Available online at www.elixirpublishers.com (Elixir International Journal)

Mechanical Engineering

Elixir Mech. Engg. 70 (2014) 24331-24333

ISSN: 2229-712X

# Study of T-Joints in Welding By Finite-Element Method and Ultrasonic Testing

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**ARTICLE INFO**

**Article history:**

Received: 2 January 2014;
Received in revised form:
10 May 2014;
Accepted: 20 May 2014;

**Keywords**

Ultrasonic testing,
Welding,
Carbon steel,
Finite element simulation.

**ABSTRACT**

In this paper, we model the arc welding process by ANSYS software, the defects of weld joints is discussed. Ultrasonic techniques have been used for this purpose. An integrated comprehensive 3D model has been developed to study the transport phenomena in welding.. This includes the arc plasma, droplet generacoppertion, transfer and impingement onto the weld pool, and weld pool dynamics. Ultrasonic Testing (UT) uses high frequency sound waves to conduct examinations and make measurements. In this paper, T-shaped junction has been modeled in the software environment. The circuit model of an element is used to simulate carbon steel. UltraSonic attachment method has been studied. The optimization model is derived.

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## Introduction

In the manufacturing plants for automobile bodies and electrical appliances, the product parts are assembled by spot-welding at multiple points. When viewed exteriorly, spot-welds usually appear as small dimples. Typical spotwelding is performed by pressing 2 to 4 steel sheets between two electrode tips several mm in diameter. Spot-welds must be carefully inspected, as the quality of the welds directly influences the strength and durability of the welded body. One conventional method for inspecting spotwelds is to check a cross-section of the welded metal.

Another is to drive a cold chisel between spot-welded sheets to determine if the sheets can be pried apart. These methods are problematic, however, as both are destructive (breaking the spot-welds) and can only be performed using spot-welds sampled from the products. For this reason, industries have long awaited the development of a reliable nondestructive method for spot-weld inspection.

Ultrasonic Testing (UT) uses high frequency sound waves (*typically in the range between 0.5 and 15 MHz*) to conduct examinations and make measurements. Besides its wide use in engineering applications (*such as flaw detection/evaluation, dimensional measurements, material characterization, etc.*), ultrasonics are also used in the medical field.

In general, ultrasonic testing is based on the capture and quantification of either the reflected waves (*pulse-echo*) or the transmitted waves (*through-transmission*). Each of the two types is used in certain applications, but generally, pulse echo systems are more useful since they require one-sided access to the object being inspected(Fig 1).

A typical pulse-echo UT inspection system consists of several functional units, such as the pulser/receiver, transducer, and a display device. A pulser/receiver is an electronic device that can produce high voltage electrical pulses. Driven by the pulser, the transducer generates high frequency ultrasonic energy. The sound energy is introduced and propagates through the materials in the form of waves. When there is a discontinuity (*such as a crack*) in the wave path, part of the energy will be reflected back from the flaw surface. The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen. Knowing the velocity of the waves, travel time can be directly related to the distance that the signal traveled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.

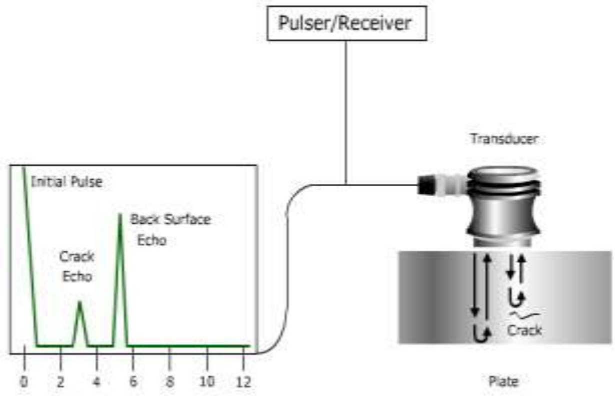


**Fig.1. Ultrasonic Testing Process**

Fig.1 shows a modern measurement method which works with ultrasound and combines a high flexibility with easy handling and high accuracy. Here a test tip is pressed manually against a workpiece. If a defined test load is passed, a spring mechanism inside the test tip is triggered and the measurement starts.

The measurement principle is based on a measurement of damping characteristics in the steel. The measurement tip is excited to emit ultrasonic oscillations by a piezoelectric crystal. The test tip (diamond pyramid) penetrates the workpiece under the test pressure caused by the spring force. With increasing penetration depth the damping of the ultrasonic oscillation changes and consequently the frequency. This change is measured by the device. The damping of the ultrasonic oscillation depends directly on penetration depth thus being a measure for material hardness.

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The display can be calibrated for all commonly used measurement methods, a meas- urement is carried out quickly and easily. Measurements can also be carried out in confined spaces. This measurement method is not yet standardised.

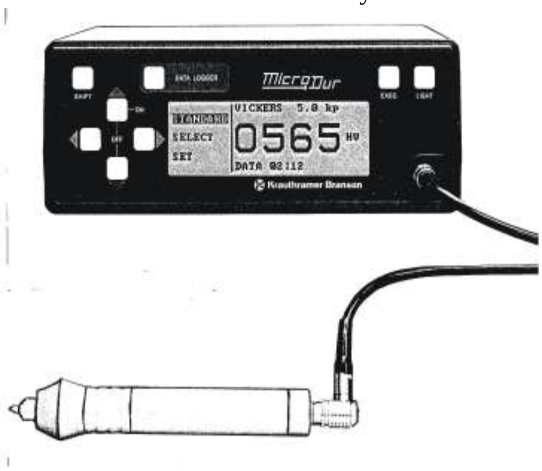


**Fig.2. modern measurement method Ultrasound attenuation measurement**

Ultrasonic testing is based on the vibration in materials which is generally referred to as acoustics. All material substances are comprised of atoms, which may be forced into vibrational motion about their equilibrium positions. Many different patterns of vibrational motion exist at the atomic level; however, most are irrelevant to acoustics and ultrasonic testing. Acoustics is focused on particles that contain many atoms that move in harmony to produce a mechanical wave. When a material is not stressed in tension or compression beyond its elastic limit, its individual particles perform elastic oscillations. When the particles of a medium are displaced from their equilibrium positions, internal restoration forces arise. These elastic restoring forces between particles, combined with inertia of the particles, lead to the oscillatory motions of the medium.

Ultrasounds (ultrasonic Lamb waves) are transmitted to a steel sheet at a ‘‘sending point’’ outside the weld metal of a spot-weld (nugget) and propagate toward the weld metal as a certain propagation mode. When the ultrasounds reach the edge of the weld metal, the propagation mode of the ultrasounds is converted into other mode by reason of change in thickness and the ultrasounds propagate toward the opposite edge of the weld metal as the propagation mode 2. At the opposite edge of the weld metal, the propagation mode of the ultrasounds is converted into the former mode (mode 1) and the ultrasounds propagate toward a ‘‘receiving point’’ opposite to the sending point. Finally through-transmitted waves are detected at the receiving point. The ultrasounds with different values are treated as different modes in the description above. Here, f is frequency of the ultrasounds; and d is the thickness of the propagation medium.

The weld metal usually has a thickness-direction-oriented structure, because the heat generated by spot-welding moves toward the electrode tips and then a temperature gradient occurs in the thickness direction. Fig.3 shows a typical optical micrograph of weld metal.

In contrast, if there is no weld metal in the spot-weld, high transmissivity for ultrasonic waves (little attenuation) is observed as shown in Fig. 3, because there is no coarse structure in the propagation path.

Whereas the estimated transmissivity with the conventional method based on the straight beam technique may take the same value at different growth stages of the weld metal.

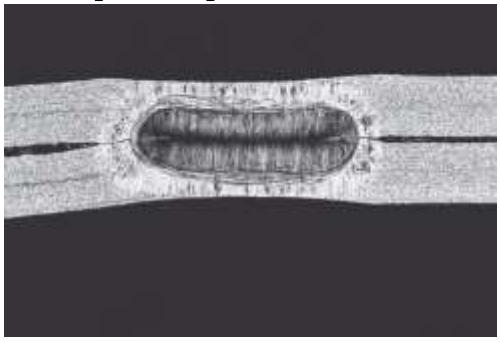

**Fig. 3 Optical micrograph of typical weld metal**

**Finite-Element simulation**

In Fig.4, finite element model is shown For meshing of workpiece (carbon steel) by considering the study of thermal field, from the thermal elements set, we chose the solid45 type. Because as axisymmetric element with conduction property, this element has 4 node with one degree of freedom.

The corresponding finite element equations of thermal and mechanical are obtained by choosing a form of interpolation function representing the variation of the field variables, namely temperature, T and displacement, U, within the corresponding finite elements of the structural model and by applying further the weighted-residual or variational argument to the mathematical models. Furthermore, with imposing the boundary and initial conditions, the discritized equations obtained are solved by finite element techniques through which the approximated solution over the finite element model considered could then be obtained.

In the present study, a thermal elasto-plastic finite element procedure was employed to simulate the thermo-mechanical response of welding problem. In the procedure, two sequenced thermal and mechanical analyses were carried out independently (uncoupled) to obtain the total or desired response of the welding structure modelled.

Fig 4 represents the mesh of T-joint fillet weld employed in this study along with the position of constraint assigned on the finite element model. The total number of nodes and elements utilized for the 3D model were 3654 and 2961, respectively. The analyses were implemented in ANSYS environment utilizing the element type of SOLID70 for the thermal analysis and that of SOLID45 for the structural analysis

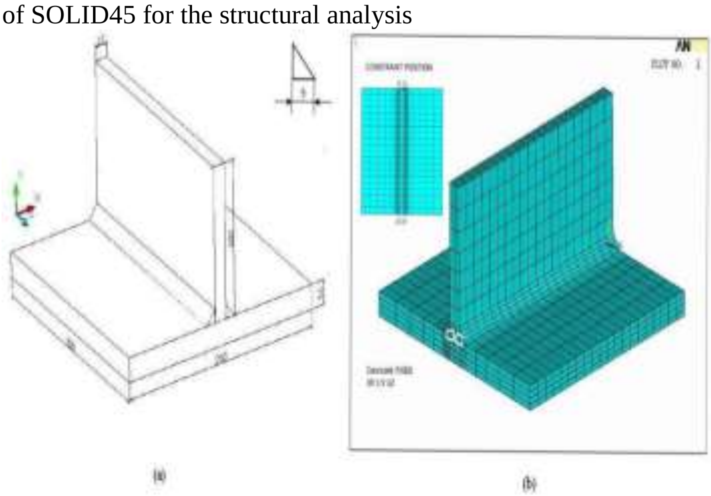

**Fig.4. 3D Finite Element Simulation of T-Joint Fillet Weld**

**Results and discussion**

With the finite element procedures described in the previous section, results on the problem considered are presented in this section. The finite element simulation for all the variation of welding was completed in 45 load-steps (LS). During the number of load-steps, the welding process took for 40 load-steps, while the cooling one took for the rest of the LS. For the presentation of welding simulation, the results of the LS which respectively represent the conditions of the peak temperature and the beginning of cooling processes were taken and plotted. Note that the temperature went down towards the reference (room) temperature after the LS of 41. Accordingly, the longitudinal and transverse residual stresses and the distortions occurred due to the welding sequences were presented and discussed.

Fig.5. illustrate the welding simulation showing the peak temperature for each welding sequence and the temperature distribution after welding towards the room temperature. From the temperature distributions, it is clear that the peak temperature achieved in the welding was greatly affected by the welding sequence. The welding sequences produced different interaction between the current step and the accumulation of heat carried out from the previous steps due to the sequential path followed.

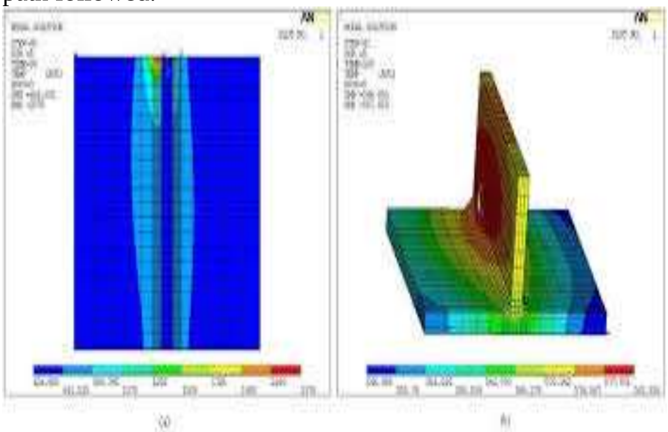

**Fig.5. The welding simulation for WS-1: (a) the peak temperature achieved at the LS of 40, and (b) the temperature distribution after the welding process at the LS of 41**

**Conclusion**

Wellding sequences effect on temperature distribution, residual stresses and distortions of T-joint fillet welds has been studied numerically in this paper. The simulation results revealed that peak temperature achieved in the welding was greatly affected by the WS and residual stress and angular distortion produced cannot both hold in minimum for a WS. The smallest longitudinal and transverse residual stresses occurred in WS-2, while the smallest angular distortion and difference in WS-4. The distributions of temperature, longitudinal and transverse residual stresses as well as angular distortions were also presented.

The results of simulation and experiments show that applying ultrasonic welding arc is suitable for fitting T-joint.

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