World Industry Demand Trends Panel: September 22, 2008
Moderator: Michael G. Metz, - President, VSMPO Tirus US

James Buch, TIMET
Engines
Several market and technology forces are impacting the design and demand for civil and military engines. This presentation will cover how these forces are likely to influence the future of titanium in this sector.

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Hunter Dalton, ATI Allvac
A Review Of Titanium's Emerging Markets
Titanium's corrosion resistance and unique combination of physical and mechanical properties makes it desirable for an increasingly wide array of new applications across a broad spectrum of markets, offering the titanium industry significant growth potential. Hunter Dalton, President, ATI Allvac, will discuss titanium usage in these emerging markets as well as challenges that may influence titanium demand in this sector.

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Dawne Hickton, RTI International Metals, Inc.
Titanium For Commercial Airframes
Ms. Hickton will provide insight and analysis of the world industry demand trends for titanium for commercial airframes. We are in a challenging era where global economic forces are negatively impacting the short term for the titanium industry, while at the same time, there remains explosive long term growth for titanium in most of the major markets, of which airframe applications factor predominately. The presentation will explore some of the newer applications for titanium consumption in airframes as well as provide a forecast for future demand.

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Markus Holz, ThyssenKrupp Titanium
THE GLOBAL TITANIUM MARKET AND THE EUROPEAN CHALLENGE
Dr. Holz will provide an overview of the European Titanium industry as a vibrant global marketplace. His focus on industrial applications will address those major market segments where the business (plates and tube), though erratic, is mostly concentrated – power generation (strong need for construction/ revamping of energy plants), PHE (booming market) and desalination (fast-growing demand worldwide). Emphasis will be placed on the number of projects that are supplied by European fabricators. The presentation will also address military and civil aerospace - where Europe is well represented by Airbus with the A400M and A380 respectively - which appear a most challenging business (continuing to boom)as well as a very sensitive barometer of the world economic development that gages the excellence the titanium industry is successfully pursuing.

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Takeshi Kurushima, Toho Titanium Co., Ltd.
Update Of Titanium Industry In Japan
Japanese Titanium Industry celebrates another record year of 2007 regarding its shipments of both mill products and titanium sponge. Mr. Kurushima is going to update the situation of the Japanese titanium industry including the capacity expansion of titanium sponge production and melting. He is also to touch upon JTS's activities to boost the titanium industry and show some of new non-aerospace applications explored in Japan.

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Hanchen Wang, Baoti Group Ltd.
The Rapid Development Of Chinese Titanium Industry
Chinese have a biggest titanium resource which ranks the world No.1, and titanium resource should be 350 billion tons (statistic by TiO_2) which share the half of the total of the world. The capacity of titanium sponge and

mill product increased rapidly after 45 years development, the capacity of titanium sponge and mill product are 60,000t/a and over 40,000t/a respectively. The output of titanium sponge and mill product are 45,000 tons and 24,000 tons respectively which increased by 149.5% and 87.4% compared with the year of 2006, and the output of titanium ranks the world No.1. For the first time, the aero application of titanium share over 10% domestic titanium market in 2007, but the biggest share is still chemical industry which share 43.6% titanium market, the third place is sports and leisure. The net export titanium product reached 4,083 tons.

As the biggest titanium enterprise in China, the titanium products of Baoti Group Ltd. have been widely used in a variety fields such as aero, petro-chemical, metallurgical, salt making, alkaline making, over-sea exploring, ship, sports and leisure and other areas which shares over 95% market in the domestic aero. Baoti has had a rapid development in these years, from year of 2004 to 2007, the output value increased from 1 billion to nearly 5 billions, and the output increase year by year.

Compared with 2006, the investment focus has changed from the titanium sponge in 2006 to titanium mill product, and this tendency will continue for years. The titanium industry should be the hot spot of investment in China in the near future, and we may say that Chinese titanium industry should has a big leap development in year 2010.

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Michael Metz, VSMPO Tirus US

<u>Summary of World Industry Trends</u>

Mr. Metz will provide a world market overview for titanium shipments, global consumption and major market drivers. Presentation will also include general comments on the current state of the titanium market and its future.

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Distinguished Luncheon Speaker

Stuart G. Hoffman , Senior Vice President and Chief Economist, The PNC Financial Services Group

Stuart G. Hoffman is senior vice president and chief economist for The PNC Financial Services Group and serves as the principal spokesperson on all economic issues for PNC. Hoffman was recognized as the second most accurate economic and interest rate forecaster for 2006 by USA Today and as the most accurate forecaster for 2004 by BusinessWeek. In addition, he was named one of the top forecasters in the Wall Street Journal economic survey covering the 1988 to 2007 period.

Hoffman joined PNC in 1980 after a six-year tenure with the Federal Reserve Bank of Atlanta. He became vice president and senior economist for PNC in 1987 and was elected senior vice president and chief economist in 1991. Hoffman is frequently quoted in The Wall Street Journal, The New York Times and Barron's. He is a regular guest on CNBC, Bloomberg TV and The Wall Street Journal Radio Report . He is regularly interviewed by the Associated Press and Reuter's news wire services.

Hoffman is a past president and a member of the board of directors of the National Association for Business Economics (NABE). He also serves on the board of directors of the Economic Club of Pittsburgh - the local chapter of NABE. He is past chairman of the American Bankers Economic Advisory Committee.
Hoffman is a 1971 graduate of Pennsylvania State University. He received a master's degree in 1973 and a doctorate degree in economics in 1975, both from the University of Cincinnati, where he was a Charles Phelps Taft Memorial Fellow. In 2004, the University of Cincinnati honored him as a Distinguished Alumni.

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Consumer Panel: September 22, 2008

Moderator: Jeff Wise - Titanium Industries Incorporated

Kenji Hirashima, Toho Technical Service Co.
Consumer Applications In Japan
In Japan titanium has been almost used for consumer application over 50 years.
Kitchenware, watch, eyeglass, sports, leisure, automobile, chemical tank, architecture, power generation, desalination, our life are supported by titanium. In this exploitation history of consumer application, Associate Committee of the Japan Titanium Society performed big role.

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Edward Rosenberg, Spectore Corporation
"All The Glitters, From Kryptonite To Tiffany"
As the virtues and benefits inherent to titanium became recognized in consumer products, titanium emerged as the material of choice through a multitude of products and applications. The popularity of platinum and other precious white metals contributed to the next meteoric ascent of titanium as the NEW Nobel Element. Titanium was truly the catalyst in the inevitable marriage of art and science. The dramatic elevation in consumer expectations has caused an equally rapid acceleration and broadening of technologies and applications in the titanium world.

We introduced titanium to a most passive and skeptical industry over 25 years ago.
Despite those barriers titanium, in the past two decades has clearly earned and proven its merit and value as a viable jewelry material. In fact in 2007 it has catapulted to the forefront of not only the jewelry industry, but numerous others. The degree to which titanium has been embraced by the consumer market is clearly evidenced by multitude of high profile brands featuring this new contemporary material and the spectacular sales performance across the broadest spectrum of industries and products.

Our focus and the focus of our distributor network is not only on the development and promotion of titanium and other contemporary materials, it is being built on "American Lifestyle" products. I believe in today's environment and with the added opportunity of the favorable exchange rate selling "American & European Lifestyle" products is a most positive initiative. Our efforts to that end have allowed us to partner with and develop these initiatives with a number of European and American preeminent brands including Harley Davidson, Tiffany & Co, Porsche Design, Movado, and a host of others.
In just the past 2 decades titanium has transformed its image from an art metal to a signature of status in the world market. Certainly this was a Herculean effort but what made it work was the reality that "titanium is simply better". In my presentation I will outline and graphically detail the evolution of products, technologies, designs, & markets.

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Gary Nemchock, Architectural Titanium
Architectural Titanium
Worldwide architectural titanium installations completed from 2006 through 2008 and others currently under construction are featured in this presentation which will include:

Grand Lisboa Casino – Macau
Cinemaplex – Roanne, France
International Conference Center – Hong Kong
Patras Museum – Athens, Greece
INCS Headquarters – Toyko, Japan
Vu Kinderstad (Ronald McDonald House) – Amsterdam, Holland
Private Residence – Hawaii

Private Residence – Palm Desert, California
Mandarin Oriental Hotel – Las Vegas, Nevada
Private Residence – Kent, United Kingdom
Methodist Church – Seattle, Washington
Lamborghini Showroom – Singapore

Also featured will be a selection of future projects, construction and development in the United Arab Emirates.

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Powder Metallurgy Panel: September 22, 2008
Moderator - Steve Fox, TIMET

Jane Adams, US Army Research Laboratory
<u>Titanium Powder Metallurgy For Armor And Structural Applications</u>
Increased use of titanium will provide weight reduction, which is the goal for armor and structural applications for all military systems. Powder metallurgy approach has great potential for low cost manufacturing of these products and can be the preferred manufacturing process for production of armor plates and composite armor module components for DoD and civilian applications. P/M approach offers cost reduction in manufacturing titanium parts as well as substantial reduction in lead time. In this presentation, Titanium PM is reviewed as a possible substitution of IM processes when a price reduction and shorter delivery time make PM approach more favorable to compare with the traditional IM. The lowest cost Blended elemental approach (BE) to produce Ti alloy components by room temperature consolidation (die-pressing, cold iso-static pressing, direct powder rolling) followed by sintering will be discussed. This BE approach would also allows to produce the low cost large ingots and slabs for subsequent high temperature deformation by forging, rolling, extrusion, flow forming and other conventional processes. Although these processes are being used in ingot metallurgy, the P/M starting material offers the lower cost and improved microstructure and properties which will be demonstrated in this presentation.

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Laurenz Plöchl, ALD Vacuum Technologies GmbH
<u>Recent Advances Of Titanium Alloy Powder Production By Ceramic-Free Inert Gas Atomization</u>
Electrode Induction-melt Inert Gas Atomization (EIGA) is a technique for powder manufacturing by gas atomization. During the process a cylindrically-shaped electrode is dipped into a conical induction coil leading to the formation of a continuous liquid metal flow off the conical electrode tip. The process can be conducted ceramic-free and is therefore especially suited for reactive and refractory metals/alloys (e.g. TiAl6V4, ?-TiAl). To date it has been limited to ca. 50-60mm diameter electrode dimensions, resulting in relatively low productivity (melt flow rate with titanium max 60 kg/h) and relatively high feed-stock cost (forged titanium alloy bar). The objective of the present work was to increase significantly the melt flow rate and the feedstock diameter without impairing the resulting powder particle distribution. The electrode dimensions were increased step-wise from 60 to 80 to 100 to 120 and finally 150mm (6 inch) which represents for the first time a feedstock dimension which can be produced by VAR (Vacuum Arc Remelting) not requiring any hot forming. Likewise, the melt rate was increased from 60 to 90 kg/h. An outlook to VAR electrode diameters >150mm seems realistic based on the achieved results. Concluding, the present work resulted in a significant increase of productivity and decrease of the feedstock cost and specific argon consumption cost of the EIGA technique and thus is expected to widen the potential field of application of high-purity spherical titanium alloy powders.

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Eric Baril, Louis-Philippe Lefebvre, National Research Council Canada/Industrial Materials Institute
<u>Titanium Foams Based On A Powder Metallurgy Approach</u>

Metallic foams offer a combination of attractive properties such as low density, good specific mechanical properties, fluid permeability, high surface area, good thermal resistance, high electric conductivity, high energy absorption characteristics, etc. These materials have already been considered or used in various applications including structures, biomedical implants, high specific surface electrodes or catalysts, fluid control device, cryogenic gas storage applications, thermal protection systems, etc.
This paper presents the properties of titanium foam structures produced using a powder metallurgy approach. A metallic powder, a solid polymeric binder and a foaming agent are dry-mixed and molded into the desired shape. The molded powder is then heat-treated to foam, debind and sinter the material. Porous titanium structures with porosity between 50 and 70% were produced using this approach. This porous titanium manufacturing process offers significant production flexibility for the development of various applications. The foams can be easily machined, used as a coating on dense structures or coated with dense material. This paper presents the evolution of the structure during the process and the properties (structure, chemical composition, density, permeability, specific surface area, compression behavior) of titanium foams produced under different conditions. Prototypes (orthopedic and dental implants) produced using this process are also presented.

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V. S. Moxson, ADMA Products Inc.

Innovative Powder Metallurgy Process For Producing Low Cost Titanium Alloy Components

Titanium alloys exhibit attractive mechanical properties, good corrosion resistance and low density, but they are expensive. This presentation is related to use of low cost powder metallurgy process to produce titanium and titanium alloy products from hydrogenated Titanium powder. A low cost blended elemental (BE) approach was used in this study in which hydrogenated titanium powder produced by a modified Kroll process was alloyed with a master alloy to achieve the required chemistry. 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. This presentation reviews the innovative and cost effective process to produce titanium and titanium alloys with desired microstructures and mechanical properties using hydrogenated titanium powder. Specific topics covered will include the process to produce the hydrogenated titanium powder, room temperature consolidation processes, sintering and mechanical properties.

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Lawrence Kramer, Concurrent Technologies Corporation

<u>Low Cost Titanium Pipe For Naval Applications</u>

The advantageous combination of low density, high specific strength and excellent corrosion resistance led to the use of CP grade 2 titanium in some Naval ship seawater piping applications. However, the increase in the cost of titanium has caused the Navy to return to using copper – nickel piping for some of these applications, even though the titanium piping typically exhibits a three times longer life than Cu-Ni pipe. The goal of this work is to investigate the possibility of using a low cost titanium starting stock along with a novel low cost manufacturing process to produce titanium pipe that would be about equivalent to the cost per unit length of Cu – Ni piping. The approach taken was to utilize low cost powder pressed performs and flowform net shaped pipe. This paper will show the details of this process and the properties of the resultant pipe. In addition to the pipe, the properties of gas metal arc weldments of pipe sections will be presented.

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Sami M. El-Soudani, The Boeing Company

<u>Canless Extrusion Process Development For Blended Elemental Powder-Based Titanium Ti-6al-4v Alloy</u>

The feasibility of canless extrusion in ambient environment of hydride/dehydride blended elemental Ti-6AL-4V ADMA-processed powder previously direct-consolidated by cold isostatic pressing (CIP), followed by vacuum sintering has been successfully demonstrated. Extrusion process trials of these billets were conducted at both RTI International Metals, Inc. and Plymouth Engineered Shapes, Inc. whereby the extrusion processing sequence and parameters were derived separately based on prior extrusion experience at both RTI and Plymouth Engineered Shapes, but were found to be essentially similar to those used for billets prepared from wrought ingot-based Ti-6AL-4V material. Using the results of a workability study program conducted at RTI, the elevated temperature workability tests of powder-based elevated temperature compression specimens showed that powder-based consolidated billets of similar baseline composition as for wrought ingot-based Ti-6AL-4V billets will require slightly lower extrusion pressures at same extrusion temperatures and strain rates. Laboratory analysis showed that the canless powder-based billet extrusion processing step conducted in air added no more than 200 ppm oxygen to the as-vacuum-sintered billet oxygen content. Preliminary tensile properties of the blended-elemental ADMA powder-based extrusions of a Ti-6AL-4V composition processed both in the beta or alpha-beta ranges of extrusion temperatures showed equivalent or superior tensile properties as compared to identically processed wrought, ingot-based and extruded Ti-6AL-4V billet materials. Additionally, in the blended elemental powder-based extrusions both nitrogen and carbon contents were within specification limits for Ti-6AL-4V alloy, while any excessive residual hydrogen was successfully vacuum degassed after extrusion to within specification limits. Further optimization for fracture toughness, stress-corrosion resistance and fatigue properties will build on these encouraging results, while monitoring and controlling the only remaining powder-based interstitial element, namely oxygen uptake during pre-extrusion powder-consolidation processing steps.

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Medical and Dentistry Applications: September 22nd -
Moderator: Brett S. Paddock - Titanium Industries Incorporated

Rod McMillan, Synthes Incorporated
<u>Titanium Usage For Medical Devices And Instruments – A Designer's Viewpoint</u>
Titanium and its alloys present the medical device designer with many exciting properties that can be exploited for the benefit of the patient. Titanium offers advantages over other material systems in the areas of strength to weight, biocompatibility, corrosion resistance, fatigue strength and coloring options. Extremely low magnetic permeability helps to assure that titanium products can be routinely used in MR scanners. Why then are there so few alloys being used by the industry and why is the adoption rate for new alloys so slow?
This paper will present the alloys currently used for device designs, some alloys being considered for design and the issues that the designer must deal with when contemplating new alloys for design. A review of the design considerations including cost, availability, manufacturability, regulatory hurdles and material properties will be discussed. Opportunities for new and improved titanium alloys, as well as product forms will be discussed in relationship to the needs of the medical device designer.

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Corby Anderson, Center for Advanced Mineral and Metallurgical Processing
<u>Corrosion Resistant Titanium Alloys For Medical Tools And Implants</u>
New corrosion resistant Ti-8N-Cr system alloys with increased mechanical properties are developed for medical tools and implants. The development was made based on study chromium influence on the phase constituents, micro structure, mechanical properties, corrosion resistance and electrochemical investigations of Ti-8Ni alloy.

Optimum regime of thermal treatment, guaranteeing high strength, hardness and corrosion resistance of alloys has been defined at content of chromium in alloys up to 1-3% .

Study of Mechanical properties of quenching alloys Ti-8Ni-(0-3)Cr show that chromium increases hardness (48 HRC) and tensile strength (1000 MPA) and slightly influences on plastic properties of Ti-8Ni alloy. Tensile strength of titanium commercial alloys Ti-6Al-4V and Ti-5Al-3Sn do not exceed 900 MPA.

Corrosion tests of Ti-8Ni-(0-3)Cr alloys in medium that contains the human body: blood, physiological solution, gastric juice and tissue liquid reveal high corrosion resistance, after 100 hour tests corrosion rate of all alloys, containing about 3% chromium did not exceed 0,0002 g/m2hr. Corrosion testing of the Ti-8Ni-(0-3)-Cr and titanium commercial alloys has been carried out also according to the following regime: cleaning+disinfection+sterilization in aggressive solutions with addition of hydrogen peroxide. The results after 20 cycle tests show that new alloys have high corrosion resistance. Corrosion losses of the commercial alloys, used now a day in medical technique, are ~ one order more than the losses of new alloys.

Study of toxic properties of alloys Ti-8Ni-(1-3)Cr during their implantation in subcutaneous connective tissue and abdominal cavity of animals show, that they do not cause local irritative actions on different tissues, they do not suppress local tissue reactions and do not have any toxic effects during long implantation conditions. The development of new alloys and their application in medical engineering will allow improve functional properties and increase quality, reliability, service life of medical tools and implants.

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Mari Koike, Baylor College of Dentistry

<u>Cast Titanium Alloys For Dental Applications</u>

In view of the proven, excellent biocompatibility of titanium, this metal has been considered as a potential metal for biomedical applications. A research group at Texas A&M Health Science Center Baylor College of Dentistry has formulated experimental titanium alloys to evaluate various characteristics in search of good candidate alloys for dental prosthetic use. By adapting applicable technologies from the titanium casting industry, the evolution of casting by casting machines and investment materials specifically made for dental casting has greatly advanced during the last 20 years. It appears that dental titanium casting has now almost reached the stage where its practical applications should seriously be assessed. This presentation is a continuation of our presentation about the historical development of dental titanium casting given at the International Titanium Association Meeting in 1999. In the presentation this time we report our on-going research project which tested the casting performance, mechanical properties, grindability, wear resistance, electrochemical behavior and biocompatibility of titanium alloys. The alloys we tested were experimental titanium alloys with a low fusion temperature and a few select industrial titanium alloys, as well.

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World Industry Supply Trends Panel: September 23, 2008 -
Moderator: Mike Kearns – TIMET

Sylvain Gehler, Managing Director - Specialty Metals Company

<u>Titanium Sponge Production In Kazakhstan, Russia, And Ukraine</u>

Titanium sponge production in Russia, Kazakhstan and Ukraine is stable backed up by a regular flow of titanium feedstock. Nevertheless Mg supply is still very tight and would limit any increase of Ti sponge production if required.

Kazakhstan and Ukraine by not adding production capacity did the right thing since the Ti market has slowed down and is not expected to pick up for a while. Russia who has a need for additional sponge has found alternative sources of supply. CIS producers are now concentrating their efforts in downstream development.

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Henry Seiner, TIMET

<u>Balancing Your Raw Materials Portfolio</u>

Our business is not unlike the weather - difficult to predict and subject to change. Just as you wouldn't travel around the world for years with only one change of clothes and no umbrella, you shouldn't set out to navigate the titanium business for years without a varied wardrobe and some protection against the elements. Sourcing decisions are frequently made at all stages of the titanium supply chain. Whether you represent a mill, a parts supplier or an end user of titanium, it is important to craft an all weather sourcing strategy.

This presentation considers the merits of a balanced sourcing portfolio which includes a range of raw material types, melting technologies and sources to help in strategy selection for all levels of the supply chain. Pro's and Con's of utilizing Sponge versus Scrap, VAR melting versus CHM, and Captive versus Partnership arrangements will be discussed. A flexible portfolio which recognizes the merits and pitfalls of each element will help each of us adapt to the inevitable change in seasons. In addition, sponge capacity trends in North America and Japan will also be reviewed and summarized as well as trends in the scrap and alloy markets.

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Mr. Nishino, CIS Trading group, Advanced Material Japan Corporation

China Titanium Sponge Industry And Foreign Trade Trends

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 2007, China's total titanium sponge capacity comes to near 60,000t, output volume reached about 45,000mt, over 150% increase compare to the previous year. The number of sponge actual producer increased to more than 10, and sevens of them with a capacity more then 5000t a year. At the same time, mill products also showed a big step forward to about 24,000mt, near 85% increase compared with 2006. Backed up by output increase, foreign trade reached a historical level. According to the customs statistics, in 2007, sponge export was 5584 and import was 1133t, a net 4450t export, this is less then 10% of total sponge production. The good aspect is that the development of China's titanium sponge industry definitely relieved global tight supply situation since 2005 and encouraging titanium consumers all around the world to keep on using this material and R&D people to dig out more applications for this magic material. Of course, not all people happy with a possible over supply of titanium sponge and causing price downward or instability in the industry. We should notice that about 53% of sponge production comes from private company, basically Chinese sponge production is free market needs orientated. Chinese sponge manufacturers still needs some time to compete with other major sponge manufacturers in the world on quality and productivity matters. Chinese sponge export increase may take some market share from existing players, but we should also realize that Chinese sponge production cost is not an advantage for them in the competition at all and this is a fare game. Raw material price increasing and government environmental restriction are already started to increasing the cost for them obviously. Chinese domestic titanium related market is growing faster; mills are planning to produce coil, welded tube and Big Aircraft Production Project was announced. We believe most of the sponge productions will continually consuming domestically in China. In coming years, we will see aliened sponge manufacturers in the world will manage to keep their orders; and new Chinese sponge manufacturers will face a hard competition domestically and worldwide as well.

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Mark Wilson, Thompson Creek Metals Company

Molybdenum: Strong Demand Growth And Limited Supply Maintain Upward Pressure On Pricing

Molybdenum is a critical alloying metal used in irons, steels and superalloys. It imparts corrosion resistance, improves strength, abrasion resistance and retains its mechanical properties at high temperatures among other favorable attributes. Molybdenum also serves critical roles in certain chemical markets.

Molybdenum supply has lagged demand growth for the past several years as growth in mine supply has not kept up with the strong demand. Lack of investment in molybdenum production capacity left the world short of readily available molybdenum resources once the strong demand from China, oil and gas development, and other industrial applications coincided and hit the market by 2003 and 2004. By mid year 2005, prices had increased nearly ten-fold from historic levels and have remained at this level as supply remains tight and inventory stocks continue to fall.

Despite the rise in prices, molybdenum demand has not slackened and the prospects for growth remain very strong led by the oil and gas industry as well as for other industrial applications. At the same time molybdenum exports from China are declining as a result of the Chinese government intervention in molybdenum trade. Increasingly restrictive export quotas have limited and are reducing the volume of molybdenum available to the world outside of China.

Additional molybdenum resources are planned for development, however, supply is still expected to fall short of demand through to the end of 2010 at the earliest. Continued strong demand may well extend the high molybdenum prices beyond 2010 as additional mine development is hindered by environmental regulation, escalating costs, limited mine personnel and a lack of a forward market for pricing molybdenum. Without a forward market, companies are not able to defray price risk by forward sales and potential creditors are not able to hedge the price exposure. These elements create an expectation for strong molybdenum prices into the future.

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Thomas McHugh, STRATCOR, Inc.

Vanadium: Bright Future, Manageable Risks

Vanadium, a key component of titanium alloys critical to the aerospace industry, has seen substantial changes in its markets, pricing, and industry structure over the past 5 years. Following a prolonged industry downturn that ended in 2003 with booming demand from steelmaking applications - especially in China - the industry experienced a sharp inventory drawdown followed by unprecedented price spikes starting in early 2005. New production and new production plans naturally followed, along with consolidations, acquisitions, and significant changes in the trade and competitive landscapes.

Although vanadium demand remains strong, its potential for further growth is especially strong, primarily because its value as a microalloying element for steel has yet to be realized in several important economies. Accordingly, its future appears bright. Nevertheless, the recent rapid growth in both supply and demand, even if balanced at any particular time, risks sudden shortfalls in one or the other. Such risks underscore the importance of long-term relationships between the titanium industry and its vanadium suppliers, both on technical and commercial levels.

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Irv Brown, Perryman Company

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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Economy: September 23, 2008
Moderator: Paul Jones, Reading Alloys Inc.

John Griffiths, Boeing Company

High Fuel Prices And The Airline Industry: Disruption, Restructuring, & Return To Trend Growth
The airline industry is uniquely exposed to the impacts of high oil prices, especially in a slowing global economy. As the price of jet fuel has spiked to unprecedented levels in the first half of 2008, airlines have been forced to adapt their operations in a variety of ways. This presentation examines evolving airline strategies and assesses the prospects of the industry as it deals with the fuel price shock. It then addresses how the industry may emerge from the near term period of adjustment, restructured for long term viability, and able to return to trend growth rates.

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Nick Pastushan, CIT Aircraft Leasing
A Discussion On The Impacts Of The Credit Crunch And The Oil Price Spike On Commercial Aircraft Demand
Financing markets in turmoil, Economic issues spreading around the globe and a record spike in energy prices. What will this all mean to order and delivery activity for commercial aircraft? Hear a top executive in the leasing business discuss the forward view of travel demand, and how the financing markets will recover from their shocks to fund a record level of order backlog.

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Eric Klenz, KeyBanc
Commodity Prices And Their Impact On Producers And Consumers Of Titanium And Related Metals
The discussion will review the economic factors influencing the significant rises in commodity prices and their impact on producers and consumers of titanium and related metals. Starting with introductory remarks on the titanium industry, the major producers, and end markets, the discussion elaborates on global growth expectations and demand forecasts for key end markets and/or geographies. Subsequently, the recent price movement of titanium is compared with that of various commodities, including critical natural gas, fuel oil, and other raw materials used by titanium producers, as well as with price increases for carbon and specialty steel, alloy metals, and aluminum. Global supply and demand issues that have contributed to recent run-ups in these metal commodities are also noted.

Macroeconomic effects, such as increases in Producer Price Index (PPI) and Consumer Price Index (CPI), changes in manufacturer profitability, liquidity requirements and employment, are studied in light of the recent run up in commodity prices. Furthermore, the discussion touches upon the performance and outlook for some of the major titanium manufacturers and/or fabricators serving the aerospace, defense, and construction markets. Publicly announced capacity expansions, and potential industry consolidation are also discussed. Finally, public company valuation metrics and those from recent mergers and acquisitions in the titanium space are also presented to complement the comments on industry momentum and near-term outlook.

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Corrosion and Energy: September 23, 2008
Moderator: Jim Grauman, TIMET

Jim Grauman, TIMET
Field Evaluation Trials Of The Pgma Corrosion Protection System
TIMET has recently initiated several full scale field demonstration trials of its patented PGMA (platinum group metal appliqué) corrosion protection system. The PGMA process utilizes a small patch of a pure PGM (platinum group metal) or a Ti-PGM alloy on an unalloyed (commercially pure) titanium article to provide enhanced corrosion protection. The enhanced corrosion protection can provide the equivalent of using ASTM grade 7 titanium. Depending on the appliqué and environment, protection ratios can be as high as 5,000/1, meaning that a 1 square inch PGMA patch will protect an area of 5,000 square inches of CP titanium. Advantages of this system include the ability to ”retrofit” enhanced corrosion protection to an existing CP titanium unit;

significantly reduced costs as compared to grade 7 titanium; and greatly decreased lead times since CP grades of titanium are often available from stock, whereas palladium grades 1, 7, 16, & 17 are not routinely stocked due to the inherent price volatility of the precious metal additions.

TIMET has proved the concept of this system through numerous laboratory studies and has now taken the next step of field testing full-scale titanium equipment in a variety of corrosive process environments. This paper will give an overview of the PGMA process along with the current field trials and anticipated commercial applications for the method within the chemical process industry.

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John Williams, Mogas Valve

Titanium Valves For Hydrometallurgical Metal Extraction

A major contributor to the successful operation of high–pressure acid leach (PAL) operations has been the valves about the autoclave. The valve of choice has been the metal-seated floating ball valve. The corrosion resistance and strength of titanium has made titanium a key building material for equipment utilized in PAL operations. The objective of this paper is to provide knowledge into the design challenges for valves in PAL, the specific applications of valves in PAL, and the specific materials in common use today.

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Mitch Dziekonski, Titanium Engineers

The Influence Of Titanium Properties On The Design And Application Of Downhole Oil & Gas Equipment

Titanium alloys have successfully been used in the oil industry for a variety of applications. Some of the applications are both offshore and downhole and consist of titanium stress joints, riser systems, drill pipe, logging and drilling tools, safety valves, packers, and tubing hangers. Titanium was chosen for its corrosion resistance, strength, and low density for the aforementioned systems. As the search for oil and gas encounters significant aggressive downhole environments, a new category of hydro carbon reserves are being identified as high pressure, high temperature (HPHT). These environments can exceed 30,000 PSI and temperatures of 450°F with an excessive amount of H2S sour gas, CO2 and chloride levels. One must carefully review titanium's unique physical and mechanical property characteristics for the evaluation and design of HPHT components. Historically, many oilfield components are substituted with titanium using prints based on nickel, stainless or steel alloys systems.

Titanium's characteristics require design engineers to consider things such as mechanical property degradation at high temperatures, low thermal expansion, and its unique stress-strain curve compared to other alloys. Tensile residual stresses generated by a variety of manufacturing methods can have a major impact on the performance of a downhole titanium component. Finite Element Analysis (FEA) is highly recommended as a design method in order to incorporate titanium's unique property characteristics.

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Bob Tippee, Oil & Gas Journal

World And Us Oil And Gas: Where's The Turning Point?

Signs began to appear in mid-2008 of relief from market conditions that have elevated prices of crude oil and petroleum products to extraordinary levels. Global inventories of crude and idle production capacity available in the leading oil-exporting nations both remain very low. When consumption is rising, these conditions, prevalent since 2003, make oil futures prices tend to jump with any rumor about supply problems. But major projects in the Middle East and Africa will bring new production capacity on stream in the second half of 2008 and in 2009. Global consumption growth, meanwhile, is decelerating. The increased supply coupled with a flattening of demand will ease price pressure unless supply sustains a major disruption—such as from hurricanes in the Gulf of Mexico, strikes in Venezuela or Nigeria, or warfare in the Middle East. In the US, oil consumption is down and oil production slightly up, year on year. A new worry in the US is adequacy of supply of highway diesel, the cost of making which jumped in mid-2006 and demand for which, unlike that for gasoline, is rising.

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New Materials Panel: September 23, 2008
Moderator: Terry Perles STRATCOR, Inc.

Roque Panza-Giosa, Goodrich Landing Gear
<u>Mechanical Properties Of Heat Treated Ti-5al-5v-5mo-3cr, An Attempt To Define Critical Properties Of Various Microstructural Features</u>
The properties and microstructure of Ti-5Al-5V-5Mo-3Cr were characterized under various stress states after the following heat treatments:
1) beta anneal and air cool;
2) beta anneal + solution heat treatment in the alpha-beta range;
3) beta anneal + solution heat treatment and ageing in the alpha-beta range.
For each condition, the damage mechanisms and final fracture modes were evaluated and rationalized on the basis of microstructural features. The true fracture stresses for the various conditions are compared.
Beta annealed material exhibits intense localized slip deformation leading to early crack formation and fracture. This mechanism is explained in relation to the presence of fine metastable phase precipitates resulting from the air cool step. Grain size dependence of the yield stress is described in terms of the Hall-Petch relationship.

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Chuck Pepka, Renton Coil Spring
<u>New Devolvement's in Titanium Spring Materials</u>
Testing of Ti 200 for springs has begun. Successful devolvement requires cooperation between the Material suppliers, The Wire or bar mill converting the material, The Spring manufacturer, and the Customer. The paper will explore the devolvement of materials, testing, and product applications for new Titanium spring alloys.

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Yoshio Itsumi, Kobe Steel, Ltd.
<u>A Newly Developed Press-Formable High-Strength Titanium Alloy</u>
The quantity of cp titanium sheet products shipment has been increasing over the last 10 years. Now a day, plate type heat exchanger (PHE) has become major application. At present, though the highest press-formability of cp titanium (that is the softest: ASTM Gr.1) is required in manufacturing "plates" parts, PHE users request higher working pressure for higher performance in some cases. In other words, titanium sheet itself must have higher strength without deterioration of press-formability. In this paper, in order to satisfy this demand, we have proposed a newly Ti-1.5Fe alpha-beta alloy, which has superior combination of high tensile strength over 500MPa and excellent press-formability, comparing ASTM Gr.2 sheet. These characteristics have been achieved by adding appropriate Iron content to obtain higher strength and maintaining alpha-beta dual phase microstructure, consequently refining microstructure and suppressing Oxygen content in order to maintain higher ductility / press-formability.

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Industrial: September 23, 2008
Moderator: Kevin Cain, Uniti Titanium

Dennis Schumerth, VALTIMET
<u>TITANIUM & THE NUCLEAR RENAISSANCE A POLITICAL & PRACTICAL UPDATE</u>
Notwithstanding the current world economic downturn coupled with spiraling oil prices, the global demand for energy continues unabated. It is also clear the continued use of fossil fuels for electric power generation

remains the bane of the PowerGen industry. Global warming, green power, carbon capture and sequestration, emission cap & trade and other political agendas touting global warming principals continue unabated. In some circles, scientific consensus indicates that rising atmospheric concentrations of carbon dioxide and other greenhouse gases are changing the earth's climate. The ultimate objective of the Gore Principal, the United Nations Framework Convention on Climate Change (UNFCCC) and other pundits is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference within the climate system. Fact or fiction, this concept appears to be the main driver for demise of fossil fuels and the tacit acceptance of nuclear energy by the prior foes.

Unfortunately, the Electric Power Generation Industry will not know if a full nuclear renaissance is underway for several more years. Assuming this energy source conceives and bears the gestated fruit of the renaissance, the next several years will indeed, be telling. However an immediate and positive sign lies in the action taken by several utilities and NSSS suppliers in ordering long lead time items recognizing that both from a political and purely practical position, the first in line will reap the rewards. Where and how does all this rhetoric impact the titanium industry? 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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Murray Pearson, HATCH Engineering

<u>Market Opportunities For Titanium And Ti Alloys In Pressure Hydrometallurgical Applications</u>

The development of new hydrometallurgical processes operating at elevated temperatures and pressures over the past two decades has made possible the extraction of precious metals and high value base metals from formerly uneconomic sources. Examples include the extraction of gold, silver and Platinum Group Metals (PGM's) by pressure oxidation (POX) of refractory sulphide minerals, high pressure acid leaching (HPAL) of nickel and cobalt from lateritic ores, and partial oxidative leaching (POL) of nickel, cobalt, copper and zinc from sulphide mineral concentrates.

Such unit operations occur in pressurized reactors ("or autoclaves") under process conditions which produce highly aggressive environments, and as such, offer unique opportunities for the application of reactive metals such as titanium, zirconium and tantalum in materials selection decisions.

This paper presents the market opportunities for the application of titanium and titanium alloys in hydrometallurgical extraction facilities, the major participants in the mining and metallurgical business sector, and the associated EPCM firms that undertake the design work. It also outlines some of the process implications, operating advantages and economic factors that are considered by engineers and owners in evaluating the preferred materials of construction and their potential application in modern autoclave facilities.

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Charles Hulswitt, Titanium Fabrication Corporation

<u>Titanium For Oil & Gas & Chemical Industries: A Fabricators Perspective</u>

With reaction conditions of chemical production processes becoming more arduous in terms of temperature, pressure and concentration of the reactants, more sophisticated materials in the construction of Chemical plant is necessary.

Titanium provides resistance to attack of: sea-water; moist chlorine; metallic chloride; chlorite and hypochlorite solutions; nitric and chromic acids; sulphides; organic acids; and many industrial gaseous environments. This makes titanium the ideal material for the construction of a wide range of chemical equipment. TiFab has a long history in this in this market sector. The following are the specific products fabricated in Titanium or Titanium clad which are supplied:

* Vessels
* Reactors
* Shell & Tube Heat Exchangers
* Titanium pipe spools
* Condensers
* Agitators

Most types of chemical plant can be made in titanium, including reaction vessels in solid, lined, or explosion-clad construction, agitators, gas scrubbing plant, and piping. Oil & Gas and Chemical plant equipment manufacturers include titanium among their standard ranges of materials. Market trends will be presented on the growth of both the domestic and international markets which have resulted in a variety of experiences each differing based on the destination point of the equipment. This paper presents an overview on the use of Titanium in these respective market sectors with brief references to some of our experiences on the recent projects we have completed.

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Ulrich Fehlauer, GEA Ecoflex GmbH

Titanium Plate Heat Exchangers In Industrial Processes

Ulrich Fehlauer will introduce GEA Group AG and its spectrum of products, that includes its global Plate Heat Exchanger (PHE) business first. Secondly he will provide a comprehensive general overview of the global market of PHE, in specific gasketed and welded types of PHE. He will of course focus on the role the titanium industry plays in the support and continued growth of the titanium PHE business. Space will be given to the industrial applications in particular to the marine- and petrochemical- application where titanium is the preferred material when it comes to seawater-cooling. The presentation will have an actual and future approach and will end with a message to the titanium industry.

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Opening Lecture: Wednesday, September 24th

Kathleen Housley, Sims Metal Management, Inc.

The Turbulent Founding Of The Titanium Industry

Titanium was only a tantalizing laboratory curiosity prior to World War II, defying attempts to make it in quantity until William Kroll, a brilliant metallurgist in Luxembourg, developed a process that could be scaled up for industrial use. Kroll was ahead of his time. It would take the protracted arms race between the United States and the U.S.S.R. to create the need and then solve most of titanium's complex metallurgical problems, bringing it to maturity as an aerospace metal. Spurred on by the insistence of the U.S. Armed Forces that titanium was critical to maintaining military superiority, the Federal government provided huge amounts of money to jump-start the industry, which included TIMET, Rem-Cru, Mallory-Sharon, and Oremet. Not until the top-secret spy plane, the SR-71 Blackbird, did the metal come of age, and then only through the enormous effort of many brilliant young metallurgists and engineers. Illustrated with 100 rare photographs from the 1940s and 50s, the presentation focuses on the struggles of getting an entire industry up and running rapidly, in so doing setting the stage for titanium's extreme volatility. The presentation is based on the book Black Sand: The History of Titanium published in 2007.

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How REACH Will Impact Your Organization

Elena Kostadinova, Assistant to the Hearing Officer of Directorate General for Trade of the European Commission

How Reach Will Impact Your Organization

Explanation of the objectives, principles and practical implications of REACH for companies based outside the EU who do business in the EU.

- Particular focus on practical issues such as which metals fall under REACH, what is a registration and who and why should register
- Useful information on pre-registration
- Comprehensive overview of the basic principles of REACH, including joint submission of a registration dossier, data sharing and SIEF participation
- Discussion on the purpose and importance of concluding a Consortium Agreement.

Elena Kostadinova or Raminta Dereskeviciute will also provide a list of key REACH dates and tips for ITA members on REACH compliance.

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Manufacturing Panel: September 24, 2008
Moderator: Jeff Klingerman, ATI Allvac

Stanley Abkowitz, Dynamet Technologies
<u>The Reinvention Of The Ti-6al-4v Alloy</u>
The Ti-6Al-4V alloy is the most commonly used titanium alloy of the titanium industry (70% of all alloys) and generates a considerable annual volume of scrap machining turnings (over 30 million pounds globally). These machine turnings currently find application as partial additions to the titanium ingot melting operations or as alloy additives to steel melts. Although useful, the value of these turnings in such applications is limited. The recycle of machined turnings directly to titanium alloy prime billet or to component shape will offer significant cost reduction.
This presentation will review the technical work underway at Dynamet Technology under Marine Corps. sponsorship to produce a cast shape from innovative casting feedstock composed primarily of Ti-6Al-4V alloy machining turnings. These are specially processed to purify the material of contaminants and uniquely consolidated to high density casting electrodes (feedstock). Chemical analysis, microstructure and the impressive mechanical properties achieved with cast material will be discussed along with the potential for significant cost savings. This innovative process, in addition to producing low cost titanium components represents the green manufacturing of titanium offering significant energy savings along with highly desirable environmental benefits.

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Xiqun Wang, TechSolve
<u>Performance-Based Optimization For Titanium Milling</u>
In the manufacturing industry, especially defense and aerospace, many component designs and characteristics of titanium materials make them expensive to machine. A considerable amount of stock must be removed from the initial form such as forgings, plates, bars, etc. In some instance, as much as 50 to 90% of the primary form's weight ends up as chips. Maximum machining efficiency for titanium alloys is required to minimize the costs of stock removal and maximize productivity.

A performance-based methodology of machining optimization has been developed by TechSolve to optimize machining parameters in order to achieve optimum machining performance of machines and cutting tools. This technology has been recently applied in milling operations on titanium alloys. The optimization method has been validated for a dozen of tool-material combinations in face-milling and end-milling operations. Optimum cutting parameters, speeds and feeds, are derived based on the user requirements of the overall machining performance including surface roughness, cutting forces, material removal rate and tool-life. Applications of the machining optimization system can improve process planning, increase productivity and reduce machining cost. A case study will illustrate the optimization of end milling operations on Ti-6Al-4V parts. The comparison of machining performance between pre-technology and post-technology shows that understanding the machining process leads to productivity improvement by optimizing machining parameters without any capital expenditure.

It is also a challenge for machining process planners to select appropriate machining parameters for new titanium alloys. Generally, the selection of machining parameters for tooling material combinations is based on experience, handbooks or static databases. However, since there is little experience and little knowledge about the machinability of the new material, process planners will have great difficulties in the selection of machining parameters and cutting tools. Inappropriate machining parameters may cause high scrap rate, short tool life or even tool failure. It will be helpful for process planners if the vendor of the new material could provide a range of safe machining parameters with which they can start process planning. A standard methodology has been developed by TechSolve to evaluate the machinability of new titanium alloys and recommend starting machining parameters for process planners. A case study will illustrate the evaluation of machinability for the new titanium alloy Ti-5-5-5-3 and process planning of end milling operations to produce a part using the obtained machinability information.

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David Pang, Ducommun Company

<u>Chemical Milling Of Titanium Alloys</u>

Chemical milling is used to establish intricate structural feature which can not easily obtained by mechanical methods on titanium alloys parts. The goal of chemical milling is to achieve defined precision in structural features with good surface finishing and low hydrogen content. The chemicals involved in the process include hydrofluoric acid, nitric acid and surface tension reducing agent. The chemistry involved in the chemical milling of titanium alloys is described. Different type of etchant with different composition of chemicals is presented. Titration is used to determine the concentration of available free acid, ion chromatography is used to determine the total fluoride and nitrate in the solution & spectrophotometer is used to determine the concentration of dissolved titanium metal ion exist in the solution by measuring the absorbance at 395 nm after oxidation in the presence of phosphoric acid & sulfuric acid.

Factors affect the result of the chem mill process are; type of Ti alloys, fabrication methods, geometry, racking, movement of parts, acid/Ti concentrations/ratio, solution temperature, mixing & operator.

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Richard Turner, University of Birmingham

<u>Temperature Profiles Achieved During The Linear Friction Welding Of Titanium 6/4</u>

Titanium 6/4 is the most common titanium alloy used within the aerospace industry. In particular, it is an important material for the production of rotor blades and disks. A key issue when forming blades and disks is how difficult it is to attach them, to produce a component known as a blisk (bladed-disk). One method of joining these components together is linear friction welding (LFW). LFW uses linear reciprocating motion, where one component is rubbed across the face of a rigidly clamped mating component. This linear reciprocating motion generates a frictional heating of the two mating faces of the components, causing the material here to soften, providing a weld interface. Axial loading applied across the weld interface causes some material to be extruded out of the weld. This is referred to as the flash.

This paper explores the temperature profiles caused through frictional heating and heat dissipation during the LFW process. Holes were cut axially into the component, and Type K thermocouple wires fixed inside these holes, mounted at different depths away from the mating surface. Different methods of attaching the thermocouples in to place were explored, and differing key process variables of the LFW process were inputted to produce a selection of thermal profiles relating to differing parameter sets for the LFW process. The temperatures experienced by the component will be dependent upon the parameters of the motion. The flow of the material as it is being extruded will also be very dependent upon these temperatures generated within the components, as will the microstructure of the Ti6/4 alloy along the weldline, further from the weldline and within the extruded flash material.

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Jyrki Tuominen, Oxford Instruments Analytical

Light Element Detection (Al, Si, Mg) by Portable Metal Analyzers

In recent years, development of portable X-ray Fluoresence (XRF) analyzer technology has grown rapidly. Analyzers are getting smaller and lighter, as well as more accurate and faster. User friendliness and data transfer capabilities have improved significantly. One of the most recent developments is the capability to measure lighter elements (Al, Mg, Si), which could not be measured with portable units 5 years ago. They form the basis for all aluminum alloys and as most titanium alloys contain significant concentrations of aluminum it is equally important in these alloys too. . Portable optical emission spectroscopy (OES) analyzers also have a role in titanium production due to limitations of XRF analyzers when measuring lighter elements.

In order to achieve relatively good detection limits and precise measurements, all XRF analyzers on the market use either Helium gas or vacuum technology to make light element detection possible. OES analyzers are much larger but detection limits and speed of analysis are better than of XRF. Therefore each of these technologies has certain drawbacks, as well as, unquestionable benefits. Additionally certain key components, such as the X-ray source or the detector, limit achievable accuracy. The sample surface and matrix composition also affects the measurement of light elements. The aim of this presentation is to highlight certain technical limitations and latest technical developments to analyze light elements in Ti alloys.

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Thomas Hofmann, ATI Stellram Division

The Art And Science Of Milling Titanium

Increasingly titanium and composite materials are replacing traditional aluminum and steel alloys in many aerospace applications. Today, the aerospace industry consumes roughly 42% of the total titanium produced with double-digit demand growth expected to continue throughout this decade. In fact, experts say we're in the "Age of Titanium" for aerospace. Both commercial and military markets are driving this demand as the new aircraft take full advantage of the high strength to weight properties titanium provides. The reasons for this transition are many: Titanium alloys provide high strength, fracture toughness, good weld ability and good corrosion resistance. For example, the inherent corrosion resistance of titanium alloys relative to steels reduces operating and maintenance costs for the airline industry. Titanium also bonds to composites much better than aluminum. Titanium's high strength to density ratio provides significant weight savings of large components, while simultaneously increasing system operating efficiency.

Along with these advantages, however, comes the challenge of machineability. Machining titanium is more difficult than common steel alloys and, for that reason, is considered a "difficult-to-machine" material. For example, typical metal removal rates for Titanium are roughly only 25% of the rates of these other materials, thus taking approximately 4 times as long to machine a component. In addition and typically, titanium components are forgings where up to 80% of the material must be machined away to achieve the final component shape. These new alloys are changing the traditional machining methods and cutting tool material requirements.
Difficult to machine isn't an absolute term, but a relative one. The use of these new materials does change the cutting tool requirements (metal removal rates, tool life, product quality and machining security – all critical to efficient, safe component manufacturing), however using the right combination of cutting tool designs, speeds and feeds, can result in effective production rates.

This presentation will review various ways to increase machining capability and capacity through a better understanding of how to more effectively machine titanium alloys. This is accomplished thru the technology of the tooling as well as how the part is processed on the machine, however, component rigidity, fixturing, coolant, cutting tooling and machining strategy are all factors that need to be balanced for the best result. One additional key factor of this optimization is a thorough knowledge of the inherent structures of the materials which allows one to design the optimum cutting tool system. For example cutting tool manufacturers have improved the capability of their tools by increasing the density of the substrates and developing new coating technologies to manage the heat generated in the machining of aerospace alloys. Heat is one of the main reasons for premature failure of cutting tools when machining the various titanium alloys.

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Keynote Speaker:
Dr. Joe MacInnis, Physician-Scientist and Deep-Sea Explorer

What is it like to dive under the ice of the Northwest Passage and discover, after three years of searching, a three masted British barque that sank in 1853 and is still intact? How does it feel to be among the first to descend more than two miles under the Atlantic and land your mini-sub on the rusting deck of RMS Titanic?
Dr. Joseph MacInnis, a medical doctor and one of the world's foremost explorers, has done this and much more. He is the first person to dive and film under the North Pole. He has led or participated in more than fifty major undersea expeditions and logged more time inside the Arctic Ocean than any other scientist. As a physician, he has spent twenty years studying human performance in high-risk environments.
In his speeches, Dr. MacInnis shares the values including courage, communication, and teamwork that enhance performance under the ocean and in the corporate world. Dr. MacInnis' keynote presentations include dramatic footage from James Cameron's film. Drawing on compelling examples he provides an inspirational framework on how to deal with the challenge of sudden change. Using a combination of wit, humor and scientific acumen he tailors his insights to the theme of your meeting, making him a relevant and indispensable resource for your audience.
Dr. MacInnis latest book Aliens of the Deep has just been published by National Geographic Books in Washington. His other books include Titanic: In a New Light, Saving The Ocean, and Fitzgerald's Storm. On February 14, 2005, Dr. MacInnis was made a founding member of the Commercial Divers Hall of Fame.

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Automotive Panel: September 24, 2008
Moderator: Kurt Faller, Faller Consulting

Mr. Koyanagi, Daido Steel Co., Ltd.
<u>Development Of New Gamma Tial For Turbocharger Application</u>
Gamma TiAl has a great potential for use in aircraft engine and automobile engine components. Since we demonstrated the potential of gamma TiAl as a turbocharger turbine wheel in 1987, a great effort has been paid in order to put the gamma TiAl turbine wheel to practical use. Through successful development of gamma TiAl alloy and of processes of casting and joining between the turbine wheel and an alloy steel shaft, we got into mass production of TiAl turbine rotors of turbocharger for passenger car application in 2003. Currently, heat resistance required for turbine wheels has become severe, because of the rise of exhaust gas along with development of fuel saving technologies to reduce CO2 emission. Therefore, the new gamma TiAl was developed based on a conventional gamma TiAl under mass production. The new gamma TiAl showed high creep and oxidation resistant than the conventional gamma TiAl. In addition, it was confirmed that the new gamma TiAl has equal manufacturability to the conventional gamma TiAl.

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Tomaz Bucar, Akrapovic Exhaust
<u>Lightweight And High Performance Titanium Exhaust Systems For Porsche Sports Cars</u>
Automotive applications of titanium follow logically from the high strength, high temperature durability and unique density of titanium and its alloys, and their excellent resistance to corrosion and wear. Exhaust systems

represent an attractive entry point for titanium into the automotive market. However, the use of titanium has been limited to racing cars and a few top-of-the-range road models, mainly because of cost. The achievements in titanium manufacturing, exhaust design and testing will contribute to future advances in exhaust systems and a broader use of titanium on mass-produced vehicles. In response to the Porsche and other customers' criteria, Akrapovi company recognized an optimal new car exhaust systems could be made from titanium. The Akrapovi design addresses the differences between titanium and stainless steel, including characteristics such as spring back, vibration and resonance frequency. New muffler components were custom developed for titanium fabrication and a unique acoustic tone, to meet customer sound and car performance requirements. When titanium emerged as the solution for car exhaust systems, the manufacturing technology to produce them in mass-market quantities did not exist. Working with titanium manufacturers to optimize an exhaust grade of titanium and the experience in producing motorcycle titanium exhaust systems that was acquired over many years, Akrapovi successfully adapted its stamping, bending, cold forming and welding methods for specific titanium properties. Since racing exhaust systems is the obvious and best proof of the quality of our products that the public can get, exhaust systems for some of the top racing cars were also developed. The company's efforts were rewarded at one of the hardest 24-hour endurance races in the world where the Porsche 997 RSR car equipped with a titanium Akrapovi exhaust system achieved a resounding victory.

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Silvia Gaiani, Akrapovic Exhaust

Mechanical Characterization Of Heat Resistant Titanium Alloys For Automotive Application

In the last five years, the increasing market demand of motorcycles and cars with high performances, oblige vehicles manufacturer to design and produce engines increasingly extreme and powerful. This aspect obliges consequently the exhaust systems producers to use materials which present awfully high mechanical and physical characteristics. From this point of view, titanium alloys represent the best compromise between mechanical behaviour, thermal characteristics and lightness; thank to these reasons, actually they're the most used metallic materials for the realization of exhaust systems designated to equip vehicles with high performances. Actually, all the bigger titanium manufacturers worldwide developed and launched on market special heat resistant titanium alloys, each of them with its specific qualities and peculiarities. In order to evaluate properly the characteristics of this wide range of products, Akrapovi has been in need to standardize a classification method and a range of controls to be performed on incoming materials. The data obtained from these trials are important information that could be used to choose a particular type of alloy for every specific application. From a practical point of view, build all the several members of an exhaust systems demands multiple technological operations. Akrapovi perform in its plant all the different phases, like tube forming, bending, sheet metal forming, welding... Moreover, the exhaust systems itself have to resists to high thermal stresses, fatigue phenomena, alterations of the superficial aspect. Having to hold on account all these aspects, the performed tests have the target to investigate the behaviour of alloys under various points of view, which:

- Strength
- Work Hardening
- Anisotropy
- Strain rate sensitivity
- Microstructure
- Heat resistance

During the lecture, the main results obtained after more than four month of tests will be showed and discussed. Moreover, some ideas and methods concerning how these results can became profitable for production will be also displayed and argued.

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Gary Latham, Pratt-Miller

Titanium In The Automotive Racing Industry

In racing, weight is everything. Designers are constantly looking to shave a few extra grams of weight from their design and material choice plays very large part of the design equation. The discussion will focus on the use of titanium in the automotive racing industry. Several examples of titanium's use in race cars include springs, transmission cases, uprights, fasteners, and engine components such as connecting rods, valves and rocker arms. Initial use focused on high end race cars such as F1 and the 24 hours of Le Mans but is becoming more common across many other forms of racing. In conclusion, we will take a look at how material cost is a relatively small part of a component's overall cost for a low volume race car component made from titanium vs. high strength steel.

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Paul Stratton, The Linde Group

Surface Hardening Titanium With Carbon Monoxide

Titanium has very poor tribological properties and cannot be used for applications like drive train components. Various coatings can be used, for example TiN and DLC, to improve them, but the loading is limited by the low strength of the substrate. In recent years thermochemical diffusion treatments have been developed. To produce a layer that is sufficiently thick to support a load in a reasonable time, these treatments have to be carried out at high temperatures: 950ºC and 1050ºC for oxidation and nitriding processes respectively. The high treatment temperature degrades the core properties to such an extent that they must be heat treated again after the surface layer has been produced.

An alternative is desirable that would give a substantive load bearing layer with good wear properties at a treatment temperature of 850ºC or lower. The use of such technology would allow the manufacture of a gear box that was 40% lighter than its steel equivalent. An initial study had shown that the layers formed using carbon monoxide were the most promising at lower temperatures and these were studied further. The effects of some of the treatment variables were determined, along with some of the characteristics of the optimised ceramic layer.

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Military Panel: September 24, 2008

Moderator: John Fanning, TIMET

John Fanning, TIMET

Advantages Of Titanium For Ballistic Applications

Titanium offers a useful combination of ballistic, physical and mechanical properties for ground vehicle and other military applications. Depending on the particular threat requirement, titanium alloys provide a weight savings of 10 – 40% in comparison to steel or aluminum armor. Also, titanium provides good multi-hit capability and excellent long-term corrosion resistance. Armor development activities focus on studying the interactions between processing, microstructure and ballistic performance.

Programs that have incorporated titanium armor products from TIMET include the Abrams Main Battle Tank, the Bradley Fighting Vehicle and the Stryker Mobile Gun System. Much of this armor is fielded – and shot – very soon after procurement. Titanium has met or exceeded the expected performance levels in all instances.

This presentation provides quantitative comparisons of the ballistic performance of titanium alloys with steel, aluminum, and other armor materials.

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Stephen Luckowski, US Army ARDEC

New Titanium Armor Application Provides Protection In A Lightweight Kit

The U.S. Army Armament, Research and Development Center (ARDEC) provides both lethality and gunner protection systems in support of the US Army's operations in Iraq and Afghanistan. ARDEC is the design activity for the Army's standard gunner protection kit for HMMWV and mine resistant ambush protected (MRAP) vehicle platforms. This gunner protection kit, known as Objective Gunner Protection Kit (O-GPK) is designed and configured to provide U.S. soldiers enhanced protection against enemy rifle fire and improvised explosive device (IED) blasts and still allow full visibility. This Army-wide solution is made of steel.

In order to meet the requirements of a more specialized application, the Special Operations Command (SOCOM) United States Special Operations Command (USSOC) requisitioned a titanium-based version of the O-GPK to support their operational needs. Titanium's high strength would provide the needed force protection, while its light weight would allow designers to meet these needs at a much reduced weight. This presentation will discuss the process of re-designing the O-GPK using titanium and the challenges faced. It will also discuss the advanced titanium processes and production equipment used to design, fabricate and manufacture the titanium products.

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Matt Burkins, US Army

<u>Titanium Alloys For Armor Applications</u>

Titanium alloys have long been used for reducing system weight in aerospace 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 systems. The advantages of low density, high strength, a large competitive industrial base, and mature forming and shaping techniques make titanium an excellent choice for many military applications. The U.S. Army Research Laboratory has invested significant research efforts in understanding the material processing requirements for ground applications and this paper will provide an overview of that research. Major efforts have been investigating alternative alloys and amending existing military specifications to allow the use of alternative and lower cost alloys that meet specific ground applications.

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Carrie Davis, Naval Surface Warfare Center, Carderock Division

<u>Productivity Enhancements For Gmaw Of Titanium</u>

While titanium has been used extensively in seawater cooling systems on US Navy surface ships, increased use of the material is limited by high material and fabrication costs. Welding costs in titanium are driven by labor intensive precautions relating to cleanliness and shielding required for sound welds and the productivity limitations of the gas tungsten arc welding (GTAW) process. Gas metal arc welding (GMAW) offers productivity benefits over conventional GTAW, but it is not used because it has historically been associated with lower weld quality from arc turbulence and exposure of the droplets to impurities in the arc atmosphere. This effort is focused on enhancing the titanium GMAW process to allow broader use of titanium within the Navy and establishing GMAW as a viable alternative to GTAW for titanium use. The research associated with this effort includes optimizing pulse waveforms, determining the effect of gas composition on bead shape, and evaluating commercially available products for GMAW.

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Commercial Aerospace: September 24, 2008

Moderator: Oscar Yu, RTI International Metals, Inc.

Ian Gale, Osborn Metals Ltd

<u>The Role Of Extrusion In The Quest For Near Net Shape</u>

The escalating cost of aerospace quality titanium alloys and the predicted imbalance in the supply and demand position demands that aerospace applications dramatically improve buy to fly ratios.

Extrusion of titanium profiles represents one of the most cost effective proven routes to improve the utilisation of available material whilst providing the bonus of reducing the amount of time and cost needed to machine away unwanted material.
The hot extrusion of titanium alloys as an established production process for over thirty years but was very much an also ran providing a few profiles to the aircraft producer and with a slightly higher level of activity in the engine sector.
The growth in the usage of titanium per aircraft has grown and is predicted to continue at an accelerating rate. The balance of the presentation would seek to demonstrate actual benefits obtained in material usage and machining as well as exploring the potential for further development.
Examples would include the use of improved die materials, special coatings and improved lubrication to tighten tolerances and reduce attrition of the dies and thus allow even closer adherence to the finished shape.

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Bill Swale, Aeromet International plc

Fabricated Titanium Structures Using Laser Welding & Hot Forming

"The new generation Civil Aircraft utilise Carbon Composite structures with the Aluminium components replaced by Titanium. Normally fuselage and structural components are made from Aluminium but a Carbon/Aluminium combination could result with adverse galvanic corrosion. To overcome this the structural frames, stringers, ribs etc are designed to be made from Titanium based alloys which have little or no adverse corrosion reaction with Carbon Composites.

Having made this design decision the manufacturing challenge is to find sufficient titanium materials, extrusion sources, forming sources and machining houses that can produce titanium structures of similar configuration to those typically made from aluminium. It has become apparent that the choice is limited and the cost of titanium prohibitive to the extent that innovative manufacturing methods have to be developed to meet costs and weight targets. To meet this challenge, Aeromet, which has an extensive experience in forming Titanium materials, joined with the United Kingdom Welding Institute to demonstrate methods for producing thick section frames from thin plate Ti6/4 material using the Hot Forming and Laser Welding processes. This development resulted in radical cost and material savings greater than 50%. In addition Aeromet has demonstrated the ability to accurately Hot Form thick section extrusions (25mm thick) which offers the opportunity to closer to size extrusions thereby reducing material.

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Jean- Michel de Monicault, Snecma Space Engines Division

Issues And Progresses In Manufacturing Of Aero Titanium Parts

Titanium alloys are strategic materials for components applications in aeronautic and space equipments which are developed and manufactured by SAFRAN Group companies :

- Commercial and military planes aero turbo-engines, helicopter engines, rocket aerospace turbo-pumps and engine nacelles, operating from cryogenic (20K) up to high (900K) temperatures.
- Landing gears for the new Boeing and Airbus planes requiring high strength and fracture toughness titanium alloys. The titanium alloys enable significant weight saving in those parts and reduced maintenance for the airlines. Two alloys are competing : Ti5553 and Ti1023 for which economical and technical criteria are to be taken into account

In this paper, a review of the status and the progress of titanium alloys for such applications will be first presented. The French research and development orientations, led by design strategies and titanium parts evolutions, will be subsequently addressed. The scientific, industrial and economic aspects will be considered: raw materials elaboration, microstructure monitoring in forged components, forming processes, machining, surface properties improvement (in relation with tribology and environment), new design requirements (reduction of properties scatter, higher temperature use …) and eventually future evolutions and perspectives for titanium base materials.

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Mario B. Coracides Pratt & Whitney (UTC)

Next Generation Product Family Business Overview

Mario B. Coracides has been hired to the new position of Executive Director of Supply Chain for Next Generation Product Family (NGPF) at Pratt & Whitney, based on Hartford, Connecticut. He leads a matrix organization of procurement, engineering, quality and aftermarket employees to source production parts, raw materials and assemblies for the next generation engine part families (Military and Geared Turbo Fan). He will also be responsible for helping to optimize the supply base capability, capacity and cost through strong relationships and ACE Gold partnerships.

Mario has 14 years of leadership experience in global sourcing, Six Sigma and supply chain management. Prior to joining Pratt & Whitney, Mario was, most recently, general manager at the Honeywell Inc. Aerospace Division in Puerto Rico. Prior to Honeywell, he was the vice president of Global Operations for GE Commercial Finance. As a master black belt in Six Sigma, he established strategic direction for the operations team using the Six Sigma methodology and philosophy. Mario holds a B.S. in supply chain management from Arizona State University.