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POWER MEASUREMENT IN ULTRASONIC WELDING.

This paper is a description of an experimental investigation of a simple ultrasonic welding procedure and the influence of various physical parameters upon the process. Strong bonds can be produced between similar or dissimilar metals when the overlapping materials held in close contact with a certain clamping force, are subjected to high intensity vibrations. The experimental set-up is shown schematically in Figs. 1 and 2, the welding tip of the transducer vibrating horizontally, while a steady compressive force maintains the contact between the foils and the anvil. The vibratory motion transmitted to the interface of the foils results in slipping and the break-up of any oxide layer while the interface temperature will rise.

It appears a minimum displacement must occur before welding ensues, for below this value the energy dissipation is insufficient for the required temperature to be reached. With clean metallic surfaces welding will occur at the points of contact between them, the real contact area being only a fraction of the total area. Microslip will occur when a shear stress becomes sufficient to fatigue or fracture the joint asperities and plastic deformation of the weld area will give a hysteresis loop, under cyclic excitation, the loop area being a measure of the energy loss per cycle. The plastic flow and temperature rise will result in a diffusion of the metals across the interface, but melting will only occur in thin layers at high vibrational intensities, as is revealed by crystallographic analysis of the bonds.

There is an optimum welding time for given conditions, and a continued application of ultrasonic energy for a longer period does not increase the interfacial temperature, which may slightly decrease, and may have an adverse effect on weld strength, for in fact the maximum of the breaking force coincides with that of the highest temperature reached. Under conditions of a constant clamping force the build-up time to the final temperature decreases as the input power to the transducer increases. The initial temperature rise is rapid, but there does not appear to be any metallurgical bonding until a critical temperature is reached. Using the 'welded' samples as their recording thermojunctions, the optimum temperatures so found were lower than expected, i.e. appreciably lower the melting point. The radius of the welding tip controls the extent of the deformation of the welded material and governs the area of the weld which also depends on the power and the welding time. If a flat tip is used the weld area is large but is formed by non-continuous tiny welds. A higher efficiency of coupling of acoustic energy into the weld is obtained if slippage is minimised by roughening the weld tip and the anvil. In general it can be said that the materials of the tip and anvil should have a low thermal conductivity and a high shear strength. High speed tool steel or preferably harder materials, such as Iconel X, are favoured tip materials, with mild steel and carbon drill rod for the anvil although glass is satisfactory for low energy applications. For a given tip displacement there is a maximum sheet thickness for maximum transmission of acoustic energy to the working face, and with greater thicknesses the clamping force becomes distributed over a wider area, thus necessitating a higher power input, as does prior cold working of the welded material. In ultrasonic welding the temperature rise is much smaller than with other methods, e.g. resistance welding, so only the cladding layers and not the substrate is affected and in fact photomicrographs of ultrasonic spot welds showed the interpenetration of one material into the other was usually less than 5% of the material thickness. Again strong welds in aluminium of 0.07" thickness can be obtained using 4Kw equipment but a machine of 100 Kw or more would be required for resistance welding.

Observations on the Welding Process

The easiest combination to weld of those attempted were the 0.001" thick aluminium foils with their polished sides in contact with each other to improve the slippage between the two surfaces, and furthermore the rough surface of the upper strip being in contact with the welding tip will minimise any relative motion between them, and so reduce unnecessary loss of power. In welding materials of different thicknesses the thinner material should be nearer the welding tip to reduce the energy dissipation within the thicker material and also to prevent strong deformation of the thinner specimen, as was usuallly observed when it was placed directly in contact with the anvil.

For a specific welding time and clamping force when low power is employed no deformation of the foils is detectable and no weld is obtained. By increasing the power a value is reached at which sticking occurs between the foils but on applying force to the spot they come apart, without any breaking of the materials. A further increase in power will produce a good spot weld with little deformation of the foils and the spot will be nearly circular. A good weld will be deemed to be obtained when during the peeling of the two foils, or while applying shear stress to the spot, one of the materials tears out and leaves the 'nugget' firmly attached to the other specimen. An increase of power above this optimum produces an increase in weld area, and consequently the force needed to break the weld, and also the shape of the spot becomes elliptical as the upper foil is strongly dragged by the welding tip backwards and forwards while the lower foil is held on the anvil. At large input powers it is quite easy to detect cracks and fissures in the spot as a result of the high stresses induced in the material by vibration.

Clamping Force Experimental Results

Fig. 4 shows the influence of the clamping force on the minimum power required for a good weld and is similar for other metal combinations used. By way of explanation at low clamping forces the amplitude of vibration is large because of the small loading imposed by the specimens, and associated with this condition the coupling is poor so that little power is transmitted to the welding zone. Furthermore slippage will occur at the metal foil-anvil interface due to the small friction. An increased clamping force results in better coupling and a reduction in power to achieve the same effect but at high clamping forces the vibration amplitude is so restricted by the large loading that the input power must be increased. It is worthy of note that work hardened copper required nearly as twice as much power as annealed copper to weld. The breaking strengths per unit area for ultrasonically produced aluminium to glass welds were approximately the same as for Al to Al or Al to Cu.

Temperature Rise in the Weld Zone

The general temperature time pattern at the junction was a very fast rise(Fig. 5b), followed by a slower increase to the maximum, the welding times being 1.2 to 1.6 sec. The weld interface formed the hot junction of a thermocouple which could be suitably calibrated after formation by placing it in a temperature controlled oil-bath. The main conclusions were that the maximum temperature increases linearly with input power (Fig. 5a) in the range studied and the different temperatures attained at equal input power for each material suggests a rather complex relationship between temperature and the elastic modulus, yield strength, hardness and thermal conductivity of each of the materials involved.

Submerged Welding

The possibility of welding thin metallic foils under liquids was tried with benzene, water and oil and the observations indicate the marked affect of the presence of oil on the foil.

Calorimetric Measurement of Welding Power.

The input power to the transducer was observed for each value of the clamping force for each metal combination,and simultaneously a recording was made of the signals from two small crystal microphones stuck at the node and antinode of the velocity transformer (Fig. 3) and which gave a measure of the vibration level at two selected points.

When the load on the system increases power will be delivered by the transducer,the nodal and antinodal signals respectively increasing and decreasing; the resonant frequency of the transducer and its impedance will also change. In order to evaluate the actual power delivered by the transducer through the welding tip, a small calorimeter was constructed which allowed the mounting of the ultra sonic welding system directly above the closure lid enabling the tip to radiate directly into the calorimetric fluid. The input power and the microphone signals were adjusted to the values recorded during the welding process so that the power delivered to the calorimeter was approximately the same as that used in forming the weld. The calorimeter had been previously calibrated by an electrical heating technique. The value thus deduced is somewhat higher than the true since power is also dissipated in the anvil.

GENERAL REFERENCES

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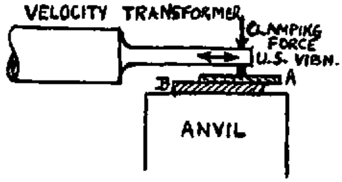

Fig 1

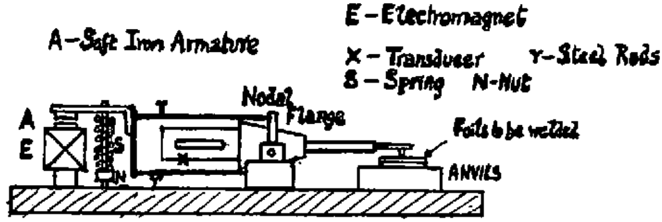

Fig 2. Mounting System.

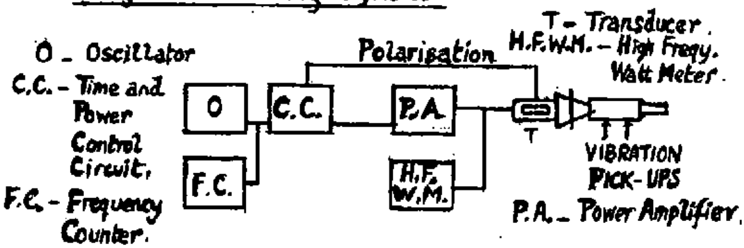

Fig. 3. Block Diagram of Measuring System.

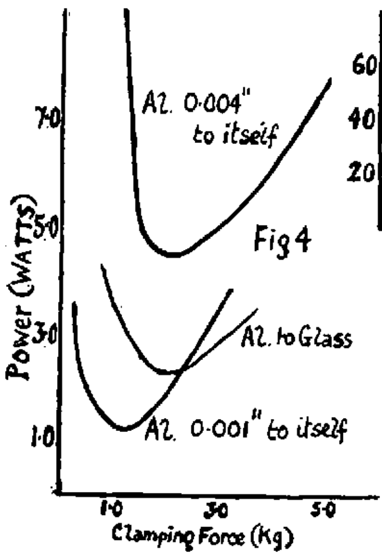

Fig 4

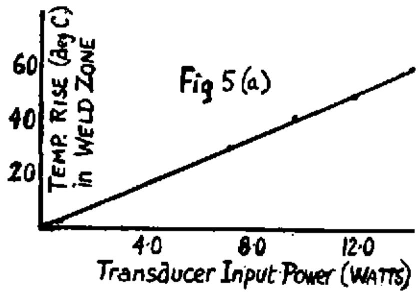

Fig 5 (a)

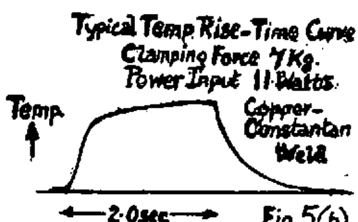

Fig 5(b)