INNOVATIONS IN MATERIALS AND THEIR APPLICATIONS

Proceedings of the
ASM MATERIALS CONFERENCE

25-27 October 1977
Chicago, Illinois

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INNOVATIONS IN MATERIALS AND THEIR APPLICATIONS

Proceedings of the 1977 ASM Materials Conference

Part of the Triple Engineering Shows and Conferences

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Energy Division
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Mechanical Working and Forming Division
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Conference Chairman
Fred J. Wall
Westinghouse Electric Corporation

AMERICAN SOCIETY FOR METALS
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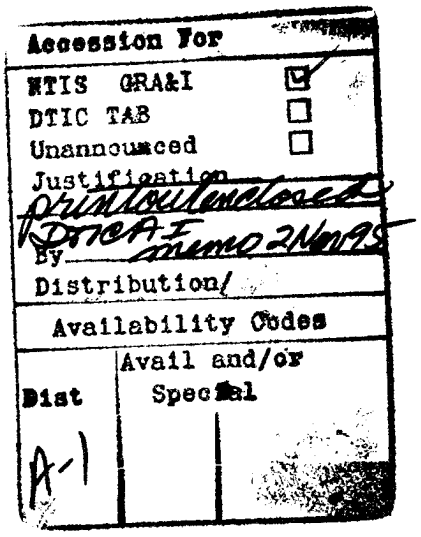
PREFACE

The 1977 ASM Materials Conference focuses on the theme "Innovations in Materials and Their Applications." The conference presents information on newly emerging materials and process technology as well as current state-of-the-art information on existing materials and processes.

The printed proceedings provide a one-page or two-page abstract of the presentations. These abstracts are arranged in chronological order according to the conference program. All complete manuscripts received prior to the publication deadline are contained on microfiche in the pocket in the back inside cover of this volume. These papers are also in program sequence.

The conference organizers would like to thank all the speakers at the 1977 ASM Materials Conference, particularly those who took the time from their busy schedules to submit manuscripts. A special word of thanks is due the Metal Properties Council for programming two sessions at this conference. Special thanks also should go to Mr. John Vaccari, Editor of Materials Engineering Magazine, for his contributions to the program, and to Mr. Fred J. Wall of Westinghouse Electric, who, in his position as conference chairman, guided the overall programming efforts.

Elliot B. Boardman
Director of Technical Divisions
and Activities
American Society for Metals



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SLENDER PRECISION, INJECTION-MOLDED STRUCTURAL TYPEWRITER PARTS

JON C. NIPPLE
ASSOCIATE ENGINEER
IBM CORPORATION
LEXINGTON, KENTUCKY
October 25, 1977

This paper attempts to deal with some of the questions an engineer must answer in changing from a metal part to a plastic part. Considerations such as strength, rigidity, close tolerances and manufacturability of long slender polymeric parts will be discussed. Two related examples from the typewriter industry will be cited. These parts were once made of metals with several broaching, machining, deburring, and straightening operations performed on them. By changing these two parts to plastic and pushing the technology to the limit, numerous secondary operations were eliminated. A significant cost reduction was achieved without sacrificing performance.

INNOVATIONS IN STRUCTURAL FOAM DESIGN FOR OFFICE AND ELECTRICAL COMMUNICATIONS EQUIPMENT

William C. Victor
Plastics Sales Department
General Electric Company
Pittsfield, Massachusetts

The increased utilization of structural foam in the fields of office and electrical communications equipment has recently spawned many advance design philosophies. This paper will deal with the tracing of their origin and expansion of these ideas for their use in the future. General topics to be covered will include: Discussions of the design approach in early materials with emphasis on the emergence of plastic, engineering plastics, and engineering structural foam as an accepted design medium. Examples of early use of foam in the fabrication of business machine housings will be addressed including today's accepted modes of design and the advanced materials that will allow the designer to expand his approach for tommorrow's requirements. Also, included will be discussions of the five major design techniques used today to design and predict performance with engineering structural foam.

THERMAL SPRAYED COATINGS FOR OFFICE PRODUCTS

Brad A. Teal
IBM Corporation
Rochester, Minnesota

The solution to many of the severe wear problems associated with electro-mechanical devices in data processing machines has been the specification of wear resistant thermal sprayed coatings.

Thermal spraying technology is being used at IBM to produce coatings which provide a wide range of properties. This paper describes recent advances in thermal spraying techniques for computer components. The presentation describes:

(1) Application of thermal sprayed coatings on mechanical components.

(2) Coating applications for EMC properties on plastic parts.

(3) Material, processes and equipment developments in thermal spraying.

(4) Specifications and quality control of thermal sprayed coatings.

INNOVATIONS IN THE DESIGN OF SMALL METAL AND PLASTIC SPUR GEARS

Robert S. Lundin
Superior Electric Company

Familiar to most mechanical designers and engineers are the traditional methods for the design of spur gears presented in engineering handbooks. Such methods provide relatively simple procedures for the practicing engineer to follow. Those willing, however, to spend a little more effort and depart from traditional practices can realize appreciable performance improvements.

Such innovative design techniques become increasingly important in spur gear design when considering plastics. The manufacturability, economy, and durability are interrelated factors which must be weighed carefully in making use of the options available using non-traditional designs.

SLIP CASTING AND INJECTION MOLDING OF CERAMIC COMPONENT FOR HIGH PERFORMANCE APPLICATIONS

John Mangels
Andre Ezis
Eugene A. Fisher
Carl Johnson
Ford Motor Company
Dearborn, Michigan

Ceramic materials are currently being investigated for application in heat engines so that engine efficiency may be increased through higher operating temperatures. This paper discusses the development of forming and processing techniques for the fabrication of ceramic gas turbine components.

These components, in this case, are made from reaction sintered silicon nitride, one of the new ceramic materials having good strength and high thermal stress resistance. The forming techniques being developed for fabrication of these complex-shaped components are slip casting and injection molding of fine-grained silicon powder which is subsequently converted into silicon nitride. This paper discusses the general concepts involved in slip casting of silicon metal powder and the injection molding of highly loaded silicon metal powder/polymer systems. The nitriding techniques are also briefly described. It will be shown that the ability of these processes to fabricate high performance turbine components depends on the accurate control of all process variables, from slip casting or injection molding through nitriding. Selected material property data and test results will also be presented.

THE CLOSED LOOP-CONTROLED, DOUBLE-SHOT INJECTION MOLDING SYSTEM

ROLF WUSTRAU
IBM CORP.

The normal process variations in manufacturing molded parts can be neutralized by sensing, controlling and maintaining key parameters in a molding system. Optimum results can be expected even in different combinations of materials in a doubleshot machine.

LATEST DEVELOPMENTS IN INJECTION MOLDING UTILIZING A VENTED BARREL

Robert DeCapite
HPM Corporation
Mount Gilead, Ohio

This is a presentation on the vented barrel as a viable alternative to predrying of plastic materials prior to their processing. The presentation discusses in detail the history of the vented barrel and the processing of various materials on the two-stage screw. The various materials which have been tested and are in production along with various parts are presented. Also, there is a presentation on the economics of comparing a vented barrel with predrying of the material.

DO ADVANCED STRUCTURAL FOAM MOLDING PROCESSES REDUCE COST?

WOLFGANG MEYER

Structural foam applications in markets such as building, business machines, consumer electronics, transporation, furniture and housewares require finishing due to the swirly surface appearance obtained in low pressure structural foam molding. Yet, the low pressure structural foam process utilizing rapid injection(2000 cu.in/s) provides a relatively smooth molded surface with a surface roughness not exceeding 3-5 mil. This kind of surface quality permits a significant reduction of finishing cost as compared to the surface obtained with regular structural foam and injection molding equipment utilizing slow injection rates; i.e. a medium coarse texture can be produced without application of a filler coat.

Higher savings in total manufacturing cost are obtained using advanced structural foam processes such as thermocycling, cavity pressurizing and co-injection. Advanced processes do have limitations as to part configuration and also the obtained surface quality does not eliminate the application of a paint coat in all cases. However, despite the necessity to finish with a single top coat in certain cases, savings in finishing cost reach 40-60% and thereby compensate higher capital investment in molding equipment and tools easily.

The thermocycling and cavity pressurizing processes lend themselves very well for adaptation to existing structural foam equipment. The co-injection structural foam process requires special equipment. Yet, it is applicable for more complicated products and provides an excellent surface quality.

CONSIDERATIONS IN THE DESIGN OF INSTRUMENTS FOR STEREOLOGICAL ANALYSES

J. E. Hilliard

Materials Research Center
and Department of Materials Science & Engineering
Northwestern University, Evanston, Illinois 60201

A review will be given of the basic stereological expressions relating three-dimensional structural properties to measurements made on a two-dimensional section. The relative advantages of stage scanning and field scanning instruments in making these measurements will be discussed and a description will be given of a computer-controlled scanning microscope that has recently been developed at Northwestern University.

QUANTITATIVE TELEVISION MICROSCOPES: THEIR USE, MISUSE, AND FUTURE USE

George A. Moore
National Bureau of Standards

Having first insured that the specimen surface faithfully represents the material, it is necessary to obtain valid measurements which are meaningful with respect to a practical material problem. QTM's can provide four distinct classes of data; (1) True field measurements; (2) Individual feature measurements; (3) Summarized feature measurements; and (4) Texture data. Quality control of solid materials is best satisfied by true field area and intercept data which equate stereologically to geometrical parameters of the solid. Individual feature data can be precise only under very restricted conditions, hence their sums cannot be substituted for true field data. One minor quality control application occurs in determining the true grain size when grains contain particles of another phase. Two classes of quantization of texture are possible but both require extensive measurements on each field.

Meaningful measurement of a heat or lot requires measurement of a large number of fields on each of several specimens; with full statistical analysis. Statistics cannot, however, correct for errors of machine adjustment or operation. Visually determined threshold settings are inherently biased and must be replaced by objectively determined settings. Distinctly different thresholds are required for correct area, intercept, and feature data. Full computer control and checking of all measurements may be required to prevent either machine or operator errors.

Tightening quality control requirements for materials used in critical applications indicate near-future appearance of specialized QTM's in on-line inspection service. Reasonable cost with high operating speed and reliability are essential to this application. Rugged simplified assemblies for specific inspection tasks have appeared. Full automation of measurement and data processing is generally available. Rapid progress is being made toward much higher operating speed by utilizing high speed minicomputers, parallel measurement of several parameters on each scan, and microprocessor units for simultaneous computations on parallel data inputs.

ASTM Committee E4 on Metallography is engaged in the composition of measurement specifications intended to ensure production of comparable data from any of the instruments expected to be available for inspection service.

THE MEASUREMENT OF INCLUSION PARAMETERS USING AUTOMATED IMAGE ANALYSIS

James H. Steele, Jr.
Armco Steel Corporation

Several of the problems associated with the application of automated image analyzers for measuring inclusion parameters will be discussed. The problem areas will include:

(1) Evaluation of the adequacy of sample preparation.

(2) Determination of an optimum field size and number of fields.

(3) Understanding field distribution data and the degree of correlation between the different parameters.

(4) Understanding the sources of variability in the measurements.

(5) Correlation of inclusion parameters with properties and chemical composition.

AUTOMATIC MICROTOPOGRAPHY MEASUREMENT IN THE SEM

Jozef Lebiedzik
LeMont Scientific, Inc.

The scattering characteristics of Back-Scattered Electrons (BSE) in a Scanning Electron Microscope (SEM) are used for topographical reconstruction of a solid surface on a microscopic scale.

A set of four detectors is used to monitor the intensity of the BSE in four directions. The detector system yields information used to establish a slope and orientation of the surface at the point of electron beam interaction with the solid. Since the distance between any two sampled points is known, a three dimensional approximate reconstruction of the surface is possible. The accuracy and precision of such a reconstruction depends mostly on point density and on the surface textures. Because surface reconstruction is done from slope values, the system is limited to surfaces with slopes less than 90^{o}.

The BSE signals are monitored by a minicomputer which also controls the electron beam in the SEM. The entire process is fully automatic, and the three dimensional solid surface is stored in the computer for further analysis. At the present, the following are calculated from those data: Surface roughness in arithmetic average deviation, root mean square value and surface area ratio. Since the surface is stored in the computer, any other parameter of interest may be readily calculated.

INNOVATING WITH PLASTICS FOR WEIGHT SAVINGS

Richard E. Van House
Executive Engineer, Plastics, Paint and Vinyl Division
Ford Motor Company

The most pressing problem facing the automobile industry today is to meet the Federally mandated fuel economy laws without negatively affecting the health and growth of the American economy. The industry is approaching the resolution of this problem from three directions: the downsizing of cars; new technology in engines and transmissions; and, most importantly, weight reduction.

Weight reduction, through the use of lightweight materials, can minimize the amount of vehicle downsizing required to meet future model targets. Plastics, properly applied, can be the most effective method of reducing weight. As a result, innovative plastic developments must be initiated in the following areas:

- New plastic materials.
- Unique component designs to take advantage of plastic materials.
- New manufacturing processes to utilize plastics.

These innovative actions must be implemented immediately to allow support of vehicle programs in the early 1980's.

INNOVATING WITH PLASTICS FOR CORROSION RESISTANCE

Robert J. DeGrazia
Rubber and Plastics Department
Chrysler Corporation
Detroit, Michigan

In the last few years, the weight saving properties of plastics have almost completely overshadowed some of the other important plastic properties. Corrosion resistance is one of these.

There have been many programs initiated to replace a metal part with a plastic part primarily to eliminate or prevent a corrosion problem. Many other programs that were initiated for some other reason, such as weight savings or cost reductions, were enhanced because improved corrosion protection also was achieved.

This paper will present a resume of a number of automotive programs that either directly or indirectly led to a production part with improved corrosion resistance due to substituting or designing a plastic part in place of a metal part. Examples will be drawn from each of the major domestic automobile manufacturers.

INNOVATING WITH PLASTICS FOR ENERGY CONSERVATION

Walter E. Becker
Mobay Chemical Corp.

Plastics offer to the transportation industry energy saving possibilities unmatched by natural materials. Plastics not only contribute to saving initial energy (i.e., less process energy to produce) but continue to save valuable Btu's and/or gallons via reduced vehicle weight and increased gasoline utilization.

This paper will discuss the various ways in which plastics are contributing to the solution of our energy dilemma. Primary attention will be paid to automotive applications; however, several examples of energy savings through plastics from other market areas may serve as stimuli for consideration by the automotive industry.

Special attention will be given to new material and/or process technologies which provide extraordinary possibilities to save energy. Typical of such processes is Reaction Injection Molding (RIM). The merits of RIM versus natural materials and other plastics will be explored.

INNOVATING WITH PLASTICS FOR COST REDUCTION

Clarence M. Alsys
Fisher Body Division
General Motors Corporation
Warren, Michigan

Plastic parts started to replace metal on cars about thirty years ago as simple one for one substitutions. The next step was to combine a number of adjoining metal parts and their fasteners into a single plastics part. As this development was being carried to its logical conclusion, it became obvious that certain manufacturing and formulating processes could be brought 'in-house' to effect better quality control and to reduce costs. Currently and in the near term future, the innovative applications of plastics in automotive will proceed at an unprecedented rate as a result of the strong manufacturing and development bases that have been established.

FABRICATION TECHNIQUES FOR TITANIUM ALUMINIDES

Thomas E. O'Connell
Pratt & Whitney Aircraft Group
Government Products Division
and
Martin J. Blackburn
Pratt & Whitney Aircraft Group
Commercial Products Division

A major goal in the aircraft industry is the improvement of thrust-to-weight ratio for advanced gas turbine engines. One means to this end is the development of high temperature, high specific materials such as the titanium aluminides, (TiA1 and Ti3A1). Several areas of application of the titanium aluminides to gas turbine engines have been identified including: Structural and airfoil castings, sheet metal structures, and forged blades and disks. This paper describes the various processing steps which are under development for producing the anticipated forms and shapes of titanium aluminide gas turbine engine parts.

APPLICATION OF TITANIUM ALLOYS TO UNINSULATED SUPERSONIC MISSILE STRUCTURES

George G. Myers and Dr. Ramon A. Mayor
Martin Marietta Aerospace, Orlando, Florida

Materials used in uninsulated "hot structure" air-launched missiles, flying at velocities greater than Mach 3, must withstand temperatures in the 1000°F (538°C) to 1400°F (760°C) range. Potential design criteria parameters, both mechanical and thermal, required for typical air-launched missile structures are presented herein. After preliminary screening, titanium alloys 6 Aℓ-4V (Ti 64) and 6 Aℓ-2V-4Zr-2Mo (Ti 6242), and Inconel 718 are considered prime material candidates. Further tradeoff studies and test programs have shown that Ti 6242 can withstand the required short term environment, and also permits improved missile aerodynamic performance when compared to the other candidates. Short term tensile tests of the candidate materials, both in base metal specimens and weldments, as a function of temperatures to 1400°F (760°C) and heat treatment, substantiate the advantages of Ti 6242.

SUPERPLASTIC FORMING/DIFFUSION BONDING

Leonard Ascani

Los Angeles Aircraft Division
Rockwell International Corporation

A new technology is emerging that promises to revolutionize the field of metal fabrication and design, particularly that of titanium. A process that combines both the superplastic and diffusion bonding properties of metal into one concurrent operation is being developed at Rockwell International. Estimates using this technology have indicated that this combined process will result in cost savings up to 70 percent when compared to conventional construction methods, while also saving weight. This paper describes the processes and the many structural forms that have been made possible by this technique. The total potential of Rockwell's patented new processes is limited only by the ingenuity of the designer and is expected to affect significantly future airplane concepts.

NEAR NET SHAPE PROCESSING FOR GAS TURBINE COMPONENTS

E. F. Bradley
Chief Materials Engineer, Pratt & Whitney Aircraft, East Hartford, Conn.

Increased emphasis on more efficient utilization of materials to conserve materials and energy and to reduce costs has led to the concept of near net shape processing for aircraft gas turbine engine parts. The materials for these parts are reviewed and the weight of raw material which must be purchased and processed to produce one pound of finished component, that is the Buy/Fly ratio, is discussed. Several near net shape processes involving forging, extrusion, casting and powder metallurgy are described. Particular attention is given to the manufacture of disks by the GATORIZING™ forging process and hot isostatic pressing.

CAST - CAST ALUMINUM STRUCTURES TECHNOLOGY

Donald D. Goehler
The Boeing Company
Seattle, Washington

The U.S. Air Force has contracted a program to the Boeing Company for the development of aluminum castings for large primary aircraft structures. The program was initiated in June, 1976 and will continue through June, 1979. The objective of CAST is to establish necessary structural and manufacturing technologies and demonstrate the integrity, producibility and reliability of cast aluminum primary airframe structures. It is projected that a 30% cost reduction will be attained through the use of CAST.

The results of the first year of this study will be discussed. The discussion will include work on the design of a YC-14 bulkhead and the development of manufacturing methods for cast aluminum structures.

FRACTURE AND FRACTOGRAPHY OF TITANIUM ALLOYS

David W. Hoeppner
Mechanical and Aerospace Engineering
University of Missouri
Columbia, Missouri

Titanium alloys are extremely interesting to study utilizing fractographic tools. These alloys frequently exhibit characteristics of several fracture micromechanisms for presumably the same loading/environment combinations. The role of chemical composition, microstructure, and texture is discussed as it relates to fractographic features in titanium alloys. Emphasis will be given to the procedure of fracture surfaces under cyclic loading conditions.

COMPUTER IMAGE ANALYSIS IN TITANIUM ALLOYS

M.E. Rosenblum
University of Cincinnati

As a result of suspected and partially proven correlations between mechanical properties and microstructures in titanium alloys, attempts were made to analyze structures with a computer. Successful correlation of microstructural parameters with mechanical properties could produce a system for eliminating expensive tests in quality control and could serve to establish alloy specifications based on microstructure. The software for this task was produced and the methodology and results are presented.

Some of the problems encountered in applying computer image and data analysis techniques to microstructures will be discussed. The presentation of an image to a computer in a useful form is probably the major hurdle to overcome in this analysis and methods are still under investigation. The choice of measurements also can be a problem unless there is a firm metallurgical basis to go along with the knowledge of stereological principals. Finally, the choice of data pattern recognition techniques is critical in establishing the necessary correlations.

Classical hand measurements were made on the same microstructures and will be compared to the computer output.

QUANTITATIVE CHARACTERIZATION OF MICROSTRUCTURE

Dr. James H. Steele, Jr.
Armco Steel Corporation

The stereological problem of defining and measuring a set of geometric and statistical parameters which will provide quantitative characterization of a three dimensional microstructure will be discussed. The extent of characterization that can be obtained by simple manual counting measurements will be described along with the equivalent parameters that are measured by automated image analyzing systems. Statistical problems and the complexities involved in obtaining more complete microstructural characterization, such as homogeneity or size distribution, will be illustrated. Several problems associated with the quantitative correlation of microstructural parameters with properties will also be discussed.

NONMETALLIC ASSESSMENT IN AEROSPACE ALLOYS

Don A. Nail
Cameron Iron Works, Incorporated
Houston, Texas

The influence of exogenous nonmetallics in steels and exogenous and indigenous nonmetallics in high temperature alloy systems is briefly reviewed with examples of effects on selected mechanical properties.

Nonmetallic rating systems based on planar light optical examination (e.g., E45 procedure for steels) are briefly assessed in terms of utility and limitations.

Certain advantages of nonplanar methods are illustrated by SEM assessments of nonmetallic content, continuity and distribution in high temperature alloys and steels on fractures produced at selected strain rates and test temperatures.

OBSERVATIONS ON PREPARATION OF SPECIMENS FOR QUANTITATIVE MEASUREMENT OF INCLUSION CONTENT

George A. Moore
Charles H. Brady
National Bureau of Standards

Attempts to establish a reliable practice for quantitative measurement of inclusions have been seriously handicapped by inability to reasonably duplicate results after repolishing a specimen. When the area threshold of a QTM is objectively set so that an electronic change of resolution does not change the reading, the bias error can be reduced to 0.01% absolute or 1% of the reading. The mean of 12,000 measurements on 10 specimens changed by 27.5% on repolishing the set, although a confidence limit of about 4% was expected statistically. Visibly imperfect specimens still acceptable for chart comparison rating were an order of magnitude more variable.

Surface imperfections which alter the QTM measurements; but are not seen in normal illumination; are clearly revealed under DIC (Nomarski) examination. DIC micrographs show that inclusions are fragmented at grinding levels down to 600 grit, with some fragments broken away. Normal polishing smooths but does not flatten this damaged surface, generally showing the inclusions too large at first, but in the end removing many of the fragments and showing the inclusion area much to small. True flat grinding with several grades of diamond down to 1 μm is necessary to generate an undamaged plane surface in which the inclusions are shown true size. This operation must remove much more metal than polishing and thus will require longer time. Use of mechanized polishing equipment normally will be necessary.

Neither the fiber mats nor assorted polishing cloths presently offered accomplish the desired fine grinding. Grinding on paper has been successful manually. Fiber mats bonded and partially filled with a soft plastic appear to be indicated. A large variety of felt mats loaded with rubber have been made and all tested yielded a grinding operation. A highly satisfactory mat is made by first saturating billiard cloth with a dilute true solution of agressively tacky rubber in an amount to add 10-12 wt. % dry rubber. The dried mat is hot pressed to weld the fibers. The front and back are then successively loaded with a diluted emulsion of non-tacky rubber (latex) in amounts to leave the desired porosity at the front and nearly fill the back. The finally dried mat is again hot pressed and air cured until non-tacky before use. Such laps are quite wear-resistant and are expected to have a service life in excess of 40 hours.

PROPERTIES OF NEW ALUMINUM ALLOY 3008

Dr. Juergen Althoff
Dr. Hansjürgen Hauck
VDM Aluminium GmbH, Frankfurt, W. Germany

The new aluminum-manganese alloy 3008 has been setting new standards combining excellent heat resistance, good deep drawing properties, high corrosion resistance and superior brazing and porcelain enameling properties. Application of 3008 may help to save energy and material.
Examples :

- Porcelain enameled parts, e.g. cookware, retain a yield strength of 100 N/mm^2 (14.5 Ksi) after firing at 560° C (1040° F); in comparison with conventional alloy 3003 this means considerable improvement of buckling resistance or the possibility of gauge reductions. Furthermore, firing temperatures of up to 1100° F may be applied.
- Brazed heat exchangers with fins from 3008 may be run with 20 - 30 % higher pressure.
- Automobile exhaust mufflers made from 3008 save weight and yield longer life.

USING THE SCANNING ELECTRON MICROSCOPE AND X-RAY ENERGY SPECTROMETER IN A PRODUCTION LABORATORY

Bobby Garner
Chung-Chu Wan

The Scanning Electron Microscope (SEM) and X-ray Energy Spectrometer (XES) are powerful research tools. However, they can be effectively used to study metallic material in a production oriented situation. Conventional light microscopy is used first to establish overall material properties then the SEM and XES are focused on the unique characteristics to be studied. Five case histories are presented. A small gray iron casting, a two-pound sintered metal part, porcelain enamel defect, fractured fastener, and a high carbon steel stamping.

MALLEABLE AND NODULAR IRON--AN EVALUATION

Hans J. Heine
Technical Editor, Foundry Management & Technology
Penton/IPC Inc., Cleveland

By comparing significant properties it can be shown that both malleable and nodular iron play important roles in casting design considerations. Nodular iron embodies one of four significant design properties: Ferritic nodular iron has a higher yield strength than ferritic malleable iron. With respect to other properties, ferritic malleable iron is equal to, or outranks, ferritic nodular iron. In some cases pearlitic malleable iron can be substituted for nodular iron and vice versa.

Economics between the two materials are in a constant state of flux as a function of manufacturing processes, influencing choice of material of construction. Favorable and less desirable characteristic of both materials are examined and practical examples from industrial applicatons will be discussed. It is concluded that, as additional advanced process techniques are developed, differences between malleable iron and nodular iron will undoubtedly become less and less pronounced and may ultimately disappear altogether.

MICROSTRUCTURES AND PROPERTIES OF WIRE INOCULATED CAST IRONS

S. David Sanders
Baltasar R. Weiss
John R. Nieman
All Associated With Caterpillar Tractor Co.

Mold and stream inoculation techniques are being used more widely by the foundry industry to control chill and graphite morphology in cast irons. Development work has been underway at the Caterpillar Tractor Co. on a process that feeds an inoculant-core wire into the downsprue of a mold during the pouring operation. The effectiveness of this inoculation process has been evaluated with the aid of a test casting that consists of a series of different thickness plates, tensile bars and locations for obtaining cooling curves. Results were determined for the effect of this late inoculation event on the microstructures, hardnesses, and tensile strengths of gray and nodular irons. Comparisons were made between ladle and wire inoculated castings.

Evaluation of cooling curves, microstructures, cell counts, and chill depths for gray iron indicated that wire inoculation was superior to ladle inoculation. This increase in inoculation effectiveness was true even though the inoculation additions by the wire were about 1/10 of that added to the ladle. Hardnesses and tensile strengths of the irons were similar. Results obtained for nodular iron indicated that a wire inoculation addition of 0.06 percent eliminated chill carbides from nodular iron produced by a NiMg treatment.

SPECIFICATION FOR NODULAR IRON CASTINGS - A COOPERATIVE APPROACH BY MATERIALS ENGINEERING AND MANUFACTURING

D. A. Duszak
International Harvester Company
Hinsdale, Illinois
and
Jon L. Dossett
Lindberg Heat Treating Company
Melrose Park, Illinois

Often engineering materials specifications are developed based on limited data or derived from previous or existing specifications. This approach does not generally consider the actual manufacturing capability for production of the material.

The subject paper shows how manufacturing capability studies and engineering data were used in the development of a new nodular iron material specification at International Harvester. The manufacturing capability study data was used to establish process and quality control procedures that assure consistent casting property conformance to the new specification.

PROGRESS IN THE USE OF COMPACTED GRAPHITE CAST IRONS FOR ENGINEERING APPLICATIONS

M. J. Lalich
S. J. LaPresta

Foote Mineral Company
Exton, PA 19341

The structure and properties of compacted graphite cast irons (frequently referred to as vermicular iron) are generally considered to be intermediate to those of gray and ductile cast irons. The unique combination of properties of compacted graphite cast irons, however, offers a number of significant advantages over both gray and ductile cast irons.

Need for the properties of compacted graphite cast irons, coupled with the advent of a single addition alloy which makes commercial production of these irons practical, has led to a surge in interest in their development.

In the present paper the structure and properties of compacted graphite cast irons are reviewed. Recent attempts to establish commercially viable manufacturing processes, which have resulted in limited commercial production of compacted graphite cast irons, are also discussed, along with current and potential applications of the irons.

CONTINUOUS CAST IRON BARS OFFER COMPONENT DESIGN OPTIONS

H. L. Coolidge
Wells Manufacturing Company
Woodstock, Illinois

Continuous cast ferrous bar stock offers component design options for production-scale applications. The production techniques produce a material with metallographic structure, mechanical properties, and casting soundness which are distinctive among cast irons. The application of these properties together with a large selection of alloys, sizes and shapes allows the design engineer another avenue for producing a quality component.

THE PROJECTED EFFECT OF CONTINUOUS CASTING ON ENERGY CONSERVATION IN THE UNITED STATES STEEL INDUSTRY

John R. Stubbles
Youngstown Sheet and Tube Company
Youngstown, Ohio

The role of the continuous casting process in the energy conservation programs of the U. S. steel industry is discussed for various scenarios. After analyzing energy requirements in the process itself, the potential energy savings relative to conventional ingot production are illustrated for integrated plants and mini-mills. There are options for the industry as to how the savings can be handled. These are explored by discussing the projected growth of continuous casting and its impact on scrap, hot metal and critical energy resources.

ENERGY CONSERVATION IN MELTING, HOLDING AND CASTING ALUMINUM

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Batch Melting Furnaces are used by the aluminum industry to remelt scrap, and a mixture of scrap and ingot (primary aluminum). Molten metal is then transferred to holding furnaces, cast and later fabricated.

This paper discusses the energy consumed by the aluminum industry for the melting and holding operation, and the potential fuel savings using existing technology, such as optimum firing rates, air fuel ratio control, furnace pressure control, and optimum operating practices. Specific devices for saving energy are discussed. Emphasis will be on systems in current use or the development stage, such as heat recuperation for preheating combustion air, air dampers for pressure control and methods for determining optimum firing rates.

ENERGY CONSERVATION IN PRODUCTION OF BRICK AND REFRACTORIES

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The shortage and high cost of natural gas, the most popular fuel for firing structural clay and refractory products, has perpetuated a crash program aimed at conservation and conversion to alternate fuels. Fuel cost, once considered a small part of the total production cost, is now a significant and increasing operating cost. Shortages caused many plants to curtail operations completely or limit production during the most recent winter.

Three basic areas are the focus for coping with the energy challenge, i.e. combustion control, insulation and reclaiming waste heat. Combustion control utilizes high velocity burner arrangements to heat the product uniformly quicker to shorten firing cycles thus reducing total fuel requirements. Insulation, particularly new refractory fibers has reduced heat storage in kiln walls and resulted in faster firing. Waste heat utilized for drying, space heating and even the generation of power has proven to be one of the best ways to stretch the energy dollar.

Along with conservation, there is a definite conversion to coal firing taking place. Several direct firing systems are now in use in the industry.

COMPUTER-AIDED MATERIALS CHARACTERIZATION AND SELECTION

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Computers have figured prominently in the development of improved approaches to assuring the mechanical reliability of components and structures. Applications in the materials area include automation of mechanical testing and analysis procedures for generating materials properties and computer based property data storage-retrieval systems. Property information of this type provides a key input into modern structural analysis and life prediction programs, which may be used to evaluate component performance in service situations. Such design tools represent the basis for the selection of materials to achieve desired performance levels.

Examples of computer applications in these areas are presented to demonstrate their current level of development and help identify directions for further work. Then a conceptual scheme os a considerably more integrated computer-based package is presented to illustrate the potential for increasing the efficiency of these design tools.

CHRYSLER'S COMPUTERIZED STEEL SELECTION SYSTEM

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Chrysler's computerized steel selector is an interactive system which allows engineers of all disciplines to quickly obtain accurate information on hypo-eutectoid (low carbon) steels. The system currently predicts hot rolled and spherodized mechanical properties, hardenability, quenched and tempered properties and material cost.

Subroutines are being developed to predict hyper-eutectoid (high carbon) hardenability and carburized hardenability in addition to calculating manufacturing cost as a function of the specific processes involved.

All of these subroutines will then be combined in a master program for optimum analysis. With this, a component in its concept stage can quickly be evaluated on the basis of its critical design requirements as a function of minimum material and processing costs.

DEVELOPMENT OF A MULTI-TUBULAR SPAR COMPOSITE MAIN ROTOR BLADE

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Hughes Helicopters, Division of Summa Corporation

The Multi-Tubular Spar (MTS) composite main rotor blade was developed by Hughes Helicopters for the Eustis Directorate, USAAMRDL, in a 2.5 year program that advanced the wet filament winding, co-cure manufacturing process. The MTS Blade was designed to replace the AH-1G helicopter production metal blade (in pairs), and to have a 3600 hour fatigue life, ballistic tolerance against the 23 milimeter threat, low radar cross-section, and erosion and lightning protection. Laboratory and flight test showed it to meet all requirements. Estimates indicate production MTS blade costs significantly lower than those of current metal blades.

SOME THOUGHTS ON DESIGN PHILOSOPHY FOR ADVANCED COMPOSITE MATERIALS

Leslie W. Lassiter, Lockheed-Georgia Company

Achievement of the full production potential of advanced composite materials has, from the start, been strongly dependent upon cost considerations. Some cost-effective applications have been demonstrated, but really widespread usage has not yet occurred. That breakthrough appears to be awaiting further reduction in basic material prices.

This paper suggests that there are elements of design philosophy which, when diligently practiced, may hasten cost-effective applications. For example, the finished part is likely to be less expensive if the design objective is to produce a hybrid part with just enough graphite or boron added to meet rigidity requirements - than is one designed in graphite and then converted to a hybrid. The least possible amount of advanced composite should be the prime objective.

Most studies confirm that subassembly costs are significantly improved with composites in lieu of metals. The author suggests that a fairly wide spectrum of technologies exists for achieving minimization of part count, and that close attention to that aspect of the design usually pays off rather well.

In some applications, an even more powerful means to cost-competitiveness lies in part standardization, or commonality of a detail so as to be useful in multiple places within the particular structure. Using the example of a transport fuselage, commonality benefits and penalties are examined in some detail. In such a structure, quite a high degree of commonality is achievable, and the cost-saving potential is shown to be quite high.

DEVELOPMENT OF HYBRID WING CONCEPTS FOR THE F-16

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Vought conducted a design study program to develop three hybrid composite/metal preliminary designs for the F-16 wing box demonstration article. The objective was to obtain cost effective composite/metal structure with reduced weight compared to the baseline F-16 wing construction. The three design concepts resulting from this study involved aluminum material in the upper skins and substructure. The concepts for the lower skin assemblies utilize graphite composite material and make use of imbedded or bonded spar caps to eliminate fasteners penetrating the skin. Projected cost savings up to 20% and projected weight savings up to 16% have been described.

ADVANCED METALLIC BOX BEAM PROGRAM

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Four advanced concepts for future fighter/attack wing structure were demonstrated in the design and fabrication of a series of six foot long single cell box beams. These concepts include various advanced structural technologies such as bonded aluminum laminated skins, integral sine wave formed spars, multi-material systems, all-bonded assemblies and rivet bonded assemblies. The fabricated articles indicate cost savings on the order of 10 to 15% and weight savings up to 20% compared to baseline A-7 wing data. Fatigue testing of the box beams has shown that durability can be improved by a factor of 2.5 over conventional riveted construction.

BONDING PRIMARY AIRCRAFT STRUCTURES

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Presented are the program results which will justify the use of an adhesive (modified epoxy) for joining together primary aircraft structural parts. The history and current service experience are reviewed. To date the durability of bonded joints has been very poor. The test results for the surface treatment investigation are presented to show why the new phosphoric acid anodize has been selected as the most durable. Similarily, the PABST test program results for adhesive selection are presented. American Cyanamid adhesive FM-73 (with a mat carrier) and including primer BR-127 proved to be the most durable and moisture-resistant of the four adhesives tested. Presented next are the design requirements used for designing the 42-foot, full-scale demonstration component. This test section is a realistic section of the forward fuselage of the YC-15 (AMST) airplane. All of the various bonded joint details are shown. Finally presented is the current environmental test program that is being conducted. These include the results from long-term test specimens placed on an ocean beach test site 19 months previously.

*PABST = Primary Adhesively Bonded Structure Technology

THE INFLUENCE OF THICKNESS AND ROLLING RATIO ON THE INCLUSION BEHAVIOR IN PLATE STEELS

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The effect of various advanced steelmaking techniques on the resulting non-metallic inclusions and mechanical properties of plate steels has been investigated in previous publications. In this work two additional variables are examined, the plate thickness and rolling ratio, and their influence on the previously reported results is presented. Conventional practice, calcium treated and electroslag remelted aluminum-killed A516 carbon steels are investigated in plate thickness from 2 - 15 inches (51 - 381 mm) and with rolling ratios from 1:1 to 10:1. A total of 11 production plates are evaluated. The primary emphasis is made in comparing the conventional to the calcium treated steels. Some electroslag remelted information is also presented.

The inclusion structure of each of the steels is reported via photomicrographs of inclusions in the 3 principal metallographic cross-sections relative to the rolling direction. In addition quantitative image analysis is used to quantify the inclusion structures in each of these cross-sections. The Charpy-V-notch and dynamic tear upper shelf energies and tensile percent reduction of area are used to compare the properties of the investigated steels.

The calcium treated steels were found to be superior to the conventional practice steels in all thicknesses and for all rolling ratios. In particular, there was very little anisotropy found in the calcium treated steels even with a rolling ratio of 10:1. The reasons for the improved toughness, ductility and isotropy of the calcium treated steels are the lowering of the overall sulfur level, the prevention of the development of Type II MnS and alumina galaxies typical of conventional steels and the calcium modification of the remaining inclusions. The modified inclusions are hard at hot rolling temperatures and thus do not elongate. The electroslag remelted steels are still found to be the best quality because of having generally smaller inclusions than either of the other steelmaking techniques. Correlations between the inclusion sizes and the toughness and ductility properties are determined and compared to previous A533B results.

METALLOGRAPHIC METHOD FOR MEASUREMENT OF RETAINED AUSTENITE

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The increasing demand for control and even certification of the amount of retained austenite in heat treated steels required that a relatively simple and rapid procedure for measurement be available. Analysis by X-ray diffraction, although considered a most accurate method by many, has limitations. Also, the equipment and operating personnel are available to few heat treaters or even manufacturing plants. The method of this paper was developed within the limits of talent and equipment available to most heat treating installations. A cross section of the workpiece or adequate test bar is polished by careful but not extensive mechanical and electrolytic techniques, to prevent mechanical deformation of the surface. The method is based on the selective displacement of copper ions from a dilute aqueous solution by the martensite phase, but not the austenite. The selectivity is explained as a function of the greater magnitude or unbalance of stresses in the martensite as compared to those in the austenite. The thin copper deposit is partially converted to sulfide in another aqueous solution to increase contrast for ease of counting or comparison with a standard chart. X-ray diffraction and hardness measurements confirmed the validity of the method. The compositions of polishing electrolyte, and aqueous solutions and nominal electrical and time conditions for the method, are detailed. Microphotographs and a standard illustrating various quantities of austenite are included. The paper discusses limitations of X-ray techniques for analysis of surfaces as a consequence of surface contamination during heat treatment and also the limited depth of X-ray penetration.

SOLIDIFICATION OF CAST IRON AND RELATED MODEL SYSTEMS

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Recent work has shown that the morphology of graphite in cast irons is controlled by two main factors. 1) The solidification rate controls the scale of the microstructure (nodule size and inter-flake spacing) and may effect a transition from a flake shape to a rod shape. 2) The change from a flake shape to nodular is controlled by the graphite-liquid interfacial chemistry.

In the present work the model for graphite growth based on interfacial chemistry is extended to consider solidification mode and ingot macrostructure. In particular the relationship between divorced or cooperative solidification, and the columnar to equiaxed transition to graphite morphology will be discussed.

SIGNIFICANT NEW DEVELOPMENTS IN PLASTICS FOR APPLIANCE APPLICATIONS

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With the projection that an estimated 1.5 billion pounds of plastics will be used in appliance applications this year, alone, there is no doubt that plastics are satisfying appliance manufacturer's tests of price and performance. Beyond price and performance, appliance design engineers, like other users of plastics, are concerned about how plastics will fare as a result of recent developments regarding energy, materials availability, and government regulation. The paper will survey these developments, as well as some of the newest applications for plastics that continue to keep costs down and performance up in appliances.

The following subjects will be developed with supporting data and appropriate examples:

(1) Plastics have an enviable future among the competing materials used in appliances, in regard to the amount of energy they require in both production and end-use manufacturing. Because plastics are less energy-intensive than die-cast metals, for example, their price and availability should be relatively stable in the next ten years.

(2) Plastics are meeting today's government safety regulations on flammability and food and water contact. The lemming-like scurry to produce all plastics for household applications with V-0 UL ratings has begun to settle. Now, we see the pendulum swinging back to an equilibrium point of common sense -- one that emphasizes safety, but not at the expense of critical performance properties. And many more plastics are qualifying for FDA approval in food and potable water contact environments.

(3) A profound shakeout period continues, in which types of plastics are finding their own best use levels with respect to cost and performance. The demand for less expensive plastics such as polypropylene, ABS and the styrenes should more than triple in the next ten years as they qualify for applications that were perhaps over-designed in higher performance plastics.

(4) Engineering plastics, such as nylon, acetal and polycarbonate, will continue their more steady increase in usage. They will find increasing roles to play in electric motor parts, in gears and assemblies, and in applications requiring high heat and impact resistance. Some of the newest appliances on the market today demonstrate how appropriate selection of plastics is leading to innovative product design.

The paper will conclude with a summary of the major trends which major appliance manufacturers see in regard to their use of plastics in the next ten years.

ADVANTAGES OF FILLED POLYPROPYLENE FOR APPLIANCE APPLICATIONS

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Dramatic increases are forecast for the use of polypropylene. Increasing technical demands accompany the increasing market demands for polypropylene. New product development efforts have been directed toward meeting a wider range of structural and environmental requirements with polypropylene based products.

Recent developments include the incorporation of mica to achieve higher stiffness than is traditionally accomplished with talc filler. Mixtures of mica and talc as well as mica and glass fiber provide a combination of good physicals and economics. Surface treated mica matches some of the distinguishing characteristics of glass reinforced polypropylene.

Calcium carbonate is one of the very few fillers that simultaneously increases stiffness and impact resistance of polypropylene. Outstanding low temperature impact resistance can also be achieved with calcium carbonate by the use of special matrix technology.

Glass reinforcement has made polypropylene of value for many parts where high stress levels, temperatures and cyclic loads would otherwise prohibit its use. Chemical coupling and the use of copolymer further increase its structural capabilities. Continuous glass filament in sheets of polypropylene can be stamped into parts on conventional metal stamping equipment.

Examples of new developments which provide added value to the use polypropylene include a direct platable formulation which can be electroplated without pretreatment and using metal plating procedures.

Filled and reinforced polypropylene are of particular interest for structural foam parts where light weight and stiffness are the major engineering requirements.

Composite structures of metals or other plastics with polypropylene combine the outstanding characteristics of each material and provides new opportunities for the use of polypropylene.

INNOVATIONS WITH PLASTICS IN SMALL APPLIANCES

F. S. Pang/K. R. Davis
General Electric Co.

The small appliance business is traditionally a fast moving, short cycle, highly competitive industry. A typical small appliance product cycle curve is presented to illustrate the dynamic nature of these products. General Electric has a comprehensive line which involves many different products. They can be divided into five major groups - food preparation products, personal care, garment care, home security and time and information products. The nature of this business and opportunities for plastics innovations will be discussed. Two recent new products and the innovative utilizations of plastic materials are described in detail. Namely there are the "Light and Easy" plastic iron with drop resistance, cool to touch, colorful and light weight and the "Coffee Corner" drip coffeemaker with its unique one piece construction and attached coffee grind dispenser.

A UNIFIED PREDICTIVE TECHNIQUE FOR THE FATIGUE RESISTANCE OF CAST FERROUS-BASED METALS AND HIGH HARDNESS WROUGHT STEELS

by

M. R. Mitchell
Department of Theoretical and Applied Mechanics

A technique which treats the free graphite in gray and nodular cast iron, gas pores and microshrinkage cavities in cast steels and inclusions in wrought, high hardness steels as notches in a steel matrix results in quantitative predictions of the fatigue resistance of these ferrous-based systems.

FCP Report No. 23

A Report of the
FRACTURE CONTROL PROGRAM

College of Engineering, University of Illinois
Urbana, Illinois 61801
September, 1976

FATIGUE PERFORMANCE OF TRUCK FRAME SIDERAILS

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A fatigue evaluation of two different steels with different yield strengths is presented. Both of these materials, a high strength low alloy steel with a yield of 80 ksi and a quenched and tempered steel with a yield exceeding 110 ksi, are used for truck frame siderails.

Data are presented from tests on full size siderails, notched plates and smooth specimens. Similar tests were conducted for each material. Although there is a large difference in the yield strengths of the two steels, smooth specimen data showed little difference in their fatigue resistance. This same trend was also observed for the notched plates and full size siderails.

DESIGNER'S BASIC GUIDE TO WELDED STRUCTURE PERFORMANCE

by

Victor A. Lucas
Caterpillar Tractor Company

The purpose of this paper is to provide designers with the basic ideas in evaluating the general metallurgical and mechanical conditions affecting the performance of welded structures. The effects of design and fabricating details are shown to ultimately determine performance, especially in the fatigue loadings induced in ground vehicles. Considerations in static, fatigue, and impact loadings are analyzed for each of these conditions. Factors considered are: base metal, weld metal, weld heat-affected zone, joint design, fit-up, residual stress, weld quality, and welding costs.

The discussion is rather general and basic with the primary intent being to provide engineers new to weldment design with a foundation of information from which to build.

SAE Paper No. 770528
400 Commonwealth Dr.
Warrendale, Pa. 15096

COTTON PICKER UNIT DESIGN FOR OPTIMUM MATERIAL UTILIZATION

by

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Several critical cotton picker row unit components were redesigned by using improved structures and materials. The goal was to provide improved function, reduce loading, increase machine productivity, and reduce cost.

Each component was evaluated as its function related to all other parts. Computer optimization of shape and forces was performed. These studies were verified by experimental stress and life tests.

This program resulted in a cotton picker that would operate at 10 percent faster field speeds, harvest higher quality cotton, and sell at a lower price.

MATERIALS PROBLEMS IN THE PRODUCTION OF FOSSIL ENERGY BY ADVANCED TECHNOLOGIES

T. B. Cox and H. E. Frankel

Energy Research and Development Administration

Second generation processes for producing gaseous and liquid fuels from coal beyond 1985 together with MHD and certain advanced concepts for the direct utilization of coal are constrained by some obvious materials problems. Our knowledge of the behavior of state-of-the-art materials in many of these advanced coal technologies is limited and must be expanded if reliable and cost-effective operation of the systems is to be accomplished.

In several areas, substantial efforts in alloy development should be launched to avoid an overdependence on scarce and strategically-limited minerals, to reduce the cost of suitable alloys, and to provide for improved performance and reliability. Welding technology and the non-destructive evaluation of welds must be advanced for producing large, field-erected pressure vessels for coal conversion plants.

Fabrication technology for very large rotors for the next generation of turbines and generators must be improved to realize the advantages of economy of scale. The concept of coal-fired MHD awaits advances in materials before realizing its potential.

The paper will explore these problem areas and offer suggestions for research to address them.

NEAR TERM MATERIALS PROBLEMS IN THE PRODUCTION OF FOSSIL ENERGY

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C F Braun & Co

The most likely alternative to using oil and gas for energy production prior to 1985 is conversion of coal by gasification, liquefaction, and direct combustion. The present commercial technology for coal conversion dates back to the late 1930's. There is now a major effort underway to improve each process by application of contemporary engineering know-how, including advanced materials technology, to make them more economically attractive.

Materials problems for each of the three modes of conversion have been considered in four general problem areas.

1) High temperature corrosion
2) Erosion
3) Mechanical properties of materials
4) Refractories and ceramics

The underyling problems in these areas have been reviewed and alternate solutions discussed. Some of the key research and development studies in progress have been referenced.

The conclusion is that materials of construction for major equipment items such as pressure vessels, piping, and machinery will not change significantly in the near term from present selections. However, for smaller critical components, advantage will be taken of special alloys and ceramics that are just finding their way into use.

SOLAR ENERGY AND THE MATERIALS INDUSTRY

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Despite numerous studies of industrial energy use, information has been lacking on the specific characterization of process heat. This paper summarizes the results of a survey of the quantities, temperatures, energy forms, energy sources, and costs of the process heat requirements in 20 industries. Electrical energy, space heat, and energy used for cooling are specifically excluded. A data base is built up from process-specific analysis of each industry. These basic data are then extrapolated to include components of each industry not specifically analyzed, and projected, on the basis of specific industry growth rates, to the years 1985 to 2000.

On the basis of this characterization of industrial process heat, a number of state-of-the-art process heat applications of solar thermal energy systems are identified. A summary is given of the expected performance of conceptual solar thermal systems using different collector types to supply various process heat requirements in different regions of the country. The impact of performance variations on the cost of delivered process heat is reviewed.

The results of the process heat survey indicate the research and development needed to enhance the effectiveness of solar thermal technology in industrial applications. The materials requirements for the improvement of solar thermal systems in industry are outlined.

MATERIALS INNOVATIONS IN THE DEVELOPMENT OF ENERGY STORAGE SYSTEMS

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The principal function of energy storage technology in the energy program is to permit more efficient and more economic use of intermittent energy sources, e.g., solar, wind, and off-peak electrical power, for applications in which there is a mismatch in timing of energy supply and demand. Another important function of energy storage technology is to permit more extensive use of waste heat through efficient heat storage and transport. As in many other parts of the energy program, the development of new and improved materials is a vital if not critical part of the energy storage R&D effort.

Examples of key projects in which significant progress has been made recently are media for thermal energy storage, hydrides and containment materials for chemical energy storage, composite materials for flywheels, high current conductors for superconducting magnetic energy storage, and a multitude of new materials for batteries and other electrochemical devices.

Special emphasis is now being given to storage components for electric and hybrid vehicles. Batteries with flywheels for regenerative braking offer attractive options for power systems and emerging opportunities for materials R&D specialists.

MATERIALS PROBLEMS AND CHALLENGES OF GEOTHERMAL ENERGY DEVELOPMENT

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Applied materials research and development is part of the geochemical engineering program in the Division of Geothermal Energy. The objective of the materials work in the Division of Geothermal Energy is to provide materials for geothermal applications and to reduce the cost of these materials where they have a significant effect on the cost of production of geothermal power. (Materials needs are defined by the heat extraction process and fluid characteristics.) These provide a focus for the specific materials R&D necessary for U.S. geothermal electric and nonelectric utilization. The program evaluates materials needs. These are required for well drilling and completion, control equipment, energy extraction and disposal equipment. Materials selection for some energy extraction equipment must consider secondary fluid corrosion characteristics (hydrogen embrittlement, stress corrosion cracking, and other failure modes associated with hydrogen or hydrocarbon instabilities) occurring at equipment operating temperatures. Additionally, the program reviews the materials test plans for the construction of large geothermal projects and demonstrations. Spinoff materials, chemistry and failure analysis information from all DGE projects are being combined with applied materials R&D results for a site-specific materials design handbook.

The materials technology required for geothermal development is an extension of that developed for other industries. The program is cooperating with various concerned sectors of industry and appropriate national technical societies for the purpose of setting testing and materials specification standards for the geothermal industry.

The DGE materials program is divided into two research and development areas as follows:

1. Borehole materials

The objective of the borehole materials area is to provide well drilling and completion materials for geothermal applications. These include well casing, drill bits, drilling muds, cements, packers, cable, seals, and instrumentation needs. The scope of these activities includes (a) definition of materials requirements, (b) evaluation of state of the art materials in

the geothermal environment, and (c) the development of new materials where they are required and can significantly reduce the cost of geothermal energy.

2. Energy extraction materials

These include geothermal electric and nonelectric applications. The objective is to provide materials for control, energy extraction, and disposal subsystems.

NEW SHEET METALS FOR VEHICLE WEIGHT REDUCTION

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The world-wide energy crisis is here! How can the automotive industry and the overall economy of this country survive? Recent White House energy policy and Federal fuel economy laws have clearly defined the need for more fuel efficient vehicles as a means of conserving energy. Fuel economy improves as vehicle weight decreases. One method of achieving weight reduction is reducing vehicle size. However, maintaining adequate vehicle size and comfort while meeting regulated fuel economy is a more desirable goal. A rational approach to weight reduction is by utilizing lightweight high strength sheet materials in an interactive weight reduction system. The application of high strength steels and aluminum alloys into automotive components to achieve cost effective weight reduction will be discussed. The economic justification in selecting different grades of material is also presented. Design and manufacturing parameters for these materials are outlined. Examples of formed parts are shown and stamping experience is discussed.

INFLUENCE OF PROCESSING ON PROPERTIES OF METALS

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Cold-formed parts are being more extensively used each year in the manufacture of automobiles, airplanes, appliances and all other mechanical devices. The mechanical design engineer at the present time obtains the properties of the material either from a handbook or from a materials engineer who in turn has access to the data. Unfortunately, the data listed in the handbooks are for the material in its original condition as a bar or plate whereas the properties that are needed for the stress analysis to be valid are the final properties of the part after it has been fabricated. The mechanical properties of the material are altered by the forming operations. But more importantly, the tensile and compressive strengths are not equal and the transverse properties are different from the longitudinal ones. In order for the engineer to design formed parts that are reliable and of minimum weight, he must be able to determine the appropriate strength at the locations and in the directions that he calculates the stresses.

This paper presents a new method of designating the strength of a material that includes the four important variables: the type of strength (yield, ultimate, etc); the sense of the strength (tensile, compressive, shear); the direction of the strength within the part; the sense of the last prior (processing) strain. Only when mechanical properties are specified in this manner will the reliability of the parts be high and their weight low.

THE PROMISE OF EUTECTICS FOR AIRCRAFT TURBINES

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Directionally solidified eutectics, a relatively new class of blade and vane materials, show promise of being used in advanced gas turbine engines. Their potential increase in use temperature capability of from 40° to 110°C (70° to 200°F) over current alloys offers engine designers opportunities to improve performance, increase component life and reduce fuel consumption.

The status of the first generation eutectics, γ/γ'-δ and NiTaC-13, is described. Their composition, structure, critical mechanical and physical properties are reviewed. NiTaC-13 has been successfully engine tested as an uncooled turbine blade in a J101 engine. γ/γ'-δ is currently undergoing extensive evaluation for use as a small solid blade in a helicopter and business jet turbine engine.

Several second generation eutectic systems, γ/γ'-α, NiTaC 3-116A, γ-β and COTAC 74, are also reviewed to the extent that their early development status permits. Particular attention is given to critical mechanical properties, current and future research directions, and potential applications. NiTaC 3-116A and γ/γ'-α have about 17-35°C (30-60°F) greater use temperature capability than the first generation eutectics and appear to have promise for advanced turbine blades. COTAC 74 and γ-β appear to have promise for turbine vane applications.

Results of recent cost-benefit analyses of eutectic turbine blades for commercial engines are discussed. Fuel savings of up to 400×10^9 liters (100 million gallons) per year have been projected from the increased temperature capability of eutectics. One of the biggest challenges to the promise of eutectics is the projected unfavorable economics. Eutectics are directionally solidified at low rates of less than 2.5 cm/hr (1 in/hr) often with low yields and resultant projected high prices. Additional development effort is required in automation, cluster casting, mold and core materials in order to fulfill the promise of eutectics for advanced aircraft turbine engines.

THERMOPLASTICS FOR HIGH PERFORMANCE AIRCRAFT

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Cost reduction is a continuing emphasis for production of aircraft. The combination of new high temperature, high strength reinforced thermoplastics and injection molding presents a new cost saving design concept to the engineer. Cost savings of up to 70% as compared to metal structure can be realized. The various steps involved in order to arrive at production applications of reinforced thermoplastics are described. Mechanical properties of some of the materials tested are presented. The data includes tension, elongation, flexural strength and bolt bearing at temperatures ranging from -65°F to +300°F. Several resins, such as polysulfone and polyethersulfone reinforced with glass fibers or graphite fibers were tested.

NEW DEVELOPMENTS IN DISPERSION STRENGTHENED P/M ALUMINUM PRODUCTS

Stephen J. Donachie
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High energy milling is used to produce fine dispersions of Al_2O_3 in aluminum powder. The fineness of the dispersion allows high strength to be obtained without using excessively high volume fractions of oxide. Three areas for application are described.

As an electrical conductor, dispersion strengthened aluminum possesses high strength and electrical conductivity combined with resistance to softening during annealing treatments. High strength is retained even after annealing treatments at 900°F.

Alloying dispersion strengthened aluminum with magnesium produces fine grained alloys which are strengthened by both the dispersoid and by solid solution strengthening. These alloys combine the strength of the 7000 series of aluminum alloys with the corrosion resistance of the 5000 series. Laboratory scale experiments hold much promise for the development of 90 ksi tensile strength alloys which are immune to stress corrosion cracking.

Higher levels of oxide dispersed in aluminum produce good elevated temperature strength. Because the strengthening dispersoid is thermally stable, there is no deterioration of properties with increasing time at temperature.

IMPROVED PERFORMANCE OF SILICON NITRIDE-BASED HIGH TEMPERATURE CERAMICS

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Work under four NASA contracts to improve Si_3N_4 based ceramics will be reviewed: (1) High temperature strength and toughness of hot pressed Si_3N_4 were improved by using high purity powder and a stabilized ZrO_2 additive, (2) Impact resistance of hot pressed Si_3N_4 was increased by the use of a crushable energy absorbing layer, (3) The oxidation resistance and strength of reaction sintered Si_3N_4 were increased by impregnating reaction sintered silicon nitride with solutions that oxidize to Al_2O_3 or ZrO_2, (4) Beta prime SiAlON compositions and sintering aids were developed for improved oxidation resistance or improved high temperature strength.

ADHESIVE BOND INSPECTION BY ULTRASONIC SPECTROSCOPY NDT

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Adhesive bond inspection by nondestructive testing (NDT) methods is an important task in the quality control of multi-layered adhesive-bonded structures and structures with components made of advanced composite materials. In this study, ultrasonic spectroscopy method has been applied successfully in characterizing the adhesive bond between metallic substrates. 10 MHZ pulsed ultrasonic signals reflected from the interfaces of ultrasonic-transmitting media in the adhesively bonded system were Fourier transformed by a PDP 11/45 digital computer. The RF signals in the time domain and the frequency spectrum from the Fourier transform were displayed and stored in the computerized system. These informations can characterize the adhesive bond conditions such as bondline thickness, surface preparation as well as the acoustical property and density of the adhesive. They can also indicate the existence of debond in the bondline. Principles of this emerging NDT technique and applications on single lap-shear specimens will be presented.

THE INTRODUCTION AND UTILIZATION OF NEW MATERIALS INTO THE CHEMICAL PROCESS INDUSTRY

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The acceptance and utilization of new materials into the Chemical Process Industry is a vital aspect of the fight to improve reliability and maintain profitable operations.

The acceptance of new materials travels a long, rough road. The physical, mechanical, metallurgical and corrosion resistant properties must be examined by potential users and the National and Governmental standards bodies. A series of testing programs move from the laboratory to the field and then to actual equipment installations, each step in turn takes another bit of precious time. Finally problems with fabrication and availability of accessories must be dealt with before a new material can make a significant impact in the Chemical plant.

LOCALIZED CORROSION OF HIGH PERFORMANCE ALLOYS

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Localized attack in the forms of pitting corrosion, crevice corrosion, corrosion under deposits, or intergranular corrosion is a major problem limiting the safe and successful use of many alloys. Field experience and failures in service have been used to define empirical limits on the temperature, pH, and chloride ion concentration for acceptable performance of materials.

Several accelerated laboratory tests were used to generate data comparable to those obtained from service applications. The potentiostatic polarization method appears to be one of the most promising in that it defines the damaging potential range where localized corrosion occurs. Also, the dependency of this potential range on temperature, pH, and Cl^- concentration can be clearly outlined. Ranking of various alloys (stainless steels, Incoloys, and HASTELLOYS) by order of their resistance to localized corrosion, using this potentiostatic method, was in accordance to their established service performances.

Finally, when considering the effects of alloying elements on the resistance of an alloy to localized corrosion (through their effects on the damaging potential range), a new direction in materials' innovation appears promising.

THE APPLICATION OF CORROSION-RESISTANT HIGH-STRENGTH LOW-ALLOY STEELS IN THE CHEMICAL INDUSTRY

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Research
U. S. Steel Corporation

Various applications for corrosion-resistant high-strength low-alloy steels in the chemical industry will be reviewed. These include the use of such steels in the bare condition for chemical plant structures, in stacks, in pollution-control equipment involving exposure to condensation corrosion and/or oxidation, and in bins, hoppers, and chutes for handling coal and coke. For each of these applications, guidelines are presented to help the user take advantage of the unique properties of corrosion-resistant high-strength low-alloy steels.

FATIGUE PROPERTIES REQUIRED FOR CHARACTERIZATION OF TRANSITION JOINT WELDMENT AND COMPOSITE MATERIAL IN SUPPORT OF ELEVATED TEMPERATURE ENERGY CONVERSION SYSTEMS*

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Piping systems in Breeder Reactor as well as Fossil Fuel plants frequently require transition joint weldments between austenitic and ferritic materials. Specifically, annealed 2 1/4 Cr-1 Mo steel may be welded with ERNiCr-3 using the hot wire automatic gas tungsten-arc process in some Breeder Reactor plants. These weldments will see elevated temperature service for periods of up to 30 years and, accordingly, prototypic weldments will require extensive mechanical property characterization. It was the objective of this effort to define the strain controlled low cycle fatigue behavior of as-deposited and stress relieved ERNiCr-3 weld metal and to develop test methods for establishing the cyclic behavior of heat-affected-zone (HAZ) material. Low cycle fatigue and cyclic stress-strain response for ERNiCr-3 were established over the temperature range of 295 to 866 K. A number of low cycle fatigue test results are reported for hourglass-shaped specimens that demonstrated that the low cycle fatigue behavior of HAZ material adjacent to the fusion line could be characterized.

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*Research sponsored by the Energy Research and Development Administration under contract with the Union Carbide Corporation.

REACTOR VESSELS FABRICATED FROM LARGE FORGINGS: METALLURGICAL CONSIDERATIONS

T. R. Mager, N. Scrimgeour, J. Caplan

Normal practice is to manufacture reactor pressure vessels from a combination of forged rings for the flanges and rolled plates or forged sections for the cylindrical shell courses. Westinghouse Nuclear Europe (WNE) evaluated the concept of utilizing a single large forging to form an integral flange-nozzle shell course. In the new design, the maximum section thickness at the quench and temper stage is 722 mm in the flange region and 528 mm in the nozzle shell course region. The proposed reactor vessel modification raises a number of metallurgical questions. These efforts were applied to code requirements, soundness of forgings, hydrogen effect, location and orientation of test specimens, through thickness properties, section thickness effects and effectiveness of quenching. The conclusion of the evaluation was that the concept of using monobloc forging for an integral flange-nozzle shell course was feasible.

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Principal Engineer, Westinghouse Nuclear Europe
Principal Engineer, Westinghouse PWRSD

USE OF ULTIMATE TENSILE STRENGTH IN CORRELATING AND PREDICTING CREEP AND CREEP-RUPTURE BEHAVIOR OF AUSTENITIC STAINLESS STEELS*

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Elevated temperature tensile and creep properties of several heats of types 304 and 316 stainless steel were used to show that the short-term ultimate tensile strength of a given heat at the creep test temperature and at a fixed strain rate can be used as an index for correlating and predicting creep and creep-rupture behavior. The short-term elevated temperature ultimate tensile strength helps to account for changes in creep properties due to test temperature as well as to heat-to-heat variations. Generalized models of time to rupture and minimum creep rate were derived in terms of stress, temperature, and ultimate tensile strength.

Ultimate tensile strength was used in a creep equation to predict the strain-time behavior of individual heats. Several possible reasons are presented for the observed relationships between the short-term ultimate tensile strength and the long-term creep properties. Design and materials engineering implications of the observed relations are also discussed.

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*Research sponsored by the Energy Research and Development Administration under contract with Union Carbide Corporation.

FACTORS AFFECTING THE ELEVATED TEMPERATURE PROPERTIES OF AUSTENITIC STAINLESS STEEL WELDS*

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In the thinner regions of a reactor pressure boundary, shielded metal-arc (SMA) and gas tungsten-arc (GTA) welds are frequently preferred. Submerged arc (SA) welding is more economical than the other two processes for welding thick sections where its inherent high deposition rate can be used. We have previously reported that the additions of 0.5% Ti, 0.042% P and 0.006% B to types 316 and 308 stainless steel gas tungsten-arc welds enhance the creep strength and ductility. We have made and tested types 316, 16-8-2, and 308 stainless steel submerged-arc welds with similar minor element additions. These additions have enhanced the creep strength and ductility. For example, a type 16-8-2 stainless steel submerged-arc weld with minor element additions, when creep-rupture tested at a temperature of 649°C (1200°F) and a stress of 138 MPa (20 ksi), ruptured after straining 31.4% in 1287 hr with a total reduction of area of 70%. Although there are few comparable data for conventional commercial 16-8-2 submerged-arc welds, this 16-8-2 with controlled residual elements is both stronger and more ductile at the test conditions than any known conventional 16-8-2 SA weld. It is significant that this wire was drawn in a commercial wire shop from a 1000-lb air-induction heat melted by a commercial steelmaker. Wire from smaller heats will be used to further refine the range of chemical composition in wire that will produce these desirable properties.

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*Research sponsored by Energy Research and Devlopment Administration under contract with Union Carbide Corporation.

DEVELOPMENT OF A FERRITIC STEEL FOR HIGH TEMPERATURE POWER PLANTS

Bhaven Chakravarti
G. C. Bodine, Jr.
C. T. Ward

This paper discusses the development of a high-strength ferritic 9 Cr Mo steel for use in high temperature power plants, where ordinarily austenitic alloys would be utilized. A ferritic material, with its a priori advantage of higher thermal diffusivity and thus thermal shock resistance, which together with the improved creep strength as developed, provide an attractive alternative to available alloys. The 9 Cr Mo alloy developed has stress intensity advantage over SS 316 up to 1100°F as calculated by the high temperature code case 1592. This was achieved without detriment to ambient temperature fracture toughness, which is better than presently used pressure vessel material. The alloy shows reduced aging and creep embrittlement indicating a stable microstructure.

PRINCIPLES OF DRAWING AND WALL-IRONING FOR THE MANUFACTURE OF TWO-PIECE CANS

Professor Dr.-Ing. Walter Panknin
c/o L. SCHULER GmbH, Goeppingen

Two-piece cans are made by drawing in several operations or the combination of drawing and wall-ironing. To find the best solution for producing a special can dimension fundamental equations and laws should be known.

Possibly faults during drawing of a cup or can are tearing of the bottom or wrinkling. The blankholder force that prevents wrinkling has to be calculated because higher forces as necessary will reduce the limiting drawing ratio. Tearing of the bottom occurs if the drawing ratio is above the limiting drawing ratio. The limiting drawing ratio is not only a function of the material but also a funktion of tool geometry, friction and diameter of the can in relation to the thickness of the material. These functions will be given in the paper so that the limiting drawing ratio can be found. Also important are the drawing force, the blank diameter for a given can, wall thicknesses in a cup etc. The forces can be calculate by the material properties, tool dimensions, friction coefficient etc. In a more simple way its possible to calculated the forces only by having the altimate tensile ,stress the drawing ratio and the limiting drawing ratio. Blank diameter and wall thickness in a cup can be found by using the equations about material flow.

Using the foundamentals also forces, maximum reduction in wall thickness, blank diameter etc. can be calculated for the wall ironing process. Those equations especially allow to find the best steps for the reduction in each wall ironing ring.

A few calculated examples will show how to work with the equations.

EFFECT OF TINPLATE SURFACE FILMS ON FABRICATION OF DRAWN-AND-IRONED CANS

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Tinplate surfaces are chemically treated in sodium dichromate solutions to achieve oxide stability (resistance to oxide growth) and lubricated with dioctyl sebacate or acetyl tributyl citrate to present abrasion and to facilitate handling. The results of bench-scale studies show that the nature of the mill-applied oil films affects the wettability of some cupping and ironing emulsions used in the manufacture of drawn-and-ironed (D&I) cans. However, this variation in wetting does not affect the amount of the coolant-lubricant deposited on the can blank, nor the lubricating efficiency of the coolant-lubricant as determined by sliding friction or cupping and ironing-load measurements.

The type of chemical-treatment film does not affect the wettability of the coolant-lubricant emulsions but does affect the wettability of the can surface with water. Therefore, if water-break tests are used to determine cleanliness of the D&I cans, the undistrubed dome area of 311-treated cans may not wet with water even though it is free of D&I cupping-and-ironing lubricants. Various aspects of these test results are discussed.

INFLUENCE OF TINPLATE VARIABLES ON THE D&I CANMAKING PROCESS

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The effects of tin coating weight, steel temper and base steel surface roughness on the wall ironing of tinplate drawn and ironed containers (D&I) have been studied. D&I containers were made from a single heat of aluminum killed steel processed to yield combinations of three tempers (T-1, T-4 and DR-9), two surface roughnesses and six tin coating weights. Load measurements were made during the three ironing stages using an instrumented punch and extensive characterization of the surface morphology was determined using a scanning electron microscope, an ion scattering spectrometer and surface roughness instruments.

The ironing loads have been observed to be relatively constant as tin coating weight is reduced until a minimum level is reached below which the ironing loads rise sharply. The surface roughness and temper of the base steel seem to have little influence on the general trends during forming or on the nature of the surfaces of the ironed cans.

The heavy deformations characteristic of ironing operations cause great changes in the surface topography of the ironed cans and the distribution of the tin coating. Much of the tin is moved from high spots on the surface into low spots on valleys. The thickness of the remaining tin on the high spots and the number of valley collection points on the surface are direct functions of the initial coating weight. It is believed that these changes in the tin distribution influence the ironing load and also affect the tendency for galling.

FLANGEABILITY TEST FOR D&I CANS

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U. S. Steel Corporation
Research Laboratory

A test was developed that provides a means of determining the influence of steel and tooling variables on the flange cracking of D&I cans. The test simulates commercial flanging by using an automatic machine with a spin-flanging tool to produce an exaggerated-width flange on a D&I can. The major variables affecting the flange cracking of D&I cans were found to be (1) steel cleanliness and processing conditions, (2) design of the spin-flanging tool, (3) surface condition of the trimmed can edge, and (4) annealing of the can edge. The test performance correlated with commercial flanging performance.

IRONING

Betzalel Avitzur
Lehigh University

Ironing is normally performed after deep drawing, which is used to produce heavy or medium gauge cups of restricted depths. An economical process of producing longer cups of thinner walls is the ironing process, where the thick wall cup is forced to pass through the gap between the mandrel and a female die. The gap is smaller than the original thickness of the cup, thus the thickness is reduced while the diameter of the cup is practically unchanged.

In this study it is shown experimentally and analytically, that there is no limit to the amount of reduction that can be accomplished through a single stepped die. Unlimited reductions have been accomplished with the proper selection of die angles, and control of differential friction. The required die angle, ram friction, die friction, and cup wall tension for any desired amount of reduction are discussed and graphically illustrated.

ALUMINUM AUTOMOTIVE CASTINGS: SOME COST-SAVING OPPORTUNITIES

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Reynolds Metals Company

Aluminum castings have much to offer the automotive industry in terms of weight reduction and energy savings. Their long-term acceptability can only be assured, however, by applying the most cost-effective combinations of material and processing. This paper will point out some "cost-saving" opportunities in two basic areas: (1) The use of hypereutectic aluminum-silicon alloys to eliminate a need for ferrous wear-surface inserts, to reduce machining capital expenditures and to reduce overall part weight; and (2) The use of two processing methods, "Pore-Free" die casting and "low-pressure" casting, to produce aluminum parts with minimum metal usage and energy consumption.

ALUMINUM VACUUM BRAZING - A PROCESS AND APPLICATIONS REVIEW

J. C. Warner
ALUMINUM COMPANY OF AMERICA

Vacuum brazing has proven commercially reliable as a manufacturing process for both small and large production runs. Long lengths of high quality joints are formed rapidly to produce many types of heat exchangers, including evaporators, oil coolers, and radiators. Reduced energy consumption and absence of fluoride disposal problems combine with the natural advantages of aluminum to offer excellent manufacturing possibilities.

Composite sheet alloys have been developed to provide optimum brazing characteristics in production vacuum conditions for a variety of applications. This paper reviews the mechanisms of brazing as they influence material and process requirements, and then shows how alloys and equipment have been developed to satisfy production needs.

ALUMINUM RIGID CONTAINER SHEET

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Alloys employed in the production of can bodies and ends must provide good manufacturing characteristics and container integrity at low metal cost. These characteristics are met in a series of Al-Mg and Al-Mg-Mn alloys developed to satisfy the specialized strength and forming requirements of the various can making applications. Temper is an integral part of these developments and most sheet is supplied in the strain-hardened H19 condition. Binary Al-Mg alloys of moderate strength are preferred for the deep-drawing of cans from coated sheet. Alloys of the Al-1Mg-1Mn type are employed in the H19 temper for cans produced by drawing and ironing. High strength Al-Mg-Mn alloys are used in the manufacture of can ends from coated sheet.

"Technological Advancements in the Cleaning/Treating of the Two-Piece Aluminum Can"

Nelson J. Newhard, Jr.
Timm L. Kelly
Amchem Products, Inc.

Just as the technology involved in the manufacture of the two-piece aluminum can has improved considerably, since the introduction of the impact-extruded can, so has the technology of cleaning and treating such containers. Etching and desmutting were the initial treatments used on the impact-extruded can followed next by high temperature cleaning and conversion coating for the drawn and ironed can. The need for energy conservation, and the advent of the EPA, soon forced the direction of such processes to include low temperature cleaning and non-chrome treating, which is the present state of the art.

CLEANING & SURFACE CONDITIONING OF WALL IRONED METAL CANS.

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All major facets of cleaning and surface conditioning are discussed.

Selection of the cleaner-conditioner agent or agents employed depends on many variables, namely: base metal, surface soil, water, lubricants, time elapsed since forming.

Mechanisms of surface cleaning: mechanical action, wetting, emulsification, solubilization, saponification, and sequestration are individually dealt with.

In preparing a metal substrate for the acceptance of an organic film, cleaning and surface conditioning are by far the most important considerations. Appearance and product acceptance are contingent on proper substrate preparation.

REQUIREMENTS OF DECORATIVE AND PROTECTIVE COATINGS FOR TWO-PIECE BEVERAGE CANS

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Requirements of protective and decorative coatings for two-piece beer and beverage cans will be reviewed. When possible, these will be related to the surface conditions of the substrate. Basic requirements for interior protective coatings include: FDA acceptability, taste and odor free, moderate to excellent flexibility, product resistance and economics. The general requirements for exterior decorative coatings include: Appearance (flow, hide, etc.), odor, color retention on bake, flexibility and economics.

THE IMPACT OF RECYCLING ON THE ENERGY CONSUMPTION OF THE ALUMINUM BEVERAGE CAN

Aluminum beverage cans can be recycled for one twentieth the amount of energy required to produce cans entirely from "new" metal. These energy savings and the inherent high value of aluminum have combined to stimulate a rapid increase in can recycling. Between 1972 and 1974, the number of reclaimed cans more than tripled from 1.2 to 4 billion. Since the market grew 60% during this period, the net recycling rate increased from 13% to 26% of the production.

An analysis of the energy consequences of scrap utilization in can manufacture, shows the direction in which further improvements will be made. Three major categories are considered:

1) Direct reclamation via recycling centers.
2) Reclamation of cans from the municipal refuse stream.
3) Improved technology for remelting recovered cans.

J. H. L. VAN LINDEN
Staff Engineer
Alcoa Laboratories

THE FUTURE OF THE METAL CAN

H. S. Cannon, Continental Can Company

The use of metal cans will continue to expand in the next 25 years. Improved materials, coatings, and forming methods will permit a drastic reduction in the weight of metal cans, and eliminate all reliance on the use of tin for steel base containers. The elimination of the tin coating will promote the direct recycling of steel cans and coupled with new techniques which will recover aluminum from municipal waste, will make metal cans the safest and lowest energy cost container system available for the preservation of food products and beverages. Improved methods of attaching ends to the body cylinders will reduce the weight of the ends and increase the overall quality of the containers.

THE EFFECT OF MELTING PRACTICE ON THE MECHANICAL PROPERTIES OF PRESSURE VESSEL STEELS

By

R. H. Elwell (1)

J. K. Strattan (2)

R. A. Swift (3)

The recent emphasis on improving the mechanical properties of steels through melting practice has been precipitated by the need to satisfy stringent design requirements. A study of the mechanical properties of pressure vessel steels, such as A203D, A516-70 and A533B, produced by conventional air melt practice, ladle flux desulfurization, and calcium treatment has shown the advantages of the new melting practices. Improvements in isotropy in the three primary directions, in all energy related properties, is due to a combination of low sulfur and shape control.

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MATERIALS FOR ADVANCED GAS-COOLED NUCLEAR REACTOR SYSTEMS

O.F. Kimball* and R.G. Frank*

Materials requirements for high temperature components of advanced gas cooled reactor systems are presented, as well as materials property information needed and materials programs that will provide this information.

A brief description of the function, purpose, and types of advanced gas-cooled nuclear reactor systems and expected design parameters and property requirements for critical components of these systems are discussed. Materials information needed for design and for safety and licensing requirements and the type and amount of information needed for qualification of materials for various safety classes are reviewed.

A review of gas reactor materials programs that will provide the required materials property information and specifically detailed discussion of the ERDA/GE advanced gas cooled nuclear reactor materials program are given. The program philosophy and the relationship of the latter program to other programs and to the total information needs for materials for very high temperature reactor systems is discussed. The type of materials data that will be generated, including the effect of reactor helium with expected levels of hydrogen, water vapor, carbon monoxide, carbon dioxide, and methane at temperatures between 1400 and 2000^{o}F for times up to 15,000 h on mechanical properties and surface and bulk structural stabilities, is covered.

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The candidate materials for advanced gas cooled nuclear reactor high temperature applications, as well as those included in the ERDA/GE materials program are presented. The available data base for these alloys are summarized and compared to the data needed. Some background for alloy modifications or alloy design for VHTR helium environment applications are presented.

This paper relates the work that is currently being carried out under the ERDA gas reactor materials programs to the total materials information needed for advanced gas-cooled nuclear reactor systems. Also indicated is the desirability of integration of international materials programs to avoid needless duplication of effort and to maximize the efficiency of production of the considerable amount of materials data required for design and licensing.

HIGH STRENGTH PRECIPITATION HARDENED ALLOY STEEL FOR HEAVY SECTION APPLICATIONS

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Middletown, Ohio
and
G. J. Murphy
Armco Steel Corporation
Houston, Texas

A new low carbon alloy steel precipitation hardened by copper can be heat treated to provide a range of attractive strength and notch toughness properties in heavy plates and forgings. The effects of age hardening time and temperature and the use of stress-relief heat treatments have been determined from about 2000 tons (1800 metric tons) of plates produced by Armco Steel Corporation. These metallurgical effects and some current applications are discussed. The properties developed would seem to be suitable for construction, pressure vessels and piping, and miscellaneous applications in processing industries.

TWO SPECIALTY STAINLESS STEELS FOR HIGH TEMPERATURE SERVICE

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Sandvik AB

SANDVIK 12R72 is an austenitic stainless steel with a nominal composition of 15 per cent chromium, 15 per cent nickel, 1.2 per cent molybdenum, and with additions of titanium and boron. It is designed to give a high creep-rupture strength at temperatures between 600 and 750°C. In this temperature range, the long-term rupture strength of 12R72 is 50 to 100 per cent higher than that of TP 316H. A prominent feature is the excellent creep ductility which has proven particularly useful under conditions of cyclic deformation at high temperature. Originally designed as steam superheater material it has later found applications in the nuclear power industry, e.g. fuel cladding in the LMFBR, and in the petrochemical industry, e.g. in the convection bank of ethylene furnaces.

SANDVIK 253MA is an austenitic 21 per cent chromium, 11 per cent nickel, high silicon steel which due to additions of nitrogen and rare earth metals offers both a high creep strength and excellent oxidation resistance over a wide temperature range viz. 700-1100°C. The combination of alloying elements provides a stable austenitic structure, a higher rupture strength and ductility than TP 310 and with similar or better oxidation resistance both at constant and varying temperature. The alloy has successfully replaced more highly alloyed grades, e.g. TP 310, Alloy 800 and Alloy 600, in process furnace components such as radiant tubes. The high corrosion resistance at elevated temperatures makes it a suitable alloy for waste heat recovery systems, e.g. recuperators.

RESEARCH REPORT ON STRENGTHENING CAST AUSTENITIC HEAT RESISTANT ALLOYS

Kenneth C. Lowstetter
Abex Corporation

The cast heat resistant alloys as designated by the Alloy Casting Institute and the ASM Metals Handbook are extensively used as engineering materials in the temperature range of 1200°F to 2200°F (649°C to 1204°C). The elevated temperature strength and other thermal properties are the critique by which design engineers select from this group of distinctive alloys. Research with the objective to improve this strength without proportional increases in cost due to the addition of expensive elements was undertaken in the Abex Research Center. The knowledge gained during this research period with relation to strengthening by the carbide precipitation mechanism has opened a new dimension in alloy strengthening without sacrificing other properties. Creep rupture strength has been increased from 38% to 80% for the HH, HK, HN and HP alloys. The short time hot tensile test ductility in the range of 1200°F to 1800°F (649°C to 982°C) has been doubled for the four previously mentioned alloys. Increased hot ductility has enhanced the welding characteristics and resistance to thermal fatigue. Resistance to oxidation and carburization have not been sacrificed. The strengthened alloys can be produced by the standard melting and handling foundry techniques. The stabilization and the strengthening are graphically compared to standard grades on a log-log scale of stress versus time. The properties of hot ductility are both discussed from graphic correlations and tabulated data.

EFFECT OF CHEMISTRY AND HEAT TREATMENT ON STAINLESS STEEL WELD OVERLAY

by

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The microstructure of a stainless weld overlay contains delta ferrite to prevent cracking during welding. Postweld heat treatment, required for the backing steel, can cause some degree of transformation of delta ferrite to a brittle phase, sigma. To avoid a weld overlay with low ductility and low crack resistance, it is necessary to control the overlay composition and the PWHT to which it is subjected. Tests are described which determine the optimum composition and the effect of various PWHT conditions. By following these guidelines, it has been possible to weld overlay heavy pressure vessels so that PWHT resulted in minimal transformation to sigma.

TiCode-12 - NEWEST TITANIUM ALLOY FOR PROCESS EQUIPMENT

L. C. Covington, TIMET, Henderson, NV

I. A. Franson, TIMET, Pittsburgh, PA

The unalloyed or "commercially pure" metal is generally used when the corrosion resistance of titanium is required. Alloys of titanium, designed specifically for corrosion resistance, have been few. The Ti-Pd alloy, introduced in 1959, has not achieved its full use potential because of cost. A new alloy, TiCode-12 (Ti-0.8Ni-0.3Mo), introduced by TIMET about three years ago, is a low cost partial replacement for Ti-Pd. New data are presented which compare the corrosion resistance of the TiCode-12 alloy to that of unalloyed titanium and Ti-Pd. Application has been made to ASTM for inclusion of the TiCode-12 alloy into titanium product specifications as Grade 12. The alloy has been applied to several environments where potential for crevice corrosion of unalloyed titanium has existed. Fabrications to date have included a number of heat exchangers, several of which have shells as well as tubes and tubesheets of the TiCode-12 alloy. As experience is gained, new uses are anticipated for this new titanium alloy for the process industries.