PERFORMANCE AND COST REPORT

As of: May-98

CONTRACT NO.:	N00014-96-C-0398
TITLE:	High Performance Lightweight Metals
JOB ORDER NO.:	HX2B9
TYPE:	CPFF
P.O.P.	3/97 - 2/00

TARGETS

	CURRENT MONTH	% of Target	CUM TO DATE	% of Target	TARGET VALUE
ACTUALS (MANHOURS)	17	0%	2,375	21%	11,190
ACTUALS (DOLLARS)	$15,493	1%	$289,975	16%	$1,828,771
OPEN SUPPLIER COMMITMENTS			$441,580		
TOTAL			$731,555	40%	

AUTHORIZED FUNDING

$1,828,771

Actuals as a % of Funding	Actuals & Open Commts as a % of Funding
16%	40%

BILLINGS/CASH RECEIPTS

BILLINGS: $274,472
RECEIPTS: $268,301

NOTES:

R&D STATUS REPORT

QUARTERLY (3/1/98 – 5/31/98)

DARPA ORDER NO: D821 (BAA 95-43)

PROGRAM CODE NO:

CONTRACTOR: The Boeing Company

CONTRACT AMOUNTS: $1,828,771 (Core only)

CONTRACT NO: N00014-96-C-0398

EFFECTIVE DATE OF CONTRACT: 1 March 1997

EXPIRATION DATE OF CONTRACT: 28 February 1999

PROGRAM MANAGER / PRINCIPAL INVESTIGATOR: Donald S. Shih, Ph.D.

TELEPHONE NO: (314) 232-9202, EMAIL: donald.s.shih@boeing.com

SHORT TITLE OF WORK: High Performance Ultra-Lightweight Metals

REPORTING PERIOD: 1 March 1998 – 31 May 1998

DESCRIPTION OF PROGRESS:

LDC (Low Density Core) AlBeMet – In this quarter, Brush Wellman (BWI) and Boeing were scaling up the LDC process in order to produce 20 billets/ cans of LDC AlBeMet 162 for the Subscale Structural Porous Al-Be Production task (1.2.3.3). The HIP can dimensions increased from 0.75 x 1.5 x 3 $inch^3$ to 0.75 x 3 x 4 $inch^3$, a 266 % increase in volume. With this size, external support is not needed to keep the can from bulging when 3 atm (absolute) of Ar was charged into the can. Grade 1100 aluminum was used for the HIP can to minimize distortion during HIP'ing. The uniform compaction is expected to improve pore distribution and improve the ability to roll.

These twenty cans will have 3 HIP'ing variables as summarized in Table I. Our effort is focused on one atmosphere of argon gas charging for the sake of simplifying production process. Usually, large HIP cans will require external support to prevent the can from bulging if the backfill pressure is greater than 1 atmosphere. Because of the can size and HIP'ing pressure, these cans will be HIP'ed at IMT Columbus (Ohio) in two runs. Appropriate shipping containers for the Be containing 3 atm of Ar gas are being devised.

TABLE I. Summary of Variables in Task 1.2.3.3, "Subscale Billet Production."

Number of Cans	Backfill Pressure of Ar (atm)	HIP Pressure (ksi)
6	3	30
7	1	30
7	1	15

Two lines of experimentation, originally designed to enhance thermal induced porosity response, have been dropped because of time constraints and the relative success of one atmosphere backfill. One strategy was to reduce the core strength at the expansion anneal temperature by suppressing the solidus temperature with Mg alloying. The other was to use thermal decomposition during HIP'ing of a solid hydrocarbon addition to the powder core to generate hydrogen equivalent to possibly a very high "backfill" pressure. Both strategies offered the potential to reduce production difficulty by eliminating the need for external supports required for backfilling greater than 1 atm pressure and higher HIP pressure of 30 ksi.

HIP Modeling of LDC AlBeMet – Two Al 6061 cans filled with AlBeMet and sealed under pressure have been fabricated at BWI and LANL. Both LANL and BWI had difficulty in fabricating these cans. LANL had about 50% success in producing helium leak tight welds in the 6061 Al cans and then BWI experienced problems in trying to seal the fill tubes on the cans after filling with powder. So the 2 cans that are available for the MATSYS measurements may be of marginal integrity. However, Tony Zahrah of MATSYS said that we should be able to get good information from just 2 HIP runs. The LANL HIP facility repair is expected to be completed by the end of June 1998, then LANL will proceed with preparing the furnace for the MATSYS experiments.

LDC Ti64 – For LDC Ti64 sandwich materials, NRL had made studies on: 1) microstructural evolution during expansion, 2) XCMT pore structure analysis, and 3) computational simulation.

1. Microstructural evolution during expansion - Samples, ~3x3 cm^2 square, were cut from a LDC Ti64 panel received from Boeing for thermal treatment studies. Samples were expansion annealed in a vacuum furnace ($<1 \times 10^{-5}$ torr) at 920°C for varying times: 0 (as-received), 1.5, 3, 6, and 24 hrs. Digital image analysis was performed to measure the microstructural evolution during the expansion. Pore volume fraction in the core was estimated for both longitudinal and transverse directions as a function of soak time. The change in median pore size on a section perpendicular to the final rolling direction was also measured. The results are shown in Fig. 1 and 2, respectively. A power law adequately describes the pore fraction evolution. Mean pore (core) volume fractions approach 0.55. The median pore area after full expansion corresponds to an equivalent circle diameter of 17.4 μm. These results will be used to build realistic finite element model microstructures and as qualitative comparisons to the results of the simulated expansion of the model.

2. Pore structure analysis by XCMT - Understanding the 3D pore structure is important for predicting the mechanical behavior of the LDC Ti64 materials. Recent advances in x-ray computed microtomography (XCMT) now allow imaging the microstructure of a porous material with a resolution of at least 2 μm. A sample of fully expanded LDC Ti64 material (920°C for 24 hrs.) was examined by XCMT at the National Synchrotron Light Source (NSLS) of the Brookhaven National Laboratory with the assistance of Ms. Betsy Dowd. The resulting data set was reconstructed into an image of the microstructure and visualized using T3D by Fortner Research LLC. Sample images of Fig. 3 and 4 only begin to indicate the wealth of 3D data, which can obtained. The dark regions represent pores, and the final rolling direction is oriented up and down (short direction) in the images.

3. Computational simulation of LDC Ti64 pore expansion - 2D mesoscale models were developed to investigate the effects of pore gradients, entrapped gas in the pores, temperature and creep in the LDC titanium plate. Data from the microscopic examinations and x-ray techniques are being used to model mesoscale features contained in the actual material microstructure. The entrapped gas in the pores is modeled with an ideal gas law to account for the effects of temperature and internal pressure. The material model incorporates high temperature creep properties. Preliminary models consisted of a 10 x 10 square array of elements containing approximately 10 pores of various sizes, which were used to validate the analysis techniques. Currently, a 50 x 50 square model that includes approximately 50 elongated pores is being constructed to better simulate the LDC material. The effects of pore expansion and creep at 920°C are being modeled, which corresponds to the conditions during the actual expansion process. Pore shape data from the microstructural observations will be employed to check the validity of the finite element models at select points during the expansion process. Pore interactions and deformation due to expansion and creep effects are being evaluated to understand the development of flow and fracture connectivity across the microstructure. Tension, compression, and bending loading cases on the expanded microstructure will be examined.

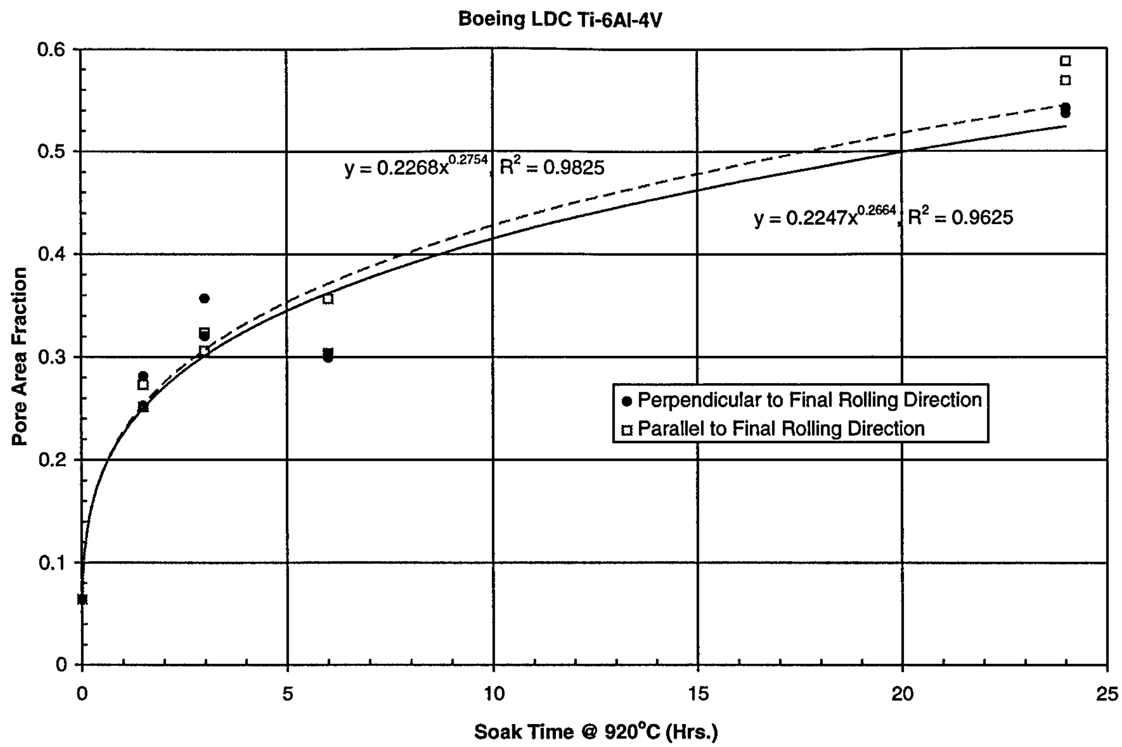

Figure 1 - Estimated pore volume fraction as a function of soak time.

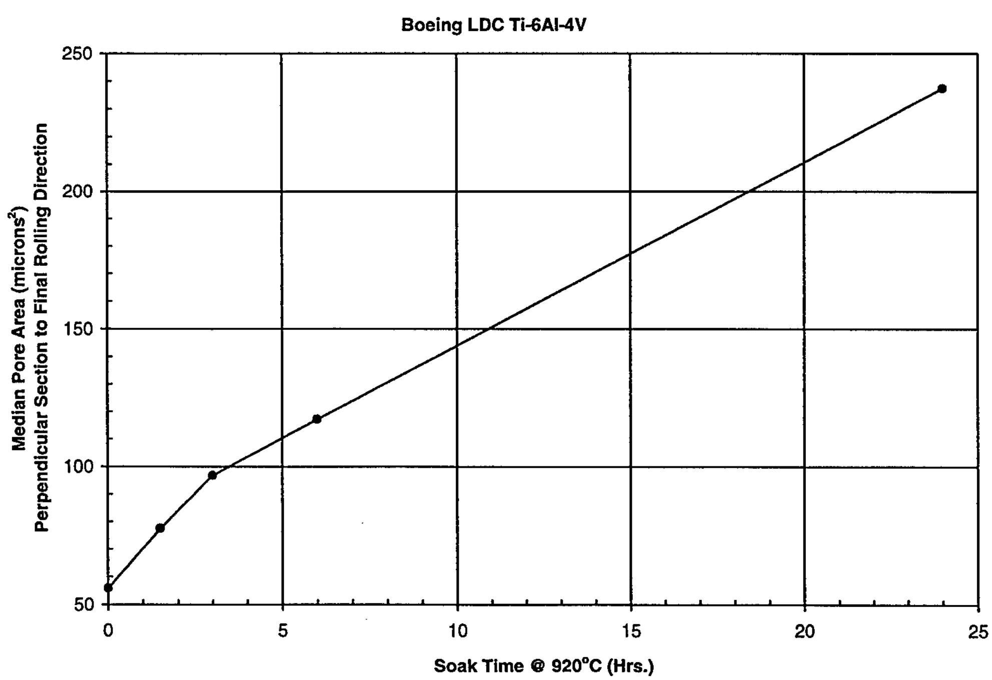

Figure 2 - Median pore size as a function of soak time.

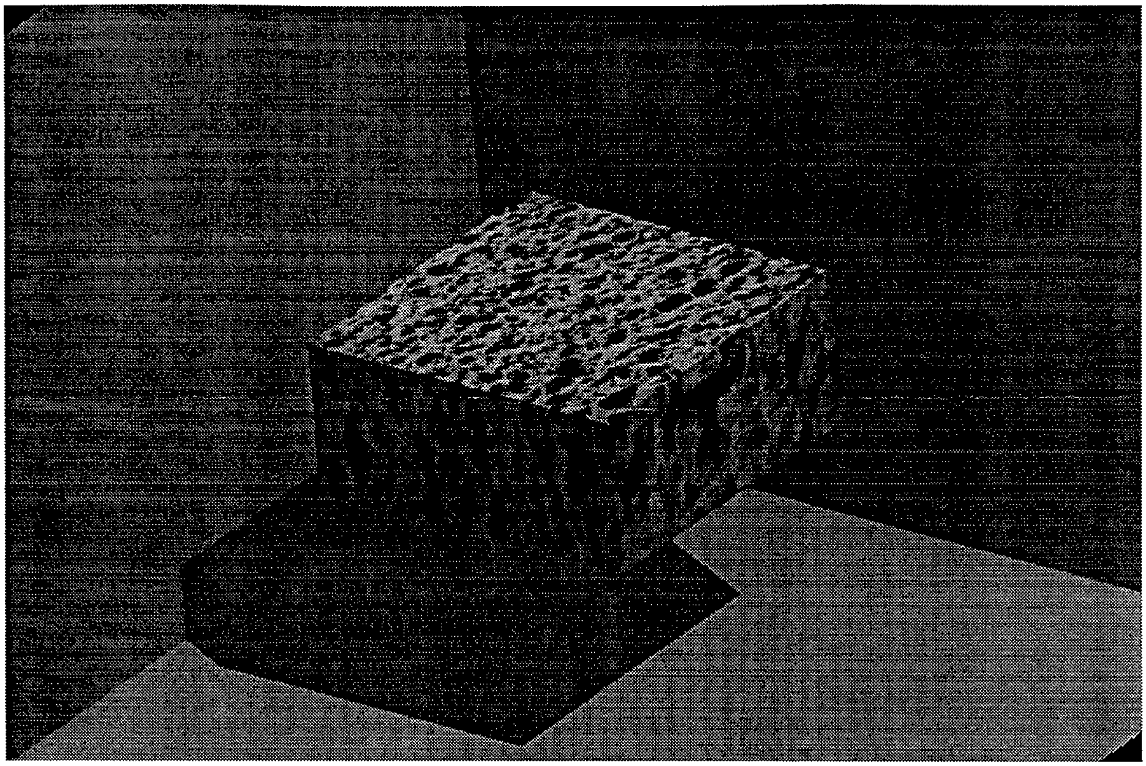

Figure 3 - Reconstructed 3D pore structure of expanded LDC Ti64 sandwich panel material.

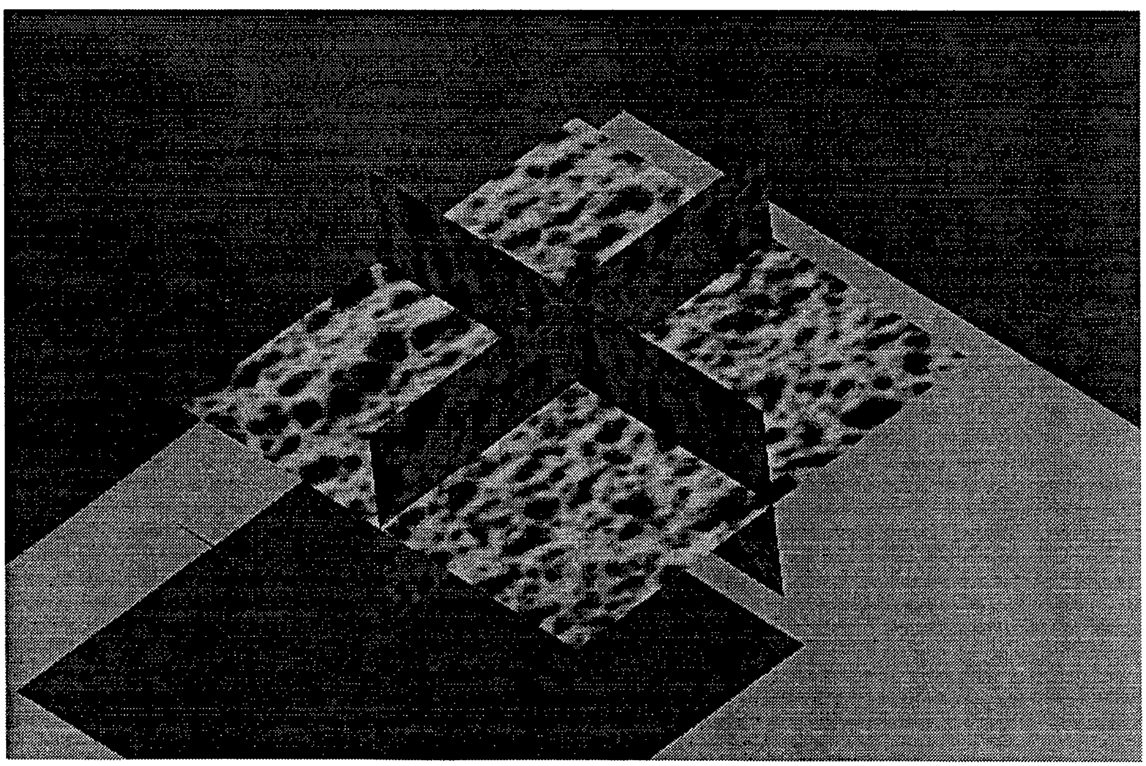

Figure 4 - Reconstructed microstructure showing three internal, orthogonal planes.

Technical Cost Modeling (TCM) – IBIS has conducted independent data collection for each step in the LDC Ti64 sandwich panel manufacturing process. This data set was reviewed by Don Shih at Boeing and areas for data refinement were defined. Additional data collection and data refinement is now ongoing. There was no transfer of new data in the LDC AlBeMet effort in this reporting period. Therefore, IBIS has made no refinement to the LDC AlBeMet model. Major action items for the next reporting period include the followings:

1. Refine LDC AlBeMet Model if new data becomes available.
2. Conduct sensitivity analysis for LDC AlBeMet, analyze specific part designs if available.
3. Refine data for LDC Titanium Model and data
4. Conduct cost structure and sensitivity analysis for LDC Titanium for specific designs if available.

CHANGE IN KEY PERSONNEL: None

SUMMARY OF SUBSTANTIVE INFORMATION DERIVED FROM SPECIAL EVENTS: None

PROBLEMS ENCOUNTERED AND/OR ANTICIPATED: None.

ACTION REQUIRED BY THE GOVERNMENT: None

The Boeing Company
P.O. Box 516
St. Louis, MO 63166-0516
(314) 232-0232 TELEX 44-857

BOEING

30 June 1998
NJP-018-39558

Subject: Contract N00014-96-C-0398, High Performance Ultra-Lightweight Metals, CDRL A001

To: Program Officer
Office of Naval Research
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660

Attention: Dr. George Yoder, ONR 332

Enclosure: (1) CDRL A001, R&D Status Report

1. In accordance with the terms of the subject contract, Boeing, acting through its wholly-owned subsidiary, McDonnell Douglas Corporation (MDC), is please to submit as Enclosure (1) CDRL 0001, Quarterly R&D Status Report.

2. Any technical questions should be directed to Dr. Donald Shih at (314) 232-9202. All other questions may be addressed to the undersigned at (314) 233-7469.

Nancy J Pollock

Nancy J. Pollock
Specialist - Contracts & Pricing
Phantom Works
Boeing, Information, Space & Defense Systems

IC: Dr. Steve Wax, MDA972 (2 copies)
Dir., Adv. Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714

Program Officer, N00014 (3 copies)
Dir., Adv. Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714

Administrative Contracting Officer, S2606A (1 copy)
Director, Advanced Research Projects Agency
3701 North Fairfax Drive
Arlington, VA 22203-1714

Director, Naval Research Laboratory, N00173 (1 copy)
ATTN: Code 2627
Washington, D. C. 20375-5326

Defense Technical Information Center, S47031 (2 copies)
8725 John J. Kingman Road STE 0944
Ft. Belvor, VA 22060-6218

Dr. Steven Fishman, ONR 332
Office of Naval Research
Ballston Tower One
800 North Quincy Street
Arlington, VA 22217-5660