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FINITE ELEMENT ANALYSIS OF LASER BEAM SPOT WELDING OF ALUMINUM (2014-0)

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ABSTRACT:- In this paper, an axis-symmetric finite element (F.E.A.) model for the resistance spot welding (RSW) of Aluminum 2014-O is developed using the (F.E.A.) software ANSYS(11). It accounts for the interactions of mechanical, thermal phenomena.

The (F.E.A.) is accomplished through the laser beam contact characteristics and thermal effects of Aluminum due to being heated to a high temperature. The phase change due to melting is accounted for a very small area near the laser spot. At the same time, temperature-dependent variable material properties are used for the simulation. In addition shear stress and strain distribution were calculated with a comparison with experimental work of recent studies.

INTRODUCTION

More recently, automobiles' interest in Aluminum is growing rapidly in Europe and North America. Because RSW is the key technique in the volume production of automobile, to produce automobiles in volume, the problems of RSW for Aluminum must be solved. Now, there are two problems in the process of Aluminum RSW, one is the fast wear of electrode, the other is the weld quality. The study about the mechanism of Aluminum laser welding process is the basis to solve these problems [1] [2] [3].

There are many attributes of laser light that are uniquely suited for laser welding. A beam of laser light is monochromatic (single wavelength) and collimated (parallel) and hence can be focused down to a very small spot where the photon density is high enough to melt metals and alloys in a matter of mille-seconds. Laser wavelengths are typically identified by the laser source used to produce laser light. The most commonly used for pulsed welding is 1.064 micron Nd: YAG laser.

A new generation of lasers called fiber lasers also have similar wavelength where the laser light is produced in the fiber itself. Fiber lasers have the benefit of producing good beam quality and hence can have much longer working distance (distance between lens and work piece), of the order of ten inches as compared to about two inches for conventional YAG lasers as shown in fig.(1). Another source commercially available is the 10.64 micron CO2 laser, thought that is more often used for continuous wave welding rather than for pulsed welding fig.(2) (4).

The laser beam can travel through air or vacuum with minimal loss of energy. In some applications, the entire laser delivery hardware including focus head and fiber can be mounted inside a glove box where the environment is controlled for oxygen and water vapor contamination as is necessary for welding of Titanium. If required, the controlled environment can be produced in a more confined space with the laser energy being delivered through quartz window (5)(6) .

GOVERNING EQUATION

The governing equations for the coupled thermal-mechanical problems during the RSW of Aluminum alloys can be written as:

$$h\frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + q \qquad (1)$$

$$\nabla \cdot J = 0 \qquad (2)$$

$$\nabla \cdot \sigma + F = 0 \qquad (3)$$

Where T, K, h, q, σ, F, J and t are temperature, thermal conductivity, enthalpy, heat generation, stress, body force, electric current density and time, respectively. Equation 1 is the energy-governing equation that includes the phase change due to melting. The enthalpy algorithm is used to solve the phase change process. The phase change occurs between the solidus and liquidus temperatures of alloys. The last term of equation 1 is a combination of heat generation due to contact resistance at the faying surface. Te flow of electric current is described by equation 2 allowing computation of the current density distribution and with our simulation represented by the laser power. The mechanical deformation, contact pressure distribution and contact area are simulated by equation 3. The heat generation can be estimated by the coupled thermal-mechanical analysis. The fully thermal modeling was used to solve the nugget development and temperature history. It is noted that the contact resistance works by a layer of solid elements with very thin thickness [7].

FINITE ELEMENT ANALYSIS

F.E model of laser welding is similar to experimental model obtained from ref-4(including chemical composition, mechanical properties and experimental procedure) were two pieces of metal of 125 mm in length and 38 mm in width as shown in fig.(3) lap positioned and exposed to heat flux of density 1500 w to simulate the laser power . the two pieces have convection surfaces since they in contact with environmental air and have zero degree of freedom for all their surfaces since no motion was included, the meshed model shown in fig.(4) which based on choosing brick-70 as solid thermal element for evaluating the governing equation with a switch to property to have structural solution from thermal solution, a little consideration will show that some pressure have to be exerted on pieces to hold them in place in addition to have a good contact between two pieces. Heat penetrated from surface of one metal to another which caused melting of these surfaces and as a result welding of two pieces. In order to ensure that a good welding was obtained two forces on each side were exerted to calculate the shear strength of welding. Weld strengths were assessed by the load (g) that achieved breakage of the weld. . The weld area was observed to be less than the 36 mm^2 area of laser exposure. The weld strength is characterized by the breaking force which increased with increasing pulse energy.

RESULTS

Spot welding is a good tool for welding metals, although there is some defects of this process due to mechanical properties of aluminum like high thermal conductivity, high thermal expansion coefficient .to reduce these defects another way for welding is used .to be able to have a primary evaluation of laser welding a computer program was used to get an idea of the results an compared it with experimental results.

In order to be sure that laser welding is more effective process than spot resistance welding of Aluminum alloy a comparison was made between experimental results obtained from ref-4 and computational results obtained by using ANSYS(11) program. Experimental results concentrated on calculating shear strength of welded material showing that shear force increasing with the increasing of welding current and that agreed with F.E analysis since shear force represented by breaking force increase significantly with increasing of laser pulse shown in fig.(5).since increasing pulse time will increase welding temperature as represented by fig.(6) which show a very good agreement with experimental result of ref-4 since in both way shear strength change rapidly with welding time and welding temperature in laser welding and that a good indication that an expected properties of metal can be obtained .stress-strain curves show original data expressed as load versus position ,representing the weld break when load reach maximum value then yielding of material occurs causing break of welded pieces as shown in fig.(7). Increasing the pulse time or the pulse energy will increase the strength of the weld, exponentially approaching a maximum strength. Above about 1750 w, the maximum weld strength was attained. In addition ANSYS (11) program gives an approach of being able to calculate stress in X, Y and Z direction as shown in fig. (8) which shows stress in X-direction with maximum value equal to 0.143E9 compression and minimum value equal to 0.180E9 compression, with strain in three dimensions as in fig.(9) which shows elastic strain in x-direction with maximum value equal to 0.370E-3 and minimum value equal to 0.261E-3 .total temperature gradient is shown in fig.(10).

CONCLUSIONS

The high temperature required for welding in both experimental and computational method represented by ANSYS program results in a lot of problems. these problems includes rapid heating and cooling of metals surfaces which leads to rapid orientation of metals particles and that leads to un expected properties of welded metal . in laser welding that could be of less effect since the laser heat focused on a small area reducing the effect of being heated and cooled quickly .in laser welding a very complicated structure could be welded since the process required a little care of focusing laser light on the required surface. Aluminum alloys are well known to be difficult to laser weld because of their high reflectivity, high thermal conductivity, and volatilization of low boiling point constituents.

Weld defects such as surface holes, undercut, porosity, and irregular beads are often observed.

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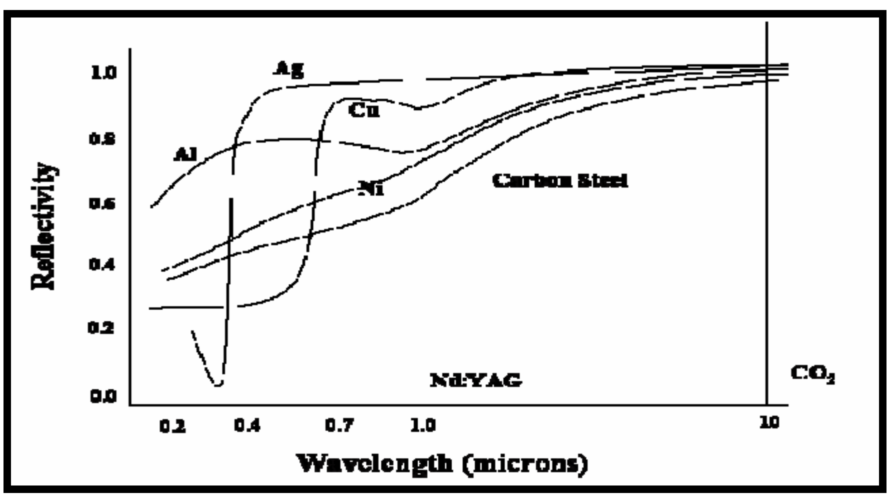


Fig. (1): Absorption of laser energy by metals at room temperature [1].

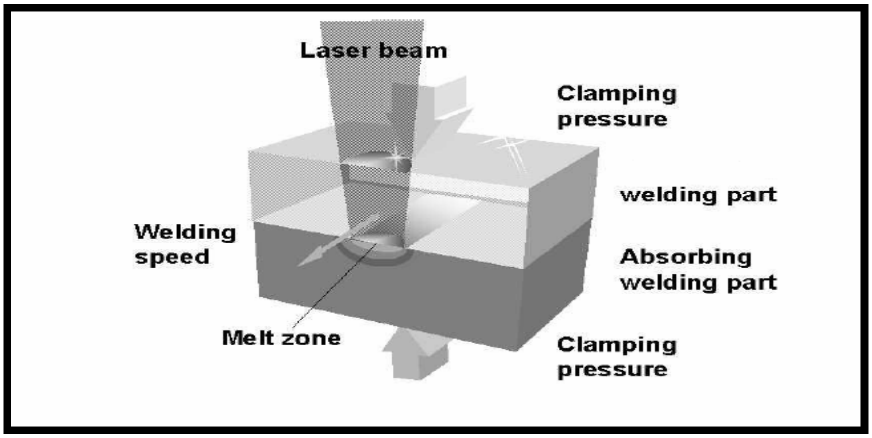


Fig. (2): Laser beam welding process [4].

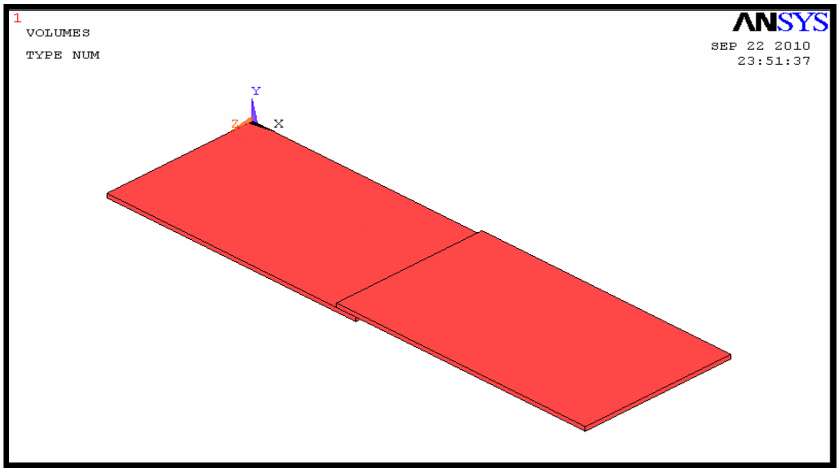


Fig. (3): Two piece of metal lap positioned to be welded.

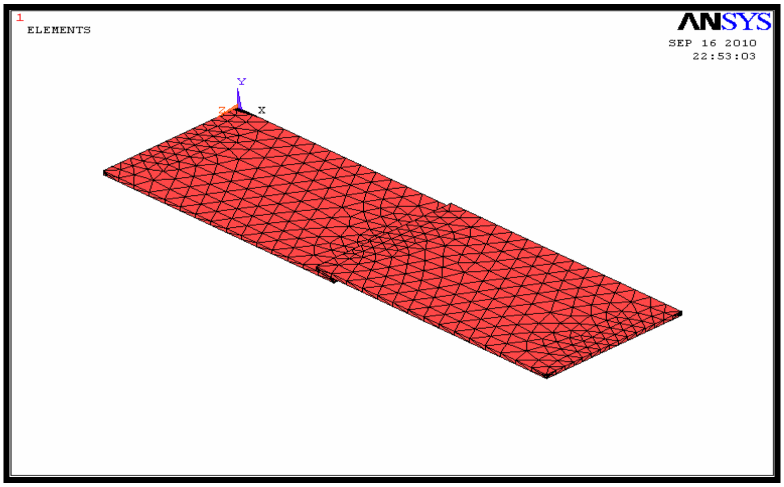
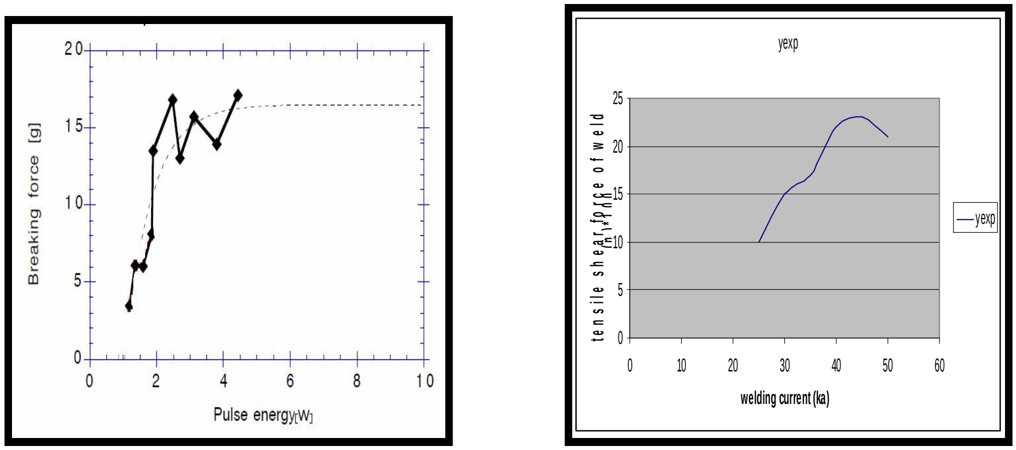
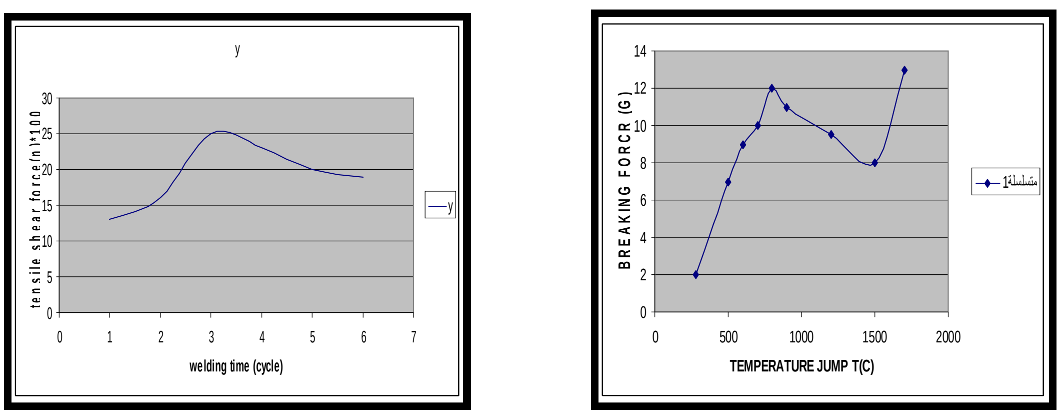


Fig. (4): Finite element meshes process of two metals.



Experimenta Computational

Fig. (5): Weld strength (breaking force) vs laser pulse energy and welding current.



Computational Experimental

Fig. (6): Weld strength vs. temperature change and welding time.

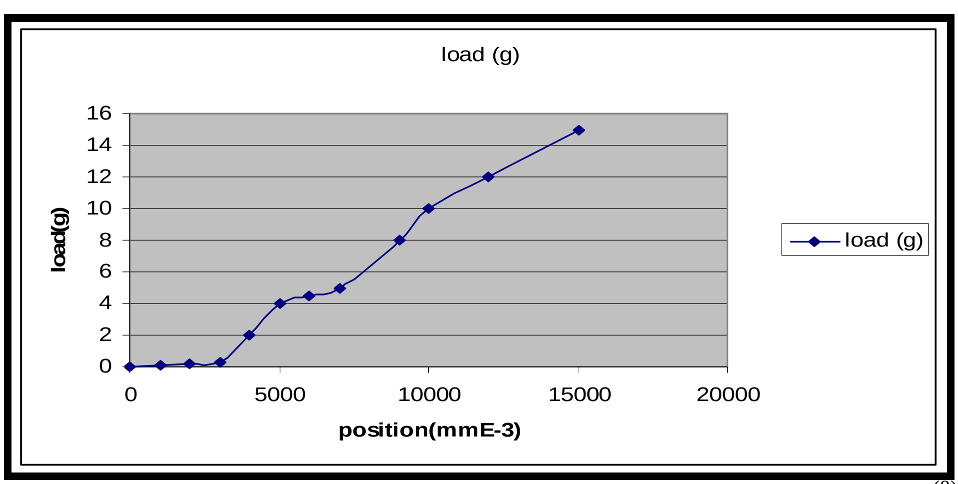


Fig. (7): stress-strain curve shows original data expressed as load vs. position.[8].

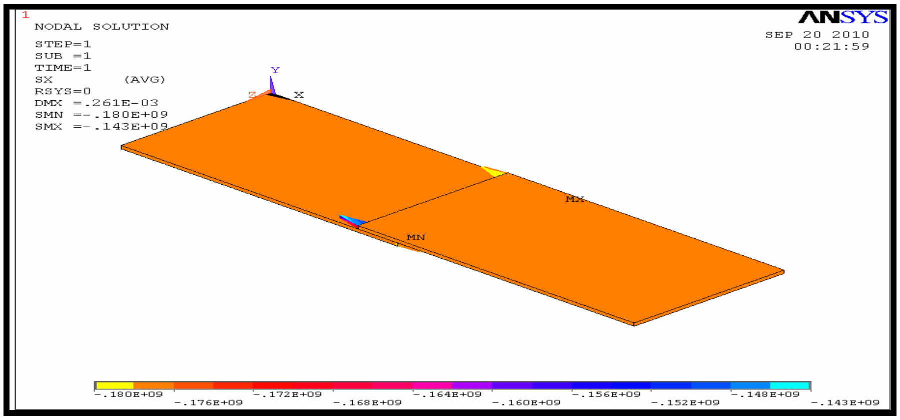


Fig. (8): ANSYS -11 stress distribution in x-direction.

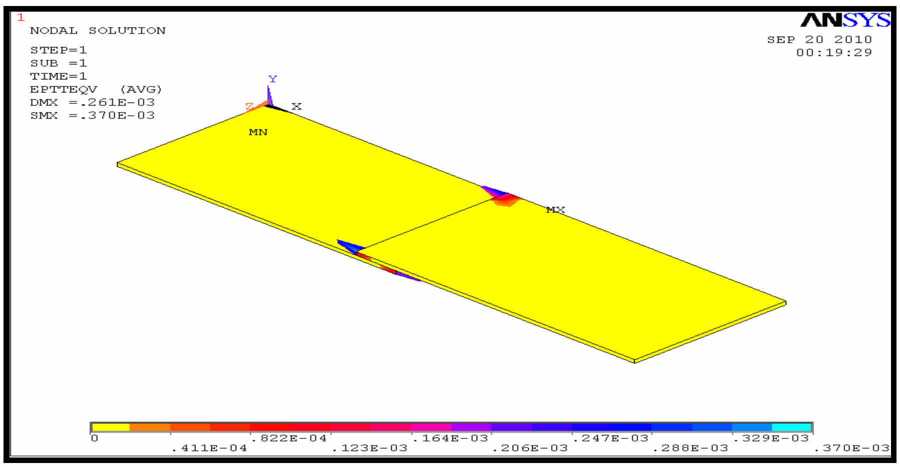


Fig. (9): Elastic strain in x-direction**.**

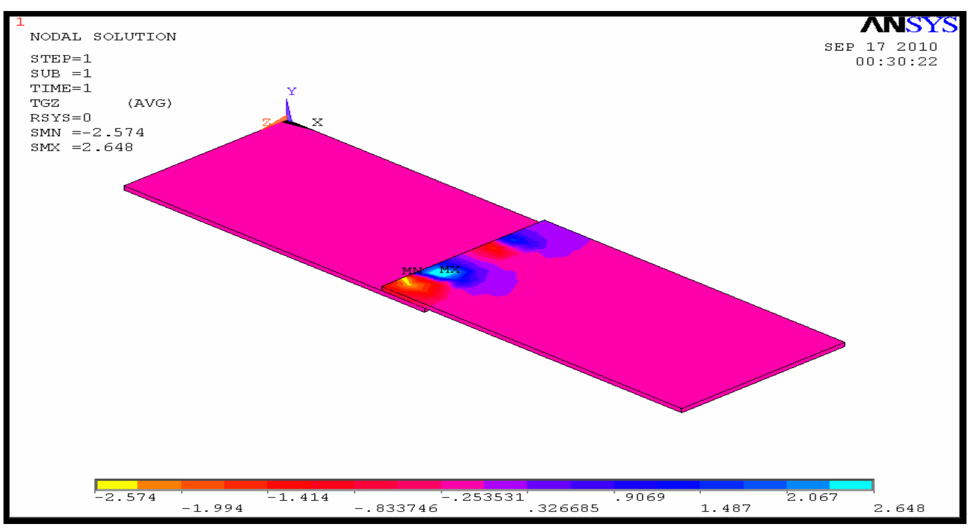


Fig. (10): Total temperature gradient in laser welding process.

استخدام العناصر المحددة في تحليل اللحام النقطي للألمنيوم بواسطة اشعة الليزر

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الخلاصة

تم بناء نموذج عددي لتحليل عملية اللحام النقطي باستخدام برنامج حاسوبي متخصص ,حيث يدرس تأثير الليزر على الخواص الميكانيكية والحرارية للمعدن.الدراسة تمت من خلال التركيز على خواص تماس الليزر على المعدن وتأثير التعرض الى درجة حرارة عالية عليه للحصول على لحام نقطى بخواص ميكانيكية وحرارية يمكن حسابها باستخدام البرنامج مع دراسة المنطقة المحيطة بمنطقة اللحام والتى تكون معرضة إلى حدوث تغيير بالطور الناتج عن التعرض إلى درجة حرارة عالية ومركزة في منطقة صغيرة جدا .خواص المادة التي اعتمدت تتغير بتغير درجة الجرارة لحساب توزيع الاجهادات ,الانفعالات , ومقاومة القص ومقارنتها مع نتائج عملية سابقة .