Experimental Analysis and Modeling of the Friction Drilling Process

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Objectives

Characterization of friction drilling process including:

- Mechanical and thermal aspects
- Mathematical and FEM modeling
- Material behavior
- Tool wear
- Friction drilling of new light-weight materials

Motivation

- One of the major problems in manufacturing engineering is joining sheet metal, tubing, or thin walled profiles in a simple, efficient and cost-effective way
- Methods currently employed: 1) Include J-nuts, weld-nuts, clench nuts, and other threaded inserts, 2) Require welding or attaching by some other means, a small part to a piece of sheet metal that has been stamped or drilled
- A method to eliminate production steps, while at the same time eliminating waste and clutter from countless nuts and inserts, is presented

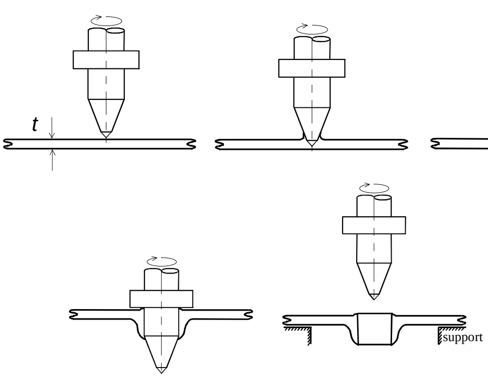


Illustration of stages in friction drilling process

Cross section of hole and bushing

Approaches

Mathematical Model
- Find temperature dependent material properties
- Develop equations for thrust force and torque
- Verify the model with experiments

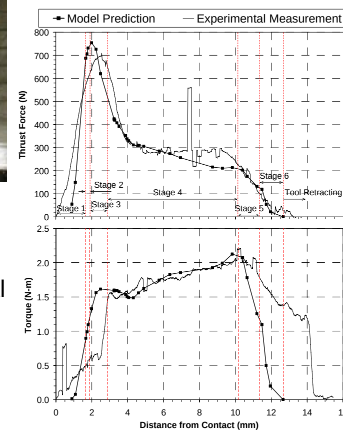
Finite Element Model (FEM)
- Form constitutive boundary equations for model
- Investigate effect of coefficient of friction in model
- Output information about work-material behavior

Experimental Analysis
- Design experiments and record data
- Verify FEM results and scientific hypotheses

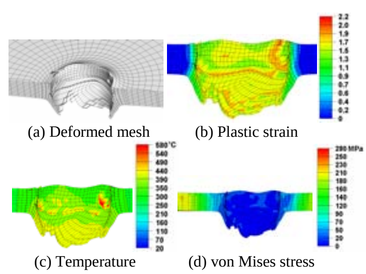
Accomplishments

Experimental setup

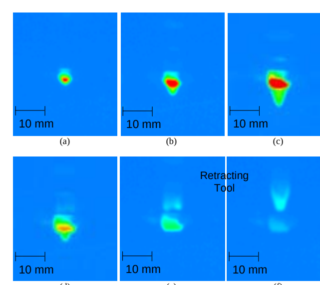
- The analytical model matched well to experimental results of thrust force and torque.
- The FEM accurately predicted the workpiece temperature and the workpiece shape.
- Effects of friction drilling on material grain micro-structure and material properties were characterized.
- Temperature was measured with infrared camera system throughout the friction drilling process.



Experimental measurements and comparison to analytical modeling results



FEM results



Thermal imaging of friction drilling using infrared camera system

Future Work

- Create a more accurate friction model with experimental measurement of the coefficient of friction dependent on temperature, pressure, sliding speed, etc.
- Incorporate self threading fasteners with the resulting hole from friction drilling

Sponsor

- U.S. Department of Energy

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Development of Ultrasonic Assisted Friction Stir Welding (UaFSW)

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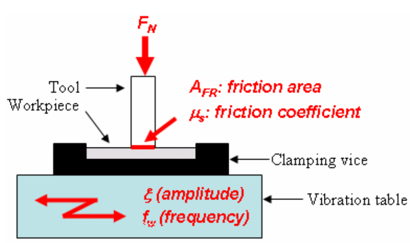
Objectives

- To investigate fundamental understanding, underlying scientific and technical challenges of UaFSW process
- To develop a methodology to investigate the effect of weld quality and tool life in applying ultrasonics to FSW of high temperature materials

State-of-the-Art

- Since invented in 1991, FSW has been successfully used for joining low melting temperature materials
- Applications in high strength alloys, such as titanium and stainless steel, remain limited due to problems in terms of required force and tool life
- Ultrasonic assisted processes have been coupled with tooling in machining, drilling, and welding in order to reduce static deformation force, increase processing rate, and improve product quality
- UaFSW will enable to reduce welding force, reduce weld time, reduce power requirement, avoid tool fracture, and increase the range of material choices.



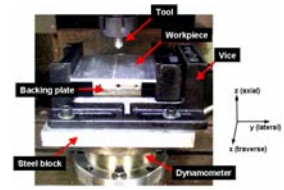
Overview of ultrasonic assisted friction stir welding (UaFSW)

Approaches

- UaFSW system should be constructed in such a way that the ultrasonic energy is effectively transmitted into the workpiece. Therefore, guidelines for the design of ultrasonic system should be developed
- Predictive models for rapid and reliable evaluation will be developed and parameters optimization will be conducted to achieve successful process conditions for UaFSW
- Numerical model and experimental investigations will be incorporated with the basic knowledge of this process

Accomplishments

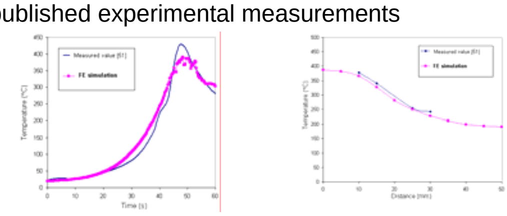
- In-house CNC drilling machine was successfully used to demonstrate FSW, and reasonable welds were obtained for 6061-T651 aluminum alloy
- It was observed that welding conditions such as rotational speed, translational speed, and plunge depth significantly influenced the weld quality



Experimental setup

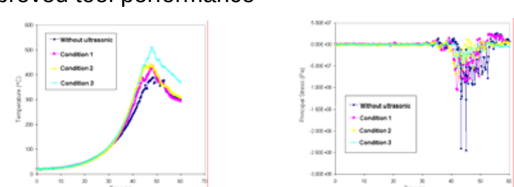
Surface appearances of welds

- FE model of FSW showed good agreements with the published experimental measurements



Validation of FE model with experimental results

- Ultrasonic assistance increased the temperature of the weld region, and consequently decrease the stress of the region when compared with FSW without ultrasound. Therefore, axial force is expected to decrease leading to improved tool performance



Temperature and stress influenced by heat flux due to ultrasound

Future Work

- Ultrasonic vibration table, which can add controlled ultrasonic actuation to the workpiece, will be fabricated
- Preliminary DOE analysis on process parameters will be conducted to investigate the effect of ultrasonic parameters such as frequency, amplitude, and directions of vibration
- Effect of ultrasound on tool fracture and wear mechanisms will be investigated in applications with high temperature materials

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