


METALWORKING TECHNOLOGY
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NCEMT Optimizes Military's Use of Thermal Batteries with Necessary Cost Reduction and Process Improvements

The use of thermal batteries has high application for the military, especially to supply the power for sonobuoys, guided artillery and systems, missiles, and countermeasure devices. But the high cost of thermal batteries limits the number of systems that can be purchased and deployed; this is especially true for the AN/SSQ-62E and the new AN/SSQ-125 sonobuoys for the Navy, in particular, PMA-264: Airborne ASW Sensors and Special Missions. In addition, the current manufacturing process that is used to produce these thermal batteries does not meet production requirements. This affects Navy ordnance, such as PMA-259: Air-to-Air Missiles and PMA-201: Conventional Weapons, as well as other Navy, DoD, and government agencies. Because budget augmentation is not an option, the obvious solution is to reduce the purchase price and improve the manufacturing process.

Under the Advanced Thermal Battery Production Project, the NCEMT; the Navy's PMA-264 Airborne Air Surface Warfare Sensors and Special Missions Program Office; the Naval Surface Warfare Center, Carderock Division; and the battery manufacturers achieved the solution by implementing technologies that improve material utilization, press efficiency, and cell component quality, thus reducing costs, increasing production, and improving the quality of thermal batteries.

To improve the quality, increase the production rate, and improve the material utilization and the assembly of the battery cell components, the power feed system and the tool set were completely redesigned. To allow the press to operate during breaks, reduce part breakage, and improve operator safety, a cell component removal/accumulation system (see Figure 1) was designed. Moreover, to reduce the learning curve and battery rework of a new assembler, a cell component stacking system was designed. In addition, press and tooling set-up procedures were generated to achieve optimum pellet quality and throughput while reducing material waste and increasing press efficiency.

Figure 1. New cell component removal/accumulation system

These technologies were implemented into production (see Figure 2) and then demonstrated specifically on the thermal battery that is used in the Joint Direct Attack Munitions (JDAM) guidance kit for converting existing unguided, free-falling bombs into accurately guided "smart" weapons. The JDAM has recently been widely used in Afghanistan and Iraq wars.

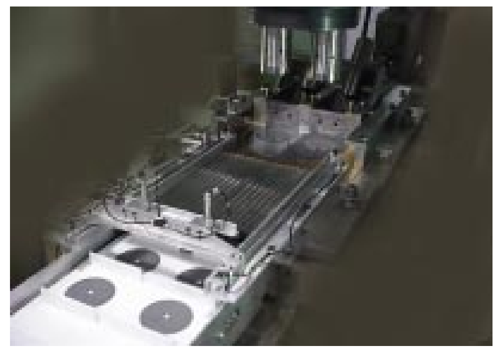

Figure 2. Redesigned powder feed shoe, tooling, wear plate, and cell component removal/accumulation system.

As a result of these process improvements, thermal battery users can potentially achieve savings of 22%. This translates into a cost avoidance of $30M over a five-year period for the sonobuoy program and $24 million over the lifetime procurement of the JDAM, Joint Stand-Off Weapon, and Paveway program. The number of combined sonobuoy batteries that could now be purchased over a 10-year period due to lower unit costs is approximately 70,000. The number of additional batteries that could be requested as a result of increased production capacity is an extra 7,400 AN/SSQ-62E or 2,900 JDAM per month. The estimated material costs savings to the thermal battery manufacturer from the process improvements potentially exceed 50% annually based on historical production levels. ■

NCEMT Paves Way for Titanium's Use in Military Applications

Recent mandates from the Pentagon to develop combat vehicles and weapons that are dramatically lighter than the current systems have caused a resurgence of interest in titanium. But despite the advantages of using titanium and its alloys for their high-performance military components when high specific strength and good resistance to corrosion is needed, titanium's high cost significantly limits its application in most military equipment. Nevertheless, the U.S. Army ground vehicle and weapons community has shown renewed interest in it. The U.S. Army Armament Research, Development, and Engineering Center (ARDEC), and the U.S. Army Tank Automotive Research, Development, and Engineering Center (TARDEC) looked to the NCEMT for a solution—a way to process titanium that makes it affordable.

The NCEMT's strategy was to develop a single-melt plasma arc melting (PAM) process for casting Ti6Al-4V into slabs that are suitable for direct rolling into armor plate. This was the genesis of the Manufacturing Technology Objective (MTO) Program that is managed by the NCEMT for ARDEC and TARDEC. RMI Titanium acted as a subcontractor. The MTO Team utilized PAM to successfully process Ti-6A1-4V titanium alloy and cast the melt into rectangular slabs that could be directly rolled into armor plate. PAM produces titanium alloys in a single melting step with a broad flexibility of raw materials, improving yield and reducing production cost. The initial strategy was to cast Ti-6Al-4V slabs using computer modeling to establish the preliminary PAM processing parameters.

Each subsequently cast slab was iteratively improved by applying the knowledge from previously cast slabs. Five 13" x 34" x 60"–132" slabs were successfully cast and rolled into various thicknesses. Some of the plate was incorporated into two demonstration articles: the Integrated Hybrid Structure and the XM777 Lightweight howitzer.

ARDEC and TARDEC consider this project a total success because it has paved the way for the use of titanium in many more military applications. ■

NCEMT Teams Up with Boeing and Northrop Grumman to Identify Metalworking Technologies for J-UCAS

The Office of Naval Research (ONR) Manufacturing Technology (MANTECH) Program has selected the Joint Unmanned Combat Air System (J-UCAS) as a key naval system in early development on which MANTECH can have a significant impact. To determine where MANTECH may best benefit the production needs of the J-UCAS Program, ONR has directed the NCEMT to perform a Metalworking Technology Concept Exploration Project that will produce viable technology initiatives and proposals that will migrate into ONR's Naval Integrated Systems Investment Strategy for FY04 and beyond.

The NCEMT, by working with the two J-UCAS industrial participants, Boeing and Northrop Grumman, will focus on identifying the enabling metalworking technologies that are needed for the production of the J-UCAS.

J-UCAS is one of two programs—one for the Navy and one for the Air Force—for which the Defense Advanced Research Projects Agency (DARPA) is currently funding the development. The primary objective of the DARPA/J-UCAS advanced technology program is to design, develop, integrate, and demonstrate the critical and enabling technologies, processes, and system attributes that are related to the J-UCAS system.

Both Boeing and Northrop Grumman have built demonstration systems. Figure 4 shows Northrop Grumman's X-47A Pegasus, J-UCAS, an unmanned air vehicle that will be used to demonstrate aerodynamic qualities that are suitable for autonomous operation from an aircraft carrier. The X-47A measures 27.9 feet long with a nearly equal wingspan of 27.8 feet. The X-47A incorporates advanced

Figure 3. Artist's rendition of Northrop Grumman's X-47A Pegasus

Figure 4. Northrop Grumman's X-47A Pegasus, J-UCAS' first flight on February 23, 2003

autonomous flight control laws to account for directional control of its tailless design. The Northrop Grumman X-47A successfully completed its planned 12-minute first flight on February 23, 2003, at Armitage Field, Naval Air Warfare Center Weapons Division China Lake.

The goal of this MANTECH project is to identify promising design concepts, and related materials and manufacturing processes, of significant interest to the industrial systems integrators. Included in these concepts and processes are those technologies that may require additional maturation prior to implementation. This project is intended to be a key step in reducing the risks associated with applying the identified technologies into the fabrication of the J-UCAS.

A successful project will produce trade studies, engineering analyses, tests, and experiments to verify the applicability of materials and manufacturing processes. This will lead to the development of several detailed project plans with projected benefits focused on enabling metalworking technologies that are applicable to aircraft designed by Boeing and/or Northrop Grumman.

Upon successful completion of this phase, it is anticipated that additional funding will be provided in FY04 and FY05 for one or more of the top identified metalworking projects. ■

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F/A-18F Super Hornet, U.S. Navy Submarine, and Destoyer USS Cushing are all courtesy of the U.S. Navy. The Pegasus photo is courtesy of Northrop Grumman Corporation.

Figures 3 and 4 are courtesy of Northrop Grumman Corporation.

NCEMT Analyzes Friction Stir Processing of Aluminum Alloy 5083 Plate for Cold Bending

Friction Stir Welding (FSW) is a solid-state welding process in which two plates are joined together by a tool rotating in the plate gap. The tool transports or stirs material from one plate to the other, and vice versa, and establishes a bond or weld. Friction stir welds in 5083 have a uniform hardness across the stir zone due to the limited aging response of this nonheat-treatable alloy. This alloy derives its strength from solid solution strengthening and cold work rather than heat treatment. During FSW, the effect of cold work is lost in the weld region, but not that of the solution strengthening, resulting in the uniform stir-zone hardness. This characteristic coupled with the high stir-zone ductility make this alloy very attractive for the fabrication of components using Friction Stir Processing (FSP). FSP is a method in which a desirable microstructure is developed in a plate by making adjacent bead-on-plate friction stir welds to generate a wide band of stir-zone material. The stir zone can have elongations as high as 30%, making this alloy a good candidate for FSP-enhanced, room-temperature cold forming. Ideally, one would like to cold bend as-received 5083 (i.e., base plate) around small-radius dies to the desired bend angle. Unfortunately, 5083 plate does not have sufficient ductility. To pave the way toward manufacturing cost reductions in structures that have angular facets, the NCEMT's Friction Stir Processing of Aluminum Alloy 5083 Plate for Cold Bending Project focused on characterizing the cold workability of friction-stir-processed 5083.

Full- and partial-penetration (50% of the plate thickness) FSW was performed on 1-inch-thick 5083 plate. Cold formability of 5083 was evaluated through 3-point bending. The table shows the entire test matrix and the results of the 3-point bending experiments. Outcomes of bending the base plate material, and full- and partial-penetration FSP material are provided. The nominal width and length of each specimen was 1.5 inches and 14 inches, respectively, while the nominal thickness is given in the table. A bending angle *q* greater than 80 degrees indicates a specimen that completely wrapped around the plunger without cracking. Note that the 1-inch-thick base plate failed during the 3-point bending test at a bend angle of 25 degrees. However, none of the full-penetration FSP specimens failed upon bending, showing a significant improvement over the base plate behavior. Partial-penetration FSP of the 1-inch plate also did not suffer failure. This was an important result, which demonstrates the possibility of additional cost savings by FSP through only a portion of the plate thickness. The results of the 3-point bending tests indicate that the cold workability of 5083 is greatly enhanced.

Detailed measurement and analysis showed that the outer fiber true strain on the bending specimen, ε (given in column 7 of the table), can be well predicted by:

$$\varepsilon = \ln\left(1 + \frac{t}{2R + t}\right)$$

where *t* is the thickness of the plate and *R* is bending roller radius. To estimate the failure strain, an upper bound, ε_U, is found to be

$$\varepsilon_U = \ln\left(\frac{100}{100 - R_a}\right)$$

based on the reduction in area R_a. In addition, a lower bound of the failure strain, ε_L, is proposed by

$$\varepsilon_L = \ln\left(1 + \frac{E}{100}\right)$$

based on the engineering elongation. They are listed in columns 4 and 5, respectively. It was found that the failure that was observed during bending coincided with the outer fiber true strain, exceeding the average failure true strain, [i.e., $(\varepsilon_U + \varepsilon_L)/2$ (column 7)].

The primary conclusions of this work are that the workability of 5083 can be significantly enhanced by FSP; properly designed, partial-penetration FSP plates can replace full-penetration FSP plates in bending applications; no macroscopic cracks were observed during 3-point bending of 1-inch 5083 plates under a punch with a radius of 0.75 inches; and simple models were able to accurately predict true strains during 3-point plate bending. ■

Vaze, Suhas P, et. al., "Friction Stir Processing of Aluminum Alloy 5083 Plate for Cold Bending," *THERMEC'2003: International Conference on Processing & Manufacturing of Advanced Materials, Conference Proceedings*, July 7-11, 2003, Leganés, Madrid, Spain.

Table. 3-point bending test matrix and results

Material	Thickness [in]	Maximum Angle q [deg]	Expected Strain to Failure [based on R_a]	Expected Strain to Failure [based on *E*]	Average Strain to Failure	Predicted Outer Fiber True Strain	Observed Failure	Cracking (Experimental)
Base Plate	0.251	83	0.377	0.148	0.263	0.134	NO	NO
	0.255	81	0.377	0.148	0.263	0.135	NO	NO
	0.500	80	0.377	0.148	0.263	0.223	NO	NO
	0.500	80	0.377	0.148	0.263	0.223	NO	NO
	1.012	25	0.377	0.148	0.263	0.339	YES	YES
	1.014	25	0.377	0.148	0.263	0.339	YES	YES
Full-Pen. FSP	0.253	85	0.503	0.262	0.382	0.138	NO	NO
	0.253	81	0.503	0.262	0.382	0.138	NO	NO
	0.500	83	0.503	0.262	0.382	0.223	NO	NO
	0.502	84	0.503	0.262	0.382	0.262	NO	NO
	0.863	80	0.503	0.262	0.382	0.311	NO	NO
	0.911	80	0.503	0.262	0.382	0.321	NO	NO
Partial-Pen. FSP	1.051	80	0.503	0.262	0.383	0.340	NO	NO
	1.049	80	0.503	0.262	0.383	0.340	NO	NO

NCEMT to Facilitate 'ShipTech 2004' Information Exchange January 27–28, 2004

ShipTech 2004: *A Shipbuilding Technologies Information Exchange* will be held at the Beau Rivage Resort & Casino in Biloxi, Mississippi, January 27–28, 2004. The event will again be cosponsored by the National Shipbuilding Research Program (NSRP), and the Office of Naval Research - Manufacturing Technology Program (ONR-MANTECH), and facilitated by the NCEMT.

The 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 technology developments. Featured will be advances that have been generated respectively by the NSRP and the Navy MANTECH Program through its Centers of Excellence and related shipbuilding initiatives. 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.

Distinguished keynote speakers will include Adrienne Gould, Deputy Director, Navy MANTECH Program, ONR, with the Welcome and Opening Remarks; Vice- Admiral Phillip M. Balisle, Commander, Naval Sea Systems Command (NAVSEA), with the NAVSEA Presentation; Lynn Torres, ONR, with the ONR Presentation; Steve Strom, Vice-President, Quality & Process Improvement, Northrop Grumman Ship Systems, with the Industry Presentation; and Rear Admiral Patrick M. Stillman, Deepwater Program Executive Officer, U.S. Coast Guard, with the Deepwater Program luncheon presentation.

Figure 5. (Left to right from *ShipTech 2003*) Moderator: Michael L. Powell, Northrop Grumman, Newport News. Panelists: David Brannon, Bender Shipbuilding & Repair; Barry Espeseth, Electric Boat Corporation; Lee G. Kvidahl, Northrop Grumman Ship Systems - Pascagoula Operations; Greg Morea, Electric Boat Corporation; and Jennifer C. Parker, Bath Iron Works

Keynote presentations will provide a high-level overview of naval shipbuilding programs as seen by NAVSEA, ONR, and the NSRP Executive Control Board. Four concurrent technical sessions will then feature completed and ongoing projects that are focused on production processes, business processes, product design and materials, and systems technologies. This event will conclude with a plenary panel discussion focused on emerging manufacturing technology requirements - Navy shipbuilding program perspectives.

For more information concerning the agenda, registration and travel arrangements, please contact Tricia Wright, Event Coordinator at *CTC* at 814-269-2567 or wright@ctcgsc.org.

Additional information and updates are available at www.ncemt.ctc.com.

(To read how ShipTech was created in 1998 and has successfully evolved since its inception, please see this publication's Summer 2003 cover article entitled "NCEMT's Growing Success with Shipbuilding Technologies Information Exchange.") ■

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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.

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