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Analysis of thermo-mechanical stress on welding electrode by using finite element method

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Abstract. RFID tag manufacturing has one of the most important processes: the welding of the circuit to the microchip. In this process, the electrode tip will press the circuit coil on the microchip and then release the electrical power through the welding tip to heat up the welding tip. The heat transfers to the circuit coil and then melted the circuit coil to microchip. The quality of the welding depends on the efficiency of the electrodes used in which the welding tip that have been used for a long time will be less effective due to receiving repeated heat and force, causing a stress on the welding tip. As a result, the end of the weld tip is deformed. This research studied the deformation behavior of welding electrodes under thermal-mechanical stress effect. The study based on simulation with using finite element software (MSC Marc). This leads to improvement for further optimal shape design.

1. Introduction

Present the Radio Frequency Identification (RFID) is popular. Because high security in private data and convenient to use. The major part of RFID is Transponder or Tag is act to stores data and sends signals to the data reader. RFID tag manufacturing has one of the most important processes: the welding of the circuit to the microchip. The quality of the welding depends on the efficiency of the electrodes welding used. RFID tag circuit is very small so welds must be small and must have a high precision in welding. The electrode welding tip used to connect the circuit is a micro resistance spot welding. Micro resistance spot welding is a group of micro joining processes [4]. Micro-resistance spot welding has been used to join high temperature microelectronic interconnects [5]. In this process, the electrode tip will press the circuit coil on the microchip and then release the electrical power through the tungsten welding. Effect of electrical resistance in material and change of cross section for electrode welding to heat up. The heat transfers to the circuit coil and then melted the circuit coil to microchip. Based on the principle above, Electrode welding receiving repeated heat and force, causing a stress on the welding tip. As a result, the end of the weld tip is deformed and will be less effective.

2. Computational model

2.1. *Governing equations*

The governing equation for calculation of the heat generation per unit volume may be shown as [1]:

$$q = \frac{1}{R}[\nabla\Phi] \tag{1}$$

where q is the heat generation per unit, R is the electrical resistivity and U is the electrical potential.

For stress and strain analysis, since the thermal–elastic–plastic behavior is a highly nonlinear phenomenon, the stress–strain relation is described in incremental form [2]:

$$d\{\sigma\} = [D]d\{\varepsilon\} - \{C\}T \tag{2}$$

where

$$\{C\} = -D_e\left(\{\alpha\} + \frac{\partial[D_e]^{-1}}{\partial T}\{\sigma\}\right) \tag{3}$$

[D] is the elastic–plastic matrix, in the elastic area [D] = [De], while in the plastic area [D] = [D_e]−[D_p]. [D_e] is the elastic matrix and [D_p] is the plastic matrix, ε is the coefficient of thermal expansion.

2.2. *Geometry and boundary conditions*

Electrode welding is micro resistance spot welding type parallel gap will be melted the top material connect to the material below and he material below should not be damaged.

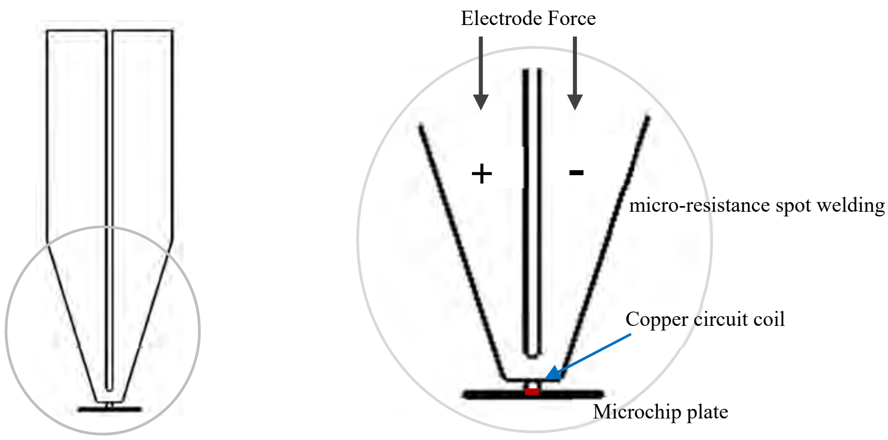


Figure 1. Schematic diagram for the model of micro-resistance spot welding.

In this process, the electrode welding will press the copper circuit coil 0.1 mm to microchip in the desired position to weld. Then applied the electrical current through the welding 170 A to heat up the welding tip can melted copper coil circuit attached to microchip. Detach the electrical current, but still hold the electrode welding on cupper circuit coil. When detach is complete and then lift the electrode welding from the weld to move position to welding the next point. As shown in the diagram of the Schematic of the welding schedule. (Figure 2.)

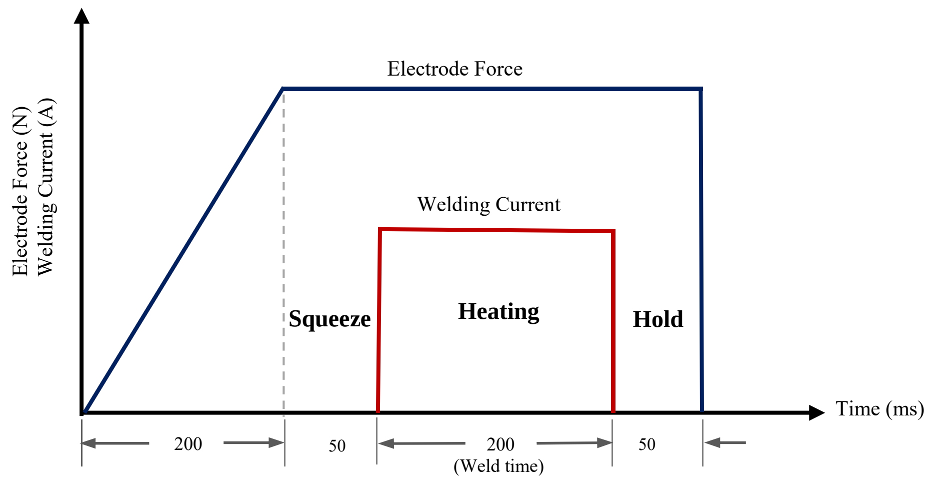


Figure 2. Schematic of the welding schedule.

2.3. *Material properties*

The data on material properties required for the numerical calculations were collected after extensive search through information of literatures and handbooks.

Table 1. Material properties for the simulation (for Tungsten and copper coil).

	Tungsten	Copper
Young's modulus (GPa)	411	130
Yield strength (MPa)	550	117
Poisson's ratio	0.28	0.33
Coefficient of thermal expansion, ε	$4.5\text{x}10^{-6}$	$1.6\text{x}10^{-5}$
Density (kg/m^3)	19,300	8,920
Specific heat (J/kg.K)	132	384.4
Thermal conductivity (W/mK)	173	401
Electric Conductivity (1/(Ω·m))	$1.79\text{x}10^{7}$	5.96×10^{7}
Resistivity (Ω· m)	$5.4\text{x}10^{-8}$	$1.68\text{x}10^{-8}$

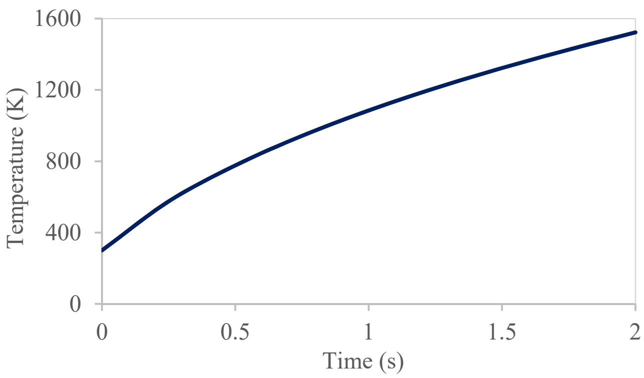
Material properties for simulate Thermo-Mechanical Stress with using finite element software for studied the deformation behavior of welding electrodes

3. Results and discussion

The simulation deformation behavior of welding electrodes under thermal-mechanical stress effect to analyzed the factors that lead to deformation of the electrode welding. So simulation is divided into 3 case is Mechanical Load, Thermal Load, Thermal-Mechanical Load to compare the effects of stress and displacement.

3.1. *Temperature Distribution*

Simulate of temperature distribution on the electrode welding. When applied the electrical current through the welding on time 0.25-0.45 s



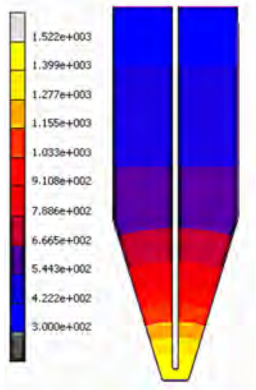


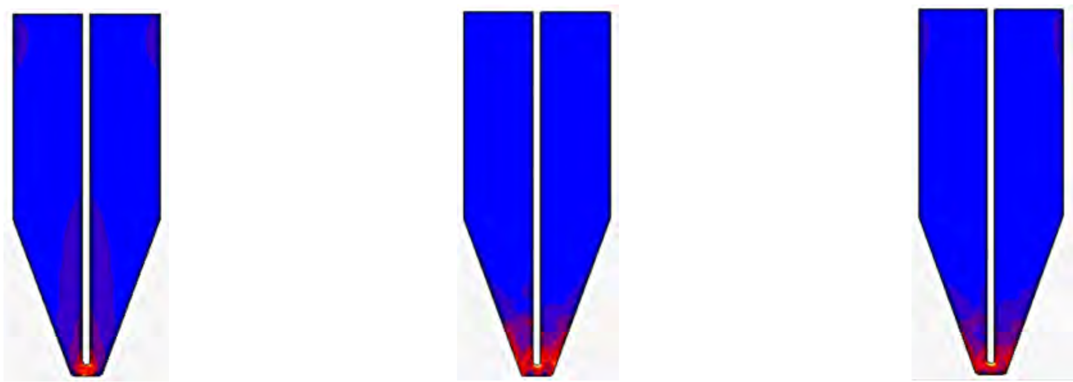
Figure 3. Temperature dependent on time

Figure 4. Temperature distribution

From the simulation of temperature distribution on the electrode welding. Found, the temperature varies with the duration of the electrical current time. When time increases the temperature is raised and applied the current to times 0.2 s, the maximum temperature is 1.522 K occurs at the tip of the electrode welding. Because it is a small area the flow resistance of the material is very high. This resulted in higher temperatures than elsewhere in the same period.

3.2. *Stress, Strain and Displacement*

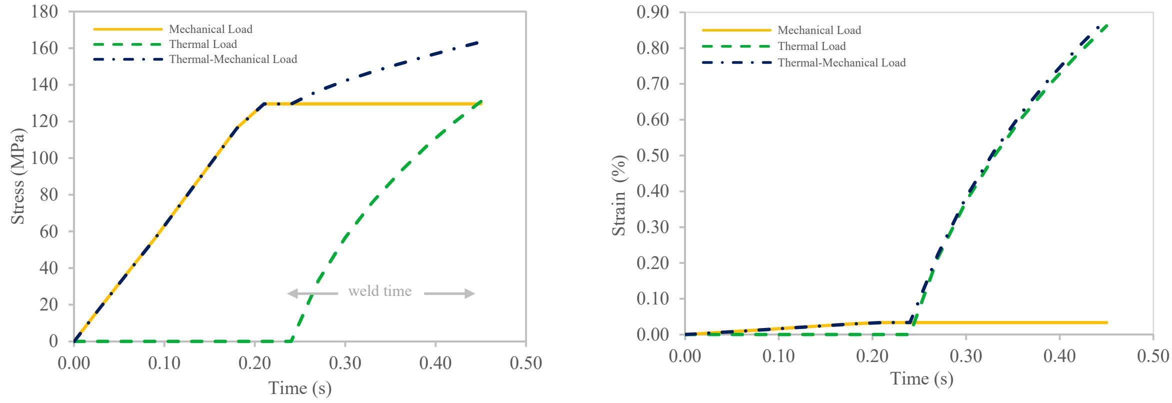
Simulation of behavior for Stress, Strain and Displacement is divided into *3* case to compare the results from each load, whichever type of load results in the most deformed electrode welding. Simulate with Schematic of the welding schedule. (Figure 2.) But show the simulation results at 0.45 s is end of weld time. Because it does not simulate the time on hold time. Since the weld time range is the most load, this will cause the highest stress, strain and displacement.



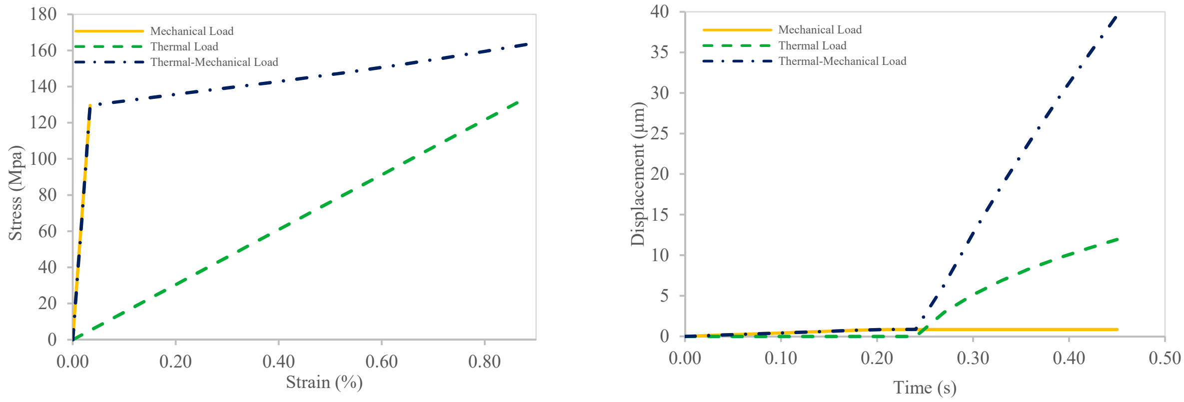
(a) (b) (c)

Figure 5. Schematic of stress distribution on the micro-resistance spot welding. (a) Mechanical Load, (b) Thermal Load and (c) Thermal-Mechanical Load

From simulation of stress behavior on 3 case of electrode welding. Found, all 3 cases have the highest stress and there is a dense distribution of stress at the tip of the electrode welding. Because the tip of the electrode welding is the contact between the wire and microchip, and also the smallest. This area receive the pressure and heat more than other area.



(a) (b)



(c) (d)

Figure 6. A graph the comparison between Mechanical load, Thermal load and Thermal-Mechanical load in welding process.

From (a) Stress, (b) Strain, (c) Stress-Strain and (d) Displacement when applied with force to the current flowing through the welding head (weld time 0.25-0.45s). The result is Thermal-Mechanical load is higher than the other two cases and tends to correspond to Mechanical load and Thermal load. But the effect of the strain for trend line of the thermal-mechanical load is approach to the thermal load, so the effect of the thermal expansion rate on the electrode welding. Displacement values clearly show that case. The thermal-mechanical load is higher than the other load due to electrode welding pressures and heat into action. This causes the weld head to expand laterally, rather than just pressing several times. When the electrode welding has both pressure and expansion at the same time. Affect stress is higher than pressure or heat alone. But the higher stress of this electrode welding is not higher than the Yield Strength of tungsten then electrode welding is not damaged. But the electrode welding has been repeatedly pressure and heat for a long time this will result in electrode welding gradually deformed and eventually lead to damage.

From the graph, compare the effect of load. . Found, (a) Stress of Mechanical Load approximate to Stress of Thermal Load but Thermal-Mechanical Load is higher than other cases. It will gradually increase over the load in both cases during the weld time. As a result, the stress of the Thermal-

Mechanical Load is higher than other ranges. But the stress is still lower than the Yield Strength of tungsten. (b) Strain of thermal load and thermal-mechanical load are very similar, but both loads are higher than mechanical load. Can be seen that in simulate Thermal-Mechanical Load the strain that occurs on all electrode welding. The result from the expansion of heat. (c) Stress-strain of the thermal-mechanical load is higher than that of other loads in weld time. (d) Displacement of Thermal-Mechanical Load is highest. The result is a combination of mechanical and thermal load. When the electrode welding is pressurized, it will expand laterally but it is very small. And when the welding head is heated together the electrode welding is more than doubled. Of course, heat can have a significant effect on the deformation of the electrode welding.

4. Conclusion

Deformation occurs on tip the electrode welding. The result of being heated during weld time because the material is heated, its Yield Strength will decrease with increasing temperature. When applied force on electrode welding is deformed at the tip of the electrode welding at high heated. Then heat causes the welding head to expand and shrink when it is not heated. The RFID Tag welding process is heated and cooled and welding head must expand and shrink for a long time. This results in fatigue in the material and the electrode welding may cause deformation. Therefore, heat is the main factor affecting the deformation of the electrode welding.

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