Sunday, September 20

Engineered Residual Stress Fields in Tool and Die Applications by Laser Shock Peening
Stan Bovid, LSP Technologies
Presentation Room A

Laser shock peening is a novel technique for precisely engineering residual stress fields in components. It has been demonstrated by others that residual stress impedes fatigue cracking and extends tool life. In contrast to standard surface enhancement techniques that utilize bulk surface coverage, laser peening residual stress fields are precisely tailored in magnitude, depth and area. The design of these treatments is optimized through finite element methods and validated by in-service testing that outperforms other techniques. Recently, laser peening has been increasingly adopted into multiple tool and die applications: Cold rolling dies have benefited from an increased performance by reducing wear and Hertzian contact damage; die casting dies have benefited from reduced heat checking during thermal cycling; and injection molding dies have benefited from reduced fatigue cracking from pressure distributions. This presentation includes background information on the process, examples of residual stress field engineering, and real-world examples of laser peening improving service life.

Investigation of Directional Surface Topography In Forging
Joseph P. Domblesky, Marquette University
Presentation Room C

Although surface topography is known to affect forming behavior, relatively little has been written about the effect that anisotropic textures (i.e. directionality) have on friction and metal flow. In the current study, compression tests were conducted using steel and aluminum and H-13 platens which had isotropic and anisotropic surface textures respectively. Side pressing was performed to investigate planar metal flow while ring testing was used to measure friction factors. Results showed friction factors parallel to the platen lay were significantly lower than those in the perpendicular direction. This can be attributed to the tool lay effectively acting as a series of parallel macro-asperities which act to promote or inhibit flow at the tool-work interface. Side pressing showed that transverse metal flow was sensitive to both platen roughness and lay orientation whereas longitudinal flow was only

Innovative High Performance Tool Steels for Hot-Forging Applications
Michael Hirtler, voestalpine BÖHLER Edelstahl
Presentation Room B

The increasing complexity of hot-forged components such as near-net-shaped parts poses various challenges to forging-die materials. Hot-work tool steels have to show excellent mechanical and thermo-physical properties to withstand the complex loading situation during the different forging processes and to lead to a high tool lifetime. Wear, plastic deformation and thermal and mechanical fatigue are considered as the typical damage mechanisms in such tools. To reduce those effects and to decrease the tooling costs the tool steel material requires an optimal combination of hardness, toughness, ductility, hot wear resistance, thermal conductivity and other properties. Over the years a lot of tool steel producers tried to improve these properties by modern alloy design and optimization in the production process. This presentation gives a resume about damage mechanisms, the property profile of new and innovative hot work tool steels and successful applications for forging tools.
influenced by the latter. It is expected that the findings will help further an understanding of how anisotropic tool surfaces influence behavior in forging and illustrate their potential for optimizing metal flow.

**Lightweight Forging – A Success Story in Four Chapters**

Hans-Willi Raedt, Hirschvogel Automotive Group

Presentation Room A

Forging is a well-established manufacturing process especially for highly loaded components in large series applications. However, (steel) forgings seem to be undervalued as far as their lightweight potential is concerned. To demonstrate the lightweight design potential of forged components, the Lightweight Forging Initiative was formed in 2013. In the first phase, a passenger car was analyzed and a lightweight potential of 2kg was demonstrated. In 2015, the consortium showed 99kg of lightweight potential in a light duty vehicle. In the third multilateral industrial phase, a consortium of 39 companies from Europe, Japan and the US has come together. A hybrid split-axle-AWD car has been purchased and disassembled. Additionally, a truck transmission, propeller shaft and rear axle have been part of the project. All components have been analyzed for lightweight possibilities. It could be found that the application of modern forging technology or advanced steel materials can lead to drastic weight savings at comparatively low cost. Numerous examples will be shown to demonstrate the approach as well as concrete lightweight potentials. Additionally, a transmission weight analysis will be presented, with which the lightweight impact of more durable steels in transmission applications can be estimated.

**Metamorphic Manufacturing: Processing Pathways to Manufacture Custom Geometry Components with Tailored Microstructures**

Kester Clarke, Colorado School of Mines

Presentation Room B

The incorporation of digital controls and active closed-loop process parameter feedback into a flexible deformation processing station intrinsically affords the capacity to employ specific thermomechanical processing (TMP) pathways as a function of location within a component. This capacity will allow for the design and production of structural engineering components with the physical and mechanical properties tailored to a location within the part. Local microstructure control is, of course, possible in conventional processing, but without the flexibility to create unlimited numbers of unique component geometries in a single processing unit. The repeatability of digitally controlled processing equipment, the incorporation of in-situ monitoring of critical processing parameters, the ability to use any input material, and ultimately, the ability to use real-time microstructural development feedback supported by fundamental understanding and modeling, has the potential to revolutionize the way we think about component design and manufacturing.

**Advanced Remote Troubleshooting and Maintenance Techniques for Induction Heaters**

Joe Stambaugh, Ajax TOCCO

Presentation Room C

This presentation will explore the advantages of remote internet access for induction heaters for the purpose of troubleshooting, maintenance implementation and programming. The safe and proper way to communicate remotely with the induction system and real-world examples of what can be accomplished remotely. Reduce downtime to a minimum via intelligent information gathering and troubleshooting analysis.

**Forging More Intelligently Through Workpiece Tracking, Adaptive Control and Machine Learning**

Mathias Liewald, Prof. Dr. and Celalettin Karadogan, Dr.

Institute for Metal Forming Tech. University of Stuttgart

Presentation Room A

Hot forging reveals great potential for improvements in the spirit of Industry 4.0.
The quality and stability of forging processes are conventionally evaluated after the heat treatment, based on produced properties of randomly selected work pieces. From this point of view, today’s state-of-the-art approach barely links the information collected from individually digitalized production processes and finished product properties. Hence, the root cause of scatter in the final product properties cannot be directly correlated with actual process parameters or any other process fluctuations. Contrary to this practice of today, the realization of work piece tracking enables the linking of such information from digitized raw materials, work piece properties and forging process parameters. This linked information is a large amount of process and property data bearing valuable correlations and constituting the base for machine learning and numerous adaptive control solutions. A prototype cyber-physical forging process chain configured as a forging factory model was established within the scope of a project (acronym EMuDig4.0) at the author’s institute. The goal of this three years project was to develop and to elaborate valid solutions for integration of real and virtual components of production systems such as heating or measurement devices into the manufacturing sequence of forging under lab conditions. Both heating and two stage forging process in the model factory was designed to collect process and condition data delivered by inbuilt and external sensors. Online data storage and real-time data analysis were performed in a cloud-server to study adaptive and self-learning control strategies acting through an online assistance system used by the operator. Gained results of finite element simulation of forging process are used to train a neural network model initially being used to calculate suitable feed forward adaptive control parameters (e.g. billet inductive heating temperature, ram displacement, etc.) based on input parameters (e.g. billet dimensions, actual tool temperatures). The developed prototype production system is capable of detecting, recording and separating scrap after the pre and final forming stages. Online work piece tracking, process parameters and product properties measured for successfully produced parts, as well as scrap, train the neural network further to increase the validity of the feed forward adaptive control solution. Digitalization and the potential capability of machine learning integrated into the controller system also facilitate a wide range of possibilities for predictive quality control of produced parts.

**Finite Element Modeling in Metal Forming and Forging Industries - What to Know and Where to Apply**

Ming (Henry) He, The Timken Company
Presentation Room B

Applications of finite element analysis have tremendously reshaped the metal forming and forging industries in recent decades. Today, the finite element modeling is commonly employed as an effective tool to help engineers (1) in conceptual development or virtual prototyping phase precisely examine the behavior of the part to be formed so that the tools can be correctly designed and (2) in product improvement phase correctly and effectively identify the root causes of product defects and provide solutions. This presentation will present examples of the applications of finite element modeling to the forging, bulk and incremental forming, and thermal treatment processes for the above-mentioned purposes. Deformation plasticity theory, as the foundation of the metal forming modeling, is also briefly described.

**Die Set Construction Options for Post Forging Operations**

Steven Janiszewski Forging Products Division Manager, Superior Die Set

A detailed look at die set construction options for post forging operations. Topics include; guiding element selection, plate material choices, as well as good maintenance and record-keeping practices. This presentation draws upon 97 years of experience manufacturing die sets, supported by FEA Analysis and field experience.
The World's Biggest Pull-Down Hydraulic Closed-Die-Forging Press in the USA at Weber Metals and Recent Developments Taking Advantage of the Given Force at the World Market
Serdar Tunçel, SMS Group GmbH
Presentation Room A

The presentation gives an overview of the investment made on the world aerospace market in recent years. Otto Fuchs increased its capabilities of Ultra-Large Forgings with an SMS-built 540 MN (60,000 US tons) hydraulic pull-down press. This machine, located at Weber Metals Inc., Otto Fuchs’ US subsidiary, entered service in October 2018 and is the strongest press of its kind and the biggest closed-die forging press in America. The ability to exactly reproduce forging and stress relief operations allows to lower airframe weight by single-piece forgings replacing multiple part assemblies. This presentation also describes the technology-leading capabilities of the 540 MN (60,000 US-Tons) hydraulic forging press. The challenging technical solutions are presented which allow this unprecedented machine to operate quickly, accurately and safely.

The New Trend in Hot and Warm Closed-Die Forging: Intelligent Lubrication
Franck Belloy, Quaker Houghton
Presentation Room B

With automotive manufacturers asking for lighter alloys, high strength steels, conversion from hot to warm forging and weight reduction requiring Near Net Shape forging, the challenges are everywhere for forgers. And the lubricants used for years no longer meet today’s requirements. The solution to this increasingly difficult situation is Quaker Houghton’s intelligent lubrication. While most stayed focused on the same requirements for years such as cooling properties, lubricity, release, grip on the surface, viscosity and particle sizes, Quaker Houghton pushes the limit by creating new tests to complement historical testing and simulation software. Welcome to Quaker Houghton intelligent lubrication.

Robotic Die & Component Welding System
Chris Kerchkof, Eureka Welding Alloys
Presentation Room C

This presentation will be a brief overview of the practices involved in forge die and component welding to date. What type of welding alloys are used for specific types of repairs to forging dies to address multiple types of failures inherent in the forging process as well as extend die life over that of virgin die block material? Also, what types of welding alloys are used for component repairs (Rams, Sow Blocks, Columns, Bases, Bolster Plates etc.)? We will introduce the Robotic Welding System, the next step in Forge Die & Component Welding. The presentation will cover the basics of how the systems software creates the welding programs in conjunction with set parameters given by a programmer. How to upload the welding programs into the robot controller and how the robot operator monitors welding jobs from that point until completion of a job. The presentation will go over the cost savings benefits of the welding system (material savings, welding time savings, machining time savings, etc.).

Comparison of Mechanical and Hydraulic Forging Presses
Ken Setze, Schuler Incorporated Canton
Presentation Room A

Forging companies often have to determine whether to produce a given part on a mechanical or on a hydraulic press. As a leading press builder who is offering both solutions, we are comparing these concepts in terms of output, part geometry, portfolio, lot size and required flexibility. Also, we take a look at process requirements such as forming speed or duration of contact. Typical parts for production on mechanical and hydraulic presses will be shown and also a recommendation will be given which parts should not be made on one or the other concept. A brief overview of the major differences between both press types will explain the technical reasons behind the findings of this presentation.
Bringing the IIoT to Forging Forefront
Paul Hogendoorn, FreePoint Technologies
Presentation Room B

Many have heard the terms “Industry 4.0” and the “IIoT” and understand the general concept, but wonder what that means and how it applies to the Forging industry. Forging is different from most manufacturing industries today; there are many old machines still in productive use today, and, forging is still as much an ‘art’ as it is ‘science’. So, what can IIoT, big data analytics, and cloud computing do for companies in this industry? How can you connect your old machines, and should you? What benefits can you and should you expect? Every manufacturing industry in North America faces the same problem of competition from low-cost regions, escalating environmental regulations, a growing skills shortage, and attracting young people to the industry. Learn how other industries have leveraged IIoT technologies to face these common challenges, using data to not only improve their processes but also to engage their people, and how these technologies and ideas can be applied effectively in this industry. Paul Hogendoorn has over 30 years of experience across many industry sectors helping manufacturers apply new technology for the purpose of connecting to machines and with people. The IIoT is about giving your people better tools.

Applying Non-Destructive Examination Methods to Forge Presses
Ronald P. Manganello, Carlesa NDE Services
Presentation Room C

This presentation will discuss the application of nondestructive examination to forge presses and how it can benefit operations. Presentation content will cover preparation and planning, necessary access to critical components, safe application of nondestructive examination procedure, and why regular nondestructive examination is important to mitigate and manage the risk of press failure.

Hot Forging Die Steel Review and Modeling of Cost Reduced Solutions
Manuel Roman, Manuel Arean, Salvador Perez, CIE Automotive
Presentation Room A

Hot working tooling steel selection, post processing route and resulting parameters are factors affecting the performance of the tooling in service conditions. Due to the performance of the tooling costs of operation vary throughout the project life. Background studies in this field on the latest years are reviewed as a starting point to review possible methodologies for wear analysis and die life optimization. Simulation, lab tests and visual inspection capacities are discussed. To establish a model and optimizing the current solution for a specific process, a design of experiments is used. This design of experiments includes raw materials from key manufacturers of tooling steel, different processing routes to achieve initial blocks, machining, heat treatment and surface treatment process on the imprints. The performance is measured with standardized tests for finishing conditions, mechanical tests and metallurgic results. Visual inspection on die surface are included to help in process decision. Solutions are tested under different forging process conditions and performance indicators are obtained. Through statistical analysis these elements are included in a regression model with the aim of obtaining alternatives for material selection, processing conditions and in process parameters for hot forging with reduced cost of operation and extending time for batch change and tool renewal.

How Virtual Process Manufacturing Will Meet Today's and Tomorrow's Challenges in the Field Of Aluminum Forging
Nicolas Poulain, Transvalor Americas Corp.
Presentation Room B

Forging is an essential manufacturing process as it combines unbeatable advantages such as high component strength with the possibility of mass production. However, challenges such as light weighting have emerged and drive today’s demand for extensive use of aluminum alloys.
This presentation aims at demonstrating how virtual manufacturing using FORGE® software provides crucial guidance to process and design engineers to improve production of high-performance forged components. The presentation focuses first on the material flow challenges in the context of aluminum forging sequence. Hand-picked examples show the benefits of simulation to detect forming defects and guarantee optimum grain flow. In the second part, the presentation focuses on the prediction of the final mechanical properties. Heat treatment is crucial to meet the final mechanical properties required by customers. Treatments such as solution treatment, quenching and aging are simulated to predict accurately the outcome. Based on the implementation of several research works on Quench Factor Analysis (QFA) and Shercliff-Ashby models, simulation results will be presented and discussed.

**Isostatic Forging - The Fit with Other Forging Processes**
Robert M. Conaway, Isostatic Forging International
Presentation Room C

Isostatic Forging (IF) is the use of forming pressure in the yield, flow stress, or rapid creep, range of forming pressures. IF processes have virtually no practical limits on pressure applied and the temperature used. IF is generally regarded as a hot isostatic pressing (HIP) process, but now quite different. This paper will present the IFI view of how IF fits in with the forging industry technologies.

**Modern Design Solutions of Forging Devices for Forging Ingots and Blanks using Four Dies on Hydraulic Forging Presses**
Sergey Kuralekh, Lazorkin Engineering LLC
Presentation Room A

Three decades of hands-on experience in operation and design development of four-die forging devices (FDFD) under various industrial conditions on a variety of hydraulic presses proved that in every particular case and with a view to particular production needs, an individual approach is required to select both the proper FDFD design and the proper forging technology. The main selection criteria for proper device design and forging technology are: high production output, which should be significantly higher as compared to existing production technology output; improved metal quality and quality of products (in terms of dimensional accuracy and surface quality); cutback of the whole production cycle extent due to reduction of forging cycle, heating period and auxiliary operations duration; higher good metal yield. The paper describes new FDFD design solutions and new technologies, which meet these criteria for solving various technological tasks. It is also shown which changes to the technological process can be eventually required to gain the maximum benefit from using the FDFD. This paper also provides an overview of the similar forging equipment from other companies and a comparison of its functionality with FDFDs of our patented design.

**Newest Developments in Ring Rolling**
Robert Bolin, SMS Group Inc.
Presentation Room B

Recently there have been some major developments in ring rolling machine design that reduce cost, greatly improve efficiency and provide real time dimensional information during the rolling process. Our paper will introduce the concept of compact hydraulic systems as applied to ring rolling machines. The compact hydraulic design eliminates the need for a central hydraulic station, reduces installation costs and drastically improves energy efficiency. Our paper will also address advances in real time laser measuring systems that constantly monitor the ring profile during rolling and comparing it with the ideal shape allowing corrective action to be taken before the part becomes unusable.
Friction Stir Additive Consolidation for Bulk Forging Feedstock
Kester Clark, Colorado School of Mines
Presentation Room C

A significant obstacle to the widespread use of powder alloys for critical structural components is the complexity and expense of consolidation from powder to solid capable of meeting service performance requirements. The friction stir additive process may provide a more economical and practical method to build bulk structural forms from powders. As consolidation takes place below solidus temperature, defects resulting from AM dependent upon melting at or above liquidus may be avoided. Using friction stir additive consolidation, high-performance aluminum alloys that are commonly processed via rapid solidification, i.e., in thin cross-sections, may be able to be processed in bulk form without compromising performance.

Monday, September 21

IForge and Industry 4.0 - Digitalization is Key for Performance Enhancement in the Forging World
Martin Scholles, SMS Group GmbH
Presentation Room A

Digitalization and Industry 4.0 will rock the forging industry now and in the years to come and will become Key for Major breakthroughs in regard of Optimization of Energy Consumption and Minimizing of Downtimes by Predictive Maintenance. SMS group develops easy-to-use Tools and Applications for its customers to provide them with Hands-on Solutions that support them to stay ahead of the competition. The presentation will provide an overview of the SMS group approach in regard of maximizing the benefits out of Industry 4.0. Examples like the world’s most modern steel plant BIG RIVER STEEL supplied by SMS group prove the Benefit of those applications.

Increasing Forging Die, Tool Life, Preventing Rejections and Reducing Energy Consumption by the use of Protective Coatings
Srikar Shenoy, Steel Plant Specialties, LLP
Presentation Room B

Protective Coatings play a major role in increasing productivity and reducing costs in metal forming and treatment processes like hot forging and heat treatment. This technical paper presents details and successful case studies of three such protective coatings: (1.) Die, mould and tool wear are major reasons for production downtime and increased costs in most industries. Carbide coating to protect only the wear-prone areas of dies using cold-welding technology is a practical and economical technique that has proven to increase die and tool life. This technique, though similar to welding, does not pose difficulties of smoke emission, pre and post-weld heat treatment and requirement of skilled labor. It can be carried out on the die or tool without unloading it from the forging press, without the need of a weld shop. (2.) Oxidation and resultant scaling at high temperatures is caused during heating of billets, ingots for forging and during heat treatment of formed components. Scaling leads to enormous losses by way of rejections of produce, reduced yield and increase in non-value adding operations like shot blasting, grinding, pickling, etc. These parameters are becoming increasingly sensitive in open and closed die forging, especially of expensive grades of steel like SS, Nickel-bearing steels and aerospace forgings. Anti-scale protective coatings can be used to prevent or substantially reduce high-temperature oxidation and scaling. (3.) When forging die is in use, it is mandatory to keep it well lubricated and the die temperature maintained as per the required application. Die protective coating cum lubricant is used to achieve these objectives. Graphite-in-water formulations are popularly used as die lubricants until recently. Though effective as a lubricant, graphite is highly polluting and dirties the surroundings. Effective white lubricants using environment friendly materials are now developed that have proven
to eliminate graphite and associated pollution. Substantial increase in die life and reduced pollution is possible by the use of white lubricant. These techniques can be easily adopted by all metal forming units, big and small.

**Improve your Plant Productivity by Choosing the Right Lubricant and the Right Material**

**Todd Smith, Condat Corp.**

**Presentation Room C**

Through the decades’ several lubricant technologies have been developed to respond to the forging workshop technical needs. Economical, environmental and societal stakes have led to the development of graphite free and water-based lubricants in replacement of graphite and oil base solutions. Each of those technologies has its advantages and disadvantages that will have an impact on plant productivity, global cost, operator’s safety and environment. The chosen solution will be a compromise between those parameters. To optimize plant productivity, choosing the right equipment that will be in interaction with the lubricant should also be taken into high consideration (dilution and spraying systems, tools equipment etc.)

**Laboratory Testing to Identify Permanent PVD Coatings to Minimize Lubricant Use During Forging**

**Kester Clarke, Colorado School of Mines**

**Presentation Room A**

Die coatings may have the potential to reduce the friction coefficient between the work piece and the die during forging operations, and may also provide improved wear characteristics. A coating that provides a lower coefficient of friction could reduce the need for lubricants during forging and improve the repeatability and accuracy of forging operations. Here, we have produced die sets with replaceable inserts to measure friction coefficient during room-temperature and elevated temperature ring forging of various commonly forged metals as a function of die coating. The focus of the project is on permanent plasma vapor deposition (PVD) coatings, but baseline measurements on uncoated dies have been performed, along with evaluations of other thin coatings, with the goal of evaluating coatings that apply to real-world forging thermal conditions for a given work piece material. Results include the measured friction coefficient for selected coatings and material conditions, both with and without additional lubricant. Metallographic evaluations of the coatings and substrate after forging are also discussed.

**Automating the Uniformity Certification Process for the Forge and Heat Treat Furnaces**

**Justin Dzik, Fives North American Combustion, Inc.**

**Presentation Room B**

Quality is of the highest importance to most manufacturing processes. Specifically in the forge and heat treat industry, correct material properties for a given part allow the part to serve its correct purpose. Material properties are set during the heating and forging process, so having the correct furnace conditions are key. Achieving uniformity in furnaces can be time consuming to both personnel and manufacturing. Fives will present an automated process through which the time required for tuning and performing a furnace certification may be drastically reduced. The process includes a combination of control logic and combustion hardware that reduces the overall time and maximizes the consistency between certifications.

**State of Art in Forging Lightweight Alloys and High Temperature Super Alloys**

**Mr. Carlo Maffei, FICEP SPA**

**Presentation Room C**

FICEP, an important worldwide manufacturer of forging presses and cutting systems for billets, prepared a global report of all the available technologies in billets preparation offered to the forging industry. The final goal, towards which the entire forging industry is striving, is to reduce production costs and improve product quality. This led to the tendency of using more and more frequently closed-die forging processes to eliminate flashes by producing a near net shaped parts, with a consequent material and energy
saving. The MUST for the closed die forging is to use billets having the volume (weight) included within strict tolerances. However, some fundamental conditions have to be met in terms of machinery, tooling and material for the billets to be suitable for the subsequent forming process. They represent the best opportunity for any forging industry to be abreast of the latest developments in this particular field and also to produce high quality forgings at the most competitive costs. Starting from the latest installations, FICEP developed a specific program for a complete comparison between all the different cutting systems (disc sawing, hot, warm and cold shear).

**Initiative Lightweight forging; Geometries Made Easy by Forging**

Marco Laufer, Hammerwerk Fridingen GmbH  
Presentation Room A

Light weighting introduction of the company Hammerwerk Fridingen GmbH. Developing the light weight parts is a matter of combining different positive influences during the designing phase of a product. You know the expectations even better you can fit the demands. The inputs are the most influencing information like loads and stresses. Using this information there are special programs available to reduce unnecessary volumes of the part. The estimations are expecting the maximum allowed displacements and the design space limits also. For a class 8 trucks brake bracket and for different carrier plates of cranes and construction machinery, it is shown how the design evaluation may be worked out. To get the most proper results new steel concepts have to be taken into focus. These new steels have enhanced structural durability of cyclic loaded forged components in comparison ordinary quenched and tempered (+QT) steels. Another way to increase the value and benefit of a forged part and to shorten used material steel or power metal parts is to have integrated functional elements like ready to use gearings. Examples will be shown. To summarize light weighting is an option to reduce design space necessary. Less weight is affecting the material and energy costs. And the functional integration leads to less machining and assembly work.

**3C's (Cool, Comfortable and Clean)**

Danny Pittman, Asahi Bluegrass Forge  
Presentation Room B

Emphasizing the core 3 principles of “Good Associate,” “Good Work Environment” and “Good Equipment” to help people understand how Asahi Forge prepared for and continues to have a Cool, Comfortable and Clean working facility.

**Porosity and A-Segregation Prediction in Hollow Ingots for Large Forgings**

Ovidiu Bogdan, Industrial Soft  
Presentation Room C

Macro-segregation in forging ingots has adverse effects on the quality of final product and is one of the reasons why the forgemen have to choose the ingot function by both forging part shape and steel type to get a low cost, save time and energy, and improve the internal quality of the part. The goal of this work was to analyze comparatively axial porosity and A-segregation in carbon and several low alloyed steels poured in conventional and hollow ingots to avoid or reduce internal defects in a pressure vessel or ring type forgings with high quality requirements. An integrated online mold design and the solidification simulation software SimCADE v.2.0 has been utilized to simulate the solidification process and model the porosity and A-segregation appearance. The data we get by simulation have been calibrated and validated using sulphur print of cut conventional and hollow ingots having weights between 20 and 140 tons. The results of the experiments we made show that the material homogeneity of pressure vessels or ring type forgings can be drastically improved if we choose the hollow ingots instead of conventional ingots, no matter the steel type.
**Effect of Billet Forging Temperature on Grain Size, Heat Treat Response and Final Part Properties**
Chuck Hartwig, ThermTech
Presentation Room A

This presentation will review the results of a forging study conducted between ThermTech and Clifford Jacobs. 4140 billets were heated to a varying time and temperature schedule before being forged to the same reduction ratios and then subjected to the same heat treatment schedule. The effect of billet temperature on final grain size and final part properties obtained from the controlled heat treatment practice will be examined. Factors that will be examined include the ability of material to recover and recrystallize using a normalization heat treatment, hardness profile after quenching, tensile properties, and Charpy impact properties. While heating practices may vary from forger to forger, the goal of this study is to provide forgers with knowledge of billet temperature profiles that may cause permanent damage to the end product.

**The MOBI-HEARTH Furnace® - The World's Most Flexible Batch Heat Treating System**
Michael K. Klauck, Can-Eng Furnaces International
Presentation Room B

Conventional Car Bottom Furnaces are the norm for the global forging industry for heat treatment applications (Normalizing, Stress Relieve, Quench and Temper). Most open die forge shops have numerous car bottom (bogie hearth) furnaces in their heat treatment facilities. The rail bound car hearth is limited to in-line motion (car in / car out) without the ability for lateral movements in most cases. The patented MOBI-HEARTH Furnace® system utilizes the same basic furnace principle as traditional car bottom systems, but employs a highly flexible AGV (Automated Guided Vehicle) and Furnace Skid arrangement to allow almost unlimited movements within the heat treatment complex. In doing so, defined mission recipes controlled through the LEVEL II Automation system allow for a lights out heat treatment cell that can virtually eliminate 2nd and 3rd shift manpower. The MOBI-HEARTH Furnace® technology allows for material movements into and out of the heat treatment cell allowing for product staging (loading and unloading) of furnace skids offline. The presentation will cite the world's first commercial application the MOBI-HEARTH Furnace® System operating at a major North American Forging facility for Power generation components.

**Optimization of Blank Weights in Forging Lines**
Michael Siegl, Linsinger
Presentation Room C

At the beginning of every forging process is the raw material, e.g. the ingot. Requirements to the forging process are constantly increasing in terms of material saving, productivity and yield. An increase in the quality of the forging blank is unavoidable. For sawing machines we therefore identify 3 key tasks: Forging blank weight accuracy; Automation and inline-handling; Increase of productivity and lowering cutting costs. Objectives cutting with cold circular sawing machines have the advantage of straight and perpendicular cuts with no thermal influence to the cutting surface. In combination with a material feeding tong as positioning device, exact cut-off lengths can be achieved. Especially for the closed-die forging although, cutting to a set weight is important. For that reason, the incoming ingot is passing through a volume measuring device, capturing the complete ingot surface and therefore can take into account any material diameter variations, flat spots and ovalities in calculating the cut-off length. After cutting the ingot every cut-off is put on a weighing scale. This helps in optimizing the cut weight for the next cut off. A complete system including the incoming material handling, the positioning and cutting as well as the handling of the cut-off with a direct connection to the furnace is necessary. The required material tracking is also established by connection of the control system to higher levels as well as labeling and marking devices and readers. The cutting tool is an essential part of guaranteeing the performance of a sawing line. The disc miller system LINCUT, designed, developed and produced by Linsinger enables...
higher cutting speeds and at the same time, longer tool lifetime. Results: When using other cutting methods, like hot shearing, “turning and breaking” or band saws, the quality requirement cannot be met and weight deviations up to 20kg are commonly. The prescribed weight optimization and carbide circular cutting achieves weight tolerances in the area of 0–5kg for cut-off weights up to 1 ton. With the use of the disc miller system LINCUT, it is confirmed to have only a third of the cutting costs compared to band saws, and compared to using regular carbide tipped blades still 50% less cutting costs. Conclusions: The use of a sophisticated and automated sawing line enables higher quality and productivity. The higher investment costs are amortized only by the costs per cut in less than 2 years.

Forge Shop of a New Generation
Jim Kravec, Amir Tanbakouchi, Dr. Rene von Dombrowski, Siempelkamp Maschinen & Anlagenbau GmbH
Presentation Room A

Due to the close development partnership of plant operator and plant manufacturer, the world’s most modern forging shop for the fully automated forging of certified components for the aerospace industry was able to start operation at the end of 2019. The heart of the forging shop is built by two presses, an open-die forging press and a closed-die forging press, which are completed by several manipulators and rotary furnaces. Not only does every system itself offer an enormous degree of automation, but also the interactions of the different systems are fully automated. The main planning focus of this innovative forging shop was outstanding production efficiency as well as plant intelligence of the individual systems and their interlinking with each other.

To meet the high demands placed on the production efficiency of the forging shop, special attention to the core aspects of energy efficiency, throughput and availability was paid in the development of the press systems in particular. To increase energy efficiency, both presses were equipped with the Siempelkamp intelligent Power System (in short iPS). In addition to an intelligent start-stop system for the main pump units, the Siempelkamp iPS also includes the demand-based regulation of the auxiliary drive units. With the help of the iPS, the energy consumption of the open-die forging press could be reduced by 25% and the closed-die forging press by 46% compared to conventional system designs.

Another innovation is the process of multi-cavity open-die forging. Through the use of forging dies with multiple cavities and the rapid cavity change by a simple lateral movement of the manipulators, time-consuming tool changes are eliminated and previously unimaginable throughput times can be realized. The compensation of the occurring eccentric loads is ensured by a unique torque compensation system. This compensates not only the eccentric tilting moments and protects the mechanical press structure, but at the same time guarantees the parallel movement of the tools and thus guarantees the highest precision even at eccentric forging operations.

In general, the topic of precision has received a great deal of attention, to ensure the most effective use of materials and to minimize mechanical finishing to a minimum. Thus, with the help of new control algorithms in the press control, accuracies of less than ±1 mm are realized in the closed-die forging press and in the open-die forging press from the first to the last stroke.

To increase the plant availability and to provide the maintenance and operating personnel with detailed data for the general function monitoring as well as for the wear detection of the components, the Siempelkamp Condition Monitoring System (SCMS) was also implemented for both press systems. The SCMS enables the condition monitoring of the main components and thus provides the operating personnel with the basis for condition-based maintenance. It includes additional sensor technology on the one hand, as well as intelligent evaluation algorithms and corresponding visualizations within the control on the other hand. With the SCMS not only maintenance work can be reasonably
planned, but also unplanned plant downtimes can be avoided by the possibility of early error detection.

To meet the high requirements of the aerospace industry, the process data management system DAHMOS is used for the complete documentation of the component-specific process data. By recording, evaluating and archiving the process data, the traceability of the production history of each component is guaranteed.

**Vibration Isolation and Forge Shop Foundations**  
Victor Salcedo, GERB Vibration Control  
Presentation Room B

A properly planned foundation is an integral part of maintaining long-term performance of machinery. GERB Spring-VISCODAMPER mounts provide superior vibration isolation and settlement protection for Forging Hammers, Presses, Lathes, CMMs and other forge-shop equipment. Coupled with a GERB designed foundation you can expect a reduction in settlement, machine wear, precision equipment errors due to vibration, and operator fatigue.

**CFD Modelling of Immersion Quenching Process for Prediction of Metal Parts Thermodynamic Conditions**  
David Greif, AVL-AST d.o.o. Slovenija  
Presentation Room C

The multi-phase quenching model is used to predict the thermodynamic conditions during the immersion of metal parts into the liquid quenchant. Heat transfer occurring during the rapid cooling occurring during the immersion quenching plays an important role in achieving the desired mechanical properties of different mechanical parts. The numerical simulations of mass and heat exchange is based on a conservative 3D approach using the commercial computational fluid dynamics code AVL FIRE®. The developed quenching transfer model has empirically correlated heat transfer coefficients separately defined for each of the boiling regimes. With such a model, it is possible to distinguish all relevant surface boiling regimes, such as film transitional, transitional, nucleate, and full nucleate boiling regime. Governing equations are based on the Eulerian multi-fluid approach where liquid and vapor phases are treated as interpenetrating continua coexisting in the flow domain. The phase coupling is achieved through the modeled inter-phase transfer terms. The focus of this research is on validation of a new comprehensive model capable to predict heat and mass transfer during the immersion quenching process. The model is validated against the available experimental data for different conditions. Simulation results are found to be in good agreement with the experimental data.

**Experience with Industry 4.0 at Equipment In Open/Closed Die Forging Shops and Visions in Automation**  
Mr. Arno Dienenthal, Dango & Dienenthal Maschinenbau  
Presentation Room A

It is obvious that industrial plants and engineering of special machines, as well as the design of commodities, have a new focus today since the opportunities the Internet offers along with cloud and server-based applications are continuously growing. Dango & Dienenthal has implemented options in this respect to support predictive maintenance and plant operation with machine data and its analysis via telemetric services. Within a conservative environment like an open die forging plant it could be successfully demonstrated to capture a lot of operational data and after analyzing this data by data specialists to find correlations and define threshold values systematically according to analysis. A different but most interesting topic within the field of Industry 4.0 is the autonomous movement of special machinery in the plant. The Dutch company Hencon, a rather new member of the Dango & Dienenthal Group, has developed such machinery for material transportation in some Aluminum smelters in the world. It is obvious that one want to benefit of this development within the group for other mobile equipment, such as transport manipulators in forging plants. Another topic of this paper is a newly developed special machine tool that is capable to cut rolled rings.
and sleeves into thin slices. This Ring Cutting Machine is just now being launched by Dango & Dienenthal. The use of that machine significantly reduces the material consumption and the machining time. At the same time, the accuracy and surface flatness of the end product is within the lowest tolerances. The first test pieces have been produced on a prototype machine with very good results. With add-on modules, the machine becomes a machining centre that performs several functions such as turning, milling or drilling or ultrasonic testing in one clamping process.

**Enhancing Tool Life by Manipulating the Punch & Die Elastic Strain Field During Forging**
Gracious Ngaile, North Carolina State University Presentation Room B

In the forging industry, tool life is a major factor in the cost of forgings, productivity, and part integrity. This presentation will discuss a new methodology of enhancing the tool life of forging tools by manipulating the elastic strain field induced in the die and punches during forging, such that the contact stresses at the tool-workpiece interface are minimized or eliminated during punch ejection and release of the forging from the dies. The retained contact stress at the tool-workpiece interface after the forging load is released is mainly attributed to the spring-back of the dies/punches. The retained contact stress has detrimental effects on tool life, as it exacerbates tool wear, increases temperature dissipation from the workpiece to the tools, and worsens the tribological conditions. Finite element simulations of the proposed forging tooling architectures which facilitate the relaxation of elastic strain field in the die at the end of the forging stoke will be presented. To assess the viability of this technique, a number of forging geometries have been simulated including, CV joint, pinion shaft, hub spindle, and gearbox main shaft. The researchers are currently developing a laboratory-scale tooling setup for experimental validation.

**How Forging Simulation Saves Time and Money**
Nick Biba, Qform/Forge Technology, Inc. Presentation Room C

Simulation is significantly more cost effective than the outdated trial and error method of forging design and simulation ensures the shortest time period from the start of design to delivery of the optimal product. Simulation eliminates the need for shop floor verification of designs that takes a press out of production as well as eliminates the high cost related to trial tools and potential tool modifications. Simulation of the entire forging process ensures that the final product will be delivered quickly and defect free with the dimensional and mechanical properties required by the customer. This presentation will evaluate several multi-step forging operations and show how simulating various methods can eliminate defects and optimize production very quickly without any shop floor trials. Many real-world examples will compare actual forgings with simulated results from QForm simulation software. Special tools in QForm will be used to identify laps, non-fill and other material flow issues.