METALWORKING TECHNOLOGY
UPDATE
Fall 2002

NCEMT Identifies Promising Corrosion Protection Coatings for AAAV

The National Center for Excellence in Metalworking Technology (NCEMT) was tasked by the Office of Naval Research to undertake an effort to evaluate corrosion protective coatings for use on the Advanced Amphibious Assault Vehicle (AAAV)—the United States Marine Corps' newest weapon system. The AAAV is an advanced weapon system that moves three times faster and carries greater firepower than the current amphibian.

To meet the AAAV mission requirements, aluminum alloy 2519-T87 is being considered as the primary structural material for the hull. It is an Al-Cu alloy developed as a weldable material with superior ballistic penetration resistance compared to Al-Mg (5xxx series) armor alloys, such as 5083. Alloy 2519 was selected on the basis of its ballistic properties even though the high copper aluminum alloys are generally more susceptible to corrosion compared to the 5xxx series alloys. Adequate corrosion protection of these alloys is essential in order to minimize general corrosion, largely in the form of pitting. Without such protection measures, there is considerable potential for increased operating and support cost for the AAAV.

A comprehensive approach was undertaken for identifying, testing and evaluating both commercially available and specially tailored coating systems that could provide corrosion protection for the alloy. However, because the AAAV Program has an objective of using only environmentally safe and acceptable materials, candidate systems were limited to the use of nonhexavalent-chromium-containing materials. An initial matrix of 79 coating systems was evaluated in performance and quality assurance tests. Results were reviewed by a working group comprised of the NCEMT, the Naval Surface Warfare Center - Carderock Division (NSWC-CD), the AAAV Program Office, and General Dynamics Land Systems (GDLS). Systems were then downselected and modifications were suggested for improving corrosion resistance and/or wear and abrasion resistance.

Advanced Amphibious Assault Vehicle (AAAV)

The most promising coating systems and modifications were then subjected to in-depth testing designed to evaluate their combined performance in both corrosion and wear resistance, both as-applied and after field repair. A combination of tests was used consisting of accelerated corrosion, gravelometer and repair testing. The Accelerated Corrosion Test (ACT) is a cyclic corrosion test that provides a combination of conditions to accelerate metallic corrosion. The gravelometer test was conducted to evaluate the durability of selected coating systems on exposure to stone and gravel impact. The repairability test was used to determine whether coating systems that performed well in ACT could be adequately repaired in the field and whether the repair would be effective in preventing subsequent corrosion. These tests were performed individually and in combination to provide a clearer picture of how the coatings might perform in service.

Tests indicate that a successful paint/coating system for the AAAV will result from this work. The combination of ACT, gravelometer and repair tests has provided sufficient information to GDLS and the AAAV Program Office to enable them to select paint systems for evaluation on the new AAAV, now being manufactured. The test protocol was particularly useful for indicating how well surface preparations, pretreatments and primers worked in combination both to prevent corrosion and to continue providing corrosion protection after damage and repair. Presently, GDLS plans to use the two best-performing systems from the NCEMT testing on the next several vehicles being manufactured. ■

NCEMT Teams Up with Dynamic Machine Works, Owego Heat Treat, MCS Associates, and Pratt & Whitney to Develop Flowforming Processes

The NCEMT is teaming up with a number of commercial manufacturing firms in support of flowforming process development. The NCEMT has teamed with Dynamic Machine Works, Billerica, MA; Owego Heat Treat, Apalachin, NY; and MCS Associates, Greensburg, PA to develop a new process for the manufacture of the 5"/54 steel cartridge cases (see Figure 1) used by the Navy.

Figure 1. Flowformed steel cartridge casings

Traditionally these cartridge cases have been manufactured by the deep drawing process. Flowforming is being evaluated by the Navy as an alternative to the deep drawing process because the original supplier (sole source) closed. In addition, the flowforming process offers some potentially significant cost savings. The deep drawing process requires seven or more process steps with an annealing operation between each step. The flowforming process requires fewer process steps. The cost savings is a direct result of fewer process steps as well as a reduced cost for tooling and equipment.

The NCEMT was requested to support the Navy efforts in this process development. The focus was on selection of the correct material to provide the high ductility that the flowforming process requires while subjecting the part to deformations as high as 70% (*Advanced Machining Technology Handbook*, Brown, James, McGraw-Hill) per pass to shape the part. Supporting efforts were also required in the area of heat treatment. The cartridge case requires a unique combination of strength properties in different areas. Detailed process development, in combination with proper balance alloying element in the material, provided the right combination of formability and hardenability for this product/process combination. The industrial partners, Dynamic Machine Works and Owego Heat Treat, are currently manufacturing a final lot of cartridge cases for final proof test by the Navy.

In a separate effort, the NCEMT is also teaming up with Pratt & Whitney, East Hartford, CT to adapt rotary-forming processes like flowforming, shear forming and/or roll forming to the manufacturing of integral arms and flanges of gas turbine engine disks and integrally bladed rotors. Specialized integral arms and flanges of turbine disks (Figure 2) are added for attachment and mounting, structural rigidity, flow path sealing, and access. Due to their size, location, and frequency, these features disproportionately drive the cost of manufacturing the components. Currently, disks are made on closed-die forging presses (only axial die motion) in shapes that encompass the integral arm features (Figure 2). Notice that a significant amount of additional material is associated with and under the arm feature. This leads to a high buy-to-fly ratio, which is defined as the input material volume divided by the finish machined part volume. In addition, this leads to considerable post forge machining. Typically, buy-to-fly ratios for integral arm compressor disks range from 4:1-8:1 and in some cases they can be as high as 15:1. The NCEMT and P&W are employing new forming practices such as flowforming, coupled with both forge-over-finish (FoF) preform design concepts and contour following ultrasonic testing (CFUT), to significantly reduce input forging weight. ■

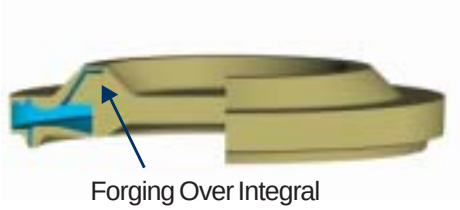


Figure 2. Typical forging disk shape to accommodate integral arm

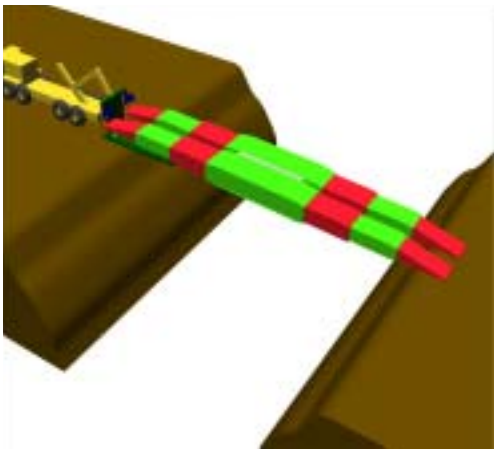
NCEMT Meets TACOM Design Requirements for Advanced Metallic Army Bridge

The U.S. Army Tank-automotive and Armaments Command (TACOM) called on the NCEMT to engineer two advanced bridge design concepts for the Advanced Metallics Army Bridge (AMAB)—a lightweight and rapidly deployable bridge. These concepts are expected to take full advantage of advanced metallics and manufacturing techniques established under the Tank-automotive Research Development and Engineering Center (TARDEC)-sponsored Combat Vehicle Research (CVR) Program.

Specific TACOM objectives for the advanced bridge included the ability to traverse gaps ranging in length from 13–24 meters while supporting wheeled and tracked vehicles up to Military Load Classification (MLC) 30 for Normal Crossings and MLC 40 for Caution Crossings. Furthermore, the bridge must be compatible with the Common Bridge Transporter (CBT) and the C-130 aircraft, which requires the weight of the bridge system to be less than 26,000 pounds (the maximum payload for the CBT). Finally, the bridge must be deployed or recovered by two soldiers within 10 minutes.

The NCEMT, with technical support from TACOM, developed two rapidly deployable bridge design concepts for the AMAB that meet all of these requirements. One bridge design concept incorporates multiple bridge sections that are coupled together during deployment to obtain the desired length. The second design accommodates the required gap by telescoping overlapping bridge sections to the desired length. The feasibility of each concept was evaluated through the use of various engineering analyses and modeling tools to assess the bridge deployment dynamics, reaction forces, deflections, and corresponding stresses resulting from a worse-case applied load. Advanced manufacturing methods, including full-length extrusions and friction stir welded joints, integrated with advanced alloys such as the 7055 (Al-Zn-Mg-Cu) and 2094 (Al-Cu-Li) aluminum alloys and the Ti-15-3 (Ti-V-Cr-Al-Sn) titanium alloy, are expected to yield lightweight bridge structures compatible with the CBT and the C-130 aircraft.

Through the design of two AMAB systems, the NCEMT has demonstrated to TACOM its ability to effectively integrate design, analysis, advanced materials and manufacturing technology. TACOM has expressed its satisfaction with the NCEMT's responsiveness, efficient utilization of funds, and engineered bridge concepts by indicating its intent to fund further work to refine one of the advanced metallic bridge designs, thus bringing the AMAB one step closer to actual deployment. ■



A rapidly deployable bridge designed by the NCEMT to traverse gaps to support tracked and wheeled Army vehicles

www.ncemt.ctc.com

NCEMT Launches Upgraded Web Site

'Enabling technology transition to the U.S. Navy/industrial base'

This upgrade:

- Enables intuitive access to content
- Organizes information for readers according to the NCEMT's capabilities, technologies and projects
- Features Engineering Knowledge Bases
- Emphasizes work in progress and success stories
- Provides improved search capability
- Offers "What's New" feature to billboard new timely information
- Facilitates new partnerships.

NCEMT Reduces Powder Injection Molding (PIM) Process Time and Cost with Computer Analysis Tools

Powder injection molding (PIM) offers a feasible and economical route to produce small intricate metal or ceramic parts. In this process, metal or ceramic powder is mixed with a polymer binder, which is then molded into shape under high pressure. After molding, the binder is removed and the remaining powder structure is sintered to its final density. Complex parts can be made to net or near-net geometries with improved mechanical properties and excellent surface finish requiring little or no machining. The greatest economic payoff is attained for parts that are difficult and costly to form and machine. Process development and control in PIM can be significant issues because processing steps are interrelated, which results in unforeseen problems in processing.

Significant progress has been made in the effort to fabricate rhenium components via powder injection molding at the NCEMT. A proprietary polymeric binder system has been developed that can impart viscous flow characteristics to the mixture that aid die filling and part uniformity. The binder system also enables complete debinding with very little oxygen, carbon, or nitrogen impurities in the resultant parts. PIM is a complex process requiring in-depth technical experience and knowledge and necessitates a planned approach to process development. In order to reduce development time, several computational tools have been established to determine the parameters for mixing, molding and sintering. The computation techniques are used in conjunction with simple experiments. These equations are implemented into Microsoft Excel™ spreadsheets and other PC programs. The calculation tool set is termed Quick Tools. This pragmatic approach to process development, computational analysis of individual process steps integrated with experiments, has reduced the time and cost of process development. Furthermore it can be done rapidly without intensive computational resources. A key feature of Quick Tools is the correlation of capillary rheometry data to actual molding temperatures and pressures. Using this data correlation, the freezing time as a function of part thickness, required vent size, and molding conditions for new parts can be determined *a priori*. Other Quick Tools' capabilities include the amount of material for mixing the feedstock, guidelines for debinding time and temperature, and selection of the sintering time and temperature. The calculation tools that have been developed have been used to assist in determining the parameters for mixing, molding and debinding for PIM of rhenium and tungsten.

A test geometry was fabricated using PIM employing the processing methods described. Quick Tools was used to determine barrel pressure profile during molding for given molding speed and temperature. The barrel pressure and feedstock temperature are calculated using a flow-network model, which correlates the capillary rheometry test data to molding pressure in the actual molding machine. Quick Tools was used to select the molding pressure and temperatures, hence reducing the time and labor needed for trial-and-error.

The calculation tools have been tested extensively in the NCEMT effort to fabricate rhenium components via PIM, and have significantly reduced the NCEMT's time in designing and optimizing PIM processing steps. Computer analysis coupled with experiments enable rapid determination of the amount of material for mixing the feedstock, design requirements for the mold, estimation of the correct molding speed and pressure, venting requirements, guidelines for debinding time and temperature, and the time and temperature for sintering. The overall result is a PIM process for rhenium that saves 25%–85% over current processes. ■

Test geometry for PIM rhenium

Program News/Events

NCEMT Exhibits at ARMTech 2002

NCEMT work in support of combat vehicle research being demonstrated to Congressman John P. Murtha

On July 31–August 2, the NCEMT was one of 60 exhibitors to participate at the fourth annual ARMTech Showcase of Industry and Technology in Armstrong County at the Belmont Arena, Kittanning, PA. U.S. Congressman John P. Murtha, PA D-12, was primarily responsible for starting the annual showcase to develop relationships between local suppliers and major defense contractors. The annual showcase has grown from initially 20 exhibitors to 60. The NCEMT had the opportunity to meet with large defense contractors such as Lockheed, Boeing and Raytheon. The NCEMT specifically showcased its work on combat vehicles, shipbuilding, and low-cost titanium. ■

NCEMT to Facilitate ShipTech 2003, January 16–17, 2003

ShipTech 2003: Shipbuilding Technologies Information Exchange, will be held at the Beau Rivage Resort & Casino in Biloxi, Mississippi, January 16–17, 2003. The Office of Naval Research - Manufacturing Technology Program (ONR-MANTECH) and the National Shipbuilding Research Program - Advanced Shipbuilding Enterprise (NSRP ASE) are again sponsoring this event, which is being facilitated by the NCEMT, a Navy MANTECH Center of Excellence.

This two-day event is intended as a forum for the domestic shipbuilding industry, its supplier base, the U.S. Navy Program Offices and the U.S. Navy-sponsored shipbuilding research programs to exchange information on shipbuilding technical developments. Advances that have been generated respectively by the National Shipbuilding Research Program and the Navy MANTECH Program through its Centers of Excellence and related shipbuilding initiatives will be featured. The overriding objective of the information exchange is to reduce total ownership costs of naval ships while enhancing the competitiveness of the domestic shipbuilding industry.

Keynote presentations will provide a high-level overview of naval shipbuilding programs, as seen by the Naval Sea Systems Command, the Office of Naval Research, and the National Shipbuilding Research Program Executive Control Board. One plenary session will examine future trends in shipbuilding technology, both in the U.S. and abroad. Technical sessions will then focus on completed and ongoing projects aimed at providing innovative materials, process technologies, and business processes to the shipbuilding community. This event will conclude with a second plenary panel discussion focussed on identifying the near-term shipyard needs for technology development, and likely sources of funding. More information can be found at www.ncemt.ctc.com. ■

NCEMT is Co-Organizing Second Annual Friction Stir Welding Conference

The second annual Friction Stir Welding (FSW) Technology for Defense Applications is scheduled for October 14–15, 2003 in Johnstown, PA. The workshop will be hosted by Concurrent Technologies Corporation (*CTC*) and again co-organized by the Navy Joining Center (NJC) and the NCEMT.

The first workshop, held May 14–15, 2002, in Columbus, OH, was attended by approximately 75 persons. This (ITAR-restricted) workshop was jointly organized by the NCEMT and the NJC, hosted by the Edison Welding Institute (EWI), and sponsored by the Navy MANTECH Program of the Office of Naval Research (ONR).

More details will follow in future issues of this newsletter. ■

Concurrent Technologies Corporation

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Concurrent Technologies Corporation (*CTC*) operates the National Center for Excellence in Metalworking Technology (NCEMT) for the U.S. Navy Manufacturing Technology (MANTECH) Program. The NCEMT serves as a national resource for developing and disseminating advanced technologies for metalworking products and processes. The NCEMT applies these technologies to solve productivity problems in support of the Navy and Department of Defense needs.

CTC is committed to assisting industry and government achieve world-class competitiveness. Through a unique concurrent engineering framework, *CTC* provides comprehensive solutions that improve our clients' product quality, productivity, and cost effectiveness. The professional staff of *CTC* has the requisite experience, knowledge, and resources to rapidly and effectively meet the diverse needs of our clients by transitioning appropriate science, technology, and management applications.

For further information about topics in this publication or about Concurrent Technologies Corporation, please contact Information Services at (814) 269-2809.

Metalworking Technology Update is published by Concurrent Technologies Corporation, 100 *CTC* Drive, Johnstown, PA 15904-1935.

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