



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: Experimental investigation and numerical modeling of plasma and laser microwelding processes

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SHORT ABSTRACT

In the growing technological field like micro-electro-mechanical systems (MEMS) and biomedical devices, the microwelding has potential application as encapsulation of miniature components. This thesis work is primarily motivated to develop plasma microwelding system for butt joining of different materials. At first the major efforts are put forward to experimentally investigate the thermo-mechanical and microstructural behavior for joining of titanium alloy, stainless steel and low carbon steel. A comparative study between plasma and laser microwelding on titanium alloy put forward about the fundamental advantages over the processes. Using controlled and regulated arc current, the micro plasma arc welding process is specifically designed where the weld quality is assessed by carefully controlling the process parameters and by reducing the formation of oxides. A process window in terms of welding current and speed is evaluated to predict the defect-free microwelded joint. The plasma current range of 8 – 13 A produces high quality welded joints for all the selected materials. The weld joint quality is affected by specifically designed fixture that controls the oxidation of the joint and introduces high cooling rate. In laser microwelding of titanium alloy, high peak power is actually dampen by pulsation of Nd:YAG laser cratered to use in microwelding process. The feasible range of process parameters like laser scanning speed of 3-7 mm/s and peak power of 1-5 kW produces high quality weld joint.

A 3D finite element based thermo-mechanical model is developed to study various aspects of plasma and laser microwelding processes. Large deformation theory is used to predict the distortion of microwelded joint. A dedicated pulse mode of heat flux model is developed for laser heat source. To analyze the heat transfer process by an ultra-short pulse laser, the 3D finite element based numerical model is developed assuming finite speed of thermal wave propagation with two phase lags. The transient heating and cooling phenomena are also analyzed for the effect of two relaxation times, variation of pulse width, and multiple pulses. The finite element modeling of laser transmission welding is developed using contact condition that accounts all physical phenomena such as heat radiation, thermal conduction, and convection heat losses. Material flow behavior in micro weld pool influences the temperature distribution to some extent. Hence, a well-tested 3D finite element based heat transfer and fluid flow model is used to analyze the flow behavior in laser microwelding process. A harmony search-based meta-heuristic algorithm is also integrated with the physics based numerical model to identify most suitable unknown model parameters in an inverse approach within overall kernel of optimization algorithm.