Position Paper: Manufacturing MEMS

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An area of research that I believe worthy of investment is motivated by the research that I have been directing for the last five years (mostly funded by DARPA). At LSU, we have spent the last five years developing the LIGA process. I believe that the LIGA process can be used to economically fabricate a variety of conventional scale products whose performance is enhanced by micro scale effects, particularly heat transfer. Applications that are rigorously being pursued in my research group are turbine blades, cross flow micro heat exchangers, and mechanical seals, all with performance advantages by virtue of strategically positioned micro heat exchangers [1,2,3]. Test results on the mechanical seal and cross flow heat exchanger have been completed and the results compare favorably with modeling efforts. In both cases, the ability to remove heat is superior over conventional scale heat exchange schemes. In fact, my personal belief is that the scaling advantages are a given and that overcoming manufacturing and materials issues will dictate when these MEMS -based products reach the market. This need to find fabricate MEMS -scale components from a wider variety of materials and to apply MEMS structures with coatings that have superior properties is a research area worthy of funding.

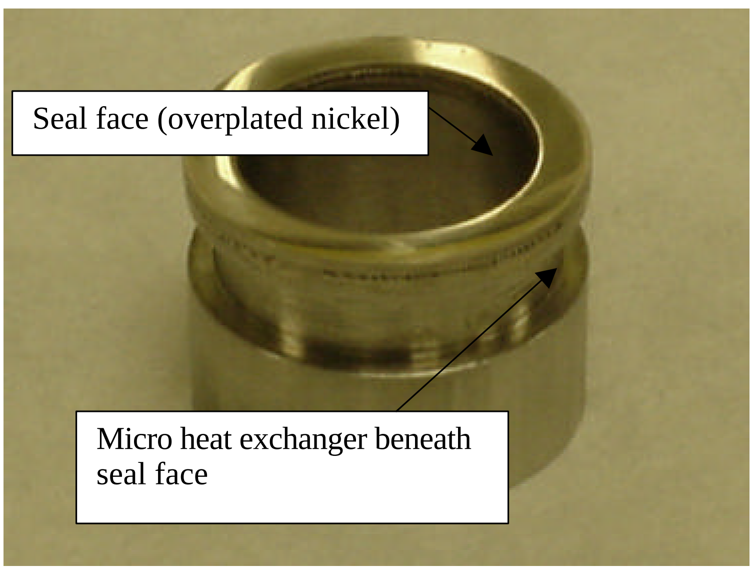

Figure 1:Mechanical seal prototype

Examples are as follows. First, a mechanical seal prototype (Figure 1) has been built that utilizes a micro heat exchanger just beneath the load-bearing surface of the seal face, making it possible to remove heat so effectively that there is virtually no increase in temperature of the seal face during operation. The main technological barrier remaining is to provide a low friction, high hardness coating on the seal face so that the proper combination of MEMS geometry and surface properties exist. This is probably the easiest challenge of those that will be listed, but it is typical of the theme that materials development combined with MEMS -scale components is a crucialstep that must be addressed before many concepts can be commercialized.

A second application involves the fabrication of a cross flow heat exchanger. This heat exchanger is presently fabricated from a polymer using the LIGA process and, for identical operating constraints, exchanges heat between a gas and a liquid 30-50 times more effectively than the most advanced car radiator (an application that the cross flow heat exchanger could address). Further materials and manufacturing developments could result in a low-cost heat exchanger that will be a proximately 2-3 millimeters thick, approximately 30 cm x 30 cm in frontal cross section, and will remove exchange heat at a rate comparable to a car radiator (with less volume, weight, and cost). Materials development (i.e. fabrication of this heat exchanger from a ceramic or metal) and manufacturing infrastructure, both of which are being addressed at LSU, are the crucial obstacles that need to be overcome before such heat exchangers are seen commercially.

A third application involves the fabrication of a micro heat exchanger on conformal surfaces such as turbine blade. A fairly complex heat exchanger on a cylinder has been fabricated and heat transfer tests are being completed (Figure 2)

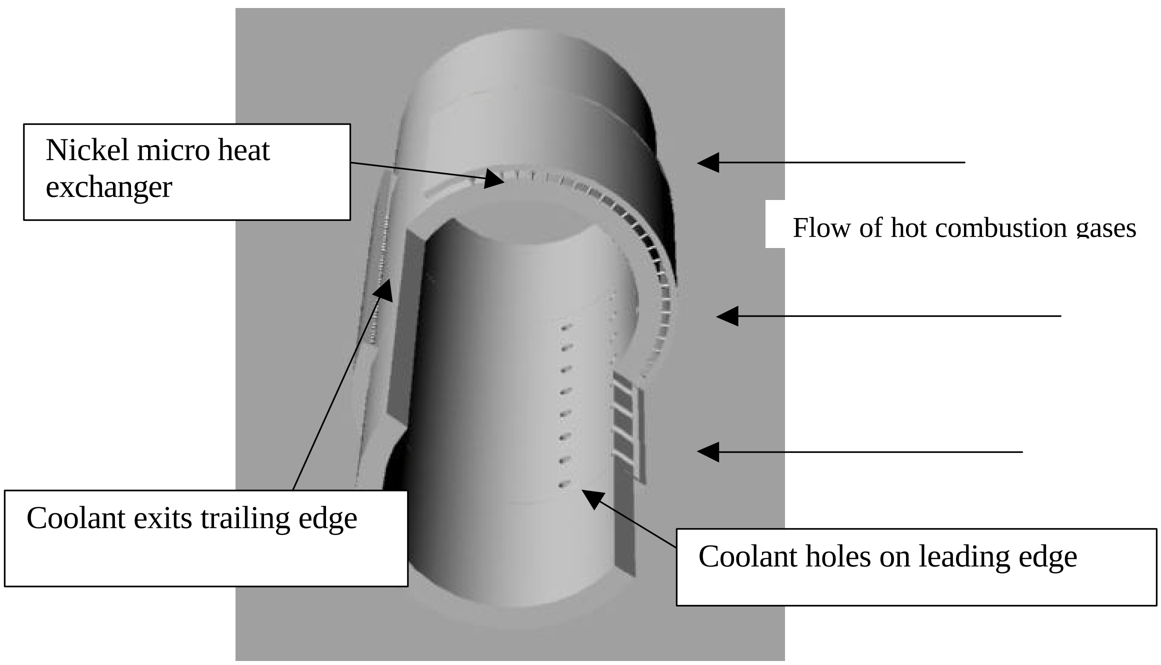

Figure 2: Schematic Of Heat Exchanger On A Tube.

The geometry that is achievable using a derivative of the LIGA process promises significant improvements in heat transfer. However, the present heat exchanger is fabricated from nickel. The ability to electroplate high strength alloys is a crucial step towards introducing such heat exchangers into gas turbines. Again, the crucial need is materials research. Yet another area of interest is to fabricate such heat exchangers from ceramics, which again combines the theme of micro scale geometry and materials processing.

A fourth example is polymer molded medical devices. These are routinely molded now at LSU using the LIGA process. However, methods need to be advanced to bond polymer components together, incorporate electronics, fiber optics, etc. Again, materials and processing knowledge is crucial.

I could list numerous additional examples. In summary, fabrication of components with MEMS -scale structures made of superior materials (not just silicon or plastic or electroplated nickel) will find many insertion points both in the military and the commercial sector.

1. C. Harris, K. W. Kelly, M. Despa, "Design And Fabrication of A Cross Flow Micro Heat Exchanger", Accepted For The Journal of Microelectromechanical Systems. will be published in December of 2000.

2. L. S. Stephens, K. W. Kelly, D. Kountouris, J. Mcclean, J. Coynel, "A Micro Heat Sink For Cooling Macro-Scale Conformal Surfaces Under The Influence of Thrust And Frictional Forces", Submitted to the Journal of Microelectromechanical Systems, July 2000.