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LETTER TO THE EDITORS

COMMENTS ON THE PAPER "HEAT TRANSFER AT THE INTERFACE OF DISSIMILAR METALS—THE INFLUENCE OF THERMAL STRAIN"

A. M. CLAUSING, *Int. J. Heat Transfer* 9(8), 791–801 (1966).

FOLLOWING a stimulating paper by G. F. C. Rogers on this topic in the Journal in 1961 I was rash enough to proffer an explanation for thermal rectification effects, also in the Journal in 1961, but soon afterwards realized that my comments did not cater for all contact conditions. The explanation was therefore extended to include the effects of thermal strain. These were discussed in a paper [1] to the Aeronautical Research Council (Structures Committee) in February, 1962, which examined the changes of contact geometry arising from the reversal of heat flow direction through a joint between dissimilar metals. The importance of an unwanted radial heat flow from cylindrical test specimens was pointed out, as it can cause flat contact faces to become spherical, thereby reducing the joint conductance. The explanation and its accompanying diagrams were very similar to those produced independently by Professor Clausing in his recent paper.

The paper also contained the results of preliminary tests on joints of steel/aluminium, and between gold plated steel faces, in which the heat flow was reversed several times.

A feature of some of these tests was that an electrical connection was made to shunt the contact face, without interfering with the local heat flow pattern, and the joint conductance was measured both with and without the electrical shunt in circuit. There was no significant difference between the two modes of test.

During a subsequent two years on thermal rectification work, forty different joints were tested under various conditions of contact pressure, surface finish and interface air pressure. The results are summarized in Section G of the writer's Ph.D. Thesis dated January, 1966, of the University of Manchester. This work was obviously not known to Professor Clausing and it would be unfair of me to refer to its findings in making comments on his recent paper. The following observations therefore are based only on data publicized prior to the preparation of that paper.

Firstly, the mating materials do not need to be dissimilar to exhibit the directional effect. The temperature difference across contacts between similar metals can cause macroscopic changes of geometry sufficient to produce apparent thermal rectification, especially if the surfaces are rough-flat (as obtained for instance by rough grinding), or when the radial heat losses from the cylindrical test specimens are important compared with the axial heat fluxes.

Secondly, a knowledge of the direction of the first application of heat flux to the joint is important. In the absence of radial heat losses, the conductance of a flat, smooth faced joint at a specified load and temperature will probably improve after the first reversal, irrespective of whether the original direction was from the steel to aluminium or vice versa. Similar joints may exhibit apparently opposite directional effects depending upon the test procedure and upon the relative magnitudes of heat losses. The importance of this point has apparently not been appreciated previously.

Thirdly, the directional effects due to thermal strain are very sensitive to the original shapes of the surfaces, and suitable shapes may produce thermal rectification in either direction. Consider, for instance, a circular faced steel/aluminium joint in which the aluminium face is flat and the steel very slightly concave, so that the original contact shape is annular. Heating in the steel to aluminium direction may distort the concave surface by making it plane, thereby bringing it into contact with more of the aluminium, thus improving the conductance. Reversing the heat flow direction may prevent the mating of the centres of the faces, and the conductance of the joint will thus be lower for the aluminium to steel direction than for the steel to aluminium direction. For slightly convex surfaces, or flat surfaces subjected to radial heat loss, the opposite "rectification" would occur.

Fourthly, is the rectifying effect permanent or does it occur mainly as a result of the first reversal? Professor Clausing's explanation of the effect is independent of the number of heat flow reversals, but he does not seem to have checked this point experimentally. I would suggest that the rectification effect decreases rapidly as the number of reversals increases.

Readers may be interested to hear that in most of my tests I have used a column assembly, similar to that of Professor Clausing, but with three test specimens instead of two. A typical assembly would be aluminium/steel/aluminium, so that for each direction of heat flow, similar joints are subjected to "normal" and "reversed" heat fluxes. Test materials of steel, aluminium, copper, constanton, Nilo 36 (a very low expansion alloy similar to Invar), have been tested in many combinations, both with and without interface shims of mica.

I reported some of my test findings to the International Conference on Thermal Conductivity held at the National Physical Laboratory, London, in July 1964, during discussion on a paper by H. Y. Wong of Glasgow University.

REFERENCE

1. A. WILLIAMS, Heat transfer at the interface of dissimilar metals—a further contribution, Aeronautical Research Council, ARC 23, 498, Strut 2409 (1962).

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