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LLNL-TR-748520

PNGV Superplastic Forming of Stainless Steel Auto Components (USCAR) Final Report CRADA No. TC-0881-94

J. Elmer, D. Nielsen, M. Royce, W. Caldwell, A. Sherman, B. Bridges, M. Smith

March 26, 2018

Disclaimer

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

PNGV Superplastic Forming of Stainless Steel Auto Components (USCAR)

Final Report
CRADA No. TC-0881-94

Date: 5/7/98 Revision:

A. Parties

The project was a relationship between the Lawrence Livermore National Laboratory (LLNL) the DOE/DP partner,

University of California
Lawrence Livermore National Laboratory
7000 East Avenue, L-795
Livermore, CA 94550
Dr. John Elmer, (925) 422-6543

and the following organizations:

Lockheed Martin Energy Systems, DOE/DP
PO Box 2009
Oak Ridge, TN 37831-8096
Bob Bridges, (423) 574-2837

Battelle Pacific Northwest National Laboratories, DOE/ER
Battle Blvd.
Richland, WA 99352
Mark Smith, (509) 376-2847

USCAR LEP Partners

Chrysler Corporation
800 Chrysler Drive East
Auburn Hills, MI 48326
Michael Royce, (810) 576-4996

Chrysler Corporation
800 Chrysler Drive East
Auburn Hills, MI 48326
David Nielsen, (810) 576-1047

General Motors, Delphi Division
4800 S. Saginaw St.
Flint, MI 48501
William Caldwell Jr., (810) 257-2961

Ford Scientific Research Laboratory
Mail Drop 3182
PO Box 2053
Dearborn, MI 48121
Dr. Andrew Sherman, (313) 594-6897

B. Project Scope

The DOE/DP CRADA consisted of three tasks that were to be performed concurrently by LMES and LLNL. LMES evaluated mechanical properties of candidate duplex stainless steel alloys at various temperatures and strain rate to determine forming behavior. LLNL evaluated the weldability and the effect of the heat affected zone (HAZ) from the weld on the microstructure of duplex stainless steel. At the beginning of the CRADA, commercially available duplex stainless steel was purchased to provide material that would have optimum characteristics. Superdux 65 (SD65) was acquired and tested and was used to form initial test parts. LMES cast and processed a couple of duplex stainless steel alloys that exhibited superplastic forming (SPF) behavior in case a domestic material was unavailable.

Task 1 – Alloy selection and concept demonstration
The objective of this task was to select commercially available duplex stainless steel alloy from a U.S. supplier and to combine SPF and welding techniques to fabricate a simple double wall pipe section. Electron beam and different laser beam welding techniques were compared for welding the duplex stainless steel. CO2 laser welding was selected and used for the remainder of the program. To demonstrate the concept, the double wall pipe section was laser welded in flat sheet form, formed by internal pressure, and then evaluated for prototype acceptance. At the end of the first project year a cost analysis study was to be performed by the LEP to determine cost efficiency of this technology, or to select some other forming method to manufacture components.

Task 2 – Domestic SPF alloy and finite element analysis/laser welding design
In this task a U.S. stainless steel supplier was brought into the project through the LEP to develop a commercially produced duplex stainless steel alloy that was superplastic. The laser cutting and welding effort involved the following evaluations:

(1) applying conventional and/or new generation lasers developed for cutting and welding stainless steel
(2) mechanical assessment of the weld quality
(3) metallurgical assessment of the effects of the HAZ and on subsequent superplastic behavior

Evaluation of the double wall pipe section would be used for more geometrically complex designs.

Task 3 – Project demonstration for automotive production
This task was to provide a prototype double wall exhaust manifold fabricated with forming and joining techniques developed from forming double wall test pipes. A joint technical plan developed during this project will help facilitate the transfer of this technology to automotive designers. Part of this technical plan includes the lessons learned by each participant to avoid repeating costly mistakes that might be inherent from other forming and joining methods.

C. Technical Accomplishments

All of the milestones and deliverables were met in Tasks 1 and 2 with the exception of the cost analysis study. The cost analysis study was started late in the second project year as in-kind participation from the LEP and was not concluded when DOE/DP funding was eliminated. A domestic stainless steel supplier partnered with the LEP during the second project year. This domestically produced duplex stainless steel meets or exceeds most of the criteria stipulated by the project team. This alloy is cost effective, exhibits superplastic behavior, welds easily and is compatible with other alloys used in exhaust systems.

The domestic duplex stainless steel alloy was being tested to determine SPF parameter ranges and laser welding requirements when DOE/DP carry-over funding from year one ran out for LMES. The DOE/DP funding for the second and third project years was withheld at LMES because of a stipulation requiring an amendment be written to the CRADA contract. The contract amendment

was in the approval and signature process for over ten months before it was signed. The LMES funding ran out long before then and additional funding was never provided; however carryover funding was made available to LLNL for continued laser welding studies. Laser welded and SPF formed dual wall 2-into-1 exhaust system component test pieces were formed using the technology developed to date. These components were scheduled to be tested by the LEP partners, but these tests were not conducted to LLNL's knowledge due to the completion of the project prior to receiving year 3 funding.

D. Expected Economic Impact

No significant economic impact is expected since the project was canceled prior to implementation of this technology into production.

E. Partner Contribution

See above tasks 1-3. The partner contributions are marked as completed or conducted by "LEP".

F. Documents/Reference List

No publications were issued to LLNL's knowledge from this CRADA. Quarterly status meetings and copies of viewgraphs presented at these meetings were distributed to all parties.

There was no intellectual property developed during this CRADA.

G. 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 all reports either completed or in process are listed and all subject inventions and the associated intellectual property protection measures generated by his/her respective company and attributable to the project have been disclosed or are included on a list attached to this report.
4) The Participant certifies that if real 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.

May 11, 1998

John Elmer Date
Lawrence Livermore National Laboratory

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

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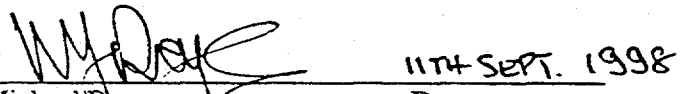

11TH SEPT. 1998

Michael Royce Date
Chrysler Corporation

pp. RETED.

PNGV Superplastic Forming of Stainless Steel Auto Components (USCAR)

Final Abstract
Attachment I
CRADA No. TC-0881-94

Governmentally controlled exhaust emission standards are increasingly stringent, forcing alternate strategies to meet these standards. One approach to improve the efficiency of the exhaust emission equipment is to decrease the time required to get the catalytic converter to optimum operating temperature. Automotive manufacturers accomplish this by using double wall stainless steel exhaust manifolds to reduce heat lose of the exhaust gases to the converter. The current method to manufacture double wall stainless steel exhaust components is to use a low cost alloy with good forming properties and extensively form, cut, assemble and weld the pieces. Superplastic forming (SPF) technology along with alloy improvements have potential at making this process more cost effective by eliminating many of the current manufacturing steps. The DOE/DP portion of this multi-lab CRADA consisted of three tasks that were to be performed concurrently by LMES and LLNL. LMES evaluated mechanical properties of candidate duplex stainless steel alloys at various temperatures and strain rate to determine forming behavior. LLNL evaluated the weldability and the effect of the heat affected zone (HAZ) from the weld on the microstructure of duplex stainless steel. At the beginning of the CRADA commercially available duplex stainless steel was purchased to provide material that would have optimum characteristics. Superdux 65 (SD65) was acquired and tested and was used to form initial test parts. LMES cast and processed a couple of duplex stainless steel alloys that exhibited SPF behavior in case a domestic material was unavailable.

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Technical Transfer Initiatives Program, P.O. Box 808 L-795, Livermore, CA 94551

PNGV Superplastic Forming of Stainless Steel Auto Components (USCAR)

Project Accomplishments Summary (Attachment II)
CRADA No. TC-0881-94

Date: 5/7/98 Revision:

A. Parties

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Mail Drop 3182
PO Box 2053
Dearborn, MI 48121
Dr. Andrew Sherman, (313) 594-6897

B. Background

The DOE/DP CRADA consisted of three tasks that were to be performed concurrently by LMES and LLNL. LMES evaluated mechanical properties of candidate duplex stainless steel alloys at various temperatures and strain rate to determine forming behavior. LLNL evaluated the weldability and the effect of the heat affected zone (HAZ) from the weld on the microstructure of duplex stainless steel. At the beginning of the CRADA, commercially available duplex stainless steel was purchased to provide material that would have optimum characteristics. Superdux 65 (SD65) was acquired and tested and was used to form initial test parts. LMES cast and processed a couple of duplex stainless steel alloys that exhibited superplastic forming (SPF) behavior in case a domestic material was unavailable.

C. Description

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D. Expected Economic Impact

No significant economic impact is expected since the project was canceled prior to implementation of this technology into production.

E. Benefits to DOE

Advanced laser welding has application across all of the Laboratory's programs including Weapons, Stockpile Stewardship, Lasers, Environmental and Physics.

F. Industry Area

Automotive exhaust system components.

G. Project Status

The project was canceled prior to implementation of this technology into production.

H. LLNL Point of Contact for Project Information

Dr. John Elmer, (925) 422-6543

I. Company Size and Point(s) of Contact

Company size: large
Chrysler Corporation
800 Chrysler Drive East
Auburn Hills, MI 48326
David Nielsen, (810) 576-1047
Michael Royce, (810) 576-4996

Company size: large
General Motors, Delphi Division
4800 S. Saginaw St.
Flint, MI 48501
William Caldwell Jr., (810) 257-2961

Company size: large
Ford Scientific Research Laboratory
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PO Box 2053
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Dr. Andrew Sherman, (313) 594-6897

J. Project Examples

All of the milestones and deliverables were met in Tasks 1 and 2 with the exception of the cost analysis study. The cost analysis study was started late in the second project year as in-kind participation from the LEP and was not concluded when DOE/DP funding was eliminated. A domestic stainless steel supplier partnered with the LEP during the second project year. This domestically produced duplex stainless steel meets or exceeds most of the criteria stipulated by the project team. This alloy is cost effective, exhibits superplastic behavior, welds easily and is compatible with other alloys used in exhaust systems.

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tests were not conducted to LLNL's knowledge due to the completion of the project prior to receiving year 3 funding.

K. 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

12/11/98
Date

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.

Michael Royce
Chrysler Corporation
pp. [illegible] LEP.

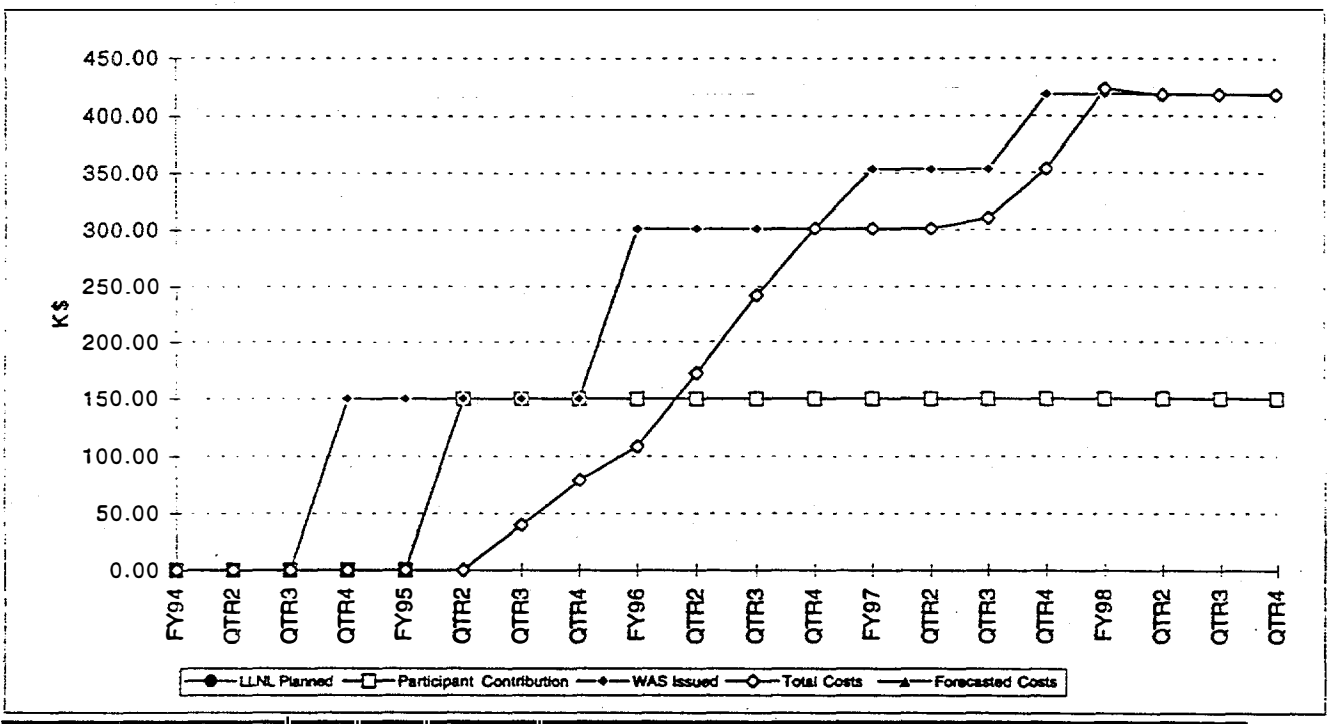
11TH SEPT. 1998
Date

Lawrence Livermore National Laboratory

Title:	PNGV Superplastic Forming of Stainless Steel Auto Components (USCAR)	Reporting Period:	09/30/96 - 02/28/98
Participant:	USCAR Low Emissions Partnership	Date CRADA Executed:	1/30/95
DOE TTI No.:	94-MULT-905-ES-1	DOE Approval Date:	3/31/95
CRADA No.:	TC-0881-94	Scheduled Ending Date:	2/1/98
Account Numbers:	4785-18 to 20	Project Completion Date:	N/A
Accounts Closed:	N/A	B & R Code (S):	DP030101

Approved Funding Profile ($K)

	FY94	FY95	FY96	FY97	FY98	Total
LLNL Planned	0	150	0	0	0	150
Participant In-Kind	0	150	0	0	0	150
Participant Funds-In	0	0	0	0	0	0
WAS Operating	150	0	151	52	65	419
WAS Capital	0	0	0	0	0	0
Total Costs	0	79	222	52	65	419



DP0301	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	FYTD
FY94	0	0	0	0	0	0	0	0	0	0	0	0	0
FY95	0	0	0	0	0	0	8	20	12	10	16	14	79
FY96	7	12	11	17	22	25	33	15	22	14	20	25	222
FY97	0	0	0	0	0	0	0	0	9	12	13	19	52
FY98	31	31	9	2	-7	0	0	0	0	0	0	0	65

419

35DP03	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	FYTD
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
FY97	0	0	0	0	0	0	0	0	0	0	0	0	0
FY98	0	0	0	0	0	0	0	0	0	0	0	0	0

0

STAFF w/phone:

Lab PI: John Elmer (510) 422-6543

Resource Manager: Michelle Doggett (510) 422-3209

DOE OAK: Jerry Scheinberg (510) 637-1653

Participant: Jodi Beckley (810) 257-7224
AC Delco Systems World Headquarters
P. O. Box 1360, Mail Code: 485-301-150
Flint, MI 48501-1360

DOE HQ:

Reporting Period : 09/30/96 - 09/30/97
DOE TTI No.: 94-MULT-905-ES-1
CRADA No.: TC-0881-94

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
Subtask 1.2 Laser Welding Studies	FY95, Q2	FY95, Q2
Subtask 1.3 Finite Element Analysis		Terminated
Subtask 1.4 Material Assessment and Characterization	FY96 Q1	FY96 Q1
Subtask 2.2 Laser Welding Studies	FY97 Q4	FY97 Q4
Subtask 2.3 Finite element Analysis		Terminated
Subtask 2.4 Material Assessment and Characterization	FY97 Q2	FY97 Q2

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

None

Accomplishments

Describe Technical/Non-Technical lessons learned (address and be specific about milestones, participant contributions)
Summarize causes/justification of deviations from original scope of work. Continue on a separate page if necessary.

Subtask 1.2: Laser welding studies were conducted using electron beam, CO2 laser beam, and NdYAG laser beam techniques to weld SuperDux 64, SuperDux65, Inconel 718 SPF, and Nitronic 19D.
Subtask 1.3: Finite element modeling terminated due to reduced funding level
Subtask 1.4: Materials assessment and characterization was completed on SuperDux 64, SuperDux65, Inconel 718 SPF and Nitronic 19D laser welds. Tensile tests were conducted on laser welds in SuperDux 65 material.
Subtask 2.2: Laser welding studies were performed on cutting and laser welding Nitronic 19D sheet packs for superplastic forming at PNL
Subtask 2.3: Finite element modeling terminated due to reduced funding
Subtask 2.4: Materials assessment and characterization of laser welds in Nitronic 19D were completed and heat treating studies were conducted on N19D laser welds to see how long it takes to recover the microstructure during SPF operations.

Reviewed by CRADA project Program Manager: Date:

Reviewed by Karena McKinley, Director, LLNL/IP&C: Karena McKinley Date: 12/10/98
Direct questions regarding this Report to IP&C Resource Manager, Carol Asher, at (510) 422-7618