World Industry Demand Trends Panel: September 14, 2009
Moderator: Michael G. Metz, VSMPO Tirus US

Mr. James M. Buch, TIMET
<u>Commercial and Military Engines</u>
Mr. Buch will review the primary aero engine demand drivers, update future engine programs, and conclude with how these factors will influence the likely long-term growth in titanium demand in the coming years, despite near-term uncertainties.

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Mrs. Dawne S. Hickton, RTI International Metals, Inc.
<u>Military Aerospace and Armor Demand</u>
Ms. Hickton will provide insight and analysis on the proposed overhaul of defense budgetary priorities and review important titanium-related programs like the F-35 Joint Strike Fighter, F-22 Raptor, the tanker replacement, V-22 Osprey, tactical vehicles, and other armor weapons. Near-term and long-term outlooks for military titanium will also be presented to assist attendees in business planning.

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Mr. Hunter Dalton, ATI Allvac
<u>Outlook for Commercial Aerospace Market and Titanium Demand</u>
Mr. Dalton will present a current view of the commercial aerospace market, a fundamental driver in the demand for titanium. Titanium is used extensively in new airframe designs and the jet engines that power them. OEMs adopt titanium for its excellent strength to weight ratios, mechanical properties, corrosion resistance, and heat resistance. His presentation will outline historic and forecasted commercial airframe build rates, and an estimate of titanium metal demand. This presentation will depict key challenges that face the titanium industry to sustain and increase growth as commercial aerospace expands in the coming decade.

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Mr. Kevin Cain, President, Uniti Titanium
<u>Industrial and Corrosion Applications and Markets</u>
The global economy is pulling out of its deepest recession in a generation. The opinion on the pace of the recovery is varied; some expect a powerful recovery, and others expect a slow climb over the next few years. Some economists believe we'll have an abbreviated rebound followed by another slump. Regardless of what shape this recovery is taking, it's apparent that two broad market influences have taken shape within the industrial sector. This presentation will review the influences that consumer demand and infrastructure requirements will have on the recovery of the industrial titanium market sector.

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Mr. Yasuyuki Tozaki
Sumitomo Metal Industries, Ltd.
President of the Japan Titanium Society
<u>Titanium Industry Outlook in Japan</u>
After Japan's titanium industry recovered from the slump caused by the impact of the 9/11 terrorist attacks in 2003, it has steadily recovered to the extent of achieving the record highs in production of both sponge and mill products in 2008.

Dr. Tozaki will provide an overview of the Japanese titanium industry: current conditions, how the recent economic recession affected the industry; and influence that demand for different applications is having in production (seen through shipments), as well as trends in exports and imports.

After introducing the activities of the Japan Titanium Society (JTS), which have contributed to the development of the world titanium industry, and the applications characteristic of Japan's domestic market, Dr. Tozaki will make some proposals for the world titanium industry's further development.

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Mr. Xiao Dong Wang, China Titanium Association (CTA)
Report on Titanium Industry of China
China is experiencing and encountering development opportunities, such as China's plan to build big aeroplanes, the circumlunar statellite Chang'e-1 project, space station project, power station project, marine service station, petroleum and gas exploration project, and those that of rapid growth industries such as steel industry, non-ferrous metallurgy industry, chemical industry, automotive industry, sport and recreational industry, etc., have demanded higher qualities and volume of titanium products, therefore the titanium industry of China still has a big room for growth.

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Mr. Michael G. Metz
VSMPO Tirus US
Mr. Metz will provide a summary of the panel presentations, creating a market overview from each of the various pieces discussed by the panelists so the attendees have a complete picture of the total demand for titanium worldwide.

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Automotive Panel: September 14, 2009

Moderator: Kurt Faller, Ti Solutions Consulting

Tomaz Bucar PhD , Akrapovic d.d.
A Development Study Of Titanium Exhaust System For Sports Cars
One of the most important reasons for using titanium in exhaust systems is weight reduction, which brings better results both in the vehicle performance and fuel efficiency. The application of titanium and its alloys to automotive parts has grown dramatically in the last years. Exhaust system applications, including mufflers and exhaust pipes, have been a main target for titanium in cars. In addition to weight savings, the visual appearance of titanium as well as performance with titanium attracts customers. A car exhaust system looks simple at first glance. But a closer look shows that it is a complex system that has a significant effect on the performance of a racing or a regular sports car. Successful design of a titanium exhaust system commences with considering the conditions to which a particular exhaust components are to be exposed. The titanium alloy should be selected according to the operating conditions, especially the maximum operating temperature under upset conditions. In turn, the physical and mechanical characteristics of the alloy selected can dictate some design features. Therefore the titanium exhaust system design has been improved by the help of computer-aided design (CAD) in combination with thermal, structural and fluid dynamic analyses based on the finite-element method (FEM). Usually, the final exhaust form is confirmed after intensive and successful experimental analyses of physical prototypes. The aim of this paper is to demonstrate the development process of the titanium exhaust system using different numerical analyses as well as experimental methods. Finally some of the newly developed Akrapovic lightweight and high performance titanium exhaust systems for sports cars are presented.

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Silvia Gaiani PhD, Akrapovic d.d.
Investment Casting Of Titanium Alloys
During last year, Akrapovic Company established inside its plant of Ivancna Gorica, Slovenia, an investment casting facilities (lost wax process) dedicated to titanium and reactive alloys.

The reasons for acquiring this new technology are multiple, as affirm the company in consolidating experience and technical knowledge in titanium alloys transformation, and furthermore allow the production of components with dedicated shapes and reduced thickness to be used in our exhaust systems production.

Another important aspect to take in to account concerning this process is the possibility to make use of titanium scrap originated by other technological processes (tube production, bending, deep drawing, welding ...) as initial raw material for casting operation.

In order to develop our specific knowledge about different casting materials, a considerable amount of characterization test has been performed, with the aim to observe the mechanical, physical and metallurgical properties of different types of titanium alloys.

For the specific application of casted parts in our exhaust systems, good thermal properties and improved oxidation resistance is obviously required. In order to inspect this specific field of application, wide ranges of oxidation tests at different temperatures have been performed in cooperation with Material Engineering Department of Modena University, in Italy.

This contribution will present and discuss the main results obtained after more than six months of tests. Moreover, some ideas and methods concerning how these results can be implemented and became profitable for production will be also displayed as well.

All the research work and development activities performed in the field of titanium casting have been considered also with the clear objective to gain a high level of specific knowledge, which can allow Akrapovic Company to consolidate its own business also in different fields of application than automotive industry.

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Kurt Faller, Ti Solutions Consulting
<u>New Fuel Efficiency Standards Provide Large-Volume Titanium Opportunities</u>
A confluence of circumstances brings tremendous large-volume opportunities to the titanium industry: 1) US consumers are finally sensitized to fuel economy, 2) US federal emissions and CAFE standards have tightened, and 3) the global titanium industry has excess capacity, well-matched for the opportunities.

Fuel price peaks in 2008 increased US demand for small cars and hybrids, but true demand remains for larger vehicles, now with heightened interest for better fuel economy. In addition, the Obama administration recently passed the first major change to US corporate average fuel economy (CAFE) standards and emissions testing in 25 years. Phased in between now and vehicle model year 2016, the global auto industry urgently needs to implement technologies to meet the new standards.

The most cost-effective means for large vehicles to deliver better fuel efficiency is through light-weighting and turbocharging. Titanium is ideally suited to achieving both of these goals, with 35-70 kg per vehicle weight-savings through use of titanium springs and exhaust, and certain of titanium’s unique properties making it the best choice for turbochargers. Previous titanium development programs, carried out in the late 1990’s were “put on the shelf” out of concerns for titanium industry capacity and pending CAFE changes.

Since that time, the titanium industry has dramatically expanded sponge and melt capacity, while aerospace production delays and the weakening global economy have left the industry underutilized. Compounding the titanium industry’s dilemmas is that much of the new capacity won’t be qualified for aerospace use for a number of years. Automotive applications present large-volume opportunities that once established have relatively little annual volume volatility. The timing is right for large-volume titanium for the auto industry.

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Luncheon and Keynote Address: Monday September 14, 2009

AIRBUS GLOBAL MARKET FORECAST
Mr. Simon Pickup, Director of Business Operations and Analysis for Airbus

The Airbus Global Market Forecast (GMF) gives a detailed analysis of world air transport developments, covering nearly 300 passenger and freight traffic flows, as well as a year-by-year fleet evolution of the world's aircraft operators, through fleet analysis of nearly 700 passenger airlines and 177 freighter operators.

Highlights include a review of significant developments that have influenced passengers and airlines, affecting the shape and direction of the aviation industry, as well as determining the level of future demand around the world.

The GMF takes into consideration international travel, equipment trends, load factors and frequencies, the demand for more fuel and eco-efficient airliners, plus the need to replace older generation aircraft.

Network evolution, in response to population growth and resulting air traffic congestion is discussed, as is the role of hub and secondary operations. Airport infrastructure challenges, environmental constraints and the needs of emerging and potentially emerging nations are considered.

All of these factors result in a projected demand, by number and dollar value, for new aircraft, by region, nation and size, from very large to small single-aisle aircraft.

Airbus, a subsidiary of EADS based in France, produces about half of the world's jet airliners. Mr. Pickup has over 16 years of experience in airline marketing, primarily helping airlines analyze aircraft performance, economics and fleet planning.

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Consumer Applications Panel: September 14, 2009

Moderator: Edward Rosenberg, Spectore Corporation

Akemi Tanabe, HORIE Corporation

Examples of New Titanium Consumer Products Produced by Coloring and Etching Technologies

Titanium and its alloys are traditionally used for aerospace and corrosion resistance applications. Over the last twenty years, however, titanium's applications for consumer goods such as golf club heads, sporting goods, architecture, cookware, jewelry, house ware, office ware and motorcycle mufflers have increased significantly. Horie Corporation has developed many kinds of new titanium consumer goods by using new technologies such as anodized oxidation coloring, etching, grain size control by recrystalization, and Horie's proprietary surface treatment. The main approach of Horie is to produce specialized high value titanium consumer goods which can utilize the unique characteristics of titanium such as photo-catalysis and biocompatibility to humans. This presentation will show many examples of Horie's new products. The technical approach for developing these new products will also be discussed.

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Steve Midgett, Extrusion Patterned Metals Corporation

The Cutting Edge

Three hundred and fifty years ago a Japanese swordsmith invented the metal lamination technique of Mokume Gane (wood grain metal). The technique was used to adorn Samurai swords which are widely recognized as some of the most remarkable metal objects of all time. Renowned not only for their great beauty and functionality, these swords represented mans highest metallurgical achievements. Until modern times, the techniques used to create them have been tightly guarded secrets. Through tireless research and experimentation a handful of western metalsmiths have unlocked those secrets and continue to innovate new processes for the production of patterned metal laminates. The latest, most cutting edge technology makes possible the manufacture of exotic metal laminates that the swordsmiths of old could not even have imagined. This presentation will show examples of historical Japanese and modern western work as well as the latest high-tech incarnations of the technique.

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Jim Dippel, Ti Squared

Making Competitively-Priced Titanium Components For Commercial /Industrial Markets Using Low-Cost Manufacturing Methods

The words “low cost” and “titanium” are rarely used in the same sentence. As a material developed for the aerospace industry, titanium has been relegated to expensive, highly engineered components. The unique properties of titanium are rarely found in every day products that can benefit from its high strength to weight, excellent corrosion resistance, superior heat transfer characteristics and general popularity as an exotic metal. Low cost manufacturing processes for consumer products in steel and aluminum are mature and stable; however it wasn’t until the golf industry discovered its benefits that titanium became more of a commodity. Now, methods like lean manufacturing with just-in-time delivery are used to lower the price of titanium components. Rapid prototyping and concurrent engineering are frequently used to assure the shortest possible cycle time from design to market. Proprietary methods to reduce raw material costs have been developed. Processes such as chemical milling and heat treatment can be eliminated in most cases when there is no added benefit to the function of commercial components.

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Edward Rosenberg, Spectore Corporation

The Production and Sale of Consumer Products In A Global Recession

The extraordinary economic events of this past year have drastically reshaped history and significantly altered the way society thinks and lives. With few exceptions, this global recession has dramatically impacted nearly every industry and market segment.

Among those most severely affected were companies involved in the production and sale of consumer products. What further exacerbated the dilemma were the persistent government warnings against any form of “discretionary spending”.

As retail sales plummeted in all sectors, icons of industry fell in dramatic numbers causing a ripple that further perpetuated downward spiral to their support systems and vendors. This recession clearly demonstrated the delicate balance and connectivity of our industries. What started at the retail counter impacted the manufacturers, and then the material suppliers.

Yet those with vision and fortitude often find that nestled within great challenges, there are abundant benefits and opportunities. It is events like these which force us to reevaluate conventional wisdom and business practices to see if they are still viable or need to be radically changed to meet the new environment. This event should be thought of as an evolutionary process. It will prove to be a chapter in the history of industrial development and as such should evoke an even greater sense of urgency to create our way to the future.

Being that this presentation is directed at the consumer product industry, we will use that context to demonstrate the value of innovation.

Today’s consumers are better educated, more aware, and have greater access to information than ever before. Their expectation and appetite for new and improved products, technologies, and visual appeal is constant and continually elevating. If we are to build sustainable businesses and be successful long term we must meet those needs. It is that philosophy, innovative products and services coupled with a commitment to exceeding consumer expectancies that has enabled companies like Apple, IBM, Wal-Mart, Skype, Enterprise, South West Airlines and others to perpetuate growth and consumer equity. If it wasn’t clear until now, consumers drive our economies.

This panel is representative of our industry’s commitment to development and growth of consumer products. In the jewelry industry titanium has pioneered the way to the dominance of the new category defined as “contemporary metals”. In less than 25 years it has secured well over a 25% market share in the wedding band category world wide. It has journeyed from obscurity to the cover page of renowned international publications and featured in 30 minute segments on major networks throughout America, Europe, and Asia. The model works. Th consumer is waiting for innovation in all categories. Our time has come.

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Parts Manufacturing Panel: September 14th, 2009
Moderator: Stephen R. Giangiordano
RTI International Metals, Inc.

Jeff Bernath, Edison Welding Institute
Friction Stir Welding And Hybrid Laser Welding Provide New Solutions For Titanium Manufacturing
Welding of titanium is a challenging process that has been dominated by conventional arc welding, primarily Gas Tungsten Arc Welding (GTAW), and is prone to weld contamination and defects. Operator skill and excellent gas shielding are required to produce welds of inspection quality. The GTAW process is inherently slow with relatively high heat input resulting in low production rates, weld induced distortion, and grain growth that can lower weld properties.

Friction Stir Welding (FSW) and Hybrid Laser Welding (HLW) are two new methods of welding technology that have advanced rapidly to address many of these concerns and are being applied readily to titanium applications. Both processes have gone through extensive process development for many titanium applications with great success and commercially available systems are being implemented at manufacturing facilities to improve welding capabilities.

FSW is a solid state process that can be used to weld titanium in a single pass up to 1.00-in (25-mm) thick. The process dramatically increases production rates while producing a low heat input weld with no melting. FSW is entirely automated using machine based CNC type controls that can join material in plate, tubular, or complex geometries. This process produces a weld that is extremely similar to the base material in all regards with matching mechanical properties. Due to the similar weld microstructure, this process is an excellent choice where mechanical properties are critical such as in structural or fatigue sensitive components. Through grain size matching, this process can also be readily applied to components prior to hot stretch forming or Super Plastic Forming (SPF) with even forming results through the weld region. FSW is an excellent option for producing near net shaped components or joining large sheets of material required for an assembly with little to no distortion.

HLW is a competing fusion welding process that combines Gas Metal Arc Welding (GMAW) and Laser Welding (LW) to produce welds with similar benefits. The hybrid process combines the robustness of GMAW with the penetration of LW to produce high quality and high productivity welds in an automated environment. This process is capable of welding in excess of 0.50-in (13-mm) thick titanium at ever increasing travel speeds through the use of fiber laser technology. The result is a low heat input weld with excellent mechanical properties and low distortion. The HLW process can also be used to stabilize welding in thin section titanium.

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Sid Clouser, SIFCO Applied Surface Concepts
Selective Plating on Titanium Alloys

A selective electroplating process was researched which produces adherent coatings on titanium alloys. The inherent difficulty caused by the oxide film with plating a coating onto titanium alloys was overcome by the use of a selective electroplating process. The surface of titanium 6Al-4V was electrochemically treated to increase surface area, reduce the oxide film, and immediately apply an adherent metallic coating by brush plating. The anodic pretreatment etched and microroughened the surface while the cathodic pretreatment reduced the oxide. Rinsing between steps was avoided to prevent reoxidation. A nickel strike electrolyte was applied directly into the anode – cathode gap to displace the pretreatment solution while the titanium surface was maintained under cathodic potential control. The thin nickel strike layer plated on the titanium 6-4 surface had good adhesion and provided a substrate for subsequent deposits. The adhesion of the coatings to titanium 6Al-4V was verified by passing bend, chisel, heat-quench, scribe, and tape tests and demonstrating > 6,000 psi tensile adhesion. The non-hydrogen embrittlement nature of the process was demonstrated by static loading at 85% yield strength without fracture. The coatings can improve the wear, galling, conductivity, and lubricity of the Ti 6Al-4V surface and are useful in brazing, resizing and repair applications

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Prof. Andrzej Nowotnik, Rzeszow University of Technology
Laser Surface Alloying of Titanium Alloy with Boron Nitrides
The intention of this paper is to provide a brief overview of the research on surface layer modification of Ti-6Al-4V two-phase titanium alloy using laser alloying technique. Therefore the samples coated by graphite and BN powders were treated by laser beam in stream of nitrogen in order to form martensitic ?' phase, titanium nitrides, titanium carbides and borides that form as a consequence of the laser irradiation. Topography of the surface of laser melted layer was investigated. The laser melted zone was examined and its microstructure and phase composition were determined. Microstructural analyses were carried out using Epiphot 300 optical microscope and Novascan 30 scanning electron microscope equipped with EDS X-ray detector for compositional analysis. The phases were identified by X-ray diffractometry (Philips) with CuKα radiation. The Vickers microhardness under the load of 1.96 N and thermo-electric power was measured on the cross-sections of treated surface.

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Presenter: Jeff Bernath, Edison Welding Institute
Developments in High Power Ultrasonic Manufacturing Processes & Bi-Metallic TPS
Developments on the application of high power ultrasonics to the ultrasonic additive manufacturing (UAM) and ultrasonic machining (UM) processes will be reviewed. Thus, work is underway on the development of a very high power ultrasonic additive manufacturing (VHP UAM) system. The UAM process involves ultrasonic welding of successive layers of metal tape, with periodic machining operations, to form a final, net shape solid object. Higher powers are required in order to permit welding thicker, wider tapes of more advanced materials at higher production speeds and for larger parts. A 9.0kW "Push-Pull" ultrasonic welding system has been developed and installed on a test bed, to prove out basic welding capabilities. Recently, EWI was awarded a multi-million dollar award from Ohio's 3rd Frontier Program to complete the development and commercialization of the VHP UAM system. Recent progress on applying VHP UAM to several advanced materials (Ti 6-4, Cu, Al 6061 and 304 SS) will be reported, while the main features of the VHP UAM system, presently under construction, will be reviewed.

Work on ultrasonic machining – where this term refers to developments focused on ultrasonics as applied to traditional machine tool processes, such as turning, drilling, and milling – has been underway since 2007, with special reference to applying high power to the twist drilling process. Progress on development of drilling performance data for various alloys will be reported, as well as improvements made in the drilling equipment. The adaptation of ultrasonic drilling to high production drilling systems will also be described. Adding this capability to machine tools is expected to increase productivity and feature control abilities in a substantial manner.

Bi-Metallic (Nb/Ti) TPS (Thermal Protection System) aka, honeycomb materials have been developed through a Phase I program and will be presented. These two materials have been successfully joined in the proper ratio creating higher temperature TPS and the possibility for future cost effective acreage coverage at an affordable price.

Medical and Dentistry Applications Panel: September 14, 2009
Moderator: Howard Freese, ATI Allvac

Conrado Ramos Moreira Afonso, PhD, Laboratório Nacional de Luz Síncrotron (LNLS)
Hardening mechanism of phase separation in β Ti-35Nb-7Zr-5Ta alloy for implant applications
Titanium alloys are widely used in medical and surgical devices. However, some concern has been expressed about Ti–6Al–4V alloy because of the alloying elements V and Al. When replaced by certain β-stabilizer elements (Nb, Ta, Zr, Mo), the newer β titanium alloys (such as Ti-35Nb-7Zr-5Ta) have certain advantages over CP grades and α+β alloys for biomedical applications due to higher specific strength, corrosion resistance, improved biocompatibility, and, for TNZT, a much lower elastic modulus around E = 55GPa (closer to E_{bone}= 30GPa). The mechanical properties of Ti alloys can be adjusted through compositional variations, thermo-mechanical processing and microstructure control [1]. Therefore, this work aims to clarify the hardening mechanism on β TNZT alloy using different characterization techniques.

Ingots (50 g) of Ti-35Nb-7Zr-5Ta (wt%) alloy were arc-furnace melted in $Ar_{(g)}$ atmosphere homogenized, hot rolled, solubilized, and finally aged at several temperatures, from 200 to 700°C for 4 h [2]. Microstructure characterization was performed using X-ray diffraction (XRD), optical microscopy, scanning (SEM) and transmission electron microscopy (TEM). Mechanical properties variation was monitored through Vickers microhardness (HV) measurements for different aging temperatures (200 to 700ºC for 4 h).

XRD did not indicate the precipitated phases during the 4 h aging up to 400°C, while in a 90 h aging the precipitated phases were α and ω. The 4h aging showed that the highest hardness values were found when aged at 400°C with an increase of ~20% in hardness 336±9 HV for the TNZT alloy. TEM image for sample aged at 400°C/4h presented the coexistence of two separated phases (β and β'), which can be related to the hardness improvement. The combination of yield strength, hardness, and very low Young's modulus suggests that the Ti-35Nb-7Zr-5Ta alloy is suitable for medical applications such as load-bearing orthopedic implants.

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John Disegi, Synthes USA

Ti-15Mo for Trauma Applications

Commercially pure (CP) titanium and $\alpha + \beta$ titanium alloys represent a major class of materials that have been used for a multitude of orthopaedic trauma applications. These titanium materials have a successful track record as the material of choice for a wide array of implant products. Ti-15Mo represents a newer generation of beta titanium alloys that have been developed to take advantage of desirable alloy attributes such as low modulus of elasticity, improved bending properties, and enhanced fatigue life. The ability to tailor Ti-15Mo heat treatments to provide either a beta or an alpha + beta microstructure offers many design opportunities.

This presentation briefly describes alloy design history and includes modifications to the binary alloy that were proposed to overcome thermal handling difficulties and microstructure instability. Notch tensile strengths and notch strength ratios are compared for beta annealed Ti-15Mo and conventional titanium implant alloys. Smooth and notched corrosion fatigue data in DI water and Ringer's solution is documented for Ti-15Mo, TAV ELI, and CP Grade 4. Improved reverse bending and bending fatigue properties are compiled for small maxillofacial plates. Bending stiffness, yield, and displacement are compared for Ti-15Mo and CP Grade 4 Distal Radius Plates that are used primarily to stabilize complex intra- and extra-articular fractures of the wrist.

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Dr. Mari Koike, Baylor College of Dentistry Texas A&M Health Science Center

Electron Beam Melting for Rapid Prototyping of One-Component Biomimetic Dental Implants

Currently, endosteal dental implants are made of titanium alloys which consist of the root-form fixture and transmucosal abutment. Traditional implants are placed in the jawbone after a socket hole is drilled to accept endosteal implants. With the advent of electron beam melting (EBM), we developed the method for micro-CT scanning of teeth in need of extraction and rapid prototyping of one-component biomimetic implants that fit within the existing root socket. In view of potential applications of these products, we characterized some properties relevant to dentistry of Ti-6Al-4V ELI specimens prepared using EBM equipment (Arcam A2, Arcam, Sweden). We tested tensile properties, hardness, grindability and corrosion resistance. We also examined specimens implanted in rabbits. We will summarize these results in the presentation.

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Michiharu Ogawa, Daido Steel Co., Ltd.

Non-toxic and Good Cold Formability Titanium Alloys for Medical Applications

Ti-6Al-4V ELI and Ti-6Al-7Nb was widely applied to medical application because of their high strength and high corrosion resistance. However these materials have not good cold formability, so it is difficult to apply for cold drowning wire. Recently beta titanium alloy, Ti-Nb-Ta-Zr was developed for biomedical application. This material has non-toxic and good cold formability. But its contain high melting point metals such as Niobium and Tantalum, so it is required to attention to manufacturability. In order to supply more economical and stable price alloy, we developed new beta alloy Ti-Nb-Cr-Sn which was composed of non-toxic and non-allergic elements like Niobium, Chromium and Tin. This New Ti-Nb-Cr-Sn alloy has non-toxic, low elastic modulus and good cold formability.

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Processing Advancements Panel: September 14, 2009
Moderator: Stanley Seagle, Consultant

W. Jürgen Ammerling,Friedrich Kocks GmbH
3-Roll Technology – The Ideal Process To Produce Titanium Wire Rods And Bars
"3-roll technology is applied in long product hot-rolling applications where traditional 2-high rolling is unable to produce a defect-free, close tolerance product. In certain applications, the 3-roll process can allow the economical use of hot rolled product as a replacement for drawn or turned product."

These general statements will be validated in the presentation with detailed explanation. It will be shown in particular why the 3-roll technology with its high deformation efficiency is ideally suited to roll wire rod and bars from difficult to process materials such as Titanium.

Typically, this equipment becomes economical at production rates of greater than 2,500,000 kg/year. The productive capacity of the mill is much higher and realistic production rates can easily exceed 10,000,000 kg/a.

The hot-rolled quality of rod or bar produced on a 3-roll system can provide a significant competitive advantage. Surface finish and dimensional tolerances far exceed the quality of material produced using a two-roll configuration. This allows the economical production of hot rolled Titanium rods and bars with optimal properties that allow for problem-free cold processing.

Introduced in 1954, the 3-roll technology for wire rod rolling was an evolution of technology used for the reduction of seamless tubes. In the period since its introduction, the 3-roll technology has undergone significant evolution with regards to machinery, automation and process. The result is a precision hot rolling mill that allows easy and trouble free operation. This evolution will be explained in detail.

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Bernd Friedrich, RWTH Aachen University
Recycling of Titanium-Aluminide Scrap
Due to high scrap generation during the manufacturing of semi-finished and final products made from titanium and titanium alloys, recycling shows a great potential to substitute titanium sponge, economize the titanium market and to apply secondary low cost titanium in new applications. This article deals with the development of a new recycling process for Titanium-Aluminide scrap, which is presently downgraded as a deoxidation agent in steel production. This process is an innovative combination of industrialized processes like Vacuum Induction Melting (VIM), Metallothermic Desoxidation, Pressure Electro Slag Remelting (PESR) and Vacuum Arc Remelting (VAR).

The preliminary melting of scrap is done by VIM using specialized ceramic linings and includes pre-deoxidization by metallothermic reactions. The second process step is final deoxidization by Pressure-ESR using a continuously activated Ca-reactive slag. Finally VAR removes small slag inclusions as well as dissolved Ca and allows for hydrogen degassing. For each step the special equipment requirements, the metallurgical challenges as well as opportunities are described. Thermochemical modeling on refractory reactions in contact with liquid titanium alloys, on the involved deoxidization by calcium metal, on the chemistry of deoxidation by active slags and on the removal of excess Ca and H in VAR are presented in the fundamentals section.

The paper will show, as a significant innovation for the Titanium industry, the results of semi-pilot scale experiments at IME for the production of 30 kg VIM-PESR-VAR-ingots from 100 % scrap regarding process window definition and material characte-risation. The presentation will close with a cost benchmark estimation against pri-mary TiAl-production.

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Alain Honnart, Metalvalue Ltd.

Innovative Process To Manufacture Tailor-Made Titanium Products

Present processes to manufacture titanium long products are hindered by a long supply chain implying plants often located far apart and are practically limited to the use of standard specifications and alloys which are available in relatively large lots of at least a few tonnes. A group of European companies has conducted a research project aimed at developing a “fast track” supply chain with high flexibility allowing to manufacture small quantities of tailor made alloys in record time (down to a few weeks) and at strongly reduced costs.

The process has been developed for the production of extruded tubing and profiles, which the involved companies can deliver machined and bent to customers' specification.

Patents are pending and trial orders have already been manufactured on industrial equipment. The originality is both in the process itself which is being patented, but also in the cooperative R&D performed between nearby companies belonging to 2 industrial groups:

-PFW Aerospace AG in Speyer Germany: a tier-one supplier of Tubing, Ducting, Cargo Loading Systems and Structure to Airbus, Boeing and other aerospace constructors. PFW is a subsidiary of Safeguard International.

-GFE Metalle une Materialien Gmbh in Nuremberg Germany, a manufacturer of master alloys and other special products (powder, aluminides, etc..). GFE belongs to AMG Advanced Metallurgical Group NV of which Safeguard International is a major shareholder.

-Cefival in Persan –France: a specialist of the hot extrusion of titanium tubing and profiles, with a long experience of supplying the aerospace industry and other titanium consuming industries. Cefival is controlled by the Italian Group Calvi.

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Claudia Moeller, RWTH Aachen University

Molten salt electrolysis of Titanium using a TiO_2-C composite anode in halide electrolytes

The currently used Kroll process for Titanium production has many techno-economical disadvantages, that even the inventor thought his process would be substituted within a few years. But even today no alternative has succeeded in implementation. However today's increasing demand for Titanium requires a cheaper and quicker production process more than ever. Since all commercial light metals are produced by molten salt electrolysis due to their ignoble character this process seems to be the promising way for the production of titanium as well. Hence many electrochemical approaches have being tested in the past and at the moment, but none of them has reached a stable production state until now.

At RWTH Aachen University investigations are ongoing in order to establish a molten salt electrolysis of titanium using a TiO_2/C composite powder anode. The main challenge of this electrochemical process is to dissolve the right titanium ions below 600 °C. The main idea of the invented process is based on the following principle. In a titanium halide (Hal) enriched and, halide based electrolyte, $TiHal_x$ is split into Ti^{x+} and xHal- by a defined potential (current density). Subsequently Ti^{x+} is deposited at the cathode and Hal-atoms form at the anode. In “statu nascendi” the Hal-atoms react with the components of the composite anode consisting of TiO2 and C. $TiHal_x$ is formed again, which is dissolved in the electrolyte.

To investigate the technical feasibility of this process, a research group at IME develops the concept of this composite anode in a lab scale molten salt electrolysis cell since 2003. A suitable electrolyte with a melting point below 550 °C has been determined and the process window is set by electrochemical methods. The paper will give an detailed overview of the individual projects tasks and will show that the process invented in Aachen is applicable for the synthesis of titanium.

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Friedrich J. Reitz, PhD, RWTH Aachen University IME Process Metallurgy and Metals Recycling
Tracing Ca and F during Remelting of Titanium-Aluminides in ESR and VAR
Pressure Electroslag remelting (PESR) of titanium and its alloys under a Ca-CaF2-CaO slag has been under investigation as a suitable means for the refining and de-oxidation of scraps and intermediates from alternative titanium winning processes. Little is known on the effect of Ca and F on the properties of the remelted materials, yet assumptions are that these elements would proof to act disadvantageous on me-chanical properties. On the other hand, recent research on titanium aluminides has shown positive effects of fluorine surface treatment on high temperature corrosion behaviour.

A first modelling of calcium and fluorine activities in CaF2-based slags suggest that a solution of Ca and F in the melt can be expected in the ppm range during PESR of titanium and titanium aluminide alloys. Thus the concentration of the elements should be analysed and tracked precisely when evaluating the suitability of alternative remelting processes for recycling purposes and also with regard to the properties of titanium material obtained by these processes. This paper presents a review of the analytical techniques presently applied to analyse traces of Ca and F in titanium and titanium aluminides. Samples of titanium aluminides have been prepared by ESR ,VAR subsequent combination of the two processes in order to demonstrate the concentration changes of these elements before and after the remelting and highlight analytical possibilities and challenges.

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Military Panel: September 14, 2009
Moderator : Gus Gustin, TIMET

Stephen Luckowski and Delfin Quijano, US Army ARDEC
New Titanium Add-On Armor Provides Enhanced Soldier Protection in a Lightweight Solution
The dynamic nature of current U.S. military ground force operations in Iraq and Afghanistan has put increased emphasis on the need for lighter weight, add-on armor solutions to a number of vehicle platforms. The U.S. Army Armament, Research and Development Center (ARDEC) is the Army center of excellence for lightweight and novel armor solutions. ARDEC has numerous titanium innovations around emerging welding and continuous-melt furnace technologies, as well as advanced, production-ready manufacturing processes to rapidly and intelligently design titanium solutions currently being used in Stryker, Abrams, and Bradley combat vehicle systems.

Based on the titanium-based Gunner Protection Kit (GPK) that ARDEC successfully designed, developed, and deployed, the Special Operations Command (SOCOM) asked ARDEC to do the same for a lightweight titanium seat for the SOCOM Humvee (Ground Maneuver Vehicle – GMV). The titanium armor seat increases the level of personal protection for the driver and passengers with increased ergonomics. In addition to the GMV, the new titanium armor seat is also being developed with application for most of the U.S. Army’s Humvee variants, including the M1114, M1152, and others.

ARDEC was able to leverage the design, material technologies, and processes developed for the titanium SOCOM GPK to rapidly produce these GMV titanium seats and enable accelerated delivery to the warfighter at a drastically reduced cost, ensuring long-term producibility and availability. This presentation will discuss how the role of titanium in add-on armor protection continues to expand; will highlight the titanium seat as well as prior solution successes as well as plans to develop a modular crew capsule.

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Jeffrey Schutz, US Army RDECOM-ARDEC
Novel Processing Technique for Titanium Weld Wire
As the military services, especially the U.S. Army, move toward transformation, titanium has become vital to meeting transportability, maneuverability and survivability requirements. Welding and prototype fabrication are playing an increasing role towards the implementation of titanium into future weapon systems. Cost continues to

be a barrier to entry for insertion of titanium. To help mitigate some of the cost burden, all aspects of the supply chain are examined for potential savings. A recent feasibility study has demonstrated the technology to produce titanium weld wire in a more efficient and cost effective manner, resulting in savings in both dollars and logistics lead-times for the DoD. The key to the success of this program relies on the ability to directly roll a cast titanium structure as opposed to the more conventional method that hot forges very large diameter ingots. Present technology incorporates a process of many forging and rolling operations of ingots with starting diameters up to 31 inches. The proposed process significantly reduces the number of operations (deformation steps) required by reducing the starting diameter to less than 4 inches. The presentation will discuss the results of the project, which demonstrated that 4-inch diameter cast material can be processed by hot rolling and wire drawing to final sizes of 0.060”, 0.045” and 0.035” inch diameter wire.

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Michael Trzcinski, Defense Metals Technology Center

<u>Armor Plate Using 100% Titanium Scrap Solids Evaluated by ARDEC</u>

The US Army Armament Research, Development and Engineering Center (ARDEC) at the Picatinny Arsenal has been able to justify the use of titanium by using life cycle costs and the need for increased performance for some battlefield systems. A larger amount of titanium can be used if other applications can meet similar requirements or if the cost of titanium can be reduced. The Defense Metals Technology Center (DMTC) commissioned a project to evaluate the use of scrap titanium solids in armor plate for potential cost reductions. In addition, economic comparisons were developed using historical prices of five types of scrap and sponge.

Titanium plates, made from 100% Ti-6Al-4V scrap solids, have passed major milestones that could enable ARDEC to reduce their cost of titanium for armor applications. The presentation will report on the material properties, ballistic performance, and how and when 100% scrap solids prove more favorable than traditional methods. When the Army purchased ½” plate in 2008, it was determined that they could have achieved a savings of $4.72 per pound if the plates were made from 100 % scrap solids.

Part of the initiative was to organize a team of small manufacturing companies and organizations: Mega Metals, MetalWerks, the Picatinny Arsenal, DSN Innovations, Truefit Solutions and CostVision. These companies offered their expertise in project management, scrap acquisition, melting, supply chain management, manufacturing cost models, and economic research to build the business case for taking this alternative approach to sourcing titanium.

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Cornel A. Holder, Defense National Stockpile Center

<u>DNSC Expands Mission ...Building a Better Defense</u>

The National Defense Stockpile (NDS) was created in 1939 to preclude dependence upon foreign sources of supply in times of national emergency, Over the years, the National Defense Stockpile fell under the auspices of different agencies for administration and management. Between 1949 and 1988, the General Services Administration and Federal Emergency Management Agency were responsible for the NDS. In 1988, the responsibility for the program was delegated to the Secretary of Defense. The management and overall policy responsibilities for the NDS rest with the Undersecretary of Defense for Acquisitions, Technology and Logistics as the Stockpile Manager. Program management was assigned to the Defense Logistics Agency (DLA). The Defense National Stockpile Center (DNSC) was established within DLA to manage the program.

The requirements for materials in the NDS were based on military and national security scenarios which resulted in build-up and reduction phases. In 1992, the requirements determination process concluded most of the materials held in the stockpile were excess to defense industrial and essential civilian needs. Congress authorized the sale of the excess materials. There were 90 commodities stored in 85 locations then and today there are 24 commodities stored in 11 locations. The remaining inventory is valued at about $1.4 billion.

Concerns regarding the global availability of strategic and critical materials by both DoD and Congress resulted in a re-examination of the need for a reconfiguration of the NDS. Congress, subsequently, passed legislation and directed DoD to review the current NDS program and assess the need to reconfigure the NDS to meet current and future strategic and critical material needs. The National Materials Advisory Board of the National Academy of Sciences (NAS) was commissioned to conduct an independent study to assess the effectiveness of the NDS to respond to current needs and threats. The NAS study addressed two areas: (1) the need for a new NDS strategy to satisfy materials needs of DoD and (2) creation of a new system for managing the supply of materials. In 2008, the Office of the Undersecretary of Defense for Industrial Policy chartered a working group, comprised of representatives from the military services, other DoD agencies, Dept. of Commerce and the USGS, to respond to the congressional concerns. The consensus of the group was that the NDS should be reconfigured to be more responsive to DoD and essential civilian material requirements, particularly in light of the U. S. manufacturing growing dependence on the global marketplace. A report outlining the working group's findings was forwarded to Congress in April 2009. Mr. Cornel Holder, Administrator of DNSC, testified before the House Armed Services Committee, Subcommittee on Readiness, to discuss the proposed reconfiguration. This information was favorably received.

The reconfiguration will result in the transformation of the NDS into the Strategic Materials Security Program (SMSP) to enable the Nation to more quickly adapt to current world market conditions and ensure the future availability of materials required for defense and national security needs. The SMSP will include a broader internal DoD profile with a reduced footprint for actual stockpiling activities, an expanded interface with other federal agencies, greater latitude in entering and exiting markets and flexibility to develop risk-based value propositions. The proposed reengineered program will be more properly align to sense and respond to today's military material needs in scenarios ranging from non-conflict to full mobilization. Today's military must respond to asymmetric national security threats wherever and whenever they occur – frequently on several simultaneous fronts.

The DNSC plans to mobilize its organization to address an expanded mission to meet the needs of DoD and essential civilian agencies. The expanded mission will include the following support: provide constant surveillance of global marketplace to assess changes in market conditions, geo-political issues, economic trends, reduced access to foreign sourced material and loss of access due to natural/man-made disasters; impacts of MERIT and REACH that could jeopardize the availability of materials and determine potential risk to existing supply chains. DNSC would recommend a strategy to minimize any identified supply disruptions ranging from executing strategic sourcing contracts, traditional stockpiling contracts and partnering with foreign nations to potentially reduce lead times and ensure material availability to meet specified requirements at predictable/steady prices.

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William Gooch, US Army Research Lab

<u>The Design and Application of Titanium Alloys to U.S. Army Platforms</u>

Titanium alloys have long been used for reducing system weight in airframe structure and jet engine components. The high cost of titanium, however, has historically prevented the application to military ground vehicles. In recent years, the cost of titanium has fallen relative to the cost of composite and ceramic armors and titanium is now a valid option for some Army applications, whether for weight reduction or improved ballistic performance. The distinct advantages of low density, high strength, a large competitive industrial base, and well established forming and shaping techniques establishes titanium as an excellent material for many military applications. The U.S. Army Research Laboratory has invested significant research efforts in understanding the material processing requirements for ground versus aerospace applications and this paper will provide an overview of that research. A major concurrent effort has been the amending existing military specifications to allow the use of lower cost, higher oxygen content titanium alloys that meet specific ground applications. The paper will end with a review of some of the current applications of titanium in use worldwide.

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World Industry Supply Trends: September 15, 2009
Moderator: Irvin Brown, Perryman Company

John Churley, United Alloys & Metals, Inc.
Global Market Assessment for Titanium Scrap
Titanium scrap has once again played the role of friend and foe during the current "up" cycle which has lasted close to 4 years. The industry has found itself in what may someday be considered the best run ever. This run successfully funded much needed capital investments to ensure ample raw material production, scrap processing and product manufacturing capability/capacity to allow for the future growth of our industry.

It is always interesting to reflect on the availability and supply side of Titanium scrap since the start of the cycle but one must not lose sight of what appears to be ahead. My presentation is an attempt to summarize what the supply and demand scenario for Titanium scrap is as we move forward.

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Jung Wen Lee, Tianhe Titanium
A New Independant Titanium Sponge Producer In China
Sponge production has been historically a quasi-monopoly of Japan, USA and former CIS countries. China has emerged a few years ago with a few national suppliers. Most of those sponge manufacturing companies are still belonging to State non-ferrous Institutes (the main one being Sunyi) or to big State controlled group such as Chinalco (who took recently the control of Fushun). Due to the booming prices paid for titanium sponge in the last few years, a number of projects appeared in China and small companies involved in titanium tetrachloride emerged as spot suppliers of titanium sponge. One company escapes to this model and has set the ground to becoming one of the leading world players: Tianhe Titanium. The company is original in many respects: it is privately owned with a small portion of the shares quoted at the Hong Kong stock exchange. It is a fully integrated sponge producer, located on the sea side, with ample electricity supply (2 nearby power plants), a chorine supply through pipe line from the chemical plant located a few hundred meters away and with a magnesium electrolysis plant under erection in 2009. All the steps of the process are in a compact plant entirely new with a capacity of up to 15000 tonnes per year. (Pictures to be shown)

Knowing that investment costs are 4 times lower in China compared to Western countries, and knowing the part of depreciation in the cost of titanium sponge, this gives a significant cost advantage to Tianhe. The relatively dry environment and good insulation of the building guarantees a low oxygen content in the sponge. A state of the art laboratory is guaranteeing a superior quality as shown in the analysis.

With no downstream production (no melting shop), Tianhe ambitions to be a partner of all independent titanium manufacturer looking for a competitive and reliable source of sponge non-competing with its own customers.

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Turgyn Rakhman, Advanced Materials Japan Corp
Chinese Titanium Market in 2008
In the past year, Chinese titanium industry experienced a very high speed of growth. Strong demand from both domestic and overseas provided China with a golden opportunity for the industry. China has started its engine transforming from a country whose demand largely rely on export, to domestic market; from a country which could only produce primitive products to big mills, to a possible supplier for airspace, shipbuilding, chemical industries.

In 2008, China's total titanium sponge capacity reached 71,000Mt (No.1 in the world), over 11% compare to the previous year. Output volume reached about 50,000t (No.1 in the world), over 10% increase compare with 2007. The number of sponge actual producer increased to more than 10, and eights of them with a capacity more then 5000t a year. At the same time, mill products also showed a big step forward to about 28,000t (No.1 in the world) near 17.3% increase compared with 2007 According to the customs statistics, in 2008, sponge export was 6292t and import was 1221t, a net export was 5071t, this is more then 12% of total sponge production.. Mill product export was 8570t and import was 6387t, a net export was 2183t, this is more then 30.9% of total mill product production.

Global tight supply situation of titanium since 2005 has encouraged Chinese titanium production. Now china has become the No.1 country on titanium sponge capacity, real production, titanium mill product production. One of the reason of titanium sponge price down is over increase of Chinese sponge production. As the other metals, the major world sponge makers have started to receive influence of Chinese low sponge price. We should notice that grade 0 and grade 1 is about 70% of total sponge production. The quality of Chinese titanium sponge has been improved.

But Chinese titanium producers need some time to compete with other major titanium manufactures. Chinese titanium market has been increased. China has become a big titanium country.

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James Robison, Reading Alloys Inc. An AMETEK Company
<u>Molybdenum, 2009</u>
After eight decades of stable prices and supplies that met or exceeded demand, molybdenum this decade has exhibited rapid growth in both demand and supply, with long periods of demand exceeding short-term supply. This led to unprecedented volatility and elevated prices in the molybdenum market. In this presentation we examine the broad applications of molybdenum and its more narrow applications in titanium; sources of molybdenum; market changes which contribute to its recent volatility; the relative size of the molybdenum and titanium markets; and fluctuations in the molybdenum market over the past twelve months.

Since 2003 the rapid expansion of steelmaking in emerging economies, along with increased production of more sophisticated end products (automobiles, appliances) led to corresponding demand for molybdenum. Increasing copper production helped supply by-product molybdenum to meet this demand, but a "tight supply" situation persisted for almost five years, with corresponding elevated prices. Changes in governmental policies on imports and exports contributed to price fluctuations during this period. With the sudden drop in economic activity in October of 2008, molybdenum was again in oversupply, with prices falling abruptly but still well above historical levels. The recent increase in steel production, particularly in China and India, has led to price increases amid concern some suppliers might be holding back stock waiting for still higher prices.

The molybdenum market is experiencing historic changes. This presentation attempts to present current information as well as thoughts on what might be expected in the coming year.

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Kenneth Zenkevich, STRATCOR, Inc.
<u>VANADIUM: Recession, Rebalance & Resilience</u>
The current economic recession has had a major impact on all commodities, including Vanadium, a key component of many critical titanium alloys. After a five-year period which saw unprecedented growth, both the demand and supply of vanadium have dropped sharply since October 2008. Because the demand has dropped more sharply than supply, prices have fallen by more than half since mid-2008, with recent re-balancing of supply and demand resulting in price recovery from near-term lows.

The presentation will examine the impact of the most severe demand shock to the Vanadium supply chain in industry history, its relation to the steel industry, producer response and the potential risks and opportunities that lie ahead as the global economy recovers. These risks highlight the importance of long-term relationships between vanadium suppliers and the titanium industry."

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Sylvain Gehler, Specialty Metals Company

Titanium Sponge Production In Kazakhstan, Russia, And Ukraine

Mr Gehler will review Titanium ilmenite mining and sponge production in Ukraine, Russia, and Kazakhstan. The speaker will analyze the consequence of the collapse of ti demand on titanium sponge production of these countries the consequences on future world sponge supply and planned capital investments.

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Henry Seiner, TIMET

Global Sponge Capacity Developments

During the conference last year, the World Industry Supply Trends panel presented various aggressive sponge capacity expansion plans from all around the globe. Unfortunate developments both within the consuming markets for titanium and from external market forces have dramatically reduced near-term demand for titanium sponge. Uncertainty as to the timing and magnitude of recovery continues as 2010 approaches. So what is the status of both existing and expanding capacities?

This presentation attempts to update the situation at many of the global producers highlighting changes which have occurred or are occurring in contrast to the situation 12 months ago. The scrap market and its relationship to sponge demand will also be reviewed.

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New Manufacturing Panel: September 15, 2009

Moderator: Jonathan Blank, PhD

GE Aviation

James Withers, MER Corporation

Novel Processing To Produce Ti And Ti Alloy Powders On A Continuous Basis

The Kroll process that produces titanium is a multistage sporadic complex heterogeneous slow-speed, uncontrolled, labor intensive, high energy and cost intensive batch process that has defied well over a half century of investigations to simplify into a continuous process. Even with modern engineering current productivity is barely over 1 ton/day per reactor that produces an iron contaminated lumpy sponge product that is formed at the reactor wall interface which limits the capability for continuous operation. Serious environmental issues are prevalent in spite of controlled circulation of Mg, Cl_2, $MgCl_2$ and electrolysis of the $MgCl_2$. An innovative approach has been demonstrated to metallothermically produce titanium continuously in a powder morphology in a single reactor that in-situ produces the reductant metal and $TiCl_4$ without environmental issues. The feed to the reactor is a carbothermically refined TiO_2/ore that provides the source for the in-situ formed $TiCl_4$. The metal reductant can be magnesium or other alkali earth or alkali metals. The concurrent addition of other metal chlorides produces titanium alloy powders. The powders can be used for powder metallurgy processing for meltless manufacturing, as well as rapid manufacturing technology to produce components.

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Matthias Scharvogel, TiJet Medizintechnik GmbH

Metal Injection Molding of Titanium and its Alloys

The development of our process started well over ten years ago with the focus to offer an alternative manufacturing method for the medical device industry. Today, we have several products that are being implanted in Europe. We expect to have products with Asian an USA FDA approval by the end of this year. We do operate as an OEM and do not offer medical devices as TiJet, but still we are certified to ISO 13485.

The mechanical properties of our Titanium MIM components are tailored to the application. But we can manufacture CP Titanium with an elongation of well over 20%. The Ti6Al/4V components reach tensile strength of over 930 MPa and elongation over 15%.

We are in the process of writing ASTM standards in order to help the medical device industry in the usage of our technology.

We are also working on complementing Titanium powder manufacturing processes for Titanium and its alloys that we would like to introduce in our presentation as well. These technologies are mainly for manufacturing Titanium sheets and porous Titanium products.

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Co-Presenters:
Mark Bertolini, Metalysis Ltd
Lee Shaw, Metalysis Ltd
<u>The FFC Cambridge Process for Production of Low Cost Titanium and Titanium Powders</u>
The current status and recent advancements in the use of the FFC Cambridge process for the production of low cost titanium and titanium powders is presented. This will include an overview of the process, current and future process equipment and recent results in terms of chemistry, structure and properties of powder and consolidated product. The future direction and activities for the FFC Cambridge process will also be briefly discussed.

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Andy Woodfield, GE Aviation
<u>Meltless Ti for Aerospace Applications</u>
Recent advances in synthesis of Ti alloy powders by direct reduction methods (meltless Ti) have led to new opportunities to produce Ti alloys with enhanced capabilities. The meltless Ti alloy powders can be consolidated into mill products, or used to manufacture near-net shape components. A vision will be outlined for creation of a new supply chain producing meltless Ti alloy powders, leading to the production and application of innovative turbine engine components. This paper will highlight the benefits of meltless Ti alloys, detail GEA's current assessment of meltless Ti alloy technology, and outline the remaining challenges before the new supply chain can be fully established.

Examples of the benefits of the meltless Ti alloy technology will be presented, including (i) overall energy efficiencies and carbon footprint reductions related to the production of meltless Ti alloy mill products, (ii) microstructural refinement and associated increases in fatigue strength, (iii) improvements in inspectability, and (iv) novel alloys/microstructures that cannot be produced by conventional cast and wrought technology.

Progress aimed at addressing some of the remaining challenges will be highlighted, such as (i) separation of the meltless Ti alloy powders from the reaction by-products, (ii) consolidation of the typically spongy powders coming from the reduction reaction, and (iii) considerations relating to minimizing/managing extrinsic defects.

The supply chain vision outline for meltless Ti alloy mill products will include a number of options for producing a variety of products such as billet and bar. Targeted areas for further work to accelerate the formation of the new supply chain will be highlighted.

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Economics Panel: September 15th, 2009

Moderator: Michael G. Metz
VSMPO Tirus US

Gautham Khanna, Cowen and Company, a leading investment bank
Aerospace Market Data
This presentation will evaluate current aerospace market data, including a review of the backlog at Boeing and Airbus, and assess how this data informs our thesis on aftermarket trends, along with original equipment orders and deliveries over the next two years. In addition, the defense budget for FY 2010 and future trends in overall defense procurement will be examined along with an in-depth look at the Joint Strike Fighter program.

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Nick Pastushan, CIT, a leading global finance company
Health Of The Global Aircraft Financing Markets
This presentation will focus on the health of the global aircraft financing markets. This will include the aircraft lessors, and the implications to them of the financial crisis, as they are a large part of the aircraft backlog as well as buyers through sale leaseback transactions. We will explore the linkage of the financing market to the delivery forecasts as the health of the airline purchasers.

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Henri Courpron, President Aerospace Division - Seabury Group, a leading independent transportation-focused investment banking firm. Formerly, Executive Vice President, Procurement; Airbus
The World is Flat: From GDP Forecast to Aerospace Outlook
The recent economic turmoil has been the worst global downturn since the deregulation of commercial aviation. To cope initially with rampant fuel prices in 2008, airlines announced plans to slash capacity in order to maintain profitability. The cost pressure of high fuel promptly disappeared, replaced by a far worse concern: evaporating demand. Passenger numbers and fares (particularly premium class) both rapidly declined, and cargo revenues were extremely had hit. Fortunately the actions taken to combat high fuel prices were the same required to deal with declining demand, and airlines continued to reduce capacity. Signs are appearing that the economy is now stabilizing, but the question for airlines remains: How long will it take for demand and fares to return? How rapidly will an economic recovery translate into an air travel recovery?

Aerospace companies face an even greater challenge. Production cuts and new program delays have severely hurt most players, with cash flows required to offset the huge non-recurring R&D costs of new programs not materializing, and inventory building up. Concurrently, the aircraft being pulled from service by airlines or reductions in utilization of in-service aircraft drive a decline in aftermarket revenues. A recovery in air travel is critical to both new aircraft production and restoration of aftermarket revenues, leading aerospace companies to ask: How long after air travel recovers will we see stabilization of our commercial revenues?

Seabury has built proprietary methodologies to understand and forecast these relationships and help the aviation industry better predict and understand the links between economic factors and revenues, as well as the timing of a recovery. Understanding each aspect – GDP, personal consumption, fuel, airline demand, airline profitability, financing, retirements, production, and utilization – enables Seabury to forecast realistic base, downside and upside scenarios for industry participants.

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Heat Treating/Testing Panel: September 15th, 2009
Moderator: Patrick E. Connell
Kocks Pittsburgh CO (KPC)

Jim Pasmore, Thermo Scientific Niton Analyzers
Recent Developments In Handheld X-Ray Fluoresence Instrumentation
Handheld x-ray fluorescence (HHXRF) analyzers have become the standard for non-destructive quality control testing of finished titanium alloy products. These systems are routinely utilized for rapid quality control inspection and analysis to ensure product chemistry specifications are met. Like most scientific technologies, XRF instruments have evolved dramatically over the last forty years to harness miniaturization and computer advancements and to meet increasing demands from the industry.

Most recently, the introduction of new proprietary large area silicon drift detectors (SDD) into HHXRF instruments has produced significant performance improvements over traditional XRF capabilities. Known as GOLDD (Geometrically Optimized Large area Drift Detector) technology, these systems process much higher count rates, with excellent resolution and shaping time, to produce up to three times better limits of detection than traditional SDD systems, and up to 10 times better sensitivities over conventional silicon PIN detector instruments. As a result, a handheld XRF can now be used for the analysis of tramp elements in production facilities and ultralow residual element detection in specialized inspection work.

Coupled with a high output, 50kV, miniaturized x-ray tube, the GOLDD system can also perform light element analysis work without vacuum or helium purge, something considered impossible with a handheld instrument as recently as one year ago. Aluminum, sulfur, magnesium, phosphorous, silicon and other light elements can be measured in titanium alloy materials directly, with little if any sample preparation necessary. When optimal sensitivities are necessary, the GOLDD system can be combined with a portable helium purging mechanism to produce two times better limits of detection for light elements than without the purge.

This paper will offer an explanation of the XRF technique and the evolution of HHXRF systems. It will also offer an in-depth discussion of new silicon drift detector technology. Performance considerations and specific applications will be explored.

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Albert R. Fletcher, West Penn Testing Group
The Future of Titanium Bar and Billet Inspection for the Commercial Aerospace Industry
Due to requirements of the Federal Aviation Administration, titanium bar and billet manufacturers have been required to tighten inspection criteria on such material.

Due to the inherent nature of sonic material noise in titanium billet, increasing testing sensitivity presents a potential problem. There is existing technology to accomplish this inspection but it is limited to a single source of equipment and technology. The current goal is to provide an alternate more economically sensible approach utilizing equipment that is now available and test probes specially designed for the inspection process.

West Penn Testing Group is working with a group in a cooperative activity involving OEM and suppliers with the intent to implement and refine this alternative approach to the current methods. West Penn will act as the test bed for the technology, this experimentation is under way, and results should follow shortly. The testing technology would be applied to rotor grade bar stock and could prove to be a valuable tool for the inspection of large diameter titanium bar and billet at a higher level of inspection sensitivity.

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Robert Hill Jr, Solar Atmospheres of Western PA
The Future of Thermally Processing Titanium In A Vacuum Furnace
A brief historical background on the development of the vacuum furnace and its importance to the early emerging titanium industry will be given. From the early laboratory scale furnaces of the past century, to today’s large capacity car bottom designed vacuum furnace, we will discuss the numerous improvements that have been made in this field of vacuum technology.

Many precautions must be heeded whenever one thermally processes titanium. These dangers primarily exist due to the fact that titanium is not found in its natural state. Therefore our element #22 is very reactive with many other elements- in particular oxygen and hydrogen. These specific elements are very detrimental to the ultimate desired properties especially within aerospace applications. The discussion of being able to heat treat "alpha case free" will thus ensue. Additionally, the importance of the strict adherence to the pyrometric specification AMS 2750 Rev D will be presented.

Numerous real life examples of commercially vacuum thermally processed parts will be presented. The markets represented will be from the aerospace, medical, power generation, and commercial arenas. The thermal processes of these various markets will be examples of vacuum degassing, vacuum hydryding, vacuum annealing, vacuum stress relieving, vacuum creep forming, vacuum homogenizing, vacuum solution treating and vacuum aging.

The talk will conclude summarizing the many pitfalls that are encountered industry wide within our antiquated titanium specifications. It is my belief that if we are to continuously improve our thermal processing, and thereby enhance the properties of this wonder metal, we must be proactive and serve on these most important specification review committees.

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Powder Metallurgy Panel: September 15, 2009

Moderator: Dr. Stephen Fox
TIMET – Henderson Technical Laboratories

Paul Miranda, Center for Advanced Mineral and Metallurgical Processing
<u>Free-Form Production Of Complex, Net Shape Titanium Parts</u>
High quality, metal parts are being produced using rapid prototyping techniques at the Center for Advanced Mineral and Metallurgical Processing (CAMP). Various metals are being used with titanium one of the two principle metals being investigated. Complex, free-form net shape parts are produced that have variable porosity and mechanical properties. Part distortion is minimal, even with small extremely complex pieces. Advanced three-dimensional printing creates the initial part followed by sintering and if required, secondary infiltration to control density. The method holds promise not only for industrial pats but also for medical parts.

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Mattias Svensson (M.Sc), Arcam AB
<u>Ti6Al4V Manufactured with Electron Beam Melting</u>
In recent years, Electron Beam Melting (EBM) has matured as a technology for rapid manufacturing of fully dense metal parts. The parts are built by additive consolidation of thin layers of metal powder, using an electron beam. With EBM, it is possible to create parts with geometries too complex to be fabricated by other methods, e.g. fine network structures, internal cavities and channels. The process is run in a vacuum chamber, which makes it well suited for materials with a high affinity to oxygen, e.g. titanium. A complete study of the mechanical and chemical properties has recently been made on both RAW and HIP condition on Ti6Al4V, including fatigue tests such as high cycle fatigue, strain controlled fatigue and rotating beam fatigue. The results reveal exceptional properties comparable to wrought material. With its production-like environment it delivers full traceability from ingot to the final part and complies with the industry-driven standards for both medical and aerospace applications.

Two European orthopedic implant manufacturers are currently using EBM for series production of CE-certified Ti-6Al-4V acetabular shells with integrated network structures. The EBM process is described in detail, with focus on the derived material properties on Ti6Al4V.

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Vlodymyr A. Duz , ADMA Products, Inc
<u>Powder Metallurgy of Titanium</u>
Titanium alloys possess a unique combination of high strength, low density and good corrosion resistance which makes them very attractive for many structural applications. However the cost of titanium produced by conventional ingot technology is high compare to competing materials. A powder metallurgy (P/M) is an attractive

method to reduce the cost of titanium components under the stipulation that a low cost powder supply can be developed. ADMA has a patented process to produce a low cost hydrogenated titanium powder via a modified magnesium reduction method. The process produces a powder that reduces manufacturing costs to make strip, plate, or structural components. A low cost blended elemental (BE) approach in which hydrogenated titanium powder was alloyed with a master alloy to achieve the required chemistry was used in this study. Consolidation at room temperature may be performed by conventional P/M processes such as die-pressing, cold isostatic pressing, or direct powder rolling. Utilization of hydrogenated titanium powder instead of traditional titanium powder significantly improves the sintering providing higher sintered density (up to 99%) and better homogeneity of synthesized alloys. Ti-6Al-4V as well as some other compositions were successfully processed with such approach. The compacts were evaluated for microstructural homogeneity, residual hydrogen, mechanical properties and uniformity of density. Room temperature consolidation to form the near net-shapes and subsequent vacuum sintering produced near full density titanium alloys with optimized microstructures and mechanical properties equivalent to those of the ingot metallurgy.

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Alain Honnart, Metalvalue Ltd

A New Process To Manufacture Titanium Near Net Shapes

Reducing the buy-to-fly ratio is a major concern for the aerospace industry. A number of development programs are aiming at reducing this ratio.

METEC Powder Metal AB has developed a technology which allows to manufacture near-net shape parts up to 6 lbs (limitation only linked to the present equipment not to the process).

The process starts from aerospace quality gas atomized powder which is agglomerated and compacted under a proprietary multistage process. 98% density have already been achieved after sintering giving already properties comparable to forged products. 99,5% to 100% density is under development giving the products better qualities than any conventional process (homogeneity, low impurity content, mechanical properties).

The process allows to make parts in pure titanium as well as in any other titanium alloys.

It is extremely economical due to the huge energy and material saving and to the high productivity which is achievable. It uses only environmentally friendly components.
Multilevel prismatic shapes with ribs, indents or holes can be easily manufactured.

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Leonardo Batista Rosa, UESC – Universidade Estadual de Santa Cruz

Review of Titanium Production: Kroll Process

Titanium is an attractive material for structural and biomedical applications because of its excellent corrosion resistance, biocompatibility and high strength-to-weight ratio. Its high melt temperature and high reactivity in the liquid phase makes the titanium difficult to be produced. Powder metallurgy has been shown to be an adequate technique to obtain titanium alloys at low temperatures and solid-phase consolidation. This paper makes a review of the Krool process – the most common way for titanium production. This process uses magnesium chlorine to convert the titanium ore into a sponge – so that it can be pressed with low stresses. Then, the material is sintered. The result can tell that the particle size control is the most important point for porosity control. Some sample images will be showed using scanning electron microscopy (SEM) images.

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State of the Industry in China: September 16, 2009

Moderator : Michael G. Metz
VSMPO Tirus

Mr. Hanchen Wang, Mr. Wang Hanchen is the President of Shaanxi Nonferrous Metals Holding Group Co., Ltd., the President of Baoti Group Ltd., and his is also the Board Chairman of Baoji Titanium Industry Co., Ltd. In 2006-2008, Mr. Whang Hanchen was the Chairman of Chinese Titanium, Zirconium and Hafnium Society.
Overview of the China Titanium Industry

Introduces the capacity, production, shipment as well as the import and export of titanium sponge and titanium mill products in China. Presents the development plan of the titanium industry and application prospect of titanium in China.

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Machining Panel: September 16, 2009
Moderator: Tom Grasson
Associate Publisher/Editorial Director, Aerospace Manufacturing & Design

Scott Walker, Mitsui Seiki USA
Machine Tool Design Elements for Machining Triple Nickel Titanium
This encompass' work that began with Boeing Auburn R&D personnel in 2006. Mitsui Seiki built a machine specifically for machining new titanium materials that are to be used in the new Boeing 787 and it was on loan to them for over a year for testing purposes. These materials are classified as "Triple Nickel" titanium materials. From this test machine we built a group of machines (4 and 5 axes machines) for manufacturing the rear engine mounts for the 787.

These machines were tested extensively with Kennametal tooling prior to shipping the machines to the Portland, Oregon facility to accommodate tooling design changes for these new materials.

We have also supplied machines to Airbus for similar materials and worked with other tooling suppliers with very positive results.

The first tier supply chain has not seen any of these new materials in volume, as of yet, but it is coming with the release of the Boeing 787 production ramp up and know how will be key in effective bidding and cost controls as these contracts are released.

Subsequently, these styles of machines have been tested in many new grades of titanium and stainless steel materials and have also shown improved performance in high temperature and corrosion resistant alloys to provide a platform for meeting the objectives of higher stock removal rates and extended tool life.

Conference attendee's will understand what has been learned to date and what needs further development and can assist them in asking the correct questions to machine tool suppliers and cutting tool suppliers when working on capitol acquisitions for these new materials.

Visual support data and testing data will be presented.

The following outlines the presentation topics:

- Prototype machine testing and its results.
- Analyzing low frequency machining and its impact on tool life.
- Tool taper interface bending moments and it's limitations of stock removal and tool life.
- Design elements for heavy metal machines.
- Current stock removal rates and tool life studies.

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Greg Foltz, CIMCOOL Global Industrial Fluids
<u>Titanium and Metalworking Fluids</u>
In machining operations on titanium, metalworking fluids are an important and essential component in dissipating the heat and providing lubricity. The types of fluids available, as well as their functions, requirements and testing will be reviewed. Some basic laboratory tests that are used to design these products will be discussed along with tests that are specific to companies that evaluate a fluid's performance and qualify it for use on titanium. A new metalworking fluid will also be introduced that has been developed by Milacron Global Industrial Fluids that has shown superior performance in titanium machining.

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Francois Gau, Kennametal
<u>Effective and Efficient Titanium Machining</u>

Kennametal delivers productivity to its customers by providing materials expertise and application knowledge. Kennametal is constantly investing to improve the costs and leadtime associated with shaping components made of various titanium alloys. Kennametal presentation will focus on best practices and will give a glimpse on some of the newest technologies available on the market to make this material more affordable to many industries through machining breakthroughs. Typical savings can range upward of 30% on total part costs and 60% on leadtime. You will be amongst the first to learn more about Kennametal's CoolTekh technologies that aim to extend tool life and improve material removal rates significantly in Titanium machining. Kennametal is the leading tooling supplier to most of the titanium parts manufacturers around the world. Our brands such as Kennametal and Hanita are well known in the Aerospace market. Also, our subsidiary International Specialty Alloy supplies most of the casting and forging suppliers with high purity alloys.

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Mike Sess, MAG Industrial Automation Systems
<u>Titanium Machining: Friend or Foe?</u>
Our presentation, Titanium Machining: Friend or Foe?, breaks down the critical success factors needed, explains them, and wraps up with holistic examples that illustrate how each factor contributes to the overall goal – cost-effective production with precision. We will discuss why industry uses different methods to machine titanium, how the right cutting tools can reduce part manufacturing costs, why good part fixturing is critical to success, the importance of machine design, and how the use of the right coolant can reduce cycle time, increase tool life and produce better quality parts. The presentation is informal and provides essential background on what it takes to machine titanium efficiently. It draws on MAG's decades of experience in joint-venture development of new machines, new materials, tooling and associated technologies that are today used around the world by the most successful aerospace companies.

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Erin Morrissey, The Boeing Company
<u>Boeing's Scrap Revert Program</u>
The Boeing Revert Program is designed to increase the recoverability of titanium scrap for aerospace applications. Boeing is developing a "closed loop" revert program to secure our supply of titanium while reducing the impact of price volatility which in effect is physical hedging. The expected challenges are ensuring the aerospace quality of scrap from our supplier to the contracted mills. The program is designed to reduce these challenges and minimize the logistic costs as well as incorporating best practices throughout Boeing's supply chain. of some of the treatment variables were determined, along with some of the characteristics of the optimised ceramic layer.

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Industrial Applications Panel : September 16, 2009
Moderator: Kevin Cain
Uniti Titanium

Michael Blakely, Dynamic Materials Corporation
Explosion Welded Titanium
As an alternative to solid titanium construction, titanium clad steel is a proven material for a number of applications. There are many occasions where the economics do not favor solid construction with titanium, but the properties of titanium are still desirable on the surface. Explosion clad can create a titanium surface backed by nearly any metal. Topic will include discussion of the explosion weld cladding method. In order to give a better understanding of industry application, the discussion will also cover how dissimilar metal explosion welded interfaces – specifically titanium clad – can be used in fabrication of vessels and equipment.

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Akio Okamoto, Titanium Division of Kobe Steel, Ltd.
Kobe Steel Develops Pre-coated Titanium with Excellent Press-Formability
As new applications expand in various markets, titanium sheet with good press-formability is growing in important. Kobe Steel, Ltd. has developed a pre-coated titanium sheet with excellent press-formability properties. This material provides excellent press-formability without using conventional lubricants. In addition, it enables higher strength material to be pressed. Pre-coated titanium is suitable for mass production, because the coating layer can be easily removed by an alkaline cleaning line.

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Yuxuan Du, Western Superconducting Technologies Co., Ltd.
Investigation to a Ti45Nb Alloy for Rivets
A Ti45Nb alloy is widely used for fasteners in aeronautics and space applications. It is characterized by relatively good tensile strength (490MPa) and shear strength (365MPa) and excellent plasticity (elongation of 10%, reduction of area of 50%). And compared with other materials, the specific strength of Ti45Nb alloys is higher. Therefore, it is applicable to connection of composite connecting structures. In present investigation, a large scale of?620 ingot was manufactured with VAR() and combination of titanium sponge and Nb bars. By means of precise control of chemical composition, optimization of forming processing and heat treatment, a Ti45Nb of uniform chemical composition and good mechanical properties was produced i.e. tensile strength is 550MPa, shear strength is 365MPa, elongation is 20% and reduction of area is 50%.

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Dennis J. Schumerth, VALTIMET
The Big, Green, Clean Machine – A Nuclear Renaissance Update for the Titanium Industry
Notwithstanding the current world economic downturn, continuing instability in global oil prices and a real and unprecedented decline in domestic electric energy load capacity, the nuclear power sector faces burgeoning and continuing challenges. Industry banter including green power, carbon capture, cap and trade, wind power, photovoltaic, biomass, solar and other noble, yet largely unsustainable compass points are often used to identify the new energy de jour. Purported methods by the administrative pundits to increase energy independence and stabilize greenhouse gas concentrations in the atmosphere to a level that would prevent dangerous anthropogenic interference with the climate system have taken front page headlines. The Renaissance gestation period has ended and a new era has begun begging the question as to when the nuclear phoenix will eventually rise.

As noted above, it is also clear the continued use of fossil fuels for electric power generation remains the bane of the PowerGen Industry. Indeed, new coal-fired power plants, currently generating some 50% of the U.S. domestic power needs, have been largely abandoned as long-term grid additions leaving renewables and solar as the only current political options. Paraphrasing the Obama administration rhetoric and the application of their own political stimulus package to the energy industry – of course coal-fired generation power plants can be built – it's just that you will not be able to afford them.

Currently, the US NRC (Nuclear Regulatory Commission) is moving through the legal, technical, commercial and political conundrum of evaluating 17 COL's (Combined Construction & Operating License) representing 26 new nukes in the US. Similarly, it is predicted that the world may add an additional 160 units over the next 15 years. Loan Guarantees, as proposed by the Bush Administration (Energy Policy Act) remain precariously in place and noted to cover only the first 19 plants. Design licensing constraints still tug at the bureaucratic shirttails slowing the progress of these COL's through the approval process. Strict adherence to NRC licensing policy, red tape, continuing pressures on the credit markets and the predicted demise of Yucca Mountain leaving the spent fuel question to future technology/generations has kept both lawyers and utility personnel alike begging the question – "Who's on first?".

However, continuing positive signs lie in the committed action principally taken by China and Western Europe in expanding their nuclear horizons. Even several domestic utilities and NSSS suppliers have ordered long lead time items recognizing that both from a political and purely practical position, the first in line will reap the rewards. In the midst of this turmoil, this author will attempt a reevaluation of the "Nuclear Renaissance" in progress. Globally, the solutions remain classically technical. In the U.S., prophetic answers unfortunately lie in a future political agenda. This paper charts a course through the practical and political landscape of each and suggests a revised impact on the world titanium industry.

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Aerospace Materials & Processes Panel: September 16, 2009
Moderator: Edward F. Sobota, Sr.
TSI Titanium

Dr. Steven Keener, The Boeing Company
Improved Properties of Lower-cost Titanium-alloy Materials for Aerospace Fastener Applications
A potentially lower-cost approach for the production of advanced titanium and titanium-alloy materials has been demonstrated using cryogenic technology. Near-nano and nano-sized grain material have been produced through a variety of methods, including severe Plastic deformation achieved with high-energy ballmilling and subsequent consolidation techniques. The resulting materials produced have a near-nano, nano-grained structure, high-angle boundaries, and finely-dispersed particulates having near nanometer-scale size. These features combine to impart excellent strength levels, good ductility, and excellent microstructural thermal stability. In addition, the powders are macroscopically in the micrometer range having pre-alloying capabilities. This feature allows for easy handling, cleaner surfaces, and no environmental dangers.

This paper summarizes the preliminary results of the macrostructures, microstructures, chemistries, and mechanical properties achieved via this cryogenic processing approach. Initial results for commercially-pure titanium material will be presented, that show near-nanometer size nitride particles formed in-situ during processing, and increased temperature stability of the alloy into the 925°F temperature range.

The Boeing Company and its suppliers are actively engaged in collaborative efforts involving development and processing technologies associated with the production and fabrication of titanium and titanium-alloy powders, including cryogenic milling, to achieve long-term reductions in raw material costs. Nearterm applications are focused on aircraft fastener installations, where the goal is to replace certain conventional Ti6Al4V titanium-alloy fasteners. Further work remains to optimize the process through internal Boeing and government funded efforts and ready it for commercialization.

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Lauren Moody, Weber Metals Inc.
Forging and Heat Treating 5Al-5V-5Mo-3Cr (Ti 5553)
Ti-5Al-5V-5Mo-3Cr is currently being utilized for a number of structural and landing gear forgings for the new Boeing 787 Dreamliner program. Weber Metals performed production studies on a variety of forging (alpha-beta and beta) and heat treating (BASCA-160 and STA-180) practices in multiple die forging configurations in

accordance with Boeing specification requirements. This presentation will be a summary of the work done in these studies. In addition, forgeability comparisons with Ti-6-4 and Ti-6-6-2 will be presented.

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Maciej Motyka PhD, Rzeszow University of Technology

<u>The Effect of Microstructure on Hot Plasticity of $\alpha+\beta$ Titanium Alloys</u>

Hot deformation behaviour of two-phase titanium alloys is determined by the type of microstructure developed in heat treatment and plastic deformation processes. The influence of initial and final heat treatment parameters and degree of plastic deformation on hot plasticity of Ti-6Al-4V and Ti-6Al-2Mo-2Cr alloys is discussed in the paper. Tested alloys were hot deformed at the temperature range of 1123÷1323K and at the strain rate from 0.01 to 0.5 s^{-1} strain rate range (including superplastic conditions). Microstructural investigations were carried out using light microscopy and TEM techniques. Stereological parameters of microstructure before and after hot deformation were determined. Evaluation of their influence on hot plasticity (maximum flow stress σpm and relative strain ε) of two-phase titanium alloys was performed.

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Baoquan Fu, Western Superconducting Technologies Co., Ltd.

<u>Fabrication High Homogeneous Ti30mo Alloy For Titanium Master Alloy In Aerospace Application</u>

β-titanium alloy has good elevated temperature properties and resistance to oxidation, it widely used to aerospace application. Molybdenum is usually added to β alloy (such as Ti-10Mo-8V-1Fe-3.5Al (Ti-1023), Ti-15Mo-10.7Nb-3Al-0.2SiB-21S) and Ti-3.0-.6V-5.0Mo (BT16) et.al.) as a stabilized β-phase element. But molybdenum has very high melting point than titanium. It is very difficult to add in titanium alloys which have relatively high molybdenum content. The normal Al-60Mo alloys cannot satisfie these alloys requirement for high molybdenum content. It is necessary to produce high homogeneous Ti-30Mo alloy as titanium master alloy. The common melting method for Ti-Mo alloy is combination method of skull furnace and VAR furnace or power metallurgy method. The rates of final products are usually very low and the chemical elements are also very difficult to control for combination method. The power metallurgy method is easy lead in oxidized impurity elements. This paper reports a new method to fabricate high homogeneous Ti-30Mo alloy. Triple VAR method is used and gets a very high homogeneous ingot. The SEM and X-RAY are used to analysis the homogeneous of Ti-30Mo alloy. The difference of molybdenum element is smaller than 2%. It can be satisfied the requirement for special β-titanium alloy.

The impurity elements are also very low. The molybdenum content of BT16 alloy who adds the Ti-30Mo master alloy has also very homogeneous. It is indicate that this master alloy can be used to special β-titanium alloy for aerospace application.

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Bernd Oberwinkler, University of Leoben, Institute of Mechanical Engineering

<u>Light Weight Design of Ti-6Al-4V Forgings</u>

Forged parts made of Ti-6Al-4V are generally used in aerospace industry, e.g. for engine mounts, pylon fitting and frame parts etc. A lot of different thermomechanical treatments are possible resulting in a wide variation of microstructure and fatigue strength respectively. To achieve light weight design of such parts an accurate lifetime prediction on the basis of local microstructural-oriented S/N-curves and further important fatigue influences is necessary. Damage tolerance is achieved by consideration of local stress intensity thresholds in respect of local microstructure.

Two different forgings (open and closed die forgings, respectively) and two feedstock bars were used for this research work. Additional varying thermomechanical treatments were performed on these forgings to achieve a high diversity of microstructure. High cycle fatigue tests and crack propagation tests were done for characterization of the fatigue behavior in regard of microstructure. A Hall-Petch relationship was used for linking fatigue limit and primary alpha grain size. The influence of bimodality of microstructure on the endurance limit is also considered in the model. The finite life region was linked with grain size and alpha lamellae width. So it is possible to generate local microstructural-based S/N-curves for linking the local microstructure with fatigue strength. For lifetime prediction further influences have to be taken into account. Therefore the influence of relative stress gradient on the fatigue behavior was evaluated with unnotched and notched specimens. The mean stress sensitivity was determined with tension/compression tests on unnotched hourglass specimens. A model for linking local stress intensity threshold and microstructure was developed, too. So it is possible to calculate the local maximum allowed crack size with the El Haddad-model. This research work provides a holistic basis for purpose-aimed forging and heat treatment process layout and finally for light weight design of Ti-6Al-4V forgings.

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William Swale, Aeromet International plc.

Superplastic Forming – Cost Effective?

When Superplastic Forming (SPF) was offered as a production process it became the panacea of all processes for products designed to be made from Titanium and Aluminium materials. The claims were (1) Reduced part count (2) Reduced assembly time (3) Weight reduction (4) Monolithic parts and (5) Stronger structures.

Following Pearson's work in the mid 30's with Lead-Tin and Bismuth-Tin alloys, showing higher than 1000% elongation without failure, the Aluminium industry developed SPF alloys and launched into numerous commercial applications. Other research facilities focused on the potential of achieving superplasticity in Titanium alloys. This was demonstrated in the late 60's using the now well established Ti 6 Aluminium 4 Vanadium alloy. Considerable funding was allocated, both in the USA & UK specifically for the development of the process. The USA focused on the Military Programmes and the UK on the Civil Aircraft (Concorde) and some Military Aircraft. Success in these programmes and the claims made, resulted with a production process. Companies invested in suitable plant and equipment and designers grasped the process potential and applied SPF to their sheet metal designs expecting to reap the claimed benefits.

The claims are valid if applied to correctly chosen components. All too often the SPF manufacturing choice did not deliver its claims. In many cases cost of material, need to chemical mill and higher energy costs were either not envisaged or taken into account.

Today all processes, material cost and alternative material types have to be assessed before the manufacturing method is chosen. The aerospace industry is attacking the Buy-Fly ratio, and energy and labour cost are at a premium and these have caused the SPF and Hot Forming community to examine ways of producing products (a) from less material (b) by Hot Forming (eliminating the need to apply chemical milling to remove the Alpha Case) (c) questioning the material choice (CP instead of Ti6/4) and (d) by applying modern fabrication methods.

This paper will illustrate this change in philosophy; shows today's choices and demonstrates how the SPF process can be cost effective and in fact does have a major role to play in producing Airframe and Engine Structures in titanium.

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Commercial Aerospace Panel: September 16, 2009

Moderator: Kevin Michaels

AeroStrategy LLC

John Byrne, The Boeing Company

Evolution of Titanium in Boeing Aerospace

Boeing's has been evolving the use of Titanium in its airplane manufacturing market. The supply chain has been working to improve buy-to-fly ratios as it improves efficiencies in production and reduces cost. The titanium industry needs to take certain steps to remain competitive in the raw material supply within Boeing's supply chain.

Boeing's long-term market outlook remains strong for both passenger and freighters. Boeing remains committed to the utilization of titanium as a primary raw material commodity for its products. Greater application of titanium will depend upon the competitive solutions the industry provides both technically and financially.

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David Linger, GE Aviation

<u>Titanium Utilization And Vision For The Next Decade: A Gas Turbine OEM Perspective</u>

Aviation OEM's seek to optimize product performance, such as strength to weight ratios and fuel efficiency with cost. This balancing act becomes even more difficult with raw material price volatility. In fact, in the last few years the aviation gas turbine industry has been replacing titanium with heavier but lower cost iron and nickel-based materials.

Today, titanium is being reintroduced onto aviation gas turbine products thanks to novel manufacturing, joining, and powdered metal consolidation technologies. This trend will not only continue but will accelerate as these low cost, high yield, or near net shape technologies mature and become certified for use. Further, titanium's value will reach entitlement when the various novel, cost-effective titanium production processes that synthesize Ti alloy powders by direct reduction (Meltless Ti) are combined with these complementary manufacturing and powder consolidation techniques.

The Meltless Ti alloy powders can be consolidated into mill products that will benefit from the same emerging machining and joining technologies, or the powder will be directly manufactured into near-net shape components. For this vision to happen, a coordinated supply chain will need to be established similar to that created for the plastic industry in the 1960's.

It is anticipated that early qualification and use of Meltless Ti alloy materials by the aerospace industry will lead to an accelerated adoption of the technology by other markets, leading to an expansion in overall titanium use.

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Kevin Michaels, AeroStrategy LLC

<u>Aerospace Design And Advanced Material Trends: Implications For The Titanium Market</u>

- How will material usage change on future generation aircraft and where does titanium fit in?
- What are the implications of escalating composite content?
- How will OEM's tackle the green challenge and what are the implications for aeroengine designs?
- How could materials in the next generation aeroengines change and what are the implications for titanium?
- What are the key trends shaping the aerospace raw supply chain?
- What is the outlook for the aerospace aftermarket and what role does it play in titanium demand?

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