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LETTER TO THE EDITOR

COMMENT ON ROGERS' PAPER "HEAT TRANSFER AT THE INTERFACE OF DISSIMILAR METALS"*

I READ with interest G. F. C. Rogers' paper in the March issue of the INTERNATIONAL JOURNAL OF HEAT AND MASS TRANSFER, entitled "Heat Transfer at the Interface of Dissimilar Metals". My own researches during the last year have been on the subject of thermal resistance of metal contacts and have dealt mainly with pairs of similar materials, although I have tested several combinations of copper/steel, aluminium/steel generally similar to those described in the above article.

For the tests carried out in a vacuum, the heat transfer across the faces is entirely by solid conduction, radiation being negligible at the temperatures quoted. The governing factors are thus:

(a) the number of microscopic metal to metal contacts (referred to as a-spots),
(b) the average size of these contacts,

and by no means least

(c) the condition of the surfaces within the contact spots.

For surfaces with the low surface roughness (2–19 μ in) tested by Rogers, the number of metal to metal contact spots can vary considerably from one pair of specimens to another pair of nominally identical geometry. This difference tends to diminish as the contact pressure increases, but at the low pressure of 122 lb/in^2 used for Rogers' tests, I have always found great difficulty in obtaining consistent experimental results. An important factor which accentuates this scatter is the initial flatness of the faces, and the quoted parallelism of 0·0003 in would seem to be the controlling factor, rather than the micro finish. It would be interesting to learn how the overall flatness was measured and just what shape the "flats" were.

Factor (c) may well be responsible for the effect measured by Rogers, a possible explanation being as follows.

The heat flux through the a-spots is the heat flux through the nominal contact area multiplied by the ratio of the nominal contact area to the true contact area. This ratio is usually calculated by dividing the applied pressure into the Meyer hardness of the softer metal. For typical conditions, e.g. 122 lb/in^2 with steel to aluminium specimens (Meyer hardness for pure aluminium is approximately 20 kg/mm^2), the area ratio is approximately 230. The heat flux through the a-spot is thus 230 times the nominal heat flux and when one considers that the thermal conductivities of any surface contaminant films may be about 1/50th of that of the parent metal, the overall effect of these films is to produce a temperature drop equivalent to that consequent upon an additional metal thickness of approximately 11,500 times the film thickness. With harder metals this effect is further exaggerated, although in many engineering contacts the interface fluid relieves the a-spots of some of their heat load. Rogers, in his paper, does not discuss these effects nor does he specify the previous history of his specimens.

I would suggest that the effect found by Rogers is a direct result of surface contamination, which could be presented before assembly or even deposited at the modest vacuum of 0·02 mm Hg quoted. In the case of heat flow from aluminium to steel the differential radial expansion of the aluminium surface across the hard steel surface could cause the film to be scoured off, thereby allowing better metallic contact compared with that of the reverse direction of heat flow, in which the relative movement is reduced. This effect may be exaggerated by the method of machining the contacting faces, i.e. diamond turning, as the differential radial movement will cause severe interference between the two sets of tool marks. There may be a further small contribution to the directional effect caused by the reduction in hardness of the aluminium as the temperature increases, but this is possibly negligible at the temperature quoted.

I would suggest that the simple mechanical engineer's explanation is adequate for a qualitative analysis of the effect but would be very interested to hear the opinions of the specialists in metal physics. I would be more convinced of the existence of a direction-conscious surface thermal potential barrier if the effects were found with tests having the following controls:

(a) a much higher contact pressure,
(b) a specified contact geometry,
(c) a controlled film thickness.

It would also be interesting to observe the results of repeated tests on the same pair of specimens to check whether the contact resistance remained at its low level once the film had been damaged.

You may be interested to hear that my own tests are being conducted at present with contact pressures rising above 3000 lb/in^2 the mating surfaces having previously been gold plated.

A. WILLIAMS

Engineering Department,
University of Manchester,
Manchester

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