A Clear Vision for the Future
May 19–21, 2020
Hyatt Regency Orlando • Florida USA

Join us for the 50th Anniversary Celebration of the most anticipated event in the aluminum extrusion industry!

ET20.org

100+ Technical Sessions • ET Expo
nETworking • Extrusion Showcase
Add-On Workshops & Classes
Anniversary Special Events

Scan this code with your smartphone, or visit ET20.org for program updates!
ET ‘20: A Clear Vision for the Future
May 19 – 21, 2020
Hyatt Regency Orlando
International Drive • Florida, USA
ET20.org

Your Golden ET Opportunity!
Join us for the 50th Anniversary Celebration of the most anticipated event in the aluminum extrusion industry!

Why Attend?
ET ‘20 expands your depth of knowledge and the full breadth of possibilities for innovation, research, technology advancements, product applications and more, in a global gathering that holds the extrusion industry to the highest standards of excellence.

Technical Exchange
Experience the latest aluminum extrusion technology developments during an intensive three-day program. With 100+ technical presentations presented in six topic-specific tracks, you navigate your own path according to your interests and needs. The brightest minds in the extrusion industry assemble under one roof to contribute to the advancement of the industry. This technical exchange is essential to increasing your knowledge to benchmark and improve operations.

The Team Advantage
When you attend ET as a Team, you’ll not only receive discounted registration, you will gain the advantages of learning, solving challenges together, and connecting with like-minded professionals – maximizing your ET week – an investment that will benefit your organization for years to come. See the Registration Form (inside back cover) for details.

ET Expo
Held in conjunction with the ET ‘20 Seminar, ET Expo offers a vibrant marketplace of 100+ aluminum extrusion industry suppliers showcasing equipment, products and services to optimize your business. At ET Expo you’ll meet the problem-solvers who know how to bring ideas from concept to reality in a shared vision of aluminum extrusion’s true potential. Exhibitors at ET Expo are ready to help solve your challenges!

nETworking
Where else can you meet, share new ideas, discuss challenges, and relax with colleagues and mentors, competitors, and teachers all in the spirit of friendship and industry advancement? Connect to a pipeline of extrusion industry experts from 50+ countries. ET is the perfect place to expand your industry connections.

The ET Foundation reserves the right to alter the program or substitute speakers as needed.

Start Planning Your ET’20 Experience Today!
Join Us in Orlando!

Orlando’s top-rated meeting destination is the perfect backdrop for connecting with colleagues, exchanging ideas and seeking knowledge to meet challenges for the future. Excitement and non-stop fun combine with sunshine, warm breezes and plenty to see and do in Orlando, Florida. Gourmet cuisine, entertainment, music & dance, sporting events, nightlife, theme park thrills, golf, fishing, luxury resorts – Orlando is the destination for great times and an exciting conference!

Getting to and Around Orlando

Orlando, located in Central Florida, provides the ease and convenience of multiple travel options, including the Orlando International Airport, just 15 minutes (12 miles) from the Hyatt Regency Orlando. The Orlando Health/Amtrak train station is just 10 miles to the Hotel. Once in town, taxi, shuttle, limo, trolley, bus, and rental car – all are available at your fingertips to get around with ease. Getting to the conference hotel, the Hyatt Regency Orlando, is a breeze. For more details on transportation and parking options, visit ET20.org and choose Hotel & Travel/Transportation.

Travel and Lodging

Hyatt Regency Orlando
9801 International Drive
Orlando, Florida 32819 USA

Reservations, cancellations and changes to accommodations must be made directly with the Hyatt Regency Orlando via the link found on ET20.org or the phone number provided above.

A block of rooms at the special rate of $239/night (single or double, plus tax and resort fee) for ET’20 delegates is being held at the Hyatt Regency Orlando until April 20, 2020. After that date, group rates can no longer be guaranteed and rooms will be subject to availability, so be sure to make your room reservations as soon as possible.

*If calling to make reservations, be sure to mention Group Code: G-MEXT to obtain the special rates.

International Guests

Generally, all international travelers require a visa to enter the United States. The ET Foundation recommends that you apply for your visa at least three months in advance of your scheduled trip to avoid processing delays.

Letter of Invitation

If required for travel to the U.S., a Letter of Invitation can be supplied only after you have registered for ET’20 and payment has been received in full. Details regarding obtaining an invitation letter can be found on the ET’20 website.

To make your trip go as smoothly as possible, please take some time to review the information provided on the ET’20 website regarding travel to the United States.

For complete details and updates on Orlando travel, lodging and attractions, visit the ET website at ET20.org.

ET’20 Program Ahead

See Schedule at a Glance on back cover.

The ET program includes two General Sessions, one each at the opening and closing of the event, featuring dynamic speakers, industry information and important announcements.

General Sessions Highlights

Tuesday Keynote Speaker

Charlie Straface, Hydro

Charles Straface, Business Unit President for Hydro’s general extrusion operations in North America, will provide the Opening General Session keynote address. Mr. Straface will share Hydro’s view and vision of the aluminum extrusion industry. As the president of the largest extruder in North America, Charlie will provide a unique view as the industry leader.

Thursday Keynote Speaker

Mike Massimino, NASA Astronaut

Michael Massimino, or Astro Mike, is a Professor of Mechanical Engineering at Columbia University, New York, and a former NASA Astronaut whose tenure includes two Space Shuttle missions to the Hubble Telescope, and four space walks (EVAs) to make critical telescope repairs. Mike is senior space advisor to the Intrepid Sea, Air & Space Museum in New York City. He offers his unique perspective on teamwork, innovation and leadership.

Best Paper Awards

The best of the best are highlighted at ET! Awards for the best papers of the Twelfth International Aluminum Extrusion Technology Seminar will be presented during the General Sessions.

ET Foundation Design Competition Awards

Winners of the 2020 Aluminum Extrusion Design Competition, including students and professionals, will be presented. Watch for the 2020 Design Competition Call for Entries coming this fall at ETFdesign.org!

This is an early preview of the General Session program. Visit ET20.org for updates as they become available.

The ET Foundation reserves the right to alter the program or substitute speakers as needed.

Visit ET20.org for the latest information
ET ’20 Expo: Your Global Extrusion Information Center

The ET Expo, is the marketplace and information center where aluminum extrusion industry suppliers connect directly with decision makers. It’s more than a trade show – it’s an extension of the learning experience at ET where you can hear about the latest innovations from top suppliers in the industry. Knowledgeable exhibitors assist you and your team by answering questions, sharing ideas and offering solutions to your challenges.

ET Expo Hours

<table>
<thead>
<tr>
<th>Day</th>
<th>Hours</th>
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<tr>
<td>Tuesday, May 19</td>
<td>12:30 p.m. – 6:30 p.m.</td>
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<tr>
<td>Wednesday, May 20</td>
<td>10:00 a.m. – 7:00 p.m.</td>
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<tr>
<td>Thursday, May 21</td>
<td>10:00 a.m. – 3:00 p.m.</td>
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*Hours subject to change.

For an updated exhibitor list, as well as an interactive floor plan featuring product and service details and links to company websites, visit ET20.org

ET Showcase
Near the ET Expo, ET Showcase highlights ET Foundation Professional and Student Design Competition winning entries, and reveals aluminum extrusion applications that inspire and amaze.

From automotive to industrial, cutting edge and exciting applications will be highlighted to demonstrate the advantages of aluminum extrusion.

ET Expo Exhibitors

At press time, the following companies are scheduled to exhibit at ET EXPO.

Abtex Corporation
Albarrie Canada Limited
Almax Mori SrL
Almax USA, Inc.
Aluminium International Today
Alvarez Schaer S.L.
American Plating Power
AMCOL Corporation
Azon
BASF/Chemetall US, Inc.
BCI Surface Technologies
Belco Industries Inc.
Butech Bliss
Castool Tooling Systems
Comblift Ltd.
Compes International
Danieli BREDABarnings

Die Cleaning Equipment and Supply, Inc.
Eastern Oil Company
ECOFILL BV/ECOFILL USA, LLC
Emmebi
EXCO
Extec Ltd.
FOM USA
Foy Inc.
Graf Technik GmbH
Granco Clark Inc.
Inductotherm Heating & Welding – Banyard
International Aluminium Journal
ISRA Parsytec GmbH
Italtecnno SrL
Kautec Solutions
Kintner, Inc.
Lake Park Tool & Machine, LLC
Light Metal Age
MARX GmbH & Co. KG
Nitrex Metal Inc.
Novatec Process Systems Inc.
Nuteck Bickley
OMAV SpA
Otto Junker GmbH
Perfection Servo
Phoenix – Youngstown Tool & Die
Powder Coating Institute
Presezzi Extrusion Group
QForm Extrusion/Forge Technology, Inc.
Quaker Houghton

S.A.I. SrL - Società Automazione Industriale
SAT (Surface Aluminium Technologies) SrL
Schmolz + Bickenbach USA
Secat
SMS group Inc.
STAS Inc.
Tellkamp Systems, Inc.
Thermika Systems Inc.
Thumb Tool & Engineering
Trasmetal SpA
Tuff Temp Corp.
Turla SrL
UBE Machinery Inc.
Wagstaff Inc.
WEFA Cedar Inc.
Weite Extrusion Press

Start Planning Your ET’20 Experience Today!
Add-On Workshops: Education at ET ’20

Take advantage of the opportunity while at ET ’20 to save time and enhance your learning experience by adding one or more of the following in-conjunction workshops during ET Week. Workshops and courses are offered on Monday, May 18 and Friday, May 22 – before and after ET ’20. Register early; space is limited. Registration includes lunch and all course materials. For complete course information visit ET20.org.

Monday, May 18

Process Analysis & Optimization
8:30 a.m. – 5:00 p.m.
This one-day workshop is conducted by top experts from the Manufacturing Technologies Group at the University of Bologna, Italy. Topics covered include Introduction to Practical and Analytical Extrusion Concepts, Material Flow and Friction in Direct Extrusion, Die Failure Modes and Die Life Prediction, and much more. Fee: $450

Anodizing Essentials
8:30 a.m. – 5:00 p.m.
The Aluminum Anodizers Council’s Level 1 Course, Anodizing Essentials Workshop, details the foundation of quality anodizing from beginning to end. AAC anodizing experts designed this program, which will benefit production personnel at every level, from veterans to newcomers alike. The program includes such topics as metallurgy basics, cleaning and rinsing, rackaging, dyeing, sealing, power for the aluminum surface treatment industry, safety and much more. Fee: $450 for AAC Members / $850 for Non-Members

Monday and Friday, May 18 and 22

Extrusion Excellence: Applied Fundamentals for Aluminum Extruders
8:00 a.m. – 5:00 p.m.
Theory and practice combine in this intensive one-day course that presents a fundamental engineering approach to the aluminum extrusion process, covering the manufacturing process from billet production through the press at the runout table. This course will benefit those new to the industry, as well as experienced production personnel. Course topics include Extrusion Concepts, Aluminum Extrusion Alloys, Aluminum Billet Metallurgy, Extrudability, and much more. Fee: $450 for AEC Members / $850 for Non-Members

AEC Die Clinic
9:00 a.m. – 5:00 p.m.
An abbreviated version of one of AEC’s most valuable training events comes to ET ’20! This one-day practical course provides highlights of previous Die Clinics taught by members of AEC’s Die & Tooling Team—experts in die correction, die manufacture, extrusion operation, and related skills. They readily share key insights and their most valuable experiences focusing on issues related to die tooling in this condensed course. Learn what Die Clinics are all about and how you can benefit from future clinics. If you are involved in extrusion die and related operations, this is a must-attend event! Fee: $450 for AEC Members / $850 for Non-Members

Special Events

ET ‘20 will include a variety of special events designed to foster nETworking connections. Choose from the following events; additional registration and fees apply as noted. Visit ET20.org for complete details.

ET 50th Anniversary Celebration
“Spirit of Aloha” Dinner Show
Thursday, May 21 • 7:00 p.m. – 11:00 p.m.
Cost: $95.00 per person
Join this Golden ET Anniversary Celebration Event – the Spirit of Aloha Dinner Show at Disney’s Polynesian Village Resort, Luau Cove. Register early to guarantee your seat at this fantastic event of tropical-inspired food and exciting South Seas entertainment. Dinner and show is scheduled from 8:15 p.m. to 10:15 p.m.
Includes bus transport to/from the event; All-you-care-to-enjoy Luau feast, beer, wine, soft drinks, lemonade, or coffee (cocktails on your own). (Taxes, service fees and tip included. This is a non-smoking outdoor/covered facility.)

ET Founders Golf Tournament
Friday, May 22 • 7:00 a.m. – 4:30 p.m.
Cost: $155.00 per person
Optional equipment rental: $48.00 per person;
Join us for the 50th Anniversary ET Founders Golf Event at Disney’s Palm Golf Course. The tournament on this PGA-rated course features a shotgun start. Optional equipment rental, including golf clubs, balls and shoes, is available for an additional $48 per person (includes tax). Registration is very limited – reserve your spot early!
Your round includes round-trip bus transport to/from the tournament, greens and cart fees, pre-round practice range balls, bag handling & locker room; plus prizes and box lunch at the Tournament’s end. Bus departs from the Hyatt for the golf course at 7:00 a.m., and bus shuttles return to Hyatt starting at 1:30 p.m. Last bus departs course at 4:30 p.m.

Kennedy Space Center Tour
Friday, May 22
8:00 a.m. – 3:00 p.m.
Cost: $95.00 per person;
Join us for an out-of-this-world ET special excursion to the Kennedy Space Center (KSC) and Visitor’s Center Complex. Includes round-trip Motor Coach to/from the Hyatt; 45-minute KSC Staff-Guided Tour; approximately two hours to visit KSC Museum, including Apollo, Space Shuttle, Saturn V Rocket exhibits and IMAX movies; and Noon Lunch with an Astronaut.
Bus departs the Hyatt at 8:00 a.m. arriving by approximately 9:15 a.m. Return bus departs KSC Visitor Complex at 1:45 p.m., returning to the Hyatt by approximately 3:00 p.m.

Visit ET20.org for the latest information
The following pages contain the edited abstracts for papers accepted for presentation at ET’20. Papers will be presented in six concurrent topic-specific tracks over two days. All of the research is new or updated, making ET uniquely relevant. Contributions from the international aluminum extrusion community reflect a wide range of issues, and will cover topics that are encompassed in the following areas:

- Best practices
- Improved processes and new techniques
- Product and market developments
- Alloys and manufacturing research
- Emerging technologies and applications
- Sustainable practices and other environmental aspects of extruded aluminum production and use

**BP: Billet Process & Equipment Track**

**BP31**

**Modeling the Precipitation of Dispersoids during Homogenization of 3xxx-Series and 6xxx-Series Extrusion Billets**

Warren Poole and Chenglu Liu, The University of British Columbia; Lei Ray Pan and Nick C. Parson, Rio Tinto Aluminium, Canada; and Qiang Du, SINTEF Materials and Chemistry, Norway

A chemistry dependent model for precipitation of dispersoids during homogenization is developed for 3xxx-series and 6xxx-series aluminum alloys. Diffusion of solute is considered at two length scales. The precipitation model follows the Kampmann Wagner numerical (KWN) approach and is coupled to the Thermocalc thermodynamic database. Dispersoid nucleation, growth and coarsening behavior are reviewed. The model predicting local size and volume fraction of dispersoids and its evolution over time is experimentally validated.

**BP37**

**Optimal Billet for Best Extrusion in AA6063**

Sutayan Parida and Ihab Mouallem, National Aluminium Products Company SAOG, Oman

Most Middle East extruders who use AA6063 alloy for architectural profiles have minimal control over billet quality. Points affecting extrusion quality are outlined. Extruder expectations for optimal billets are presented: good speed and high productivity; streamlined metal flow throughout the billet length; introduction of common alloys overlapping the characteristic of two or more alloys; straight and square end cuts; good casting with uniform grains to reduce break-through pressure; and special high-speed alloys for thin-wall profiles.

**BP57**

**History and Development of Aluminum Dross Processing**

David Roth, CPS Global Solutions, USA

Over the past 60 years, aluminum’s value has increased and the way oxidation products (dross) are viewed has changed from a material sent to landfills to a raw feed, completely recycled as valuable downstream products. Aluminum melting generates dross; dross removal carries out free aluminum. Systems developed to minimize these realities have seen dramatic improvements hit the marketplace. Past and still-in-use practices, and the newest technologies reshaping how dross processing is perceived are examined.

**BP66**

**Effect of Change in Amounts of Main Alloying Elements on Structural Properties of Direct Chill Casted 6xxx-Series High-Strength Aluminum Alloy**

Osman H. Celik, Mert Altay, Mehmet B. Guner, and Gorkem Ozcelik, ASAS Aluminium, Turkey

Four 6056 aluminum alloy compositions with differentiated main alloying element amounts (Mg, Si, Cu, Mn) were produced with direct chill casting. Chemical composition changes affect microstructure, solidification and homogenization behavior are investigated. Sample structural characterizations use an optical microscope and energy dispersive spectrometer equipped scanning electron microscope; and for thermoanalytical studies, differential scanning calorimetry is utilized. Thermodynamic modeling and estimation of alloy microstructural changes and solidification behaviors and outputs are compared with experimental results.

**BP67**

**How to Adjust the Size and Distribution of Dispersoids in AA6082 for a Perfect Microstructure**

Andreas Schiffi and Daniel Hillebrand, Hammerer Aluminium Industrien Extrusion GmbH; Aurel Arnold, Leichtmetallkompetenzzentrum Ranshofen, Austria; and Philip Goik, FAU Erlangen-Nürnberg, Germany.

High-strength 6082 alloys are demanded for European automotive applications, but ductility, crash performance, low quench sensitivity, high corrosion resistance, and small grain size are also demanded. Mn and Cr form stable dispersoids during homogenization, hindering microstructure recrystallization during extrusion. Adjusting dispersoid density and size is crucial to influencing profile microstructure for the aforementioned properties. Dependency of homogenization regime (time and temperature) and influences of Mn, Cr and Cu content on dispersoid formation are examined.
BP69 Influence of Heat Treatment on Interfacial Bonding in Co-Extrusion of Compound-Cast AA7075/AA6060 Bi-Layer Billets
Hui Chen and Noomane Ben Khalifa, Leuphana University of Lüneburg; Danai Giannopoulou, Helmholtz-Zentrum Geesthacht; Thomas Gress, Tim Mittler, and Wolfram Volk, Technical University of Munich, Germany
A compound casting process with optimized parameters can generate metallic bonding between interfaces of AA7075/AA6060 layers. Partial weak bonding exists due to locally unequal thermal conditions at the interface during two-step casting. Plastic deformation, hot extrusion of as-cast billet, is conducted to improve interfacial bonding. Annalining's influence in inhomogeneous bonding along as-cast billet, and bonding after hot extrusion are investigated by metallography and mechanical testing. Interfacial bonding after casting, annealing and hot extrusion are compared.

BP70 Producing Quality Billets in a Safe and Sustained Environment
Hussain Mohd Amin Faqihi and Arun Kumar Gosal, Aluminium Bahrain BSC (Alba), Bahrain
An overview is presented of the casthouse equipment and testing required to produce billets with consistent product quality in a safe and sustained environment. Casthouse advanced technologies are described, including electromagnetic stirrer (EMS), dual CFF filtration, ACDs, batch homogenization furnaces with step heating and cooling facility, helical ultrasonic billet inspection tables, etc. In-house testing and measurement facilities ensure that products meet exacting customer demands and requirements for end-use applications, from building and construction to transportation.

BP86 AA6063 Billet with Reduced Boride Particle Content
Paul Rometsch and Nick C. Parson, Rio Tinto Aluminium, Canada
Grain refinement effectiveness of the Al Ti C system (TiC) is compared to the Al Ti B system (TiB2), and whether similar benefits are achievable using various ways of reducing boride or carbide content. TP1 contact time tests were conducted on 6063-type alloys with different process parameters to evaluate grain refiners' effectiveness; then, AA6063 billets were cast with high and low grain refiner additions, and extruded to determine whether differences could be observed post-extrusion.

BP113 Can Our Industry Prevent Molten Metal Explosions?
Alex W. Lowery, Wise Chem LLC, USA
Mitigating molten metal explosions in aluminum plants, specifically in casthouses, has become a central focus in our industry. Past studies failed to use historical industry data to investigate past trends. Through analysis of the Aluminum Association's Molten Metal Incident Reporting Program data, past and future trends are considered and explored. It is proposed that through reviewing past and present explosions, the aluminum industry can set a path to prevent future explosions.

BP119 Quality of Billet and Its Influence on the Extrusion Process
Arif Hussain, Mushtaq Mohammed and Mansoor Mohammed, Gulf Extrusions, LLC, UAE
Billet quality's effect on extrusion process is reviewed/assessed using physical and metallurgical characteristics of dimensional control, top/bottom crop length, center cracks, porosity, mechanical damage; influence of chemistry, balance between Mg, Si and excess Silicon of chemical composition consistency and flexibility in defining a sub-alloy to achieve specific requirements; importance of homogenization – chemical & morphology, assessing the extrudate; billet metallurgical characteristics and their influence on extrusion; and billet chemistry's influence on processes such as anodizing.

BP127 5xxx-Series Extrusions for Automotive Applications with Outstanding Intergranular Corrosion Resistance
Hubert Koch and Luisa Marzoli, TRIMET Aluminium SE, Felix Gensch, INGWERK GmbH; and Soeren Mueller, Extrusion R&D Center, TU-Berlin, Germany
While 6xxx-series aluminum alloys offer wide-ranging mechanical properties and good extrudability for automotive applications, most of them are sensitive to intergranular corrosion or stress corrosion cracking. In contrast, 5xxx-series alloys exhibit low intergranular corrosion rates, but their extrudability is limited to simple shapes. By modifying a 5xxx-series alloy, hollow profiles were extruded with porthole dies in collaboration with the Extrusion Research and Development Center of the TU Berlin, and resulting properties are presented.

BP130 Automated Billet Surface Inspection
Dominic Vezina, Pascal Cote and Jean-Pierre Gagne, Stas, Canada
New fully-automated equipment, Billet Surface Inspection in 3D (BSIS), uses state-of-the-art proven 3D scanning and image analysis technologies. The equipment is fully objective and consistently detects and records surface defect characteristics. It is programmed to precisely evaluate bending of the billets i.e., straightness. The equipment allows for casting process optimization, helping improve the billet recovery rate and reduce overall operating costs. An equipment overview and its performance and benefits for the extrusion sector are presented.

BP159 The Implementation of a Comprehensive Dross Management Program
James Herbert, ALTEK, USA
Dross handling and treatment upon dross removal from the furnace is important. Specialty alloy producers for aerospace are particularly interested in maintaining metal chemicals and values. A comprehensive dross management program implemented over 12 months is presented. The latest generation dross press technology is shown to improve dross recoveries and reduce environmental emissions. In-house and secondary metal recoveries and additional savings are outlined, working with the secondary processor.

BP160 Case Study of Air-Cooled Electromagnetic Stirred Melting Furnace
James Herbert, ALTEK, USA
Retrofitting a circulation device to an existing furnace can be cost-effective, yet offers a relatively quick return on investment. The SIBERFORCE® electromagnetic stirrer is an air-cooled device that overcomes the negative aspects of traditional EMS devices. The retrofitting of this system to the bottom of a melting furnace is presented. Work required during installation is reviewed, as well as performance testing results that benchmark improvements in melt rate, specific energy consumption and dross generation.

BP161 The Industrial Application of Molten Metal Analysis (LIBS)
James Herbert, ALTEK, USA
Laser-induced breakdown spectroscopy (LIBS) provides quick, reliable molten metal analysis in production settings. LIBS fires a high-energy laser into the melt, creating microscopic plasma that emits light characteristic of each element's type and concentration. A spectrometer identifies each element and its concentration within the melt. The OnSpec® LIBS system, developed for the aluminum industry, provides real-time bulk metal chemistry of molten metal in furnace and launder applications. System field tests, applications and benefits are discussed.
BP164  
Billet Casting Technology for Increased Production and Diversified Alloys  
Gary Grealy, Wagstaff, Inc., USA  
For industrial casting technology, solutions are presented in two categories. Hardware design and engineered solutions are discussed, focusing on technical challenges and considerations that enable an increase in billets cast for a given casting pit footprint. Comparisons are made with standard billet technology and new, high-density mold tables. The second area of discussion focuses on casting the more challenging Zn-containing 6xxx-series and the high Zn-containing 7xxx-series extrusion alloys increasingly used in the automotive and aerospace industries.

BP174  
The Maturing of Low-Pressure Casting (LPC) Technology  
Arlid Hakonsen and Rune Ledal, Hyecast AS, Norway  
Low Pressure Casting (LPC) technology produces hard and soft alloy aluminum extrusion billets with superior surface quality compared to conventional gas-assisted mold technologies. Metallostatic pressure in the liquid metal inside the LPC mold is zero exudation, thus eliminating most surface segregation, and yielding several homogenization and extrusion advantages. LPC technology has matured, encompassing numerous improvements. LPC's industrialization process is described, highlighting improvements made and current status of the technology.

BP176  
Performance Evaluation of High Flow Ceramic Foam Filters on Aluminum 6061 Alloys  
Bob Eivani, Drache USA; Jochen Schnelle, Drache Umweltechnik GmbH, Germany; and Jason Evoy, Matalco, Inc., USA  
A filter’s standard range for metal flow provides optimal filtration efficiency. If metal flow exceeds filter capacity, the filter could create backflow and could cause an aborted cast. High-flow (HF) filters are produced using certain steps to ensure their ability to handle higher flow rates, while producing filtration efficiency similar to standard filters. HF filter performance has been tested using PODFA techniques for 6061 Aluminum alloys vs. standard filters and results are presented.

BP178  
High-Quality Forging Material  
Arlid Hakonsen and Rune Ledal, Hyecast AS, and Ulf H. Tundal, Knut O. Tveito, Lars A. Moen and Magne Boge, Hydro, Norway  
New low-pressure casting technology (LPC) offers high-quality cast forge stock in 80mm and larger diameters. LPC technology reduces friction between the ingot surface and mold during casting, and nearly eliminates inverse segregation; further process steps — scalping, extrusion or machining are unnecessary. HyForge™ material is used directly during forging. LPC technology is optimized and implemented in a large-scale billet casthouse, showing how to process cast forge stock to minimize cost and produce high-quality forged parts.

EE: Extrusion Equipment Track

EE23  
Extrusion Spray Quench with Distortion Control System  
David Jenista and Drew Griffin, Granco Clark, Inc., USA  
At ET ’16, a geometric distortion reduction method was demonstrated for extruded profiles using Finite Element Analysis (FEA), which reduces the profile’s cooling rate from quench entry until reaching maximum quench-critical temperature range. Most presses extrude multiple products with highly variable geometries across a wide speed range. A solution for general-purpose extrusion lines is presented: a high-performance spray quench with an entry zone featuring fully adjustable cooling rate and adjustable effective zone length.

EE33  
Functional Guarding of Horizontal Extrusion Presses  
Bradley C. Wyatt and Mark C. Eliopoulos, Kaiser Aluminum, USA  
Expanding risk mitigation strategy is discussed, to ensure that extrusion presses produce world-class product, while also protecting world-class employees during complex systems operation. Achievement of comprehensive safeguarding for horizontal extrusion presses is presented, sharing challenges/obstacles and successes during the 10-year-long journey. Risk assessment and alternative method processes are highlighted: how they are foundational to safeguard an aluminum extrusion press and enable critical tasks to be performed safely with the extrusion press under power.

EE34  
Billet Magnet Heater: ZPE  
Mario Bonifacio, Presezzi Extrusion SpA, Italy  
Unlike traditional induction heating, the ZPE's variable field is obtained by alternating North and South poles around a fixed billet during rotor rotation. The magnetic field's low-frequency force lines axially and perpendicularly penetrate the material to be heated. The rotating magnetic field is generated by electric motors that are coaxial to cylindrical magnets positioned around the billet. The faster the magnets' rotation, the more force lines flow through the billet, causing a Joule heating effect.

EE41  
Applying Non-Destructive Examination Methods to Extrusion Presses  
Ronald Manganello, Richard Manganello and Alyssa Porter, Carlesa NDE Services, USA  
Applying non-destructive examination (NDE) methods to extrusion presses is presented, demonstrating how cracks are identified, where/why common cracks are detected in presses, limitations press conditions place on testing, and mitigating those limitations. Preventive measures are recommended to mitigate cracking development and propagation, including press alignment and preventive maintenance methods. Decision-making behind recommending press repairs over press replacement is reviewed. Examples shown from global extrusion clients demonstrate better operational efficiency, reduced costs, and improved employee safety.

EE44  
Automatic Surface Inspection during Aluminum Extrusion  
Dominik Recker, ISRA Parsytec GmbH, Germany  
To demonstrate aluminum industry digital manufacturing, in-plant extrusion surface inspections are presented. Surface defects – blisters, inclusions, streaks, scratches and grooves are caused by insufficient process parameters, the die, input material, or handling. The Surface Inspection System signals the finishing saw where to cut, so that defective parts are automatically sorted out. According to detected defects, the system further alarms the operator to change the die, or check input material or process parameters.

EE47  
Log Heating System Controls – Better Data Collection for a Better Process  
Davide Turla and Alessandro Guerrini, Turka Srl, Italy  
Log heating system controls can tackle extrusion problems by storing and retrieving process data. Modern log heaters have hardware and software features that conduct real-time surveys, correction and control of parameters: log/billet tracking and intermediate storage; surface temperature inside log heater and at press delivery; temperature evolution before pressing; presence of hot spots; cut precision and quality. Log heating systems’ advanced features, and their utilization of information for better extrusion process analysis is presented.
Increase equipment reliability and reduce downtime, improving performance – electrified motions and increases process repeatability; downstream equipment minimizes manual handling and guarantees the highest surface quality – adequate cooling rates provide the most economical and simplest hydraulic/electronic equipment combination with smart, green technology. Danieli BREDA, Italy.

Extrusion Presses

Mauro Baldassi, Danieli BREDA, Italy

The number of installed hydraulic press pumps is driven by the need to reduce downtime. Danieli’s approach to hydraulic pump usage during the extrusion cycle is presented: reduce component number and complexity; select off-the-shelf equipment and digitalize system tuning for a smart, green solution for hydraulic pump selection and control. Benefits discussed include: operational cost/reduced energy and maintenance costs; capital expenditure/less equipment and digitalize system tuning for a smart, green solution for hydraulic pump selection and control. Benefits discussed include: operational cost/reduced energy and maintenance costs; capital expenditure/less and simplest hydraulic/electronic components; performance/reduced DCT and maximized equipment reliability.

New Concept for Handling Systems of Aluminum Extrusion Presses

Dario Bracesco, Davidi BREDA USA; and Mauro Baldassi, Danieli BREDA, Italy

Latest generation state-of-the-art downstream equipment combines with smart, green solutions and a highly automated process to yield the handling system benefits presented: quality – adequate cooling rates provide the highest mechanical properties and protective handling guarantees the highest surface quality; productivity – appropriate cooling rates and quick handling increase stem speed and productivity output; cost – highly automated downstream equipment minimizes manual operations and increases process repeatability; and performance – electrified motions increase equipment reliability and reduce maintenance costs.

A Step Ahead in Human Machine Interface and Remote Support for Aluminum Extrusion Plants

Dario Bracesco, Davidi BREDA, USA; and Mauro Baldassi, Danieli BREDA, Italy

Modern human machine interface design for extrusion is focused on allowing safe, immediate operator corrections, while performing other production tasks. High-level automation and wireless technology enable extrusion line operators to become mobile, leaving classic stationary positions to focus on quality or added-value tasks. Maintenance managers utilize an innovative tool for remote support, interaction with supplier specialists and to archive technical documents. Presented benefits: simplified information access; easier communication and reporting; and quick equipment issue solutions.

Frequency Control for Induction Heating of Billets Prior to Extrusion

Jacob G. Friend, Inductotherm Heating & Welding Ltd., UK

The LFI Smart System controls frequency from 20Hz to 200Hz to multi-zone higher temperature, increasing heating productivity and improving temperature control/accuracy. Using lower frequency enables induction heating currents to circulate deeper inside the billet, allowing more heating power to be applied while maintaining surface temperatures. Low frequency benefits its conditions where maximum permissible temperature is close to final target temperatures. Theoretical improvements of this frequency control are explored, reinforced with real-world data from existing installations.

Cost Preventive Extrusion

Arvind Singh, Jindal Aluminium Limited, India

During study over 12 years, observation of extruders using graphite oil for lubrication showed it to be harmful, emitting thick, black smoke, and resulting in breathing problems for workers. Such smoke blackened the entire press area, floor, rooftops, and settled on finished extruded products while stacking in the basket for T4/T5/T6 process. Finished material quality became very bad, with utilization of an innovative tool for remote support, interaction with supplier specialists and to archive technical documents. Presented benefits: simplified information access; easier communication and reporting; and quick equipment issue solutions.

Innovative Fast Die Cleaning of Extrusion Dies with Safe and Automatic Operation

Marcello Rossi, Fabio Vincenzi and Federico Vincenzi, Italtecnco Srl, Italy

Increased die cleaning efficiency via better optimization of chemicals and physical parameters is evaluated using a more ecological, faster and fully automatic method. This technology’s advantages confirm improved efficiency and operator safety. The entire plant is automatically operated by a programmable PLC; operators must place the dies before cleaning in suitable baskets in loading positions, and take out the cleaned dies from the same baskets loaded in unloading positions after being transferred automatically from the treatment tank.

Save over $1.4 Million Dollars in Utility Costs Utilizing Electric Induction Billet Heating

Thomas Kearney, Induction Professionals, USA

An innovative, 60Hz or 50Hz line frequency, high-efficiency electric induction billet heater is introduced that utilizes a breakthrough winding design, saving customers up to 23%+ over a conventional induction heater’s average electricity cost – potentially saving $1.4 million over a 25-year equipment lifetime. Advantages of utilizing solid-state power control are highlighted, including process consistency, repeatability, accuracy, and minimal downtime. Units have no moving power control parts or expensive vacuum bottles and do not generate harmonics.

Modernization of a 6k-Ton Extrusion Press Hydraulic System

Steve Demar, Haunichco, USA

A 6000-ton high-speed extrusion press hydraulic systems and controls modernization is examined, focusing on its complete water hydraulic system upgrade. Highlights include: press hydraulics; original water hydraulic system; engineered system solutions to meet new specifications; new water hydraulic scope of supply; service support in the years since startup, to troubleshoot operational problems and demonstrate real-world maintenance requirements. New improvements and challenges to the upgraded system and press operation during its four-plus years in production are summarized.

Innovative Approach for Extrusion Billet Loading: Robots

Zachary Yost, SMS group, USA

Robot technology offers repeatability, reliability, and long life expectancy for extrusion billet loading. Paired with custom-designed EoAT, a robot can load billets with precise positioning and point-to-point repeatability from oven or billet saw to the press center line. Robots require less maintenance, have no hydraulics, and offer added process flexibility, enhanced safety and increased production. Connectivity and predictive maintenance packages further reduce downtime. Robot technology design, development and deployment are examined.

A New Approach to Safeguarding a Modern Extrusion Plant

Tyson Bunker, Hydro Aluminum; and Carsten Dede, OMAV, USA

Extrusion plant operators must quickly and accurately see what their machine is doing, and how to stop and restart the line safely. Innovative solutions are shown to visually safeguard extrusion. A plant modernization project shows best practices, implementation steps, challenges, and how to generate operator buy-in. Safeguarding and how to overcome operator complacency when running an extrusion line are discussed, focusing on what really works in a practical day-to-day environment.

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EE126 Billet-End Scrap Detection
Troy M. Rice, Tubelite Inc., USA

A new billet-end detection standard reliably captures material hanging up between die stack and container. Three-dimensional time-of-flight sensing is applied to the extrusion process, capturing a hanging billet-end via PMD technology, which uses infrared light to determine spatial data for all objects in the regions of interest. Complementary software creates these regions of interest in order to instruct the press to stop the container, via the PLC, based on user-defined parameters.

EE143 Advantages of High-Convection Heaters for Combined Billet Heating
Jan van Treek, OTTO JUNKER, Germany

High-convection heaters for combined billet heating are shown to have unique advantages over combined gas and induction heating: high efficiency and energy cost savings; little wear inside the heater; high temperature accuracy and no risk of overheating/melting. Systems’ design characteristics, advantages and disadvantages are evaluated based on technical decision-making criteria (quality of temperature accuracy, flexibility) and cost considerations (investment and operating costs, especially energy and maintenance). Criteria are quantified and comparisons made.

EE145 Advantages of Induction Billet Heaters versus Magnetic Billet Heating
Jan van Treek, OTTO JUNKER, Germany

The global standard for combined billet heating to extraction temperature has been the classic induction heater. New developments like magnetic billet heaters were said to offer tremendous advantages (higher efficiency, low consumption and low operational costs). Years of systems operation have proven these assumptions to be wrong. Serious problems occurred during installation and commissioning; and at several plants, problems were not solved and magnetic heaters never became operational. Comparisons between magnetic and induction billet heaters are presented.

EE147 Achieving True Press Alignment with Precision Laser Tracker Measuring
James Cunningham, Brilex Technical Solutions, USA

Laser measuring technology helps to achieve true press geometry and alignment, promoting longer tooling life, reducing maintenance downtime, and achieving proper press frame loading. Precision laser measuring systems are accurate to within one ten-thousandth of an inch or 0.00001mm, in three dimensions, allowing quick press geometry and alignment determinations. Modern laser tracker systems precisely measure press component movements in real time. Collectively, the presented information assists with correcting and maintaining proper press geometry and alignment.

EE154 Modernizing the Extrusion Press and Handling System: Rebuild & Retrofit or Replace?
David Turnipseed, Aluminum Extrusion MarketPlace, LLC; and Al Kennedy, Kennedy Eurotech, Inc., USA

Aluminum extrusion management and engineers project and plan for upgrades or replacement, either by rebuilding and retrofitting, or by replacing aging equipment. The rule of thumb: if repair and upgrading exceeds 40% of the cost of replacing with new equipment, replacement is probably the better choice. Advantages available with updated machine technology, plus labor, time and resources are considered. Current factors and available machine features are examined to help decision-makers choose to upgrade vs. replace.

EE179 Your Equipment at a Glance
Giovanni Sacristani, MAV SpA, Italy

Understanding the extrusion process into the 21st century.extrusion productivity.

EE183 System: Rebuild & Retrofit or Replace?
Michael Kramer, Bosch Rexroth, USA

The Connected Future offers increased productivity and profitability through reduced downtime, lowered maintenance costs, improved quality and increased machine performance. Complete press system engineering, integrated hydraulic and electrical disciplines, requires understanding press drive and control system design. The aluminum extrusion industry navigates hydraulic equipment performance claims, electronic controls, software and application techniques, and integrated press control concepts. Realizing productivity and profitability through time-saving hydraulics and preparing extrusion press drives for the future are presented.

EP: Extrusion/Die – Practical Track

EP6 Accurate Pyrometer for Control and Logging
Aluminum Profile Cooling Rate
Boris Shartker, Orel Yitzchak and Ofer D. Yoely, Accurate Sensors Technologies, Israel; and Alan Castle, Service Extrusion Consultants Ltd., UK

Three main parameters that determine the metallurgical properties of the aluminum profile are the temperature profile at the exit from the die, temperature profile after cooling, and the time that passes between the two. The most common problems in aluminum profile temperature measurement are discussed, including basic requirements and different methods of temperature measurement. The need to use infrared pyrometers that identify the variable emissivity and measure accurately below 390°F (200°C) is discussed.

EP7 Extrusion Productivity - Billet Geometry/Container/Dummy Block
Paul H. Robins and Yahya Mahmoodkhan, Castool Tooling Systems; and Chris Jowett, Rio Tinto Aluminium, Canada

The best billet geometry for achieving high extrusion productivity is presented that minimizes press force, allowing minimized billet temperature and maximized extrusion speed. Blindly increasing billet length or diameter and expecting improved productivity may create other process problems: dummy block functioning; extrusion dimensions; butt shearing; metal flow, etc. Increasing billet weight may increase contact utilization, but not increase productivity. These subjects are addressed to better understand how billet geometry affects extrusion productivity.

EP9 Recovery Improvement - A Continuous Process
Dosi Uttram Chand and Devaraj Padavu, Jindal Aluminium Limited, India

For any given profile, recovery is the major factor determining production cost, price and profitability. Factors impacting recovery are reviewed, and parameters like billet temperature, pressure during extrusion and extrusion speed are presented as greatly affecting final product recovery. Too low billet temperature causes rejection due to low hardness; too high temperature causes hot rub and shearing problems. Factors directly and indirectly affecting recovery and how they can be controlled to improve recovery are highlighted.
EP10
Importance of Temperature in Extrusion Technology
Dosi Uttam Chand and Devendra Kumar Sain, Jindal Aluminium Limited, India
Correct die and container temperatures at different extrusion process stages are key to press efficiency, product quality and reduced die wear. Valuable press time may be wasted and excess scrap generated if dies are too hot or too cold. Tremendous heat generated within the container during extrusion depends on billet length, billet temperature, alloy type, extrusion speed and ratio. The influence of billet, exit profile, container and die temperatures on optimal temperature management is presented.

EP11
Innovative, Environmentally-Friendly Release Agents for the Dummy Block
Martin Hartlieb, Motultech Baraldi, Canada; Cosimo Roone and Piero Parona, Motultech Baraldi, Italy
Traditional technical solutions for release agents are presented, and development of new water-based solutions is described that helps extruders avoid environmental, health, safety, and quality problems. Challenges include: application on hot metal surfaces (far above water boiling point); ability to quickly form a thin film with sufficient adhesion (during application); and releasing power (dummy block - billet). The water-based release agent is shown to rely on a synthetic active component that effectively uses chemical solutions.

EP13
Quality Requirements of Aluminum Extrusions for Aerospace Applications
Pradip K. Saha, The Boeing Company, USA
Extrusion quality for critical structural and non-structural aircraft components requires: quality primary raw materials including alloying elements; billet casting, homogenizing and pre-heating systems; and die and tooling design performance, extrusion press control parameters, extrusion variables, and post-extrusion heat treatment process control parameters. Quality systems that control process variables at various extrusion stages are explored. Quality requirements are highlighted for extruded aluminum aerospace products, 2xxx-series/7xxx-series alloys, and solutions are presented to maintain consistent extrusion quality.

EP14
High-Performance Multi-Micro-Port Extruded Tubes
Rolf Beckert, WEFA Inotec GmbH, Germany; Pawel Kazanowski, Hydro Precision Tubing Rockledge; and Joachim Maier, WEFA Cedar Inc., USA
Multi-micro-port extruded tubes (MPEs) are commonly used for production of automotive heat exchangers and HVAC&R products. MPE tubes' performance requirements are continuously increasing, to best serve the automotive industry's lightweight energy-saving vehicles. Extruded profile designs use an increased number of ports, minimizing wall thicknesses; inner enhancements developed and production methods established show high potential for outperforming heat exchanging efficiency. Examples of high-performance MPEs and die designs are compared, and design and performance limits are discussed.

EP15
Achieving Mechanical Properties by Using Liquid Nitrogen and Chilled Water: A Special Device
Sutayan Parida, National Aluminium Products Company SAOG, Oman
Uniform mechanical properties are challenging when heavy profiles have higher wall thickness and low extrusion ratio. The presented solution uses special channels to quench profiles post-die exit; and a better die bearing cooling design uses liquid nitrogen channels. A heat-exchanging box design is described featuring two copper tube coils, and the box has a chilled water flow as a conduction medium. Tube1 passes liquid nitrogen for bearing cooling; Tube2 passes compressed air for profile quenching.

EP16
Maintenance Guidelines to Enhance the Life of Fixed Dummy Blocks
Sutayan Parida, National Aluminium Products Company SAOG, Oman
Fixed dummy block failure modes are analyzed: resistance to return ram movement; aluminum accumulation in backside area; pressure disc seizure to the expandable body; or pressure disc detachment from expandable body. Maintenance guidelines are proposed: outer contour, turned to a new shape, could reestablish flexible properties; ring expansion could be controlled by maintaining a correct gap between pressure disc and ring-body. Accurate gap measurement between disc and body is described, using soap, then clay parts.

EP17
Factors Affecting Flashing (Mushrooming) of an Extrusion Press
Sutayan Parida, National Aluminium Products Company SAOG, Oman
During the extrusion process, when the contact surface area or force is not proper, it creates a path for aluminum to leak out and subsequently force open the contact area, known as flashing, flowering or mushrooming. Factors affecting flashing are described: malfunctioning hydraulic system; insufficient sealing force; dimensional accuracy of die and tooling; uncleaned die rings; correct size dummy; and uneven contact surface area. Five specific control measures for flash-free operation are examined in detail.

EP18
The Die Shop of the 21st Century
Yair Levin, Profal Ltd, Israel
The die shop's future is discussed, focusing on die correction, optimization and automation. Direct die performance feedback updates the design, yielding a 3D file that allows die performance analysis before die production. In the future, steel printing will ensure ideal die geometry, above CNC capabilities. All production data, including past performance and previous die corrections will be automatically collected, entered into the database, and provide ideal recommendations and instructions for die correction and future designs.
**EP49**

*Inline Continuous Surface Inspection for Aluminum Extrusion*

**Björn Biehler,** Ascona, Germany; and **Brad Allen,** INOEX, USA

An inline Continuous Surface Inspection (CSI) development is introduced, consisting of sensor units placed around the profile being extruded, and a control unit. Inline beta test results focus on: defect types detected; prerequisites on the line; and limitations on the technique and profiles that can be monitored. Integrating surface defect found information into the production process with few line modifications is discussed, and opportunities for process improvement are shown, based on integrating the CSI solution.

**EP54**

*Isothermal Extrusion System and Die Cooling with Liquid Nitrogen*

**Agostino Sala,** S. A. I. Srl – Società Automazione Industruale, Italy

An isothermal Extrusion System (IES) improves extruded profile quality and productivity levels by automatically monitoring and managing key variables: exit temperature, extrusion speed, billet temperature, etc. Constant profile temperature and near ideal die values are achieved that reduce extrusion time with better structural quality. For difficult-to-extrude profiles – small-thickness tubular, extrusion time with better structural quality. For temperature, etc. Constant profile temperature extruded profile quality and productivity levels are improved with Liquid Nitrogen.

**EP65**

*Predict Extrusion Scrap for Quoting*

**Emily A. Veltman** and **Justin Clark,** Benteler Automotive, USA

Extruders are challenged when quoting correct scrap amounts for new profiles; quoting errors can reduce profit margins or result in shipping unacceptable material. Extruders depend on experience to accurately estimate front scrap amounts, relying on a die design, which is rarely developed before the quoting process. An alternate estimation method is presented, utilizing profile cross-sectional area to predict required front scrap. This method relies only on profile design, which is available during the quoting phase.

**EP68**

*Digitalization in Extrusion – We are Already on the Road*

**Madhukar C. Pandit** and **David Kaestel,** Kaiserslautern University; and **Christian Schwarz,** 2 HMT Hofer Metall Technik, Germany

The road to digitalization consists of the processes to integrate, exploit and extend existing digital control, communication and data handling systems. The means to exploit the potential of installed systems is proposed, considering practical issues concerning digitalization in extrusion. The means concern basic functions such as simplifying the process of using sensors, the scheme layout and the sequence of operations in control.

**EP71**

*Optimization of Aluminum Extrusions Utilizing Industry 4.0 Strategies*

**Edward Steihl,** Steihl Consulting, Norway

An Industry 4.0 case study describes how IT concepts are integrated and put to the test of optimizing aluminum extrusion lines. BIG DATA concepts are highlighted, e.g., raw material chemical composition as an indicator of material extrudability. As this indicator changes, process parameters are adjusted in order to optimize extrusion in real time. BIG DATA benefits are discussed, such as centralizing all information to help process managers identify relationships between data (patterns) in seconds instead of weeks.

**EP74**

*Lateral Angular Co-Extrusion of Aluminum and Steel for the Manufacturing of Coaxial Composite Profiles*

**Susanne E. Thürer,** Johanna Uhe, **Florian P. Schäcke,** Norman Heimes, **Florian Nürnberg**, Bernd-Arno Behrens and **Christian Kloge,** Leibniz Universität Hannover, Germany

Hybrid components manufactured via Tailored Forming technology offer great potential for lightweight constructions. Co-extrusion of aluminum-steel semi-finished products is described. A Tailored Forming process chain was developed to produce coaxial composite profiles featuring an aluminum alloy EN AW-6082 exterior layer and a case-hardening steel 20MnCr5 interior rod or tube. The modular tool concept allows hybrid hollow sections with different reinforcement contents to be produced by varying the extrusion ratio on a 10MN industrial extrusion press.

**EP77**

*An Experimental Verification of Thermite Reactions during Extrusion of Aluminum Alloys*

**Oddvin Reiso,** Hilde-Gunn Øverlie, **Ulf H. Tundal,** Jostein Røyset and **Terje Iveland,** Hydro Aluminium, Norway

To help find direct evidence of a thermite reaction after extruding several billets over a die bearing, and obtain information on the reaction's initiation phase, experiments are performed to simulate the extrusion process and determine what happens between die bearing and aluminum during extrusion. Experiments use a Gleeble machine as a physical simulator of processes, such as aluminum extrusion. Results are presented, showing that thermite reactions may take place during extrusion of aluminum alloys.

**EP83**

*Improvement of Caustic Bath Performance through Optimized Composition and Process Parameters*

**Pawel Kazanowski** and **Jonah Melegrito,** Hydro Precision Tubing, USA

Various aluminum alloys are examined to determine the alloying elements' effect on die-aluminum dissolution. Alloying elements' effects on bath composition and dies after dissolution are investigated. Utilizing bench-scale testing models and chemical analytics, a model for industrial scaleup uses inline testing methods to forecast bath chemistry and effectiveness. This work aims to better understand caustic performance as a function of bath composition and controllable environment parameters and apply this to cost savings.

**EP84**

*Maximizing Material Savings through Precision Measurement - Where is my Weight?*

**Brad Allen,** INOEX; and **Bobby Parson,** Bonnell Aluminum, Div. Futura Industries, USA

Understanding aluminum distribution within an extrusion profile is financially critical. With an accurate optical measurement system capturing the complete profile, aluminum distribution throughout an extruded profile is visible. The Promex Expert System captures profile weight measurements and detailed wall thickness measurements. These results clearly identify tool performance, wear patterns and profile areas where excess material can be actively saved. The value of this measurement capability and methodology is highlighted for productivity improvement, and financial gains.

**EP88**

*Multistep Aging of Extruded 6xxx-Series Alloys*

**Paul Rometsch** and **Nick C. Parson,** Rio Tinto Aluminum, Canada; and **Marco J. Starink,** University of Southampton, UK

Research is presented where several 6xxx-series alloys were extruded in a well-controlled manner and then subjected to various aging treatments, including single-step aging with different heating rates and various multistep aging treatments aiming at producing different hardening precipitate characteristics. Aging curves were constructed based on hardness, strength, ductility, and electrical conductivity measurements. Development of an aging model is described to enable the prediction of yield strength as a function of temperature-time history for multistep aging.

**EP98**

*How Controlled Nitriding and Ferritic Nitrocarburizing Improve Productivity, Quality, and Bottom Line*

**Jack Kaluczy,** Nitrex Metal Inc., Canada

An overview of nitriding and ferritic nitrocarburizing technology and mechanisms is presented. Three aluminum extrusion die nitriding approaches are evaluated, analyzing actual specifications and results. Classical controlled nitriding is compared to ferritic nitrocarburizing, and to a different nitriding approach; these process types have similar case depth, yet provide specific, unique benefits. Nitriding and ferritic nitrocarburizing essentials and operational strategies are summarized to increase die life, decrease tooling cost, and limit unplanned maintenance and die corrections.
EP107  Can We Eliminate Manual Lubrication in Aluminum Extrusion?  
James E. Dyka, AMCOL Corporation, USA  
Manually lubricating extrusion press tools to reduce/eliminate aluminum buildup and sticking was common. Today's highly-automated aluminum extrusion presses cannot easily undergo manual lubrication. Many believe that manual lubrication is required; however, this age-old practice is random and often unsafe. The process and machine parameters affecting press tool lubrication requirements are presented. Best practices are discussed relating to automatic lubrication, in order to completely eliminate manual lubrication of dummy blocks, butt sheets, and container/die pressure seals.

EP114  The Effect of Water Temperature on Quench Rates  
David Jenista, Granco Clark, Inc.; and Jeffrey Victor, Hydro Extrusion North America, USA  
Low- and medium-velocity quenches have two heat transfer modes over common extrusion temperatures, so simple entry- and exit- temperature measurements don't allow separate performance evaluations. High-impact quenches operate in nucleate boiling mode across the entire extrusion temperature range. Instrumented lab testing measures water temperature's impact on quench rate, allowing heat transfer coefficient calculations in both nucleate boiling and film boiling. This provides operational and process control information for utilizing spray quench systems that operate in either/both heat transfer regimes.

EP120  Implications and Influence of Extrusion Process Parameters on High-Precision Extrusion  
Mushqaq Mohammed, Suresh Annadurai and Mansoor Mohammed, Gulf Extrusions, LLC, UAE  
Research demonstrates that certain production process parameter constraints act as hidden failures, highlighting ways to overcome them. Failure count, from profile design to die design, affects the extrusion process. Coordinating design modifications with system designers makes intricate profiles simpler to produce with controlled process parameters, improving performance and die life. Continuous improvement of process parameters and sharing data with the die shop and lab is shown to overcome constraints and yield reliable, high-quality precision extrusions.

EP128  Understanding the Effect of Quench Delay and Alloy Chemistry on Various 6xxx-Series Alloy Systems  
David Shoemaker and Robert A. Matuska, Kaiser Aluminum, USA  
The extrusion industry's ability to directly link the extrusion operation to the quench enables the industry to supply various extruded products at an otherwise unachievable cost, but risks quench interruptions that can reduce the extrusion's localized strength, reducing performance consistency. A better understanding of two key inputs to these quench interruptions (i.e., quench delay time and alloy chemistry) is presented with the goal of making the process more robust, and therefore less sensitive to quench delays.

EP129  Novel Measuring System for Process and Quality Control in Aluminum Extrusion Plants  
Sven Gall and Felix Gensch, INGWERK GmbH; Vidal Sanabria, Martin Jaehnke and Soeren Mueller, Extrusion R & D Center, TU Berlin, Germany  
The MAUs measuring and analyzing system is presented to enable complete digital documentation of extruded products over the entire process chain. Using commercially available measurement instrumentation and sensor components the system environment, extrusion plant with heterogenous machinery, is time- and cost-efficiently connected, and industry 4.0 technology is implemented/applied. MAUs identifies disruptive factors and provides input requirements for actual and subsequent process control, based on analyzing real-time measurements, databases and software-apps containing metal-physical and technical equations.

EP137  Comparing Hot-Work Tool Steels Performances for Extrusion Dies  
Barbara Reggiani, University of Modena and Reggio Emilia; Lorenzo Donati and Luca Tomasani, University of Bologna, Italy; and Mehdil Ben Tahar, Constellium C-TEC, France  
Three hot-work tool steels commonly used to manufacture extrusion dies are compared in terms of dynamic performances under the creep-fatigue regime. An experimental set-up tested the steels using specimens that replicate the porthole die mandrel. The H11, H13 and TQ1 are compared at different temperature and load levels, evaluating the specimen deflection at a fixed testing time or number of loading cycles to failure. An analytical model predicts the specimen lifetime at further load/temperature levels.

EP139  Why Die Fails in Extrusion  
Hanif Hamzah, Press Metal Berhad, Malaysia  
To achieve greater die stability, a die index is created for troubleshooting problems such as die lines, surface pickups, and dimensional and shape changes. The presented die index identifies areas such as die life, number of nitriding processes, bearing condition in the dies, and die design adopted, and links the index to press process factors. The die index is shown to enable die correctors to anticipate die issues with higher predictability to enhance die performance.

EP140  A Review Of Thin-Wall Extrusions  
Hanif Hamzah, Press Metal Berhad, Malaysia  
The demand for thin-wall extrusions increases with the pressure for extruders to make dies with a lower output from the presses. However, the demands for thin-wall extrusions can be handled through creative die designs that allow the extrusion ratio to be controlled using a specific extrusion pressure from the presses. New techniques in the die design approach for thin-wall extrusions are discussed, including the die design's minimum allowable wall thickness that is required to extrude.

EP141  Liquid Nitrogen Experience in Using AA6060, AA6063 & AA6005A  
Hanif Hamzah, Press Metal Berhad, Malaysia  
Liquid nitrogen has been widely used and accepted as a method to increase productivity and to improve the extrudate surface finish before anodizing, painting or as delivered from the mill. The three aluminum alloys namely used for production are discussed: AA6060, AA6063 and AA6005A. Productivity gained and improvement in the recovery using liquid nitrogen are discussed in detail, highlighting the benefits. These three alloys used in production are reviewed with or without gaseous nitrogen extrusions.

EP144  Back-to-Front Variations in a Typical Extruded Material AA6063  
Abu Bakar Sugianto, Press Metal Berhad, Malaysia  
A typical front-to-back variation always occurred in the open back channels or large wide extrusions typically exceeding the billet diameters. More extruders are using the advantage of spreader die designs to extrude a large profile using a smaller container size, but face large variations in the extruded material. The approach to die design is discussed in detail, with a close look at the die stack design, flow control plate and pocket recess control die plate.
TH: Extrusion/Die – Theoretical Track

TH8
Extrusion Productivity - Ram Speed/Container/Die
Paul H. Robbins and Yahya Mahmooodkhani, Castool Tooling Systems; Chris Jowett, Rio Tinto Aluminium, Canada; and Richard Dickson, Hydro Aluminium, USA
Predicting maximum ram speed is proposed, based on current billet, available press load and tooling, particularly container design/materials and die parameters. Correct container design and material, container set and billet temperatures are suggested to improve productivity. The impact of billet temperature, container set temperature, container temperature taper and container steel conductivity is examined. Studying what happens inside the container before metal reaches the die, and studying profile geometry, extrusion ratio and die design are presented.

TH17
Microstructural Changes in Al-Mg-Si Alloys through the Extrusion Process Chain
Eva A. Martsell, Takeshi Saito, Endre A. Hennum, Oddvin Reiso, Ulf H. Tundal and Jostein Rayset, Hydro Aluminium R&D; Calin D. Marioara, SINTEF Materials and Nanotechnology; and Randi Holmestad, Norwegian University of Science and Technology, NTNU, Norway
Processing steps, from casting to artificial aging, evoke significant changes to the microstructure in Al-Mg-Si alloys. Macroscopic properties of these age-hardening alloys are highly dependent on how the microstructure develops throughout the process. Microstructural phases are outlined during casting, homogenization, extrusion, natural and artificial aging. The hardening nano-sized precipitate needles that form during artificial aging are emphasized, disclosing how features like number density and phase structures are altered by changing chemical composition or thermal treatment.

TH19
Interactive Simulations of Strength, Grain Structure and Surface Appearance of 6xxx-Series Extruded Profiles
Geir Øyen, Ole R. Myhr and Øystein Bauger, Hydro Aluminium R&D; Rune Østhus and Anders Nesse, SINTEF Manufacturing; and Trond Furu, Norsk Hydro, Norway
Complex, computer-intensive models’ transformation into real-time models with user-friendly graphical interfaces is demonstrated. Process models presented follow the production chain, calculating final properties like yield strength, grain structure, surface appearance, and corrosion susceptibility. Carefully planned real-time full-scale simulations cover variations in alloy composition, extrusion parameters and heat treatment schedules. Computer-intensive simulation results are consolidated into meta models that respond in milliseconds to user inputs. Results are presented for properties like yield strength, grain structure and gloss.

TH22
Modeling of Recrystallization, Quench Sensitivity and Surface Tearing of 6xxx-Series Alloys
Ole R. Myhr, Hydro Aluminium R&D; Rune Østhus, SINTEF Manufacturing; Anders Nesse, Norwegian University of Science and Technology; and Trond Furu, Norsk Hydro, Norway; and Kai Zhang, Hydro Extruded Solutions, Sweden
It is challenging to extrude 6xxx-series aluminum alloy at high speed that yields non-recrystallized grain structure, high strength, and low surface tearing susceptibility. This difficult balance between conflicting requirements is addressed by process chain simulations using physical-based models. Models are coupled and run automatically in iterations using an optimization procedure. Based on simulation results, process diagrams are constructed showing combinations where the above-mentioned requirements are fulfilled. Diagrams are validated for small- and full-scale extrusion experiments.

TH29
Numerical Simulation of Continuous Rotary Extrusion of Flat Sections of AA6061
Nijenthan Rajendran and Wojciech Z. Misiolk, Lehigh University, USA; Monika Mitka and Marzena Lech-Grega, Institute for Non-Ferrous Metals, Poland
Tooling geometry, mainly two-step deformation process from rod to feeder plate, into the main deformation chamber and to the die orifice is optimized for AA6061 flat sections. Numerical simulation and optimization are performed using commercial DEFORM™ software; flow stress data was taken from literature. Effects of different tooling geometry and how the feeder plate’s presence affects metal flow inside the extrusion chamber are compared in continuous rotary extrusion (CRE, aka Conform™). Experimental verification of numerical predictions is provided.

TH32
The Effect of Press Quench Rate on Grain Boundary Precipitation and Fracture of 6xxx-Series Alloys
Veeraj Poole, Mojtaba Mansouri Arani and Zhijun Zhang, The University of British Columbia; and Nick C. Parson, Rio Tinto Aluminium, Canada
Precipitation of Mg-Si phases on grain boundary and the associated precipitate-free zone is examined. High-resolution digital image correlation characterizes plastic strain localization near the grain boundary and its effect on grain boundary fracture. The extent of plastic strain localization in the precipitate-free zone is quantified for different quench rates, dispersed contents and precipitation tempepers. Results are discussed in terms of optimizing the compromise between reducing quench rate to avoid distortion and strength and ductility degradation.

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TH45
Temperature Evolution during Direct Extrusion of Magnesium and its Alloys AZ31 and AZ80
Jonas Isakovic, Jan Bohlen and Karl Ulrich Kainer, Helmholtz-Zentrum Geesthacht; and Noomane Ben Khalifa, Leuphana University of Lüneburg, Germany
A die with integrated thermocouples is designed to enable measuring developing temperature during hot extrusion of magnesium and alloys AZ31 and AZ80. Process parameters are varied; FEM simulations enable temperature distribution analysis in the forming zone. To correlate temperature distribution to the profile’s achieved microstructure, samples are taken from extruded round bars that were directly assigned to measured and simulated process temperatures. Microstructure behavior of magnesium materials on heat development is discussed.

TH50
The Effect of Bridge Geometry during Porthole Extrusion on the Mechanical Properties of 6xxx-Series Alloys
Yu Wang and Mary A. Wells, University of Waterloo; Yahya Mahmoodkhani, Castool Tooling Systems; Andrew Zang and Warren Poole, The University of British Columbia; and Nick C. Parson, Rio Tinto Aluminium, Canada; and Mei Li, Ford Motor Company, USA
Three bridge geometries (flat, streamlined and no bridge) are used to produce an AA6082 extruded strip. Experiments show that microstructure and texture along seam welds are dependent on bridge geometries; the streamlined bridge promotes a deformation texture; whereas, the flat bridge exhibits a recrystallization texture. Extrusion is simulated using DEFORM™, indicating that bridge geometry affects temperature and strain history at the weld line. Tensile testing on porthole extruded samples across the weld seam is presented.

TH55
Comprehensive Extrusion Technology Development: Process Simulation Integrated with Die Design and Product Quality Control
Nikolay Biba, MICAS Simulations Ltd., UK; Tom Ellinghausen, Forge Technology, Inc., USA; Ivan Kniiazkin and Sergey Stebunov, QuintorForm Ltd., Russian Federation
Program QEExDD creates die geometry that undergoes verification/optimization by QForm simulation of material flow, coupled with elastic tool deformation and transient temperature evolution during extrusion, detecting and correcting defects early in die development. The simulation estimates seam weld quality, charge weld length, and predicts possible die deformation and expected tool life. Profiles obtained from a simulation-verified die design are subject to microstructure and heat treatment simulation, where final profile shape and mechanical properties are estimated.

TH61
Development of a Porthole Die with Mechanism for Extrusion of Hollow Profiles with Axial Variable Wall Thickness
Maik Negendank, Vidal Sanabria and Soeren Mueller, Extrusion R&D Center, TU Berlin, Germany
Extrusion dies offering more flexibility regarding achievable profile cross sections allow profiles manufactured with load-adapted cross sections. Such tailored components can reduce fuel consumption and emissions for combustion engine vehicles, and extend range of electric drive vehicles. Development of a porthole die is presented, allowing extrusion of aluminum hollow profiles with axially variable wall thicknesses. FEM-simulations are applied to investigate die design feasibility, force requirements for wall thickness variation, as well as die stress analysis.

TH72
The Equal Channel Angular Reverse Pressing Process and Its Influence on the Microstructure of Pure Magnesium and AZ31
Florian P. Schäfke, Marcus Engelhardt, Norbert Grittner, Susanne E. Thürer and Christian Kloze, Leibniz Universität Hannover, Institut für Werkstoffkunde, Germany
Using Equal Channel Angular Reverse Pressing (ECARP), material is pressed back and forth by two alternating, perpendicular extrusion presses, allowing billet to be efficiently deformed without its removal from the press channel. Alternating pressing direction's influence on Mg and AZ31 microstructures is shown. Material's local mechanical properties are analyzed via micro-tensile specimens. ECARP enables magnesium microstructure modification by shear stress in a more economic timeframe than the ECAP process, allowing simplified ultrafine-grained (UFG) aluminum production.

TH75
Investigation of Profile Exit Temperature during Indirect Extrusion of AA6005A
Vidal Sanabria and Sören Müller, Extrusion R & D Center, TU Berlin; and Dong-zhi Sun, Fraunhofer-Institut für Werkstoffmechanik IWM, Germany
The presented study involves experimental determination of profile temperature evolution during direct and indirect extrusion of aluminum alloy 6005A, and analytical and numerical profile temperatures are estimated via mathematical formulations and FE-analysis. Extrusion trials were conducted with an BMN press at different ram speeds, initial billet temperatures and extrusion ratios; press load and temperature inside the bearing channel were simultaneously measured. Experimental results are discussed and compared with analytical and numerical calculations.

THB1
Production of Sheets by Hot Extrusion of Aluminum Chips
André Schulze, Christoph Dahmke and A. Erman Tekkaya, Institute of Forming Technology and Lightweight Components, TU Dortmund, Germany
Solid-state recycling is promising for overcoming material loss during remelting. Aluminum chips, processed by direct hot extrusion into semi-finished or near-net shape products, require relatively low energy. A new process chain for sheet production is presented, using AA6060 chips. Chips are consolidated at room temperature, hot extruded to an open profile and expanded by a subsequent rolling process. Sheets examined by tensile tests and microstructural investigations are compared to sheets based on as-cast material.

THB2
Influence of Extrusion Process Parameters on Microstructure and Mechanical Properties of Aluminum Profiles
Dong-Zhi Sun, Andrea Ockewitz and Florence Andrieux, Fraunhofer Institute für Werkstoffmechanik IWM; and Soeren Mueller, Extrusion R & D Center, TU Berlin, Germany
Process parameters' influence on microstructure, mechanical properties and component behavior is determined for optimized extrusion process. AA6005A L- and U-profiles are extruded at three temperatures under two velocities using forward and backward extrusion methods. Grain size distributions are measured with EBSD; specimen tests determine flow stresses and fracture strains, and hardness measurements are performed. Profiles are tested under static compression loading to determine inhomogeneous microstructure's influence on component behavior. Extrusion simulations with HyperXtrude® are performed.

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TH104
Numerical Simulation of Thermomechanical Streaking of AA6060 Extrusions
Steven Babaniaris and Matthew R. Barnett, Institute for Frontier Materials - Deakin University; and Aiden Beer, School of Engineering - Deakin University, Australia
A specialized die with internal geometry designed to produce regional thermomechanical variations is used to study thermomechanical streaks. Extrusion is conducted at various ram speeds; profiles are subsequently given a commercial anodization pre-treatment process, producing streaks. Numerical simulations are performed using HyperXtrude®, to study profile thermomechanical evolution during extrusion. Extrusion tooling, workpiece geometry and process parameters are modeled to match the experimental extrusions. Exit temperatures and extrusion loads are compared for simulated and experimental extrusion.

TH105
The Effect of Scandium and Zirconium on the Strength-to-Extrudability Trade-Off in Al-Mg-Si Alloys
Thomas Dorin, Steven Babaniaris and Mahendra Ramajayam, Institute for Frontier Materials - Deakin University; and Timothy J. Langan, Clean TeQ Ltd., Australia
The impact of added Scandium (Sc) and Zirconium (Zr) on Al-Mg-Si alloy extrudability is explored. Extrudability depends on; pressure required to deform the material (determined by flow stress); and temperature at which hot cracking initiates. An analytical model is utilized to estimate and compare the extrusion limit window for a model Al-Mg-Si alloy with/without added Sc and Zr. Results of adding Sc and Zr are reviewed regarding final product yield strength and impact on extrudability.

TH112
Scrap Prediction in Direct Extrusion by Means of Finite Element Analysis
Tomasmo Pinter, Almax Mori Srl; Barbara Reggiani and Riccardo Pelaccia, University of Modena and Reggio Emilia – DISIM; and Lorenzo Donati, Marco Negozio and Luca Tomesani, University of Bologna, Italy
Finite Element Analysis (FEA) offers a big opportunity to extruders: to estimate accurately not only charge weld extension, but also billet skin contamination. The dynamics of back-end and front-end defects in the direct extrusion of a solid profile are examined through the use of FEA. Numerical results are compared with industrial experiments, with the aim to understand the effects of the chosen boundary conditions on the accuracy of the predictions.

TH117
Introduction of Intrinsic Hot Aluminum-Polymer Extrusion
Johannes Gebhard, Oliver Hering and A. Erman Tekkaya, Institute of Forming Technology and Lightweight Components, TU Dortmund; Fabian Günther and Markus Stomme, Plastics Technology, TU Dortmund, Germany
Aluminum-polymer window parts provide aluminum’s stiffness/environmental resistance and polymer’s thermal/acoustic insulation. Aluminum and polymer extrusion process windows vary significantly regarding pressure and temperature. A new intrinsic hot co-extrusion process combines aluminum hot extrusion and polymer extrusion, injecting polymer melt into aluminum’s material flow at a modified porthole die’s weld chamber. Co-extrusion performance is reviewed for the EN AW-6060 and polyethersulfone (PESU) material combination, and continuous polymer core/aluminum shell profiles are produced and examined regarding their bonding.

TH118
Modeling of Nitrogen Cooling in the Extrusion of Aluminum Alloys
Riccardo Pelaccia and Barbara Reggiani, University of Modena and Reggio Emilia; Lorenzo Donati and Luca Tomesani, University of Bologna, Italy
Effectively reducing exit temperature during die cooling is achieved using liquid nitrogen, however, die optimization parameters must include number/position of die inlets/outlets, and nitrogen channel shape/dimension. A nitrogen-cooled extrusion process simulation method is presented: a simplified 1D channel model is integrated in a 3D FE extrusion process model. Two experimental campaigns monitoring nitrogen cooling efficiency in industrial plants are simulated; results are compared in terms of die and profile temperatures and extrusion load in cooled/uncooled conditioned.

TH119
Synthesis of Ultra-Conductive Aluminum Alloys with Graphite Nanoparticles by Hot Extrusion Alloying
Aditya K. Nittala and Frank Kraft, Ohio University; Keerti S. Kappagantula, Pacific Northwest National Lab; and Alex Poznak, Hydro Extrusion USA, LLC, USA
This study examines a novel solid-phase processing technique, hot extrusion alloying (HEA) process, which synthesizes aluminum/graphite nano-alloys using commercially available AA100 and graphite nanoparticles (GNP) as precursors. GNP content’s effects on electrical and mechanical properties are evaluated. Results are presented, showing improvements to the aluminum substrate’s electrical conductivity, current density, ultimate tensile strength and yield strength, compared to control sample with no GNP additives. Al/GNP nano-alloy’s ductility is shown to decrease with increasing GNP content.

TH121
Improvement of Wear Resistance and Friction on Extrusion Dies Combining TriboWearTester and Finite Element Analysis
Joachim Maier, WEFA Cedar Inc., USA; and Verena Merklinger, HTWG Konstanz, Germany
Predicting wear on die bearings is difficult; improved trial set-up of the TriboWearTester and Finite Element Analysis (FEA) post-calculation have broadened the database and understanding of corresponding phenomena. Wear and friction trial results are discussed, and optimized programming is accompanied by parameter studies. TriboWearTest results are compared with other friction testing equipment. Aluminum and some heavy metal alloys are tested. Results are presented regarding improvements in the FEA friction model, to better predict die filling and flow.

TH122
Die Corrections & Die Design Enhancement Using Profile Simulation in Extrusion Industry
Suresh Annadurai, Mustaq Mohammed and Imran Mulla, Gulf Extrusions, LLC, UAE
The die correction process studies die design and balances metal flow to achieve required geometry during extrusion. Predicting which metal flow correction method gives the best results is difficult, in order to achieve shape, higher productivity and recovery. Dies are often corrected based on trial-and-error, delaying on-time delivery and increasing operational cost. Profile simulation is presented, which is introduced prior to correcting dies and is used prior to die manufacturing, thus reducing trials, die failures and operation cost.

TH123
A Review of Finite Element Method Codes Accuracy for Reliable Extrusion Process Analysis: ICEB ExtrusionBenchmark Conference
Lorenzo Donati and Luca Tomesani, University of Bologna; and Barbara Reggiani, University of Modena and Reggio Emilia, Italy
An ICEB benchmark conference overview highlights trial results comparing different Finite Element Method (FEM) codes’ accuracy in predicting critical process outputs. Experiments check the FEM codes’ ability to predict a particular phenomenon. Profile lengths, process load, die deflections, die and profile temperatures were benchmarking parameters for FEM comparison. Post-trials, seam and charge weld locations are metallurgically analyzed and used as benchmarking parameters. Computational times, simulation set-up times and required hardware information are compared, and output parameters are discussed.
TH165
Analysis of the Extrusion Pressure Curve to Monitor and Stabilize the Alloy Extrusion Process
Giacomo Mainetti, Marcello Aiello, Massimo Bertolotti, Enea Mainetti, and Teodoro Mainetti, ATE Uno Informatica, Italy; and Bernard Bourqui, Nicola Fietti and Olivier Rey, M-TD SA, Switzerland
Tracking and analyzing the extrusion pressure curve enables calculation of two Key Performance Indicators (KPIs): mean flow stress, Kf, and shape efficiency factor, Phi. Kf yields alloy quality and billet temperature information to help stabilize the extrusion process with constant casting and alloy quality control. From Phi, die extrudability information allows comparison of different shapes and die layouts. Monitoring methodology is described, extracting examples and processing real data to validate Kf and Phi evaluation algorithms.

TH166
Bearing Profile and Shape Optimization of an Industrial Hollow Profile Die
Narendra Singh and R. Mayavaram, Altair Engineering, Inc.; J. Skinner, Thumb Tool & Engineering, USA; and Garima Singh, Altair Engineering India Pvt., India
Optimization techniques combine to improve die design and process. Mandrel and die shape are optimized, followed by bearing profile optimization. Material flow and heat transfer in an extrusion die are analyzed using finite element modeling. Fluid flow and optimization problems are solved to produce a die design that satisfies constraints and meets objectives. After die shape optimization, automatic bearing profile optimization corrects the bearing profile to modify bearing region friction and produce balanced material flow.

TH168
Experimental and Computational Analysis of Hybrid Additively Manufactured Extrusion Dies with Cooling Channels Integration
Chiara Bertoli and Pavel Hora, ETH Zurich; Institute of Virtual Manufacturing; and David Hora, Inspire AG, Switzerland
To achieve homogeneous cooling rates and to cool tools where most needed, a hybrid, partially selective laser-melted die is proposed. Position and shape of cooling channels implemented into the additively-manufactured insert made of 1,2709 tool steel is analyzed based on a computational design exploration. Hybrid die tests, with/without cooling are discussed. Finite Element Method (FEM) extrusion process simulations are used with extrusion trial results to inversely analyze/describe cooling process heat transfer characteristics for a given cooling fluid.

TH169
Modeling of Extrusion Welding Conditions for Aluminum Alloys
Dariusz Lesniak and Pawel Gromek, AGH University of Science and Technology, Poland
Simulated conditions occurring in a porthole die welding chamber are presented. Weldability tests compare 7xxx-series and 6xxx-series alloys in a range of welding temperatures/pressures. Microstructure and seam weld strength are examined. Fractographic research of welding fractures is conducted. Welding conditions for hard deformable AlZnMg(Cu) alloys are compared to 6xxx-series alloys. The parameter describing weldability is defined as the stress necessary for welding to the yield stress ratio, and determined for analyzed alloys as temperature dependent.

TH171
Forecasting Seam Weld Quality during Extrusion of Aluminum Hollow Profiles through Numerical and Experimental Approaches
Michele Croso and Pavel Hora, ETH Zurich; Institute of Virtual Manufacturing; and David Hora, Inspire AG, Switzerland
Ensuring seam weld quality along the hollow extruded profile’s entire length requires extrudate investigation at intervals. Numerical methods are a valid alternative to estimate weld quality during die design. Seam welds analysis is described in detail, integrated in the FE-code PF-Extrude. Quality criteria are integrated; Q-criterion (Plata and Piwnik), K-criterion (Donati and Tomesani) and J-criterion (Yu et al.) are considered and compared. Experiments with various extrusion dies calibrate different criteria and investigate critical conditions required for successful bonding.

MI: Management Issues Track

MI1
ETs: Leading Technology for 50 Years; Harvesting Valuable Information from the First ET in 1969
Craig Werner, Kaiser Aluminium, USA
ET, the premier global aluminium extrusion industry technical event since 1969, offers key knowledge and research from prior ET conferences that remains relevant today. Maurice Roberts and organizers established ET to drive disseminate key industry information. Significant worldwide contributions and attendance speak to the ongoing relevance and importance of ET. Knowledge gained from 50 years of published ET papers is demonstrated. Today’s industry teams are encouraged to reference/use prior ET knowledge, while anticipating future ETs for inspiration and improvements.

M13
Automotive Consumption of Lightweight Materials and the Impact of Electric Vehicles
Roberto Boeker, Alumag Automotive, USA
The arrival of electric cars: When? Country and OEN expectations BEV 15-20% share by 2025; pros and cons; key consumer concerns; cast aluminum consumption over time; top automotive alloy foundries; and worldwide electric vehicles and lightweight materials consumption are presented. Sample applications and automotive aluminum consumption within BW/Frame applications (2010 – 2020) are discussed. Automotive CFRP consumption within BW applications, current use/outlook and BMW supply chain sample applications are reviewed. What comes, what goes and what stays.

M128
To Cast or Not to Cast, a Review of Recent Industry Impacts to Billet Manufacturing
Jim Madgett, Almay USA Inc., USA
Extruders face well-known concerns when procuring billet. Recent U.S. aluminum import tariffs and global disruptions in recyclable aluminum flow significantly complicate matters. In-house billet casting addresses some issues, but owning/operating a casting center brings challenges: capital costs; lack of billet casting technical expertise; raw material costs and availability vs. casting capacity; safety (molten metal); and environmental issues (water/air), dirty vs. clean scrap. Pros and cons are investigated, highlighting conclusions on whether or not to self-cast billet.

M139
Recycling Post-Consumer Scrap into High-Quality Extrusion Ingots
Stig Tjøetta, Hydro Aluminium, Norway; and Ludovic Dardinier, Hydro Aluminium Clervaux, Luxembourg
Advances in mechanical sorting of shredded extrusion scrap and casethouse processes enable high-quality extrusion ingot production consisting 75-100% post-consumer scrap. Technologies are discussed for the scrap sorting and casthouse melting processes needed to produce extrusion ingots with high post-consumer scrap content, without compromising ingot quality. Results in melt quality and chemical composition capabilities are presented. Unprecedented low carbon footprint obtained by using post-consumer scrap is discussed, including examples of recycling used for competitive advantage.
MI43
A Digital Twin for Production of Aluminum Extrusions
Trond Furu, Norsk Hydro ASA; Rune Østhus, SINTEF Manufacturing; and Ole Runar Myhr, Hydro Aluminium, Norway
A specially-designed digital twin for dedicated aluminum extrusion production is presented. The digital twin, used for applications including adaptive control and optimization, quickly assesses production data to detect if corrections are needed in subsequent processes; if so, the digital twin calculates modified process parameters to ensure that final extrusion properties are within pre-defined tolerances. Digital twin use in planning/pre-production is illustrated. Digital twin predictions are validated through comparison with full-scale trials at an extrusion press.

MI52
Die Ordering Documentation and Characteristics of a Good Die Supplier
Sutanay Parida, National Aluminium Products Company SAOG, Oman
Standard die ordering documentation practice is presented. Basic criteria defining essentials of a die manufacturer, design endorsement, drawing standard features, etc., eliminates error and saves time. Added value for die suppliers, including after sales service, compression support, redesign and repair of broken dies is reviewed. Standard design drawings format for manufacturers and die ordering drawing is presented, highlighting important details and trial feedback for making backup dies with absolutely zero trials and optimal die life.

MI53
LME Fluctuation Impact on Profit and Loss of Business
Ihab Mouallem and Sutanay Parida, National Aluminium Products Company SAOG, Oman
LME fluctuation tremendously impacts aluminum extrusion markets; thus, inventory cost and market selling price directly impact Profit and Loss (P&L) figures. Market behavior, customer interaction and cash flow monitoring become vital. Hedging billets and bulk ordering mitigates risk. Price fixation agreement with finite delivery tonnage per month creates a confident workplace. Dies share major process cost; correctly calculating backup-die quantities, timely ordering and full-life utilization are critical to die management. P&L analysis vs. LME fluctuation is presented.

MI56
Predictive Maintenance Strategies Using Machine Learning
Daniel Meier, Tobias Frick and David Beinder, MCE, Liechtenstein
Expected benefits of applying different machine learning techniques are evaluated, highlighting correlations between sensor and operations data to predict equipment failure ahead of occurrence for aluminum extrusion process. Techniques are developed for downtime prediction on CNC machines, then adapted and applied to extrusion operations. While models have limitations, they provide tangible benefits at this early stage and are a platform for future deployment. A roadmap is presented for further improved system accuracy and future potential.

MI87
Maintaining Traceability of Extruded Lots
John Stenger, Foy Inc., USA
Increased automotive and aerospace applications make complete lot traceability critical for all aluminum extruders. Extrusion management systems must track each delivered bundle back through all billet casts, production machines, shifts/crews, and tests, producing detailed certification reports for customer/internal use. The system must allow splitting lots for any operation that changes the extrusion’s physical or chemical properties. The EPICS Manufacturing Execution System is presented, providing full traceability for made-to-order jobs and for material from stock inventory.

MI89
Attracting and Developing Talent for the Aluminum Extrusion Industry
Duncan Croudies, Alexandria Industries; and Lynn Brown, Long Point Associates, USA
To attract and develop talent, a process for the aluminum extrusion industry to engage multiple education levels is described beyond colleges and universities, to community colleges, high schools and middle schools. Highlights include: purpose of intervention at each education level; roles played by educators and industry; specific programs implemented by extruders at various educational levels; and process used to take first steps. Potential for educator-industry partnerships to open up attractive career options for students is proposed.

M195
The Benefits of Bar Code, QR Code and RFID Scanning in Managing Extrusion Production Information
Scott L. Wilson, Foy Inc., USA
Using bar code or RFID scanners virtually eliminates data input errors and significantly increases user efficiency. Training new users on a scanner-enabled software system is easier. An effective extrusion management system allows scanner input at key production steps such as: press production, downstream production, packing production, shipping, pull from stock and physical inventory. EPICS software is presented as an example of a Manufacturing Execution System that provides scanner capability at each of these key steps.
M1136
**Quality Management Plays a Central Role in Aluminum Extrusion Industry 4.0**

Michael Hoenen, ISRA Parsytec GmbH, Germany

Quality Management Systems (QMS) interact with Enterprise software and other systems, defining customer-specific quality for each production step. During aluminum extrusion production, QMS determines quality based on surface inspection results, gauge and test data, triggering material transport/stoppage, and sorting/removing defective bars/parts. A key factor in Smart Factories, QMS can communicate modified process parameters to manufacturing execution systems, or negotiate re-routing/reassignment to another order with APS. QMS is presented as one cornerstone of Metals Industry 4.0.

M1149
**Journey of an Architectural Extrusion to an Automotive Extrusion Plant**

Mansoor Mohammed, Mushtaq Mohammed and Arif Husain, Gulf Extrusions, LLC, UAE

This case study showcases an extrusion plant’s journey from producing architectural extrusions, to producing automotive extrusions; challenging, due to low rejection rates and superior material quality specifications. This extruder achieved TS-16949 certification, showing effective deployment of automotive quality requirements. Automotive supply excellence is benchmarked at rejections (ppm) percentage and customer quality satisfaction. This presentation describes an effective extrusion plant transformation (preparations, training, 5S, control plants, PFMEAs and SPCCs), becoming a capable, sustaining automotive extrusion supplier.

M1156
**How the Aluminum Industry can Help Customers Reduce their CO₂ Emissions and Environmental Imprint with 3D-iExtrusion, Optimization and Integration**

Mark J. Krogh, Relieved AB, Sweden

3D-iExtrusion enables energy-efficient 3D production in existing extrusion lines. Thermally and/or structurally optimized 3D-iExtruded profiles demonstrate reduced energy leakage 30% in window/facade systems; reduced weight and material use 20-40% in automotive parts/structures; and reduced battery box weight/cost for Lithium-ion packs. 3D-iExtruded profiles integrate several functions, making affordable, practical recycle-friendly products that reduce energy and material use in production and eliminate post-extrusion machining and remelting. Applications are presented, with their projected and simulated CO₂ reductions.

M1157
**Automation is More than Bolting Mechanics to a Press**

Richard F. Dickson, Hydro Aluminum Metals; Brian Echavarria, Hydro Aluminum; and Carsten Dedo, OMAV, USA

Challenges of adding automation to an existing press line are examined: one must begin with a smooth operating system and reliable components; project teams can over-focus on technical challenges like space utilization, equipment capacity, budgets, timeline; plant operators/crews must participate for extrusion line automation to succeed. Interdependent press operations are highlighted; steps and thought processes are described for adding automation to an existing press line, citing practical examples, best practices and our Manufacturing Excellence Model.

M1162
**Racing for Performance: Comparison of Three Extruders’ Countries**

Abubakar Subiantoro, Extruders & Sheet & Foil Aluminium Association, Indonesia

Total efficiency is analyzed and evaluated for extruders in Thailand, Malaysia and Indonesia to determine best extrusion performance. Overall efficiencies (Eo) are measured, based on extruder’s primary data, focusing on press machine performance on presses with 127mm-diameter billets. Performance efficiency is evaluated based on Wally Bennett’s formula, calculating basic efficiency from extrusion process speed, press machine utilization, recovery metal, and extrusion ratio. Calculations are processed and compared to extruders’ Benchmarking results (Roger A.P. Fielding, ET’16).

M1163
**A Fine Balance, the Difference between Excellence and Mediocrity**

Richard F. Dickson, Hydro Aluminum Metals, USA; and Paul H. Robbins, Castool Tooling Systems, Canada

Management teams’ extrusion performance questions are addressed. Extrusion is highly dependent on tooling, equipment and processes. Certain key parameters, if uncontrolled, inhibit progress, irrespective of efforts put into remaining processes. Extruder learning and development toward world-class results, and why they drop at/ below average industry levels is assessed. Focus areas resulting in performance growth or decline are highlighted. Technical expertise and exceptional management successfully working together are outlined. Key insights and recommended focus areas are presented.

VA2
**Structural Design of Extrusions in the 2020 Aluminum Design Manual**

Randy Kissell, Trinity Consultants, USA

The Aluminum Association’s Aluminum Design Manual, Part I, is the Specification for Aluminum Structures, just updated in 2020. Specification compliance is required by the International Building Code; Specification changes directly affect most aluminum extrusion U.S. building applications. Specification’s provisions are used by the American Welding Society (AWS) and the American Association of State Highway and Transportation Officials (AASH-TO) in their standards on aluminum structural components. Changes to the 2020 Specification that affect extrusions are reviewed.

VA5
**Accelerated Light Fastness Testing of Anodic Coatings**

Pinakin Patel and Tej Patel, Techevon LLC, USA

Possibilities are discussed for using special light sources to accelerate the testing process to determine the light fastness of anodic coatings. Xenon light sources that can effect a change in color within 24 hours are compared to other specified accelerated tests done for 1000 hours, or as specified for the application. The goal is to provide a process to be able to check production parts routinely for performance behavior to mitigate light fastness failure.
ET'20: Technical Sessions – continued

VA20
Influence of Trace Elements and Temper Conditions on Spangling and Gloss on Anodized Aluminum Profiles
Oystein Bauger, Hans Bjerkas, Tom Hauge, Snorre K. Fjeldbo and Oddvin Reiso, Hydro-Aluminium, Norway
Laboratory and industrial trials investigate trace elements in alloys found in post-consumed aluminum scrap, and extruded product surface quality. Retention of zinc (Zn), copper (Cu) and iron (Fe) is monitored. A new method for characterizing anodizing trials demonstrate gloss and spangling tendencies in 6060 profiles with increasing Zn-content. Increasing the Fe- and Cu-content in alloys containing Zn is shown to help reduce or avoid spangling during alkaline etching. Profile conditions for susceptibility and resistance to spangling are presented.

VA26
Technical Solutions of Rotative Anodizing for Aluminum Extrusion Profiles
Elia Schaefer, Alvarez Schaefer S.L.U., Spain
Typical anodizing limits are outlined, and describing how construction of the first and only compact anodizing plant in the world has been achieved. The plan demonstrates results from a new product that includes the latest engineering technology combined with specific development of chemical processes that ensure a perfect aesthetic material finish. The plant enables automated anodizing process implementation with only three tanks in minimal space, meeting the market's highest quality regulations such as Qualanol.

VA27
New Eco-Friendly Sealings at Low Temperature
Alberto Abad, Alvarez Schaefer S.L.U., Spain
Cold sealing with nickel allows process implementation at low temperatures, but toxic nickel salts in the anodic layer give a greenish aspect to anodized aluminum. Low-temperature alternatives to classical sealings are presented, including a new cold sealing method without nickel salts, which meets Qualanol and AAMA directives, without affecting the intrinsic aspect of anodic coatings. Spectroscopic and electron microscopy techniques are used to characterize anodic layers sealed with these new processes and study the sealing mechanism.

VA30
Automation and Industry 4.0 in Thermal Break Assembly
Remco Dumortier, Aluco, Belgium
Automated thermal break assembly uses fewer people, reducing/integrating steps into one smaller footprint machine. Optimized changeover times and quality management through adaptive knurling and crimping to extrusion tolerances ensure a more efficient assembly process with consistent shear strength and quality. Industry 4.0 creates a reduced human error risk environment; integrated vision systems scan strips and extrusions, checking for mistakes and verifying extrusion tolerances contributing to the fully-automated process. Robots handle repetitive extrusion load/unload and fully-automated strip insertion.

VA40
Aluminum-Intensive L7e Micro-Car Concept Study
Stig Tjøetta and Lars Moen, Hydro Aluminium, Norway; Leif Hagebeuker, Hydro Aluminium Extruded Solutions; Klaus Vierregge, Hydro Aluminium Rolled Products; and Rainer Wolfsfield, Ika GmbH, Germany
An L7e-class Battery Electric Vehicle concept car is presented, demonstrating that aluminum-intensive designs can meet conventional passenger safety requirements, even for ultralight cars weighing below 450kg. Exterior construction and design space are based on a Pforzheim University School of Design student's winning design entry. Extensive aluminum use with high specific energy absorption is key for meeting defined safety requirements considering front/side/rear crash. The aluminum-intensive body weighs 163kg, comprising 82% aluminum, 17% plastics and 1% steel.

VA51
Shipping Container Loading-Unloading Solution: A Smart Giant Pallet Truck
Sutanay Parida, National Aluminium Products Company SAOG, Oman
A smart solution for loading the shipping container with very minimal investment has been designed and developed in-house, taking into account loading at the extruder, and unloading at the customer end. This is a simple hydraulic jack mechanism with crams and rollers. Design features of the solution are presented, explaining the design functionality at loading and unloading areas. The solution is shown as part of customer support, describing its simplicity, cost-effectiveness, and customer affordability.

VA58
A Virtual Tool to Predict Damage and Failure of Extruded Components for Crash Applications
Jean-François Béland and Guillaume D’Amours, National Research Council of Canada; and Nick C. Parson, Rio Tinto Aluminium, Canada
Extruded aluminum crash structure design depends on stored energy level, maximum allowable crush force, space available, etc. During the design phase, material crash performance evaluation is challenging, due to complex states of stress/strain path, alloy, temper and processing conditions may be slightly modified after initial extrusion trials to reach required ductility levels. A virtual tool is developed, to more accurately predict crash performance of a given material/process route combination, upstream at the design phase.

VA60
The Evolution of Vertical Powder Coating
Andrea Trevisan, SAT Srl., Italy
Technology for aluminum extrusion vertical powder coating originally allowed significant aluminum market share growth in a range of applications, especially in architecture. Vertical coating lines quickly spread globally, with Australia, Italy and Belgium as the first countries to see this technical solution installed and operational. The latest developments and evolution of verticality in aluminum powder coating are analyzed, from traditional lines to more compact and flexible solutions that recently brought numerous new installations worldwide.

VA78
Special Effects in Anodizing: The New Trend in Europe
Marcello Rossi, Walter Dalla Barba, Alberto Brandoli, and Fabio Vicenzi, Italtecnco Srl, Italy
Special effects technology developed for the European market includes digitally printing anodized aluminum sheets and producing myriad effects and designs. The digital printing machine masks parts of anodic coating after the first anodizing step, and then polymerized masking ink is removed after the second anodizing step. Another effect creates small holes in anodized or painted sheets. An innovative process is presented, which creates permanent decoration on metal surfaces via controlled growth of protective oxides.

VA79
Investigation of Longitudinal Weld Streak Defects on Anodized Aluminum Profiles
Johannes M. Gebhard, Oliver Hering and A. Erman Tekkaya, Institute of Forming Technology and Lightweight Components, TU Dortmund, Germany
To investigate extruded profile weld defect streaks, the process chain, including billet casting, extrusion, quenching, artificial aging, and anodizing is performed under industrial conditions. Extruders' die makers design a porthole die to force streaking, using it at different extrusion plants. Billet quality, extrusion parameters and quenching strategy are varied, determining relevant process parameters and defining guidelines to prevent longitudinal weld streaks on anodized profiles. During different process chain steps, samples are taken and their microstructures investigated.

VAB5
Method for Improving the Load-Bearing Capacity of Welded Aluminum Extrusions
Rune Oeusthus, SINTEF Manufacturing; Anne Hamarsnes, Norwegian University of Science and Technology, NTNU; Ole R. Myhr, Hydro Aluminium R&D; Hallvard G. Fjaer and Dag Lindholm, IfF, and Trond Furu, Norsk Hydro ASA, Norway
An efficient method increases welded aluminum extrusions' structural integrity and load-bearing capacity based on interplay between different heating operations, leading to favorable spatial distribution of weldment properties. Heat source positioning and power are optimized using temperature and microstructure simulations, combined with artificial intelligence. The method is applied to structures produced by Friction Stir Welding and Gas Metal Arc Welding. Cross-weld load-bearing capacity and ductility tests show significant improvements using this method, compared with as-welded structures.
VA92
Effects of Variations in Alloying Element Concentrations on the Anodization and Finish of AA6063
George N. Oh and Nathan H. Sheffield, Quaker Houghton, USA
Workhorse aluminum alloy AA6063 is examined to see how, even within the accepted range, variations in elemental composition in the allowed range of alloying elements affect the anodizing process and final product, characterized by parameters including gloss, appearance, color, smut generation, and coating quality. These variations have implications for anodizers that use metal from multiple sources, especially relevant in light of current aluminum supply, emphasizing the importance of tighter alloy constituents control when finishing aluminum.

VA93
Increasing the Amount of Trace Elements in Recycled 6xxx-Series Alloys
Alexander Lutz and Iris De Graeve, Vrije Universiteit Brussel, Hendrik Claes, Carlos Kampen and Dimitri Fotij, E-MAX, Belgium
Smooth or spangled surface appearance of alkaline-etched 6xxx-series extrusion alloys (Al-Mg-Si) strongly depends on zinc (Zn) amount in the alloy. Zn whereabouts above/below critical concentration limit is investigated in 6xxx-series alloy microstructures. Research is presented showing Zn content can be increased without causing spangling, if equal copper (Cu) amounts are present in the alloy. Effects of higher Cu and Zn levels on film formation of powder-coated 6xxx-series alloys, and higher-alloyed recycled alloys’ properties are discussed.

VA94
Improved Corrosion Resistance of Round Tube Plate Fin Heat Exchangers by Alloy Selection
David Ellerbrock, Hydro Extruded Solutions, USA; and Esma Senel, Jan Halvor Nordlien, Xiao-Jun Jiang and Bard Fiskum Lillestøl, Hydro Extruded Solutions, Norway
Aluminum tubing’s inherent corrosion resistance is critical to extending the Round Tube Plate Fin (RTPF) heat exchanger’s lifespan, since tube hairpin and return bends are not cathodically protected by less corrosion-resistant fins. High corrosion-resistant alloys and protective coatings are developed for increased RTPF heat exchanger life spans. The applicability of protective zinc (Zn) arc spray coating on extruded and drawn tubes is documented. Alloy selection for improved heat exchanger lifetime is demonstrated using component corrosion test results.

VA99
Innovative Approaches in Metalworking Fluid Development
Yixing (Philip) Zhao, Shilpa Beesabathuni and Dave Slinkman, Quaker Houghton, USA
Innovative technologies and new product development are described to achieve high-performance metalworking fluids. A systematic approach to develop water-based metal removal fluids includes utilizing advanced instruments to evaluate product and additive lubricity and emulsion stability. Sophisticated and systematic formulation methods are demonstrated for new product development: design of experiments (DoE); and statistical analysis tools (ANOVA) to optimize lubricity and emulsion stability. High-performance examples of water-based metal removal fluids from successful field applications are shared.

VA100
Powder-Coated Tough: High-Performance Applications for Aluminum Surfaces
Trena Benson, Powder Coating Institute; Fiona Levin-Smith, IFS Coatings, USA
A discussion of powder coatings’ growing role as a global, high-performance aluminum finish. Discussion includes technical, process and environmental considerations from across the finishing spectrum. Topics include overview; technical performance of powders – mechanical, chemical performance, weathering; best practices – the importance of pretreatment, powder and good application technique working together; trends in aluminum powder-coat finishing; and environmental benefits of powder coatings, and how these help aluminum professionals deliver on sustainability goals.

VA108
Incremental Extrusion Stretch Forming for Lightweighting Applications
Hal Pluennke, Fairmount Technologies LLC, USA
Stretch Roll Forming (SRF), an incremental cold forming fabrication method for producing lightweight aluminum structural components from extrusions, allows cold-working and contouring of extrusions without part-specific tooling. The lack of monument tooling required by traditional stretch forming makes SRF valuable for sectors where tooling is a major portion of manufacturing component cost, e.g., aerospace, maritime vessels, specialty transportation vehicles, and architecture. The SRF process uniquely combines stretch force and rolling. The SRF process is described.

VA111
Rectifiers and Controls for the Aluminum Anodizing Process – Latest Developments
Frank Munk, Munk GmbH, Germany
Industrial rectifiers’ energy efficiency ranges between 87–92%; rectifier technologies convert AC into DC at 90% efficiency. How can new technology ensure an ROI based on energy savings over a reasonable amount of time? Dedicated process-controls help to improve productivity and are becoming more affordable in times of IoT. The latest developments in power conversion and process controls are presented, and practical aspects are considered when identifying areas that help to improve actual installation efficiency.

VA116
New Method for Correlating Etch Rate to Fluoride Activity
Scott A. Wojciechowski, Bulk Chemicals Inc., USA
The fluoride activity meter measures fluoride activity in chemical conversion coating solutions used to process aluminum. Qualicoat and GSB defined a minimum etch rate or mass loss for architectural aluminum components; a minimum of two grams per square meter greatly reduces filiform corrosion on wrought alloys. The preferred aluminum etching method uses an acidic chemical solution containing fluoride. The fluoride activity meter’s ability to indicate etching efficiency and etchant concentration meeting these standards is investigated.

VA118
Metallurgical Assessment of Acid Etch as an Anodizing Pretreatment
Jerome Fourmann, Rio Tinto Aluminium, USA; Nick C. Parson and Marc Lebleu, Rio Tinto Aluminium, Canada
A test program measures the acid etch process response to various alloy compositions. Profiles tested include some with deliberately produced extrusion streaks. The impact of acid etch and combined caustic etch times is assessed, along with surface topography produced by these treatments. Comparisons are made when profiles are treated with conventional caustic etching. Differences between acid etch and caustic etching are described for final finish’s sensitivity to alloy composition and ability to hide extrusion streaks.

VA124
Mechanism of Grit Formation on Aluminum Extrusions
Xinquan Zhang, Alumtech Consulting Pty Ltd.; Marcos Varayud, Rio Tinto Aluminium; Christopher East and Natalia Danilova, Queensland University of Technology, Australia
Case studies demonstrate that pimple surface defects are usually related to aluminum grit particles on extrusion surfaces. Studies show that grits significantly differ from conventional pick-ups, exhibiting a layered structure and only forming a loose connection to extrusion surfaces. A grit formation mechanism is suggested, involving three stages: aluminum film coating on die bearing surface; coating layer accumulation forming a particle; and particle detachment from the bearing surface. Contributing factors and key countermeasures are discussed.
VA125  
**A New Extrusion-Based Additive Manufacturing Process for Deposition of Aluminum Alloy Structures**  
Jørgen Blindheim, Torgeir Welo and Geir Ringen, Norwegian University of Science and Technology, NTNU, Norway  
Hybrid Metal Extrusion & Bonding Additive Manufacturing (HYB-AM) is introduced as solid-state AM technology based on continuous aluminum extrusion. During extrusion, wire feedstock is deposited stringer-by-stringer, forming layers. The die outlet scrapes the substrate surface, creating an oxide-free interface between extrudate and substrate. Near-net shapes are produced at high deposition rates, reducing material waste. Compared to fusion welding-based AM technology, energy consumption and residual stress-related problems are reduced. The process is demonstrated for AA6082.

VA132  
**Innovative Solution for Protection and Packing of Aluminum Profiles**  
Raffaele D’Andrea, Emmebi Srl, Italy  
Protecting exposed surfaces in vertical painting lines requires high volume, many section changes and high manpower, because standard tape application machines require tape roll changes. Usually, profiles are moved to the packing department, where single-profile machines apply protective tape. Easy-peel, a peelable protection, is applied inline with vertical painting lines, saving manpower and profile handling. The process is described, applying a layer of compound after vertical powder coating, solidifying, and forming a peelable protective layer.

VA133  
**Fully Automatic Robot Packing**  
Raffaele D’Andrea, Emmebi Srl, Italy; Damir Merdovic, Capral Aluminum; and Paul Wong, Applied Robotics, Australia  
A case history is presented on how to apply a fully robotic packing system to most architectural profiles from an extrusion basket with limited operator input, dealing with several application limitations. The system automatically detects the profile and either decides itself or given a recipe for packing, prepares bundles by picking profiles from an extrusion basket and placing them correctly into a formed, nested pack. Auto-detecting method, picking system, configuration, application, and productivity are described.

VA134  
**Use of IoT for Aluminum Profile Fabrication Shops**  
Romina Giardi and Giovanni Barbareschi, FOM Industrie Srl, Italy  
The Log On Live Automation (LOLA) system is presented, a cloud-based service to monitor production and system data made available by IoT-compatible machines. Through sensors already available for each machine, LOLA receives real-time data of state-of-the-system and production progress; data is then processed and consolidated for further end-user analysis. LOLA is a tool in line with current manufacturing process optimization and integration trends, whose final aim is demonstrated to increase productivity and implement predictive maintenance.

VA142  
**Cost-Effective, Precision Calibration of Aluminum Extrusions for Automotive Applications**  
Torgeir Welo and Christian Arne Raknes, Norwegian University of Science and Technology, NTNU, Norway  
A new method for improving automotive aluminum extrusion accuracy is presented, using a mechanical calibration strategy, combining in-plane stretching and local bending of cross-sectional members. Wedge-type tools are employed, forming the profile exterior up against fixed die surfaces. Combined stretching and bending ensures limited springback; tool surfaces dictate final calibrated part geometry, rather than actual incoming part geometry. Calibration basis mechanisms are discussed. Experimental results are compared with numerical simulations, using an AA6082 control arm.

VA150  
**Enhancements in Anodizing Line to Improve the Plant Capacity and Conserving Natural Resources – Energy-Efficient Process**  
Mansoor Mohammed, Mubshag Mohammed and Arif Husain, Gulf Extrusions, LLC, UAE  
To reduce environmental impact and save energy resources, an energy-efficient process is presented, wherein the same amount of energy spent, more anodized material is processed. This energy efficiency project is accomplished hand-in-hand with our chemical supplier, developing the formulation, and introducing and implementing an advanced chemical in the hot sealing bath of the anodizing process, which not only reduces and saves energy consumed in the sealing, but also increases anodizing process productivity by three-fold.

VA153  
**Framework for Predicting Dimensional Accuracy of 3D-Formed Aluminum Profiles Based on Industry 4.0 Principles**  
Torgeir Welo and Geir Ringen, Norwegian University of Science and Technology, NTNU, Norway; and Taekwang Ha and Jyhwen Wang, Texas A&M University, USA  
An operational research project was presented for improving dimensional accuracy for complex extruded shapes, approaching zero-defect manufacturing. Combining data representing profile thermo-mechanical history and alloy composition with the in-line and real-time process data from drives, cameras, strain gauges, etc., an optimization model then calculates path-positions and strain to repeat required product quality. A physical three-dimensional laboratory bending machine for extruded aluminum profile applications validates this model, featuring an open protocol control system that enables transition towards Industry 4.0.

VA167  
**Advancements in the Manufacture of Large Deck Panels by Friction Stir Welding of Extrusions**  
Dave Hofferbert, Bond Technologies, Inc., USA  
When multiple panels are Friction Stir Welded (FSW) sequentially to produce large structures, irregular geometry can result from FSW’s thermal effects. Technique advances are examined for producing high-quality FSW panels; clamping technique effects are considered. Circumstances that require trimming, and trimming techniques, are evaluated. Different clamping requirements for single thickness and hollow extrusions are compared. Clamp force requirements and their effects are described for sequentially welded profiles that are more than two extruded panels wide.

VA172  
**An Aluminum Oxide Thermal Variable Process**  
Walt Ahland, Lights Camera Action, LLC, USA  
New research and data is presented for this aluminum coating process. The TriPlex process changes the molecular structure of the oxide coating and the aluminum substrate, integrating the oxide and aluminum. The presented coating process enhances the anodizing process, and meets or exceeds requirements for six types and two classes of anodizing for the MIL-A-8625 specification, enabling impact, corrosion, acid, and wear resistance, and malleability. This process is being used in aerospace and LED applications.

VA173  
**Thermal Break Advancements to Increase Production and Reduce Labor**  
Scott E. Kochevar, FornUSA, USA; and Marco Cigarini and Mirco Fantini, Comall International Srl, Italy  
Thermally-broken aluminum door and window profile production is presented at 120 bar/hr, with guaranteed finished profile quality, despite imperfect extrusion tolerances. Minimal set-up timing and Industry 4.0 software sets profiles/programs remotely. A 200 bar/hr production goal is achievable using two operators managing fully-automated loading, handling and unloading systems. Profile production up to 500mm with short set-up times for highly complex profiles is achievable, and a laser marking system is described for profile traceability.
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Use this form for individual or team registrations. Only those registered may attend scheduled program sessions, entrance to ET Expo, one copy of the ET’20 Proceedings (digital) per registered delegate (non-exhibitor), and scheduled networking and meal functions. *(Printed ET’20 Proceedings will be available for purchase after ET.)*

Registration Fees  
**U.S. Funds only**

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*TEAM DISCOUNT:* Companies sending 5 or more delegates will qualify for the Team Discount. All registrations and payment must be sent together if cancellation occurs, and fewer than 5 delegates attend, the appropriate fee will be charged. Discount applies to ET 20 registrations only. Delegate substitutions may be made at any time.

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Complete this section for individual delegates and team registrations.

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Complete this section for each delegate who will be attending. Individual email addresses must be provided for registration confirmation purposes.

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Payment total above must accompany registration form; registration is not complete until payment in full is received. Send completed registration form and payment to:

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**ET’20 Schedule at a Glance**

**Monday, May 18**
7:00 a.m. – 5:00 p.m. Registration Open
8:00 a.m. – 5:00 p.m. AEC Extrusion Excellence Course*
8:30 a.m. – 5:00 p.m. Process Optimization & Analysis Workshop*
8:30 a.m. – 5:00 p.m. AAC Anodizing Essentials Workshop*

**Tuesday, May 19**
7:00 a.m. – 6:00 p.m. Registration Open
9:00 a.m. – 11:30 a.m. ET ‘20 Opening General Session
11:30 a.m. – 12:30 p.m. Lunch
12:30 p.m. – 6:30 p.m. ET Expo Open
3:30 p.m. – 6:30 p.m. Welcome Reception in ET Expo

**Wednesday, May 20**
7:00 a.m. – 6:00 p.m. Registration Open
7:00 a.m. – 8:00 a.m. Breakfast
8:00 a.m. – 11:55 a.m. Concurrent Technical Sessions ET Expo Open
12:30 p.m. – 6:30 p.m. Extrusion Showcase Open
4:30 p.m. – 6:30 p.m. Welcome Reception in ET Expo

**Thursday, May 21**
7:00 a.m. – 5:00 p.m. Registration Open
7:00 a.m. – 8:00 a.m. Breakfast
7:00 a.m. – 8:00 a.m. Concurrent Technical Sessions ET ‘20 Closing General Session
6:30 p.m. – 7:30 p.m. Welcome Reception in ET Expo

**Friday, May 22**
7:00 a.m. – 5:00 p.m. Registration Open
7:00 a.m. – 5:00 p.m. ET Founders Golf Tournament*
8:00 a.m. – 5:00 p.m. Kennedy Space Center Tour*
8:00 a.m. – 5:00 p.m. AEC Die Clinic*
8:00 a.m. – 5:00 p.m. AEC Extrusion Excellence Course*

* Additional registration and fees required. See inside for details. Times are subject to change.

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