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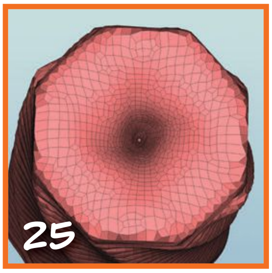

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On the Cover: A T&W Forge production team in action at a hammer.

EDITORIAL
Dean M. Peters

To AM or not to AM?

Those fortunate enough to have attended FIERF's Tech Days in early April (generously hosted by The Timken Company) got eyes- and ears-full about additive manufacturing (AM) technologies from a few presenters. AM is a topic and technology about which we've run feature articles and spoken of in this column before, and great strides are being made in AM as a means of maintaining and improving the competitiveness of the U.S. manufacturing sector.

To this end, President Obama in 2012 called for the creation of a National Network for Manufacturing Innovation (NNMI) consisting of regional hubs that would accelerate the development, scale-up and adoption of cutting-edge manufacturing technologies. In May of that year, the federal government solicited proposals from teams led by nonprofit organizations or universities to establish an Additive Manufacturing Innovation Institute. The solicitation sought proposals that included technical and business plans and detailed steps to accelerate research, development and demonstration in AM and to transition the technology to manufacturing enterprises in the U.S. In August 2012, a consortium led by the National Center for Defense Manufacturing and Machining (NCDMM) was selected to establish the National Additive Manufacturing Innovation Institute.

Last October, the Institute announced a new identity – America Makes. Based in Youngstown, Ohio, America Makes is an extensive network of nearly 100 companies, nonprofit organizations, academic institutions and government agencies from all over the country. According to Ralph Resnick, founding director of the Institute and NCDMM president and CEO, "America Makes is a vehicle for the National Additive Manufacturing Innovation Institute to raise our profile, reach a wider audience to include the hobbyist and the entrepreneur and, ultimately, provide a richer member experience. America Makes sets the stage for us to realize our mission of reinvigorating the U.S. manufacturing industry and jobs market by serving a strong message."

This mission is fostered through the open exchange of AM information and research; the development, evaluation and deployment of manufacturing technologies; the inclusion of companies and academic institutions to train a skilled workforce; and the development of its role as a clearing house between commercial, academic and government institutions that seek to further the AM industry to the benefit of the U.S. manufacturing sector.

So, what has all this to do with the forging industry, you might reasonably ask? The full answer, of course, lies years into the future, but for starters AM shows promise in the areas of part prototyping, tool and die making, and short-run small-component manufacture.

Or is AM more of a threat to the forging community? What used to be called rapid prototyping is, after all, now called additive manufacturing. AM has truly made great strides in its development during the past two decades, but when it comes to the mass manufacture of high-strength metal components rapidly and for a reasonable price, forgers have not much, as yet, to worry about.

As for America Makes, it is a good thing to see the U.S proactively protecting and nurturing its lead in global AM research, deployment and market development.

In August's Editorial we'll take a closer look at the business side of additive manufacturing.

Dean M. Peters

Dean M. Peters, Editor

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FIA'S PUBLIC POLICY WATCH

Laurin M. Baker

Lobby Day 2014

It's become a familiar site in the halls of Congress every year: members of the Forging Industry Association attending FIA's Lobby Day and meeting with members of Congress to discuss issues of concern to the forging industry.

This year's event took place April 2-3. By all accounts, it was among the most successful to date. Nineteen FIA members from all across the country (Michigan, Pennsylvania, California, Oregon, Connecticut, Indiana, South Carolina, Ohio, Illinois and Wisconsin were represented) had 45 meetings with individual Representatives and Senators and their staffs, as well as staff for several key committees and Senate Minority Leader Mitch McConnell.

Beginning at lunch on April 2, attendees were briefed on the issues to be discussed, received their individual meeting schedules and fanned out across Capitol Hill. Rep. Keith Rothfus (R-PA 12) and his Chief of Staff were guests at dinner on the first day, which was held at the historic Capitol Hill Club. Rep. Rothfus talked to the attendees following dinner, thanking them for being willing to take time to come to Washington to meet with members of Congress. He spoke eloquently of the privilege he feels in being able to serve as a member of the House of Representatives, and he urged FIA to continue to communicate with elected officials on issues of concern to the industry.

In their meetings on Capitol Hill, Lobby Day participants communicated with lawmakers on four key issues of potential impact on the forging industry: energy policy, the EPA's proposed greenhouse gas regulations (GHG), comprehensive tax reform and regulatory overreach.

On energy policy, FIA pointed out that forgers are uniquely positioned in the energy supply chain, since forging is both energy-intensive and also critical to energy production. As a result, FIA strongly supports an "all of the above" energy policy designed to produce adequate, affordable supplies of natural gas and electricity to make the critical parts needed for every energy sector (oil and gas; shale production; pipelines; nuclear reactors; and geothermal, solar and wind power).

Regarding proposed GHG regulations for power plants, FIA told members of Congress that the EPA's heavy-handed approach would virtually assure that no new coal-fired power plants could be built, which would increase costs and reduce competitiveness for U. S. forgers. As an alternative, FIA urged support for a legislative solution sponsored by Rep. Ed Whitfield (R-KY 1) and Sen. Joe Manchin (D-WV). Their legislation, HR 3826 and S 1905, would provide a reasonable path forward for the EPA while ensuring that coal would remain a viable source of energy for the future. HR 3826 has passed the House of Representatives, and S 1905 is pending in the Senate.

FIA also supported comprehensive tax reform that would simplify the tax code, lower rates and broaden the tax base, provided that any tax-reform measure treats all manufacturers alike. FIA urged that the retroactive repeal of LIFO should not be part of the tax-reform debate, arguing that repeal of the long-accepted method of accounting for inventories could bankrupt some small companies while doing nothing to reform the tax system.

Finally, the group told Representatives and Senators of their increasing concerns about regulatory overreach from federal agencies. For the past several years, agency after agency has promulgated rule after rule, including the Department of Labor, the Occupational Safety and Health Administration and the National Labor Relations Board. FIA gave examples from these and other agencies of regulations that the industry believes are beyond the scope or authority of the issuing agency and are hindering the competitiveness of U.S. manufacturers, including forgers.

Working for sound policies to enhance economic growth and avoiding counterproductive policies is hard, thankless work that can seem fruitless at times. But the FIA members who give up time from their businesses each year to come to Washington and lobby on behalf of the forging industry know better. They know that Thomas Jefferson was right when he said, "The price of freedom is eternal vigilance."

Laurin M. Baker, Founder & President • The Laurin Baker Group, LLC.
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Left to right:
Senate Minority Leader Mitch McConnell, Rep. Keith Rothfus, Rep. Ed Whitfield and Sen. Joe Manchin


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Hands-on (and Eyes-on) Experiences Make a Difference to Students

The Colorado School of Mines (CSM) offers an elective course at the senior/graduate level on "Forging and Forming" in its Department of Metallurgical & Materials Engineering. The course is taught by FIERF Professor Chet Van Tyne.

"This class is filled with metallurgical and materials engineering students, along with a few mechanical engineering students," said Madeline Hatlen, a Finkl Scholarship recipient finishing her senior year in materials engineering at CSM. "One of the best parts of this class is how hands-on it is. Lecture is three times a week along with a three-hour lab. The laboratories allow us to process and put to use all the information from the week. Another important aspect to the class was an exciting field-trip opportunity to visit A. Finkl and Sons Co. in Chicago. This field trip was not like any other I have been on with a class before, and it provided more knowledge than anticipated."

Guy Brada, director of technical services at A. Finkl & Sons Co., explained that the genesis of the tour goes back to 2000 when Professor Van Tyne saw the benefit for his students to see first-hand the processes conducted at Finkl and combine them with an intensive one-day seminar. Finkl management and CSM embraced the idea, and the CSM-Finkl Forging Forum was born. Costs for travel and accommodations are shared between the MME Department at CSM, Finkl and the students.

"Student evaluations for the course have risen dramatically since those visits began," Van Tyne said.

Hatlen described her impressions. "Everything was big, heavy and hot! It was like taking our laboratory experiments and putting them on steroids. The forging process was mesmerizing, and seeing the product cycle from steelmaking to finished product put everything into perspective. The addition of lectures from the staff of A. Finkl and Sons added to the experience by providing more learning opportunities. Engineers and shop managers were able to connect with our classroom knowledge and apply it to a large-scale operation while answering our questions."

"Fourteen CSM-Finkl Forging Forums have reached more than 300 students from the fields of metallurgy and mechanical engineering," Brada said. "Every year the company receives positive feedback from the students about how the experience has made a lasting impression. One of the students of the inaugural CSM-Forging Forum in 2000 now works as a valued member of the A. Finkl & Sons metallurgical team. Today, these CSM-Forging Forum graduates are spread throughout our industry and the world. Ask any one of them and they will remember their visit to A. Finkl & Sons in Chicago."

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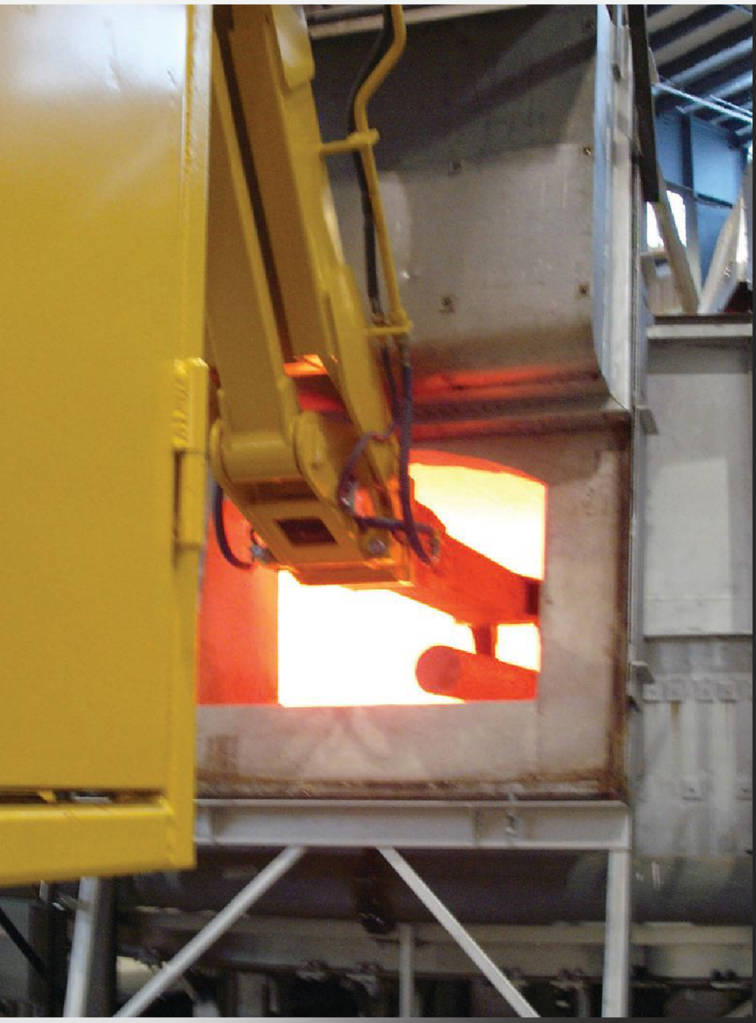

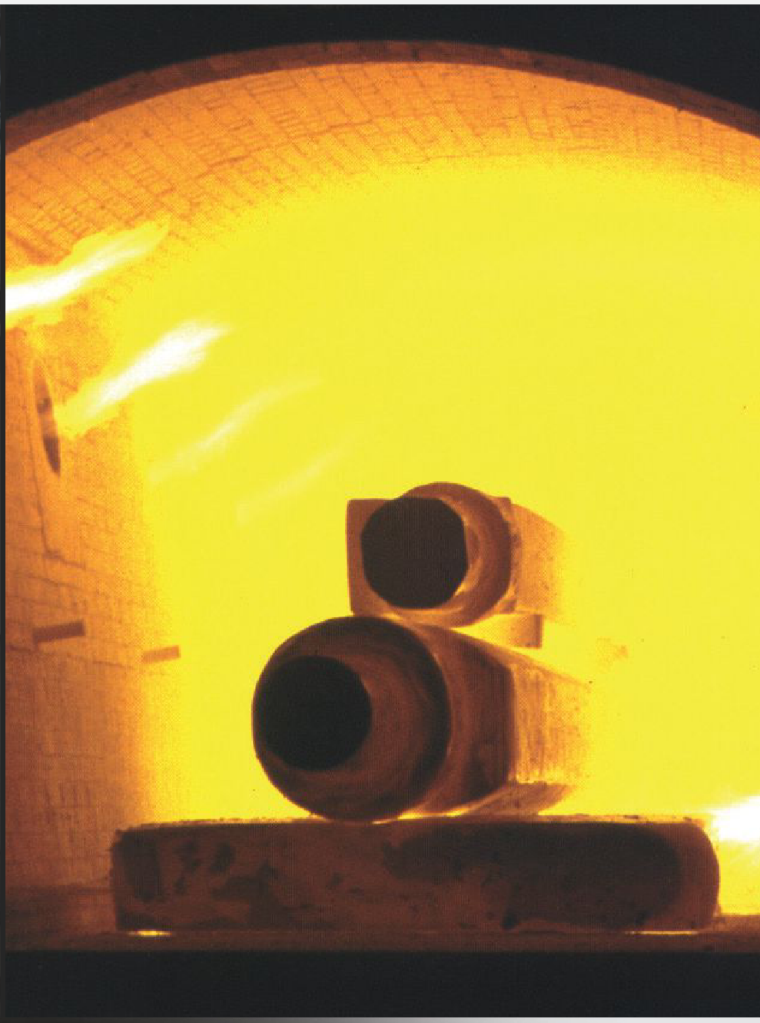

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NEWS
Affecting the Forging Industry

New Press for North American Forgemasters

Ellwood Group Inc. and Scot Forge are expanding the capabilities of their 50-50 joint venture, North American Forgemasters (NAF), in New Castle, Pa. NAF, which was established in 1997, recently announced an $80 million investment project to add a new open-die press facility to meet customer demand for larger forgings. Danieli Breda has been contracted to build the 10,100-ton (90-MN) press that will be serviced by a 200-ton rail-bound manipulator and a 100-ton mobile manipulator as well as three additional forging furnaces. The facility, which is adjacent to primary material supplier Ellwood Quality Steels, has been designed to process ingots up to 165 tons. The new press, which claims to have the greatest tonnage in North America, is scheduled to commence production in the first quarter of 2015.

Siemens, Mitsubishi Heavy Industries Form JV

Siemens and Mitsubishi Heavy Industries (MHI) are establishing a joint venture to cooperate in the metallurgical industry. The companies will partner to be a complete provider for plants, products and services for the iron, steel and aluminum industries. MHI will hold a 51% stake in the joint venture, which will start operations in January 2015, and Siemens will hold the remaining 49%. By combining product portfolios, Siemens and MHI can offer customers the entire value chain, from technologies for processing raw materials to surface finishing at the end of the production process. The JV, which will be based in the U.K. with approximately 9,000 employees, includes supply agreements for Siemens' Industry Automation and Drive Technologies divisions.

Dongbei Special Steel Starts Up Radial Forging Machine

Dongbei Special Steel put a hydraulic radial forging machine from SMS Meer into operation at its facility in Dalian, Liaoning Province, China. The machine has two forging manipulators and has the capacity to simultaneously shape rods of different cross sections and steel grades. It operates with a press force of 16 MN per cylinder and achieves a maximum pass of 800 mm (31.5 inches). The two manipulators provide a clamping torque of 120 kNm and are able to move forgings weighing up to 8 tons. Rods with round, square, flat or octagonal cross sections are produced on the machine. Structural steels, tool steels, stainless steels, titanium alloys or superalloys can be processed.

Weber Metals Gets Historical Landmark, Breaks Ground for Large Press

ASM International recently awarded Weber Metals of Paramount, Calif., with a historic landmark plaque for its 38,000-ton hydraulic forging press. This Mesta press, installed in 1982, was used to make parts for the SR-71 Blackbird and the U-2. Upon its installation 32 years ago, this press was the largest of its kind west of the Mississippi. Weber Metals also held a groundbreaking ceremony for its planned 60,000-ton press, which will permit the forging of lighter, more advanced materials. The groundbreaking is the beginning of a three-year project that will mark the largest aerospace forging press in the Western Hemisphere and the largest in the world installed with private investment. Weber Metals' parent company is Otto Fuchs Metallwerke of Germany.

Kobe Steel to Supply Titanium Forgings for Airbus Planes

Kobe Steel Ltd. and Messier-Bugatti-Dowty (Safran Group) signed a contract for Kobe Steel to supply the French company with titanium forgings for the main landing gears of the next-generation, wide-body Airbus A350 XWB planes. The main landing-gear parts will be manufactured by Kobe Steel and its group company, Japan Aeroforge Ltd. of Kurashiki, Japan. Equipped with a 50,000-ton hydraulic forging press, Japan Aeroforge manufactures large titanium forgings for the global aerospace industry.

FIA Releases 2013 North American Sales Figures

Final revised figures showing 2013 sales of metal forgings produced by independent (custom) forging plants in North America have been released by the Forging Industry Association (FIA). Total industry shipments for the custom impression-die forging industry were $7.3 billion in 2013, a slight decrease from 2012. Bookings of impression-die forging orders during 2013 increased to $7.1 billion, 7% above 2012's figure of $6.7 billion. Total industry shipments by the custom open-die forging industry were $1.8 billion in 2013, 15% below 2012's levels. Bookings of open-die forging orders during 2013 amounted to $1.8 billion, 6.4% below the $1.9 billion reported in 2012. Total 2013 industry shipments for the custom seamless rolled-ring forging industry increased to $1.6 billion, slightly above 2012's volume. Bookings of seamless rolled-ring forgings for 2013 increased to $1.6 billion, 3% above 2012.

NEWS
Affecting the Forging Industry

American Axle Achieves ISO 50001 Certification

American Axle & Manufacturing (AAM) announced that its world headquarters in Detroit, Mich., earned ISO 50001 certification – the company's first facility to receive it. ISO 50001 is the top international standard certification for driving continuous improvements in energy efficiency through energy management systems. Currently, only 34 companies in the U.S. are certified to this standard, and only 15 of those are in the automotive industry.

Alcoa Expands in Hungary to Make Aluminum Truck Wheels

Alcoa is investing $13 million to expand its wheel manufacturing plant in Europe. The project will help the company meet growing demand for its lightweight aluminum truck wheels. The expansion of the Szekesfehervar, Hungary, facility will enable Alcoa to double its production of Dura-Bright EVO surface-treated wheels in Europe. Construction on the production line began in January 2014, with completion scheduled for early 2015. The project will create 35 new permanent jobs and approximately 215 temporary jobs.

CALENDAR

June 29-July 4 IFC 2014 (21st International Forging Congress), Berlin, Berlin, Germany www.ifc2014.org

Sept. 8 -10 30th Forging Industry Technical Conference, Plymouth, Mich. www.forging.org

Sept. 29-Oct. 3 IFM 2014 (19th International Forgemasters Meeting), Tokyo, Japan www.ifm2014.com

Oct. 12-14 FIA Fall Meeting, Indianapolis, Ind. www.forging.org

PEOPLE IN THE NEWS

Allegheny Technologies Inc. (Pittsburgh, Pa) – John S. Minich has been named president of the ATI Forged Products business unit, which is part of the company's ATI High Performance Components Group. Robert S. Wetherbee was named president of the ATI Flat Rolled Products business unit.

Forging Industry Association (FIA), Cleveland, Ohio – Arnold Visser (IMT Partnership) was elected association chairman; Bruce Liimatainen (A. Finkl & Sons) was elected association vice chairman; Charles Hopper, Jr. (Composite Forging Ltd.) and Glenn C. Fegely (Ellwood National Forge) were elected to the FIA Executive Committee to serve with Visser and Liimatainen. All officers are elected to one-year terms. Four new directors have been elected to the FIA Board of Directors for three-year terms: Martin R. Essig (Aichi Forge USA), Ron Hahn (Scot Forge Co.), William D. Hoban (Cleveland Hardware & Forging Co.) and Jeffry D. Jones (Forging Equipment Solutions).

Forging Industry Educational and Research Foundation (FIERF), Cleveland, Ohio – Rob Mayer (The Queen City Forge) was elected president; Paul Janike (McInnes Rolled Rings) was elected vice president for the coming year; Rick Recktenwald (Walker Forge Inc.) and Chris Scheiblnofer (Scot Forge) will serve on the FIERF Executive Committee with Mayer and Janike. All officers are elected to one-year terms. Four new members of FIERF's Board of Trustees were also elected to three-year terms: Paul Dennis (Weber Metals), David Larkins (Eaton Corp.), Matt Morrison (SIFCO Forge Group) and Jorge Ortiz (Frisa Forjados).

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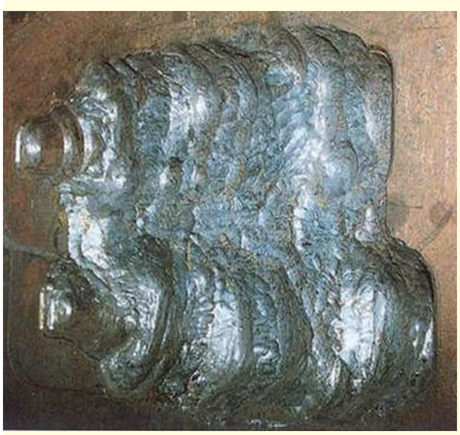

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T&W Forge Builds Business by Selling Value

Ohio's T&W Forge, part of SIFCO Industries since 2010, is a supplier of alloy, carbon and stainless steel parts to its industrial customers. The company's major market is the power-generation industry, to which it supplies parts for land-based gas turbines. Other markets include commercial and agricultural equipment as well as components for aerospace applications.

About an hour from its parent company in Cleveland, SIFCO Industries Inc., in an industrial complex in Alliance, Ohio, lie the large facilities of T&W Forge. This huge 250,000-square-foot facility has seen 115 years of manufacturing history in its day, but its deep origins go back even farther than that.

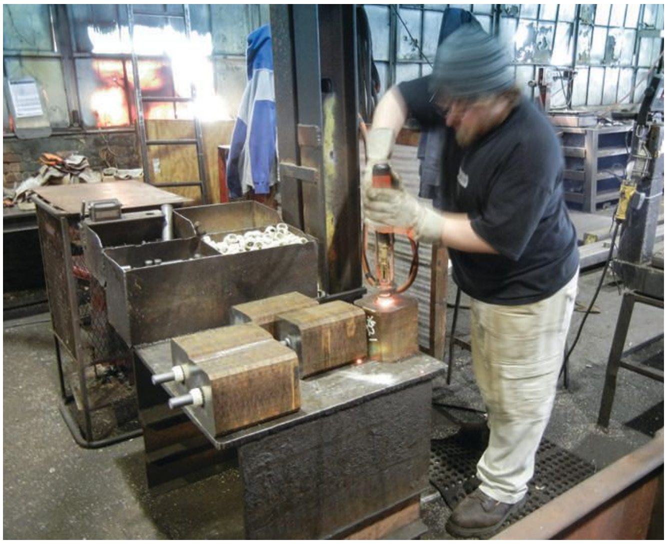
In 1865, Thomas Morgan arrived in the U.S. from Glamorganshire, Wales. He opened Marchand and Morgan, a manufacturer of steam hammers. He sold his interest to Silas J. Williams in 1877, and the company became the Morgan-Williams Company. This business dissolved in 1884, and Morgan formed the Morgan Engineering Corporation. Frank Transue got involved with the business in the ensuing years, and he, along with Silas J. Williams (an Ohio Senator), opened the Alliance Manufacturing Company, which specialized in stump pullers, heaving and dragging machinery, and other products.

(above) A modern sign identifies a historic facility. (below) An Amada band saw generates billets for the hammers.

In 1895, the Transue & Williams (T&W) Company was formed to produce drop forgings of all kinds. T&W Forge originally opened elsewhere in Alliance, but rapid growth required a physical expansion of the company's facilities. As a result, the company broke ground at its current location in 1898, and construction was completed a year later. Since then, the company has operated steadily, providing shaft solutions to Henry Ford for his early model; and supplying reliable military parts in support of two World War efforts and other conflicts. In more recent memory, T&W Forge supplied the fully developed automotive industry, as well as blades and vanes for gas turbines, static aircraft parts and aircraft-engine blades and vanes.

In 2010, T&W Forge became part of the portfolio of companies that comprises SIFCO Industries. Today, T&W Forge's specialty is parts for land-based gas turbines, primarily for the power-generation industry, which account for about 75% of its output. About 15% of its production is parts for commercial and agricultural equipment; and 10% is parts for aerospace applications. In 2013, this plant processed nearly three million pounds of metal.

T&W Forge employs almost 75 people, 20% of which are salaried positions. The hourly associates are members of Local No. 1603 of the International Brotherhood of Boilermakers, Iron Ship Builders, Blacksmiths, Forgers



A stud is resistance-welded to a billet for easier manipulation at the hammer.

A production team is in action at one of the plant's hammers.

and Helpers AFL-CIO. Plant manager Scott McNees indicated his operation has had a harmonious relationship with its union membership.

Cutting it Close

Production starts in T&W Forge's large raw-materials yard. About 70% of the company's throughput is stainless steel; 20% alloyed steel grades; and 10% carbon steel. Raw material arrives as round or round-cornered bar stock, usually in 4, 5 or 6 inch diameters/sides. However, round stock from 1 inch to 10 inch diameters can be processed. This material is used to make parts from 2-300 pounds.

Once material is selected for a customer order, a recently installed outdoor overhead crane delivers the material to the doors of the plant's sawing area. Five or 6 years ago, the saw department worked 24 hours to feed the workload of the forging hammers. This department has since gotten more efficient. There are four band saws and one metal-cut saw. The band saws now only run 20 hours per day while supporting higher production levels.

Once the material is cut into billet-sized pieces, about 75% of them go to a welding station, where a stud is resistance-welded onto them to facilitate subsequent handling with tongs. The geometry of the parts determines whether or not it requires a welded stud. Larger, heavier billets are moved about by powerful magnets.

Hammers Aweigh

Prepared billets are transported to a holding area, where they await preheating prior to hammering. Each of T&W Forge's hammers is fed from a preheat furnace. All forgings are hammered, because the only presses in the facility are used for flash trimming.

SIFCO Poised for Growth

SIFCO Industries opened its second century of existence this year with a vision of growth built on both the strength of its core markets and a renewed focus on a successful past.

After beginning as a steel heat-treating specialist in its early years, SIFCO quickly acquired forging capability and shortly thereafter adopted the fledgling U.S. aerospace industry as its core business in the late 1930s. Over the next 50-75 years, SIFCO would see unprecedented growth. It acquired and/or helped establish forging operations around the globe, expanded into the engine component repair business with operations in Ireland and the U.S., and grew a specialty coatings company.

With all this expansion and changes in its various markets, SIFCO, for a time, became a group of unrelated companies. Thus, over the last four years, the company has worked to strengthen its portfolio of companies by returning to its roots of providing extensive forging capabilities and technical expertise to its customers. It acquired T&W Forge, a major supplier of blades and vanes to the IGT market, and two aluminum aerospace forging component suppliers (Quality Aluminum Forge and General Aluminum Forge). These moves allowed SIFCO to double its maximum forging size, add precision aluminum forging and expand its press forging capabilities, all while increasing value-added content to its customer base. In the process, the company sold Applied Surface Concepts and wound down its engine component repair facility. Consequently, SIFCO is currently a diversified forging and machined component supplier to the aerospace and energy markets.

Looking to the future, SIFCO is committed to an aggressive growth strategy to expand its core capabilities while continuing to provide world-class performance.

Two batch heat-treat furnaces are shown.

An associate maps and verifies part dimensions according to specification.

Once preheated, smaller parts are removed by tongs to the hammers. Larger parts are moved with manipulators onto dies installed in the hammers. All die fabrication and repair is performed by outside vendors.

T&W Forge's hammers range in capacity from 1,500-25,000 pounds. These hammers were all steam-driven many years ago, but today's hammers are driven pneumatically. Two electric-motor-driven compressors (located in an adjacent building to the main plant) supply the pneumatic power to the heavy equipment. Operators claim pneumatics offer them better control.

When a heated billet is placed on the hammer, its head is brought down once to knock scale off the part. Larger parts may be pre-formed on one hammer then reheated and brought to a larger hammer for final net-shape deformation. Most parts are struck multiple times to achieve their near-net shapes.

As they come still glowing off the forging hammer, parts are sent to a neighboring trim press, where excess material is removed. There is at least one trim press near each forging hammer. For situations in which additional punching or bending operations are necessary, a second press may be used.

The Heat's On

Once through all the required hammer and trim press steps, parts are thermally processed. About 90% of all parts are heat treated at the plant, but some customers of carbon-steel parts machine them first and then heat treat them at a later time.

T&W Forge operates four heat-treat furnaces: two production and two batch. Most parts processed in-house are air quenched, though facilities for oil quenching are available.

Each forging hammer station has a "hot inspector," whose job is to ensure that a quality product is produced each and every time. These inspectors are T&W Forge's front line of quality control.

Quality is Key

Once parts are forged, trimmed and cool enough to handle, they are inspected at other stations for flatness or other shape parameters. Adjustments may be made mechanically for parts to be consistent with specified flatness or shape contour requirements. After physical inspections and any required adjustments are made, the part goes into a low-temperature heat treatment for further stress relief. The plant also conducts a magnetic liquid penetrant inspection on parts.

Final part dimensions are mapped by a Faro laser scanner, which generates hundreds of thousands of dimensional data points in a matter of minutes. These are computer-mapped and checked against required specifications for dimensional integrity.

According to John Cherr, T&W Forge's manager of sales and marketing, a challenge he faces is competition from foreign "low-cost" forgers. This type of competition, he said, can only be met by selling the value of his company's products. This is where the plant's quality program kicks in. The plant is ISO 9001:2008 accredited and pays strict attention to principles and programs that foster efficiency and quality in the workplace.

An Impressive Customer List

One of T&W Forge's major assets is its more than 100 years of experience in supplying quality products to its customers. The company has been able to generate a lot of good will in the markets it serves, and it is reflected in its customer list. Among T&W Forge's key customers are Allison Transmission, Caterpillar, Dana, Doncasters, Eaton, General Electric, Lockheed Martin, Mitsubishi Power Systems, Siemens and other leading companies.

Its long history of serving customers like these, coupled with its attention to quality and efficient operations, will continue to serve T&W Forge well as it conducts its second century of business.

About 100 people attended Tech Days at Timken's meeting facility in Ohio.

FIA, FIERF and Fraunhofer Partner for Tech Days

Dean M. Peters, Editor

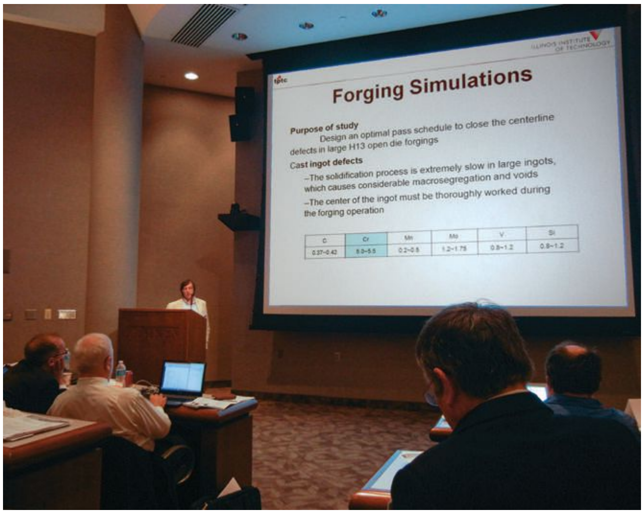
The Forging Industry Association (FIA), the Forging Industry Educational and Research Foundation (FIERF), affiliated U.S. colleges and Germany's Fraunhofer Institute recently conducted a technical conference to present and indentify potential collaborative research projects related to resource-efficient manufacturing and productivity improvements.

On April 7-8, about 100 industry leaders from forging companies, their supplier base, academia, FIA, FIERF and the Fraunhofer Institute gathered at The Timken Company's modern meeting facilities in Canton, Ohio, to discuss the status of their research programs and the potential for future collaborative projects.

On the first day of the program, attendees heard presentations from professors at leading U.S. academic institutions that have a significant profile in forging-related research programs, representatives from Germany's Fraunhofer Institute and others.

Roundtable discussions were conducted on the program's second day dealing with the following topics: lightweight design, process optimization, tool and die making, material developments and additive manufacturing. The program was such that each participant could attend two roundtable topical discussions with a general recap of these discussions before adjournment in the afternoon.

Taylan Altan (The Ohio State University) introduced most of the speakers on the first day of the event, including a number of his academic colleagues. Colleges represented at the podium for brief collegiate profiles to start the event were Case Western Reserve University (David Schwam), Colorado School of Mines (frequent FORGE contributor Chet Van Tyne), Illinois Institute of Technology (Philip Nash and Sammy Tin) and the University of North Texas (Peter C. Collins). Each university was profiled briefly in the morning session of day one, with more detailed technical



IIT's Philip Nash discusses forging simulations.

Timken's lobby begins to fill prior to the start of the morning technical session.

Chet Van Tyne discusses trends in ferrous metal development.

Several representatives from the Fraunhofer Institutes were on hand to give talks on their respective research activities.

Jon Tirpak discusses sources of research funding and offers his thoughts on collaborative projects.

papers presented later in the day.

Schwam, as part of the technical program, presented his introduction to additive manufacturing (AM) technologies, focusing on potential forging-specific applications and the use of metals in AM processes. Van Tyne spoke of trends in ferrous metal development, detailing his presentation around microalloyed steels, rapid heating of steels and high-strength low-alloy (HSLA) steels for gear applications. Nash and Tin presented, respectively, on the topics of forging and AM simulations and the characteristics of ultrafine grain materials. Collins spoke about the activities of the Center for Advanced Non-Ferrous Structural Alloys (CANFA), a joint project between his school and the Colorado School of Mines.

Several representatives from Germany's Fraunhofer Institutes were present to introduce their respective organizations and give attendees an overview of the work they are doing. The two institutes represented at the conference were Fraunhofer IWU and Fraunhofer IPT (see sidebar for additional details).

Rounding out the day of technical offerings were two presentations that dealt with financial, administrative and strategic matters relating to joint research activities. Fraunhofer IWU's Dr. Andreas Sterzing and (frequent FORGE contributor) Jon Tirpak, executive director – FDMC, SCRA Applied R&D, each gave their views on research funding and potential collaborations stretching across the Atlantic.

What is the Fraunhofer Society?

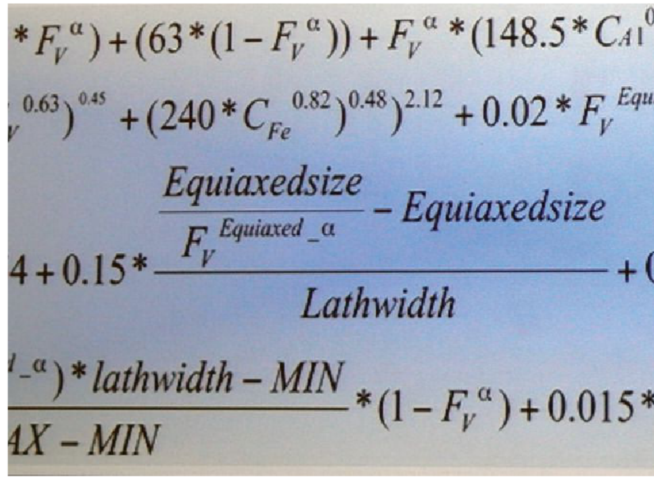
The Fraunhofer Society for the advancement of applied research is a Germany research organization with 67 institutes spread throughout Germany, each focusing on different fields of applied science. The organization employs about 23,000 people, mainly scientists and engineers. Some funding for the Fraunhofer Society is provided by German taxpayers, but more than 70% of funding is earned through contract work, either for government-sponsored projects or from industry. The society is named after Joseph von Fraunhofer, who, as a scientist, engineer and entrepreneur, is said to have superbly exemplified the goals of the society.

The "Fraunhofer Model" has been in existence since 1973 (though the Society was founded in 1949) and has led to the society's continuing growth. Since most funding comes from research revenue from specific commissions, the society's overall budget is largely based on maximizing revenue from its contracts. This funding model applies not just to the central society itself but also to the individual institutes that comprise it. There were two Fraunhofer Institutes represented at Tech Days in Canton: Fraunhofer IWU and Fraunhofer IPT.

Fraunhofer IWU, as translated, is the Fraunhofer Institute for Machine Tools and Forming Technology. Its motto is "Research for the Future," as exemplified by its strong emphasis on application-oriented research and development in the field of production technology for the automotive and mechanical engineering sectors. With an annual budget of about $52 million and nearly 600 engineers and scientists on staff, Fraunhofer IWU is recognized as one of Germany's leading contractual research and development institutions.

Fraunhofer IPT (Institute for Production Technology) combines knowledge and experience in all fields of production technology. In the areas of process technology, production machines, production metrology and quality, as well as technology management, the institute offers partners and customers customized solutions and applied results for modern production.

CWRU's David Schwam introduces his discussion on additive manufacturing.


Some of the presented topics were not for the faint of heart.

Tech Days Program

The Technical Program on day one began with some welcoming remarks by FIA, FIERF and The Timken Company. These were followed by brief introductions to the Fraunhofer Institutes represented and collegiate profiles of the schools present. The program listed here followed.

"Challenges in Today's Manufacturing Industry – Relevance for the Forging Industry"
Andreas Sterzing, Fraunhofer IWU and Martin Bock, Fraunhofer IPT

"Additive Manufacturing – Trends, Potentials, Opportunities"
David Schwam, Case Western Reserve University

"Trends in Ferrous Material Development"
Chet Van Tyne, Colorado School of Mines

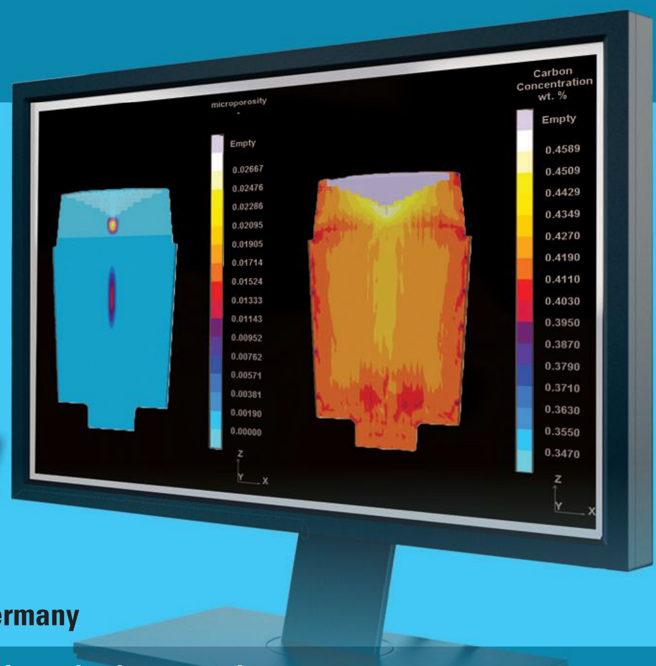
"Opportunities to Increase Efficiency"
- **Lightweight Design**
  Andreas Sterzing and Markus Bergmann, Fraunhofer IWU
- **Forming Processes/Process Chains**
  Andreas Sterzing and Daniel Heinen, Fraunhofer IWU and IPT
- **Tool and Die Making**
  Martin Bock, Fraunhofer IPT

"Advancements in Simulation and Modeling"
Philip Nash and Sammy Tin, Illinois Institute of Technology

"The Center for Advanced Non-Ferrous Structural Alloys (cooperative research venture of the University of North Texas and the Colorado School of Mines)"
Pete Collins, University of North Texas

"Overview of Funding Possibilities (U.S.)"
Jon Tirpak, Executive Director – FDMC, SCRA Applied R&D

"Possibilities of Cooperation with Fraunhofer/Overview of Funding Possibilities (Germany/Europe)"
Andreas Sterzing, Fraunhofer IPT



Sequential Casting/Forging Simulations Aid Forged Steel Quality

I. Hahn, M. Schneider – MAGMA Giessereitechnologie GmbH; Germany
H. Schafstall, C. Barth – Simufact Engineering GmbH; Germany

Quality problems of forged steel products may originate from the ingot casting process. Simulation tools for both casting and forming processes are available to analyze and optimize the quality and productivity of each. There is a clear need for a through-process simulation of both to predict possible defects and to optimize the entire process chain.

The final quality of forged steel products is the result of their sequential production steps. After steelmaking, molten metal is tapped from a ladle and poured into a mold, where it solidifies. The solidified ingot is then brought to its semi-finished shape through a series of reheating and forging steps, each of which influences final product quality. Many defects in forged or hot-rolled products originate from the casting process.

Computer simulation is a tool used to investigate, understand and predict the effects of production processes on product quality. For the two main parts of the process – ingot casting and forging – dedicated simulation solutions are available. Simulation is applied in many plants to predict and optimize the properties of an as-cast product as well as a forged one.

Using casting simulation models it is possible to predict shrinkage, centerline porosity, segregation, inclusions, residual stresses and cracks that originate during casting. With forging simulation it is possible to conduct virtual hot, cold, bulk, sheet and incremental forming processes to predict the shape of the part, the process forces and the resulting material properties. These are typically temperatures, strains and stresses, but material damage, phase constitution and grain size are increasingly simulated. Even die wear and die stresses can be analyzed.

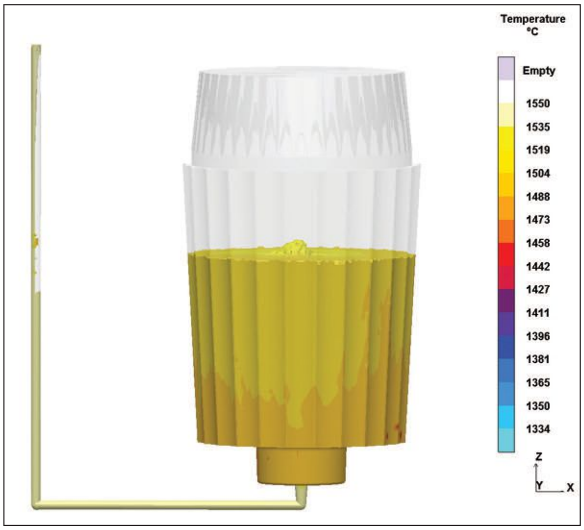


Figure 1. Simulated temperatures after 15 minutes of teeming.

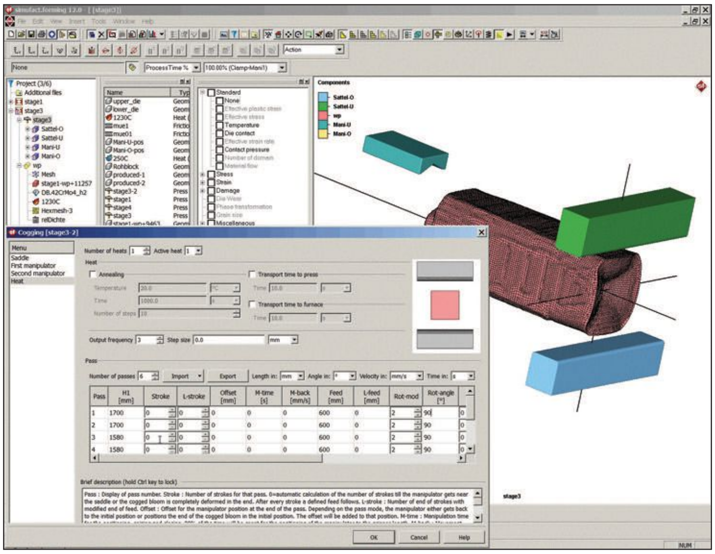


Figure 2. The simulation model of the breakdown (cogging) process.

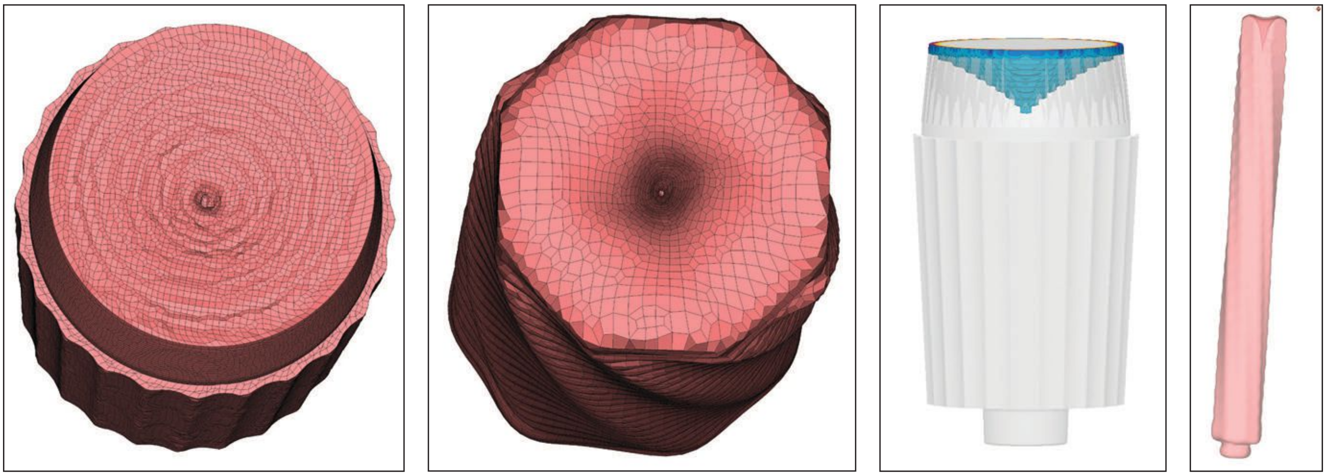


Figure 3. Shrinkage cavity at the beginning of the cogging process, as predicted by the casting process simulation, (left) and at the end (right).

Ensuring the Best Quality

Until recently, the worlds of casting and forging have only rarely intersected. There is significant reason that they should, however, since the origin of defects in forged or hot-rolled products may be found in the casting process. As-cast ingot quality is the starting point for all the subsequent reheating and deformation steps and plays a decisive role in final product quality. For example, the severity of porosities may be decreased by closing voids during forging if favorable forging conditions are achieved. Also, the position of local defects in the semi-finished product is affected by material flow during deformation. Inclusions or residual stresses remaining in the as-cast ingot negatively impact product quality when the ingot is intensively deformed.

This article illustrates how casting and forging simulations can be combined to predict the influence of as-cast defects on forged steel products. The simulated properties of the as-cast ingot are transferred to a subsequent forging simulation. The shape of the shrinkage cavity at the top of the cast ingot is predicted by the casting simulation. This shape is used as the starting point for the forging simulation. Also, parts of these linked simulations are the position and extent of defects in the semi-finished product and the effect of the deformation on the severity of these defects.

Casting Simulation

In the past 30 years, casting process simulation has developed considerably. Virtual casting processes are done to determine the potential risks for defects and to predict material properties. Temperatures, metal-flow velocities, flowing particles, potential defects and also material properties can be analyzed. With MAGMA simulation software, parameters affecting ingot quality – such as shrinkage, porosities, macrosegregation, cleanliness and cracks – are predictable. These can be modified to help limit or eliminate quality problems. Figure 1, for example, shows the temperatures at one particular point of time during teeming of a 90-ton ingot.

Linking Casting and Forging Simulations

To simulate casting and forging processes, specialized software packages are applied sequentially for each process step. The transfer of simulations from one software package to the next is an often-discussed bottleneck of closed process-chain simulations. The problem lies not with different file formats so much as with the elements, meshes and symmetry conditions tailored to the specific processes.

The main challenge for the transfer of results is transferring the *meaning* of the results themselves. Certain results are only meaningful in combination with a specific material model, which may be only valid for the specific application. For example, porosity may be a geometric result in one simulation but a material property in a subsequent simulation. A clear concept of how to deal with such transitions is needed when the transfer of results is to be designed.

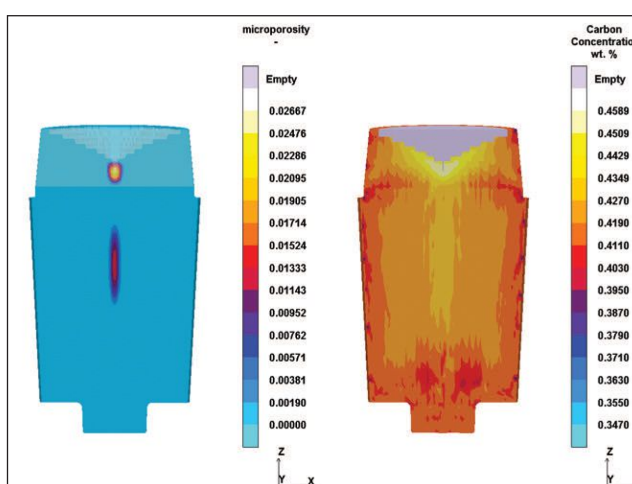


Figure 4. Typical appearance of the shrinkage cavity and the centerline porosity in a cast ingot (left) and carbon segregation (right). The light/yellow areas indicate positive segregation, and the red areas indicate negative segregation.

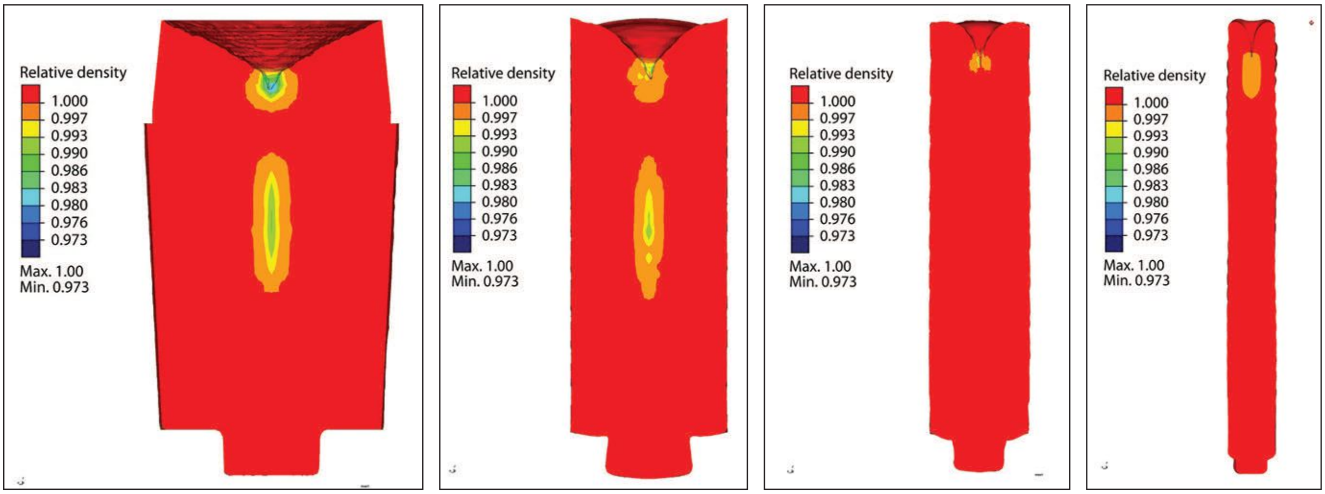


Figure 5. Development of the porosity during breakdown (not to scale).

In this example, the casting simulation (MAGMA) and forging simulation packages (Simufact.forming) both support the transfer of results from one package to the other. For a quick transfer of data from MAGMA to Simufact.forming, a file is produced from the casting simulation using the I-DEAS universal format. This information is imported as "geometry with results" into the forging simulation, where it can be used with the existing mesh from the casting simulation or with any new mesh tailored to the forging process. In the present case, the porosity and the local concentration of specified elements (macrosegregation) are carried over from casting to forging as results. During the import, porosity is interpreted as a relative density, which will change during the forging process.

Details of Open-Die Forging Simulation

A breakdown (cogging) process was simulated using an ingot (Figure 1) as the input condition. Simufact.forming was used for this, utilizing the implicit finite-element method. Because the solver allows for rigid-body movements, all movements of the workpiece can be simulated. Elastic/plastic material behavior was used in a fully mechanical-thermal coupled analysis with hexahedral elements known to deliver the most accurate predictions.

The software contains a kinematics module that enables the simulation of open-die forging and ring-rolling processes. The standard cogging kinematics control used for this simulation allows the setup of complex simulations using input parameters that are close to factory language. Several heats with several passes each can be defined. For each pass, the final height and translational and rotational movements must be specified.

To simulate the closing of centerline porosity from casting, a macroscopic approach was used. The porosity is described by the relative density of the material, which is increased during the forming process based on a material law using the following equation:

$$\rho_r = \rho_0 + \frac{1-\rho_0}{p_{\max}}\sigma_m \qquad (1)$$

where ρ_r is the relative density, ρ_0 is the initial relative density, σ_m is the hydrostatic pressure obtained from the analysis and p_{max} is the maximum hydrostatic pressure needed to close all voids.

Once the relative density reaches 1.0, all voids are closed and the material is fully consolidated. The implemented relative-density model assumes that the initial porosity allows treating the material as homogeneous and that the effect of voids on the material properties during hot forging can be neglected.

The simulated process consists of three heats with a total of 23 passes with different rotations, leading to a total of 459 blows. The maximum diameter of the ingot is reduced from 100 to 55 inches and the length simultaneously increases from 177 to 492 inches. The simulation uses about 50,000 hexahedral elements with automated re-meshing. To precisely include the mechanical and thermal interactions of the workpiece not only with the saddles but also with the manipulators, a single, uniform mesh with elastic-plastic material was used for the whole workpiece. Figure 2 shows the simulation model.

Shrinkage and Porosities

The solidification pattern of ingots leads to a characteristic shrinkage in the as-cast ingot (Figure 3). There is always a shrinkage cavity in the hot top, and it must not extend into the final workpiece. During the forging process, the remaining shrinkage cavity is deformed together with the workpiece, and the forging simulation tracks this deformation together with the workpiece's overall shape. Figure 3 shows that even a small shrinkage cavity can lead to a considerable affected area at the end of the cogging process. With the simulation, different cogging strategies can be evaluated easily to minimize this effect.

In many cases, problems with centerline porosity are reported. This porosity is small in comparison to the hot-top shrinkage

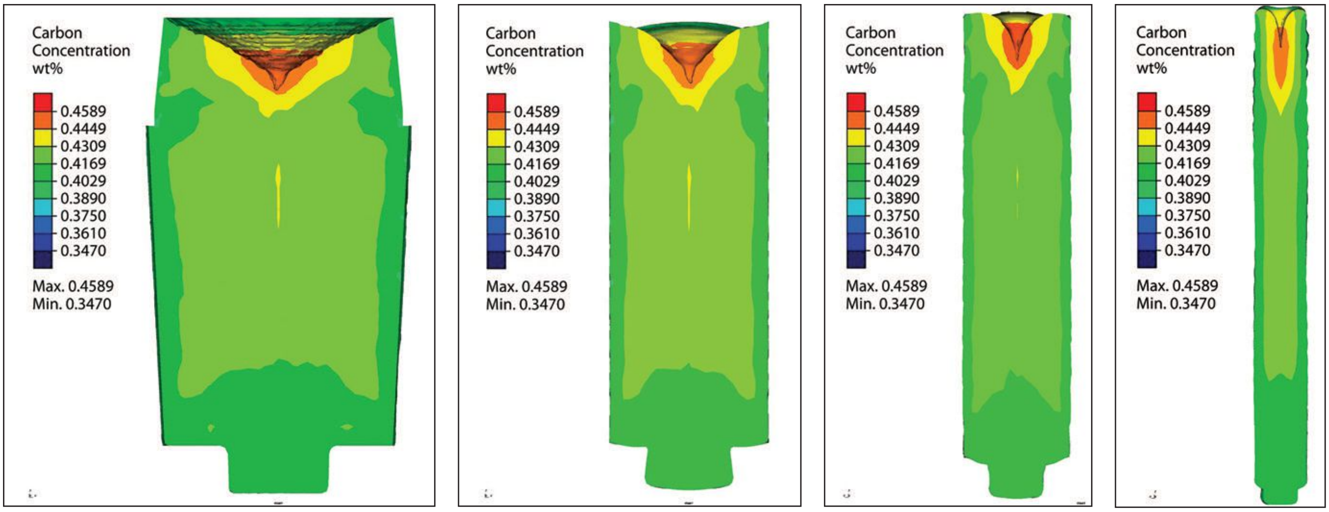


Figure 6. Development of carbon segregation during breakdown (not to scale).

cavity and is typically found along a line in the center of the ingot, as shown in Figure 4 (left). Depending on the size and location of porosities, it is possible to close them in subsequent forging processes if the hydrostatic pressure in the area of the voids is sufficiently high. The process design should be optimized to provide the required hydrostatic stresses.

Casting simulation can be applied to optimize the process to prevent porosity from forming in the first place. If its presence is inevitable, it is important to transfer information about the size and position of the porosity to the forging simulation, where it is possible to determine the process parameters required to close the porosity. Figure 5 shows how centerline porosity is removed during a simulated breakdown (cogging) process.

Macrosegregation

Segregation is an inhomogeneity of the concentrations of alloying elements and impurities in the steel. Most alloying elements are more soluble in the liquid phase than in the solid phase. Thus, as the metal solidifies, alloying elements in the "mushy" zone are rejected by the growing solid dendrites into the neighboring interdendritic liquid, which becomes increasingly enriched with alloying elements. This is termed microsegregation.

Macrosegregation can result in an ingot with regions having a composition quite different from the nominal value. Segregation can lead to locally lower material properties and to variations in thermochemical behavior, such as the formation of precipitates or local hot spots that induce shrinkage porosities.

The casting process simulation shows local concentrations of all relevant elements in the steel chemistry as they may be expected in the cast ingot in Figure 4 (right). If this information is transferred to the forging simulation, changes of the distribution of the concentrations due to the material flow during deformation can be analyzed and the expected local chemistry of the forged workpiece can be predicted (Figure 6).

During forging, cooling and reheating operations, local chemistry concentrations are not only influenced by the material flow but also by several diffusion effects. The simulation of these effects is an area of ongoing research. Simufact.forming supports this by its flexible data structure for material data. The material database considers the chemical composition and provides the infrastructure for phase-dependent material properties, which are used in the industry today for phase-transformation simulations.

Conclusions

The existence and the locations of defects in a semi-finished product have been predicted by simulations of the casting process. These play a significant role in the quality of the final, deformed product. The coupled through-process simulation gives valuable information that could not otherwise be obtained. This information can be used to optimize both casting and forging processes to target the best properties of the final forged product.

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ISO 50001 Highlights Energy Savings for Forgers (part 2)

Induction-heated bar stock as it emerges the furnace.

Dirk M. Schibisch and Loïc de Vathaire – SMS Elotherm; Germany
Adapted by George Burnet – SMS Elotherm; United States

The ISO 50001 international standard for energy performance was introduced in part 1 of this article. In this concluding installment, the individual stages of an induction heating line are examined for individual energy efficiencies. An actual energy audit is also summarized.

ISO 50001 is primarily about lowering energy consumption, reducing the reactive power and increasing the efficiency of a production plant – in this case a forge. To understand the individual energy-efficiency drivers, an overview of the relevant principles is provided.

Induction Heating of Forging Billets and Bars

With induction heating for hot and warm forging, the metal blank (bar, billet or block) is placed in an alternating electromagnetic field generated by a coil (Figure 1). Eddy currents are thereby induced inside the material to generate heat. Consequently, induction heating occurs rapidly, and the resulting workpiece temperature can be very precisely adjusted.

The overall efficiency of an induction furnace is the product of the individual efficiency levels of the various single components – namely, the medium-voltage transformer, frequency converter, bus bars and inductor (the coil), as well as the thermal degree of efficiency.

The individual efficiencies are not equal. Rather, there are components in which an improvement has a significantly positive influence on the system's overall efficiency. Whereas the medium-voltage transformer, for example, has a high operating efficiency of around 99%, the induction coil – with an individual operating efficiency of close to 75% – has considerable impact on the system's overall efficiency.

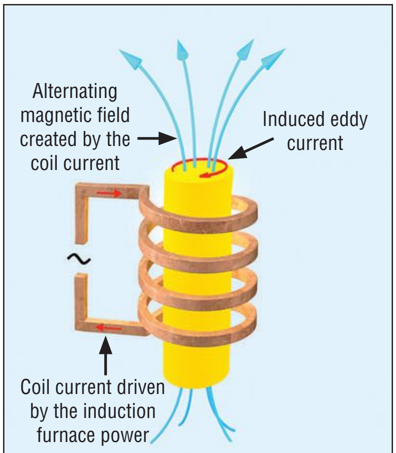

Figure 1. Induction heating of forging billets and bars using a copper coil

The example given in Figure 2 shows a real situation in a forge shop. Of the 1,253-kW grid energy consumption, only 812 kW actually heat the workpiece to 1250°C (2282°F), corresponding to an efficiency of about 65%. The energy losses of the individual components of the heating plants total 441 kW, of which the coil makes up for more than 200 kW of power loss. It is worth taking a close look at this to identify the factors that have a positive effect on the overall result.

The Induction Coil

The nature of induction heating is such that the smaller the difference between the coil diameter and heating material diameter, the greater the energy efficiency. Forgers should be mindful of this.

The influence of the electromagnetic penetration depth is also of interest. According to Lenz's law, the eddy current builds up a field that opposes the inductor current. The net result of both fields is in the diminishment of the magnetic field in a radial direction inward. The associated eddy current intensity also drops. The depth at which the current intensity has fallen to 37% of its maximum value is known as the penetration depth (δ), as given in the accompanying equation:

$$\delta = \sqrt{\frac{\rho}{\pi \cdot f \cdot \mu_r}}$$

ρ = specific electrical resistance of workpiece material
μ_r = permeability of the workpiece material
f = frequency

The formula shows that the penetration depth depends substantially on the frequency of the induced current. As the frequency increases, the current penetration depth is reduced. In the case of heating operations where optimum through-heating of the material cross section is required, a low frequency should be chosen. As shown in Figure 1, very rapid, homogeneous temperature distribution is achieved over the cross section when the cylindrical workpiece diameter is around 3.5 times greater than the penetration depth. These conditions are the result of a trade-off between direct, consistent heating over the cross section with a correspondingly low frequency and increasing energy efficiency at high frequency.

Clear evidence of this elementary connection was demonstrated in trials performed decades ago in which cylinders of different sizes were heated simultaneously in a common coil. With the varying coloration it was easy to see that both excessively small and excessively large diameters did not produce optimum through-heating. Interestingly, this effect easily overrides the influence of the position of the material being heated within the coil. The optimum-diameter sample, shown at the bottom left of Figure 3, is not centered in the middle of the coil yet still produces the best result in terms of through-heating.

Ideally, the induction coil would be perfectly matched to each material diameter. However, it is usually not practical to have a custom heating coil for each and every billet diameter. The forging shop product spectrum needs to be analyzed and grouped into diameter ranges to be heated by a finite set of coils. The design of the coil, therefore, always represents a compromise between being a geometrically perfect match and production flexibility.

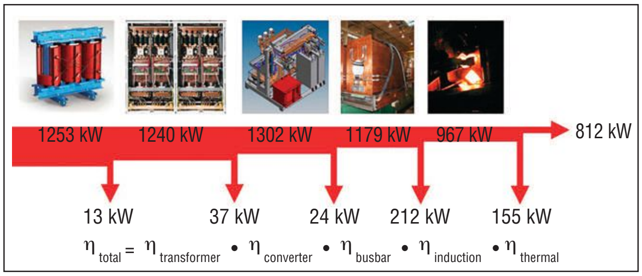

Figure 2. Grid energy consumption example: throughput = 3,500 kg/hour; network consumption = 358 kWh/ton; workpiece temperature = 1250°C

Induction modules are used in series to heat billet material to temperature.

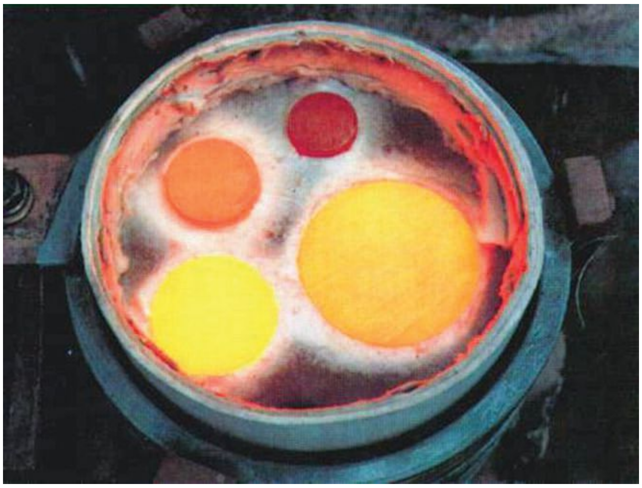

Figure 3. Varied heating/through-heating at constant frequency and material parameters as a function of workpiece geometry

Copper-Coil Alloy Selection

In addition to the operating frequency and coupling distance (i.e. the ratio of coil and workpiece diameters), another efficiency driver is the material quality of the coil. The specific electrical resistance of the heating-coil copper alloy is also an important consideration.

Table 1. Comparison between Cu-DHP and Cu-HCP

	Cu-DHP	Cu-HCP
Full description	Deoxidized,high-residual phosphorus	High-conductivity phosphorus
Material	CW024A	CW021A
Proportion of copper	> 99.9%	> 99.95%
Weldability and solderability	Very good	Good
Machinability	Very good	Good
Energy efficiency	Good	Very good

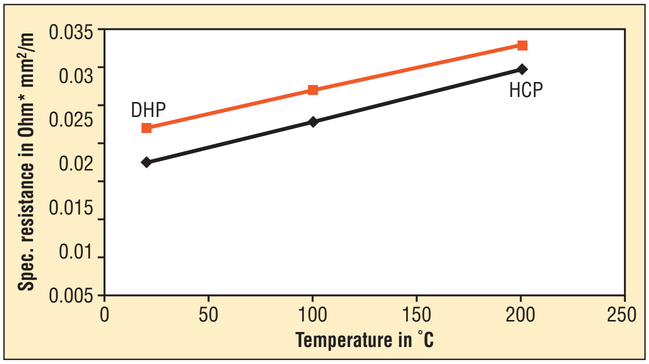

Figure 4. Specific resistance of DHP and HCP-copper as a function of the temperature

Table 1 shows the key differences for the two copper grades commonly used in electro-technical components. They differ in terms of copper content and machinability, which is particularly important for coil manufacturers. Cu-DHP can be more easily worked, both mechanically and with regard to welding and soldering. Therefore, some coil manufacturers choose this material grade, which has a slightly less copper content.

Coils made from Cu-DHP and Cu-HCP appear to be identical. If we compare the specific electrical resistance of both grades, however, it can be seen that the Cu-HCP material with the higher copper content (greater than 99.95%) shows a lower (i.e. better) resistance value. Over the temperature trajectory, which is of particular interest for copper coils when used for induction heating, the specific electrical resistance of Cu-HCP is about 30% better than that of Cu-DHP at every temperature point. The energy-efficient properties of the higher-grade Cu-HCP represent an interesting option for saving energy and money over the working life of the coil.

Converter (Power Supply) Technology

In the example given in Figure 2, the operating efficiency of the converter (power supply) is the third-largest influence on total heating efficiency – after the inductor and thermal efficiencies.

As shown in the example, the new generation of converter with

Induction-Line Energy Audit

This is a specific example of how a sustainable reduction in grid power consumption – and thus increased energy efficiency – can be achieved with the optimal design of an induction heating line.

In this example, a forge shop has an induction furnace with a nominal power of 1,500 kW in use upstream of a horizontal multistage press. Bars 25-40 mm in diameter are heated to 1250°C (2282°F) through a series of five induction coils. A single set of coils is used for the entire product range.

The data in Tables A and B were gathered for this induction audit.

This data clearly shows that grid consumption increases substantially if the coil and material diameters are not ideally coordinated. Given the annual tonnage, optimized heating of 28-mm bars, in particular, is desirable. The calculation of the induction coil designed for bar diameters of 28 mm and 32 mm shows that the grid consumption is as shown in Table C.

This results in two optimization strategies as shown in Table D.

In this example, optimization strategy 1 proves to be the better result of the induction-related audit.

Nearly $15,000 can be saved every year with just one additional set of induction coils. The investment in an additional set of coils would increase the savings made by a few percent and would therefore not be cost-effective. Since bars in the greater-than 32-mm-diameter range make up just a small proportion of the annual output (~3%), they should be produced wherever possible using intelligent production schemes to keep changeovers to a different set of coils to a minimum.

As far as the aims of ISO 50001 are concerned, this result – in real terms – means annual savings of around 166 tons of CO_2 using a conversion factor of 1 KWh of electricity to 0.566 kg CO_2.

Table A

Bar diameter (mm)	Tonnage/year
25	620
28	3,150
32	850
> 32	150
Total	4,770

Table B

Bar diameter (mm)	Grid consumption (kWh/ton)
25	515
28	430
32	370
36	361
40	353

Table C

Bar diameter (mm)	Grid consumption with inductor for 28 mm bars (kWh/ton)	Grid consumption with inductor for 32 mm bars (kWh/ton)
25	369	376
28	361	367
32	--	358

Table D

	Optimization strategy 1: Production with two sets of inductors	Optimization strategy 2: Production with three sets of inductors
Required induction coil sets	Set 1: Existing set for diameters >32 mm Set 2: New induction coils for the 25- to 32-mm range	Set 1: Existing set for diameters >32 mm Set 2: New induction coils for 32 mm Set 3: New induction coils for the 25- to 28-mm range
Potential energy cost savings	Approx. 294 MWh/year	Approx. 318 MWh/year
Electricity price/kWh	$ 0.05	$ 0.05
Potential energy cost savings	$14,700/year	$ 15,900/year
Setup costs	Low	High

an efficiency level of 97% ($\eta_{converter}$ multiplier of 0.97) and with an L-LC oscillating circuit is already in use. Conventional converter topologies characteristically have far lower efficiencies. With an uncontrolled rectifier, intermediate circuit capacitor, IGBT (insulated-gate bipolar transistor) inverter and output choke, this converter features a constant cos ϕ (power factor) of greater than 0.95, regardless of the output power level.

The L-LC circuit features two points of resonance: one with parallel and one with series resonance. Depending on the desired circuit properties and application, both may be used. To control the inverter, special algorithms have to be used to find the desired point of resonance (parallel or serial) and clearly establish the working point. For this, the L-LC circuit has the advantage that both the frequency and power can be controlled via the inverter.

Conclusion

This article has dealt with the reduction in energy consumption and the improvement in the overall efficiency and power factor of an induction heating line. For these plants in particular, manufacturers offer a variety of possibilities for increasing part efficiency levels through intelligent plant design.

In addition, the specific energy-audit calculation (sidebar) shows that long-term energy cost savings can be made by optimizing just one system component – in this case the coordinated coil set – and that significant reductions in emissions can also be achieved.

In the short term, energy-efficiency audits can be used to work out and implement practical solutions that directly improve the energy efficiency of induction heating lines upstream of forming equipment and, thereby, reduce energy consumption.

Over the long term, the costs of implementing a DIN ISO 50001 energy management system are worthwhile given the continual increase in the company's overall energy efficiency.

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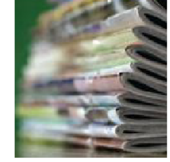

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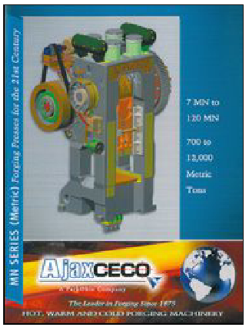

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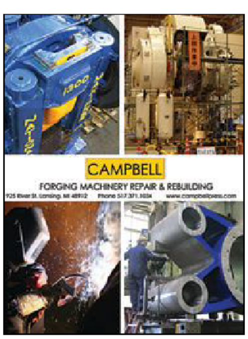

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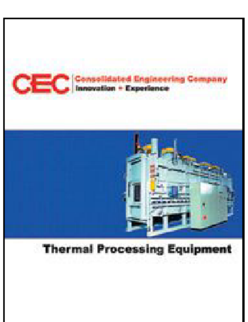

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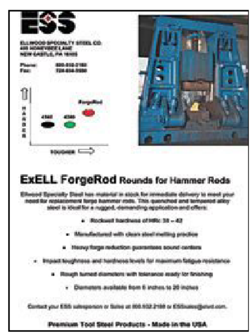

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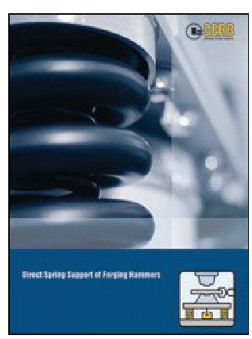

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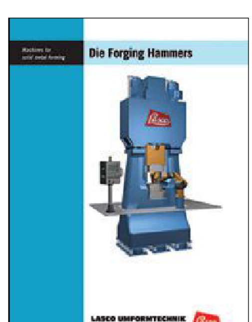

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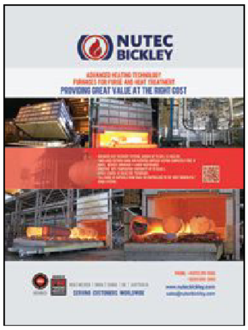

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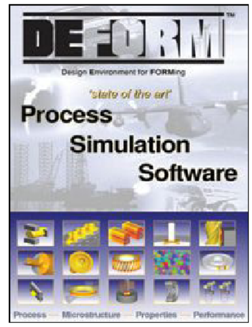

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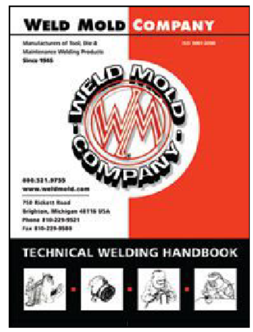

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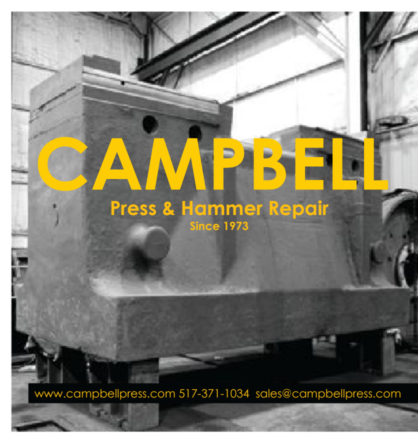

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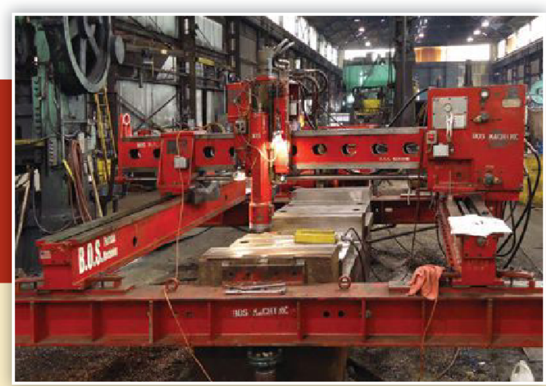

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