TMS

Become A TMS Member

TMS derives its strength from its members, who take a hands-on approach to shaping the policy, programming, and publications of the society. Guided by these volunteers, TMS serves all segments of its professional community by:

FACILITATING NETWORKING:

By sponsoring numerous annual meetings and specialty conferences, TMS maximizes the opportunities for professionals from industries, universities, and government agencies worldwide to meet face to face and exchange technical ideas and experience, offer customer/client insights, find a mentor and/or serve as one, and just plain chat with peers and colleagues.

PRODUCING JOM AND OTHER PUBLICATIONS:

Every TMS member receives a complimentary subscription to JOM. Formerly Journal of Metals, this highly respected monthly journal, explores traditional, innovative, and revolutionary issues in the minerals, metals, and materials fields. Designed to be of maximum and immediate benefit to readers throughout the world, JOM is on-line before the print version is mailed.

TMS also publishes three other journals (*Journal of Electronic Materials* and *Metallurgical and Materials Transactions A and B*), numerous conference proceedings volumes and textbooks, and videos designed to give materials scientists and engineers the latest information on scientific and applied advances in areas as diverse as electronic materials, automotive manufacture, and extractive metallurgy.

PROMOTING LIFE-LONG LEARNING:

TMS is dedicated to the education of the materials science and engineering professional as well as to cultivating an interest in the field by young people.

For the practicing professional, TMS and its five technical divisions sponsor continuing education courses, primarily technical but also nontechnical, to promote the education and development of current and future professionals.

For student members, TMS participates on both the Accreditation Board for Engineering & Technology (ABET) and the National Council of Examiners for Engineering and Surveying (NCEES) to help, respectively, maintain the highest possible standards in the accreditation of metals and materials programs in academia and in the registration of professional engineers.

—All individuals registering for the 130th Annual Meeting & Exhibition at the non-member fee will automatically receive a one-year complimentary introductory membership for 2001. Your membership will be activated upon completion of your registration form, membership application, and payment of the non-member registration fee. You will receive a membership card and new member packet immediately after the meeting.

• Members from 77 countries and six of the world's seven continents.

• All new members will begin receiving a monthly subscription to JOM.

• New members will also be able to continue networking with a prestigious membership at future TMS meetings that fit their area of interest at a discounted member fee.

• Additional benefits include access to, and inclusion in the TMS Membership Directory on TMS OnLine at www.tms.org., professional development and continuing education opportunities, and group insurance programs. See the membership page on TMS OnLine for a complete list of membership benefits.

• Please direct any questions regarding your complimentary membership to the TMS Member Services Department via email to abartholomay@tms.org or via phone to Anne Bartholomay at (724) 776-9000 Ext. 241.

TMS THE MINERALS, METALS & MATERIALS SOCIETY

PROMOTING THE GLOBAL SCIENCE AND ENGINEERING PROFESSIONS CONCERNED WITH MINERALS, METALS, AND MATERIALS

184 THORN HILL ROAD
WARRENDALE, PA 15086-7514
USA

TELEPHONE: (724) 776-9000
(800) 966-4867
FAX: (724) 776-3770
WEB: www.tms.org

GREAT MEMBER BENEFITS

- Five distinct technical divisions which are composed of 52 separate, highly specialized committees
- Periodicals: JOM, Metallurgical and Materials Transactions A and B, Journal of Electronic Materials
- Conference Proceedings, Monographs, and Textbooks
- TMS OnLine & the TMS Document Ordering Center
- TMS Conferences: TMS Annual Meeting & Exhibition, TMS Fall Meeting, TMS Fall Meeting for Extraction & Processing, Electronic Materials Conference, Specialty Conferences
- Professional Development and Continuing Education Opportunities
- Professional Registration
- TMS Young Leaders
- TMS Resume Referral Service
- TMS Gold or Platinum MasterCard
- Group Insurance
- TMS Membership Directory
- TMS Speakers Directory
- International Healthcare Plan
- Hertz Car Rental Discounts
- Auto and Homeowners Program
- PROinsure Program
  A Professional Liability/Errors and Omissions Program
- PRObop Program
  A Professional Business Owners Package Program
- Member Benefits Program
  Receive a 20% Rebate Buying or Selling Your Home
- Nelson Financial Services Program
- WAAIME Auxiliary Activities

THE VISION OF TMS IS TO BE THE PROFESSIONAL SOCIETY OF CHOICE FOR THE WORLDWIDE MINERALS, METALS AND MATERIALS COMMUNITY.

ADMISSION REQUIREMENTS

FULL MEMBER

A candidate for election as full member shall be a person of integrity in activities associated with minerals extraction, processing, fabrication, or with materials applications. A candidate shall hold: (a) A baccalaureate degree in metallurgy, metallurgical engineering, materials science, or materials engineering, and at least 3 years' professional experience. (b) A baccalaureate degree in science or engineering in a discipline other than identified and at least 5 years' professional experience. (c) A baccalaureate degree from a recognized university in a discipline other than (a) or (b) and whose main activities lie in, but are not limited to, the development, management, administration, welfare, sales, or services to the minerals, metals and materials industries, with at least 7 years' experience. A credit in experience of one year for a masters degree or two years for a doctoral degree shall be granted.

Annual dues: $90.00

ASSOCIATE MEMBER

A candidate for associate member shall be a person of integrity who, while not possessing the academic or technical experience of a member, is active in fields that are sufficiently related to the advancement of, or service to, the minerals, metals or materials extraction, processing, or applications industry.

Annual dues: $90.00

The Minerals, Metals & Materials Society is a member society of the American Institute of Mining, Metallurgical and Petroleum Engineers, Inc.

LIFE MEMBER

A candidate for election as life member shall be a person who qualifies as a full member or associate member and desires to only pay dues once.

Dues: $1,350.00

Pay dues once, effective for lifetime regardless of dues increase(s).

REINSTATEMENT

Those members who may have let their dues payment lapse may reinstate in the same grade as when they left by submitting a new application and paying a reinstatement fee of $10.00 plus current dues. If original election year is desired, back dues must be paid to date (half the annual dues fee for each year of lapsed membership); otherwise, election year will be year of reinstatement.

The TMS membership year runs from January 1–December 31. Applications received January 1–September 30 will be processed for the current calendar year.

Applications received after September 30 will be processed for the remainder of the current calendar year and the entire following year. Membership benefits commence upon processing; subscriptions commence January–December of the following year.

Two weeks required for processing of complete applications submitted with full payment. Incomplete applications will not be processed. Allow eight to ten weeks for subscriptions to start.

MEMBERSHIP APPLICATION

PLEASE TYPE OR PRINT

❒ Mr. ❒ Mrs. ❒ Ms.
❒ Dr. ❒ Professor

SEND MAIL TO:
- ❒ Business Address
- ❒ Home Address

TECHNICAL DIVISION SELECTION:
- ❒ Electronic, Magnetic, & Photonic Materials Division
- ❒ Extraction & Processing Division
- ❒ Light Metals Division
- ❒ Materials Processing & Manufacturing Division
- ❒ Structural Materials Divison

THROUGH WHAT MEANS WERE YOU ENCOURAGED TO JOIN TMS?
- ❒ TMS Annual Conference
- ❒ TMS Fall Conference
- ❒ Specialty Conference
- ❒ Exhibitor
- ❒ TMS Staffed Booth
- ❒ JOM
- ❒ MET TRANS, JEM, Etc.
- ❒ Publications Catalog
- ❒ TMS Mailed Brochure
- ❒ Non-TMS Advertisement
- ❒ Continuing Education
- ❒ TMS OnLine/Web
- ❒ Colleague
- ❒ Other _______________

BIRTHDATE:

_______/_______/_______

Members automatically receive a monthly print subscription to JOM.

If you prefer to receive your copy only electronically, please check here. ❒

If you prefer to receive your subscription in both print and electronic formats, please check here. ❒
(You must include $8 extra charge.)

If you would like additional information about member subscriptions and discounts to JOM, Journal of Electronic Materials, or Metallurgical and Materials Transactions A and B, please check here. ❒

FOR OFFICE USE ONLY
ID
BIRTH
ELECTED
TYPE
CATEGORY
SECTION
APPROVED

NAME: ____
LAST FIRST MIDDLE INITIAL

TITLE: ____

COMPANY OR ORGANIZATION: ____

BUSINESS: ____
STREET OR P. O. BOX CITY STATE 9 DIGIT ZIP/POSTAL CODE COUNTRY

____
PHONE FAX TOLL FREE # E-MAIL WEB ADDRESS

HOME: ____
STREET OR P. O. BOX CITY STATE 9 DIGIT ZIP/POSTAL CODE COUNTRY

____
PHONE FAX E-MAIL

____
MONTH DAY YEAR

WHAT IS THE PRIMARY ACTIVITY OF YOUR PLACE OF EMPLOYMENT? (check one)
- ❒ Commercial Laboratory
- ❒ Government/Nonprofit Laboratory
- ❒ Engineered Materials Producer
- ❒ Manufacturer of Parts/Components
- ❒ Manufacturer of Finished Products (OEMs)
- ❒ Primary Metals Producer
- ❒ Secondary Metals Producer
- ❒ Producer/Processor of Materials
- ❒ Educational
- ❒ Engineering or Consulting Firm
- ❒ Other ______________

WHAT BEST DESCRIBES YOUR PRIMARY JOB FUNCTION? (check one)
- ❒ Applications/Product Development
- ❒ Basic Research
- ❒ Product Engineering and Design
- ❒ Technical/Lab Management
- ❒ Process Engineering
- ❒ Metallurgical Materials Selection
- ❒ Corporate Management
- ❒ R & D Engineer
- ❒ R & D Scientist
- ❒ R & D Management
- ❒ Manuf./Production Management
- ❒ Quality Engineering
- ❒ Marketing or Sales
- ❒ Other ______________
- ❒ Consultant
- ❒ Educator
- ❒ Student

OTHER SOCIETY AFFILIATIONS: ____

EDUCATION TO DATE:

	Name of School	Dates Attended Month/Year–Month/Year	Major Subject/ Engineering Field	Degree Received or Expected Graduation Date: Month/Year
B.S. ❒				
M.S. ❒				
Ph.D. ❒				

REGISTERED PROFESSIONAL ENGINEER? ❒ Yes ❒ No STATE: __________ YEAR OF REGISTRATION: __________

RECORD OF EXPERIENCE:
(List most recent record of employment. If you do not possess a qualifying degree, please include your last seven years of experience.)

From: __________ Title: ______________________________
Company: ______________________________
To: __________ Nature of Company's Business: ______________________________
Total Time with Company: ______________________________
Engineering Responsibilities: ______________________________

TO APPLICANT

If you have been encouraged to submit this application by a current member of TMS, please complete the following information:

Member's Name ______________________________ Member # ______________

I agree, if elected, to accept election, and to abide by the TMS bylaws.

Signature ______________________________ Date ______________

PREPAYMENT IS REQUIRED (checks should be made payable to TMS in U.S. dollars drawn on a U.S. bank)
- ❒ Check enclosed
- ❒ Bill my credit card: (check one)
  - ❒ American Express ❒ VISA ❒ MasterCard ❒ Diners Club

Credit Card # ______________________________ Expiration Date ______________

Cardholders Name ______________________________

Signature ______________________________

COMPLETE APPLICATION AND MAIL WITH PAYMENT TO: **184 Thorn Hill Road, Warrendale, PA 15086-7514**
Phone: 800-966-4867 or 724-776-9000 • Fax: 724-776-3770

Advance Registration Form

FOR THE TMS ANNUAL MEETING AND EXHIBITION ■ FEBRUARY 11–15, 2001 ■ NEW ORLEANS, LOUISIANA

PLEASE CHOOSE ONLY ONE OPTION FOR SENDING FORM

WEB	FAX	MAIL
Take advantage of the convenience of on-line pre-registration via the TMS website: **http://www.tms.org** Web registration requires credit card payment.	Fax this form to TMS Meeting Services **USA (724) 776-3770** Fax registration requires credit card payment.	**Return this form with payment to** Meeting Services, TMS, 184 Thorn Hill Road, Warrendale, PA 15086

TMS2001
130TH ANNUAL INTERNATIONAL MEETING & EXHIBITION

Advance Registration Deadline: January 22, 2001
PAYMENT MUST ACCOMPANY FORM.
Forms received past this date will be processed at the on-site fee.
Instructions: Check your selections and fill in the necessary information. Please print or type.

MEMBER OF: ☐ TMS ☐ ISS ☐ SME ☐ SPE Member Number: ______

THIS ADDRESS IS: ☐ Business ☐ Home Employer/Affiliation: ______

☐ Dr. ☐ Prof. ☐ Mr.

☐ Mrs. ☐ Ms. ______
LAST NAME FIRST NAME MIDDLE INITIAL

Address: ______

City: ______ State/Province: ______ Zip/Postal Code: ______ Country ______

Telephone: ______ Fax: ______
COUNTRY AREA/CITY LOCAL NUMBER COUNTRY AREA/CITY LOCAL NUMBER

E-Mail Address: ______ Guest/Spouse Name: ______
GUESTS DO NOT RECEIVE ADMISSION TO TECHNICAL SESSIONS.

REGISTRATION FEES:

	ADVANCE FEES (until 1/22/01)	ON-SITE FEES (after 1/22/01)
☐ Member	$390 M	$490 ML
☐ Non-Member Author	$390 NMA	$490 NMAL
☐ Non-Member *	$520 NM	$600 NML
☐ Student Member ##	$0 STU	$0 STUL
☐ Student Non-Member ## *	$25 STUN	$25 STUNL
☐ TMS Retired Member	$200 RM	$200 RML
☐ Exhibit Booth Personnel	$0 E	$0 EL
☐ Exhibit Attendee	$35 EO	$35 EOL

* Includes TMS membership for 2001
Students must attach a copy of their school's student identification card.

PUBLICATION ORDERS:

ALL pre-ordered books not indicated for shipment MUST be picked up at the Publications Sales area in the convention center.

Please ship to the above address: No. of books ______
$15 per book $______(SB)

- ☐ 4801 Light Metals 2001 (CD-ROM & Book Set) $164
- ☐ 478X Chemistry and Electrochemistry of Corrosion and Stress Corrosion Cracking $96
- ☐ 4798 Cyanide: Social, Industrial, and Economic Aspects $86
- ☐ 4895 Elevated Temperature Coatings CD-ROM $60
- ☐ 4887 EPD Congress 2001 .... $125
- ☐ 4909 Innovations in Processing and Manufacturing of Sheet Materials $97
- ☐ 481X Magnesium Technology 2001 .... $124
- ☐ 4879 Structural Biomaterials for the 21st Century $65

TUTORIAL LUNCHEON LECTURE TICKETS:

OPTIONAL BOX LUNCHES	FEE	NO.	TOTAL
Monday 2/12/01 (SPONSORED BY YOUNG LEADERS)			
☐ Young Leaders Extractive Metallurgy	$15	______	$______ EM

SOCIAL FUNCTION TICKETS:

	FEE	NO.	TOTAL
Monday 2/12/01			
☐ Larry Kaufman Honorary Dinner	$55	______	$______ KD
Tuesday 2/13/01			
☐ TMS Banquet	$60	______	$______ AD
☐ Tables of 8	$480	______	$______ AD8
Table Sign to Read: ______			
☐ Extraction & Processing Division Luncheon	$25	______	$______ EP
☐ Tables of 8	$200	______	$______ EP8
Table Sign to Read: ______			
Wednesday 2/14/01			
☐ Light Metals Division Luncheon	$25	______	$______ C
☐ Tables of 8	$200	______	$______ L8
Table Sign to Read: ______			
☐ Roger Staehle Honorary Dinner	$55	______	$______ SD

PLANT TOUR:

	FEE	NO.	TOTAL
Thursday 2/15/01			
☐ Nasa Michoud Assembly Facility	$35	______	$______ NT

2001 MEMBERSHIP DUES—FOR CURRENT TMS MEMBERS ONLY:

Advanced registrations received after December 31, 2000 must be accompanied by your 2001 dues payment to be processed at the member fee.

- ☐ Full Member .... $90 FM
- ☐ Junior Member .... $55 JM
- ☐ ASM/TMS Joint Student Member .... $25 ST

TOTAL FEES PAID: $ ______

PAYMENT ENCLOSED:

☐ Check, Bank Draft, Money Order
Make checks payable to TMS. Payment shall be made in US dollars drawn on a US bank.

☐ Credit Card Expiration Date: ______

Card No.: ______

☐ Visa ☐ MasterCard ☐ Diners Club ☐ American Express

Cardholder Name: ______

Signature: ______

REFUND POLICY: Written requests must be mailed to TMS, post-marked no later than January 22, 2001. A $50 processing fee will be charged for all registration cancellations.

Housing Registration Form

FOR THE TMS ANNUAL MEETING AND EXHIBITION ■ FEBRUARY 11–15, 2001 ■ NEW ORLEANS, LOUISIANA

RESERVATIONS MUST BE RECEIVED AT THE HOUSING BUREAU BY JANUARY 4, 2001

TMS2001 130TH ANNUAL INTERNATIONAL MEETING & EXHIBITION

RETURN HOUSING FORM: (choose only one option)
Hours of operation: 8:00 am–5:00 CST Monday–Friday

- VISIT www.tms.org
- CALL 847-940-2153 (International); 800-424-5250 (Domestic)
- FAX to 847-940-2386 (International); 800-521-6017 (Domestic)
- MAIL to TMS Housing Bureau, 108 Wilmot Road, Suite 400, Deerfield, IL 60015-0825

Arrival Date ______________ Departure Date ______________

Last Name ______________ First Name ______________ MI ______

Company ______________

Street Address ______________

City ______________ State/Country ______ Zip/Postal Code ______

Daytime Phone ______________ Fax ______________

E-mail (confirmation will be sent via e-mail if address is provided) ______________

Accompanying Person ______________

☐ Non-Smoking Room Requested ♿ ☐ Special Needs

INDICATE 1st, 2nd AND 3rd HOTEL CHOICE AND TYPE OF ACCOMMODATION

1. ______________
2. ______________
3. ______________

If all three (3) requested hotels are unavailable, please process this reservation according to: (check one) ☐ Room Rate ☐ Location

Accommodations (check one)

- ☐ 1 person/1bed
- ☐ 2 people/1 bed
- ☐ 2 people/2 beds
- ☐ 3 people/2 beds
- ☐ 4 people/2 beds
- ☐ One bedroom suite
- ☐ Two bedroom suite

Hotels

Headquarters
Hilton Riverside
$188/Classic s/d
$208/Deluxe s/d
$243/Towers s/d

Doubletree Hotel
$169/single
$189/double

Embassy Suites
$179/single
$199/double

Hampton Inn & Suites
$164/single
$164/double

Hilton Garden Inn
$182/single
$202/double

Holiday Inn Select
$165/single
$165/double

Marriott Hotel
$199.00/single
$199.00/double

Wyndham Canal Place
$195/single
$195/double

Wyndham Riverfront Hotel
$179/single
$199/double

CONFIRMATIONS
Confirmation will be mailed, faxed or e-mailed to you from the TMS Housing Bureau once your reservation has been secured with a deposit. You will not receive a confirmation from your hotel. If you do not receive a confirmation within 2 weeks, please call the Housing Bureau.

CHANGES/CANCELLATIONS
All changes and cancellations in hotel reservations must be made with the TMS Housing Bureau on or before January 4, 2001 to avoid a $16 processing fee. After January 4, 2001 and prior to 72 hours before arrival date, changes and cancellations must be made with your assigned hotel. Your deposit will be refunded less a $16 processing fee. Any cancellations made within 72 hours of the arrival date will result in forfeiture of the full deposit.

RESERVATIONS/DEPOSITS
All reservations are being coordinated by the TMS Housing Bureau. Arrangements for housing must be made through the TMS Housing Bureau and NOT with the hotel directly. All housing reservation forms must be received by Thursday, January 4, 2001. Deposits: A $150 per room deposit is required to make a reservation; a $300 deposit is required for a one-bedroom suite and a $450 deposit is required for a two-bedroom suite. The deposit amount is payable by credit card or check (mail only). The credit card will be charged immediately. If paying by check, mail your payment with this completed housing form. All checks must be made payable to the TMS Housing Bureau in US funds drawn on a US bank. No wire transfers will be accepted.

CREDIT CARD:

☐ Visa ☐ MasterCard ☐ Diners Club ☐ American Express ☐ Discover

Expiration Date: ______________

Card No.: ______________

Cardholder Name: ______________

Authorized Signature: ______________

Please read all hotel information prior to completing and submitting this form to the Housing Bureau. Keep a copy of this form. Use one form per room required. Make additional copies if needed.

Continuing Education Registration Form

FOR THE TMS ANNUAL MEETING AND EXHIBITION ■ FEBRUARY 11–15, 2001 ■ NEW ORLEANS, LOUISIANA

PLEASE CHOOSE ONLY ONE OPTION FOR SENDING FORM.

WEB	FAX	MAIL
Take advantage of the convenience of on-line pre-registration via the TMS website: **http://www.tms.org** Web registration requires credit card payment.	Fax this form to TMS Cont. Education Dept. **USA 724-776-3770** Fax registration requires credit card payment.	**Return this form with payment to** Cont. Education Dept. TMS 184 Thorn Hill Road Warrendale, PA 15086

TMS2001 130TH ANNUAL INTERNATIONAL MEETING & EXHIBITION

Advance Registration Deadline: January 22, 2001
PAYMENT MUST ACCOMPANY FORM.
Forms received past this date will be processed at the on-site fee structure.
Please print or type

Member of: ☐ TMS ☐ ISS ☐ SME ☐ SPE **Member Number:** ____________________

☐ Dr. ☐ Prof. ☐ Mr. ☐ Mrs. ☐ Ms. ____________________
LAST NAME FIRST NAME MIDDLE INITIAL

Employer/Affiliation: ____________________

Address: ____________________

City: __________ State/Province: __________ Zip/Postal Code: __________ Country: __________

Telephone: __________ Fax: __________

E-Mail Address: __________

CONTINUING EDUCATION SHORT COURSES	ADVANCE TO 1/22/00		ON-SITE AFTER 1/23/00	
Check your selections. *See brochure for cancellation and refund policies.*	MEMBER	NON-MEMBER	MEMBER	NON-MEMBER
Excellence in Professional Communications ☐ Sunday, 2/11/01	$260	$310	$260	$310
Molten Salt Chemistry and Process Design: from Smelter to Casthouse ☐ Saturday, 2/10/01 & Sunday, 2/11/01	$645	$735	$695	$785
Heat Treatment of Wrought and Cast Aluminum Alloys ☐ Saturday, 2/10/01 & Sunday, 2/11/01	$645	$735	$695	$785
Total	$ __________			

PAYMENT ENCLOSED:

☐ **Check, bank draft, or money order made payable to TMS**—Payment shall be made in US dollars drawn on a US bank.

☐ **Credit Card**—Card No.: __________ Expiration Date: __________

☐ Visa ☐ MasterCard ☐ Diners Club ☐ American Express

Cardholder Name: __________

Signature: __________

REFUND POLICY:
Written request must be mailed to TMS, post-marked no later than January 22, 2001. A $50 processing fee will be charged for all registration cancellations.

Accompanying Tour Registration Form

FOR THE TMS ANNUAL MEETING AND EXHIBITION ■ FEBRUARY 11–15, 2001 ■ NEW ORLEANS, LOUISIANA

DESTINATION MANAGEMENT, INC. NEW ORLEANS has arranged tours for members/guests of the TMS Annual Meeting & Exhibition, February 11–15, 2001.

Please make your reservation by noting choice of tour, day, and time. Pre-sold tickets will be held at the tour desk located in La Louisiane Ballroom A in the Ernest N. Morial Convention Center.

TMS2001 130TH ANNUAL INTERNATIONAL MEETING & EXHIBITION

DESCRIPTION	DATE/TIME	PRICE	NO.	AMT DUE
New Orleans City Tour	Monday, February 12, 2001 ■ 9:30 am–12:30 pm	$18	______	$_________
Jean Lafitte Swamp Tour	Tuesday, February 13, 2001 ■ 9:30 am–12:30 pm	$35	______	$_________
Mardi Gras World/ New Orleans Mint Museum	Wednesday, February 14, 2001 ■ 12:30 pm–4:00 pm	$28	______	$_________
			Total:	**$**_________

Name: ____

Address: ____

City: ______________________ State/Province: ____________ Zip/Postal Code: ____________ Country: ____________

Phone: ______________________________ Fax: ______________________________

PAYMENT OPTIONS

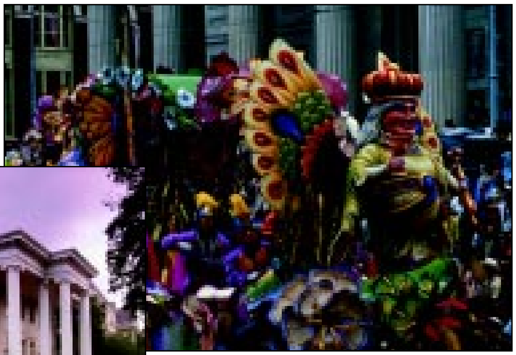
☐ Check Enclosed (Remit in U.S. Funds)

☐ Charge My Account: ☐ Visa ☐ MasterCard ☐ Discover ☐ American Express

Card No.: ______________________________ Expiration Date: ______________

Cardholder's Name: (please print)______________________________

Signature: ______________________________



WE CANNOT ACCEPT PHONE ORDERS

Please make checks payable to and mail to:

Destination Management, Inc. New Orleans
610 South Peters Street, Suite 200
New Orleans, Louisiana 70130
Fax: (504) 592-0529
Attn: Cheryl

- Please have your reservations in by January 29, 2001.
- Cancellations must be received in writing by February 5, 2001.
- You will receive a full refund for any cancellations received by this date.
- Credit card orders may be faxed to 504/592-0529.
- All tours, unless otherwise indicated, are based on 30 participants.
- DMI reserves the right to cancel any of these tours should minimum number not be met.

Q: How do I maximize my investment in the 2001 TMS Annual Meeting?

For years, TMS annual meeting proceedings volumes have acted as important reference sources for their fields. This year's proceedings selection includes new volumes in TMS's popular Light Metals and EPD Congress series:

- **Light Metals 2001**
  is the newest installment in the Light Metals series, which has become the definitive annual reference source in the field of aluminum production and related light metals technologies. The Light Metals 2001 package includes both the hardcover proceedings volume and CD-ROM.
- **EPD Congress 2001**
  is the newest edition in the Extraction and Processing Division Congress series, which has become the definitive annual forum for new technological developments in the process metallurgy community.

THIS YEAR, TMS ALSO OFFERS THE FOLLOWING SYMPOSIUM PROCEEDINGS VOLUMES:

- Chemistry and Electrochemistry of Corrosion and Stress Corrosion Cracking
- Cyanide: Social, Industrial, and Economic Aspects
- Elevated Temperature Coatings
- Innovations in Processing and Manufacturing of Sheet Materials
- Magnesium Technology 2001
- Properties of Nanocrystalline Materials
- Structural Biomaterials of the 21st Century

VISIT THE PUBLICATIONS SALES AREA TO PURCHASE ANNUAL MEETING PROCEEDINGS VOLUMES

YOU CAN ALSO RESERVE COPIES OF THE FOLLOWING PROCEEDINGS VOLUMES, WHICH WILL BE AVAILABLE SOON FROM THE 2001 TMS ANNUAL MEETING:

- Automotive and Joining Aluminum
- Lightweight Alloys for Aerospace Applications (Available in portable document format.)

. . . critical information for surviving the aggressive pace of 21st Century business.

A: PURCHASE A TMS CONFERENCE PROCEEDINGS VOLUME AND KEEP VALUABLE TECHNICAL INFORMATION AT YOUR FINGERTIPS.

PLANT TOUR
NASA Michoud Assembly Facility
9:00 AM - 12:00 PM
Outside Ernest N. Morial Convention Center –
In Front of Hall A
★★★

Aluminum Joining-Emphasizing Laser and Friction Stir Welding: Session 4 - Friction Stir Welding-Application and Performance

Sponsored by: Light Metals Division, Aluminum Association
Program Organizers: John A.S. Green, The Aluminum Association, Washington, DC 20006-2168 USA; J. Gilbert Kaufman, Columbus, OH 43220-4821 USA; Thomas J. Lienert, Edison Welding Institute, Columbus, OH 43221-3585 USA

Thursday AM — Room: 214
February 15, 2001 — Location: Ernest N. Morial Convention Center

Session Chair: Thomas J. Lienert, Edison Welding Institute, Columbus, OH 43221-3585 USA

8:30 AM Keynote
A Comparison Between Microstructure, Properties and Toughness Behavior of Power Beam and Friction Stir Welds in Al-Alloys: *Jorge F. dos Santos*[1]; Gürel Çam[1]; Alexander von Strombeck[1]; Volker Ventzke[1]; Mustafa Koçak[1]; [1]GKSS Forschungszentrum, Instit. for Mats. Rsch., Join. Tech., Max-Planck-Str, Geesthacht D-21502 Germany

Power beam welding (LBW and EBW) and friction stir welding (FSW) processes can be successfully used to achieve defect-free joints in Al-alloys. However, a thorough characterisation of the joints is needed in order to satisfy the stringent requirements of advanced applications such us aerospace, automotive and shipbuilding. In this work, LBW, EBW and FSW were performed on four different aluminium alloys, namely 5005-H14, 2024-T351, 6061-T6, and 7020-T6 (plate thickness being 5 mm except alloy 5005, which is 3 mm thick). The main objective was to establish the local microstructure-property relationships and to determine the fracture toughness levels of welded plates with weld zone strength undermatching. Microstructural characterisation of the weld metals was performed by optical and scanning electron microscopy. A very low level of porosity was observed in all LBW and EBW welds. This has been attributed to careful surface cleaning prior to welding and the welding in vacuum as required by the EBW process. All FSW welds were void and crack free. Extensive microhardness measurements were conducted in the weld regions of the joints. Global and local (microflat specimens) tensile properties and fracture toughness properties (in terms of CTOD) of the power beam and FSW joints were determined at room temperature. The effects of strength mismatch and local microstructure on fracture toughness of the joints have been considered in the analysis of the results. Due to the reduction in yield strength in the FZ of power beam and FSW joints, higher fracture toughness values were obtained at this test location than in the respective base materials. The confined plasticity (increased constrain) within the fusion zone did not deteriorate toughness because apparently the inherent properties of the obtained microstructure is still higher than that of the base material. Hence, it can be concluded that the strength undermatching observed on both power beam and FSW joints did not generally lead to a degradation of toughness properties.

9:00 AM Invited
Mixed Mode Tearing Behavior of Aluminum FSW Joints: *Michael A. Sutton*[1]; [1]University of South Carolina, Dept. of Mech. Eng., 300 Main St., Rm. A129, Columbia, SC 29208 USA

Friction stir welded, 6.35 mm thick, 2024-T3 aluminum components, with initial fatigue cracks oriented along the FSW, are subjected to combined mixed mode I/II loading in an Arcan test fixture. Crack tip conditions ranging from pure tension to pure shear are applied to the specimen up to the initiation and stable growth of the flaw. Results from the studies including (a) crack paths, (b) load-crack extension data, (c) SEM photographs of fracture surface and (d) the microstructure in the FSW along the observed crack growth path prior to crack growth.

9:30 AM Invited
The Use of Friction Stir Welding Technology in Maritime Applications: *Rollin E. Collins, II*[1]; [1]High Tech Welding, 263 McLaws Circle, Ste. 203, Williamsburg, VA 23185 USA

Friction Stir Welding has been used successfully to produce large panels for the shipbuilding industry. The recent development of truly high speed vessels has driven the builders and ship owners to search for solutions to reduce overall weight while maintaining strength and at the same time optimize fabrication techniques to reduce construction time and lower production costs. This presentation will focus on experience to date with Friction Stir Welding showing examples of different panel solutions that have been produced and the many benefits derived from using such modular elements. Finally, the critical interaction between optomized designs, the proper material selection and the fabrication processes will be discussed.

10:00 AM Break

10:15 AM
FSW in the Automotive Industry: *Christopher B. Smith*[1]; [1]Tower Automotive, Adv. Techn., 3533 N. 27th St., Milwaukee, WI 53216 USA

One of the challenges with the implementation of aluminum into automotive structures is the relative difficulty of joining aluminum as compared to steel. Techniques for joining steel (e.g. GMAW, RSW, etc.) are also applicable to joining aluminum, but their controllability in a high production environment is much more difficult in the case of aluminum. Thus, there exists a need for alternative joining process for aluminum, for which friction stir welding (FSW) offers a possible opportunity to fill. With all of its advantages, FSW has an enormous potential for use in the automotive industry. However from its inception it had several limitations, which did not make the process justifiable. These limitations, their current status, and the research towards overcoming them will be discussed, as well as the automotive applications with the most potential for use of FSW.

10:45 AM
Joining Dissimilar Aluminum Alloys and Other Metals and Alloys by Friction-Stir Welding: *Lawrence E. Murr*[1]; R. D. Flores[1]; F. Contreras[1]; M. Guerra[1]; D. J. Shindo[1]; M. Siddiqua[1]; H. S. Kazi[1]; C. Schmidt[1]; J. C. McClure[1]; [1]University of Texas at El Paso, Metall. and Matls. Eng. M-201, 500 W. University Ave., El Paso, TX 79968-0520 USA

A wide range of aluminum alloys, particularly dissimilar alloy systems, have been friction-stir welded. These include Al 2024/Al 6061, Al 5052/Al 7075, Al 7075/Al 2017, Al 5052/Al 2017, Al 2195/Al 2024, and Al 2024/Ag, Al 2024/70/30 brass, etc. In all but the last two dissimilar weld systems the weld zone is uniformly dynamically recrystallized, and though there is a very complex and non-uniform mixing and flow of the components forming intercalated, lamellar-like microstructures. There is often a 40% loss of strength for these age-hardenable alloys even though the weld integrity is flawless. The mixing and weld zone microstructures are different for Al 2024/Ag and Al 2024/brass although dynamic recrystallization also plays a dominant role. Weld zone microstructures have been characterized extensively by optical metallography and transmission electron microscopy. The weld properties and microstructures are altered somewhat with tool rotation and traverse speeds (actual weld speed) and these issues will be discussed. Some recent examples of dilute Sc(0.1%)-Al alloy joining by friction-stir welding will be illustrated. There appear to be very few aluminum alloys which cannot be successfully joined by friction-stir welding although complex, PM systems such as Al-Be alloys pose some particular challenges. Research supported by a General Services Administration (GSA) Grant PF-90-018 and NASA MURED Grant NAG8-1645.

11:15 AM

Corrosion-Fatigue Crack Propagation in Friction Stir Welded Al 7050: *Peter S. Pao*[1]; Steve J. Gill[1]; Jerry C.R. Feng[1]; K. K. Sankaran[2]; [1]Naval Research Laboratory, Code 6323, 4555 Overlook Ave. S.W., Washington, DC 20375-5320 USA; [2]The Boeing Company, St. Louis, MO 63166 USA

The corrosion-fatigue crack propagation of weld, HAZ, and base metal of friction stir welded Al 7050 were investigated. Fatigue crack growth rates in the weld in air and in 3.5% NaCl solution are slightly higher than those in the base metal. Fatigue crack growth rates in salt water are two to three times higher than those in air at high and intermediate stress intensities. Fatigue crack growth rates are significantly lower and fatigue crack growth thresholds are substantially higher in the HAZ than in the weld and base metal in both salt water and air. Post fatigue fractographic examinations revealed a variety of fracture modes such as intergranular separation in the recrystallized weld nugget in salt water and cleavage-like fracture in base metal in air. The observed corrosion-fatigue crack growth kinetics in the weld, HAZ, and base metal are discussed in terms of microstructural variations, environmental interactions, and crack closure.

Aluminum Reduction Technology: Soderberg and Prebake Cell Operation

Sponsored by: Light Metals Division, Aluminum Committee
Program Organizers: John Chen, University of Auckland, Department of Chemical & Materials Engineering, Auckland, New Zealand; Eric Jay Dolin, USEPA, MC 6202J, Washington, DC 20460 USA; Halvor Kvande, Norsk Hydro ASA, Oslo N-0240 Norway

Thursday AM	Room: 206-207
February 15, 2001	Location: Ernest N. Morial Convention Center

Session Chair: Knut Arne Paulsen, Hydro Aluminium Karmoy, Håvik, Karmøy N-4265 Norway

8:30 AM Invited

The Soderberg Cell Technology–Present Performance, Challenges and Possibilities: *Tor Bjarne Pedersen*[1]; [1]Elkem Aluminium Lista, P.O. Box 128, Farsund 4551 Norway

Søderberg Cell Technology has in general had inferior performance compared to modern PB-cells. The technology is also facing new and challenging environmental requirements. However, existing Søderberg cells may yield substantially better and satisfactory results with relatively small capital investments and alteration of operation procedures. Through systematic innovation Elkem Aluminium Lista has demonstrated that it is possible to meet coming new European environmental requirements, produce metal with high quality and at the same time increase productivity. For Lista, being a pure Søderberg smelter, this is far more economic than converting to PB-technology. The Søderberg technology has cost advantages since there is no need for rin furnace or rodding facility. Development work is going on at several locations and through gaining thorough process knowledge the technology will improve further in the coming years. This will make even small Søderberg plantscompetitive compared to modern PB-plants.

9:00 AM

Pilot Plant Operation of Russian VSS-Pots in Excess of 160 kA Following Magnetic Improvements, Installation of Pointfeeders and Process Control Systems: *T. K. Nasipuri*[1]; H. L. Stephen[1]; H. O. Bohner[1]; [1]HART, Singenbergstr. 18, St. Gallen CH-9003 Switzerland

On a total of 10 Test and 2 Buffer pots out of a line of 192 pots busbars were improved to various degrees on the basis of a model by Technology Center Chippis (TCC) of Alusuisse. Each of the pots was fitted with single-piston pointfeeders to add alumina and aluminium fluoride inside of the skirt. The main process parameters such as resistance, instability (noise), alumina and aluminium fluoride-content, skirt adjustment, beam raising, AE prediction and AE frequency as well as adaption of set resistance to stud pulling, tapping and AE voltage were process-controlled by hardware supplied by Hamilton Research & Technology (Hart), Calcutta and by software designed and developed for VSS pots by the the authors. Production per potday through higher current intensity and current efficiency, electric power and paste consumption, all improved to various degrees dependent upon the magnetic improvement of the busbar system as expressed as standard deviation of cathodic current distribution. Performance figures over a six-month test period, corrected for metal pad inventory changes are presented and discussed.

9:25 AM

Reduction of Anode Effect Frequency and Duration at VSS Line Operating with Heavy Power Modulation: *André Luiz Lopes Machado*[1]; Eliezer Duarte de Araújo[1]; João Bonfim Galvão Moraes[1]; [1]Alcan Aluminio do Brasil Ltda., Aratu Plant-Prim. Grp., Cx Postal 7391, Salvador, Bahia 41810-000 Brazil

Energy consumption is a representative factor in a Smelter operation cost, specially in Brazil. Because of high energy costs, big efforts have been carried out in order to reduce energy costs without affecting potline performance. The main operational change was the introduction of a very heavy power modulation 10 years ago, that resulted in high cost reduction, but caused a lot of fluctuation in the process. It's well known that anode effects are responsible for an important part of overall energy consumption, and also produce most of PFC's emissions in a potline. Therefore, an important tool to reduce energy consumption is to work on pot voltage control, with a special focus on anode effect detection and termination. In this paper we present our process development to reduce anode effect frequency and duration at Aratu's VSS Potline and some results of the implementation.

9:50 AM

3-D Mathematical Model for Studying Changes in Self-Baking Anode Power Regime: *S. A. Shcherbinin*[1]; V. V. Pingin[1]; V. K. Frizorger[1]; [1]PSC Krasnoyarsk Aluminum Plant, Krasnoyarsk 660111 Russia

The self-baking anodes of aluminum reduction cells undergo continuos changes of their power regime in operation. These variations of dynamic conditions are basically driven by varying anode studs positions and changed anode operating properties. A 3-D mathematical model was used in order to establish optimum operating parameters because it allowed to run evaluations of thermal and electrical fields for the whole cell. The uniqueness of the present software lays in a possibility to run prompt calculations for different sets of cell dimensional and process parameters. It was the uniqueness of the newly developed program which supported the performance of calculations and results evaluation for changing anode parameters. A developed in the package post-processor supports visualization of dynamic changes of anode power regime, in particular it allowed to run a comparison between different stud patterns and stud setting schedules. Dependencies were found based on the calculation results for changing cell thermal and electrical fields and optimization methods were established.

10:15 AM

Pot Life Prediction of Aluminium Soderberg Cells: M. A. Doheim[2]; S. M. El-Raghy[3]; *Mohamed A. Ali*[1]; [1]The Aluminum Company of Egypt, Nage-Hammadi Egypt; [2]Assiut University, Fac. of Eng.; [3]Cairo University, Fac. of Eng.

Factors affecting pot life has been identified as: thermal design, construction materials, construction practices, and cathode shell design, preheating, start-up and general operation of the cell. The actual pot life statistics records at Aluminium Company of Egypt (Soderberg cells), for the period 1980 till 2000 analyzed. Though the average Soderberg pot life over this period was 57 months, yet, there were cells with few months' life. More than one cell over 100 months. An empirical correlation for pot life prediction was developed using the three-parameter Weibull cumulative distribution. The statistical model was tested for different carbon lining suppliers. Good agreement was found between the model and actual life after excluding the early and accidental failures. This paper indicates the relative weight of parameters to be considered for longer pot life.

10:40 AM Break

10:50 AM
Aluminum Fluoride Dissolution and Distribution-An Investigation of the Dynamic Mass Balance When Adding Large Quantities to a Prebake Cell: *Ketil Å. Rye*[1]; Ingar Solberg[1]; Trygve Eidet[2]; Sverre Rolseth[3]; [1]Elkem Aluminium ANS, P.O. Box 566, Mosjøen N-8650 Norway; [2]Elkem Research, P.O. Box 8040 Vågsbygs, Kristiansand N-4602 Norway; [3]SINTEF Materials Technology, Trondheim N-7465 Norway

The dynamic behavior of aluminium fluoride in Hall-Heroult cells is not readily understood, as the AlF3 mass balance sometimes gets out of control. This is manifested as "inactive"cells, where the AlF3 content stays nearly constant for days in spite of efforts to change the situation. So far there appears to be no comprehensive theory that can explain all unaccountable observations associated with such cells. In order to throw some light on this problem, investigations were carried out to check the AlF3 mass balance when adding large quantities of aluminium fluoride to normal cells. In spite of some uncertainty associated with the determination of the volume of molten bath in the cells, it was apparent that not all of the aluminium fluoride added dissolved rapidly. Frequent measurement of the side ledge thickness after the AlF3 addition revealed only minor changes, which could not account for the "missing" aluminium fluoride.

11:15 AM
Potroom Operations and Their Impact on Anode Spike Formation: *Neal Wai-Poi*[1]; Richard Jansen[2]; Bernd Rolofs[1]; [1]Corus Aluminium Voerde GmbH, SchleusenstraBe 11, Voerde D-46562 Germany; [2]Corus Research, Development and Technology, IJmuiden Tech. Ctr., P.O. Box 1000, IJmuiden 1970 CA, The Netherlands

Since 1992, the Voerde smelter has experienced a continuing problem with anode spikes, which culminated earlier this year with over 1100 spikes in one month. The anode spike problem is a result of persistent carbon dust problem in the cells. Last year, the results from a study investigating the influence of operational practices on anode spike formation and the negative impact anode spikes have on potroom performance were presented. Since then, further studies investigating the factors which influence anode spike formation and how operational practices can be modified to minimize their formation have been conducted. Changes to operational practices have included a new energy management strategy and removal of carbon dust from the anode cover. These changes have resulted in a reduction of over 60% in anode spikes. However, despite the dramatic reduction, the results show the only sustainable solution to permanently eradicate spikes at Voerde is to reduce the carbon dust levels, including an improvement in baked anode quality.

11:40 AM
Sludge in Operating Aluminium Smelting Cells: *Pierre Yves Geay*[1]; B. J. Welch[1]; P. Homsi[1]; [1]Aluminium Pechiney LRF, B.P. 114, St-Jean-de-Maurienne, Cedex 73303 France

There has been growing concern on cathode wear in modern aluminium smelting cells, with doubts existing on the mechanistic causes. The dissolution of carbide has been shown to be an important factor, but there have been suggestions that abrasive wear is also a major contributor. The main abrasive in contact with the cathodic blocks is the sludge but, to cause wear, it would have to have considerable mobility. Sludge also introduces a resistance to the current flow path since it has been shown that on some occasions it covers significant fractions of cathode surfaces. In this investigation, the first stage was to take representative sludge samples and accurately characterize them by XRF, XRD, SEM-EDX and other chemical analytical methods. New phases have been identified and the sludge eutectic temperature has been more precisely defined. The second stage of the project was carried out to ascertain the location of sludge and its general mobility. The sludge level in pots was found to be very erratic but statistically, its average profile showed a correlation with the cathode wear pattern. Separate laboratory experiments demonstrate that the electrical conductivity of sludge is typically half that of normal electrolyte.

12:05 PM
The Behaviour of Phosphorus Impurities in Aluminum Electrolysis Cells: *Elin Haugland*[1]; Geir Martin Haarberg[2]; Elke Thisted[2]; Jomar Thonstad[2]; [1]Hydro Aluminium a.s., Tech. Ctr. Ardal, P.O. Box 303, Ovre, Ardal N-6884 Norway; [2]Norwegian University of Science and Technology, Dept. of Mats. Tech. and Electrochem., Sem Saelandsvei 6, Trondheim N-7491 Norway

Phosphorus is an important impurity element in the Hall-Heroult process, where it affects the current efficiency and the quality of the aluminium produced. The chemical and electrochemical behaviour of phosphorus compounds in molten cryolite-based electrolytes was studied in controlled laboratory experiments. Measurements were also carried out in industrial cells by analysis of electrolyte and metal samples as a function of time after additions of phosphorus compounds to the electrolyte. Phosphorus has a relatively long residence time in the electrolyte due to cyclic oxidation and reduction reactions at the electrodes. Eventually, phosphorus escapes from the industrial cells through evaporation of elemental phosphorus or as a phosphorus compound together with small carbon particles (carbon dust). Mass balance studies show that the phosphorus concentration in the metal depends on both the phosphorus content in the raw materials and on the cell operation. A relatively small increase in the normal operating temperature was found to cause a decrease in the amount of phosphorus in aluminium.

Cast Shop Technology: Solidification & Foundry Technology

Sponsored by: Light Metals Division, Aluminum Committee
Program Organizers: John F. Grandfield; CSIRO Australia, Preston, Victoria 3072 Australia; Paul Crepeau, General Motors Corporation, 895 Joslyn Road, Pontiac, MI 48340-2920 USA

Thursday AM Room: 208-210
February 15, 2001 Location: Ernest N. Morial Convention Center

Session Chair: Peggy Jones, General Motors Corporation, Powertrain, Saginaw, MI 48605-5073 USA

8:30 AM
High Quality Magnesium Castings by the New Rheocasting (NRC) Approach: *Helmut Kaufmann*[1]; Peter J. Uggowitzer[2]; [1]Leichtmetall Kompetenzzentrum Ranshofen, Ranshofen, Upper Austria 5282 Austria; [2]ETH Zurich, Institute for Metallurgy, Sonneggstrasse 3, Zurich CH-8092 Switzerland

Metallurgical and processing aspects of New Rheocasting (NRC) are discussed in terms of microstructural analysis of the slurry and the NRC castings, and in terms of mechanical characterisation. The basic concept of NRC is explained and possible production equipment is introduced. The process is based on controlled cooling of a slightly superheated melt. This controlled cooling is performed in a carousel slurry maker. The semi-solid slugs are then cast to shape in a Vertical Squeeze Casting machine. Special focus is put on the requirements on Mg alloys for semi-solid forming, and it will be shown that proper alloy design can stabilize the process and improve reproducibility of the casting properties. Magnesium casting and wrought alloys will be checked for semi-solid castability, and trial results will be presented. The results are compared with characteristic properties of High Pressure Die cast magnesium, Squeeze Castings and Thixomolding parts. An innovative recycling concept for low cost re-use of globular semi-solid runners and scrap will be presented.

8:55 AM

Prediction of Mechanical Properties of As-Cast and Heat-Treated Automotive Al Alloys Using Artificial Neural Networks: *Daryoush Emadi*[1]; Mahi Sahoo[1]; Terri Castles[1]; Hekmat Alighanbari[2]; [1]CANMET, Mats. Techn. Lab., 568 Booth St., Ottawa, Ontario K1A 0G1 Canada; [2]Ryerson Polytechnic University, Mech./Aerosp. Eng., 350 Victoria St., Toronto, Ontario M5B 2K3 Canada

The desired mechanical properties of cast automotive aluminium alloys depend on the heat treatment conditions, alloy chemistry and casting parameters such as cooling rate, mould design and melt treatment. Despite extensive work in the literature, the large number of these controlling parameters have made it difficult to predict the mechanical properties and to model them using conventional techniques. In the present study, we used an alternative method, namely Artificial Neural Networks (ANN), to predict the mechanical properties. A database of mechanical properties (UTS, YS and El%) as a function of chemical composition, heat treatment (solutionizing, quenching and ageing) and casting variables (mould type and melt treatment) was established based on published literature. Several standard multi-layer ANN models were then trained using data randomly selected from the database. The outputs of the ANN models were subsequently compared with the remaining data. The results indicate that ANN is a suitable modelling technique for prediction of mechanical properties and optimising the heat treatment process.

9:20 AM

Latent Heat Evolution During Solidification of Aluminum Based Alloys: *Carlos Enrique Schvezov*[1]; Alicia Ester Ares[1]; Sergio Fabian Gueijman[1]; [1]University of Misiones, Fac. of Sci., 1552 Azara, Posadas, Misiones 3300 Argentina

It has recently been presented a thermodynamic model for the calculation of the latent heat during solidification modeling with emphasis on its evolution in the mushy zone. The calculations were applied to Lead-Tin alloys and the results were in good agreement with experimental data. These calculations are now extended to binary aluminum alloys such as Al-Cu, Al-Mg and Al-Zn in a range of concentrations. The results show similar behavior of the latent heat as observed in Lead-Tin alloys that is, with a larger amount of latent heat being released at the beginning of the alloy solidification. In the present report these results are presented and discussed.

9:45 AM

Microstructure and Microsegregation in a Directionally Solidified Quaternary Al-Rich Al-Cu-Mg-Zn Alloy: *Fanyou Xie*[1]; Xinyan Yan[1]; Men Chu[2]; Y. Austin Chang[1]; [1]University of Wisconsin-Madison, Mats. Sci. and Eng., 1509 University Ave., Madison, WI 53706 USA; [2]Alcoa, Inc., Alcoa Technical Center, Alcoa Center, PA 15069 USA

Microstructure and microsegregation in a directionally solidified quaternary Al-3.86Cu-0.89Mg-0.99Zn alloy with cooling rates of 2, 0.78 and 0.23 K/s were studied. The solidification microstructures of the quaternary alloy were dendritic, similar to those of Al-rich Al-Cu-Mg alloys solidified at the same conditions in an earlier study. Both the fractions of solid formed and the solute concentration gradients in the dendrites were studied. While the volume fractions of solid formed were measured by image analysis, the solute concentration gradients within the dendrites were determined by an area scan technique. The fractions of solid formed were also obtained from the concentration profiles, which were in agreement with those fractions obtained by image analysis. The model-calculated fractions of solid and the concentration gradients were in reasonable accord with the measured data. The model used was a modified Scheil that includes back diffusion in the solid, dendrite arm coarsening and effect of undercooling.

10:10 AM Break

10:20 AM

Predicting Microstructure and Microsegregation in Multicomponent Aluminum Alloys: *Xinyan Yan*[1]; Ling Ding[1]; *Fanyou Xie*[1]; Y. Austin Chang[1]; [1]University of Wisconsin-Madison, Dept. of Mats. Sci. and Eng., 1509 University Ave., Madison, WI 53706 USA

Accurate predictions of microstructure and microsegregation in metallic alloys are highly important for applications such as alloy design and process optimization. Restricted assumptions concerning the phase diagram could easily lead to erroneous predictions. The best and most accurate method to treat the phase equilibrium at the interface is coupling the microsegregation calculation with phase diagram calculations according to the CALPHAD method. A newly developed numerical model for the prediction of microstructure and microsegregation in multicomponent alloys during dendritical solidification was introduced. The micromodel was directly coupled with phase diagram calculations using a user-friendly and robust phase diagram calculation engine-PANDAT. Solid back diffusion, undercooling and coarsening effects were included in this model, and the experimentally measured cooling curves were used as the inputs to carry out the microsegregation calculations. This model was used to predict the microstructure and microsegregation in some commercial aluminum alloys, such as 2024 and 7050. Microstructure and microsegregation in those multicomponent aluminum alloys were experimental investigated using directional solidification and electron probe microanalysis (EPMA). Calculated results using this model are in accord with the experimental data, while those results using Scheil model deviate significantly from the experimental data.

10:45 AM

Thermal Modeling of Ingot Chain Productivity: *Alain Chauvineau*[1]; Loic Maenner[1]; Serge Guy[1]; *Stephane Morency*[2]; Chantal Sztur[1]; [1]Pechiney, Aluminium Pechiney, 725 Aristide Berges BP n°7, Voreppe Cedex 38341 France; [2]University Laval, Dept. Min. and Metall., Ste-Foy, Québec G1K 7P4 Canada

Ingot chains casthouses are generally confronted with classical problems of productivity and reliability, sometimes difficult to analyze. Pechiney has developed a thermal model adapted to ingot chains in order to quantify the influence of the main process parameters. The PAMCAST /SIMULOR® software, dedicated to foundry casting, was used. The model utilizes industrial measurements and heat transfer coefficients determined in the laboratory. Among the many parameters explored with the model, the calculations show that the main parameters governing the productivity of the ingot chain are the water/mold heat transfer and the coating of the molds. The model is and will be used as a tool for optimizing present chains as well as for designing future generation ingot chains.

11:10 AM

The Response of Twin Roll Cast Aluminium Strips to Thermo-Mechanical Processing: *Yucel Birol*[1]; Murat Dundar[2]; Osman Cakir[1]; A. Soner Akkurt[2]; Shaun Hamer[3]; Chris Romanowski[3]; [1]MCTRI, Marmara Research Center, P.O. Box 21, Kocaeli, Gebze 41470 Turkey; [2]Assan Aluminum Works, E-5 Karayolu, 32 Km., Tuzla, Istanbul 81700 Turkey; [3]FATA Hunter, Inc., P.O. Box 5677, 6147 River Crest Dr., Riverside, CA 92507-0745 USA

The recent trend in Twin-Roll Casting has been to reduce the casting gauge to less than 3mm in order to reduce the processing costs, to take advantage of increasing rates of solidification and to increase productivity. To fully utilize the potential of their thin gauge and wide strip caster investment, ASSAN Aluminum, in cooperation with FATA Hunter and Marmara Research Center, has recently initiated an extensive R&D program to investigate the effect of casting parameters such as the casting gauge, the casting speed and tip setback on the metallurgical quality of the cast strip. 81 different samples covering a range of casting parameters for three common foil alloys, AA8011, AA8006 and AA1200, were cast on industrial scale with a 1725mm wide SpeedCaster. The effect of casting parameters on the macrostructural features of twin roll cast strips was investigated in the first phase of this program and was recently reported. This paper describes the response of the thin-gauge wide cast strips to thermo-mechanical processing with a particular emphasis on the effect of casting gauge on homogenization cycles.

Cast Shop Technology: Molten Metal Behaviour & Properties

Sponsored by: Light Metals Division, Aluminum Committee
Program Organizers: John F. Grandfield; CSIRO Australia, Preston, Victoria 3072 Australia; Paul Crepeau, General Motors Corporation, 895 Joslyn Road, Pontiac, MI 48340-2920 USA

Thursday AM	Room: 224
February 15, 2001	Location: Ernest N. Morial Convention Center

Session Chairs: M. M. Makhlouf, Worcester Polytechnic Institute, Mats. Sci. and Eng. Dept., Worcester, MA 01609 USA; George Ferguson, Auckland University, Auckland, New Zeland

8:30 AM

Effect of Ti and Zr on The Fluidity of High Strength Al-Alloys: *Young Dong Kwon*[1]; Zin Hyoung Lee[1]; [1]Korea Advanced Institute of Science and Technology, Mats. Sci. and Eng., Gusong-dong 373-1, Yusong-gu, Taejon 305-701 Korea

Ti and Zr are used as minor alloying elements and for grain refinement for high strength Al-alloys and they are known to have adverse effect on the fluidity of the alloy. The weight reduction is achieved by using high strength alloys and reducing the wall thickness. The fluidity is important to cast thin parts. The fluidity of a base alloy, Al-4.8%Cu-0.6%Mn, was measure by casting a multi-channel probe, which was proved to show a reproducible results. The results were compared with those of the well known casting alloy, A356. Initial content of Ti and Zr was varied from 0 to 0.3wt% and 0.05% respectively and Al-5Ti-B master alloy was added for grain refining. The average flow length varied linearly with the superheat of the pouring temperature. The Fluidity depended on the initial amount of Ti and Zr and the addition of the grain refiner.

8:55 AM

A New Technique to Dynamically Measure Surface Tension, Viscosity and Density of Molten Metals: *Steven John Roach*[1]; Craig Owens[1]; Hani Henein[1]; [1]University of Alberta, Adv. Mat. and Proc. Lab., 536 Chem./Min. Eng. Bldg., Alberta T6G 2G6 Canada

In many high temperature applications, knowledge of physical properties of a melt (e.g. surface tension, viscosity and density) is lacking in the literature. A new technique has been developed for measuring surface tension, viscosity and density based on flow of a melt draining from a crucible. Flowrate of a fluid stream through an orifice is not characterized by viscous losses alone; surface energy plays a significant role in fluid flow as well. A mathemeatical model based on an energy balance was developed to describe flow-rate of a melt stream through an orifice. By proper calibration of the crucible system, the surface tension, viscosity and density of the fluid can be measured as a function of processing variables such as temperature and atmosphere. The validation of the model will be discussed, and results with molten aluminum and magnesium will be presented.

9:20 AM

Measurements of Diffusion Coefficients in Molten Aluminum: *Ingeborg Birgitte Solheim*[1]; [1]SINTEF Materials Technology, Proc. Metall. and Ceram., Alfred Getz vei 2b, 7465 Trondheim, Norway

Diffusion-coefficients are important parameters in mathematical modeling of solidification and refining processes. The model's accuracy is naturally dependent on the input-data. Data found in the literature is often old and inconsistent -differing with each other. To improve foundry competence, a project in cooperation with industry-partners has been carried out. Diffusion coefficients in molten aluminum have successfully been measured by the capillary-reservoir-method. Three different alloys were tested; 99% aluminum with 1% Si, Mg and Mn, respectively. The measurements are compared with data from the literature, and a theoretical model for calculation of the diffusion coefficient. The diffusion-coefficients' dependence on temperature is also studied, along with possibility of numerically solving Fick's law. This work is still in progress.

9:45 AM

Capillary Phenomena During Filling of Fine Mold Cavities: *Jon L. Hilden*[1]; Kevin P. Trumble[1]; [1]Purdue University, Mats. Eng., 1289 Mats. and Elect. Eng. Bldg., West Lafayette, IN 47907-1289 USA

As higher demands are placed on metal casting technology, molten metal is often required to fill smaller, more intricate features in the mold. As the feature size becomes smaller, the effects of surface tension/capillary pressure become significant. The objectives of this work were to determine the capillary pressure of liquid filling cylindrical mold cavities defined by relatively large mold particles. The process was modeled by considering infiltration of a cylinder lined with 20 close-packed spheres around the circumference. Capillary pressures were determined for various liquid contact angles using Surface Evolver numerical software. Capillary pressures were compared to those obtained for liquid in a smooth-walled capillary. Comparisons show that substantially higher pressures are required to fill a rough-walled cylinder than a smooth-walled cylinder, and that the filling pressure is practically insensitive to contact angle above ~120°. This work is supported by Howmet Research Corp.

Chemistry and Electrochemistry of Corrosion and Stress Corrosion: A Symposium Honoring the Contributions of R.W. Staehle: Corrosion and Stress Corrosion of Lightweight Alloys

Sponsored by: ASM International: Materials Science Critical Technology Sector, Structural Materials Division, Corrosion and Environmental Effects Committee, Jt. Nuclear Materials Committee
Program Organizer: Russell H. Jones, Battelle Pacific Northwest National Laboratory, Richland, WA 99352 USA

Thursday AM	Room: 221
February 15, 2001	Location: Ernest N. Morial Convention Center

Session Chairs: David J. Duquette, Rensselaer Polytechnic Institute, Mats. Sci. and Eng. Dept., Troy, NY 12180-3590 USA; Robert P. Wei, Lehigh University, Mech. Eng. and Mech. Dept., Bethlehem, PA 18015 USA

8:30 AM

Rate-Limiting Processes in Environmental Fatigue Crack Propagation in 7000-Series Aluminum Alloys: Zuhair Gasem[1]; *Richard P. Gangloff*[1]; [1]University of Virginia, Dept. of Mats. Sci. and Eng., SEAS-Thornton Hall, Charlottesville, VA 22904 USA

The objective of this research is to understand the mass transport and reaction processes that govern the kinetics of hydrogen-environment enhanced fatigue crack propagation in 7000-series aluminum alloys. For pure chloride solution, crack growth rate (da/dN) is rate limited by hydrogen (H) diffusion in the crack tip process zone with rapid surface reaction kinetics. Quantitative modeling is hindered by the uncertain crack surface concentration of H, hydrogen diffusion path through the microstructure, effect of stress and plastic strain on H transport, and critical amount of H required for embrittlement. Chromate addition to the bulk NaCl solution results in reduced da/dN, presumably due to a reaction-rate limitation of H production on the crack surface. As crack tip strain rate increases, chromate inhibition is eliminated by destabilization of the passive film. Hydrogen diffusion can limit water vapor enhanced fatigue in 7000-series alloys, as suggested by an empirical correlation between da/dN and a frequency-based exposure parameter. Modeling of the transition from environment-mass transport to surface reaction to H diffusion control of da/dN is hindered by the uncertain amounts of H produced on the crack-tip surface for water vapor and electrolytes.

9:00 AM

Measurement and Modeling of Crack Conditions during the Environment-Assisted Cracking of an Al-Zn-Mg-Cu Alloy: *Kevin R. Cooper*[1]; Robert G. Kelly[1]; [1]University of Virginia, Mats.

Sci. and Eng. Dept., 116 Engineer's Way, Charlottesville, VA 22904 USA

Although it is well known that Al-Zn-Mg-(Cu) alloys are susceptible to intergranular environment-assisted cracking (EAC) in some temper conditions, the relative contribution of hydrogen embrittlement and anodic dissolution (AD) to the crack advance process is uncertain. Modeling of measured crack potential distributions and chemistry can elucidate the role of AD to the EAC process. Micro-reference electrodes were used to make in situ measurements of the crack potential during Stage II cracking of peak-aged AA 7050. The crack tip potential was -0.80 V_{SCE} and independent of the applied potential over the range -0.80 to -0.30 V_{SCE}. Near-tip potential gradients (1 V/cm) facilitated steady-state concentration gradients; the acidified tip solution was concentrated in bulk solution anions and alloy components. Modeled crack potential distributions were strongly dependent on the crack tip opening and the presumed presence or absence of a resistive salt-film at the crack tip.

9:30 AM

Effect of Stress on Penetration of Intergranular Corrosion in Aluminum Alloys; Transition of IGC to IGSCC: Xiaodong Liu[1]; Weilong Zhang[1]; *Gerald S. Frankel*[1]; [1]The Ohio State University, Fontana Corr. Cen., 477 Watts Hall, 2041 College Rd., Columbus, OH 43210 USA

Recent work has shown that the kinetics of localized corrosion in AA2024 are strongly anisotropic. The anisotropy of kinetics was associated with an intergranular growth morphology; the slower rate of penetration in the short transverse direction (through plate thickness) compared to the longitudinal or long transverse direction was a result of a longer path length around the pancake-shaped grains in the wrought microstructure. These experiments were performed using the foil penetration method, in which the time for penetration of a pit or other form of localized corrosion through a thin foil sample is determined by wetting of paper pressed against the sample back side. In this work, the influence of applied stress on the penetration kinetics was studied. ASTM G49 constant strain load frames were modified to permit the use of foil samples and attachment of one side of the samples to an electrochemical cell. Uniaxial elastic strains of varying magnitude were applied perpendicular to the nominal growth direction. This approach allows for the development of a detailed understanding of the transition from intergranular corrosion to intergranular stress corrosion cracking.

10:00 AM

Quantification of Crack Wake Hydrogen Concentrations on Small Length Scales: *John Robert Scully*[1]; George A. Young[1]; Lisa M. Young[1]; Richard P. Gangloff[1]; [1]University of Virginia, Dept. of Mats. Sci. and Eng., 116 Engineer's Way, P.O. Box 400745, Charlottesville, VA 22904-4745 USA

A damaging role of hydrogen is postulated in the mechanism for environment-assisted cracking (EAC) of many engineering alloys. One barrier to advancing an understanding of hydrogen-induced EAC has been the overall difficulty in quantifying exact hydrogen concentrations at crack tips. Recently, crack tip hydrogen concentrations have been quantified directly using newer experimental techniques. A variety of probes such as focused ion beam/secondary mass spectroscopy, thermal desorption spectroscopy, and nuclear reaction analysis offer combinations of lateral and depth resolution, as well as great sensitivity to hydrogen concentration. In our studies, these techniques are used to examine crack wake hydrogen concentrations in a classical environment-assisted cracking system; a peak aged versus an overaged Al-Zn-Mg-Cu alloy. Parallel studies with hot humid air and chromate-inhibited chloride solutions reveal high crack wake hydrogen concentrations and steep hydrogen concentration-depth gradients. Substantial hydrogen uptake occurs in both EAC-resistant overaged material and peak aged material in hot, humid air. High hydrogen concentrations are only observed in EAC-susceptible tempers exposed to chromate-inhibited chloride solution. The implications of these findings to HEAC mechanisms are discussed.

10:30 AM

Corrosion and Stress Corrosion Cracking of Al-Mg Alloys with Sc and Ag Additions: *Clyde L. Briant*[1]; Zhengfu Wang[1]; Ping Wang[1]; *Sharvan Kumar*[1]; [1]Brown University, Div. of Eng., Box D, Providence, RI 02912 USA

This paper will report a study of the microstructural development and corrosion and stress corrosion cracking properties of Al-5Mg alloys that contain additions of Sc and Ag. The results show that the main effect of Sc additions on the microstructure is to retard recrystallization. Silver additions appear to stimulate the precipitation of beta phase along the grain boundaries. The stress corrosion results for tests performed in 3.5% NaCl solution show that scandium additions have no detrimental effects on stress corrosion cracking resistance. In contrast, silver additions enhance the corrosion rate. This enhancement is greatest in samples with an equiaxed grain structure. Scatter observed in the tests can also be attributed to the morphology of the grains and its relation to the fracture path.

11:00 AM

Stress Corrosion Cracking Mechanisms for Crack-Tip/Particle Interactions with Electrochemically Active Particles: *Russell H. Jones*[1]; Donald R. Baer[1]; Michael J. Danielson[1]; John S. Vetrano[1]; Charles F. Windisch[1]; [1]Pacific Northwest National Laboratory, Mats. Scis. Dept., P.O. Box 999, MSIN P8-15, Richland, WA 99352 USA

Particles can have a mechanical, chemical or electrochemical interaction with an advancing stress corrosion crack. Particles with elastic modulii greater than the matrix will induce a repulsive force on the crack and particles with elastic modulii less than the matrix will induce an attractive force. Chemical interactions include particles that dissolve and alter crack-tip chemistry while electrochemical interactions include particles that are either anodic or cathodic to the advancing crack. Particles that are anodic to the crack, may impede crack advance until totally dissolved or until the particle/matrix interface dissolves. These particles may be highly polarized because of their contact with the matrix such as Al3Mg2 particles on grain boundaries of aged AA5083. Particles that are cathodic to the advancing crack may cause local hydrogen reduction that accelerates crack advance around or through the particle. Examples of these crack-tip/particle interactions for Al-Mg and Mg-Al alloys will be described.

11:30 AM

Corrosion of Aluminum Alloy 6061 and 6061/Al2O3 Composite Subjected to Equal-Channel Angular Pressing: Zofia Buczko[1]; *R. A. Buchanan*[1]; P. K. Liaw[1]; T. G. Langdon[2]; [1]University of Tennessee, Dept. of Mats. Sci. & Eng., Knoxville, TN 37996-2200 USA; [2]University of Southern California, Depts. of Mats. Sci. & Mech. Eng., Los Angeles, CA 90089-1453 USA

High interest is developing in a new materials processing method, equal-channel angular pressing (ECAP), because it has the capability to produce severe plastic deformation without changing the shape of an object. Under proper conditions, ECAP can produce an ultrafine-grained material, resulting in exceptional strength and ductility. The current study examined the effects of ECAP on the aqueous-corrosion properties of 6061 and a 6061/Al2O3 composite material. Two electrolytes were employed: (1) 0.5 M NaCl, and (2) a more aggressive 1.0 M NaCl+H2O2. Cyclic anodic polarization tests in solutions 1 and 2, and 6-hour chemical-immersion tests in solution 2, produced consistent results. In all cases, the dominant form of corrosion was pitting attack. In solution 1, the non-deformed alloy exhibited the lowest corrosion rate, and the ECAP increased the corrosion rates of the alloy and the composite to comparable values. In solution 2, these general trends again were evident, with the exception that the deformed alloy, as compared to the deformed composite, exhibited a much higher corrosion rate. An explanation may involve the ability of the Al2O3 dispersion in the composite to retard corrosion-pit propagation in the more aggressive electrolyte.

Chemistry and Electrochemistry of Corrosion and Stress Corrosion: A Symposium Honoring the Contributions of R.W. Staehle: Stress Corrosion of Waste Container Materials and Other Topics

Sponsored by: ASM International: Materials Science Critical Technology Sector, Structural Materials Division, Corrosion and Environmental Effects Committee, Jt. Nuclear Materials Committee

Program Organizer: Russell H. Jones, Battelle Pacific Northwest National Laboratory, Richland, WA 99352 USA

Thursday AM — Room: 222
February 15, 2001 — Location: Ernest N. Morial Convention Center

Session Chairs: Gustavo A. Cragnolino, Southwest Research Institute, Center for Nuclear Waste Regulatory Analysis, San Antonio, TX, 78238-5166 USA; Gary S. Was, University of Michigan, Nucl. Eng. and Radiol. Scis., Ann Arbor, MI 48109-2104 USA

8:30 AM
Stress Corrosion Cracking in Supercritical Water Systems for Waste Destruction: *Ronald M. Latanision*[1]; D. B. Mitton[1]; [1]Massachusetts Institute of Technology, The H.H. Uhlig Corrosion Lab., Rm. 8-202, Cambridge, MA 02139 USA

There is a need to destroy both military and civilian hazardous wastes and an urgency, mandated by public concern over the traditional waste handling methodologies, to identify safe and efficient alternative technologies. One very effective process for the destruction of such wastes is supercritical water oxidation (SCWO). By capitalizing on the properties of water above its critical point, this technology provides rapid and complete destruction of a wide variety of wastes. A major limitation to full scale commercialization of SCWO is the corrosion-related failure of the materials of construction of these engineering systems. In this presentation, forensic analysis of failures in nickel-based alloy preheater tubes exposed to methylene chloride feed solutions will be shown to provide a basis for understanding the thermodynamic conditions under which SCWO reactors can be operated successfully.

9:00 AM
Stress Corrosion Cracking of a High Performance Nuclear Waste Containment Material: *R. Daniel McCright*[1]; Joseph C. Farmer[1]; [1]Lawrence Livermore National Laboratory, Livermore, CA 94550 USA

The prediction of the performance of materials for the very long-term containment of nuclear waste in a geological repository presents an unprecedented challenge in corrosion science and technology. The United States Department of Energy (DOE) is studying the suitability of the Yucca Mountain site in Nevada as a potential repository site. The current design for a waste package consists of a 2-cm thick layer of Alloy C-22 (UNS 0022) surrounding a thicker layer of austenitic stainless steel. This purpose of the outer Alloy C-22 layer is to provide the primary long-term containment of commercial spent nuclear fuel and reprocessed defense and commercial high-level waste. The stainless steel layer gives added bulk and strength to the waste package. Various corrosion-relevant scenarios for the waste package indicate that stress corrosion cracking (SCC) remains as the corrosion mode most likely to degrade seriously the waste package, particularly in and around the welded region. This paper focuses on the approaches taken to evaluate the SCC susceptibility of Alloy C-22 in the different environments expected to develop at the Yucca Mountain site over the next several thousands of years, as well as ways to mitigate against SCC susceptibility. The final closure weld, made after the waste is loaded inside the package, presents many constraints on ways to mitigate against residual stress in the weld region, and hence potential SCC susceptibility. The experimental SCC program closely couples with deterministic and probabilistic modeling work to project the long-term performance of the Alloy C-22 container from relatively short-term data.

9:30 AM
Initiation and Propagation of Stress-Corrosion Crack in Alpha-Titanium Alloys as Candidate Container Materials for the HLW Disposal: *Masatsune Akashi*[1]; Noriko Nakamura[1]; Yuichi Fukaya[1]; Guen Nakayama[1]; Hiroyoshi Ueda[2]; [1]Ishikawajima-Harima Heavy Industries Co., Ltd., Res. Lab., 3-1-15 Toyosu, Kotoku, Tokyo 135-8732 Japan; [2]The Tokyo Electric Power Company, Tokyo, Japan

Initiation and propagation behavior of stress-corrosion crack was investigated for alpha-phase titanium alloys in hydrogen-evolution electrode potential region. The following conclusions were made; (1) a definite correlation was found between the formation of Ti-hydride layer and the crack initiation based on microscopic observation, (2) a hydride layer started to grow from the surface to the inside of the specimen, (3) when the thickness of the layer reached a critical value, the hydride layer was fractured mechanically, (4) then, a hydride layer started to grow at the tip of the crack, (5) the newly formed hydride layer started cracking mechanically, and (6) the stress-corrosion crack propagated according to the sequence. Based on the experimental data on the critical thickness of hydride layer for cracking and on the time dependency of the hydrogen evolution rate, it was concluded that HLW containers of alpha-titanium alloys were unlikely to suffer the stress-corrosion cracking damage within the coming 1,000 years.

10:00 AM
Environmentally Assisted Cracking of 316 SS Exposed to Gallium and its Oxides: *David G. Kolman*[1]; [1]Los Alamos National Laboratory, Mail Stop E530, Los Alamos, NM 87545 USA

Stabilized plutonium-gallium compounds will be housed in 316 SS containers for up to 50 years prior to final disposition. The processing and storage of these compounds presents a variety of concerns with respect to furnace storage container integrity, respectively. One prominent concern is the unanticipated failure of containers following contact with gallium and its compounds. While gallium is known to embrittle many alloys, most prominently aluminum alloys, little is known about environmentally assisted cracking of stainless steels exposed to liquid Ga or Ga suboxide gas. The objective of this work is to document the susceptibility of storage container materials to environmentally assisted fatigue, crack initiation, and crack propagation using 316 SS compact tension specimens. The cracking behavior of 316 SS will be compared to other prominent engineering alloys.

10:30 AM
Hydrogen Damage of High Tensile Steel in Concrete: *R. Abdel-Karim*[1]; *S. M. El-Raghy*[1]; A. F. Waheed[2]; M. H. Sowelam[3]; [1]Cairo University, Dept. of Min., Petro., and Metall., Giza, Cairo, Egypt; [2]Nuclear Research Center, Anshas, Dept. of Metall., Anshas, Cairo, Egypt; [3]Cairo University, Fac. of Eng., Dept. of Struct. Eng., Giza, Cairo, Egypt

Tempered martensitic high tensile steel bars of different diameters used in prestressed concrete were tested for susceptibility for hydrogen damage. Bare or embedded bars in concrete were cathodically charged in chloride solutions of different pH. The as-received tensile strength was in the range of 2000 MPa. The drop of this strength due to hydrogen entry was dependent on many factors including bar diameter reflected on the microstructure, electrolyte and type of concrete. The same factors affected the drop in the ductility of the cathodically charged steel bars. Thus maximum drop in both tensile strength and in ductility was at pH 7.5, more than in acidic or basic solutions. High quality concrete with silica fume addition reduced the hydrogen damage caused by the same impressed current intensity. Bars with 4-mm diameters were more susceptible to hydrogen embrittlement than those of 5-mm or 6-mm diameter. Further heat treatment effects were investigated and proved the least affected microstructure was the tempered martensite. All the results are discussed and compared with the available literature.

11:00 AM
A Study on Corrosion Failure of a Weathering Steel Weldment with Various Applied Potentials in Acid-Chloride Solution: *Yoon Seok Choi*[1]; Jung Gu Kim[1]; [1]Sung Kyun Kwan University,

Adv. Mats. Eng. Dept., 300 Chunchun-dong, Jangan-gu, Suwon 440-746 Korea

The stress corrosion cracking(SCC) and hydrogen embrittlement cracking(HEC) characteristics of a weathering steel weldment were investigated in aerated acid-chloride solution. The electrochemical properties of weldment were investigated by polarization test and galvanic corrosion test. Weathering steel did not show passive behavior in the acid-chloride solution. Galvanic corrosion between the weld metal and the base metal was not observed because the base metal was anodic to the weld metal. The slow-strain-rate tests(SSRT) were conducted at a constant strain rate of 7.87e-7/s at corrosion potential, and at potentiostatically controlled anodic and cathodic potentials. The weldment of weathering steel was susceptible to both anodic dissolution SCC and hydrogen evolution HEC.

Computational Thermodynamics and Materials Design: Materials Design

Sponsored by: ASM International: Materials Science Critical Technology Sector, Electronic, Magnetic & Photonic Materials Division, Structural Materials Division, Alloy Phases Committee, Jt. Computational Materials Science & Engineering, Thermodynamics & Phase Equilibria Committee

Program Organizers: Zi-Kui Liu, Penn State University, Materials Science and Engineering, University Park, PA 16082-5005 USA; Ibrahim Ansara, LTPCM-Enseeg, Grenoble, France; Alan Dinsdale, National Physical Laboratory, UK; Mats Hillert, Royal Institute of Technology, Materials Science & Engineering, Stockholm 10044 Sweden; Gerhard Inden, Max-Planck Institute-Duesseldorf, Düsseldorf D-40074 Germany; Taiji Nishizawa, Tohoku University, Japan; Greg Olson, Northwestern University, Department MSE, 2225 N. Campus Dr., Evanston, IL 60208 USA; Gary Shiflet, University of Virginia, Department of Materials Sci. & Eng., Charlottesville, VA 22903 USA; John Vitek, Oak Ridge National Laboratory, Oak Ridge, TN USA

Thursday AM — Room: 201
February 15, 2001 — Location: Ernest N. Morial Convention Center

Session Chair: John M. Vitek, Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA

8:30 AM

Computational Systems Design of Materials: *G. B. Olson*[1]; [1]Northwestern University, Dept. MSE, 2225 N. Campus Dr., Evanston, IL 60208 USA

The computational thermodynamics pioneered by Kaufman has formed the foundation of a systems approach to multilevel materials design integrating materials science, applied mechanics and quantum physics. For martensitic transformations, a combination of quantum-mechanical total-energy calculations and nonlocal continuum methods predicts the evolution of Kaufman-Cohen embryos controlling Ms temperatures. Quantitative nucleation theory permits optimization of dispersed austenite stability for transformation toughening in UHS martensitic steels efficiently strengthened by nanoscale alloy carbide precipitation. Total energy calculations further predict grain boundary thermodynamics for hydrogen embrittlement resistance. New modeling initiatives address the acceleration of the full materials development and qualification cycle, revolutionizing the materials profession.

8:55 AM

Using Computational Thermodynamics to Design CuInSe2 Thin Film Solar Cells: *Tim Anderson*[1]; Weidong Zhuang[2]; Mushin Ider[1]; Alex Chang[3]; B. J. Stanbery[1]; Jianyun Shen[2]; [1]University of Florida, Chem. Eng. Dept., Gainesville, FL 32611 USA; [2]General Research Institute for Nonferrous Metals, Beijing 100088 China; [3]Oregon State University, Chem. Eng. Dept., Corvallis, OR USA

Significant advances have been made in Cu(In,Ga)Se2(CIGS)-based solar cell performance during the past several years, while the challenge of developing low cost manufacturing processes remains. Selection of low temperature reaction pathways leading to formation of the absorber layer will permit use of lower cost substrates. Processes that convert precursor films to efficient absorber layers, however, are not optimized or fully understood, and it is likely that other pathways exist. A description of phase equilibria in the Cu-In-Ga-Se system is used to suggest alternative low temperature routes to synthesizing Cu(In,Ga)Se2. EMF measurements are coupled with literature data to provide assessed phase diagrams for selected subsystems. The associated solution model is used to describe the liquid phase with different associates. The sublattice model is used to describe the non-stoichiometric ordered intermediate phases. In addition, structure models and a point defects chemistries for ternary compounds are explored using EXAFS.

9:20 AM

Alloy Design and Life-Time Assessments of Cr Steels for Power Generation: *John Ågren*[1]; Åsa Gustafson[1]; [1]Royal Institute of Technology, Mats. Sci. and Eng., KTH, SE-100 44 Stockholm, Sweden

Tempered martensitic steels, based on 9-12%Cr, 0.1-0.2%C and W, Mo, V, Nb, B, are being developed with the objective of allowing temperatures above 650ºC in boilers and turbines of fossile-fuel power plants. The high temperature strength is goverened by the martensitic lath structure, which thus has to be stabilized at high T, and strengthening by a fine dispersion of carbo-nitrides, MX. In a long-term collaboration with the physics department at the Chalmers Institute of Technology and several industrial partners we have applied thermodynamic and kinetic calcuilations supported by experimental work using SEM, TEM, EFTEM and APFIM, to predict the microstructural changes during heat treatment and usage of the steels. In particular coarsening of MX has been considered.

9:45 AM

Optimization of the Heat-Treatment Schedule for Ni-Base Superalloys: *C. E. Campbell*[1]; W. J. Boettinger[1]; U. R. Kattner[1]; [1]National Institute of Standards and Technology, Metall. Div., 100 Bureau Dr. Stop 8555, Gaithersburg, MD 20899-8555

Reduction of costs and processing times can be achieved through thermodynamic and diffusion modeling that predicts the optimal time-temperature schedule to reach the solution temperature of the alloy. The heat treatment process is optimized to avoid incipient melting and to determine either the fastest or the minimum power usage time-temperature schedule. For an as-cast Ni-Al-Ta alloy, prediction of the optimal time-temperature schedule requires modeling first the solidification process and then optimizing a modeled heat treatment process. The microsegregation resulting from the casting process is predicted using Scheil solidification calculations and numerical simulations of the solidification process (DICTRA). The resulting composition profiles are then used as input files for the numerical diffusion simulations of the heat treatment process, considering both linear and non-linear heating rates. Initial modeling demonstrates that the predictions are strongly dependent on the accuracy of the thermodynamic and diffusion mobility assessments.

10:10 AM Break

10:30 AM

Phase Diagrams and the Aluminum Industry: *Joanne L. Murray*[1]; Douglas A. Weirauch[1]; [1]Alcoa Technical Center, 100 Technical Dr., Alcoa Center, PA 15069 USA

Phase equilibria in both metallic and ceramic systems are key to maintaining existing technologies “in-control and capable” and developing technologies for aluminum production. We organize our process into the segments: Refining-mining the bauxite and refining the ore to alumina-chemicals; Smelting-extracting metallic aluminum from alumina, traditionally via the Hall-Heroult process; Fabricating-alloying, casting, and mechanical; Recycling-cleaning, sorting, environmentally responsible disposal of process byproducts. Applications of metallic phase diagrams always address the problem of producing a tailored set of product properties, e.g. electrical properties, mechanical properties, corrosion-resistance, surface appearance. Applications of mixed-phase equilibrium include: developing refractories for highly reactive alloys, optimizing compatibility of metal and refractories and of metal matrix composites, controlling aluminum electrolysis using salt-ceramic equilibria, improving recovery in molten-metal processing, and finding optimal waste disposal strategies for bauxite residue. Existing technologies will be reviewed, and needs will be identified for emerging technologies.

10:55 AM

Computational Thermochemistry–From Its Early CALPHAD Days to a Cost-Effective Role in Materials Development and Processing: *Philip John Spencer*[1]; [1]The Spencer Group, P.O. Box 393, Trumansburg, NY 14886 USA

Computational thermochemistry has made giant strides in a relatively short time period. This rapid development is due not only to the influence of the com-puter, both on the ease of computation and on the assessment and storage of data, but also the scientific stimulation and close collaboration maintained over nearly three decades by the relatively small number of scientists participating in CALPHAD meetings and using CALPHAD calculation methods. The use of the commercial computer packages now available enables rapid and inexpensive information to be obtained on process conditions necessary to achieve a product of the required purity with minimum wastage of energy and materials. In this paper, some examples of computer-assisted materials development will be presented, illustrating how early CALPHAD discussions relating to the calculation of ternary phase equilibria from assessed binary alloy data have now been extended to enable reliable prediction of multicomponent phase equilibria in complex materials systems. Thermodynamic predictions of optimum composition ranges for the production of metastable hard-metal and oxynitride coatings by PVD methods will be described.

11:20 AM

Design of Improved Heat Resistant Materials by Use of Computational Thermodynamics: *Bernhard C. Schaffernak*[1]; Horst H. Cerjak[1]; [1]TU Graz, Mats. Sci., Weld. and Form., Koperni-kusgasse 24, Graz A-8010 Austria

Ferritic-martensitic steels are widely used for high temperature applications. Compared with austenitic materials they own a better thermal conductivity, lower thermal expansion coefficient, lower costs and a better resistance against stress corrosion cracking. In this contribution the modelling of the microstructure based on thermodynamic calculations has been used for the description and further alloy design for this steel group. The results are phase diagrams showing the precipitates to be expected as well as driving forces, phase compositions and diffusion coefficients as base for further modelling activities. A calculation model based on the determination of the (calculated) transformation temperatures Ae1 and Ae3 and the diffusion coefficients is proposed, which can help to predict the microstructural stability and the creep strength from the chemical composition. Based on this model test melts for some new alloys has been produced. First creep tests of these alloys confirm the presented approach.

11:45 AM

From Thermodynamics and Phase Diagrams to Computer Design of Stable Many-Player Many-Functional Materials: *A. L. Udovsky*[1]; [1]Russian Acadademy of Science, Inst. of Metall. and Matls. Sci., Leninsky Prospect 49, Moscow 117334 Russia

The main principles of computer design of stable many-player many-functional materials will be consider. This report will be present our new results in the following fields: 1) development of general algorithms for calculations of phase diagrams and thermodynamic properties for binary and ternary systems; 2) creation of autonomic computer programs for calculation of phase diagrams and thermodynamic properties for binary systems with up to 10 solution phases and 10 stechiometric chemical compounds; 3) carrying assessment and out optimizing calculations of phase diagrams and thermodynamic properties for the Ni-Al and Ni-Cr; 4) testing for calculated thermodynamic properties of solid alloys for the Ni-Cr system, which we have not using for optimizing procedure as input data; 5) predictions of thermodynamic properties as functions of compositions and temperature; 6) computer design of stable high-temperature two-player materials-the substrate chemically compatible with heat-resistant coating, 7) determination of compositions of substrate and coating and temperature ranges using as an examples two-layered materials from the Ni-Cr and Ni-Al-Cr alloys; 8) experimental investigations on creation of chemically compatible substrate and coating, including study of thermal stability and chemical stability of coatings on as the Ni-Cr and for as two-phase the Ni-Al-Cr substrates.

Cyanide: Social, Industrial, and Economic Aspects: Alternatives

Sponsored by: Extraction & Processing Division, Waste Treatment & Minimization Committee, Precious Metals Committee, International Precious Metals Institute, Society of Mining, Metallurgy and Exploration, Inc., Northwest Mining Association

Program Organizers: Courtney Young, Montana Tech, Metallurgical and Materials Engineering, Butte, MT 59701 USA; Corby Anderson, Montana Tech., CAMP and Metallurgical and Materials Engineering, Butte, MT 59701 USA; Larry Twidwell, Montana Tech, Metallurgical and Materials Engineering, Butte, MT 59701 USA

Thursday AM — Room: 225
February 15, 2001 — Location: Ernest N. Morial Convention Center

Session Chairs: Corby Anderson, Montana Tech, CAMP and Metallurgical and Materials Engineering, Butte, MT 59701 USA; Kenneth Han, South Dakota School of Mines and Technology, Dept. of Mats. and Metall. Eng., Rapid City, SD 57701-3995 USA

8:30 AM Plenary

Are There Any Realistic Alternatives to Cyanide as a Gold Lixivant at the Present Time?: M. J. Nicol[1]; D. M. Muir[1]; *I. M. Ritchie*[1]; W. P. Staunton[1]; [1]A J Parker Cooperative Research Centre for Hydrometallurgy, Perth, Western Australia 6150, Australia

Cyanide owes its great success as a lixivant for gold to the great strength of the Au-CN- bond. A replacement for cyanide must similarly be a strong complexant for gold (I) or gold (III). The various alternatives are briefly considered and it is concluded that only thiosulfate has a reasonable chance of replacing cyanide as a relatively non-toxic lixivant at the present time. However, there are considerable technical problems to be overcome before thiosulfate can be considered to be a realistic alternative to cyanide. Firstly, the leaching of gold using aerated ammoniacal thiosulfate with copper as a catalyst is a complex process which needs to be controlled carefully in order to achieve maximum recoveries with minimum reagent losses. Secondly, there needs to be something similar to the CIP process for concentrating the dilute gold thiosulfate solutions resulting from processing low grade gold ores. Finally, the gold must be recovered from the solution. The prospects for overcoming these technical challenges are discussed.

9:10 AM Invited

How Rapidly Do Alternative Lixiviants Leach Gold? M. I. Jeffrey[1]; P. L. Breuer[1]; W. L. Choo[1]; Monash University, Dept. of Chem. Eng., Clayton, Vic. 3168 Australia

Due to the increasing environmental and public concerns over cyanidation, there has been a large amount of research into viable alternative lixiviants. Despite these studies, there is little published data directly comparing the kinetics of gold leaching for each of these alternatives; most of the literature is concerned with gold extraction from ores. This paper will present a detailed kinetic study of gold leaching in cyanide, ammonia/thiosulfate, chloride/hypochlorite, and ammonia solutions. The gold leach rates were measured using a rotating electrochemical quartz crystal microbalance (REQCM). This instrument allows the mass of a gold sample to measured in-situ, with a sensitivity of less than 10 ng. From the results of these studies, it is possible to select experimental conditions where the leach rate of the alternative lixiviants is similar to that for the traditional cyanide system.

9:35 AM Invited
Fundamental Aspects of the Gold Thiosulfate Leaching Process: *Paul Breuer*[1]; Matthew Jeffrey[1]; Wei Lit Choo[1]; [1]Monash University, Chem. Eng. Dept., Clayton, Vic 3800, Australia

The majority of studies conducted on the leaching of gold in solutions containing thiosulfate, ammonia and copper during the past 3 decades have failed to acknowledge the undesirable side reaction between copper(II) and thiosulfate, let alone account for its effect. The kinetics of this side reaction have been studied in detail and found to be highly dependent on solution conditions. Since the solution chemistry is constantly changing it is very difficult to perform a fundamental study of gold leaching. With the advent of the rotating electrochemical quartz crystal microbalance, such fundamental studies are possible, as the leach rate can be measured in a matter of minutes and hence at essentially constant solution conditions. The effect of various parameters on the long term gold leach rate have been investigated. Studies have also commenced into the cementation and electrowinning of gold from thiosulfate solutions over a wide range of experimental conditions.

10:00 AM Break

10:15 AM Invited
Ion Exchange Resins for the Recovery of Gold from Thiosulfate Leach Pulps: *Glen O'Malley*[1]; Michael J. Nicol[1]; [1]Murdoch University, Min. Sci. Dept., South St., Murdoch, Perth, Western Australia 6150, Australia

Growing environmental concerns about the use of cyanide in gold processing has increased the interest for more acceptable alternatives that most likely to involve thiosulfate. However, as activated carbon is ineffective in recovery of the gold thiosulfate complex, the thiosulfate process lacks a proven in-pulp method of recovering the dissolved gold. Anion exchange resins do offer a possible route for in-pulp recovery. This paper describes some work undertaken at the AJ Parker Centre for Hydrometallurgy to evaluate the effectiveness of commercially available anion exchange resins for recovering gold from thiosulfate leach liquors and pulps. The effect of competing anions on the equilibrium and the kinetics of gold loading were investigated and will be discussed. Evaluation of the effectiveness of resins for gold recovery from thiosulfate pulps by counter-current adsorption will also be presented. An assessment of a proprietary elution process for the recovery of gold from the resin and an electrowinning study will also be covered within the paper.

10:40 AM Invited
Electrochemical Behavior of the Dissolution of Gold in Ammoniacal Solutions: *Kenneth N. Han*[1]; [1]South Dakota School of Mines and Technology, Dept. of Matls. and Metall. Eng., Rapid City, SD 57701-3995 USA

Ammonia has been found to be an effective leaching reagent for gold, silver and platinum group metals in the presence of appropriate oxidants. Electrochemical and kinetic aspects of the dissolution of elemental gold in ammoniacal solutions have been investigated. The cathodic reaction of aurous di-ammine on the gold cathode has been investigated first. From this investigation, the standard electropotential of the cathodic reaction and hence the Gibbs free energy of formation of the aurous di-ammine were established. The solubility of gold in ammoniacal solutions was examined in relation to ammonia concentration, temperature and concentration of various oxidants. The anodic reaction of the gold disk in ammonia in the presence of various oxidants including oxygen, ozon, hypochlorite, hydrogen peroxide, cupric and cobaltic ammines, and iodine was also examined and the results have been discussed. Excellent dissolution yielding of gold and many other metals, typically better than 95% recovery in 1-2 hours of leaching at a temperature ranging 80°C to 190°C has been observed. Test results of the dissolution of gold from elemental state as well as other sources including sulfidic ores and scrap are presented.

11:05 AM Invited
Halides as Alternative Lixivants for Processing Gold and SIlver? An Update: *Tam Tran*[1]; Ken Lee[1]; Kapila Fernando[1]; [1]The University of New South Wales, Sch. of Chem. Eng. & Indust. Chem., Sudney, New South Wales 2052, Australia

Over the last decade, halide (chloride, bromide and iodide) systems have been suggested as alternative lixiviants for the processing of gold and silver to replace cyanidation which has been widely used in commercial practice. This paper first reviews the development of the processes promoted by Kaljas Ltd (Australia) and the Great Lakes Corp (USA) using bromide/bromine systems. Several research groups subsequently evaluated the use of iodide/iodine and chloride/chlorine for gold and silver extraction, showing similar characteristics of gold/silver dissolution and recovery. The processing of silver and gold has also been dealt with by Intec Copper Ltd., in the development of their Intec copper process using chloride. The paper provides a critique on the advantages and the shortfalls of halide systems as alternative lixiviants. The stability of gold/silver halide complexes is discussed, based on practical experience and thermodynamic modelling of their speciation. The iodide system provides the most stable gold/silver complex for easier handling. However, the cost of iodide inhibits its application for ore processing. The cheapest system which involves the use of chloride for leaching (in conjunction with an appropriate oxidant) however has a major drawback related to the unstable nature of gold/silver choride in a low Eh environment. No doubt the halide systems can be used for gold/silver processing. However, their potential might be limited to applications outside mineral processing areas.

11:25 AM Invited
The Industrial Non-Cyanide Hydrometallurgical Recovery of Silver and Gold Utilizing Nitrogen Species Catalyzed Pressure Oxidation: *Corby G. Anderson*[1]; [1]Montana Tech, The Center for Adv. Min. & Metall. Proc., 1300 West Park St., Rm. 221 ELC Building, Butte, MT 59701

In the majority of industrial operations that recover gold and silver by hydrometallurgical means, cyanide is the predominant lixiviant. However, as an alternative, production of massive quantities of silver chloride was done on an industrial scale in the nitrogen species catalyzed pressure leaching of a refractory precious metals concentrate. This proven process required no cyanide. Moreover, gold bearing concentrates can also be trested by nitrogen species catalyzed pressure leaching followed by a novel non-cyanide leaching and reocvery method. In the paper an in-depth description of the proven pressure leaching system is included along with the silver and gold recovery methodologies.

11:50 AM Invited
Closing Remarks: Courtney A. Young; Montana Tech, Metallurgical and Materials Engineering, 2154 ELC Building, 1300 W. Park Street, Montana Tech, Butte, MT 59701 USA

Defect Properties and Mechanical Behavior of HCP Metals and Alloys: Alloy Design, Processing, and Applications

Sponsored by: ASM International: Materials Science Critical Technology Sector, Structural Materials Division, Electronic, Magnetic & Photonic Materials Division, Chemistry & Physics of Materials Committee, Jt. Nuclear Materials Committee, Titanium Committee
Program Organizers: Man H. Yoo, Oak Ridge National Laboratory, Metals & Ceramic Division, Oak Ridge, TN 37831-6115 USA; James R. Morris, Iowa State University, Ames Laboratory, Ames, IA 50011-3020 USA; Carlos N. Tome, Los Alamos National Laboratory, Los Alamos, NM 87545 USA

Thursday AM Room: 211
February 15, 2001 Location: Ernest N. Morial Convention Center

Session Chairs: James C. Williams, Ohio State University, Mats. Sci. and Eng., Columbus, OH 43210-1178 USA; K. Linga Murty, North Calorina State University, Raleigh, NC 27695-7907 USA

8:30 AM Invited
Magnesium Alloys for Structural Application: *Karl Ulrich Kainer*[1]; [1]GKSS Research Center Geesthacht, Inst. for Mats. Res., Max-Planck-Str., Geesthacht D-21502 Germany

Increasing demand for lightweight structural material in transportation industry leads to a renaissance for magnesium. Magnesium alloys fulfill the requirements of low density, good and economic processability by using cast technology and high recycling potential. The driving force for the constant growth in magnesium production recently has been the increasing demand for die cast parts in the automotive industry. Die-casting is the dominating production techniques for economical magnesium parts. The range of applications in automobile goes from use in powertrains, as body parts, in interior and chassis. There is also a growing interest in the use of magnesium materials in areas in which the properties of introduced magnesium alloys are not matching the requirements. Results are raising R&D-activities in developing new alloys and processes. This paper gives an overview on commonly used magnesium alloys and their application. An outlook on trends in alloy development and on potential applications is given.

9:00 AM

Twinning, Dynamic Recovery and Recrystallization in Hot Worked Mg-Al-Zn Alloy: Mikhail M. Myshlyaev[1]; *Hugh J. McQueen*[2]; A. Mwembela[2]; E. V. Konopleva[2]; [1]Baikov Institute of Metallurgy RAS, Moscow 117911 Russia; [2]Concordia University, Mech. Eng. Dept., 1455 Maisonneuve W., Montreal, Quebec H3G 1M8 Canada

The AZ31 Mg alloy was subjected to hot torsion testing over the range of 180 to 450°C and 0.01 to 1.0 s-1. The flow curves showed a peak and a decline towards a steady state regime which were lower as temperature rose and strain rate declined; however, the fracture strain increased to about 1.9 at 0.1s-1. In transmission electron microscopy, twins were observed from 180 to 360°C (in declining numbers). At low temperature, they had sharp walls and contrasting transverse bands; while the matrix showed indistinct linear streaks. As T rose, the bands became cells with tangled walls and finally subgrains (~360°C), while the twin walls became tangles of dislocations and finally serrated boundaries. The matrix developed elongated dislocation walls and subgrains at higher T. The twin intersections at 180 and 240°C consisted of diamond-shaped cells with a duplex set of orientations but at 300 and 360°C, these had developed into polygonal cells with high misorientations in dark field. The first dynamically recrystallized grains were observed at these intersections, slightly larger than the cells but free of dislocations. At 420 and 450°C, large dynamically recrystallized grains were observed, apparently in the matrix and probably at the original grain boundaries, as was observed by optical microscopy.

9:20 AM

Directional Mechanical Performance of Wrought AZ80 Magnesium: *Matthias Hilpert*[1]; H. J. Rack[2]; L. Wagner[1]; [1]Technical University of Brandenburg at Cottbus, Chair of Phys. Metall. and Mats. Techn., P.O. Box 101344, 03013 Cottbus, Brandenburg, Germany; [2]Clemson University, Dept. of Ceram. and Mats. Eng., 110 Olin Hall, Clemson, SC 29634-0907 USA

This presention will examine the effects of thermomechanical processing (rolling, pressing and swaging) on the mechanical behavior of extruded AZ80 (8%Al, 0.5%Zn, 0.2%Mn) magnesium. It will be shown that the monotonic stress-strain response strongly depends upon loading direction. For example, differences between the compressive and tensile yield strengths in the as-extruded condition can exceed 50%. These differences are also reflected in fully reversed, R=-1, fatigue loading, where a marked asymmetry in the cyclic stress-strain response is observed. These observations will be shown to result from the interrelationship between crystallographic texture development and the stresses necessary for twin deformation during compressive/tensile loading.

9:40 AM

Equal Channel Angular Extrusion (ECAE) of Beryllium: *R. D. Field*[1]; K. T. Hartwig[2]; C. T. Necker[1]; J. F. Bingert[1]; S. R. Agnew[3]; [1]Los Alamos National Laboratory, MST-6, Mail Stop G770, Los Alamos, NM 87545 USA; [2]Texas A&M University, Dept. of Mech. Eng., College Station, TX 77843-3123 USA; [3]Oak Ridge National Laboratory, Mets. and Ceram. Div., 1 Bethel Valley Rd., Oak Ridge, TN 37831-6115 USA

P/M source beryllium was processed by Equal Channel Angular Extrusion (ECAE). Billets were canned in Ni and extruded at 400°C. After two passes (using two different processing routes for the second pass) the billets display significant grain refinement with no cracking. Deformation structures were examined using transmission electron microscopy (TEM) and textures measured by x-ray diffraction (XRD) and orientation imaging microscopy (OIM). The billets develop crystallographic texture, which is dependent upon the orientation of the second pass. Anneals up to 800°C yield recrystallized microstructures, retaining the texture and much of the grain refinement developed during extrusion. The texture data were compared to simulated textures calculated using a self consistent deformation model. Deformation microstructures and texture development will be discussed in terms of the deformation modes of Be and the geometry of the ECAE process. This work was supported under DOE Contract W-7405-ENG-36.

10:00 AM

Pressure Effects on Flow and Fracture Behavior of Al-Be Composites: *Joël Larose*[1]; John J. Lewandowski[1]; [1]Case Western Reserve University, Mats. Sci. and Eng., The Case School of Eng., Cleveland, OH 44106 USA

The flow and fracture behavior of Al-Be composites are being determined under a variety of test conditions. The flow behavior is being determined in tension with different levels of superimposed pressure. Significant effects of pressure on both the flow and ductility have been observed. The effects of test conditions on the flow and fracture behavior will be summarized in addition to both optical and SEM examination of the fracture surfaces. Separate other studies on the composite constituents (e.g. Al, Be) will be also reported.

10:20 AM Break

10:40 AM Invited

Processing and Anisotropic Properties of Zirconium Alloys for Nuclear Applications: *R. A. Holt*[1]; [1]Atomic Energy of Canada Limited, Chalk River Labs., Chalk River, Ontario K0J 1J0 Canada

Dilute zirconium alloys are used extensively for structural components in the cores of nuclear reactors. These alloys are highly anisotropic because of their HCP crystal structure and the pronounced crystallographic textures developed during processing. A unique feature of the reactor core environment is the continual displacement of the atoms from their crystal lattice positions by neutrons. This causes changes in the microstructure and mechanical properties of in-core materials during service and radiation induced dimensional changes including irradiation growth, irradiation creep and swelling (which does not occur in zirconium alloys at normal reactor operating temperatures). This paper reviews the development of crystallographic texture in zirconium alloys during manufacturing, the anisotropic properties pertinent to their application in nuclear reactors and the changes induced by fast neutron irradiation under normal reactor operating conditions. The microscopic mechanisms controlling the development of texture and the anisotropic properties, including irradiation creep and growth are discussed. Two outstanding issues in this area are the mechanism of texture development during alpha-beta processing and the contribution of second phase (i.e., meta-stable beta-zirconium) to the anisotropy of textured polycrystalline material.

11:10 AM

Plastic Response of Chemical Vapor Deposited Rhenium: *Ghatu Subhash*[1]; Phil Lukens[1]; Pletka J. Bruce[2]; [1]Michigan Technological University, ME-EM Dept., 1400 Townsend Dr., Houghton, MI 49931 USA; [2]Michigan Technological University, Mats. Sci. and Eng., Houghton, MI 49931 USA

Plastic response of rhenium (Re) produced by chemical vapor deposition (CVD) was investigated under uniaxial tensile loading. The initial microstrctural analysis of CVD Re revealed layers of columnar grains and a strong basal texture perpendicular to the tensile axis. The plastic response exhibited a two stage hardening behavior with considerably higher hardening rate than other refractory metals including rhenium produced by powder metallurgy. The fracture surfaces of the specimens revealed typical ductile fracture. Microscopic observations of the lateral surfaces of the deformed tensile specimens revealed cracking at 45 degrees to the tensile axis. Extensive twinning was also observed within the deformed zone. Currently transmission electron microscopic observations are being conducted on specimen obtained from various regions of the tensile specimens. The experimental results and microscopic investigations of the micromechanisms of deformation responsible for the observed behavior of CVD Re will be discussed during the presentation.

11:30 AM
Delayed Hydrogen Cracking in CANDU Pressure Tubes as a Result of Local Reorientation of the Matrix within Zones of Stress Concentration by Tensile Loading: *Yuriy Perlovich*[1]; Margarita Isaenkova[1]; Young Suk Kim[2]; [1]Moscow State Engineering Physics Institute (Technical University), Met. Sci. Dept., Kashirskoe shosse 31, Moscow 115409 Russia; [2]Korean Atomic Energy Research Institute, Yusong, Taejon 305-600 Korea

The anisotropy of DHC in CANDU pressure tubes becomes understandable by taking into account the local reorientation of the alpha-Zr matrix under tensile loading within zones of stress concentration near tips of notches, cracks and precipitates. Because of the tangential orientation of basal planes in CANDU tubes, the local plastic deformation within these zones under transverse tensile loading realizes at first by means of twinning with the resulting reorientation of basal axes by ~85°. Due to accompanying redistribution of shear stresses, the following activation of the prismatic slip within the twinned reoriented crystallites proves to be possible, so that the plastic deformation zone with an increased lattice distortion is surrounded by a sharp boundary, separating it from the undeformed matrix. The high gradient of lattice distortion promotes intensifying of the hydrogen diffusion to the plastic deformation zone, where new stress-oriented hydrides precipitate according to the orientation relationship with the twinned crystallites of alpha-Zr. When determining the habit planes of hydrides relative to the reoriented matrix, contradictory data on habit planes can be corrected. The difference in DHC by axial and radial directions of the notch under transverse tensile loading is conditioned by features of the compressive strain along the notch direction in front of the crack tip.

Defect Properties and Mechanical Behavior of HCP Metals and Alloys: *Poster Session*

Computer Simulation of Interfacial Structure and Defect Properties in the HCP Metals: *Anna Serra*[1]; David J. Bacon[2]; [1]Universitat Politecnica de Catalunya (UPC), Dept. Matematica Aplicada III, Jordi Girona,1-3 Modul C-2, Barcelona 08034 Spain; [2]The University of Liverpool, Dept. of Eng. Brownlow Hill, Liverpool L69 3GH UK

It has been stablished by computer simulation that clusters of self-interstitial atoms (SIAs) form in the displacement cascade process that gives rise to radiation damage in irradiated metals. These clusters (or small dislocation loops) can be highly mobile and this has implications for the evolution of damage microstructure and changes in material properties. The interaction of clusters with other defects can result in hardening by the formation of atmospheres and/or resistance to glide as dislocations move through distributed obstacles. In some cases, plastic deformation is accompanied by the formation of cleared channels. In the hcp metals the interaction of clusters and dislocation loops with twin boundaries has been suggested as a possible mechanism for cleaning channels. The present research work is the first stage of a study of this by computer simulation. It is focused on the interaction of these clusters with twin boundaries that we have modelled previously. Results will be presented for the interaction of a SIA cluster with; (a) a planar twin interface; (b) a boundary with a stationary twinning dislocation and; (c) a boundary containing moving twinning dislocations under twinning shear stress.

Composition Effects on the Crystallininty of Beryllium-Rich Coatings: *Alan F. Jankowski*[1]; [1]Lawrence Livermore National Laboratory, Chem. and Mats. Sci., P.O. Box 808, L-352, Livermore, CA 94551-9900 USA

The material properties of sputter deposited coatings are sensitive to the growth morphology and microstructure of the deposit. For example, the application of an applied bias to the substrate can densify the columnar microstructure of a crystalline coating through ion bombardment thereby minimizing porosity and increasing the mechanical strength of the coating. We are developing a process to sputter deposit Be-rich, thick coatings that must be homogeneous, isotropic, mechanically strong, smooth and serve as a membrane across which gas permeation is controllable. The refinement of grain size to the nanoscale is preferable for each of these attributes. It is widely known from prior studies of evaporation and sputter deposition that the grain size of nominally pure beryllium, that is beryllium with greater than 99.8 atomic percent purity, can be dramatically refined through the incorporation of specific metal impurities like iron. Additionally, the use of boron doping may serve as a potential glassy phase former in the composition range greater than at the depressed eutectic seen in the binary alloy phase diagram. We report on the changes in crystallinity and growth morphology found in these Be-rich coatings. The effects of dopant additions are characterized with electron diffraction and microscopies. This work was performed under the auspices of the U.S. Department of Energy by University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

Dynamic Recrystallization in a Magnesium Alloy at Intermediate Temperatures: Arthur Galiyev[1]; *Rustam Kaibyshev*[1]; [1]Institute for Metals Superplasticity Problems, Khalturin 39, Ufa 450001 Russia

Effect of temperature on deformation mechanisms and microstructure formed was studied in a Mg-5.8%Zn-0.65%Zr alloy in the temperature range from 423K to 573K (0.46-0.62 Tm, where Tm is the absolute melting temperature). Microstructural evolution and mechanisms of plastic deformation were found to be in strong dependence on temperature. At T=423K the low temperature dynamic recrystallization (LTDRX) occurred. The deformation twinning is operative at initial stage of plastic deformation. Evidences for operation of basal slip and <a+c> dislocation slip were found. At temperatures ranging from 473K to 573K the continuos DRX (CDRX) took place. In this temperature interval an extensive cross-slip was developed. A mechanism for the CDRX occurring in the magnesium alloy is presented. A relationship between the operating deformation mechanisms and mechanisms of grain formation is discussed. A role of dislocation cross-slip in DRX in the magnesium alloy was considered.

Diffusion in HCP Ti and Zr at Low Temperatures: *Rodolfo Ariel Perez*[1]; Fanny Dyment[1]; [1]CNEA, Materials, Av. General Paz 1499, San Martin, Pcia de Buenos Aires 1650 Argentina

Diffusion studies of Zr, Hf, Au, Co, Pb, Sn, In and Ta in hcp Ti matrix and Pb, Hf and Au in hcp Zr were performed. The combination of Rutherford Backscattering Spectrometry (RBS) Heavy Ions RBS (HIRBS) and Direct Sectioning techniques were used in superposed ranges, in order to cover a wide temperature range, from the phase transition (1156 for Ti and 1138 for Zr) to low temperatures (between 773K and 620K according to the diffusing impurity). All the diffusing impurities in a-Ti follows the Arrhenius law whereas in the a-Zr matrix all the elements studied shows a downward curvature that follow the self-diffusion behaviour. A discussion between the fast impurities influence on the diffusion in such matrix versus intrinsic behaviour is proposed.

Heredity of Structure Inhomogeneity by Phase Transformations Beta->Omega and Beta->Alpha in the Rolled Zr-20%Nb Alloy: *Yuriy Perlovich*[1]; Margarita Isaenkova[1]; Hans-Joachim Bunge[2]; Vladimir Fesenko[1]; [1]Moscow State Engineering Physics Institute (Technical University), Met. Sci. Dept., Kashirskoe shosse 31, Moscow 115409 Russia; [2]TU Clausthal, Clausthal-Zellerfeld 38678 Germany

Development of phase transformations (PT) $\beta \rightarrow \omega$ and $\beta \rightarrow \alpha$ in the rolled quenched alloy Zr-20%Nb by its annealings at 400º and 500°C was studied by the X-ray method, combining texture measurements and X-ray line profile analysis. Both ω- and α-phases prove to be textured and inherit the substructure inhomogeneity of initial β-Zr, i.e. in texture minima their grains are most disperse and/or have the most distorted crystalline lattice, while in texture maxima crystallites of derivative phases are coarser by lower lattice distortions. However, though grains of the original β-phase differ significantly in lattice condition, grains of the athermal ω-phase have very close substructure parameters. The opposite tendency takes place by isothermal PT β->α: since α-grains form by decomposition of quenched β-Zr into two equilibrium phases, the final structure of the alloy is characterized by increased dispersity of components. Elastic microstrains in the ω-phase are higher than in the initial β-phase, though main features of the anisotropic microstrain distribution proves to be inherited. The dependence of both PT on elastic compression and extension was analyzed in details.

Mechanical Anisotropy of Textured Zr-Alloys as a Result of Differences in Plastic Deformation at the Crack Tip: *Yuriy Perlovich*[1]; Margarita Isaenkova[1]; Vladimir Goltcev[1]; [1]Moscow State Engineering Physics Institute (Technical University), Met. Sci. Dept., Kashirskoe shosse 31, Moscow 115409 Russia

By mechanical testing a wave of local plastic deformation moves ahead of any crack and is responsible for strain hardening and rotation of the crystalline lattice within the layer adjacent to the fracture surface. By means of X-ray diffractometric study of fracture surfaces as applied to sheets of Zr-alloys it was shown, that in alpha-Zr near this surface the specific texture of tension forms with the axis perpendicular to the crack plane. Structure features of the plastic deformation zone at the crack tip controls the further behavior of the fracture process. Depending on the direction of tensile loading, shear stresses in systems of possible slip and twinning vary, so that the local plastic deformation of the notched sample realizes in different manners: either by the prismatic slip resulting only in minor texture changes within a rather extended zone in the case of RD-tension or by the twinning, associated with a significant jump-like reorientation of crystallites and the following prismatic slip within a smaller zone with distinct boundaries in the case of TD-tension. The sharp texture inhomogeneity, arising near the crack tip by TD-tension, causes an additional stress concentration and therefore quickens the further movement of the crack as well as fracture of the sample.

Mechanisms of Structure Development in Hf and Hf-Zr Alloys: *Yuriy Perlovich*[1]; Margarita Isaenkova[1]; Oleg Bocharov[2]; Vladimir Fesenko[1]; Alexander Shikov[2]; Sergey Bochenkov[1]; [1]Moscow State Engineering Physics Institute (Technical University), Met. Sci. Dept., Kashirskoe shosse 31, Moscow 115409 Russia; [2]All-Russia Institute of Inorganic Materials, Rogova, 5, Moscow, Russia

The process of texture development by hot and cold deformation of Hf and Hf-Zr alloys with the Zr content up to 20% was studied using methods of X-ray diffractometry. The participation of different micromechanisms in the plastic deformation at its successive stages was evaluated by means of texture analysis. Among these mechanisms there are twinning by different systems as well as basal, pyramidal and prismatic slip. The dependence of acting mechanisms on the grain orientation, the deformation temperature and the content of Zr was considered. Substructural features of grains with different orientations were compared owing to the selective character of X-ray data. Changes of the texture of samples by the recrystallization at different temperatures were studied also. The correlation of the recrystallization textures with the nonuniform strain hardening of samples was ascertained. The effect was discovered, consisting in the formation of the omega-phase in the surface layer of rolled Hf-Zr alloys by their annealing. The volume fraction of the omega-phase depends on the content of Zr.

Substructure Inhomogeneity and Distribution of Residual Micro- and Macrostresses in Products of Zr-Alloys: New Approaches on the Basis of X-ray Diffractometry and Computer Data Treatment: *Yuriy Perlovich*[1]; Margarita Isaenkova[1]; [1]Moscow State Engineering Physics Institute (Technical University), Met. Sci. Dept., Kashirskoe shosse 31, Moscow 115409 Russia

The recent development of X-ray diffractometry resulted in the conclusion, that real textured metal materials are extremely inhomogeneous and include a very wide spectrum of substructure conditions. As applied to products of Zr-alloys, a new X-ray method of the fullest description of their structure features was elaborated, combining measurements of X-ray line profiles and texture pole figures. Distributions of physical line broadening and peak position as well as derivative distributions of coherent block size, lattice distortion and elastic microstrains are constructed depending on the grain orientation (so-called generalized pole figures). A procedure to construct the polar distribution of macrostresses on the basis of peak position pole figures was elaborated also. Rich possibilities of the method are demonstrated by an example of the comparative study of Zr-1%Nb and Zr-2.5%Nb sheets, experienced both straight and transverse rolling as well as following heat treatment and hydrogen charging. For the first time an actual scale of the inevitable substructure inhomogeneity and its connection with the texture were revealed for products of commercial Zr-alloys, modes of the equilibrium of elastic microstresses and the anisotropy of residual macrostresses were studied, effects of plastic deformation and annealing on the shape and the volume of the elementary cell in alpha-Zr grains with different orientations were analyzed in details.

Size Effects in the Hardness of Titanium Interlayers Roll Bonded With Aluminum: *Michael E. Stevenson*[1]; Jian-Guo Luo[1]; Viola L. Acoff[1]; *Richard C. Bradt*[1]; [1]University of Alabama, Metall. and Mats. Eng., Box 870202, Tuscaloosa, AL 35487-0202 USA

Laminates of titanium and aluminum sheet were roll bonded to reductions from 40 to 80% thickness. Knoop hardnesses were measured for the titanium layers for loads from 10-500 g at each layer thickness. Results were analyzed in terms of the indentation size effect. The load independent hardnesses were determined as a function of the percent reduction. These results were subsequently applied to address the effects of layer thickness in a Hall-Petch relationship.

Correlation Between Substructure and Mechanical Properties of Alpha-Ti at Varying Deformation Temperatures 4.2-373K: A. R. Smirnov[1]; V. A. Moskalenko[1]; [1]B. Verkin Institute for Low Temperature Physics & Engineering, Nat. Acad. of Sci. of Ukraine, 47, Lenin Ave., Kharkov 61164 Ukraine

The correlation between the substructure of alpha-Ti predeformed at the temperature T1 and its mechanical properties (stress of onset of plastic deformation, true rupture strength, residual relative ductility) on subsequent deformation at the temperature T2 varying within 4.2-373K have been studied. It is shown that the changes in the mechanical properties at T1>T2 and T1<T2 are fundamentally different. In contrast to the isothermal deformation at T2, in the T>T2 case the increment in the deforming stress is smaller and the total ductility does not exceed the highest isothermal value; conversely, at T1<T2 the deforming stress and the total ductility surpass the isothermal level. The different predeformation effects are connected with the stability of the the developed substructure against subsequent deformation: it is poor if T1>T2 and high if T1<T2.

Lightweight Alloys for Aerospace Applications: Deformation, Fatigue and Environmental Fracture-II

Sponsored by: Structural Materials Division, Non-Ferrous Metals Committee

Program Organizers: Kumar Jata, Air Force Research Laboratory, Materials & Manufacturing Directorate, WPAFB, OH 45433 USA; Nack J. Kim, Center for Advanced Aerospace Materials, Pohang 790-330 Korea; Eui W. Lee, Naval Air Warfare Center, Code 4342, MS5, Patuxent River, MD 20670 USA; William Frazier, Naval Air Warfare Center, Aircraft Division, Patuxent River, MD 20670-1908

Thursday AM — Room: 213
February 15, 2001 — Location: Ernest N. Morial Convention Center

Session Chair: Nack J. Kim, POSTECH, Pohang, Korea

8:30 AM Invited
Application of 3D Digital Image Processing to Quantify Frac-

ture Mechanisms in Al 7050 Alloy: Manish D. Dighe[1]; Sunit S. Mukherjee[1]; *Arun M. Gokhale*[1]; [1]Georgia Institute of Technology, Mats. Sci. and Eng. Dept., 771 Ferst Dr., Atlanta, GA 30332-0245 USA

Aluminum 7050 is an important alloy that is widely used for applications such as aircraft wing skin structures, aircraft landing gear parts, and fuselage frame structure. Commercial 7050 alloy plates have been observed to have a partially recrystallized microstructure. Thus, it is of interest to study the effect of this microstructure on the fracture properties and fracture morphology. Consequently, an attempt has been made to develop a digital image processing based methodology to reconstruct the three-dimensional (3D) fracture surface and the exact three-dimensional microstructure beneath the fracture surface using serial sectioning. This is to facilitate correlation and quantification by simultaneously observing the 3D morphology of the fracture surface and the microstructure just beneath it. This correlation has also enabled the quantification of the contributions of different types of high angle grain boundaries to inter-granular fracture.

9:00 AM
An Overview on the Fracture Behavior of Discontinuously-Reinforced Aluminum: *A. B. Pandey*[1]; [1]Pratt & Whitney, Liquid Space Prop., P.O. Box 109600, West Palm Beach, FL 33410

Discontinuously-reinforced aluminum (DRA) possesses superior specific stiffness, specific strength, wear resistance and thermal resistance as compared to the monolithic alloys. The use of DRA in aerospace structures such as ventral fin and fan exit guide vane has generated considerable interest in the materials community to widen the applications. One of the major constraints in using DRA for load bearing applications is the lower ductility and fracture toughness of DRA compared to the monolithic alloys. Considerable effort has been made in the past to understand the fracture mechanism in the DRA materials. This paper provides an overview on the microstructural effects on the ductility and fracture toughness of DRA. The influence of matrix heat treatment, particle size, volume fraction and distribution of the reinforcement on the fracture of DRA are discussed. The results indicated that the finer particle size improves the strength, ductility, and toughness of the composite. The heat treatment has significant influence on the fracture behavior of DRA. The reinforcement fracture and matrix/reinforcement interface debonding were dominant damage modes. The effects of specimen size and lamination on the fracture mechanism of DRA are also discussed.

9:30 AM
Microstructure and Mechanical Properties of Metallic Foams: *J. Zhou*[1]; Chris Mercer[1]; Seyed Allameh[1]; B. S.H. Royce[1]; A. G. Evans[1]; W. O. Soboyejo[1]; [1]Princeton University, The Princeton Mats. Instit., Dept. of Mech. and Aero. Eng., Princeton, NJ 08544 USA

The results of ongoing studies of the microstructure and mechanical properties of metallic foams are presented in this paper. These include aluminum, steel and titanium-based steel foams with a range of cell geometries and volume fractions. The microstructure of the cell walls is characterized with scanning and transmission electron microscopy. Quantitative image analysis techniques are then used to characterize the variations in pore geometry at the micro- and meso-scales. The deformation behavior of the cell walls, metallic foams and sandwich geometries, is discussed within the context of experimental observations/measurement and micromechanical models. Preliminary measurements of fatigue and fracture properties are also presented.

9:50 AM
Surface Intrusions in Permanent Mold Cast Aluminum Alloys: J. Shenefelt[1]; R. Thavarajah[1]; R. Luck[1]; *John T. Berry*[1]; [1]Mississippi State University, Mississippi State, MS 39762

Aluminum castings play important roles in a wide variety of civilian and military structures. Since many such applications involve dynamic loading, increased attention to crack initiation and propagation has been paid of late. Unfortunately, much of the current work has involved the evaluation of samples excised from laboratory-scale test castings. The present investigators have purposely conserved the the as-cast surface in determining its effect on fracture in four-pont bend tests on alloys 319-T6 and A356-T6. The samples concerned were cut from actual commercial castings drawn from particular heats in such a manner that the as-cast surface experienced tensional loading. Surface features, particularly intrusions in the case of the 319 alloy are thought to have played an important part in the fracture process.

10:10 AM
On the Effect of Thermomechanical Processing and Thermal Exposure to the Mechanical Properties of 2297 Plates: E. Acosta[1]; O. Garcia[1]; A. Dakessian[1]; K. Aung Ra[1]; J. Torroledo[1]; A. Tsang[1]; M. Hahn[2]; J. Foyos[1]; J. Ogren[1]; *O. S. Es-Said*[1]; [1]Loyola Marymount University, Res. Exp. for Undergrad. Prog., Los Angeles, CA 90045 USA; [2]Northrop Grumman, Mats. and Proc. Techn., Dept 9L26, Zone W5, El Segundo, CA 90245 USA

The objective of this study is to assess the effect of thermal exposure on the tensile properties of 2297 and to assess the feasibility of forging; compression instead of stretch. 24 blocks of 3.8 cm x 3.8 cm x 5.4 cm (1.5 in x 1.5 in x 2.125 in), were solution heat treated at 521ºC, water quenched, and naturally aged for 24 hours. After natural aging the blocks were compressed 0-15% and artificially aged. The artificial aging schedule was: 160ºC for 36 hours, and 177ºC for 36 hours. The hardness values varied in the short-transverse direction showing maximum values in the middle of the surface compared to the edges. The hardness values of the aged samples increased with longer aging times (24 versus 36 hours) and higher temperatures 160ºC versus 177ºC. A multi-step aging process was then incorporated for the compression study in order to optimize the heat treatment. Six samples were solution treated, compressed at 0, 4, and 10%, and aged at the same temperatures as the single step aging study. Three samples were then artificially aged at an initial temperature of 121ºC for 24 hours and then increased to a second temperature of 177ºC for 24 hours. The remaining 3 samples were aged at an initial temperature of 149ºC for 18 hours and then increased to a second temperature of 177ºC for 24 hours.

10:30 AM
Retrogression and Reaging of 7249 Plates: *P. Fleck*[1]; K. Koziar[1]; E. Fromer[1]; P. Herbe[1]; G. Davila[1]; M. Leal[1]; E. W. Lee[2]; Omar Es Said[1]; [1]Loyola Marymount University, Nat. Sci. Found. Res. Exper. for Undergrad. Prog., Los Angeles, CA 90045 USA; [2]Naval Air Systems Command, Code 4.3.4.2, Aircraft Div., Patuxent River, MD 20670 USA

The objective of this study was to investigate the feasibility of performing retrogression and reaging (RRA) heat treatments on 7249-T7651 aluminum alloy in muffle furnaces. The T6 temper was optimized after 39 heat treatments to be 474°C for 1 hour solution treatment followed by water quenching, 24 hours natural aging and artificial aging at 121°C for 24 hours. The retrogression temperatures and times were: 170°, 180°, 190°, and 210°C for 20, 40, 60, 90, and 120 minutes. Reaging was performed at 121°C for 24 hours. Tensile testing, hardness and electrical resistivity measurements were determined.

10:50 AM
Fracture and Fatigue Studies on Al-Be Composites: *Joël Larose*[1]; John J. Lewandowski[1]; [1]Case Western Reserve University, Mat. Sci. and Eng., The Case Sch. of Eng., Cleveland, OH 44106 USA

The fracture and fatigue behavior of Al-Be composites are being determined under a variety of test conditions. Fracture toughness is being determined on both notched and fatigue precracked specimens, while fatigue crack growth behavior is being measured at different R-ratios. The effects of test conditions (e.g. R-ratio, test temperature) on the fracture behavior will be summarized in addition to both optical and SEM examination of the fracture path and fracture surfaces.

11:10 AM
Intergranular Corrosion of RRA-Treated 7075 Aluminum Forgings: Ana Leticia Campuzano-Contreras[1]; *Harold Kelly*[1]; Roy Arrowood[1]; Lawrence E. Murr[1]; Elizabeth A. Trillo[1]; [1]University of Texas at El Paso, Metallur. and Mats. Eng., M201 Eng. Scis., El

Paso, TX 79968-0520 USA; [1]University of Texas at El Paso, Metallur. and Mats. Eng., M201 Eng. Sci., El Paso, TX 79968-0520 USA

7075-T6 stringer ties were collected after long-term service in KC135 fuel tanker aircraft. Samples cut from the forgings were used in a study of retrogression and reaging (RRA) heat treatments. Hardness and conductivity varied with heat treatment as expected from the published literature. Potential-scanning polarization tests in 3.5% NaCl solution revealed that T6 (as received) samples were at or near a localized film-breakdown condition at their free corrosion potential. Samples given a T73-like post-aging were passive. After 5- to 60-minute retrogression, followed by 120°C reaging, samples showed a fragile passivity, with the free corrosion potential being only a few millivolts below localized film breakdown. Post-corrosion microscopy revealed that the breakdown potentials correspond to the onset of grain-boundary etching and intermetallic particle dissolution. These results provide new insights into the effects of heat treatments on corrosion and stress-corrosion resistance.

11:30 AM

Stress Corrosion Cracking of a-Ti in a Methanol Solution: *W. Y. Chu*[1]; H. Lu[1]; L. J. Qiao[1]; [1]University of Science and Technology, Dept. of Mat. Phys., Beijing 100083 China

Stress corrosion cracking of a-Ti in a methanol solution containing 0.6mol/L KCl was very high and an intergranular SCC fracture was obtained. As adding 10% H2O into the methanol solution, however, no SCC occurred. In situ TEM observation showed that corrosion process itself could enhance dislocation emission and motion, and microcrack of SCC initiated when the corrosion-enhanced dislocation emission and motion reached a certain condition. Why can the corrosion process itself facilitate dislocation and motion? a-Ti foil with a protective layer formed on one side was deflected during corrosion in the methanol solution, and then a tensile stress was generated at or near the metal/passive film interface. Adding 10% H2O into the solution, decreased the passive film-induced stress from 320 MPa to zero. Maybe the film-induced tensile stress is necessary condition for corrosion-enhanced localized plasticity, and then SCC.

Magnesium Technology 2001: Corrosion and Future Trends

Sponsored by: TMS: Light Metals Division, Magnesium Committee and Reactive Metals Committee; International Magnesium Association; and ASM International: Materials Science Critical Technology Sector, Structural Materials Division, Corrosion and Environmental Effects Committee

Program Organizers: John N. Hryn, Argonne National Laboratory, Argonne, IL 60439-4815 USA; Byron B. Clow, International Magnesium Association, McLean, VA 22101 USA; David Creber, Alcan International, Ltd., Kingston R&D Center, Kingston, Ontario K7L 5L9 Canada; Russell H. Jones, Battelle Pacific Northwest National Laboratory, Richland, WA 99352 USA; Howard I. Kaplan, Magnesium Corporation of America, Salt Lake City, UT 84116 USA; Ramaswami Neelameggham, Magnesium Corporation of America, Salt Lake City, UT 84116 USA; Eric A. Nyberg, Pacific Northwest National Laboratory, Materials Processing Group, Richland, WA 99352 USA; Mihriban O. Pekguleryz, Noranda, Noranda Technology Centre, Pointe-Claire, Quebec H9R 1G5 Canada; Kevin Watson, Noranda, Noranda Technology Centre, Pointe-Claire, Quebec H7R 1G5 Canada

Thursday AM — Room: 203-205
February 15, 2001 — Location: Ernest N. Morial Convention Center

Session Chair: Gerald S. Cole, Ford Motor Company, Manuf. Sys. Dept., Dearborn, MI 48121 USA

8:30 AM

Measurement of the Corrosion Performance of Magnesium Alloys: *Guangling Song*[1]; David H StJohn[1]; Andrejs Atrens[1]; Li Zheng[1]; [1]University of Queensland, CRC for Cast Mets. Munuf. (CAST), Dept. of Min., Mins. and Mats. Eng., Brisbane, Queensland 4072 Australia

Due to a special electrochemical phenomenon for magnesium alloys called the negative difference effect, significant errors can be introduced into corrosion rate measurement when using traditional electrochemical techniques. Also, the classical weight-loss method only provides final corrosion information, and some experimental and theoretical errors are easily introduced into the final result during the removal of corrosion products and the corrosion rate calculation. This paper experimentally and theoretically demonstrates the use of a hydrogen evolution method of evaluating the corrosion performance of magnesium alloys. The advantages of this method include: 1) the amount of the collected hydrogen is equal to the amount of the dissolved magnesium through Faraday conversion; 2) the collection of evolved hydrogen can reveal the instantaneous corrosion rate as well as the final total amount of corroded magnesium alloy; 3) less theoretical and experimental errors are introduced by the hydrogen evolution collection method.

8:55 AM

Corrosion Behavior of Several Advanced Magnesium Alloys: *Michael J. Danielson*[1]; Russell H. Jones[1]; Eric A. Nyberg[1]; [1]Pacific Northwest National Laboratory, Mats. Res./Matls. Devel., P.O. Box 999; MSIN P8-15, Richland, WA 99337 USA

The corrosion behavior of Mg alloys is highly dependent on their impurities, inclusions and microchemistry and microstructure of the primary phases. New alloys are being developed to meet specific automotive needs that have compositions and microstructures very different from the well established AZ91D, AM60, etc. alloys. These modifications may greatly affect the corrosion behavior of these alloys. Therefore, the corrosion behavior of several die cast and semi-solid molded alloys have been measured and compared to their microchemistry and microstructure. The alloys evaluated were die cast AZ91D, AE42 and ZAC8506 and semi-solid molded AZ91D and ZAC8506. A JEOL 2010F high-resolution analytical/transmission electron microscope was used for the microchemistry and microstructure analysis. Electrochemical corrosion studies were performed to determine the anodic and cathodic polarization response and pitting potentials. Tests were conducted in neutral NaCl solutions at ambient temperature.

9:20 AM

Surface and Environmental Effects on the Fatigue Behavior of Wrought and Cast Magnesium Alloys: *Jens Wendt*[1]; Matthias Hilpert[1]; Jürgen Kiese[1]; Lothar Wagner[1]; [1]Technical University of Brandenburg at Cottbus, Chair of Phys. Metall. and Mats. Techn., P.O. Box 101344, Cottbus, Brandenburg 03013 Germany

The fatigue behavior of the extruded magnesium alloys AZ 31 and AZ 80 as well cast magnesium alloys AM 50 and AZ 91 was investigated. Fatigue tests were performed on hour-glass shaped specimens under fully reversed loading conditions (R = -1) in ambient air and in an aggressive NaCl solution. To study the effect of mechanical surface treatment on the fatigue life, shot peening and roller-burnishing were carried out and the results compared to an electropolished reference. In ambient air, shot peening and roller-burnishing led to a pronounced improvement in fatigue life. In the aggressive environment, only roller-burnishing markedly improved the fatigue life. The change in fatigue performance will be explained by the different surface layer properties such as surface topography, dislocation density and residual stresses as affected by shot peening and roller-burnishing results will be interpreted by the influence of there surface layer on fatigue crack nucleation and microcrack growth.

9:45 AM

Corrosion Fatigue of High Pressure Die Cast Magnesium Alloys: *W. George Ferguson*[1]; [1]University of Auckland, Chem. & Mats. Eng., Private Bag 92019, Auckland, New Zealand

Magnesium is the lightest of all the commercial metallic construction materials. With the increased emphasis on weight reduction in automobiles, magnesium is receiving much attention as a material for use on the next-generation automobiles, especially using die-cast components. Fatigue performance is one of the most important mechanical properties of engineering materials. Magnesium alloys, which are used in the automotive industry, suffer from dynamic loading when in service. The purpose of determining the fatigue resistance of AZ91D and AM50 high pressure die casting alloys, which are the most popular magnesium alloys, is to obtain a reliable database for design, research and application of these materials. Standard Charpy sized test specimens (50´10´10) with smooth surfaces were used for fatigue testing using the three point bend method. S-N curves were determined for die cast specimens of Magnesium alloys AZ91D and AM50. The environments adopted were natural seawater, tap water and air. A difference in corrosion fatigue performance has been found, between AZ91D and AM50. AZ91D has better corrosion fatigue resistance in tap water than in seawater; conversely, AM50 has better corrosion fatigue resistance in seawater than tap water. The influence of frequency was also studied. A non-metallic coating produced electrolytically on magnesium alloys by the 'Anomag' process was used as a coating to improve corrosion protection and its effect on fatigue performance was investigated. In seawater the coating had little effect on the performance of AM50 but improved the fatigue performance of AZ91D. Key words: Magnesium alloys, AM50, AZ91D, high pressure die castings, fatigue and corrosion fatigue, anodized coatings.

10:10 AM Break

10:20 AM
Magnesium's Potential for Powertrain Components: *Naiyi Li*[1]; Jim E. Kearns[1]; Gerald S. Cole[1]; [1]Ford Motor Company, Manuf. Sys. Dept., 2101 Villiage Rd., SRL, MS 3011, Dearborn, MI 48121 USA

Magnesium alloys are being considered the most attractive lightweight metal as the auto industry searches for effective and low cost ways to reduce vehicle mass. In this paper, we will address the technical challenges, and functional and manufacturing issues of using magnesium die castings in powertrain applications. An example of converting a current production aluminum automatic transmission housing to magnesium will be discussed. We will also present the FEA results of filling and solidification and their impact on shape optimization.

10:45 AM
Round Table Discussion:
Magnesium Corrosion Issues That Concern Automotive Engineers: Gerald S. Cole, Ford Motor Company, Manufacturing Systems Dept., 2101 Village Rd., Dearborn, MI 48121 USA

Materials Issues in Microelectronics - II

Sponsored by: Electronic, Magnetic & Photonic Materials Division, Electronic Packaging and Interconnection Materials Committee

Program Organizers: Michael R. Notis, Lehigh University, Department of Materials Science, Bethlehem, PA 18015 USA; Sailesh Merchant, Lucent Technologies, Orlando, FL 32819 USA; Martin Weiser, Honeywell Electronic Materials, Spokane, WA 99216 USA; Jin Yu, KAIST, Department of Materials Science, Seoul, Korea

Thursday AM	Room: 226
February 15, 2001	Location: Ernest N. Morial Convention Center

Session Chairs: Martin W. Weiser, Honeywell Electronic Materials, Spokane, WA 99216 USA; Michael R. Notis, Lehigh University, Dept .of Mats. Sci. & Eng., Bethlehem, PA USA

8:30 AM Invited
Alpha Particle Issues in Microelectronics: *Martin W. Weiser*[1]; [1]Honeywell Electronic Materials, 15128 E. Euclid Ave., Spokane, WA 99216

Alpha particles and other radiation can cause soft errors in microelectronic circuitry. These soft errors do not cause permanent physical damage, but can cause incorrect calculations up to crashing the computer system. The problem has been recognized for many years, but has come to the forefront as the device sizes and operating voltages shrink and flip chip packaging takes off. This paper will describe how soft errors occur and what can be done to prevent or correct for them. The drive for more performance from microelectronic systems is forcing circuit designers to minimize software correction and push the problem to the materials engineers, particularly those involved in flip chip packaging. As a consequence the packaging materials community must now be concerned with radiation emitted by the materials in addition to the standard processing and reliability concerns.

9:00 AM Invited
Optical Packaging Using Improved Au-Based Solders: *Hareesh Mavoori*[1]; Ainissa G. Ramirez[1]; Sungho Jin[1]; [1]Bell Laboratories, Lucent Technologies, Appl. Mats. and Metall. Res., 700 Mountain Ave., Murray Hill, NJ 07974 USA

Eutectic Au-Sn and other Au-based solders are highly creep-resistant and hence desirable for optical packaging where dimensional stability is crucial. In optical device packages, even small, micron-scale misalignments between optical components such as semiconductor lasers/detectors and optical fibers/waveguides are sufficient to cause complete loss of communication signal transmission. We have developed new Au-based solders with enhanced mechanical, chemical and thermal properties for reliable bonding of optical components and devices. Additions of ternary alloying elements to eutectic and near-eutectic Au-Sn have been employed to achieve specific, desirable combinations of properties. Addition of Ga lowers the melting point and enhances the temperature-sensitivity of creep-resistance, yielding a solder that shows promise for forming creep-resistant, low-stress bonds for packaging stress-sensitive components. Alternatively, reactive elements can be added to Au-Sn solder to improve wettability of telecommunication optical fibers without the need for metallization such as electroless Ni or sputtered Ti/Pt/Au. The metallurgy, microstructure, mechanical properties and phase equlibria of these new solders will be presented and their technical implications discussed.

9:30 AM Invited
Microstructure Development in Ag-Cu-Sn Ternary Eutectic Solder Alloys: *Michael R. Notis*[1]; Daniel J. Lewis[1]; Sarah Allen[2]; [1]Lehigh University, Mats. Sci. & Eng., 442 Whitaker Lab., Bethlehem, PA 18015 USA

The morphology & microstructural stability of binary and higher-order eutectic alloys have been the subject of continued interest for many years. Models have been developed in the past to predict lamellar versus fibrous (rod-like) morphology in binary eutectics, based solely on interfacial energy arguments, and have been successful in correlating morphology-type with phase fraction in the eutectic (rod-like structures being favored at low phase fraction). We have extended this model to ternary eutectic systems, and we will demonstrate the applicability of this model to a study of microstructural stability during processing of alloys in the Ag-Cu-Sn solder system, as well as other lead-free and lead-containing ternary solders.

10:00 AM
Model Development of Base Metal Dissolution by Molten Solder: *Kenneth Erickson*[1]; Polly Hopkins[2]; Cynthia Hernandez[3]; Paul Vianco[3]; [1]Sandia National Laboratories, Dept. 9112, MS0834, P.O. Box 5800, Albuquerque, NM 87185 USA; [2]Sandia National Laboratories, Dept. 9117, MS0834, P.O Box 5800, Albuquerque, NM 87185 USA; [3]Sandia National Laboratories, Dept. 1835, MS1411, P.O. Box 5800, Albuquerque, NM 87185 USA

An understanding of base metal dissolution by molten solder is important towards the development of soldering processes. Intermetallic compound layer formation at the solder/metal interface as well as diffusion processes within the molten solder are critical mechanisms in the dissolution phenomenon. In order to develop an analytical model describing solder dissolution processes, a series of experiments were performed that documented the such processes between 100Au and 76Au-21Pt-3Pd (wt.%) base materials and 63Sn-37Pb and 50In-50Pb solders. The extent of base material loss into the solder as well as the growth kinetics of the intermetallic compound layer were measured as a function of molten solder temperature and time of contact. The development of a computational model, and the use of the above data in that model, will be described. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the US DoE under DE-AC04-94AL85000.

10:20 AM Break

10:40 AM
Kinetic Study of Solid State Reaction of Eutectic SnPb and Pb-Free Solders on Electroplated Cu UBM: *J. W. Jang*[1]; T. Y. Lee[2]; J. K. Lin[1]; D. R. Frear[1]; K.-N. Tu[2]; [1]Motorola, Semiconductor Products Sector, MD EL 725, 2100 East Elliot Rd., Tempe, AZ 85284 USA; [2]UCLA, Dept. of Mats. Sci. & Eng., Los Angeles, CA 90095-1595 USA

The kinetics of solid-state reaction of eutectic SnPb and a variety of Pb-free solders (Sn-3.5Ag, Sn-3.8Ag-0.7Cu, and Sn-0.7Cu) on electroplated Cu were investigated using optical microscopy. From the growth thickness of Cu3Sn and Cu6Sn5 intermetallics, the kinetic data such as the consumption thickness of Cu UBM, the activation energy, and diffusion coefficient for intermetallic growth were calculated. It was found that the solid state kinetics of Pb-free solder resulted in faster interfacial intermetallic growth than those of Pb-free solders. The difference is attributed to the presence of Pb. The diffusion mechanisms in Cu6Sn5 and Cu3Sn are also discussed in terms of microstructure of the intermetallics.

11:00 AM
Phase Coarsening During Static Annealing of Eutectic Pb-Sn Solder Joints: *Kang Jung*[1]; Hans Conrad[1]; [1]North Carolina State University, Dept. of Mats. Sci. and Eng., Raleigh, NC 27695-7907 USA

The coarsening of the Pb and Sn phases during the static annealing of 60Sn40Pb solder joints was investigated. The average phase sizes D and their distributions were determined at 50°C to 150°C for t=1 to 70 hr. Employing the time law $D^n-D^n_o=At$, it was found that n decreased with temperature from 5.5 at 50°C to 2 at 150°C without change in phase size distribution. The constant $A=_o$exp(-Q/RT) with Q=50±10 kJ/mole. Possible mechanisms are discussed.

11:20 AM
Microstructures and Joint Reliabilities of the Sn-3.5wt%Ag-X (X=In, Cu, Ni) Solder Alloys: *W. K. Choi*[1]; H. M. Lee[1]; [1]Korea Advanced Institute of Science and Technology, Cen. for Electr. Pack. Mats., 373-1 Kusong-dong Yusong-gu, Taejon, Korea

The Sn-3.5wt%Ag-X(X=In, Cu, Ni) solder alloys were designed through thermodynamic calculations. Indium was selected to lower the melting temperature of Sn-3.5Ag solder. Copper and Nickel were alloyed for improving the interfacial characteristics of Sn-3.5Ag solder. The microstructures and the thermodynamic behaviors of bulk solder alloys were investigated. To examine joint characteristics, the soldering was performed on various substrates at 250°C for 60 s followed by aging at 130°C for 100 and 400 hrs. The interfacial phenomena in solder joints were observed by XRD, SEM and EDX during soldering and aging, and after temperature cycles (-65°C~150°C). The solder joint strength was tested using the ball shear test for the jointed specimens after soldering and after temperature cycles. It was found that the interfacial characteristic has a major effect on the joint reliability. And the optimum solder composition could be presented.

11:40 AM
Metal/Polymer Interface and Solder Joint Reliability of a Wafer Level CSP: *H. Han*[1]; Jin Yu[1]; [1]KAIST, Center for Electro. Packag. Mats., 373-1 Kusong-dong Yusong-gu, Taejon, Korea

Wafer level chip scale package(WLCSP) has the highest potential compared with flip chip package(FCP), because they provide the benefits of real chip size package with low cost and high reliability. We use low modulus polymers(stress buffer layer; SBL) which were designed to relax the thermal strain generated at the solder joint. However, reliability of metal/polymer interface and solder joint are still critical problems to the WLCSP. We studied the reliabilities of metal/SBL interface and solder joint according to variation of the polymer surface treatments and the metal structure. To measurement of adhesion property on metal/SBL, peel strength was evaluated. In addition, the effects of under bump metallurgy(UBM) on the reliability solder joint at the WLCSP will be discussed.

Second Global Symposium on Innovations in Materials Process & Manufacturing: Sheet Materials: Numerical Modeling and Optimal Design

Sponsored by: Materials Processing and Manufacturing Division, Powder Materials Committee, Shaping and Forming Committee, Solidification Committee

Program Organizers: Mahmoud Y. Demeri, Ford Motor Company, Manufacturing System Department, Northville, MI 48167 USA; Iver Anderson, Iowa State University, Ames Laboratory, Ames, IA 50011-3020 USA; David L. Bourell, University of Texas, Mechanical Engineering Department, Austin, TX 78712-1063 USA; Amit K. Ghosh, University of Michigan, Department of Materials Science and Engineering, Ann Arbor, MI 48109-2136 USA; John Papazian, Northrup Grumman, Bethpage, NY 11714 USA; Klaus Siegert, University of Stuttgart, Institute for Metal Forming Technology, Stuttgart D-70174 Germany

Thursday AM — Room: 228
February 15, 2001 — Location: Ernest N. Morial Convention Center

Session Chairs: Michael Saran, Case Western Reserve University, Cleveland, OH 44106 USA; A. Sherif El-Gizawy, University of Missouri, Columbia, MI USA

8:30 AM
Impact of Advances in Computer Technology on Sheet Metal Forming Simulation: *Perry R. MacNeille*[1]; [1]Ford Motor Company, 2101 Village Dr., Dearborn, MI 48121 USA

Advances in computational technology such as mass-production, miniaturization and transmission technology are making computers faster, cheaper, smaller and more connected. Advances in computer hardware drive the advances in computer software that make it possible to harness the power of the new hardware. These advances lead to both qualitative and quantitative changes in computing that will impact most aspects of industry including the processing and manufacturing of sheet materials. This paper discusses some of these advances in computer technology and their consequences for the production of stamped sheet metal parts.

8:50 AM
Optimal Design of Materials Processing Based on Mechanics Fundamentals–Next Step Beyond Numerical Simulation: *Michael J. Saran*[1]; [1]Case Western Reserve University, Dept. of Mats. Sci. and Eng., 516 White Bldg., Cleveland, OH 44106-7204 USA

Currently, most often, design of the sheet metal forming process is performed by a trial & error procedure, where the trials are performed using stamping presses and/or numerical simulation. A current design is usually improved by evaluating the latest results and making design changes based on experience or intuition. The outcome is an acceptable but usually not optimal design. There is a number of drawbacks of such approach including non-optimal final design, long times required, and incorrect results when variations of multiple process parameters are considered. In this paper, an overview of pertinent optimal design algorithms will be presented. Then, the application of the selected approaches to optimal design of the sheet forming process will be introduced. Such algorithms will calculate the optimal values of process, material, and geometrical parameters and do so in a shorter time compared to the design by multiple simulations. The theory of optimal design will be illustrated by specific examples of sheet metal forming processes.

9:10 AM
A Finite Element Simulation System for Sheet Metal Forming Using Reconfigurable Tooling: *Elias L. Anagnostou*[1]; John M. Papazian[1]; [1]Northrop Grumman Corporation, Tech. Dev., South Oyster Bay Rd., M/S A01-26, Bethpage, NY 11714 USA

A simplified front end for a finite element simulation system for prediction of a springback correct die shape has been developed for the sheet metal stretch forming process. This system has been designed for use in conjunction with a "discrete-die" reconfigurable tool. The simulation system takes into account the deformation of the unique compliant layer that is required for use with a discrete die. The system is highly automated, and is designed to be used by a tool design engineer with little finite element modeling experience. The system performs initial forming checks to determine if the part can be formed with a particular reconfigurable tool, it then prepares and submits a finite element model of the process, and retrieves and analyzes the output of the calculation. A die design algorithm is incorporated for prediction of the springback corrected die shape. The predicted die shape and the desired forming trajectory are then downloaded directly to a web-server database.

9:30 AM

Effect of Global and Local Stiffness on Blankholder Pressure in Draw-Die Forming: *Matthew Dingle*[1]; John Duncan[2]; Michael Cardew-Hall[3]; Peter Hodgson[4]; [1]Ford Motor Company of Australia/STAMP Research Group, CAE, Prod. Dev., P.O. Box 14, Geelong, Victoria 3220 Australia; [2]University of Auckland; [3]Australian National University; [4]DeakiN University

Elastic deformation in mechanical presses will influence the blankholder pressure during the operating stroke. Quantitative information is sparse in the literature and in most cases of die design, the effect is neglected. In this paper, the global effects are analysed by reducing a typical double-acting press to relatively few kinematic, rigid or elastic elements. Data from a particular press, including measurement of force in the outer slide and main ram, are used to calibrate this model, which is found to explain the observed blankholder force signature. Variation of pressure at any instant around the binders is also an important die design consideration. Simple analytical models show that the pressure distribution can be controlled by local variation of stiffness of the structure supporting the binder surface. These calculations are in agreement with more detailed finite element analysis of actual die structures. The results of this work support the view that, if incorporated in the regular die design process, quite simple stiffness analysis could significantly improve stamping performance and reduce die try-out time.

9:50 AM Break

10:10 AM

Computer Prediction of Dent Resistance of Automotive Steel Panels: *Naji Arwashan*[1]; Maurice M. Lou[2]; [1]LTV Steel Company, Auto. Dev. Grp., 2000 Town Ctr., Ste. 540, Southfield, MI 48009 USA; [2]Ford Motor Company, FEA and Die Stnds., Mail Drop 268 Cubicale GB-N78, 20910 Oakwood Blvd., Dearborn, MI 48121 USA

Dent Resistance of exterior steel body panels is an increasingly important issue in light of the current trend toward downgaging for achieving weight reduction. Predicting dent behavior of panels at the early stage of tools and die design can help save a lot of time and money. Dent resistance depends among other things on the geometry of the panel and on the strains caused by the forming operation. Hence, it is almost impossible for a simple formula to predict dent resistance for automotive panels. It is only by finite element analysis that the complexity in geometry and in forming process can be analyzed. The behavior of steel panels in resisting denting is significantly improved by the work hardening of the steel during the forming operation. A key to a successful prediction of denting is to know the distribution of the strains in the panel after forming. Therefore, simulation of dent behavior cannot be accurately performed without first simulating the forming of the panel. Explicit finite element codes are widely used for forming simulation. However, due to the dynamic nature of these codes, they are not suited to simulate quasi-static dent resistance. Only implicit finite element codes can simulate accurately the quasi-static denting problem. LS-DYNA, with its explicit and implicit solvers was used to perform seamless simulation of forming and denting. The computer simulation of dent resistance of an automotive door panel was compared with experimental results. The good agreement between simulation and experimental results supports the applicability of the approach used in this investigation.

10:30 AM

Material Variations and Springback: A Stochastic Approach: *Cedric Xia*[1]; [1]Ford Motor Company, Scien. Res. Lab., MD3135/SRL, P.O.Box 2053, Dearborn, MI 48121 USA

A robust stamping process has to have the cabability to tolerate inherent variations of both material properties and process parameters. This study attempts to examine the effect of material property variations on the springback behavior from a stochastic point of view. A plane strain flanging problem is employed to facilitate the study. Deterministic solution of the springback is first derived analytically under pure bending assumption. Random distribution of such material properties as the yield strength, hardening coefficient, and blank thickness is then introduced. A Monte Carlo simulation is performed to evaluate its springback response. Emphasis is placed on the response variance and their correlations. The level of quality control required for a robust stamping is discussed.

10:50 AM

Improvements in Numerical Prediction of Springback Aided by The Split Ring Benchmark Test: *Michael J. Saran*[1]; Mahmoud Y. Demeri[2]; Nana Andoh[1]; [1]Case Western Reserve University, Dept. of Mats. Sci. and Eng., 516 White Bldg., Cleveland, OH 44106-7204 USA; [2]Ford Motor Company, MM, 2101 Village Rd., P.O. Box 2053, MD 3135, SRL, Dearborn, MI 48121-2053 USA

Springback is one of the key factors influencing quality of the sheet metal forming process. Therefore, an accurate and reliable prediction of springback would be of great value for the part & process designer to arrive at ever-tighter targets of dimensional and surface quality, and stamping robustness. Recently, a new Split Ring Benchmark Test for springback simulation was developed to aid in validation of numerical predictions. The test encompasses complex forming modes, but avoids problems with measurement fixtures, and provides considerably improved measurement accuracy and reduced experimental error. The preliminary simulations using the "general purpose" numerical and materials settings showed a good qualitative agreement with the test results and a reasonable prediction of trends for steel and aluminum. It also indicated that a further study to obtain an improved quantitative agreement with the test results is needed. Aided by the test results, this paper investigates sources of approximation in the numerical models and attempts to identify which of the problem description parameters are important for a good springback prediction. Selected numerical, material, and process parameters are considered.

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Thermo-Mechanical Coupling Finite Element Analysis of Non-isothermal Sheet Extrusion Process: *Zhanghua Chen*[1]; T. C. Lee[1]; C.Y. Tang[1]; [1]The Hong Kong Polytechnic University, Dept. of Manuf. Eng., Kowloon, Hong Kong, China

In sheet metal forming process, the forming limit and strain distribution are governed by plastic instability and fracture following strain localization. It has been proved that the temperature gradient caused by plastic deformation as well as friction is one of crucial factors to induce the strain localization in high-speed metal forming processes. In this paper, a numerical simulation of the sheet metal extrusion process has been conducted by using thermal-mechanical coupling finite element method. An improved mixed finite element method has been used to solve the elasto-plastic problem. In thermal phase, the transient heat transfer finite element method together with the Crank-Nicholson algorithm has been employed to determine the temperature field. A comparison with the experimental result revealed that the temperature gradient plays an important role in inducing the strain localization which led to fracture failure in the sheet metal extrusion process.