Over 900 delegates from Australia, Asia, Europe, South America and North America gathered in Orlando, FL, Oct. 4-7 to meet, mingle and share timely information on the state of the titanium industry at TITANIUM 2015, the 31st annual international conference and exhibition sponsored and organized by the International Titanium Association (ITA).

Welcomed by Dawne Hickton, the president of the ITA’s board of directors, engineers, executives, stakeholders, end users, sales representatives and scientists attended and participated in speaker panels, which spanned a range of topics designed to illuminate the state of the art in the global titanium industry.

Supply and demand, and the various business and technology trends driving the industry, took center stage at Rosen Shingle Creek Golf Resort. The conference kicked off with the World Industry Demand Trends panel. Wade Leach, vice president, marketing and product management for Allegheny Technologies Inc. (ATI), declared that the future continues to look promising for titanium in the commercial aerospace business sector, considering the wave of new titanium-intensive jets that are slated to ramp up production in the near term, as well as his reading of airline profitability, moderate fuel costs and the projected, escalating trend of passenger miles. Leach did take note of “global uncertainties” in Greece, Syria and China, but added that global airline profitability rose significantly this year.

Addressing “Titanium Demand and Trends in the Airframe Market,” Leach said titanium will continue to be a material of choice in commercial aerospace, given the ongoing globalization of the supply chain, the roll out of new, higher performance titanium alloys and the anticipated technological advances in 3D/Additive manufacturing. He said the “commercial aircraft active fleet” registered 25,000 jets in 2014—a number slated to rise to double by 2035 to 50,000 aircraft.

Henry S. Seiner, vice president, business strategy, Titanium Metals Corp. (Timet), spoke on the “Evolution of Jet Engines.” Seiner said titanium continues to dominate in the compression section of jet engines, in applications such as fan blades, but today its position as a material of choice is being challenged by composites and aluminum alloys. He said titanium aluminides are making inroads in the combustion section of turbofan jets, being positioned as an alternative to nickel-based superalloys.

Of the 3,160 jet engines produced in 2014, Seiner said CFM International (the Snecma/Safran and General Electric joint venture) dominated the market, followed by GE, IAE (International Aero Engines), Rolls Royce and Pratt & Whitney.

Eric Roegner, president, Alcoa Titanium and Engineered Products and Alcoa Defense, discussed “Titanium in the Defense Market: Driving Growth Through Innovation.” Roegner said that, in terms of titanium demand, while overall U.S. defense spending has plateaued, “pockets of growth” remain in defense aerospace. As examples, he pointed to the F22 and F35 fighter jets as “great programs for titanium.”

Roegner mentioned that even though U.S. defense budgets have stabilized, it’s likely there will be growing demand for military hardware in the near term. “No one can predict what will happen,” he said. “There will be challenges and bright spots.” Among the bright spots will be a continuation of legacy programs, as well as new programs, for fixed-wing and rotary-wing military aircraft. Titanium demand for defense applications will continue to be...
driven by volatile environments throughout the world, especially the Middle East, according to Roegner. “Volatility equals opportunity,” he surmised.

Much like other panel speakers throughout the conference, Roegner continued to stress the need for supply chains to reduce costs and improve efficiencies, saying that material applications are required to “buy their way” onto a jet program. “We need to take cost out of the supply chain and improve performance. How do you win? There has to be innovation across the supply chain.” Examples of this innovation, as identified by Roegner, include the development of titanium aluminides, progress in 3D/additive manufacturing, and novel bonding, welding and joining technologies.

Given Alcoa’s wide span of manufacturing and material options, Roegner cited challenges to titanium in military applications, saying that aluminum/lithium alloys are well positioned as an alternative to titanium on composite-intensive aircraft. He said these alloys, like titanium, have no issues with corrosion.

Michael Metz, president, VSMPO Tirus U.S., provided an overview and update on the Russian titanium market, saying that engines (29 percent), aircraft (28 percent) and shipbuilding (25 percent) are the three market categories that dominate. The Russian aerospace market has consolidated into four groups: United Aircraft Corp., an original equipment manufacturer of civilian and military aircraft; engine builder United Engine Corp.; Russian Helicopters; and United Missile and Space Corp. Metz indicated that overall titanium demand from the Russian aerospace sector is anticipated to reach 8,000 metric tons by 2021, compared with nearly 7,000 metric tons this year. Total titanium demand for Russia in 2021 is expected to be 13,000 metric tons, slightly above the 2015 level of demand.

Kazuo Kagami, chairman of the Japan Titanium Society and president and representative director of Toho Titanium Co. Ltd., shared his “Outlook on Titanium Trends in Japan.” Kagami said sponge shipment for 2015 is expected to make recovery, projected to reach 45,000 metric tons, compared with 35,000 metric tons in 2014. Mill demand is gradually improving for the Japanese industrial market, expected to register nearly 15,000 metric tons this year, slightly above last year’s level.

Kagami underlined several examples of development efforts for Japan’s titanium industry, a list that included “Advanced Titanium Alloy and Production/Processing Technology for Next Generation Aircraft Structure”; “Innovative Structural Materials Association” (weight reduction of transportation equipment such as cars; “Cross-Ministerial Strategic Innovation,” which involves structural material for innovation of heat-resistant metallic materials; and the “Process of Direct Cast Titanium Slabs,” slab-cast technology by electron beam (EB) melting for industrial applications.

Kevin J. Cain, president of Uniti Titanium LLC, presented his “Industrial Titanium Demand Forecast,” an overview of the next five years. For Cain’s overall projection, he said industrial titanium demand this
year (oil and gas, heat transfer equipment, electrical power, chemical processing, and desalination) is slated to reach just over 25,000 metric tons in shipments, down slightly from the previous year. The demand is expected to grow to nearly 30,000 metric tons in 2020 (excluding shipments to Russia and China).

Cain said that demand for oil is forecasted to increase 15-20 percent over the next 20 years, while natural gas demand is likely to increase 45-50 percent. For electric power generation, he said approximately 6,000 metric tons of titanium will be consumed per year over the next five years in applications such as welded tubes, tube sheets and heat transfer equipment.

The chemical processing sector is expected to draw $100 billion of incremental capital investment by 2025. Cain estimated that the average annual consumption of titanium in the chemical process industry will be 10,000 metric tons per year for the next five years. For desalination, titanium consumption is estimated to be in the range of 2,000 metric tons per year, with the possibility to reach 3,000 metric tons by 2020.

**World Supply Trends**

**Derek Folmer**, chief marketing officer for Sierra Rutile Marketing Ltd., discussed “Rutile Economics: The Outlook for a Raw Material Critical to Manufacturing High-Quality Sponge.” The company, based in Sierra Leone, West Africa, a London-listed mining enterprise, supplies about 20 percent of the world’s rutile, according to Folmer.

Regarding global rutile supply, Folmer said only three companies are able to produce over 100,000 metric tons of rutile per year, with over 20 percent of supply held by vertically integrated companies. Global rutile production in 2014 was 745,000 metric tons, with Australia accounting for nearly half that total.

Rutile is commonly found with ilmenite, zircon, and other heavy minerals and represents the highest quality TiO2 feedstock. As for key industry trends affecting rutile, Folmer listed: declining reserves and grades; increasing ore body complexity; TiO2 pigment consumption growth outpacing rutile supply; rapid aerospace growth and vertical integration; and the emerging Chinese chloride TiO2 sector.

**David McCoy**, managing director of TZ Minerals International Pty Ltd., Victoria Park, Australia, provided a detailed review of the global titanium sponge market. McCoy identified key sponge producers around the world beginning with China, which had an output estimated at 68,000 metric tons in 2014, compared with 81,000 metric tons each year in 2012 and 2013. It’s believed China has an overall sponge production capacity of 150,000 metric tons, composed of more than 10 sponge producers. He said ongoing consolidation in China is expected to phase out smaller, less efficient sponge production plants, reducing the capacity to an estimated 100,000 metric tons.

China’s sponge exports have fluctuated sharply in recent years, according to McCoy, going from 1,000 metric tons in 2009, to 11,000 metric tons in 2011, to 6,000 metric tons in 2014. The largest export market for Chinese sponge produced in 2014 (36 percent) was South Korea followed by the United States (28 percent).

Titanium powerhouse Verkhnyaya Salda Metallurgical Production Association (VSMPO) of Russia produced 40,000 metric tons of sponge each year in 2013 and 2014. Japan’s sponge production was just over 30,000 metric tons in 2014, down from about 35,000 tons in the previous year. McCoy said Japan’s sponge exports have decreased in recent years, to 16,000 metric tons in 2014 compared with 31,000 metric tons in 2012. Sponge production in the United States registered 12,000 metric tons in 2014 compared with about 15,000 metric tons in 2013.

Several sources have estimated that the global production capacity for titanium sponge is in excess of 300,000 metric tons.

**Edward J. Newman**, senior vice president of United Alloys and Metals Inc., offered a review of titanium scrap processing trends. Regarding the vacuum arc remelting (VAR) method for producing ingots, the advantages for this process are that scrap can be included in raw material mix, but VAR melting does not remove high-density inclusions (HDIs) contamination. HDIs are particles of with a higher density than titanium, which diminish the mechanical properties of titanium, with the contaminating particles serving as crack-initiation sites. As such, VAR is best used for processing titanium scrap in its early stages.

As for cold hearth melting scrap processing, Newman said processed turnings can now be used without X-ray monitoring due to cold hearth’s ability to remove HDI’s. This advantage, he said, substantially increases the volume of titanium turnings returning to the titanium industry. He estimated that there are now 14 cold hearth furnaces operating in the United States.

Newman said the titanium industry must find a way to retain more of the scrap titanium units that are generated. For example, he pointed out that half of all titanium scrap generated goes to ferrotitanium or other “sacrificial” applications. Newman cited a 2014 United States Geological Survey (USGS) estimate of 25 million pounds of titanium scrap being consumed by steel and other industries.

In his summary points, Newman said scrap supplements sponge and master alloys to provide substantial low cost units to the market place. Advances in melting and processing technology have allowed for the continuing increase in titanium scrap recycling. “Titanium industry needs to continue to move towards capturing a
Implementation of buyback programs along with industry consolidation has stabilized both pricing and supply of scrap to producers. Scrap processing industry continues to provide valuable product, services, and innovation to the titanium industry."

Matt Schmink, vice president of sales for Global Titanium Inc., Detroit, examined ferrotitanium demand trends. According to Schmink, the use of ferrotitanium and titanium scrap as an alloying additive in the production of carbon steel and stainless steel has become an integral part of the titanium mill products “production spectrum.” Global steel production in 2014 is estimated to be in excess of 1.6 billion metric tons. Roughly 80 percent of titanium use in steel is attributable to automobiles and appliances. Titanium’s requirement for steel production in 2014 was 73,684 metric tons.

Schmink showed a bar chart that projected the titanium requirement would reach more than 70,000 metric tons by 2022. He concluded that the ferrotitanium market will be well-supplied in the years ahead with a strong possibility for over-supply. He said this should act to keep prices for off-grade scrap and ferrotitanium depressed. However, innovation in the titanium industry could counterbalance this oversupply through improved scrap utilization and the development of new markets to utilize titanium scrap.

Terry T. Perles, president of MoTiV Metals LLC, Bridgeville, PA, examined market trends and analysis for master alloys. A master alloy is a value-added, semi-finished product, created for use as a raw material by the titanium industry, which typically contains two or more alloying elements to achieve enhance properties, such as enhanced heat and corrosion resistance, for a specific application. Master Alloys in the titanium industry are binary, ternary or multi-component alloys used to efficiently and effectively allow the melting of titanium alloys. Vanadium and molybdenum master alloys account for approximately 90 percent of the total annual demand volume.

Perles said quality is an essential attribute for master alloys given their use in critical applications. A highly variable cost component in master alloy production is the market price of raw materials. “The ability of the master alloy supplier to design solutions for titanium alloy producers is a critical value added factor in the relationship,” he stated.

Global vanadium consumption this year will register 93,000 metric tons, with 92 percent of demand coming from the steel industry, compared with 5 percent from the titanium alloy industry. The 3-percent balance represents demand from chemical and energy storage applications. Global molybdenum consumption is estimated to be 525 million pounds for 2015.

Vanadium and molybdenum markets are experiencing 10-year lows in market prices today and current prices are not sustainable in the long run, according to Perles. Rationalization of vanadium production in South Africa and China could set the stage for a change in the vanadium market fundamentals in the near future. He said the molybdenum market is under pressure due to inventory accumulation over the past several years, combined with softening demand from the oil and gas sector, while primary molybdenum mines in China and North America will be under pressure.

Distribution Roundtable Panel
Titanium distributors throughout the United States are in a holding pattern regarding their business plans and metal inventories, waiting for a three-year business “sweet spot” that’s expected to begin unfolding by mid-2016. This was an example of the discussion among titanium executives participating in a “distribution trends roundtable” panel.

Brett Paddock, the president and chief executive officer of Titanium Industries Inc. (TI), Rockaway, NJ, served as the moderator of the panel. The roundtable included Greg Himstead, vice president of sales and marketing for TI; Dr. Igor Kjenitski, executive vice president of Grandis Titanium, Rancho Santa Margarita, CA; Ron Krajcik, director of sales and marketing of Tricorp Metals, with divisions in the Midwest, Texas and California; Stephen Patera, vice president of sales for Titanium Processing Center, New Baltimore, MI; Oliver Frankenheim, director of sales from S & D Spezialstahl Handelsgesellschaft, mbH, Stelle, Germany; Vladimir Dolyuk, president, Tico Titanium, Wixom, MI; along with market analyst Chris Olin, the president and founder of the Olin Research Group LLC, Avon, OH. According to information posted on their respective websites, these distributors carry a wide range of inventory: titanium plates, sheets, wire, bars, tubes, ingots and billets, and most provide other high-end industrial metals such as nickel alloys.
The executives indicated that the current holding pattern is due to tepid business conditions in the industrial and oil and gas sectors, which have offset generally positive activity in the key commercial aerospace industry. “In the macro business environment for titanium, things were more positive just four months ago, Olin said. “We’ve been seeing weakness in the industrial categories—everything non-aerospace.” As a result, he said distributors have been hedging away from the industrial sectors and adjusting their inventory levels accordingly.

Olin anticipated that the “sweet spot” for the titanium supply chain will kick in next year, when production begins to ramp up for titanium-intensive commercial jet platforms such as the Boeing 787 and 777X and the Airbus Neo, A380 and A350. It’s expected that the aforementioned industrial and oil and gas sectors will show signs of improvement during this time frame (2016-2018), complementing the commercial aerospace business activity, and thus creating the sweet spot, all of which is expected to spur the supply chain to boost titanium inventory levels.

The sweet spot may be off to an early start for the titanium supply chain as Alcoa Inc., on Oct. 5, announced a $1-billion deal to supply aerospace fastening systems to Airbus, with many fasteners fabricated from titanium. Earlier this year Alcoa fortified itself to expand its aerospace business through the acquisition of RTI International Metals, Inc.

Regarding the potential effects of Alcoa’s purchase of RTI, or Berkshire Hathaway’s acquisition of Precision Castparts Corp., distributors, speaking generally, said they initially saw the deals as positive developments, providing “confidence and capital” to the titanium aerospace supply chain. “The merger and acquisition activity we’ve seen this year means that companies with deep pockets are investing in the titanium industry,” Paddock said.

“All of this will help to expand the industry and open up distribution channels. It also will bring new talent and new ideas into the titanium industry.” Olin picked up on this point during his remarks, saying that the titanium industry needs a greater influx of young people to help spark innovation.

Himstead said that inventory management remains the number-one tool for distributors to control costs. This involves not just tracking levels of in-house titanium, but also predicting industry cycles and minimizing the shipment time of mill to customers. “We’re all doing our best to understand the cycles of the titanium industry, to put inventory stock in at the right time,” Krjenitski said. “We always want material on the shelf to support our customers. Managing inventories doesn’t necessarily mean lower inventories.”

Krajcik said the titanium industry deserves credit for overcoming the extreme price volatility that has hampered the industry over the decades. The result of this has been an eight-year period of relative price and supply stability, which has enabled service centers and distributors to better manage their inventory levels. “Titanium is value priced,” he said. “Titanium today is a great value, especially in the corrosion market.”

### Commercial Aerospace

**Waldir Gomes Concalves**, senior vice president, customer support and services worldwide for Embraer Executive Jets of Brazil, presented a profile of his company and offered a market forecast. Concalves said Embraer is composed of four divisions—Commercial Aviation, Executive Aviation, Defense and Security, and Systems. Embraer has operations in Brazil, North America, Europe and Asia, with more than 19,000 employees and 2,300 employees in joint ventures and affiliates.

Regarding his commercial aviation market forecast, Concalves said that for planes with 70-130 seats, Embraer projects 6,350 jet deliveries during the next 20 years, a market valued at $300 billion. The United States represents the largest market for this category during that time span, followed by Europe and China. As for executive jets, he said the company forecasts deliveries of 9,250 jets during the
next 10 years, with a value of $265 billion. North America represents the largest market for executive business jet category. Concalves displayed a pie chart that illustrated Embraer's annual titanium purchasing profile. Fasteners (41 percent) represented the company's biggest titanium procurement category, followed by forgings (36 percent), plates and bars (19 percent), sheets (3 percent) and tubing (1 percent).

William T. Shaffer, director-materials and standards for Boeing Co., gave an “Outlook for Titanium in the Commercial Aerospace Market.” Boeing’s projections were for 38,000 new jet deliveries through the year 2034, a market dominated by Asia at 14,300 units, followed by North America, 7,890 units and Europe, with 7,310 units. A graphic by Shaffer offered details on Boeing’s commercial jet supply chain: 1 billion parts procured each year; $43 billion spent; 5,400 factories and 500,000 people.

Thomas T. Cochelin, head of titanium and special alloys raw material procurement for Airbus S.A.S., shared his thoughts on “Key Strategic Enablers for a Successful Airbus Titanium Supply Chain.” Innovation is occurring as a result of a “supply centered” (and not just a “product centered”) supply chain. He provided a list of the strategic supply chain enablers as defined by Airbus: reducing costs; “de-risking” with the ability to meet ambitious ramp-up production schedules; creating an efficient and consistent global footprint; innovation on current and future programs; and developing synergies within the Airbus group.

Citing 2014 company consumption levels, Cochelin said that, “every working day,” the manufacturing operations of Airbus require 30 metric tons of titanium. He summarized his presentation with this statement: “Together, a strong Airbus supply chain community can create the new costs/standards that are requested to deliver what Airbus has sold to its customers and shareholders.”

Melting

Thomas Branscomb, director of technology, Buntrock Industries, discussed “Shell Materials and Casting Methods for Casting Titanium Alloys with Minimum Alpha Case.” Branscomb’s recommendations to make titanium castings with minimum alpha case: use a low shell temperature; use small gates to avoid high metal/mold interfacial temperature; use centrifugal casting; use ytria as a face coat ceramic rather than zirconia. Potential metal savings and less chemical milling may more than offset the cost premium of ytria compared to zirconia.

Stephen Fox, director, corporate research and development for Timet’s Henderson technical laboratories, presented “Recent Developments in Melting and Casting Technologies for Titanium Alloys.” Fox said that, during the last 20 years, melting and casting technologies have evolved to meet industry needs. He reviewed the expansion in melting capacity and provided overviews on melting technologies (cold hearth, vacuum arc, electron beam, plasma arc, skull), along with information on powder and additive processes. Fox concluded his talk by saying that technological challenges for the future include integrating accurate process information, developing an accurate prediction of critical structures and rapid and transient events associated with powder and additive processes.

Christopher Jackson, a market analyst with Retech Systems LLC, presented information on gamma PAM (plasma arc melting) of near-net shape titanium aluminide alloy ingots. As noted by other speakers, Jackson said that titanium aluminide alloys are finding expanded applications in aerospace and automotive markets. Nathaniel Slinkert, director of VAR products, Retech Systems LLC, presented information on increased productivity using flexible hearth melting configurations, which he said enhances production flexibility while increasing throughput.
Industrial

“Case Studies Supporting a Titanium-Tubed Heat Exchanger Upgrade from Copper Nickel” was a talk given by Dennis Schumeth, the principal and owner of Titanium Tubular Consultants. He pointed out titanium’s advantages of superior corrosion resistance, reduced weight, ease of fabrication, conventional lead times, expanded industry capacity and competitive costing.

Gary Lantzke, the chief executive officer of Callidus Welding Solutions Australia, shared insights in “Wear Resistant Options for High-Pressure Acids Leaching Applications” and the advent of titanium nitride surface modification.

MariaPia Pedeferri, associate professor, Politecnico di Milano, Dipartimento di Chimica, Materiali e Ingegneria Chimica, addressed “Advances in the Development of Surfaces Functionalities of Titanium.” Pedeferri said her research focuses on developing precise control of the anodizing process. She said titanium anodic oxidation is a powerful technique for tailoring the surface properties of titanium oxide surfaces—affecting everything from color to corrosion resistance of the metal.

Automotive

James Hostetler, vice president of TMS Titanium, presented an overview of “Titanium and the Auto Racing Industry,” demystifying the welding, cutting and machining of titanium to create application solutions for auto racing. He also stressed the weight-saving advantages of titanium components compared with steel components.

Dr. Jurgen Kiese, head of the department for process development of titanium at VDM Metals GmbH, unveiled results of research work that targets “A New Class of Oxidation-Resistant, Microstructure-Stabilized and Cold-Workable Titanium” for automotive exhaust system applications. Kiese indicated the development work involved CP titanium Grade 1S that attained enhanced oxidation resistance through the addition of silicon, iron and niobium, along with an improved microstructure stability.

“Rethinking the Automotive Uses of Titanium as a Result of the New Emissions Paradigm,” a paper by Graham Withers, president of CYCO Tech Corp. Pty Ltd., reviewed proposed emission standards issued last June by the U.S. Environmental Protection Agency and the Department of Transportation’s National Highway Traffic Safety Administration. Withers said the standards already in place for model years 2014-2018 will result in emission reductions of 270 million metric tons and save vehicle owners more than $50 billion in fuel costs. As such, he then considered the use of titanium in automotive springs, fasteners and exhaust, engine and brake systems, all of which would highlight titanium’s weight savings and corrosion resistance advantages.

Government Funded Projects

“Innovating the Future of Titanium Production at the U.S. Department of Energy,” a talk by Dr. James Klausner, program director of the Advanced Research Projects Agency—Energy (ARPA-E), outlined research programs at ARPA-E that include over 380 energy technologies across 20 focused program areas in transportation and stationary energy initiatives. The programs include vehicle lightweighting through the use of titanium, aluminum and magnesium; titanium metal and
powder research projects; and innovations in metals recycling.

Jordi Perez, a scientist at SRI International, spoke about “Fluidized Bed Processes for Production of Metal Alloys and Composites.” Perez said applications include metal/ceramic nanocomposites, nanostructured powders, and the infiltration/deposition of metals such as aluminum and vanadium on titanium sponge. These technologies have the potential to develop scalable production of feedstock for 3D printing, laser sintering and powder metallurgy; materials with better mechanical properties at high temperatures; and new lightweight, high-strength alloys and composites.

Z. Zak Fang, a professor of metallurgical engineering at the University of Utah, presented a paper on “A Novel Energy Efficient, Low Cost Chemical Pathway for Titanium Production.” Fang provided details on the University of Utah’s Direct Reduction of Titanium Slag (DRTS) process. He stated that high-purity, low-oxygen titanium powder can be produced directly from “upgraded titanium slag” (UGS), without high-temperature processes such as chlorination.

Economics

Nicholas Pastushan, chief investment officer, CIT Transportation Finance, shared his thought on “A Lessor’s View of Aircraft Markets and Global Economics.” Pastushan tracked various trends in the commercial aerospace industry, such as the rising annual delivery rate of aircraft and the growth in global air traffic, with an emphasis on the upward trends of Asian markets.

Peter Zimm, principal, ICF International, examined “Aerospace Production and Supply Chain Outlook.” Zimm said current aggregate aerospace raw material demand is 1.56 billion pounds, with titanium representing 11 percent of that total (compared with aluminum at 47 percent and steel alloys at 21 percent). Aerospace titans Boeing and Airbus account for nearly two-thirds of that raw material demand.

Zimm estimated that the total aerospace raw material market is worth $12.4 billion, with titanium representing the largest material by market value at $3.4 billion. As for the supply chain outlook, he pointed to Alcoa’s acquisition of RTI and the purchase of Precision Castparts Corp. by Berkshire Hathaway. Much like presentations in the Commercial Aerospace and Industrial Titanium Demand Forecast panels, Zimm said the supply chain must be ready to adapt to the “new reality” of higher service level deliveries and downward cost pressures.

Machining

“Advancements in Insert Cutting Edges and Coatings,” a paper by Kevin Maples, cutting tool solutions specialist with Walter USA LLC, indicated that grade development and cutting edge preparation are key factors when machining titanium. He said the cutting edge of the tool is subject to high thermal loads due to the relatively low thermal conductivity and density of titanium.

Maples said a higher degree of “rake” angle is required to form a chip, while honing or “rounding” the cutting edge helps protect the insert from chipping and notching. Coolant concentration is a key factor in chip removal and cooling and for titanium machining the coolant concentration should be 10-12 percent when mixed with water, according to Maples. In addition, Maples provided details on two coating processes: CVD,
a chemical process used on carbide indexable inserts with cutting edges that are less sharp; and PVD, a physical process that is used on carbide indexable inserts with sharp cutting edges.

Another Walter USA representative, William Radtke, manager of regional competence center Americas, described “Cryogenic Machining,” which can improve tool life and productivity when machining titanium through the use of carbon dioxide (CO2), known as the “CryoTec” process.

Reinhard Fitz, sales director, North American operations for the Starrag Group AG, discussed “High-Volume Titanium Cutting Challenges, Technology and Solutions.” He shared a detailed analysis on ways to boost cutting speeds, increase tool life, and improve overall machining productivity through the optimization of chip removal.

**Advanced Titanium Manufacturing**

**Kurt Faller**, chief executive officer of MetCon LLC, presented a paper on “The Largest Cost Reduction Opportunity for Titanium in a Quarter Century: Electrochemical Conditioning and Finishing.” According to Faller, a significant factor leading to the high cost of titanium mill products is the “relatively poor yield from ingot to finished mill product. The single greatest contributor to this yield loss is the conditioning required to remove cooling cracks and alpha case caused by each thermo-mechanical processing step (forging, rolling, extrusion and hot forming).

Faller said MetCon’s electrochemistry technology retains the bulk metal, while focusing on “healing” the cooling cracks. According to Faller, MetCon’s technology delivers a 4-percent yield and a 5-percent cost improvement for each electrochemical conditioning step, compared with conventional, “subtractive” ingot conditioning methods such as grinding and bar peeling.

**Dr. Berthold P. Erdel**, president, IMS Co., discussed “The Shift to Material-Centered Manufacturing,” with a focus on aerospace production. In his presentation abstract, Erdel said his prediction that the concept of “Light, Small, Simple, Fast, Smart, and Strong” will permeate all of manufacturing, has turned out to be what constitutes today’s manufacturing networks. He explained that lean manufacturing principles dominate efforts on the factory floor, followed by government mandates of “green” manufacturing (environmentally friendly practices) and more recently “blue” manufacturing (strategies to minimize energy consumption).

“Spurred on by the need to become more fuel efficient, operate lighter, faster, safer, and lower the environmental footprint, the aerospace industry, even more so than automotive, has begun to turn to ever more advanced materials,” according to information in his abstract. “Innovative manufacturing processes have part material at the center of it all to secure components and subassemblies that can meet the stringent demands for increased strength, minimum weight, higher temperature resistance, less maintenance, lower noise level and safe, extended service life.” He said that, given these characteristics and the necessary product changes and enhancements in form and function, advanced manufacturing has moved from machine-centered to “material-centered” regimes.

Erdel also shared his insights on the “360 Impact on Manufacturing,” which involves the development of new generations of metal alloys to meet higher physical demands, such as the high-performance titanium 5553 alloy (Ti-5Al-5V-5Mo-3Cr). The 360 Impact also includes “innovative recovery and recycling processes and solutions of 100 percent of metal returned into the supply chain.”

**Yoshinori Ito**, senior researcher at Kobe Steel Ltd., presented “Technologies for Reliable Titanium Alloy Forgings Focusing on Ultrasonic Inspection in the Aerospace Industry.” Ito said process design is a key technology to provide high quality titanium forgings. “Establishment of forging simulation technique and processing window is essential.” Kobe Steel recently opened production facilities that produce large titanium forgings to meet stringent aerospace specifications. One facility, Japan Aeroforge, which opened in 2013, operates a 50,000 metric ton forging press.

A joint presentation by representatives from Vulcan Engineering and Norton Abrasives Saint-Gobain focused on “Advancements in Titanium Conditioning.” They defined metal conditioning as the process to remove defects such as scale,
cracks, forge marks from ingots and billets prior to metalworking operations. The talk reviewed a list of metal grinding techniques and related equipment, and noted advances in safety features and digital machine controls “that allows for greater mastery over the entire grinding process.”

### 3D/Additive Manufacturing

For intriguing developments regarding the buzz over 3D/additive manufacturing, the most noteworthy announcement came one month before the start of TITANIUM 2015. Alcoa, in a Sept. 3 press release, trumpeted a $60-million expansion of 3D/additive operations at its research and development center in Pittsburgh. The investment, which targets complex, high-performance aerospace components, features Alcoa's Ampliforge™ process, a technique that combines additive and traditional manufacturing for enhanced properties, according to the press release.

“Alcoa is investing in the next generation of 3D printing for aerospace and beyond,” Klaus Kleinfeld, Alcoa chairman and chief executive officer stated in the press release. “Combining our expertise in metal alloys, manufacturing, design and product qualification, we will push beyond the limits of today’s additive manufacturing. This investment strengthens our leadership position in meeting fast-growing demand for aerospace components made using additive technologies.”

Rob Gorham, director of operations for America Makes, said the interest for 3D/additive manufacturing at his group involves “smart collaboration and the growth of the ecosystem” for the leading-edge technology. Components of the roadmap to develop the technology involve a focus on design (product and process), materials (next-generation alloys), process (next-generation production equipment), value chain (advanced sensing and inspection), and the 3D/additive manufacturing genome (physics-based modeling and simulation).

America Makes is associated with the National Network for Manufacturing Innovation (NNMI), a network of 45 regional hubs throughout the United States that coordinates public and private investment in emerging advanced manufacturing technologies.

Alex Kingsbury, group leader, additive manufacturing for CSIRO of Australia, said her organization's Lab 22 is a center for development work in additive manufacturing. Kingsbury said this thrust by CSIRO reflects an ongoing effort throughout Australia to transition out of low-tech, high-volume manufacturing into high-tech, valued-added production. The hope, she said, is that this initiative will help create a robust supply chain for additive manufacturing in Australia.

Equipment at Lab 22 includes powder bed and blown and spray machines, polymer 3D printers and scanners, and testing operations.

Ryan R. Dehoff, Ph.D., a member of the research staff at Oak Ridge National Laboratory, provided an update of “In-Situ Process Monitoring and Big Data Analysis for Additive Manufacturing of Ti-6Al-4V.” The work at Oak Ridge involves all phases of 3D/additive manufacturing: planning, execution, outcome and data analysis. He noted the development work on data analytics for “merging science and manufacturing,” creating a 3D/additive framework. Process monitoring is critical in understanding the dynamics of 3D operations.

Denhoff said Oak Ridge is the largest science and energy laboratory for the U.S. Department of Energy, with 4,400 employees, a $1.65 billion budget, and $500 million in modernization investment.

### Powder Metallurgy

Professor Z. Zak Fang of the University of Utah, who also delivered a presentation for the Government Funded Projects panel, presented “Sintering Ti-6Al-4V in Hydrogen to Achieve Wrought-like Microstructure and Properties.” He began by stating long-standing issues that have hampered conventional powder include problems with mechanical properties such as fatigue performance and fracture toughness, a coarse lamellar as-sintered microstructure, and the high costs associated with post-sintering thermal mechanical processing.

As an alternative, he presented details of his work on a new, patented, hydrogen sintering and phase transformation (HSPT) process. He said that sintering titanium in hydrogen can deliver wrought-like microstructure and properties by simple press and sintering, without costly processes. He summarized by stating...
that sintering Ti-6Al-4V in hydrogen yields ultrafine microstructure. The as-sintered HSPT microstructure can be heat treated to achieve wrought like microstructure, and that Ti-6Al-4V produced by HSPT has excellent fatigue properties equivalent to that of wrought alloys.

Dr. Vladimir Moxson, president and chief executive officer of ADMA Products Inc., discussed the “Manufacturing of Hydrogenated Titanium Powders and Titanium Components for Critical Applications.” He said ADMA has developed an innovative process for manufacturing of titanium hydride (TiH₂) powder. ADMA’s proposed process can transform the titanium production because it overcomes the technical challenges of the Kroll’s process by partially replacing molten magnesium with hydrogen gas as a reducing agent to produce TiH₂ instead of titanium, according to Moxson. As a result, titanium components for critical applications can be produced from hydrogenated titanium powder via the ADMA process. ADMA has a pilot-scale unit for manufacturing of TiH₂ powder, with an annual capacity of 250,000 pounds, developing ADMA’s “blended elemental powder metallurgy approach.”

Dr. J.C. Withers, chief executive officer of Materials and Electrochemical Research (MER) Corp. addressed the topic of “Electrolytic Titanium Powder Production from Ore Sources.” Withers stated MER discovered in the late 1990’s that TiO₂ and ore containing TiO₂ could be carbothermically treated to produce Ti₃O₅. As a result, TiO₂ and ore containing TiO₂ can be carbothermically reduced to Ti₂O₂C, which can be chlorinated at 180-400°C to produce low-cost TiCl₄. Low cost TiCl₄ can be used: as a feed to electrolytically produce titanium powder on a continuous basis; and as a feed for Kroll sponge production.

Withers said Ti₃O₅ is electrically conductive and can be used as an anode to electrolytically produce titanium powder on a continuous basis at a projected cost less than Kroll sponge. The electrolytic process provides control to produce titanium powders in preferred sizes directly useable in powder metallurgy processing. The electrolytic process has demonstrated it is possible to produce alloy powder such as Ti-6Al-4V at a cost near that of sponge.

He said a low-cost titanium or Ti-6Al-4V alloy powder provides a paradigm for powder metallurgy to produce titanium componentry as well as an enabling feed for the various additive manufacturing processes.

Recycling of Titanium

Richard Dolbec, director of research and development for Tekna Plasma Systems, delivered an overview of his company’s inductively coupled plasma (ICP) technology, which has been developed to recycle titanium powders by transforming particles of various shapes into “perfect spheres” in order to boost material flow, packing, density and purity.

Jerry Faitelson, Vice President of Goldman Titanium Inc., substituting for Stacie Greenfield Stone, the director of new business development, outlined the company’s quality, processing and safety procedures for its scrap operations. Faitelson said the role of the titanium scrap processor is: to turn unprocessed revert into a finished product that meets titanium melters’ specifications; to be a reliable way station to hold excess inventory for melters; and to have just-in-time, certified, furnace ready scrap readily available.

The title of Robert G. Lee’s presentation was straight forward and to the point: “Hazardous Titanium Does Not Belong in a Landfill.” Lee, the chair of the ITA Safety Committee and president of Accushape Inc., Portland, OR, said the ITA provides substantial safety resources for members, users and first responders, with an emphasis on fire prevention.

Lee said the mission of the ITA safety committee is to bring awareness to safety issues when handling and working with titanium. However, he reiterated numerous disclaimers during his presentation. “Every titanium producer, distributor and user must develop their own safety plans to meet the conditions unique to their use of titanium, especially the generation and storage of titanium fines that may present a fire and or explosion hazard,” Lee stated.
In particular, he cited the hazards of titanium “swarf,” which is revert produced at an estimated level of 5 million pounds per year. Swarf is a term used to describe fine scrap. Like dust and powders, Lee said swarf is considered to be a major fire hazard because it’s readily susceptible to ignition. If discarded in a landfill, swarf, over time, creates explosion hazards.

**Consumer Applications**

Professional golfer **John Cook** and **Edward Rosenberg**, designer and chief executive officer of Spectore Corp., were the speakers for the consumer panel. “Change” was the underlying theme in both presentations. Cook, a member of the 1993 U.S. Ryder Cup team and an 11-time winner on the PGA tour, discussed how titanium clubs have helped to change the game of golf. Rosenberg expounded on how his work in the “Rapid Innovation for Titanium in the Consumer Products” became an element of change in the 3,000-year-old tradition of jewelry design, craftsmanship and production. He said Spectore has spent considerable time on the “science of consumer purchasing” to develop innovative jewelry designs for women and men.

**Award Recipients**

**Walter E. Herman** received the prestigious 2015 Lifetime Achievement Award. Herman’s resume traces the early development of the titanium industry, from the Cold War days of the 1950s and through the decades of commercial development. He played a key role in the development of the first industrial electron beam cold hearth melting process (EBCHM) for removal of high- and low-density inclusions from recycled titanium. Herman also was lauded for his work in the development of corrosion applications for titanium used in the chemical and metal finishing industry.

**Christopher Higgins**, the Cecil and Sally Drinkward Professor of Structural Engineering in the School of Civil and Construction Engineering at Oregon State University, is the recipient of the 2015 International Titanium Association’s (ITA) Titanium Application Development Award. Higgins, working with Perryman Co., Houston, PA, was cited for his role in developing a novel titanium application for repairing highway infrastructure.

The Oregon Department of Transportation (ODOT), Salem, OR, selected a repair concept by Higgins—a titanium “staple” to reinforce fractures in the reinforced concrete—which was deployed by ODOT on the Mosier Bridge, an “overcrossing” of Interstate 84, which is a major east/west corridor for the state. Higgins designed the idea of the staple and the requirement of a surface treatment that would allow titanium alloy bars to be used to strengthen concrete bridges.

Perryman Co. manufactured the titanium staples and developed the methods to produce the surface treatment. Oregon State tested alternatives and selected the final pattern. Perryman handled the entire production of the staples in house—from start to finish. Perryman engineers then went on site to collaborate with repair contractors for the installation of the staples.

**Distinguished Guest Speakers**

**George Hays**, the executive director of the New York-based World Corrosion Organization (WCO), shared his expertise on the global challenges of life cycle costing for the energy industry, and now looks to impart that knowledge to the titanium sector.

**Life Cycle Costing Session**

The ITA’s Committee for Industrial Applications hosted a “Life Cycle Costing Session,” featuring **Barry Benator**, the founder and president of Benetech Inc., Roswell, GA, a leadership and management consulting and training firm. Benator said he developed a seminar on life-cycle costing for the energy industry, and now looks to impart that knowledge to the titanium sector.

As outlined by distinguished speaker Hays, life-cycle costing can demonstrate titanium’s “good value” as a material of choice in a host of industrial applications. In some cases, titanium is passed over in an application due to short-term budget constraints for so-called “less-expensive” metals.

Benator’s session was designed to give titanium executives and sales representatives the tools they need to make a more convincing case to win business. He offered insight on the economic analysis method known as life cycle costing (LCC) which calculates the total cost incurred with the ownership, lease or rental of a facility or equipment over its lifetime. Benator defines life-cycle costing as a set of calculations to determine the long-term financial benefit for an investment, taking into account the savings, benefits, maintenance and cost over the entire life of a product or system. “The basic idea is: do I spend a bit more now to get a better and more cost-effective system for the long haul,” Benator explained in an interview prior to the conference.
Industrial, infrastructure and municipal corrosion and urged the titanium industry to take a greater role in addressing the issue. According to Hays, corrosion represents an annual worldwide cost of $3 trillion for infrastructure and industry—the cost to repair, replace and maintain critical systems. Here in the United States, Hays said the cost for corrosion control and repair represents about 3.3 percent of annual gross domestic product (GDP) or well over $300 billion.

Here in the United States, there is a sense of urgency when it comes to corrosion problems with state and regional infrastructure. Hays said the vast majority of U.S. bridges already have exceeded their original design life. Two years ago the Reston, VA-based American Society of Civil Engineers (website: http://www.asce.org) issued its “Report Card for America’s Infrastructure,” which reviewed bridges, dams, levees, tunnels, roads, water systems, and other areas, and issued a cumulative grade of D-plus, compared with a D from the group’s 2009 study.

Hays said he considers titanium to be a significant material in the efforts to address corrosion problems. He said titanium, as a specified material to address corrosion problems, plays out well when a project undergoes a comprehensive life-cycle cost review. However, he said titanium’s reputation as an “expensive” material still raises eyebrows. “Corrosion is a phenomenon that occurs slowly over time. The problem is that, too frequently, management or government officials take a short-range view of a project,” he said, noting that state governments are especially sensitive to keeping a lid on short-term costs.

Regis K. Conrad, director, division of advanced energy systems, Office of Fossil Energy, U.S. Department of Energy was the second distinguished guest speaker at the conference. Conrad provided an overview of advanced energy systems, some of which offer business opportunities for the titanium industry. In his presentation, Conrad said research is underway to develop technologies that enable cost effective, environmentally sound electrical power via oxygen-fired combustion systems. He identified three national energy technology laboratories in the United States, located in Albany, OR; Morgantown, WV; and Pittsburgh.

Conrad said the world will face great energy challenges with ever increasing environmental constraints. As a result, advanced, more efficient energy power systems will be needed. He said the Materials Research Program is poised to have even greater impacts on future energy systems, developing novel materials for high-temperature applications; next-generation materials with higher strength and better oxidation resistance; advanced coatings for metals; and computational materials design and lifetime prediction for extreme environments.