Study of Process Kinetics in TLP Bonding using DSC,
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During the transient liquid phase (TLP) bonding process, a bond is formed at the base metal interface through the isothermal solidification of a melting point depressant rich liquid phase. TLP bonding shows potential in the aerospace and power generation industries for repair joining of high temperature, creep resistive superalloys. Since the base metal does not melt during the process, there are no complications caused by re-solidification. Recently, a great deal of attention has been paid to the TLP bonding process. Both analytical and numerical models have been developed to predict TLP bonding process kinetics for the isothermal solidification stage; however these solutions only work for a few simple (binary alloy) systems [1]. In practice, trial and error experiments are currently the best way to develop process parameters, especially for multiple element systems. These experiments are time consuming and expensive, rendering TLP bonding unattractive in the industrial realm. A more efficient technique using differential scanning calorimetry (DSC) was developed to study process kinetics in TLP bonding. Corbin and Lucier successfully applied a DSC procedure to study the kinetics of the transient liquid phase sintering process [2]. A similar method is used in the study of isothermal solidification during TLP bonding.

TLP joints were made using the simple silver-copper system. The experiments were conducted just above the eutectic temperature in a Netzsch 404C DSC. These trials were used to evaluate the effectiveness of DSC measurements and fine-tune the test technique. Through a melting peak on a DSC trace of material at the eutectic composition, the eutectic temperature and the latent heat of fusion are determined. Comparison of this data with a trace generated by a TLP bond at the eutectic temperature reveals some interesting features: the increased width of the melting peak, along with the heating rate, gives the time required to melt the interlayer; also, comparison of the integrals of the melting and solidification peaks gives the amount of liquid lost to isothermal solidification. Samples were held at the process temperature for varying lengths of time. Then, upon cooling, the amount of remaining liquid was measured for each. The data was then extrapolated to zero percent liquid to find the time required for isothermal solidification.

The experimental methods were then applied to more complicated ternary alloy systems. Sinclair, Purdy, and Morral have investigated TLP bonding in two-phase ternary systems, and have shown that the process is complicated by the addition of one or more elements [3]. DSC trials of ternary TLP systems indicate that this is indeed the case. Preliminary results of ternary phase bonds show a broadened melting peak and an increased re-melt temperature indicating base metal interactions.

The results of this work indicate that differential scanning calorimetry has a great deal of potential in investigating the phase transformations that occur during the various stages of TLP bonding. Work is underway to develop numerical models of ternary alloy TLP systems from the data obtained experimentally. The model could be used to optimize TLP bonding process parameters. This will significantly decrease the costs associated with developing industrial applications, making TLP bonding an attractive joining solution.

References:

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