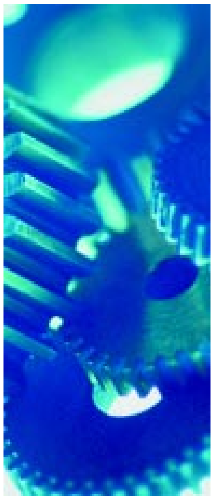



METALWORKING TECHNOLOGY

UPDATE

Winter 2002

NCEMT Develops New Ring-Rolling Design Tools for Forging Suppliers

A large number of rings and cases for aircraft jet engines are made through seamless ring rolling. In fact, in the case of the JSF F135 engine, these rings and cases account for about 12 percent of the cost of all forged components. With the current manufacturing practice in the forging industry, these ring-rolled components have unusually high buy-to-fly ratios of 5:1 to 14:1 (the buy-to-fly ratio is the ratio of raw material weight divided by weight of the finished part). The high buy-to-fly ratio stems from the fact that ring-rolled envelopes around finished part shapes are still very generous in order to minimize the inadvertent generation of scrap parts during production. With the cost of Ti-6Al-4V and IN718 (typical ring-rolled case material) not becoming any cheaper, the material costs contribute to about 62 percent of the total cost of production of these rings by ring rolling. Given this scenario, one of the affordability goals of the ongoing Forging Supplier Initiative, led by Pratt & Whitney and funded by USAF/Navy, is to develop technologies and methods to reduce the cost of seamless rolled rings by addressing new methods to reduce materials waste.

Under the leadership of Air Force/Pratt & Whitney (P&W), with the NCEMT/Concurrent Technologies Corporation (*CTC*) as co-partner, the consortium engaged Firth-Rixson Viking (FRV), a P&W supplier of rolled products, to address materials waste reduction. Current preform and die design at FRV and similar suppliers relies heavily on designer experience and expensive cut-and-try methods. FRV was tasked to adapt advanced design and simulation tools to reduce its forging envelope sizes. The forging envelopes could be made closer to the finished shapes if better methods existed to design preform and multipass die design.

To address the technical challenge, the consortium partners envisioned a technical strategy involving advancing detailed simulation using finite element analysis (FEA) as well as developing rapid tools of preform/die design under NCEMT leadership. Subsequently, MSC.Software developed a computationally efficient method to modify its 3D-FEA software (MSC.MARC) to simulate the detailed interaction between the rolls and the ring. This FEA software can now predict 3D flow of metal simulating the equivalent of 300 ring revolutions in 8–10 hours of CPU time. Shop floor experience on under-filling of dies has been duplicated through this computer tool.

To rapidly evaluate preform and die shapes and generate inputs for MSC.Software's detailed FEA analysis, the NCEMT and its two subcontractors (Anil Chaudhury of Applied Optimization and Dr. Jay Gunasekera of Ohio University) developed two rapid design tools using geometrical mapping and upper-bound elemental techniques (UBET) respectively. The geometrical mapping tool provides a unique suite of mathematical tools to generate preform and die shapes while the UBET tool is capable of carrying out approximate, yet realistic, ring-rolling simulations in a matter of minutes. Both rapid tools can be used iteratively to hone down shapes for the preform, mandrel and king roll, which will enable a leaner final forge profile to be rolled. The preform/die shapes that are suggested by the rapid tools can then be imported into the 3D-FEA tool using IGES files to predict the final resulting forge shape in greater detail. In this manner, the software tools, when extensively used along with in-house proprietary design techniques, are capable of effective process redesign to reduce material and design cycle time costs. Implementation of this technology demonstrates an incremental strategy aimed at making the U.S. forging supplier base competitive, and in turn, passes the affordability benefits to the Air Force F135 Program, which is a Joint program between the USAF, U.S. Navy and Marine Corps. ■

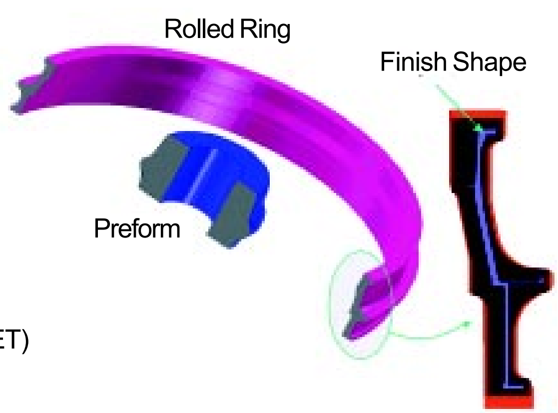
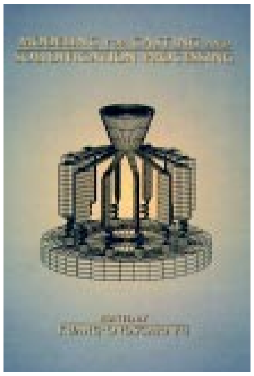


Image: Reduction in buy-to-fly ratios from rolling to leaner profiles

NCEMT Prominently Represented in Textbook



A newly published textbook entitled *Modeling for Casting and Solidification Processing* features many technical developments that are associated with the NCEMT. Half of the 26 contributors are current or former employees of *CTC*. This Marcel Dekker book, edited by Kuang-O (Oscar) Yu, covers many important theoretical and applied aspects of numerical modeling of casting, semi-solid metalworking, melting, solidification, stress analysis, defect formation, and related topics. Fundamental theory is complemented by a discussion of how this theory can be applied to solve production problems encountered by those who design, analyze, produce or use castings. Insight gained from developing and using analysis codes to solve real-world problems for the NCEMT are discussed in chapters devoted to specific shape and ingot casting methods. This includes information on the level of detail required to evaluate these processes, simplifying assumptions appropriate for a specific process or analysis, and insights that guide the user to use numerical modeling more effectively. Contributions on continuous casting, melting, spray forming, and electronic data interchange provide additional breadth and depth to the text.

As world renowned casting expert Merton C. Flemings of MIT stated, “The combination of theory and application presented in the book represents the ‘new engineering’ of casting processes. It is recommended reading for the experienced as well as for the newcomer to the metal casting field to provide tools for the present as well as an understanding of the direction and power of this new engineering.”

Many foundational developments made through NCEMT funding are described. It is with great pride that the contributing authors offer this resource as yet another method of transferring technology to the U.S. industrial base in support of MANTECH goals. ■

Titanium Plasma Arc Melting Expected to Reduce AAAV Suspension System Costs

The NCEMT Single Melt Process for Titanium Alloys project is focused on using cold hearth plasma arc melting (PAM) technology to produce hydropneumatic suspension unit (HSU) roadarms for the Advanced Amphibious Assault Vehicle (AAAV) that is currently manufactured by Ladish Company, Cudahy, Wisconsin. Unlike vacuum arc remelting (VAR), PAM of titanium can accommodate melting of loose machine turnings or other small, solid revert directly into the heat. This makes recycling simple and cost-effective, which has the potential to lower titanium ingot cost. Furthermore, production of titanium PAM ingots does not require multiple melting steps. VAR typically requires double or triple melting to ensure product quality, which makes this process more costly than PAM.

While increased use of titanium recycling provides lower cost, it also tends to increase the oxygen level of the ingot. Oxygen stabilizes the alpha phase during titanium thermomechanical processing and alters the material’s transformation behavior. In addition, oxygen is an interstitial element, which can increase strength and lower toughness in titanium. Both of these behaviors make direct substitution of the PAM ingot technology problematic. The effect of oxygen on material properties and how to correctly process higher oxygen titanium need to be established. The NCEMT and Ladish Co. are working to provide forging and heat-treatment parameters that account for and allow higher oxygen content without detrimental effects to material properties.

Initially, three PAM ingots, each with incrementally higher oxygen content, are being procured for forging and heat-treatment trials. The NCEMT and Ladish Co. are consulting to determine the appropriate trial parameters and subsequent testing matrix. The goal of the collaboration is to design parameters that are production-friendly, are transferable to PAM or VAR processed material, and define a specific allowable increase in ingot oxygen content. Ladish Co. is supplying technical and production expertise to ensure that the trials are indicative of the thermomechanical processing of the target application (HSU roadarms). In addition, Ladish Co. is working closely with the NCEMT to define alternative heat treatments and define specific parameters.

Casting of the three initial PAM ingots is expected to begin in the spring of 2002, followed by forging, heat treatment and testing during the remainder of 2002. If successful, Ladish Co., the NCEMT, and the AAAV program will produce prototype HSU roadarms the following year using the parameters developed during the project’s initial phase. The prototypes will then be rigorously proof-tested to ensure adequate performance and safe operation.

Upon successful implementation, an optimized thermomechanical processing route for higher oxygen PAM ingots will be fully defined. Implementation of PAM technology and high use of recycled product will allow Ladish Co. and the AAAV program to benefit from up to a 27-percent decrease in titanium cost. Results from this project will be available for other Department of Defense and civilian titanium end users. Thus, benefits from this technology may extend to other applications. ■

Materials Selection for Light, Strong Performance and Cost-Effective Design

Part 1 of 2

Through its skilled personnel and experience, the NCEMT helps clients to identify materials that fulfill their design requirements. These requirements include light, strong, stiff, high-vibration, damage-tolerant, corrosion-resistance, thermal- and thermomechanical-resistant, and cost-effective materials. The NCEMT also helps to identify the most suitable surface protection processes for a particular design environment.

Materials selection is a difficult decision because over 100,000 materials exist. The upside is the creation of an opportunity for innovation in design. Engineers can combine these materials to provide greater performance at a lower cost. However, choosing the wrong material(s) can lead to part failure as well as unnecessary costs. Furthermore, selecting the best material(s) involves more than finding a material with properties that provide the necessary service performance. The selection also must consider how the material will be processed into the finished product. When selecting any material, a compromise is usually necessary among its (1) mechanical properties, (2) corrosion/chemical properties, (3) toxicity (safety precautions), (4) cost, (5) availability and (6) ease of fabrication.

The NCEMT materials selection process emphasizes design by analyzing the service conditions and environment for the desired performance criteria utilizing the Ashby method ["Material Selection and Design," *ASM Handbook*, Vol. 20, pp.32–64]. This approach offers rapid access to data and gives design engineers greater freedom in exploring material potential. As a result, it leads to selecting materials that best match the requirements of a design.

The NCEMT quantitatively identifies the best performing materials for a design requirement through material-performance indices. This problem-solving process is applicable whether the materials are being selected for (1) a new product or design; or, (2) re-evaluation of an existing product or design to reduce cost, increase reliability, improve performance, etc. Only rarely does a simple material substitution occur in the same design. Usually, such a substitution means the material will not be optimally utilized. The four process steps in the material selection are:

1. *Analyze materials requirements*: Translate service and environment conditions into critical material properties.

2. *Screen candidate materials*: Create a comprehensive materials properties database to select a few materials.

3. *Select candidate materials*: Select the best materials for an application based on performance, cost, fabricability and availability.

4. *Develop design data*: Determine the key properties for a material in service.

The process begins by first translating design needs into material properties. The materials are then screened based on their properties using an absolute lower (or upper) limit requirement. No trade-off beyond that limit is allowed. The goal is to set one-sided limits that permit a "yes" or "no" to the question: "Should this material be evaluated further for this application?" In making the final selection, more properties including fabricability and cost are considered. Once materials have been selected, their design data properties must be determined to permit the design and fabrication of components that function with a specified reliability. Examples are given below for light, strong, stiff and fatigue-resistant design.

Part 2, featured in the next issue of *Metalworking Technolgoy Update*, will examine the development of performance indices and examples of material selection for light and strong fracture toughness-resistance and cost-effective materials selection. ■

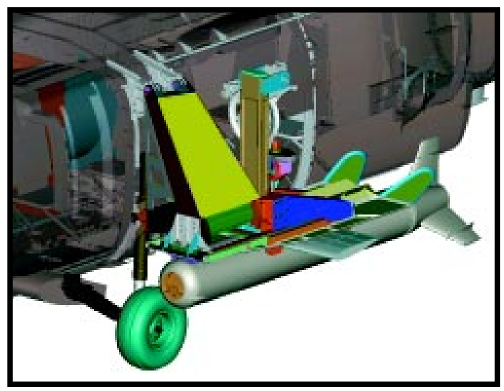
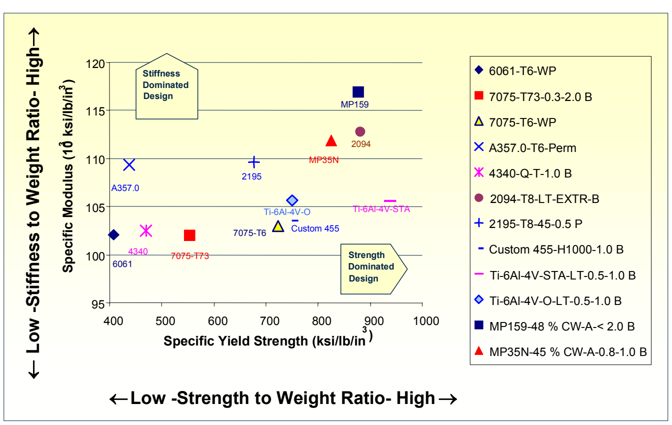
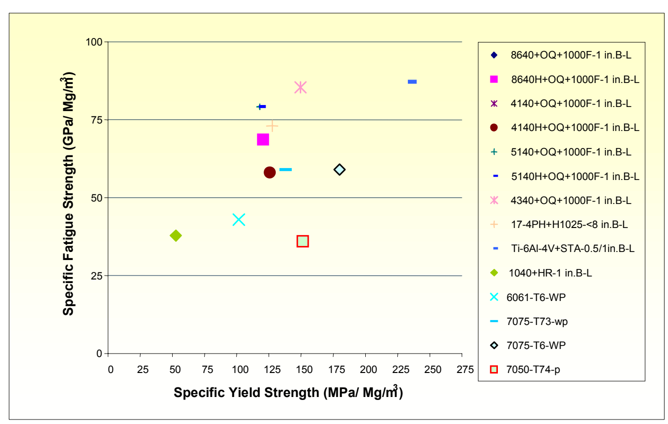


Photo: The NCEMT team selected materials for light, strong, high-fatigue resistance, high-SCC resistance, manufacturing methods and surface coating technologies.



Specific modulus versus specific yield strength of selected alloys

The lightest and strongest alloys are on the right side corner of the figure for the strength-dominated design, and the lightest and stiffest alloys are on the top left side corner of the figure for the stiffness-dominated design.



Specific fatigue strength versus specific yield strength of selected alloys

The lightest and highest fatigue-resistant alloys are on the top right side corner of the figure for the fatigue-dominated design.

Program News/Events

NCEMT Overview for ONR Industrial & Corporate Programs

On January 8, 2002, the NCEMT was privileged to host Tom Tesch, Head of the Office of Naval Research Industrial & Corporate Programs department, which oversees the Navy Manufacturing Technology (MANTECH) Program. Tom Tesch was accompanied by Steve Linder, Navy MANTECH Program Director, and Ed Coyle, ONR Contracting Officer Representative for the NCEMT. The NCEMT was the first Navy MANTECH Center of Excellence to be visited by Tom Tesch, who was recently appointed to his position. Dick Henry, NCEMT Program Director, along with representatives of Concurrent Technologies Corporation's (*CTC*'s) Executive Management team, hosted this visit that included an overview of the NCEMT program and technical capabilities, as well as a tour of *CTC*'s Manufacturing Technology Facility and Environmental Technology Facility.

Friction Stir Welding Technology for Defense Applications

This workshop is the first in a series being organized jointly by the NCEMT and the Navy Joining Center (NJC). It is sponsored by the Navy MANTECH Program, Office of Naval Research. The objectives are to update industry and Department of Defense organizations on ongoing advances in friction stir welding (FSW) technology and to obtain their input on the direction to be taken in developing this technology and removing barriers to its full-scale implementation. The first workshop will be hosted by Edison Welding Institute/NJC, Columbus, Ohio, May 14–15, 2002. The next workshop (date to be determined) will be hosted by *CTC* and the NCEMT in Johnstown, Pennsylvania.

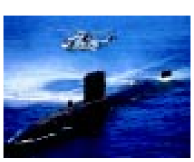
Aeromat 2002

The NCEMT has joined forces with the Naval Air Systems Command, Patuxent River, Maryland, to organize and cochair three sessions on recent advances in "Near-Net Shape Processing" at the 2002 Advanced Aerospace Materials and Processes Conference and Expo (Aeromat), in Orlando, Florida, June 10–13, 2002. These three sessions will focus respectively on Solid Freeform Fabrication, Porous and Open-cell Materials Processing, and Forming and Casting Practices. The NCEMT is a contributor to four of the 18 presentations being planned.

ShipTech 2003

The next edition of this highly successful series of information exchanges on shipbuilding technology developments is being planned for January 16–17, 2003, in Biloxi, Mississippi. The NCEMT is facilitating this event, which is jointly sponsored by ONR - Navy MANTECH Program, and by the National Shipbuilding Research Program - Advanced Shipbuilding Enterprise (NSRP ASE). This event will follow a two-day Lean Shipbuilding Enterprise workshop, which will focus on the accomplishments of this NSRP ASE-funded project and will include a tour of the Atlantic Marine shipyard in Mobile, Alabama. As in prior events, ShipTech 2003 will focus on technical developments generated by projects sponsored by Navy MANTECH, through its Centers of Excellence as well as other ONR shipbuilding initiatives, and by NSRP ASE.

Cover Photos



Left photo courtesy of Lockheed Martin Corporation. Right photo by Staff Sgt. Vincent A. Parker.

Concurrent Technologies Corporation

NCEMT Program Manager
Richard J. Henry

Editor
Debbie Roman Eisenberg

Design and Production
Amy J. Stawarz

Production Assistant
Donald Cekada

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.

CTC, an independent nonprofit Equal Opportunity Employer, is classified as a Section 501 (c)(3) organization under the Internal Revenue Code, and is recognized as a publicly supported organization. Individuals, corporations, companies, associations, and foundations are eligible to support the work of *CTC* through tax-deductible gifts.

If you would like to be removed from our mailing list, or if you would like to add your name or the name of someone else to the list, please e-mail Tricia Wright at wright@ctc.com. *Metalworking Technology Update* can also be found online at www.ncemt.ctc.com.