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LLNL-TR-747813

Design Analysis of Resin Transfer Molding (RTM) of Fiber Composite Panels Final Report CRADA No. TC-333-92

S. Deteresa, W. Stein, V. R. Yagi

March 14, 2018

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Design Analysis of Resin Transfer Molding (RTM) of Fiber Composite Panels

Final Report
CRADA No. TC-333-92

Date: December 18, 1996 Revision: 2

A. Parties

The project is a relationship between the Lawrence Livermore National Laboratory (LLNL) and Boeing Defense and Space Group.

University of California
Lawrence Livermore National Laboratory
P.O. Box 808, L-795
Livermore, CA 94551

Boeing Defense and Space Group
P.O. Box 3707, MS 4X-54
Seattle, Washington 98124-2207

B. Project Scope

This project was designed to develop a fundamental understanding of the thermal, chemical, and rheological events that govern the Resin Transfer Molding (RTM) process, and model these events to provide a rational means of optimizing quality and reproducibility.

C. Technical

Milestones and Deliverables:	Completion Date Scheduled	Actual
1. Select and characterize materials for RTM study	06/94	06/94
2. Develop 2.5 D single-porosity flow code	12/94	12/94
3. Fiber bundle capillarity measurements	06/95	06/95
4. Perform permability measurements	12/95	12/95
5. Modeling of flat panel fill	12/95	12/95
6. Develop dual-porosity flow model	12/95	12/95
7. Rheological modeling	06/96	
8. Dual-porosity flow modeling	12/96	
9. Chemorheology and model development	12/97	
10. RTM process modeling (2.5D)	12/97	
11. Develop 3D 8-node flow model	12/97	
12. RTM process modeling (3D)	06/98	

D. Partner Contribution

RTM of composite part.

E. Documents/Reference List

CRADA Reports, May 1993

F. Acknowledgment

Participant's signature of the final report indicates the following:

1) The Participant has reviewed the final report and concurs with the statements made therein.
2) The Participant agrees that any modifications or changes from the initial proposal were discussed and agreed to during the term of the project.
3) The Participant certifies that:
   a) all reports either completed or in process are listed;
   b) all subject inventions attributable to the project have been disclosed or are included on a list attached to this report; and
   c) appropriate measures have been taken to protect intellectual property attributable to this project.
4) The Participant certifies that if tangible personal property was exchanged during the agreement, all has either been returned to the initial custodian or transferred permanently.
5) The Participant certifies that proprietary information has been returned or destroyed by LLNL.

10/8/98
Victor R. Yagi Date
Boeing Defense and Space Group

10-15-98
Steve Deteresa Date
Lawrence Livermore National Laboratory

Werner Stein Date
Lawrence Livermore National Laboratory

Attachment I – Final Abstract
Attachment II – Project Accomplishments Summary
Attachment III – Final Quarterly Report

E. Documents/Reference List

CRADA Reports, May 1993

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10/6/98
Victor R. Yagi Date
Boeing Defense and Space Group

Steve Deteresa Date
Lawrence Livermore National Laboratory

Werner Stein 10/23/98
Werner Stein Date
Lawrence Livermore National Laboratory

Attachment I – Final Abstract
Attachment II – Project Accomplishments Summary
Attachment III – Final Quarterly Report

Design Analysis of Resin Transfer Molding (RTM) of Fiber Composite Panels

Attachment I
Abstract
CRADA No. TC-0333-92

Date: 1/10/97 Revision:

Lawrence Livermore National Laboratory and Boeing Defense and Space Group worked together to advance the understanding and aerospace application of the Resin Transfer Molding (RTM) process. Future aircraft designs will require the use of lightweight fiber composites in primary structures. RTM is the prime manufacturing process to replace existing labor and cost-intensive procedures. RTM's unique processing capabilities are that it is not labor intensive and that it provides speed and near net shape forming to complex aircraft parts. The qualities could reduce the cost of tomorrow's airline programs by several million dollars each.

Design Analysis of Resin Transfer Molding (RTM) of Fiber Composite Panels

Project Accomplishments Summary (Attachment II)
CRADA No. TC-333-92

Date: December 18, 1996 Revision: 1

A. Parties

The project is a relationship between the Lawrence Livermore National Laboratory (LLNL) and Boeing Defense and Space Group.

University of California
Lawrence Livermore National Laboratory
P.O. Box 808, L-795
Livermore, CA 94551

Boeing Defense and Space Group
P.O. Box 3707, MS 4X-54
Seattle, Washington 98124-2207

B. Background

This project was designed to develop a fundamental understanding of the thermal, chemical, and rheological events that govern the Resin Transfer Molding (RTM) process, and model these events to provide a rational means of optimizing quality and reproducibility.

C. Description

Lawrence Livermore National Laboratory and the Boeing Defense and Space Group worked together to advance the understanding and aerospace application of the Resin Transfer Molding (RTM) process. Future aircraft designs will require the use of lightweight fiber composites in primary structures. RTM is the prime manufacturing process to replace existing labor and cost-intensive procedures. RTM's unique processing capabilities are that it is not labor intensive and that it provides speed and near net shape forming to complex aircraft parts. The qualities could reduce the cost of tomorrow's airline programs by several million dollars.

D. Expected Economic Impact

The project will enable the aerospace industry to apply RTM's unique processing capabilities to complex aircraft parts to reduce the cost of tomorrow's airline programs by several million dollars.

E. Benefits to DOE

The project will enhance the tools and technology available to Defense Program (DP) procurement activities. Specifically, it will enhance DP capability to model relevant weapons and problems. The development of the model will expand the applicability of high-speed strength and stiffness fiber composites in land, sea, and air based weapon systems.

F. Industry Area

Manufacturing.

G. LLNL Point of Contact for Project Information

Steve Deteresa, (510) 422-6466 or Werner Stein, (510) 422-0323
P.O. Box 808, L-342 P.O. Box 808, L-140
Livermore, CA 94551 Livermore, CA 94551

H. Company Size and Point(s) of Contact
Victor R. Yagi (206) 477-4812

I. Project Examples
Print-out of computer codes available.

J. Release of Information
I have reviewed the attached Project Accomplishment Summary prepared by Lawrence Livermore National Laboratory and agree that the information about our CRADA may be released for external distribution.

Victor R. Yagi
Boeing Defense and Space Group

10/6/98
Date

RELEASE OF INFORMATION

I certify that all information contained in this report is accurate and releasable to the best of my knowledge.

Karena McKinley, Director
Industrial Partnerships
and Commercialization

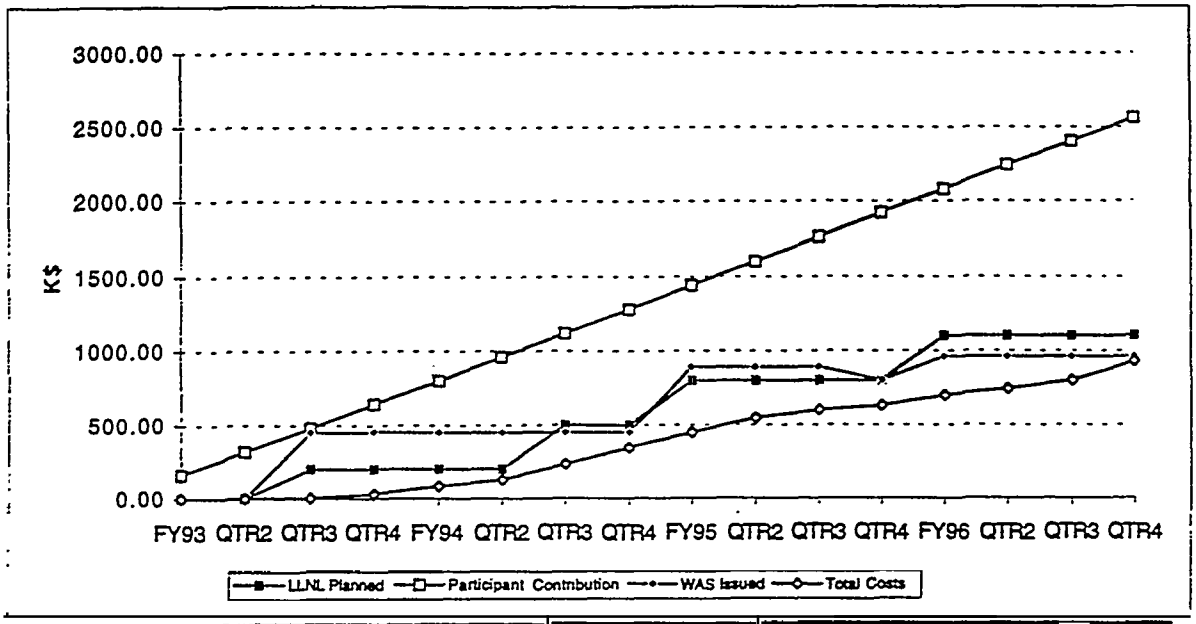
12/15/98
Date

Lawrence Livermore National Laboratory
Final Quarterly Report (Attachment III)

Title:	Design Analysis of Resin Transfer Molding	Reporting Period:	07/01/95 - 09/30/96
Participant:	Boeing Defense and Space Group	Date CRADA Executed:	5/26/93
DOE TTI No.:	93-LLNL-108-C1	DOE Approval Date:	4/23/93
CRADA No.:	TC-0333-92	Scheduled Ending Date:	5/25/98
TACT:	AMPE	Project Completed:	9/30/96
Account Numbers	4782-41 to 55	B & R Code (S):	DP0301
Accounts Closed:	9/30/96		35DP03

Approved Funding Profile ($K)

	FY93	FY94	FY95	FY96	FYOUT	Total
LLNL Planned	200	300	300	300	300	1400
Participant In-Kind	640	640	640	640	640	3200
Participant Funds-In	0	0	0	0	0	0
WAS DP0301	450	0	350	162	0	962
WAS 35DP03	0	0	0	0	0	0
Total Costs	30	316	282	299	0	927



DP0301	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	FYTD
FY93	0	0	0	0	0	0	0	0	2	9	7	11	30
FY94	20	18	14	20	12	13	16	30	60	31	28	54	316
FY95	28	29	41	31	31	41	30	-2	21	21	10	1	282
FY96	34	21	16	14	12	17	12	13	33	42	37	48	299
FYOUT	0	0	0	0	0	0	0	0	0	0	0	0	0

927

35DP03	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	FYTD
FY93	0	0	0	0	0	0	0	0	0	0	0	0	0
FY94	0	0	0	0	0	0	0	0	0	0	0	0	0
FY95	0	0	0	0	0	0	0	0	0	0	0	0	0
FY96	0	0	0	0	0	0	0	0	0	0	0	0	0
FYOUT	0	0	0	0	0	0	0	0	0	0	0	0	0

0

STAFF w/phone:

Lab PI: Steve DeTeresa (510) 422-6466 — Participant: Victor R. Yagi (206) 477-4812
Werner Stein (510) 422-0323
Resource Manager: Michelle Doggett (510) 422-3209
DOE OAK: Jerry Scheinberg (510) 637-1653 — DOE HQ: D. Bird (202) 586-0499

Reporting Period: 07/01/95 - 09/30/96
DOE TTI No.: 93-LLNL-108-C1
CRADA No.: TC-0333-92

Milestones and Deliverables:

List the complete set of milestones for all phases of the CRADA. Continue on a separate page if necessary.
Report any changes from the original CRADA or previous quarterly report on the CRADA Change Form.

		Completion Date: Scheduled	Actual
1	Select and characterize materials for RTM study	06/94	06/94
2	Develop 2.5 D single-porosity flow code	12/94	12/94
3	Fiber bundle capillarity measurements	06/95	06/95
4	Preform permability measurements	12/95	12/95
5	Modeling of flat panel fill	12/95	12/95
6	Develop dual-porosity flow model	12/95	12/95
7	Rheological modeling	06/96	
8	Dual-porosity flow modeling	12/96	
9	Chemorheology and model development	12/97	
10	RTM process modeling (2.5D)	12/97	
11	Develop 3D 8-node flow model	12/97	
12	RTM process modeling (3D)	06/98	

Verification of participants' in-kind contribution was made in accordance with LLNL policy. Explain basis of verification: Please initial: YES X NO ____

List any subject inventions by either party (include IL# for LLNL inventions), additional background intellectual property, patents applied for, software copyrights, publications, awards, licenses granted or reportable economic impacts.

Verification that all equipment and proprietary information has been returned to the initial owner or permanently transferred. Please initial: YES X NO ____

Accomplishments

Describe Technical/Non-Technical lessons learned and other observations.
Summarize causes/justification of deviations from original scope of work.

See Final Report.

Reviewed by CRADA project Program Manager: Date:

Reviewed by Karena McKinley, Director, LLNL/IP&C: Karena McKinley Date: 12/15/98

Direct questions regarding this Report to IP&C Resource Manager, Carol Asher, at (510) 422-7618.