Fall 2007 | Volume 20.4.1

Insights

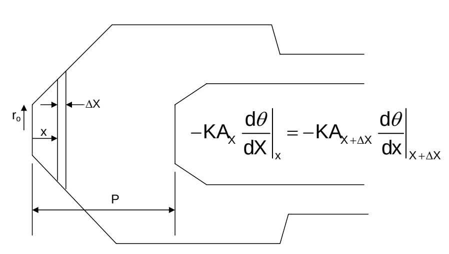
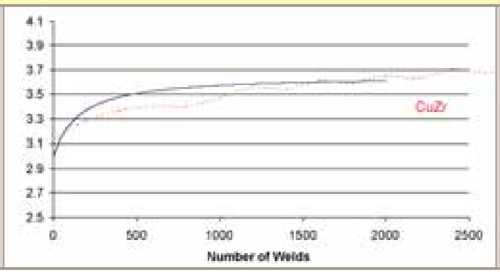


Fig. 1 Illustration of the setup of the thermal model within the electrode.

Fig. 2 Change in predicted electrode face radius as a function of numbers of welds from the thermal model.



Analytical Modeling of Electrode Wear

Jerry Gould | Technology Leader

Electrode wear as a result of resistance spot welding galvanized steels has been an industrial problem for over 40 years. Electrode wear performance is a combination of many factors. These include the characteristics of the coating, electrode geometry, electrode material properties, cooling paths, weld processing, etc.

Modeling efforts to understand the complex series of events leading to electrode wear have been hindered by the repeated nature of the process itself. Simulations are generally computationally intensive, and efforts to repeat this analysis over thousands of repeated welds (including weld to weld redefinition of electrode geometry) make generation of useful data nearly impossible. The best alternative: an analytical model combining thermal and mechanical processes for a single spot weld. With this formulation, electrode changes can be assessed on a weld-to-weld basis. Geometry variations predicted for one weld can be quickly adapted to the next, allowing wear assessments over extended wear cycles. Results can then be used to provide insight to the characteristics of electrode wear.

So, what's the best analytical methodology for predicting electrode wear when resistance welding galvanized steels? First, thermal profiles in the spot weld and electrode were estimated using a one-dimensional approach. The spot weld thermal profile is based on a thermal balance between the material stack-up, nugget penetration, and electrode geometry. Thermal profiles in the electrode are based on the results from the spot weld, as well as its relative conductivity and geometry. Results for a single weld cycle allow prediction of a forge zone at the electrode face. Deformation of this zone under the applied stress was then used to define the wear and relative resultant changes in electrode geometry. Electrode life is then predicted as a summation of these deformations from weld to weld. This is done by repeated applications of the defined equations in a spreadsheet format.

Initial results are shown consistent with representative electrode life tests. The equations are then used to understand the influences of a number of manufacturing factors associated with electrode life performance. These included the weld stack-up, weld penetration, electrode face diameter, electrode body profile, and relative depth of the cooling hole on the electrode. Results offer insight into the deformation aspects of electrode wear, as well as design solutions to minimize that wear. The current model can be used as a basis to isolate the contributions of the chemical component.

The resulting model provides a first look into the processes that govern electrode wear during resistance spot welding. Of note, wear associated with chemical interactions between the copper electrode, zinc coating, and steel substrate has been neglected in these analyses. However, this analytical modeling can be used as a basis to understand these chemical interactions and their additional impacts on electrode wear.

For more information about electrode wear, please contact Jerry Gould at 614.688.5121or jerry_gould@ewi.org.

The President's Corner


Henry J. Cialone

Recently, several business journals have debated the effects of process improvement methodologies on operations that have high expectations for innovation and R&D. With so much emphasis on processes such as Six Sigma, Total Quality Management (TQM), ISO Certification, and other "branded" approaches to optimizing the manufacturing environment, you too, may be wondering how these quality and efficiency focused initiatives are affecting our collective ability to invent, reinvent, and research new technologies.

Not surprisingly, a few engineers at some well-known manufacturing companies have argued that the path to new products and patents doesn't jive with practices that drive controlled outcomes. As a fellow engineer, I understand their concern. As a CEO and as an advocate for EWI Members, I also know that any business partner, acting as an extension of your operation, must help you achieve your objectives. In the case of EWI, you could call upon us for anything from help in meeting regulatory compliance guidelines to designing new welding and bonding procedures. In other words, our business must face the demands you face. We strive to be both proficient at systematic problem solving and renowned for unbiased, open-minded exploration of joining techniques.

I'm proud of the fact that, as an organization, EWI practices and adheres to a number of principles of operating efficiency as it strives to supplement older technologies and prove the value of new technologies. One of the ways we have demonstrated this interest was by obtaining ISO 9001:2000 certification for our Lab operations earlier this year. This is an important requirement for many of our Members who demand that consistent business and scientific methods are applied to the work we do on their behalf. Our Members often call upon us to assist their supply chain as well. And here, our Total Quality Joining Assessment services can be of value when it's critical for Manufacturers (especially OEMs) and their suppliers to achieve new production goals, or to assess any number of manufacturing steps.

And because our reputation for objectivity in materials joining is our true calling card, we expect that the opportunities we encounter to collaborate with customers are bound to prompt breakthroughs that will make a difference in the productivity of many industries across many market sectors. Each year we attempt to "seed" the development of new joining techniques through reinvestment in our organization. Through the joining challenges you bring us, through the purchase and installation of new equipment, the addition of staff trained in new technologies, the initiation of new research projects, and finally through the ongoing professional development of our highly skilled engineers and technicians, we continue to create an environment that fosters advances in joining processes and all of the work we perform.

We are admittedly eager for the next unexpected production or design dilemma. We are in the unique and enviable position to offer innovative joining solutions while we solve joining challenges — any of which may lead to new and cleaner ways of producing energy, safer ways of traveling, less costly medical devices, and more competitive manufacturing methods. To sum up, I believe that it will always be our practice at EWI to inject precision and productivity into final outcomes while allowing the investigative or analytical portion of any project to be as creative and pioneering as is practical or possible.

Upcoming Tradeshows

Look for EWI staff at the following tradeshows and events later this year:

10/15 - 10/18/2007
Fuel Cell Seminar
www.fuelcellseminar.com
Booth #238
Henry B. Gonzales
Convention Center
San Antonio, Texas

10/17 - 10/18/2007
Medical Design & Manufacturing
Minneapolis
www.devicelink.com/expo/minn06/
Minneapolis Convention Center
Minneapolis, Minnesota

10/29 - 11/1/2007
ICALEO
International Congress on
Applications of Lasers & Electro-
Optics (ICALEO)
www.icaleo.org/
Hilton-Walt Disney World Resort
Orlando, Florida

11/7 - 11/8/2007
International Automotive
Body Congress
www.bodycongress.org
Troy, Michigan

11/11 - 11/14/2007
The FABTECH International
and AWS Welding Show
www.fmafabtech.com/
Booth # 3003
McCormick Place
Chicago, Illinois

11/12 - 11/16/2007
ASNT Fall Conference and Quality
Testing Show
www.asnt.org
Las Vegas, Nevada

12/3 - 12/6/2007
Defense Manufacturing Conference
www.dmc.utcdayton.com
Las Vegas, Nevada

12/10 - 12/11/2007
69th Laser Materials Processing
Conference
www.jlps.gr.jp/
Tokyo, Japan

Jim Tighe Named Vice President and CFO

Jim Tighe recently joined EWI as its Chief Financial Officer and Vice President of Administrative Services. Mr. Tighe succeeds Robert Myers, who recently retired from the organization. In his new role, Mr. Tighe leads the finance and accounting, payroll, information technology, contracts, and legal services teams at EWI.

Henry Cialone, President and CEO of EWI stated, "Jim's combination of skills and over 15 years of experience support EWI's commitment to sound financial strategy and its plans for growth and success. We are pleased that he has joined our leadership team."

Jim Tighe commented, "I'm delighted to be associated with some of the world's foremost materials joining engineers and scientists. I look forward to helping EWI manage its fiscal responsibilities and achieve its financial targets."

Previously, Tighe served Sterling Commerce in positions that included Director of Global Finance, VP of Managed Services and Assistant Controller. Additionally, his professional experience includes the titles of Corporate Controller for Pathlore Software, CFO for SARCOM Enterprise Education Systems, and auditor for Ernst and Young. He has a BS in Accounting from Miami University and is a Certified Public Accountant.

Additional Staff Changes

Though longtime EWI associate Harvey Castner retired from his position as Vice President of EWI's Government Programs Office at the end of June, his connection with EWI continues. Harvey is now working on a part-time basis as a Technology Leader in the Arc Welding group of EWI's Engineering Operations.

Other staff changes that occurred earlier this year include promotions to Vice President for Chris Conrardy and Mark Matson. Chris is now Vice President, Technology and Innovation and serves as EWI's Chief Technology Officer. In this role, Chris is EWI's principal technology strategist and authority in the conceptualization, assessment, and leveraging of technology to develop new capabilities for innovative business solutions.

Mark Matson, now Vice President, Human Resources, is responsible for principal leadership of the organization's talent management strategy and supporting policies, procedures and programs.

EWI does *that?*

EWI recently launched a new advertising campaign to promote the full breadth of EWI capabilities and services. These ads will appear in some specific industry trade journals and other publications aligned with materials joining and welding.

Insights is produced four times per year. Please direct general questions and comments to Lisa Austin, Corporate Communications Manager, at 614.688.5130 (lisa_austin@ewi.org). Questions relating to an article may also be directed to the contact listed in the article.

EWI
1250 Arthur E. Adams Drive
Columbus, OH 43221-3585
614.688.5000 FAX 614.688.5001
www.ewi.org

Finite Element Analysis Assisted Design - Application to Ultrasonic Tooling and System

Finite element analysis (FEA) of welding processes has been utilized in the industry to cut product development cost and improve time-to-market. EWI has developed advanced FEA models to assist designs of welding tooling and systems including magnetic pulse, friction stir and ultrasonic welding, just to name a few. This article presents recent advances of FEA assisted design of ultrasonic tooling and systems. EWI's FEA modeling techniques are unique in several ways including modeling of complex tooling, inclusion of material losses to predict transducer heating, predicting the electrical impedance of the transducer and tooling system, and modeling of an ultrasonic system driven by one or more transducers.

Finite element modeling of ultrasonic tooling

Ultrasonic metal welding is a solid-state joining process that produces coalescence through the simultaneous application of localized high-frequency vibratory energy and moderate clamping forces. Present ultrasonic metal welding technology is limited to welding thin gauge materials (e.g., 1 mm) of softer metal alloys (e.g., aluminum, copper) due largely to power constraints of current welding systems. To expand the capability of ultrasonic metal welding, EWI has developed high-power ultrasonic (HPU) systems to weld higher strength and thicker gauge materials. An important task of developing the HPU system is the design process with finite element analysis.

The FEA technique has been widely used for predicting the vibration behavior of the ultrasonic tooling. It is particularly suited for the determination of natural frequencies, vibration mode shapes, and steady-state frequency responses. The advantage of using FEA in the tooling design phase is time and material savings through reduction of trial and error in the machining process, especially for tooling with complex geometry and vibration modes. In the design of HPU systems, FEA has the advantage of predicting heat generation in the transducer to prevent material overheating and damage, analyzing tooling behavior attached with transducers, and simulating the process with multiple transducers.

Design of tooling (Horn)

FEA for horn design is normally free vibration analysis. Both 2D and 3D analyses are effective depending on the complexity of the horn geometry. The important parameters for successful design are material elastic properties and basic input geometry. Fine tuning of the geometry to achieve the required frequency can be done in two ways. One is geometry adjustment through a series of modeling iterations; the other is parameter optimization study through predefined variables and targets. Figure 1 shows an FEA design of a 20 kHz “mixed-mode longitudinal-torsional” (MMLT) intended for use in ultrasonic metal welding. The essence of the approach is to slot a hollow horn such that a twisting motion is induced during the usual longitudinal vibrations of a transducer.

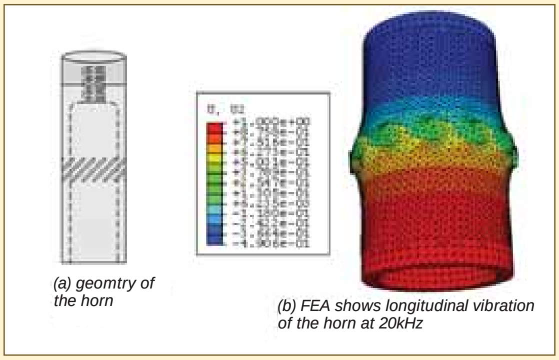


Figure 1: MMLT design: OD=38.1mm, ID=30mm, T=25.4mm, 12 slots @45° 1.6mm wide x 12.7mm long, slots center is 37mm away from the solid end

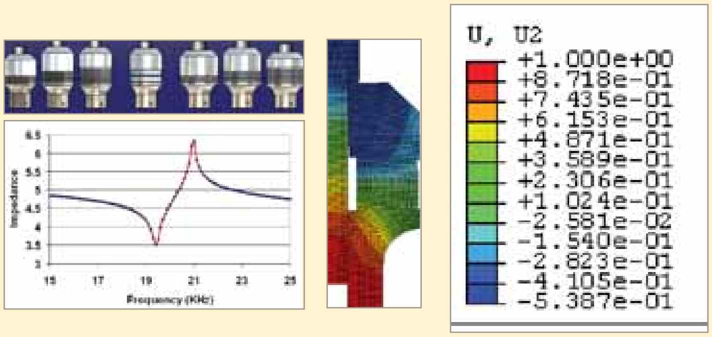


Figure 2: A series of transducer designs using free vibration and impedance analysis

The combined motion induced at the welding tip is expected to create a better bond than just longitudinal motion alone. Through a series of baseline design to different slot variations, an effective welding horn was designed and built. The analysis showed that the slot width, length, angle, and slot locations are critical parameters affecting the performance of the horn.

Modeling of HPU transducers to predict heat generation

To increase the power capacity of HPU transducers for ultrasonic welding applications, new designs must be considered that use wider and thicker piezoceramic disks as well as innovative geometrical factors. Prediction of temperature rise in the ceramic disks is essential for applying cooling and heat removal strategies. Heat generation due to material bulk and frictional losses in a transducer involve multiphysics modeling, which includes structure mechanics, piezoelectric, and heat transfer simulation.

EWI's HPU transducer modeling capabilities include free vibration analysis, electrical impedance prediction, and coupled modeling for heat generation. Free vibration is nodal analysis used to obtain the geometry of the transducer. Once the transducers are designed, electrical impedance prediction is done through harmonic vibration modeling. Resonance and anti-resonance (also known as series and parallel resonances) frequencies are obtained from the resulting impedance curves. Figure 2 shows designs with free vibration analysis and impedance prediction.

Prediction of heat generation was conducted through a fully coupled structural-piezoelectric-thermal analysis. Complex material properties were needed as input for the model to account for elastic and piezoelectric material losses. The material energy losses then transferred to heat sources for temperature prediction in the ceramic disks. This modeling permitted the temperature of the transducer at steady-state to be predicted. Heat management methods were incorporated in the design and in the model to remove heat from the ceramic disks. Figure 3 shows varying temperature distributions in the ceramics as a result of using different cooling strategies. With this design method, a 7.5kW transducer was built and tested.

Simulation of the transducer, booster and horn system

Having analyzed transducer and tooling vibration behavior, as well as impedance and heating characteristics, EWI has extended the modeling capability to simulate the entire system including transducers, boosters and horn. This includes systems involving two transducers operating in a "push-pull" configuration, as shown in Figure 4(a). This design is motivated by the need to provide higher ultrasonic power to a welding process than can typically be achieved from a single transducer. The general concept is shown in Fig. 4(a), while the simplified illustration of Fig. 4(b) shows how the components are assembled to achieve the desired push-pull – thus, the transducer on the left is "pushing" while the one on the right is "pulling." It should be noted that a general, cylindrical, full-wave "sonotrode" is shown in Fig. 4(a). In practice, a specific welding sonotrode of proprietary design would appear at this location.

The design of this system was first done through a series of free vibration analyses. After obtaining the geometry of each of the components, the overall system free vibration was also analyzed. Figure 5 shows that the system frequency is 20.08kHz. Harmonic modeling was then performed to study how the phase shift between the left and right transducer affected the overall assembly performance. Analysis was done to determine the sensitivity of the system to phase shifts between the push and pull input voltages, with it being found that even moderate shifts (e.g. 18°) had little effect on resonance and the push-pull behavior.

For more information, please contact Peihui Zhang at 614.688.5237 or peihui_zhang@ewi.org.

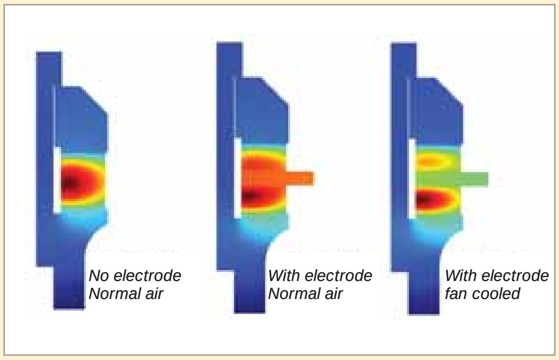


Figure 3: Temperature prediction in transducers with different cooling strategies

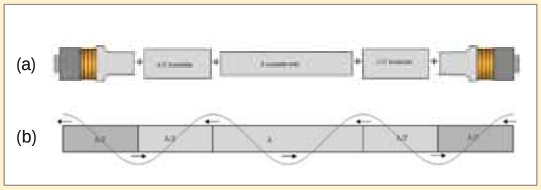


Figure 4: Design of a "push-pull" system

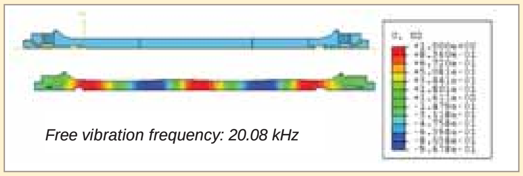


Figure 5: Free vibration of the "push-pull" system

New CRPs Now Available

Several new Cooperative Research Project (CRP) Reports are now available to EWI Members.

The topics selected for research focus on technologies and capabilities that address the current and future needs of EWI member companies in a number of industry sectors. Results of the program are available to member companies so they may take immediate advantage of the latest advances in materials joining to enhance their productivity, competitiveness, and bottom-line performance.

Recently Published CRP Reports include:

Advanced Eddy Current Inspection of Steel Structures, July 2007
Authors: Evgueni Todorov and William Mohr

Thermomechanical Fatigue Tester, July 2007
Authors: Alpesh Shukla, William Mohr, Fabian Orth, Alex Channel

Automated Weld Modeling Tool Framework, July 2007
Authors: Shuchi Khurana, Wei Zhang, Wei Gan, Suresh Babu

Improved Methods for High-Alloy Buildups, June 2007
Authors: Nick Kaputska, Matt Short, Karl Graff

Fracture Toughness Properties of Spot Welds in DP 590 Steel, March 2007
Authors: Warren Peterson, Fabian Orth

Development of an Advanced FE Structural Analysis Tool, February 2007
Author: Yu-Ping Yang

Phased-Array Ultrasonic Inspection of Clad Piping, January 2007
Authors: Mark Lozev, Pratik Patel, Roger Spencer

For more information on a specific project, contact EWI at 614.688.5000. A complete listing of EWI CRP Reports (dating back to 1987) is available through EWI's Member Central web site.

EWI Launchs E-Weld Predictor©

In early September, EWI launched E-Weld Predictor, an on-line software tool that simulates various welding procedures in support of an organization's fabrication goals. This on-demand product allows welding engineers to evaluate the changes in temperature profiles, material microstructures, residual stresses, and welding distortion when designing welded joints.

Currently, experimental welding procedure trials can be cost prohibitive due to the myriad of geometrical, process, and material combinations. By using E-Weld Predictor, engineers can explore a wide range of "what if" combinations and simulations. Until now, accessing the computer power required to generate such complex calculations has been cost prohibitive for most small- to medium-sized companies. But E-Weld Predictor couples the data processing power of the Ohio Supercomputer Center (OSC) with EWI's engineering knowledgebase so that more organizations can experiment with simulation research and thereby trim their overall scale-up and design budgets.

EWI worked with OSC staff on the engineering application and collaborated on the user interface design. "We want to help companies build better products, cut production costs, quickly solve problems, and streamline overall efficiency," said Stan Ahalt, Executive Director of OSC. "Our partnership with EWI has allowed us to work on an innovative application that will bear immediate rewards for its membership."

Henry Cialone, CEO of EWI stated, "For the last two decades, simulation tools of this kind were only accessible to large-scale industries who could afford the expertise, technology, and infrastructure required to take advantage of these simulation tools. However, the launch of this service levels the playing ground for small- to medium-sized companies."

The first roll-out of the offering, best-suited for heavy manufacturing and energy industries, is based on arc welding processes and is focused on pipe and plate weld simulation for steels. Additional processes and applications, including automotive applications, will be evaluated for future roll-out. The tool can be accessed through the Virtual Joining Portal section of the EWI website at http://calculations.ewi.org.

About OSC
The Ohio Supercomputer Center promotes and stimulates computational research and education in order to act as a key enabler for the state's aspirations in advanced technology, information systems, and advanced industries. For additional information visit: http://www.osc.edu.

EWI Receives Renewal Contract to Provide Materials Joining Technology to US Navy

Edison Welding Institute has been awarded a contract from the Office of Naval Research to operate the Navy Joining Center (NJC) for the next five years. The contract award has a ceiling value of $90 million. This award is the result of an open solicitation from the Navy ManTech Program to continue operation of the Navy ManTech Center of Excellence for materials joining and is EWI's fifth competitive win in this program. Since its inception in 1993, the NJC has brought over $63 million in applied research to EWI.

This new contract permits EWI and a team of 24 industrial, academic, and technology partners to continue to support the Navy ManTech Program's objectives of affordability, production cycle, and risk reduction. Implementing the best materials joining technologies is critical to improving the performance of Navy weapons systems and increasing the productivity of manufacturing practices needed to reduce the acquisition costs of these systems.

During the last 5 years operating the Navy Joining Center, EWI has worked with the Team Partners to develop and transition advanced materials joining technologies that directly benefit the Navy by first enhancing the war fighting capabilities of Navy platforms and weapons systems, and second, producing Navy systems at the lowest cost to the government. This has resulted in the NJC performing projects that produced an estimated $95 million in production cost reductions or cost avoidance for Navy weapon systems. The savings on each system helps the Navy increase the number of warships and other weapon systems that can be purchased with available funding and thereby increases US defense capabilities.

Dr. Henry Cialone, President and CEO of EWI stated, "We are proud of our record of transitioning affordable manufacturing processes to industry. This technical excellence was recognized with the 2005 ManTech Center of the Year award given to EWI's NJC team."

With the new contract, EWI announces promotions in their Project Management Office of Timothy Trapp to Director of the NJC and Lawrence Brown as Business Manager of the NJC. Mr. Trapp has been with EWI for 12 years and has more than 23 years of welding experience as an engineer and program manager. He has been part of the NJC since 1999 and is directly responsible for the overall management of the Center for material joining-related R&D, project planning and development, and resource selection. He is also the primary point of contact with the customer and establishes policies and implements the mechanisms required to achieve the Navy's goals for the NJC.

Mr. Brown has been with EWI for 7 years and has more than 26 years of welding experience as an engineer and project manager. As NJC Business Manager he is responsible for establishing agreed-upon annual budgets and controlling costs and deliverables, technical support, and publications. Prior to assuming present duties as Business Manager in the Navy Joining Center he was an NJC Project Manager.

To read more about EWI's Navy Joining Center, please visit http://www.ewi.org/NJC. You may also contact Larry Brown at 614.688.5080 or larry_brown@ewi.org.

New EWI Members

Band-It Division of IDEX, Inc.
Denver, CO
Business: Band-It makes a wide range of stainless steel clamping, bundling, fastening, and identification products for a variety of industrial applications.

SFP Works, LLC
Washington Twp, MI
Business: Heat treating of metals

Eastern Shore Natural Gas Company
Dover, DE
Business: Interstate pipeline company

Parker Hannifin Gas Turbine Fuel Systems
Mentor, OH
Business: Manufacturer of motion and control technologies and systems

AK Steel Corporation
Middletown, OH
Business: AK Steel produces flat-rolled carbon, stainless and electrical steel products, as well as carbon and stainless tubular steel products for automotive, appliance, construction and manufacturing markets

Laser Mechanisms
Farmington Hills, MI
Business: Design and manufacture of laser beam delivery components and articulated arm systems

Keiper
Troy, MI
Business: Vehicle seating systems

Insights

EWI
1250 Arthur E. Adams Drive
Columbus, OH 43221-3585

Non-Profit
U.S. Postage
Paid
Columbus, Ohio
Permit No. 1624

EWI is Destination for Future Engineers' Summer Camp

Earlier this summer, EWI was host to a group of 30 eighth grade girls who participated in a Future Engineers' Summer Camp program organized by The Ohio State University. The program, now in its fourth year and led by OSU's Dr. Linda Weavers, was designed to generate excitement and enthusiasm for engineering and science. The girls touring the EWI facility discussed the processes used in joining items that are used by young teens every day such as backpacks, tennis shoes, school desks, notebooks, eye glasses, and bicycles. In addition, the students were presented with information about future careers in weld inspection, testing, modeling, materials development, and other related technologies. A hands-on demonstration (using all appropriate safety gear and precautions) in EWI's small-scale laser lab allowed each student to weld paper clips together. EWI Business Development Engineer Katie Levesque commented, "It's wonderful to see growing numbers of young girls pursuing their interest in math, science and engineering. I'm proud to be part of the team of EWI associates who introduced the girls to more information about materials joining applications. I hope some of them will pursue degrees in welding engineering."

Jay Eastman discusses the basics of how an Nd:YAG laser works in EWI's small-scale laser lab.

Camp participants watch EWI Graduate Fellow Paul Boulware create a weld using a robotic GMAW.