

# **Solidification Velocity and Vapor Recoil Force Measurement in 304 Stainless Steel Laser Spot Welds for Computer Model Verification**

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## **Introduction/Background**

Small diameter (~1mm) laser spot welds are commonly used to permanently fasten components after assembly. Precise fit-up and low distortion are required to maintain the welded assembly's dimensional integrity. Finite element models of the laser spot welding process are being developed so that more effective welds can be made. These models predict keyhole formation and solidification velocities in the spot weld. It is important to experimentally verify these predictions. Experimental techniques have been developed to directly measure recoil forces and solidification velocities in laser welds. These techniques will be presented and the experimental data will be compared with model predictions.

## **Procedure**

A Nd-Yag laser was characterized and used to make a series of laser spot welds. These welds were filmed using a high-speed camera. The diameter of the liquid pool was measured from each video image. This information was used to calculate the solidification velocity of the laser spot welds. Recoil force associated with keyhole formation was measured using a force transducer. A cylindrical 304 stainless steel weld coupon (5 mm diameter X 10 mm long) was placed on top of the force transducer such that the recoil force acted normal to the transducer. Both keyholeing and non-keyholeing welds were characterized.

## **Results and Discussion**

Measurement of solidification velocities and recoil forces in laser spot welds is difficult because of the small size of the welds (~1mm diameter), the high temperatures involved (>1300°C), and the short life of the liquid pool (~10msec). Nevertheless, measurements of solidification velocity and recoil force have been made over a wide range of welding conditions (250 – 1200 watts nominal laser power). Solidification velocity data was collected for non-keyholing welds and for

keyholing welds. As expected, significantly different velocity profiles were found for keyholing and non-keyholing welds. Recoil force was measured for keyholing welds only. As expected, recoil force increased with increasing laser power. This data was compared to solidification velocity and recoil force predictions made using Sandia National Laboratories' GOMA model. The experimental measurements of solidification velocity and recoil force agreed closely with the predictions of the GOMA model. This data provided a valuable experimental validation of the GOMA model because, like the model, it captured the dynamic behavior associated with formation and solidification of the laser spot weld.

### **Conclusion**

Time resolved measurements of the liquid pool diameter and recoil force in keyholing and non-keyholing laser spot welds were made. This data was used to validate a physics based model (GOMA) of the laser spot welding process. The experimental techniques used to measure the laser spot welds in this investigation are simple, straightforward, and provide a tremendous amount of information. Comparison of experimental data from a simple laser spot weld to the predictions of the GOMA model increases confidence in GOMA predictions of more complex welds.

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