

OAK RIDGE  
NATIONAL LABORATORY

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MANAGED BY UT-BATTELLE  
FOR THE DEPARTMENT OF ENERGY



ORNL-27 (4-00)

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## Final Report

**Project Title:** Production of Turbocharger Turbine from Low Cost Titanium Powder

**ORNL WBS Element:** CRADA No. NFE-11-03486

**Covering Period:** September 30, 2011 to March 31, 2012

**Date of Report:** April 16, 2012

**Contact:** Thomas Muth, Physical Sciences Directorate/ Materials Science and Technology Division, 865-574-5264, muthtr@ornl.gov

**Corporate Partner(s):** Queen City Forging Co, Rob Mayer President, 513-321-7200, rob@qcforge.com

**Project Objective:** The objective of this Cooperative Research and Development Agreement (CRADA) between UT-Battelle (hereinafter the "Contractor") and Queen City Forging Co., (hereinafter the "Participant") is to produce turbocharger turbine rotors.

**Background:** Turbochargers in commercial turbo-diesel engines are multi-material systems where usually the compressor rotor is made of aluminum or titanium based material and the turbine rotor is made of either a nickel based superalloy or titanium, designed to operate under the harsh exhaust gas conditions. The use of cast titanium in the turbine section has been used by Cummins Turbo Technologies since 1997. Having the benefit of a lower mass than the superalloy based turbines; higher turbine speeds in a more compact design can be achieved with titanium. In an effort to improve the cost model, and develop an industrial supply of titanium componentry that is more stable than the traditional aerospace based supply chain, the Contractor has developed component manufacturing schemes that use economical Armstrong™ titanium and titanium alloy powders and MgR-HDH powders. Those manufacturing schemes can be applied to compressor and turbine rotor components for diesel engine applications with the potential of providing a reliable supply of titanium componentry with a cost and performance advantage over cast titanium.

**Technical Status:** Two 3 inch diameter billets were produced from Armstrong process™ CP-Ti powder lot OA1-20110614-15. The Armstrong process™ material was received by ORNL, attrited for 10 minutes using water as a carrier to produce powder with a bulk density of approximately 20%. The attrited powder was vacuum hot pressed at 950°C to produce the 3 inch diameter billets. Oxygen composition increased from 2,500 wppm before hot pressing to 3,245 wppm after hot pressing. The nitrogen level increased from 224 wppm before pressing to 390 wppm after hot pressing. Queen City Forging has not yet commissioned the forging press that was designated for the work and as such the in-kind work associated with the project has been deferred.

**Technical Plans for Next Quarter:** The project is considered complete. When the forging press at Queen City Forge becomes available ORNL will ship the pressed billets to QCF for trials. No additional costs are expected for ORNL. These writings shall be considered the final report.

**Commercialization Status:** None

**Commercialization Plans for Next Quarter:** None planned

**Invention Disclosures:** None planned

**Patents:** None planned

**Publications / Presentations:** None planned

### Task Schedule

Task Number	Task Description	Task Completion Date				Progress Notes
		Original Planned	Revised Planned	Actual	Percent Complete	
1	Procurement press and sintering of Cp-Ti HDH powder	7/15/2011	8/15/2011		100%	
2	Procurement press and sintering of Cp-Ti Armstrong™ Powder	7/15/2011	8/15/2011		100%	
3	Procurement press and sintering of Cp-Ti HDH plus master alloy powder to make Ti-6Al-4V	9/15/2011	8/30/2011		0%	
4	Procurement press and sintering of Cp-Ti Armstrong™ plus master alloy powder to make Ti-6Al-4V	9/15/2011	8/30/2011		20%	No additional work anticipated and project will not complete this task
5	Forging at QCF	9/30/2011	9/30/2011		0%	
6	Final report / Project Management	9/30/2011	10/30/11		0%	

Project Period: 04/01/11 to 09/30/11

Current Quarter: 07/01/11 to 09/30/11

**Spending Schedule**

Task	Approved Budget	Project Expenditures	
		This Quarter	Cumulative to Date
Task 1 Cp-Ti HDH pressings	\$10,000	\$0	\$10,000
Task 2 Cp-Ti Armstrong™ pressings	\$10,000	\$0	\$30,000
Task 3 Blended elemental HDH pressings	\$10,000	0	0
Task 4 Blended elemental Armstrong™ pressings	\$10,000	0	0
Task 5 Forging at QCF	\$50,000	0	0
Task 6 Project Management	\$10,000	\$0	\$10,000
<b>Total</b>	\$100,000	0	\$50,000
DOE Share	50000	0	\$50,000
Cost Share	50000	0	0

**Cost Share Contributions**

Funding Source	Approved Cost Share		This Quarter		Cumulative to Date	
	Cash	In-Kind	Cash	In-Kind	Cash	In-Kind
Queen City Forge		\$50,000				0
<b>Total</b>		\$50,000		0		0
<b>Cumulative Cost Share Contributions</b>					0	

<b>Project Spending and Estimate of Future Spending</b>							
<b>Calendar Year Quarter</b>	<b>From</b>	<b>To</b>	<b>Estimated Federal Share of Outlays*</b>	<b>Actual Federal Share of Outlays</b>	<b>Estimated Recipient Share of Outlays*</b>	<b>Actual Recipient Share of Outlays</b>	<b>Cumulative Actual Outlays (Federal + Recipient)</b>
	Start	9/30/10					
4Q04	10/1/10	12/31/10					
1Q05	1/1/11	3/31/11					
2Q05	4/1/11	6/30/11		\$0		0	
3Q05	7/31/11	9/30/11	\$40,000				\$50,000
4Q05	10/1/11	12/31/11	\$10,000				
1Q06	1/1/12	3/31/12			\$50,000	0	
Etc.							
<b>Totals</b>			<b>\$50,000</b>		<b>\$50,000</b>		<b>\$50,000</b>

\* Update quarterly

**General Note:** The information in this table should be consistent with the information provided in section 10 of the quarterly financial status reports (SF269 or SF269A).

Estimates should be provided for the entire project, and actuals should be provided for each quarter as it is completed. Estimates should be updated each quarter.