

#510309 (4)

PROGRESS IN SURFACE ENGINEERING RESEARCH AT DREA

by

C.V. Hyatt
Defence Research Establishment Atlantic
P.O. Box 1012, Dartmouth, Nova Scotia, B2Y-3Z7,

K. Magee
The Laser Institute
9924-45 Avenue, Edmonton, Alberta, T6E 5J1,

J. M. Cunningham
Defence Research Establishment Atlantic
P.O. Box 1012, Dartmouth, Nova Scotia, B2Y-3Z7,

and

T. Betancourt
Nova Scotia Research Foundation,
P.O. Box 790, Dartmouth, Nova Scotia, B2Y-3Z7.

ABSTRACT

DREA's progress in laser surface engineering research in the past year included determining the optimum process window for laser surface melting nickel aluminum bronze alloys, determining how laser treatment conditions affect laser induced surface topography, developing and applying a laboratory scale method of laser cladding and developing a method to assess preferential dissolution of α in the heat-affected zone of laser treated or laser clad nickel aluminum bronze. In addition the characteristics of electrostatic discharge machined surfaces of TERFENOL-D were examined.

1. INTRODUCTION

For the past three years the Defence Research Establishment Atlantic has been investigating surface engineering processes and laser surface engineering processes in particular. The first two years of work is summarized in a number of reports which cover process window development [1,2], corrosion and fatigue behavior [3,4], corrosion and stress corrosion evaluation [5-7], material characterization [7-9] and laser cladding [10]. The current document summarizes this years work. It deals mostly on the development and verification of cladding procedures for nickel aluminum bronze and a bit of new work on the surface characteristics of EDM machined TERFENOL-D. As well, our future plans are briefly discussed.

2. LASER SURFACE ENGINEERING OF NICKEL ALUMINUM BRONZE

One of the short term goals of our laser surface engineering research is to develop the knowledge and understanding required to confidently apply laser surface engineering to marine copper alloys and to practically demonstrate this technology. The technology has a number of potential applications in surface texturing, component reclamation, and surface modification for wear, corrosion and erosion resistance. It may also be useful for the deposition of metastable alloys with novel properties such as high damping capacity. Though our studies have focused on copper nickel alloys and nickel aluminum bronzes, qualitatively, the results and conclusions should be applicable to most copper alloys with a sufficiently low reflectivity and a fairly narrow, albeit as yet undefined, melting temperature range.

2.1 Laser Surface Melting of Nickel Aluminum Bronze.

Laser surface melting of marine copper alloys has some practical value. However, the most immediate benefit of laser melting experiments on nickel aluminum bronze alloys was to provide information useful in designing and assessing laser cladding experiments. This information, which is considered in detail in [11], includes information about surface character, gas shield effects, and microstructure as a function of processing conditions. Most useful was the determination that a single phase martensitic structure could be produced under a wide range of conduction limited laser treatment conditions, but that above a critical laser energy (500 J/cm at 8.5 mm/s laser scan speed) what appears to be Widmanstätten α forms in the heat affected zone.

Comparing the laser surface melting experiments on nickel aluminum bronze with previous work on Cu-Ni alloys[1] we noted the behavior of nickel aluminum bronze was quite similar to that of Cu-30Ni alloys. One important difference between these alloys is an increased tendency to what appears to be surface breaking gas micro-porosity in the nickel aluminum bronze alloys. One possibility is that this may be a result of differences in inclusion number density and type between the alloys. More work on the possible role of prior inclusions on laser induced defects and characterization of the base materials is needed however.

One final observation we have made in these experiments is that laser surface melting offers an excellent method of controlling surface roughness and waviness. It can be used to produce a uniform waviness with wavelength of 0.25 to 3 mm and amplitude of up to 50 μm–perhaps more.

2.2 Laser Cladding of Nickel Aluminum Bronze.

Laser cladding experiments on nickel aluminum bronze have been quite successful. In contrast to other workers, we have used matching clad material and concentrated on developing a process which could be implemented commercially. We considered both powder and wire feeds to provide clad material, but selected a wire feed despite conventional wisdom which suggests that this would produce a slightly rougher deposit. We did this because commercial powders in appropriate compositions are not available and special batches are prohibitively expensive, especially if one wishes to adapt the technology to other alloys. Our first experiments were performed with a wire feeder from a GMAW torch, using the smallest commercially available wire diameter (0.89 mm) at the slowest feed rate possible with this device (0.8 cm/s). A high heat input, about four times that observed to produce no α in the interpass heat affected zones, was used. These clad layers may ultimately, through erosion and corrosion assessment, prove acceptable. However, concern about the nature of material in the heat affected zone led us to use a smaller custom drawn wire with diameter 0.25 mm so that the heat input could be reduced. Using this small wire and reduced heat input and a custom built small wire feeder, we were able to produce an essentially single phase deposit, with minimal transformation in the heat affected zone. Remaining problems with the cladding procedure are mostly feeder design problems that should be worked out in the coming year.

To demonstrate the (near) commercial viability of the procedure, we laser clad part of a submarine pressure hull valve which had been rejected and partially destroyed during a failure analysis. Fig. 1 shows one area of the clad surface.

2.3 Evaluation of Laser Clad and Laser Surface Modified Material.

We have only just begun detailed investigations of the laser surface melted and laser clad nickel aluminum bronze. Erosion tests on untreated material as a baseline against which to compare the treated material are now in progress and a rapid metallographic method to assess preferential phase dissolution has been developed. Applying this method to clad specimens produced at very high power levels revealed that some preferential dissolution–probably of grain boundary and Widmänstatten α–occured under the most severe high P.H. test conditions.

2.4 Future Work

Our plans for future work on this topic include basic metallographic characterization of the specimens generated to date—much fundamental work is needed here—additional rapid dissolution tests, some long term exposure tests, mechanical tests on clad and treated specimens, and possibly some stress corrosion experiments and erosion-corrosion studies. As well, we intend to refine the design of our cladding system, especially the wire feeder, so that its operation is more consistent.

3. MICROSTRUCTURE AND TOPOGRAPHY OF TERFENOL-D AFTER ELECTROSTATIC DISCHARGE MACHINING

Giant magnetostrictive materials such as TERFENOL-D have many potential military applications; sonar transducers, smart structures and active noise suppression for example. One problem with this material, which is a brittle Laves phase, is that it is difficult to machine with conventional methods. Recently, in collaboration with DREA's Transducer Group we have investigated the effect of electrostatic discharge machining on this material. So far we have characterized surface and subsurface flaw densities and assessed the effect of various parameters on susceptibility to cracking during machining [12]. One conclusion is that significant reductions in machining damage are possible by heating the specimen during machining. This work is ongoing.

4. REFERENCES

1. K.H. Magee, *Surface Modification of Copper Nickel Alloys by Continuous Carbon Dioxide Laser Melting*, DREA CR/92/427, Defence Research Establishment Atlantic, Halifax, 1992.

2. K.H. Magee and C.V. Hyatt, *Laser Surface Melting of Copper Nickel Alloys*, to be published.

3. T. Betancourt, *Effect of High Energy Beam Surface Modifications on the Fatigue and Corrosion Behavior of Metals*, DREA CR/91/418, Defence Research Establishment Atlantic, Halifax, 1991.

4. S.J. Clarke, *Corrosion of Surface Modified Metals,* DREA CR/91/411, Defence Research Establishment Atlantic, Halifax, 1991.

5. C.V. Hyatt, K. Mackay, and T. Betancourt, *Evaluation of Laser Treated Copper Alloys*, to be published.

6. T. Betancourt, *Stress Corrosion Cracking Resistance of Laser Surface Modified Copper Alloy* UNS C36000 in Seawater, DREA/CR/91/463, Defence Research Establishment Atlantic, Halifax, 1991.

7. T. Betancourt, *Stress Corrosion Cracking Resistance of Laser Surface Modified Copper* Nickel Alloys, DREA/CR/91/477, Defence Research Establishment Atlantic, Halifax, 1991.

8. C. V. Hyatt and K. D. Mackay, *Defects in Laser Treated Copper Alloys.* in Proceedings of the International Conference on Beam Processing of Advanced Materials, Chicago, November 1992.

9. K. Mackay and C. V. Hyatt, *Laser Surface Treatment of Copper Alloy UNS C36000*, Informal report, DREA Research Note DL/90/2, 1990.

10. K.H. Magee, T*he Applications and Technology of Laser Weld Overlaying*, DREA/CR/92/419, Defence Research Establishment Atlantic, Halifax, 1992.

11. K.H. Magee, *Laser Surface Modification and Laser Cladding of Nickel Aluminum Bronze*, DREA/CR/93/421.

12. K. D. Mackay and C. V. Hyatt, *Optical and Scanning Electron Microscope Study of EDM Machined TERFENOL-D*, Research Note DL/92/3, June, 1992.

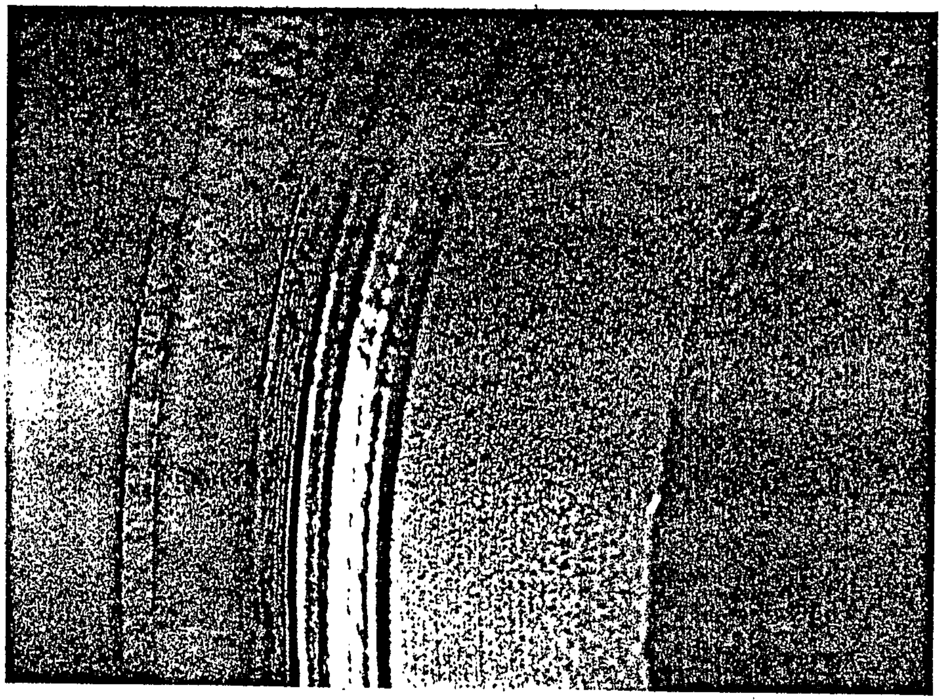

Figure 1. Laser clad Nickel Aluminum bronze valve.