7. Propulsion Materials

Advanced materials are essential for boosting the fuel economy of modern automobiles while maintaining safety and performance.

Propulsion materials enable higher efficiencies in propulsion systems of all types. For example, many combustion engine components require advanced propulsion materials so they can withstand the high pressures and temperatures of high-efficiency combustion regimes. Similarly, novel propulsion materials may be able to replace the current expensive materials in electric motors and drivetrain components, thus lowering the cost of electric-drive vehicles.

Using lightweight components and high-efficiency engines enabled by advanced materials in one quarter of the U.S. fleet could save more than 5 billion gallons of fuel annually by 2030.

The U.S. Department of Energy (DOE) Vehicle Technologies Office (VTO) collaborates with industry to improve materials that will increase vehicle efficiency while meeting consumer and industry expectations. It does this through work on both Lightweight Materials and Propulsion Materials. In the case of Propulsion Materials, VTO works closely with other VTO subprogram technology areas to identify and meet requirements for materials needed to develop cost-effective, highly efficient, and environmentally friendly next-generation heavy and light duty powertrains.

Research and development is done in collaboration with industry, national laboratories, and universities. The VTO contributes to the Materials Genome Initiative, a federal interagency effort to support Integrated Computational Materials Engineering. It also works through government/industry partnerships:

- The U.S. DRIVE Partnership focusing on light-duty vehicles
- The 21st Century Truck Partnership, focusing on heavy-duty vehicles
- The US Automotive Materials Partnership (USAMP).

The Propulsion Materials subprogram's major R&D goal is to develop high performance cost-effective materials that solve key challenges that currently limit the performance of propulsion systems (high-efficiency engines and electric drive, and compatibility with alternative fuels).

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2015 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied. These questions were used for all VTO subprogram overviews.

Question 1. Was the program area, including overall strategy, adequately covered?

Question 2. Is there an appropriate balance between near- mid- and long-term research and development?

Question 3. Were important issues and challenges identified?

Question 4. Are plans identified for addressing issues and challenges?

Question 5. Was progress clearly benchmarked against the previous year?

Question 6. Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7. Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8. What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9. Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10. Has the program area engaged appropriate partners?

Question 11. Is the program area collaborating with them effectively?

Question 12. Are there any gaps in the portfolio for this technology area?

Question 13. Are there topics that are not being adequately addressed?

Question 14. Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15. Can you recommend new ways to approach the barriers addressed by this program area?

Question 16. Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Subprogram Overview Comments: Will Joost (U.S. Department of Energy) - lm000

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:

The reviewer said that the overall strategy for materials was well identified, particularly the Materials Technology Gap Priorities slide. However, the reviewer did not see propulsion represented in this slide, only the lightweight materials. The reviewer recommended a similar prioritization be shown for the propulsion technologies, and also recommends showing a clearer breakdown of which items are higher priority.

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:

The reviewer said that the presentation gave a good overview of the challenges that the materials team is facing and some of the research and development, but delegated much of the explanation of the research and development to the individual project presentations. The reviewer recommended that it would have been clearer showing how the projects are linked into stated project goals instead of a list of projects explaining what the projects are currently doing.

Question 3: Were important issues and challenges identified?

Reviewer 1:

The reviewer said that key challenges were explained and summarized well.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:

The reviewer said that the roadmap addresses many of the challenges and the plans to address them.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:

The reviewer did not see a clear comparison to the previous year. The highlights shown gave some indication, but the few shown did not mirror the breadth of projects.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:

The reviewer said that the projects are addressing broad problems and barriers.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:

The reviewer said that the program appears well focused and managed tactically, but the broader strategic goals and timeframe to accomplish the goals were not shared.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer said that the overall plan, particularly for lightweight materials, seems to be an all of the above strategy. The reviewer expects that eventually there will be a drive to down-select some of the alloy categories, but the reviewer agrees that would be premature at this stage. The reviewer said that one strength of this program is that the projects under this program area appear to be high risk/high reward, and that one weakness is while both the lightweighting and propulsion sub-programs contain a computational or integrated computational modeling (ICME) approach, the projects seem to be separate, rather than integrated or weaved into existing programs.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer said that there is insufficient information to evaluate if the approaches are novel or innovative.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:

The reviewer said that the program seems well-integrated into federally funded research centers, industrial and academic partners.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:

The reviewer said that the program has done a good job of facilitating interaction between these groups.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:

The reviewer sees a few gaps. The reviewer asked what materials beyond magnesium (Mg) and carbon fiber (CF) composite will be needed to reduce weight beyond 37%, and how are predictive models shared and/or translated from academic to industrial use.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:

The reviewer said that it is difficult to assess if topics are not being adequately addressed. The program area is very broad, and there will always be tradeoffs on what can be accomplished with limited funding.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:

The reviewer pointed out that there are still a number of challenges in aluminum (Al) and steel that are unaddressed and sparsely represented in the projects, as well as materials for glazings and other car components that could be used to lightweight the vehicle.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:

The reviewer said that overall, the program area seems well aligned to deal with many of the barriers.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

The reviewer said that it is difficult to evaluate the effectiveness of the program area with the information provided.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Novel Manufacturing Technologies for High Power Induction and Permanent Magnet Electric Motors	Grant, Glenn (PNNL)	7-8	3.33	3.17	3.33	3.17	3.23
Materials Issues Associated with EGR Systems	Lance, Michael (ORNL)	7-11	3.00	3.17	3.33	3.00	3.13
High-Temperature Aluminum Alloys (Agreement ID:24034) Project ID:18518	Pitman, Stan (PNNL)	7-14	3.13	3.00	3.13	3.00	3.05
Tailored Materials for Improved Internal Combustion Engine Efficiency	Grant, Glenn (PNNL)	7-17	3.42	3.42	3.50	3.33	3.42
High-Temperature Materials for High-Efficiency Engines	Muralidharan, G. (ORNL)	7-22	3.10	3.10	2.70	3.20	3.06
Enabling Materials for High-Temperature Power Electronics (Agreement ID:26461) Project ID:18516	Wereszczak, Andrew (ORNL)	7-26	3.50	3.75	3.50	3.50	3.63

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
Biofuel Impacts on Aftertreatment Devices (Agreement ID:26463) Project ID:18519	Lance, Michael (ORNL)	7-29	3.33	3.17	3.67	3.17	3.27
Applied Integrated Computational Materials Engineering for New Propulsion Materials	Finney, Charles (ORNL)	7-32	3.33	3.17	2.83	3.17	3.17
Development of Advanced High-Strength Cast Alloys for Heavy-Duty Engines	Huff, Rich (Caterpillar)	7-35	3.36	3.29	3.36	3.21	3.30
Integrated Computational Materials Engineering Guided Development of Advanced Cast Aluminum Alloys For Automotive Engine Applications	Li, Mei (Ford)	7-39	3.50	3.60	3.60	3.30	3.54
Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines FOA 648-3a	Walker, Mike (General Motors)	7-43	2.92	3.00	3.08	3.00	2.99

Presentation Title	Principal Investigator and Organization	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
High-Performance Cast Aluminum Alloys for Next Generation Passenger Vehicle Engines 2012 FOA 648 Topic 3a	Shyam, Amit (ORNL)	7-47	3.25	3.00	3.08	2.92	3.06
Alloy Development for High-Performance Cast Crankshafts	Huff, Rich (Caterpillar)	7-51	3.36	3.07	3.29	3.14	3.18
Overall Average			**3.27**	**3.22**	**3.26**	**3.16**	**3.23**

Novel Manufacturing Technologies for High Power Induction and Permanent Magnet Electric Motors: Glenn Grant (Pacific Northwest National Laboratory) - pm004

Presenter

Glenn Grant, Pacific Northwest National Laboratory.

Reviewer Sample Size

A total of three reviewers evaluated this project.

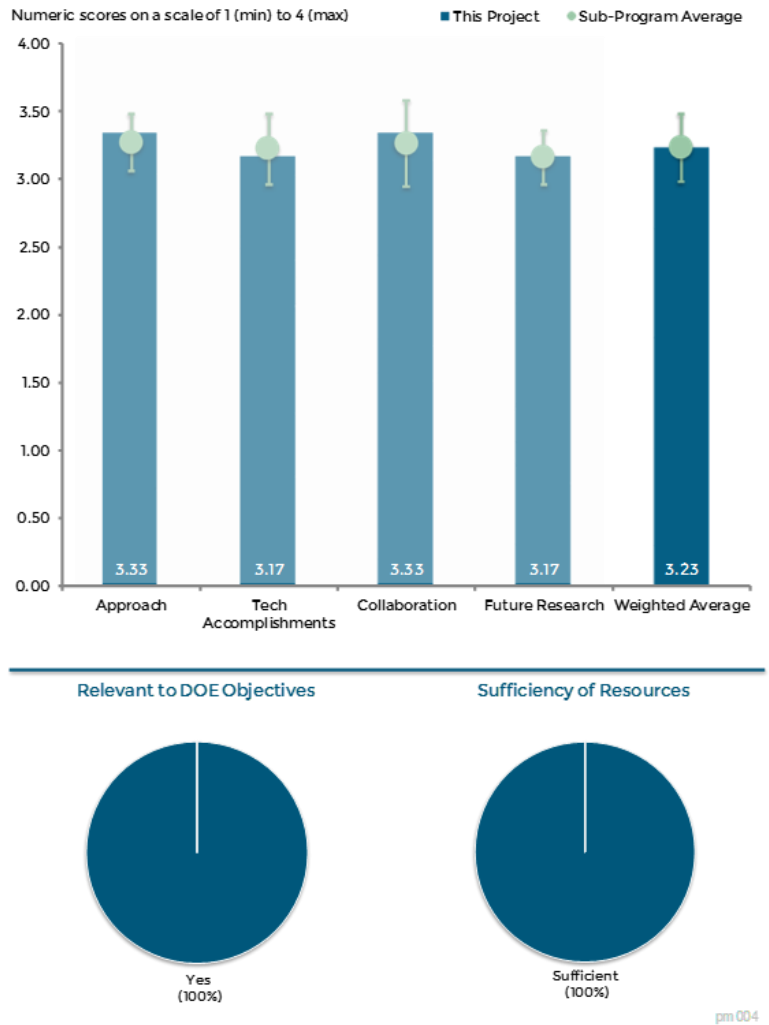


Figure 7-1 Novel Manufacturing Technologies for High Power Induction and Permanent Magnet Electric Motors: Glenn Grant (Pacific Northwest National Laboratory) – Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer believed the project appeared to be targeted to overcoming existing barriers to improved electric motors, particularly to ensure successful manufacturing. Likewise, the structure of the project was deemed focused on specific issues, with activities designed to make incremental progress toward goals. The reviewer noted that the project focus is not only on manufacturing processes, but also on development of related software and that the project also includes a few innovative approaches to resolving materials production issues.

Reviewer 2:

This reviewer praised the cooperative research & development agreement (CRADA) project as well designed, with the potential to reduce the cost of electric motors, thus enabling higher-efficiency propulsion. Terming the project high-value, the reviewer described it as primarily a manufacturing/tooling/fixturing effort, with little discussion of materials composition, structure or properties.

Reviewer 3:

In this reviewer's estimation, the work addresses a key opportunity for reducing the cost of electric motors – a significant barrier to consumer acceptance of electric vehicles. The team is working with lower-cost induction machines, and looking at the efficiency and cost aspects, which the reviewer deemed very important. The reviewer considered the team to be making good use of an existing, well-defined process previously funded by DOE VTO (i.e., friction stir welding) for a new application. This, the reviewer said, is a good repurposing of previously funded DOE work, expanding its reach. It is very important, the reviewer went on, to bridge the gap between research & development (R&D) and manufacturing, which is a goal of this project. The reviewer noted the project acknowledges the need to minimize waste of expensive copper, as a cost reduction effort.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

Most tasks appear on schedule, the reviewer said, noting that there had been a few challenges along the way. The reviewer observed that one area, namely shouldered tool assembly, had been delayed, and is currently scheduled for completion right before the end of the project. The project is still seeing a few issues (e.g., temperature increases during welding), the reviewer continued, but the principal investigator (PI) appears to feel the situation is now largely under control. The project did show successful development of friction taper plug welding as a solution to exit hole issues.

Reviewer 2:

In spite of the barriers and delays, the reviewer observed that progress appeared to have been made in controlling temperature and distortion and exit process. After almost four years, however, the reviewer believed it would have been better to see joining of an actual copper end cap, rather than the mockups. The reviewer also believed it was unclear why aluminum (Al) end caps were being attempted, since those can be overcast via a lower-cost process. Nor did the reviewer feel it had been made clear why there was no iterative plan for General Motors (GM) to test the four fully welded rotors and then come back to Pacific Northwest National Laboratory (PNNL) to further mitigate any potential deficiencies.

Reviewer 3:

Calling the temperature control achievement significant, the reviewer predicted it will be important for high-quality welds and said the team had used an interesting solution for this problem. Likewise, the team has achieved its milestone for temperature control, the reviewer said, and demonstrated the benefit of the applied solution. Noting the challenge posed by dealing with the exit hole left by the friction stir welding tool, the reviewer observed that the team has investigated several creative methods to plug exit holes, devoting a significant amount of work to addressing this challenge. The reviewer believed the team is thinking about the correct factors for the solution to accomplish this (low-cost, manufacturability), and have a realistic view of the opportunities with the dissimilar bonding effort (Al/copper), given the difficulties involved. Copper-copper weld seems to be of greater importance, the reviewer said, with success there seeming to be the most critical.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer noted that the project is proceeding under a CRADA with GM and includes biweekly project conference calls with team members. The reviewer also observed that at the conclusion of the project, the technology will be transferred to GM, which will perform the testing.

Reviewer 2:

There appeared to be good collaboration with GM, in the opinion of the reviewer, as evidenced by $1.3 million in cost share. Even better, in this reviewer’s view, would have been to have had testing of the fully welded rotors prior to the end of the project, in order to allow feedback to the processing experiments, before weld parameters were transferred to the CRADA partner.

Reviewer 3:

Noting that the team is partnering with GM, a key electric drive original equipment manufacturer (OEM), the reviewer predicted that this will assist in eventual commercialization of the technology. Collaboration with GM for testing of final rotors, the reviewer observed, also takes advantage of their expertise. Close collaboration and communication with OEM partner seems appropriate, the reviewer concluded.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that the project team are still trying to resolve issues with the dissimilar material rotor and having difficulties with the geometry of the joint to be welded. It was unclear to the reviewer that a solution will be found. However, the reviewer also observed that the PI (principal investigator) said a solution for this pathway was not critical in view of other solutions that have been developed under this project. The reviewer noted that remaining efforts are focused on the shouldered tool assembly, adding that a lot remains to be completed before the project ends.

Reviewer 2:

Proposed work for remainder of the fiscal year appeared to this reviewer to be reasonable, given the project's completion timeframe. Technology transfer, the reviewer said, is the key aspect of the future work - transferring results with minimal need for additional refinement at GM.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The project is focused on decreasing the cost and weight while increasing efficiency and durability of electric motors, the reviewer said, to enable greater penetration of electric vehicles.

Reviewer 2:

The project does address broader goals for petroleum reduction through lower-cost manufacturing of electric vehicle (EV) components which, the reviewer said, will increase consumer acceptance of these vehicles and achieve petroleum reduction.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources appear sufficient to complete the project this fiscal year, in the reviewer's opinion.

Reviewer 2:

The reviewer did not comment beyond terming resources sufficient.

Reviewer 3:

The reviewer commented that PNNL has achieved the goals set forth for them using the resources given. The project team has made good use of cost share from GM to create resource sufficiency and ensure the commercial partner has made a commitment to the technology.

Materials Issues Associated with EGR Systems: Michael Lance (Oak Ridge National Laboratory) - pm009

Presenter

Michael Lance, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of three reviewers evaluated this project.

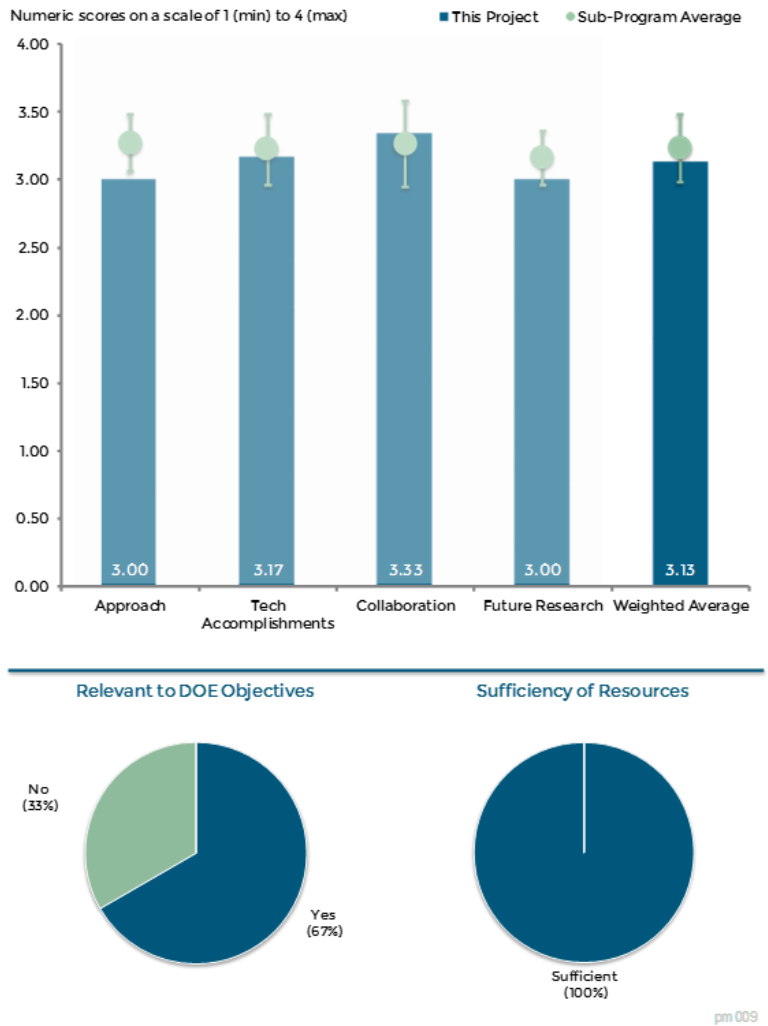


Figure 7-2 Materials Issues Associated with EGR Systems: Michael Lance (Oak Ridge National Laboratory) – Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer wondered if there is a plan to conduct tests to quantify the effects of potassium (K) on exhaust gas catalyst degradation and system performance. The presentation indicated that K may be bad actor, the reviewer noted, and asked if this will be validated in the next two years. Improved engine and validated fuel doping levels, the reviewer said, indicate proper case has been taken to ensure realistic exhaust gas conditions are achieved in accelerated engine testing, which seemed to the reviewer like the best approach to simulate and test the effects of aging on these materials.

Reviewer 2:

The reviewer speculated that the project's dependence on field samples with limited exploration of the impacts of engine operating factors may be a limitation on understanding all aspects of this phenomenon. The focus, the reviewer said, seems to be on understanding the deposition and removal processes within existing cooler designs rather than a broader, total, system-level approach that could consider other engine design changes to solve this problem.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

Though praising this as thorough characterization work, the reviewer was unsure if the actual conclusions were based on the objectives or if alternatives or improvements are being identified.

Reviewer 2:

The work accomplished has been well done, the reviewer said, but discerned no plan with an end goal. What will terminate this project, the reviewer asked.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The project displays excellent collaboration, the reviewer offered, with industry and government and professional agencies providing oversight and support of entire industry.

Reviewer 2:

In the opinion of this reviewer, the collaboration with Modine seemed closer than the interactions with the various engine companies, other than possibly with John Deere. Nor was it clear to this reviewer how the other engine companies are engaged other than in providing some field parts.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer urged that the focus be placed on sodium (Na) and asked if more work could be done on phosphorus (P) in the remaining two years. Also, the reviewer wondered if the various elements studied could be prioritized based on their impact on the various catalyst materials.

Reviewer 2:

It's good, the reviewer said, to see a design-of-experiments-driven investigation planned at Deere. However, the reviewer noted, the work to increase the water content of the exhaust gas recirculation (EGR) gas above that already present is not accompanied by a plan for actually doing this in a vehicle.

Reviewer 3:

According to this reviewer, the difference between model results and experimental data is ascribed to the grove on the uphill side of the wave structure. However, it was unclear if other parameters are evaluated simultaneously with this one or if there is any possibility that the grove is the sole and right contributor. The reviewer also questioned how the deposit thickness profile shown across the wave structure (center is thicker than edge) was explained. Finally, the reviewer suggested examining other geometric parameters, turbulence behavior and temperature gradient/dynamic change with time and along the structure.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

While unsure of the impact of this project on DOE petroleum displacement goals, the reviewer agreed that finding a solution to this problem would benefit the industry. However, if this remains a major fuel economy or warranty problem for the industry, the reviewer went on, the industry is likely to design around this problem and has several design options, including using a more expensive low-pressure EGR loop sourced from downstream of the diesel oxidation catalyst (DOC).

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

In the estimation of this reviewer, there appeared to be significant support provided through collaborations.

Reviewer 2:
The project embodies good tools, creatively used, the reviewer said.

High-Temperature Aluminum Alloys (Agreement ID:24034) Project ID:18518: Stan Pitman (Pacific Northwest National Laboratory) - pm044

Presenter

Nicole Overman, Pacific Northwest National Laboratory.

Reviewer Sample Size

A total of four reviewers evaluated this project.

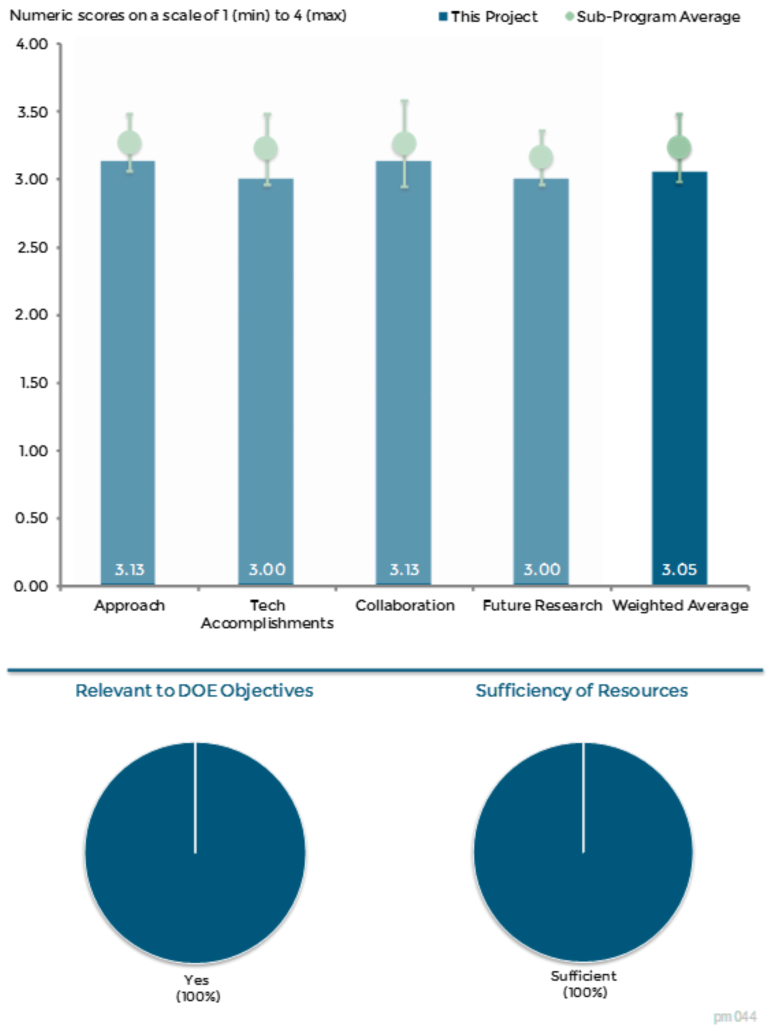


Figure 7-3 High-Temperature Aluminum Alloys (Agreement ID:24034) Project ID:18518: Stan Pitman (Pacific Northwest National Laboratory) – Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

Noting that the main focus of the work was evaluating the properties and microstructure of a consolidated flake Al-based alloy, the reviewer considered that this general focus was adhered to with an adequate presentation of the technical benefits.

Reviewer 2:

Improved materials are needed to increase engine performance and efficiency, the reviewer said, and this project appears to be specifically targeted at solving key materials barriers, namely improved-performance Al alloys, while maintaining reasonable manufacturing processes and cost. Existing high-performance Al alloys, the reviewer observed, have very high manufacturing requirements.

Reviewer 3:

The approach appears to this reviewer to have overcome the barriers identified in the project. This project is essentially complete with the exception of some final fatigue testing, evaluation, cost analysis, and project reporting/publication, the reviewer said, adding that it appeared that ultimate tensile strength (UTS) targets using rapidly solidified (RS) flake material have been met.

Reviewer 4:

The approach to developing new, higher-temperature, higher-strength Al materials was innovative, in this reviewer’s opinion. Likewise, the reviewer found it encouraging to see the process scaled up to 500-pound batches with good tensile properties. However, the reviewer added, it is unfortunate that fatigue testing has been delayed until the final two quarters of the project. The reviewer deemed this lack of knowledge of processing parameters a significant barrier, as was clearly explained by the presenter, and an unfortunate flaw resulting from limited resource availability.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The overall objective of this project, developing Al alloys with enhanced high-energy temperature strength, appears to have been met or exceeded, the reviewer said, this objective clearly fitting within DOE's goals of weight reduction and fuel efficiency. Additional work, to be performed this year, will provide key knowledge on material performance (fatigue testing) and ultimate processing/production costs, the reviewer concluded.

Reviewer 2:

Noting that there had been some issues with completing milestones on the original schedule, the reviewer nonetheless said the project team appeared to be largely back on track, albeit with a lot left to do. The project team has almost reached the ultimate tensile strength target defined by Cummins, the reviewer pointed out, but did run into a barrier with the proprietary materials processing which called for greater microstructure analysis and testing/evaluation.

Reviewer 3:

Although progress was good, the reviewer said, a lot of time and energy had to be expended on characterizing materials to understand the effects of unknown processing parameters. The reviewer acknowledged the considerable challenge of making best progress without processing knowledge, but said the investigators seem to have made progress nonetheless. The phase decomposition seen during processing suggested to this reviewer that the material might have stability issues over longer times at high temperatures. In addition to the 300°C tensile testing, in the reviewer’s opinion, it would have been valuable to include room temperature or elevated temperature tensile testing after extended periods at 300°C (e.g., 100, 200, and/or 500 hours) to evaluate microstructure and properties stability. Fatigue testing would, to this reviewer, also seem to be crucial at an earlier stage of the project. Nonetheless, the reviewer welcomed its t inclusion in future work for fiscal year (FY) 2015. This project, the reviewer concluded, seems to have unique potential if the material is stable at 300°C, and if the economics are favorable.

Reviewer 4:

The reviewer deemed this a very interesting concept. The alloy composition was described as PNNL-developed, but the reviewer heard no substantial explanation of why it was chosen.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer discerned close coordination in this project among the team members, including Transmet (for materials), Cummins (for ultimate application as well as testing and analysis), and the University of California-Riverside (technical advisor, added this year to strengthen the team). The partners are providing cost-share equal to the federal funding, the reviewer noted in closing.

Reviewer 2:

Coordination with Transmet seemed fruitful to the reviewer, who noted some apparent attempt to reverse engineer Transmet's process with regard to cooling rate. This was not presented as intellectual property (IP), the reviewer said, just a lack of sharing of information.

Reviewer 3:

Cummins and partners provided $1.15 million in cost-share, which the reviewer found impressive, but was unclear on the specific role of Cummins in the description of approach or results.

Reviewer 4:

The collaboration with Cummins via a CRADA worked well, in this reviewer’s estimation. It was unclear to the reviewer, on the other hand, why an agreement was not made with Transmet, although the reviewer noted that a lack of knowledge of processing conditions controlled by Transmet impacted the understanding of strength reductions. The reviewer was left wondering if the conclusions regarding phase decomposition related to processing were confirmed by Transmet.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the project is nearing completion and predicted that the relative newness of the technique means further development of the process will certainly be needed before production can be scaled up. Nevertheless, the reviewer said, the concept offers interesting potential.

Reviewer 2:

The project is scheduled to be completed at end of FY 2015, the reviewer observed, and while there is still much left to do, much has already been started since the presentation was prepared. The presenter (whom the reviewer noted was not the project lead) seemed to the reviewer to be confident that the work will be completed on time. An earlier subcontractor issue with equipment caused a 6-12 month delay, the reviewer said.

Reviewer 3:

Noting that the project was at or near its end, the reviewer further noted that no future work beyond FY 2015 was proposed and that work for the remainder of FY 2015 was mostly wrap-up.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

This project, the reviewer said, is aimed at improved materials necessary to increase the performance and efficiency of engines.

Reviewer 2:

The reviewer deemed this project to support DOE's overarching goal, with a caveat, namely, that while the ability to produce high-performance Al alloys certainly meets the DOE lightweight/strength objectives, the process can hardly be considered low-cost, high-volume, because it can only produce very limited sizes and geometries and requires a number of controlled consolidation steps in production.

Reviewer 3:

The project provides knowledge on the potential and value of using RS process to improve the high-temperature tensile strength of Al, the reviewer said, but its contribution to the open literature may be compromised by lack of processing knowledge from partner.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Tasks appeared to the reviewer to have been successfully accomplished with the resources provided.

Reviewer 2:

The reviewer observed that the project is completing.

Reviewer 3:

The presenter did not indicate any concerns about resources, the reviewer said, adding that the project is existing now on carry-over funding from previous fiscal years, likely due to delays in schedule.

Tailored Materials for Improved Internal Combustion Engine Efficiency: Glenn Grant (Pacific Northwest National Laboratory) - pm048

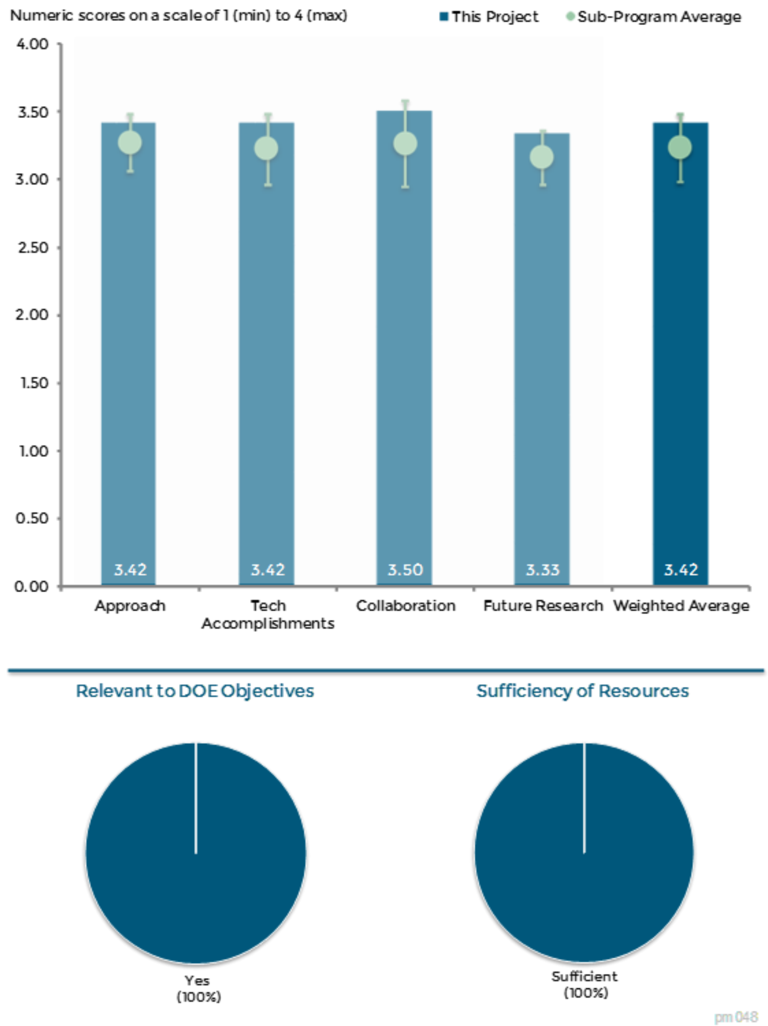


Figure 7-4 Tailored Materials for Improved Internal Combustion Engine Efficiency: Glenn Grant (Pacific Northwest National Laboratory) – Propulsion Materials

Presenter

Glenn Grant, Pacific Northwest National Laboratory.

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer considered the approach to be both interesting and novel. The concept of a tailored local microstructure in a cast component, the reviewer said, lends itself to a number of potential improvements in end-use performance. The properties being evaluated and the reasoning behind the research path the reviewer found to be very well presented. The reviewer suggested that from a process cost standpoint, proving the utility of the process in a regular production cycle may be a large barrier, but said demonstrating the feasibility of dedicated robotics seemed to address this issue.

Reviewer 2:

The reviewer considered the idea of demonstrating this on the oil hole region very interesting. It seemed to this reviewer that all relevant considerations had been included for the completion of the work. The time is short, the reviewer noted, but it appeared the project is close to completion.

Reviewer 3:

This project is nearly complete, the reviewer noted, the team having explored and developed the FSP for fatigue life enhancement in an Al alloy and a steel alloy. The team has demonstrated the potential improvements in fatigue life at high temperature and the potential benefit of localized FSP on a crankshaft surrogate, the reviewer observed.

Reviewer 4:

The project seemed well-designed to the reviewer and with potential to enable cast materials to have the fatigue life of forged components and thus lower cost. The ability to locally improve fatigue resistance of surface features that concentrate stress would be of significant value, in the reviewer's opinion, and evaluating both Al and micro-alloyed steel is the right approach. It might also be of interest, the reviewer speculated, to evaluate cast irons and determine what happens with the larger graphitic particles where a surface is exposed to friction stir processing. The reviewer pointed to the lack of fatigue testing of Al specimens with friction stir-modified surfaces, instead of mini specimens from the modified region as a weakness of the project.

Reviewer 5:

Controlling the grain size of surface and near-surface modified regions to improve high peak pressure and cycle life by varying well-known parameters appeared to this reviewer to be well thought-out. However, testing conditions, especially temperature, did not appear to this reviewer to display the same level of thoughtfulness. A more systematic approach to determine the appropriate temperature range to probe, the reviewer asserted, must be used to obtain results that accurately represent in-use performance.

Reviewer 6:

The reviewer summarized the approach as examining the existing alloy base and modifying the material microstructure to obtain improved performance parameters using friction stir processing (FSP) to modify surface and near-surface microstructures. The reviewer said the project had cost-effectively used coupons to test and modify conventional materials, noting that sufficient adjustments were available to fine-tune the microstructure by using a variety of knobs. All activities are focused on achieving improved processing to reduce the effects of fatigue on the material, the reviewer concluded.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The team has exceeded their goals for fatigue performance with Al and established a base for exploring the fatigue effects of different microstructures achievable with FSP, the reviewer said, and have also demonstrated positive results on wrought steel.

Reviewer 2:

Fatigue studies seemed complete enough, in this reviewer's view, to conclude the improvement of properties suggested.

Reviewer 3:

The project has identified an excellent application of FSP processing, the reviewer said, namely, drilled holes can be strengthened significantly if FSP treatment is applied. Manufacturing challenges remain for fillet development and the integration of newer, higher-performance materials, the reviewer noted. Steel tooling costs, while high, are not cost-prohibitive, the reviewer went on, adding that tooling could be embedded in the manufacturing process. The reviewer observed that FSP can take steel to a wrought form and porosity problems can also solved using FSP, making it appear a good approach to solving material failures occurring in the weakest link.

Reviewer 4:

Correlations of microstructures and properties provide clear evidence, the reviewer said, of the benefits of the proposed approach to tailoring microstructures. The electronic backscatter diffraction analysis, although well done in the reviewer's opinion, is probably inadequate for delving more fully into the local mechanisms. More in-depth analysis at transmission electron microscope (TEM)-level length scales would, the reviewer speculated, likely provide information critical to the observed fatigue response and may be an opportunity for future work.

Reviewer 5:

The identification of failure modes related to machining journal oil ports is significant and appropriate for improving a manufacturing process, the reviewer asserted, but, as the reviewer noted in the Approach section, careful selection of temperature conditions does not appear to have been addressed systematically. Beginning with an unrealistically low temperature for testing, the reviewer said, delayed results that should have been obtained under more realistic conditions. Likewise, the reviewer added, a second round of testing at 200°C did not appear to have been sufficient and 300°C is now planned. The reviewer noted that the investigators do not know where the break point of temperature versus cycle life will occur. Also, the reviewer said, thermal shock effects should be included in this analysis to simulate in-use conditions.

Reviewer 6:

Technical accomplishments were good, in the reviewer's estimation. The demonstrated improvements in fatigue life indicate promise, the reviewer said, although the geometric constraints of the process limit its application. However, for localized regions - such as those where holes have to be drilled, the process offers an intriguing option to reduce related stresses, the reviewer said, adding that it would have been good to see fatigue life results on Al specimens whose surface had been modified, rather than mini-specimens taken from only the friction stir-modified region. It was unclear to this reviewer why the mini specimens were used. The reviewer also noted that for the Al materials, the effect appeared to lessen at temperatures above 150°C, which the reviewer predicted will be a concern for the targeted components (heads, blocks). The reviewer found it curious that the finer-grained structure showed better fatigue life at the higher temperatures, as the presenter noted, and anticipated such a trend would not continue at 250°C for Al. The ability to reduce notch effects was of particular value, the reviewer said and urged it be further explored in an actual cast steel structure.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer praised the team for presenting a very thorough scientific and practical approach when pinpointing specific benefits to the internal combustion engine (ICE) cycle, such as work on actual crankshafts following coupon-level observations. This, the reviewer said, is testament to a good collaborative effort that includes elements of industry, academia and the national laboratory partners.

Reviewer 2:

Partnering with an OEM such as GM on this project is critical, in the opinion of this reviewer, because an OEM partner can provide essential feedback necessary to keep the project relevant to their production processes.

Reviewer 3:

The project has an excellent level of cost share (50/50) from GM, even without a CRADA, the reviewer said, which indicates an area of activity of significant interest to the industry partner.

Reviewer 4:

GM's participation on delivering component pieces to validate the studies will be useful and shows good collaboration, in the opinion of the reviewer.

Reviewer 5:

The reviewer termed industry (GM) coordination with the academic partner North Texas University (UNT) adequate for the size of the project.

Reviewer 6:

The reviewer foresaw collaboration and follow-on work with GM leading to a further understanding of the FSP process, how it can impact microstructure and how it may best be applied in industry. It was unclear to this reviewer, however, what has come out of the creep fatigue work performed by UNT.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

Noting that the program is completing and presently on carryover funds, the reviewer emphasized that the good rating offered was not indicative of any real shortcomings.

Reviewer 2:

The two primary future areas of research to further understand the benefits of controlling grain size are appropriate and should be explored, in this reviewer's opinion.

Reviewer 3:

The question of the material condition after processing through heat treatment and in hard-to- reach areas seemed appropriate to this reviewer.

Reviewer 4:

The reviewer recommended the project continue to focus efforts, if appropriate, on engine materials that fail most frequently, adding that quenching and other material hardening approaches should be compared to FSP where appropriate.

Reviewer 5:

In the estimation of the reviewer, ongoing collaboration with GM for three-dimensional (3D) development, part fabrication, component testing and commercial development provide a good path forward.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

Higher-performance components allow operating conditions beneficial to overall efficiency, the reviewer noted, adding that this program targets several specific areas for improvement and leaves the work open to additional applications.

Reviewer 2:

Improving the durability of OEM powertrains to 150,000 miles requires this type of research to lower the cost of providing the required durability, the reviewer said.

Reviewer 3:

Improving the life of rotating components should lead to innovative applications with improved efficiency, in the view of this reviewer.

Reviewer 4:

Higher-performer engine materials lead to engines that perform at higher temperatures, in turn leading to higher-efficiency engines, the reviewer pointed out.

Reviewer 5:

Localized strengthening of material in critical regions of components may yield positive results in weight reduction and performance, the reviewer said, thus leading to improved efficiency.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
This project has sufficient resources to accomplish the stated goals, the reviewer said, but additional future resources may be needed to further understand how the surface modifications will be impacted by temperature.

Reviewer 2:
Noting that the project is nearing completion, the reviewer said no shortcomings were identified.

Reviewer 3:
Good use was made of in-kind contributions from GM, in this reviewer's opinion.

Reviewer 4:
To this reviewer, it seemed this project will be a race to the finish, but the reviewer expressed the belief the team had the needed resources to complete it.

Reviewer 5:
Resources appear sufficient for this effort, the reviewer said.

Reviewer 6:
Project has been essentially completed using resources available throughout its life, the reviewer observed.

High-Temperature Materials for High-Efficiency Engines: G. Muralidharan (Oak Ridge National Laboratory) - pm053

Presenter

G. Muralidharan, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of five reviewers evaluated this project.

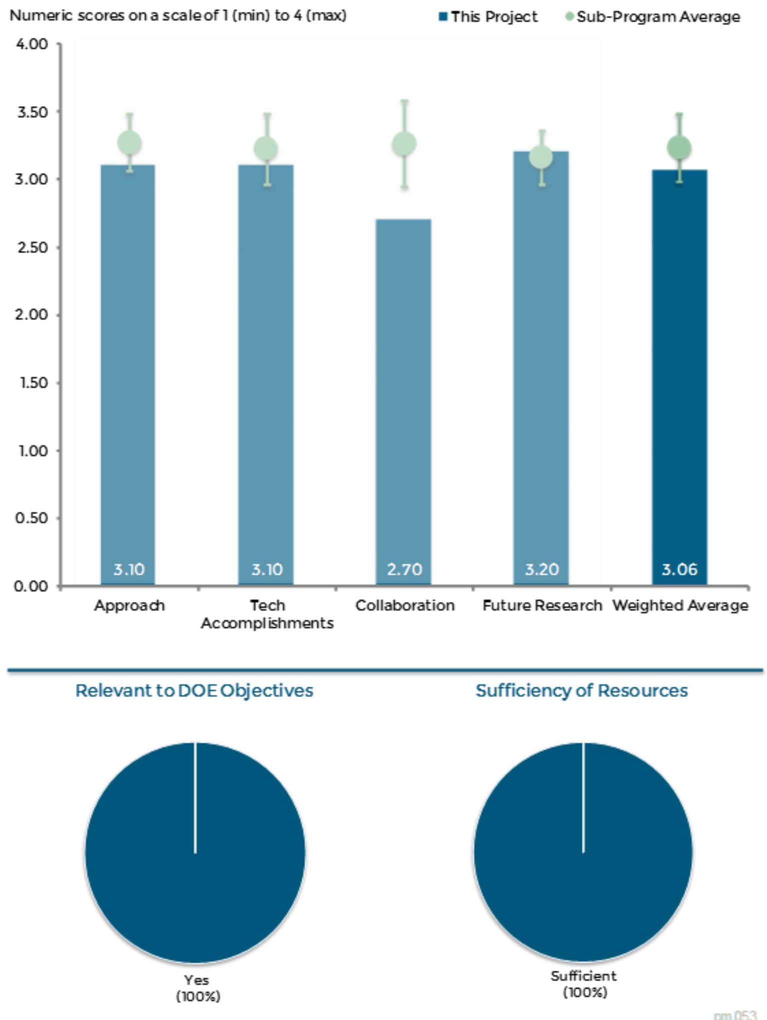


Figure 7-5 High-Temperature Materials for High-Efficiency Engines: G. Muralidharan (Oak Ridge National Laboratory) – Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

Nickel-based metals are high-cost alloys, the reviewer observed, so alternatives are being developed using ICME techniques. Any new alloy must meet both performance properties and cost parameters and ICME is a good, low-cost and efficient approach to developing new, affordable materials, the reviewer said.

Reviewer 2:

The reviewer summarized the project objective as to use ICME principles to develop lower-cost materials with desirable properties, including high-temperature strength, oxidation resistance and improved fatigue properties, a key goal being the achievement of high cycle life while reducing costs by reducing use of nickel (Ni) and cobalt (Co). The reviewer deemed the approach (i.e., identify material properties, correlate properties with microstructural characteristics, identify compositions while aiming to reduce composition contribution from Ni) to be reasonable given the objective of developing cost-effective valve materials for high-temperature (950°C) applications.

Reviewer 3:

The reviewer deemed the simulation-based composition development certainly to be an acceptable approach and regarded the principal investigator (PI) as clearly knowledgeable in this area. The results to date, the reviewer noted, depend largely upon oxidation behavior via mass loss testing. There was little mechanistic information presented, the reviewer said, noting the PI’s continued references to alloys undergoing higher levels of mass loss as fading away, which the reviewer found somewhat puzzling. Fading away how, the reviewer asked. By spallation, the reviewer presumed, requesting that more information be provided to clarify the evaluation and results.

Reviewer 4:

Noting that an integrated computational materials engineering (ICME) approach was cited at the beginning of the presentation, the reviewer nonetheless discerned little connection between the ICME results and the experimental findings. An outcome from this work, the reviewer opined, could be an assessment of where ICME tools worked and did not work to guide future research. Other than a JMatPro result at the beginning of the presentation, the reviewer also saw no connection made between the oxidation resistance or strength and any modeling results.

Reviewer 5:

To the reviewer, the approach looked reasonable. A more fundamental study was suggested by this reviewer to understand the tradeoffs among composition, oxidation status, its impact on alloy performance, and the aspects that will impact scale analysis.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The project is on track to complete in FY 2016, the reviewer said, having used an enabling technology (ICME) to cost-effectively and efficiently develop a solution. Several alloying elements, the reviewer observed, appear to weaken the alloys to a point where they cannot meet the performance parameters. The reviewer noted that the project team had developed higher-performing, lower-cost alloys (490-2 and 161-12M) based on lessons learned from oxidate alloys and that ICME had helped map the solution. Likewise, it was determined that alloying element additions must carefully balance oxidation resistance with high-temperature strength, the reviewer concluded.

Reviewer 2:

Progress has been good, in the reviewer’s estimation, with the identification, design and development of two alloys manufactured by Carpenter. The Oak Ridge National Laboratory (ORNL) alloys appeared to show improved yield strength but not improved oxidation resistance, the reviewer said.

Reviewer 3:

Development of new potential alloys seemed to this reviewer to be making progress. The major focus, however, seemed to be on making low-cost alloys by reducing Ni content. The reviewer wondered, however, what factors other than the nickel-chromium levels and what elements other than iron and titanium, which were mentioned, are being added to this low-cost alloy. Refractory alloys or rare earths, the reviewer pointed out, are generally apt to make Ni seem cheap by comparison. The presentation lacked data necessary to establish the cost structure of the new materials.

Reviewer 4:

Noting that the prior year's emphasis was on oxidation resistance, the reviewer saw little progress having been made, except perhaps to achieve equal oxidation resistance in more expensive materials. This relationship, the reviewer said, could have been made clearer to the objective of the project - higher oxidation resistance at the same strength level, or lower cost for equivalent material, etc. The final objective was not obvious to this reviewer from the presentation or discussion.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer commented that it was unclear how the mentioned potential collaborators (i.e., Carpenter and Cummins) will contribute to the project.

Reviewer 2:

The reviewer noted that parties that had a potential stake in the research were identified, but had made no actual collaborative effort with regard to funding contributions; the DOE funding level being described as 100%. The PI provided some basis for in-kind contributions from Carpenter Tech, the reviewer conceded, but found it difficult to believe that any future program proposed with a similar cost-share breakdown would be deemed agreeable at the proposal review stage.

Reviewer 3:

Collaborations were mentioned with both Carpenter and Caterpillar, the reviewer said, adding that it would be nice to know there are applications, specific properties, lower cost, or something else they are interested in. The reviewer acknowledged that such information may be sensitive, but it is nonetheless related to the objective of the project and should be clarified.

Reviewer 4:

The reviewer saw only limited collaboration with partners, because most work is done at the laboratory due to the limited budget and requirement to use the ICME infrastructure at ORNL.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

Terming the PIs extremely knowledgeable in Ni-based alloys and associated development, the reviewer said this is not a ground-up type of R&D effort, as the established knowledge base is likely carried over from other industries and will find future applications outside of the VTO. At present, the reviewer continued, the proposed research aims to develop an alloy capable of satisfactory strength and oxidation-resistance levels at 950°C, the results of which have a milestone scheduled in June.

Reviewer 2:

Downselect and complete testing of most promising alloys candidates was stated by this reviewer.

Reviewer 3:

With the experiments run so far and their results, the reviewer said, there seems to be a direction to optimize alloy and concept. The reviewer called attention to the fact that this assessment was made based on the presented experimental results, as no ICME feedback was highlighted to assist the acceleration of alloy development.

Reviewer 4:

The reviewer discerned an emphasis on oxidation resistance for future work but said it was unclear how the design of new alloys for this purpose will be accomplished. The reviewer also viewed the path to achieving the oxidation resistance goals coupled with tensile strength as rather vague.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

Higher-temperature materials can be used in more efficient engines, the reviewer noted and said this project will help accomplish that objective.

Reviewer 2:

Higher-performing alloys will be used to produce higher-efficiency engines, the reviewer asserted.

Reviewer 3:
Improved high-temperature strength properties along with reduced oxidation problems and reduced cost are key components of the DOE objectives, this reviewer said.

Reviewer 4:
Calling the criticality of this type of work to vehicle technologies debatable, the reviewer nonetheless agreed that advanced Ni alloys are certainly of interest to the DOE mission.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
With material given by Carpenter and support of Caterpillar, this project seemed to the reviewer to be adequately funded.

Reviewer 2:
Funding appeared to the reviewer to be sufficient for the proposed scope of work.

Reviewer 3:
Based on the presentation and the confidence expressed by the PI, the resources seemed sufficient to this reviewer, who noted that testing had begun at 950°C, the upper bound stated in the project objective. However, funding levels seemed cloudy to the reviewer, as the project is 50% complete, having spent $330,000, and anticipating $190,000 in FY 2015, which the reviewer presumed was planned carryover into FY 2016.

Reviewer 4:
Acknowledging that it was at best a guess, the reviewer said the resources were sufficient, given the progress to date, the relatively low funding level and the remaining work.

Enabling Materials for High-Temperature Power Electronics (Agreement ID:26461) Project ID:18516: Andrew Wereszczak (Oak Ridge National Laboratory) - pm054

Presenter

Andrew Wereszczak, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of two reviewers evaluated this project.

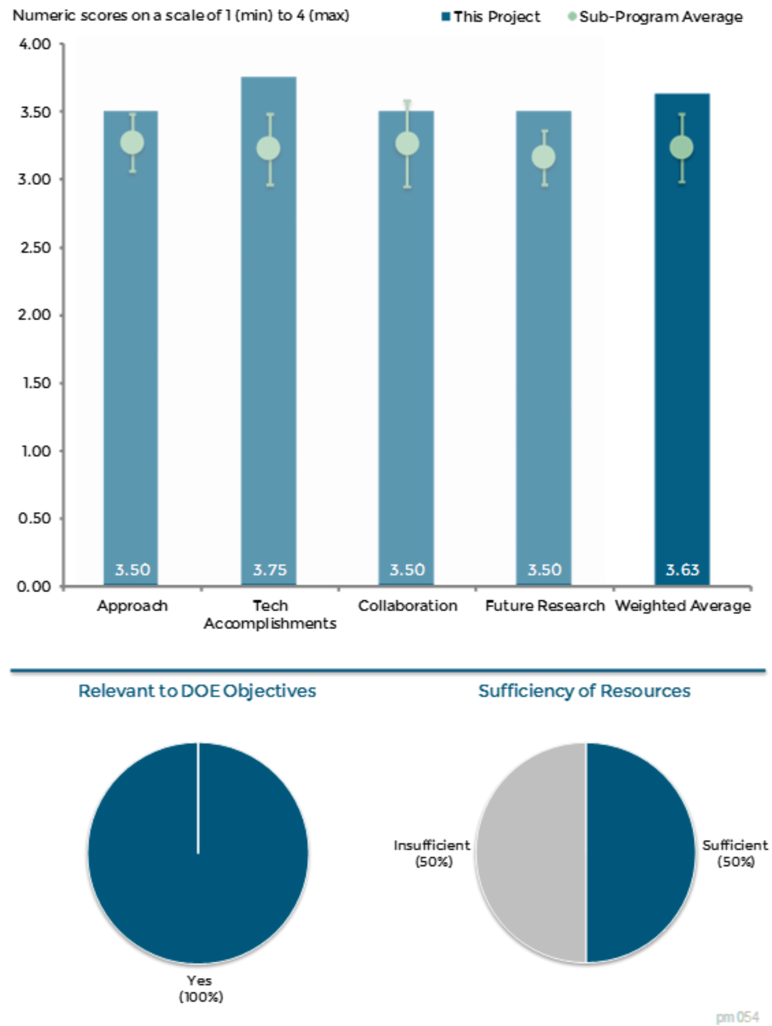


Figure 7-6 Enabling Materials for High-Temperature Power Electronics (Agreement ID:26461) Project ID:18516: Andrew Wereszczak (Oak Ridge National Laboratory) – Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This reviewer observed that the Propulsion Materials program is solving a difficult issue in power electronics, as 200°C-capable, low-cost materials would significantly decrease the cost of improved-efficiency power electronics. The reviewer lamented that funding limitations have restricted the investigation of a high-potential solution. If this solution is indeed of significant potential, the reviewer urged that DOE continue the effort fully to assess that option, because leveraging solutions from a parallel approach provides opportunity to solve more than one issue with a developed solution.

Reviewer 2:

Agreeing that this work addresses the overall Electric Drive Technologies (EDT) goals of reduced size, weight and cost, the reviewer believed the PI could have provided a more detailed explanation for the reasoning behind the 200°C target for power electronics (PE) components, as some audience members may not be clear on why that was established. The reviewer further described the work as combining materials and EDT expertise at ORNL and called the parallel efforts with PE and electric motor (EM) materials a reasonable approach, leveraging learnings between efforts. ORNL/ National Renewable Energy Laboratory (NREL) collaboration, the reviewer concluded, takes advantage of core capabilities at both labs.

Reviewer 3:

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer noted that the project team has achieved or is on track to achieve all key milestones for this 12-month period, except the dielectric work, and has provided a good technical reason for the no-go on that work. Moreover, the reviewer went on, the project team has made good use of model material to simulate semiconductors in an effective and low-cost way for residual stress work. Terming findings about differing coefficient of thermal expansion (CTE) materials and delamination important to determine parameters for use of sinterable silver as bonding agent, the reviewer pointed out that clear results were demonstrated through simple residual stress analysis for a complex problem.

Reviewer 2:

Solder failures were created in order to perform failure analysis, the reviewer noted, and reliability of interconnections will lead to optimized array sizes. This reviewer commented that using Invar as a surrogate is a good cost savings approach, because Invar has properties similar to those of silicon (Si) semiconductor material. The reviewer noted the onset of delamination in 10mm, 18mm, and 22mm diameter, but not in 10mm diameter. The reviewer also reported that the project team can effectively estimate the maximum allowable bonding size in bonding materials, which has been successfully completed). Further, periodic array of smaller sizes to avoid delamination was also observed.

Question 3: Comments on Collaboration and Coordination with other institutions:

Reviewer 1:

The reviewer praised the team for having a good and interesting list of collaborators, covering a wide spectrum of suppliers in this industry. The group covers key players in the supplier industry for the technologies being studied (sintering, polymers, etc.), the reviewer went on. There is also collaboration with OEMs, the reviewer noted, albeit indirectly through dissemination of results in the literature.

Reviewer 2:

The project embodies significant collaboration given its small budget, the reviewer said, observing that, in reality, the project entails two national laboratories (ORNL and NREL) working together.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

Proposed future work appeared reasonable to the reviewer, given the approach outlined (and the fact the project is just over half done), and includes important dissemination of results. The reviewer pronounced the project team on a path to successful completion with this future work.

Reviewer 2:

The reviewer noted that proposed future work includes placing crosscutting work in the public domain and disseminating results of this research. Shear strength has been the recent focus, the reviewer observed, and determining if thermal cycling reliability is negatively impacted will be investigated in future work.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

This work does support DOE petroleum displacement objectives, in the reviewer's view, because it will enable development of smaller and more cost-effective electric drive technology components. These, in turn, will improve the market acceptance of electric-drive vehicles and increase their petroleum displacement effects, the reviewer concluded.

High-temperature materials and high-temperature operation of EMs provide opportunity for higher-efficiency EMs.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer reiterated the estimation of resources appearing to be sufficient to accomplish the work outlined by the team.

Reviewer 2:

The reviewer noted that high-potential material is not being assessed because of funding limitations in the Propulsion Materials program.

Biofuel Impacts on Aftertreatment Devices (Agreement ID:26463) Project ID:18519: Michael Lance (Oak Ridge National Laboratory) - pm055

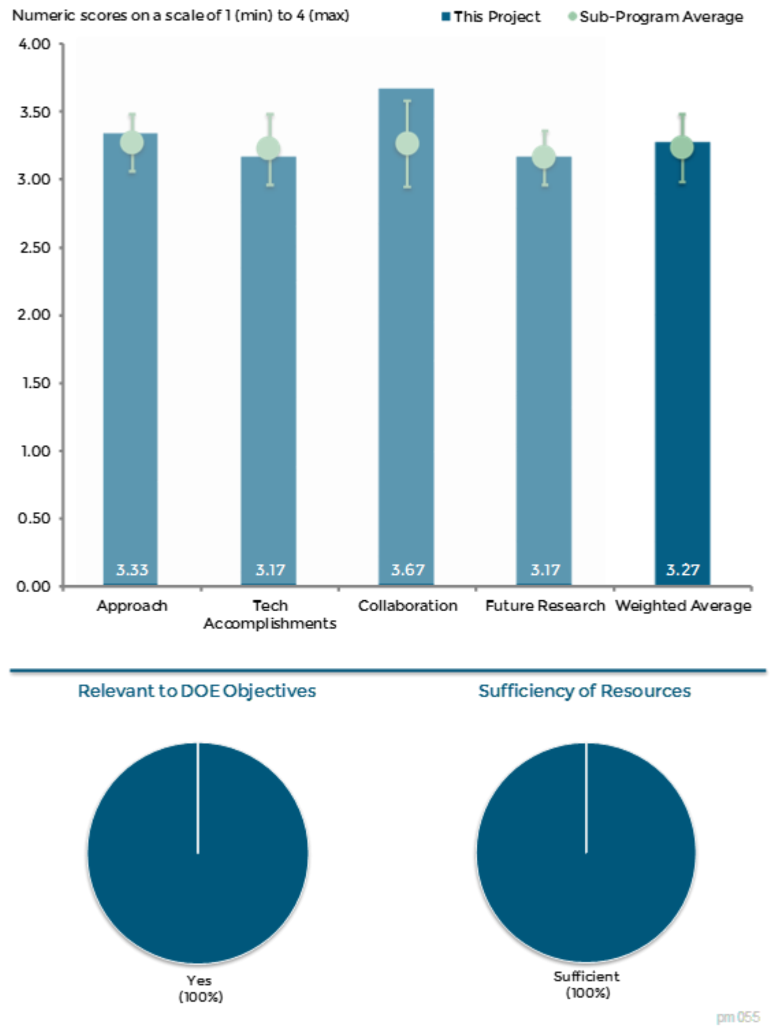


Figure 7-7 Biofuel Impacts on Aftertreatment Devices (Agreement ID:26463) Project ID:18519: Michael Lance (Oak Ridge National Laboratory) – Propulsion Materials

Presenter

Michael Lance, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The project includes a well-designed evaluation plan, in the view of this reviewer, who expressed some concerns regarding the lack of replicate aftertreatment tests, while recognizing the cost impacts of replicate tests.

Reviewer 2:

The reviewer commended the presentation for its review of data and analysis which the reviewer called very good and comprehensive. The reviewer was, however, left with a question concerning the solubility of sodium sulfate and possibility of its migrating through the filter and causing downstream impacts. It would be better, this reviewer opined, to look at various engine duty cycles that better represent real operation to understand if real operation will result in different conclusion than the experimental work shows.

Reviewer 3:

The reviewer was unsure whether the computational fluid dynamics (CFD) considered particles, noting that velocities in front of the peaks would be highest and thus impinged with the greatest number of deposits. This, the reviewer said, would lead to the suspicion that this is where the deposit layer would be thickest. On the backside of the peaks, the reviewer went on, there would be a pressure drop, meaning less flow and thus less opportunity for deposit particles to contact the wall. The stickiness of the particles, in the reviewer’s opinion, is not being correctly considered.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

The reviewer did not see characterization of the thermo-physical properties of the deposits, which was a stated objective. High flow rates seemed to the reviewer to be a logical approach to reducing deposits by introducing enough shear at the boundary to overcome the stickiness of the particles or to erode the deposits like wind on a mountain peak. High flow rates combined with proper cooler design seemed to be the best approach to this reviewer, who further recommended avoiding peaks and associated pressure drops. The reviewer also noted that removing large build-ups at infrequent intervals could cause more damage downstream to other, more critical engine components.

Reviewer 2:

Deeming this really important work not only for the biodiesel industry but also as it applies to other fuel and oil additives, the reviewer cautioned that the impacts of Na on the complete system, rather than just the DOC, remains to be explained. Likewise, separating the impacts of Na and K, apart from the demonstrated impacts of P, also needs to be addressed, the reviewer said.

Reviewer 3:

The presented data show good, integrated analytical approach, the reviewer said, which seems to be well designed and fundamentally solid.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer observed that all industry leaders appear involved in at least an advisory role with many active participants.

Reviewer 2:

The project boasts a good team, in the view of this reviewer, with the Manufacturers of Emission Controls Association (MECA) balancing the National Biodiesel Board.

Reviewer 3:

The presentation showed, in the opinion of the reviewer, that this project has the support of industrial actors and can be used to solve industrial problems.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer regarded the issue as being clearly identified, the path forward outlined and capable of addressing the key questions.

Reviewer 2:

Proposed future work includes detailed experiments involving many variables that affect hydrocarbon properties, the reviewer noted. However, the CFD model will have to be improved to properly model and correlate deposit location and thickness. The reviewer further noted that cooler geometry is not one of the listed variables.

Reviewer 3:

The reviewer observed that the well-known influence of P on aftertreatment devices seems to cloud the assessment of Na and K in this work and was left wondering how this would be dealt with in future work.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

If biodiesel is to be accepted by the automotive industry, the reviewer said, it is important that fuel specifications are adequate to protect engines from unintended impacts of contaminants from the biodiesel process. This work, in the reviewer's opinion, is an important contribution to ensuring appropriate specifications that balance manufacturing costs and vehicle protection.

Reviewer 2:

This work is emission related and its impact will be felt directly through aftertreatment systems' lifetime performance, the reviewer predicted, thus this work will support identification of problems, quantification of impacts and may facilitate future fuel specification development.

Reviewer 3:

The reviewer believed the project's probable contribution to a significant effect on fuel efficiency goals is limited. Slight improvements, the reviewer said, will not have a major impact. Improved combustion might have the largest impact on cooler fouling, in the reviewer's opinion, but combustion of fossil fuels will produce hydrocarbon exhaust gas.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found resources, timeline and target to be well aligned and apparently reasonable based on the project target and objectives.

Reviewer 2:

The reviewer expressed some concern about the conclusions being drawn from the single engine test but recognized the cost impacts of replicate tests.

Applied Integrated Computational Materials Engineering for New Propulsion Materials: Charles Finney (Oak Ridge National Laboratory) - pm057

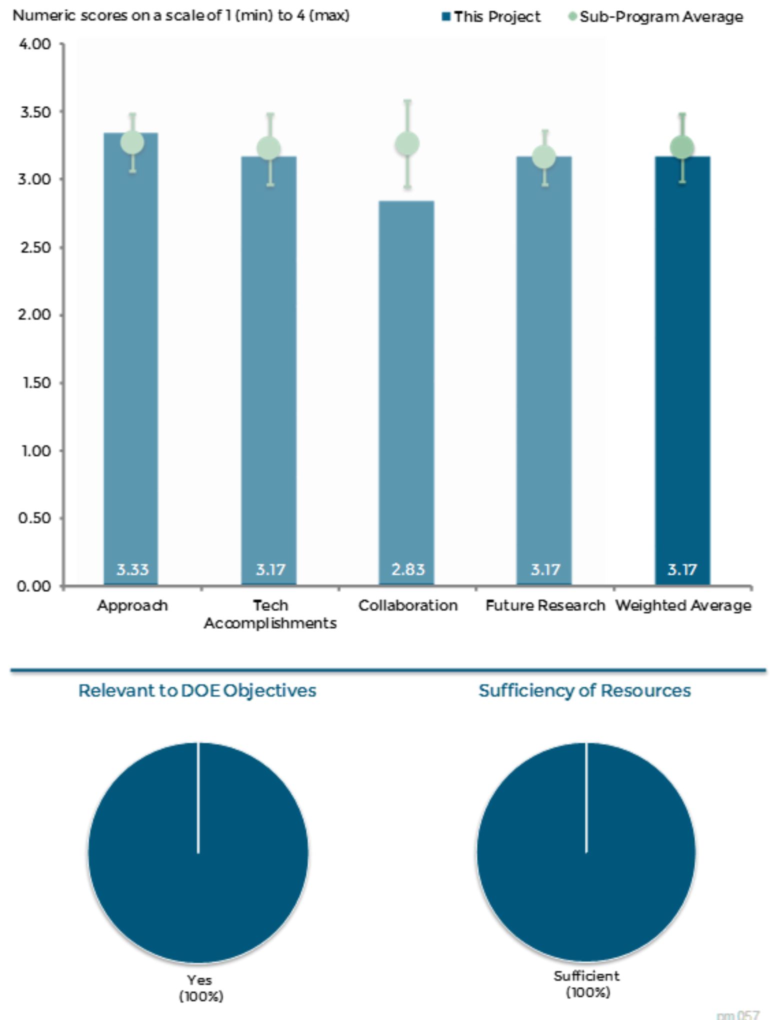


Figure 7-8 Applied Integrated Computational Materials Engineering for New Propulsion Materials: Charles Finney (Oak Ridge National Laboratory) – Propulsion Materials

Presenter

Charles Finney, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer found this work interesting and expected it would provide interesting results on material properties needs in the future. However, the reviewer added, the materials being studied, particularly the castings, will exhibit a range of properties locally in their geometry. The reviewer expressed a desire to see this accounted for in some manner. The reviewer further observed that coupling of manufacturing simulation tools with in-service modeling has been one of the innovations recently published by OEMs

Reviewer 2:

The presentation was directed almost entirely to Task 4, Modeling of Heavy Duty (HD) Engines, while the other three tasks were briefly summarized (and were previously reviewed), the reviewer observed, thus this review was based solely on Task 4. The reviewer described the approach as using CFD to estimate the thermal environment for peak cylinder pressures (PCP) operating points and finite element modeling (FEM) to evaluate effects of pressure and thermal environment on engine cylinder components. While it may be valuable and novel to incorporate CFD in this task, the reviewer went on, it does not utilize the principles of ICME significantly (i.e., multiscale integration). However, the coupled approach (CFD and FEM) appeared to the reviewer to be sensible and useful no matter what it is called. The reviewer considered that a much more thorough explanation of the intended limited goals would be appropriate, along with a concerted presentation of the next steps with an emphasis on the critical areas to study next.

Reviewer 3:

This project, the reviewer said, comprises four different tasks that are not related to each other. The approach for each task is different, the reviewer continued, and the first three tasks were presented last year. The fourth task – the focus of the presentation – is related to the materials for HD engines at higher operating temperatures, the reviewer concluded.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:

This is a big project, the reviewer said, which seems to be quite productive in generating new material choices and setting up guidance on material limits.

Reviewer 2:

The reviewer noted that most subtasks under Task 4 had been started, with the exception of FEM (at the time the slides were submitted), but believed there was insufficient information to evaluate progress with respect to spending.

Reviewer 3:

The reviewer observed that the task predicted the peak stresses in the engine cylinder at 190 and 300 bar using both CFD and FEM simulation packages, but noted the analysis is not a coupled simulation. Nor was the simulation being compared to actual conditions in engines, the reviewer said, urging that efforts be made to measure the stresses or temperatures in actual working engines and compared to the simulation. This, the reviewer believed, will give assurance that the future predictions on material requirement are valid.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer acknowledged the listing of project partners but believed collaborations on the use of ICME tools to develop these material limits could be expanded, particularly by leveraging ICME projects from OEMs.

Reviewer 2:

The reviewer characterized the team of collaborators as consisting of several well-qualified institutions, but saw very little discussion of how these collaborators are contributing to the project. More specifically, the reviewer said it was unclear which collaborators are directly contributing to Task 4, the subject of this presentation. The reviewer recalled that this had been pointed out last year by others.

Reviewer 3:

This reviewer also felt that the actual contributions of the many collaborators mentioned were not clearly defined for this task.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer had no additional suggestions other than the ones provided above.

Reviewer 2:

The research proposed under the current funding plan demonstrates a good path forward for the remainder of this project, the reviewer said, and the materials property and characterization subtask should provide validation for the modeling effort. However, the reviewer saw no discussion of work planned as follow-on to this project.

Reviewer 3:

The plan includes a coupled modeling effort and identified the material property gaps, which the reviewer considered relevant, as the performance of the material is being simulated. However, the reviewer called for the plan to include some validation of simulation results.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:

The reviewer confirmed that the task overviewed in the presentation, with the tasks, support the DOE's objective.

Reviewer 2:

In part due to the methods development and in part due to the specific application, the reviewer said, the project does appear to address the DOE objectives.

Reviewer 3:

The ICME approach is identified as the faster way to develop new materials and solutions for improving fuel efficiency, this reviewer offered.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources should be sufficient, the reviewer believed, although finding it difficult to determine remaining funds for Task 4.

Development of Advanced High-Strength Cast Alloys for Heavy-Duty Engines: Rich Huff (Caterpillar, Inc.) - pm059

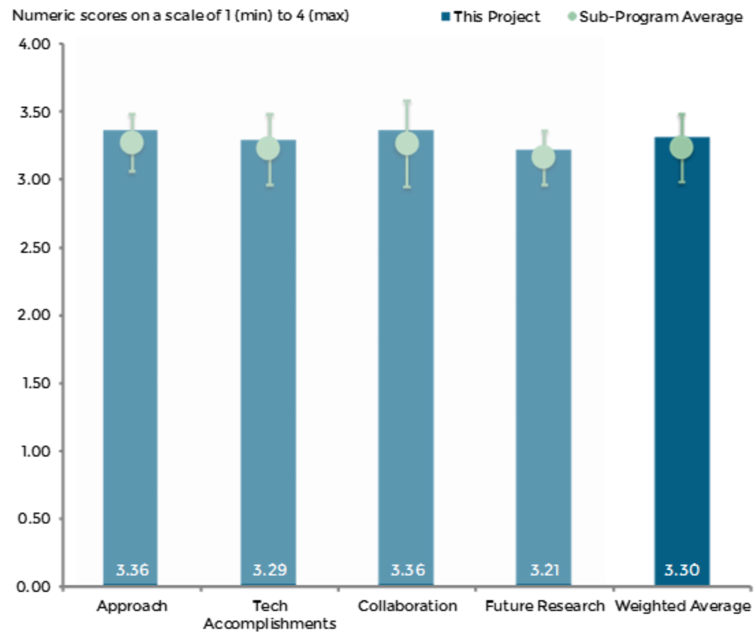
Presenter

Rich Huff, Caterpillar, Inc.

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.



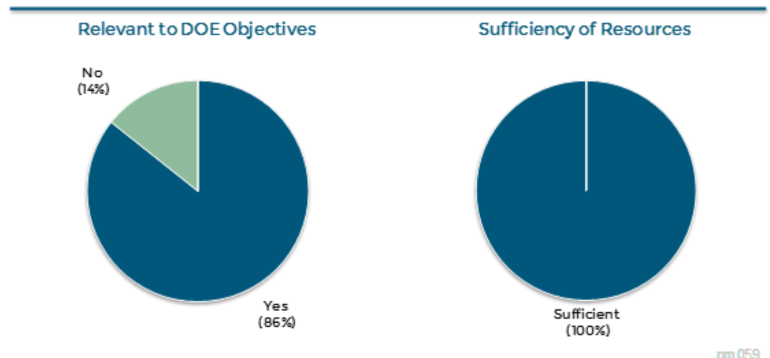


Figure 7-9 Development of Advanced High-Strength Cast Alloys for Heavy-Duty Engines: Rich Huff (Caterpillar, Inc.) – Propulsion Materials

Reviewer 1:

This is a well laid out project, with good achievements and their integration of models with the experimental work would be a major accomplishment, in the view of this reviewer.

Reviewer 2:

The project is using new methods to overcome old limitations on a problem which has a big impact on the major features of the engine, said this reviewer.

Reviewer 3:

This is a very challenging project, in the reviewer's opinion, particularly the ICME element. Noting that cast iron is a complex structure extremely sensitive to processing, the reviewer said the team seems to be making good progress in understanding the role of various elements on particle nucleation through serial sectioning. The approach taken by this team is sound, the reviewer added.

Reviewer 4:

The reviewer found the project approach to be clearly and concisely described and noted the very well-planned use and implementation of ICME for initial alloy determination, moving on to experimental melts of compacted graphite iron, as well as the novel and traditional characterization methods. The systems design chart, the reviewer said, summarizes the approach nicely.

Reviewer 5:

This is year three of this long project, the reviewer noted, calling the approach well defined, with the ICME approach being followed to develop cast iron material for engine blocks.

Reviewer 6:

The reviewer characterized the program as combining a competent team with very defined applied goals, both of which, the reviewer said, provide obvious benefits. The graphite morphology and associated analyses the reviewer found very interesting, noting that a number of advanced techniques were used. Despite the comprehensive set of casting trials that were carried out, the application of ICME (or its benefit) was not entirely clear to this reviewer, beyond the desire to refine the microstructure. Certainly with QuesTek as a partner, the reviewer said, there is no lack of understanding of ICME application, but the selection of castings and what specifically was guided by the ICME approach the reviewer believed were only addressed in very general terms. However, the reviewer concluded, the large spread of castings provides ample opportunity to relate microstructures with complex casting/composition relationships.

Question 2: Comments on Technical Accomplishments and Progress:

Reviewer 1:

The material exceeds compacted graphite iron (CGI) significantly, the reviewer noted; thus the target seems to be reached.

Reviewer 2:

Notwithstanding that several milestones are slightly delayed from the proposed schedule (or nearly so), the reviewer said, the progress has been considerable. The diverse set of evaluations performed thus far the reviewer termed impressive.

Reviewer 3:

The reviewer praised this project for its outstanding development and use of imaging tools to visualize macrostructure and provide data to support future model development. The reviewer noted the numerous references to model development, validation and comparisons, calling them key outcomes for DOE.

Reviewer 4:

The reviewer said the 3-D tomography work seemed to be a groundbreaking step in better defining the graphite microstructure of these materials. The activity to evaluate inoculant effects on nodule size and distributions the reviewer also believed will be of great value if it can eventually be published. Likewise, the reviewer deemed getting a better grip on nucleation and growth of the austenite and graphite will be valuable to the larger community – even if not all project goals are met – again provided the new understanding is published.

Reviewer 5:

The contractor goal of obtaining a fatigue endurance limit of 214 Pascal (MPa), the reviewer believed, is driving the research and development. The reviewer also noted substantial progress in performance requirements, alloy design, production and evaluation. Likewise, the reviewer discerned good progress in implementation of existing models, design and diagnostics associated with use of inoculation to understand and advance the eutectic coupled zone. Casting tasks and material evaluation are developing well, the reviewer concluded.

Reviewer 6:

The reviewer noted the very extensive characterization of the graphite morphology, and said the information on nucleation sites for graphite and austenite is excellent, predicting that it will be useful in controlling the final structure and hence the properties.

Reviewer 7:

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:

The reviewer praised the collaborations with Questek, Argonne National Laboratory and the University of Alabama-Birmingham as very good, noting that the role of each was clear and each partner had a substantial and important role.

Reviewer 2:
The reviewer described the assembled team as having a very diverse and complementary set of skills, from industrial/applied knowledge to ICME implementation to advanced characterization.

Reviewer 3:
The reviewer saw good evidence of interaction among the team members. Feedback and model enhancement based on the experimental results, in the reviewer's opinion, provide benefits for future development work and a rapid route to commercialization of the improved understandings.

Reviewer 4:
Caterpillar has assembled a very capable team of collaborators, said this reviewer.

Reviewer 5:
The team consists of university, federal national laboratory and supplier base representatives, according to the reviewer, with the role of each participant well defined and good progress being made in the project.

Reviewer 6:
The reviewer did not fully understand how the collaboration worked nor what expertise was shared.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
Noting that a considerable body of work regarding evaluation of the casting trials is still planned, the reviewer believed the progression of the program seemed to have organized the basic elements in a manner strongly indicating a successful basis for conclusions.

Reviewer 2:
The project offers a satisfactory approach to the road ahead, in this reviewer's opinion.

Reviewer 3:
Future task development is described in sufficient detail, the reviewer said, to demonstrate a high likelihood of meeting project objectives on time.

Reviewer 4:
The focus in future is to validate the models, in this reviewer's view.

Reviewer 5:
Thermal conductivity needs more attention, in this reviewer's estimation.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The project definitely supports DOE's petroleum conservation objective, the reviewer said, since it offers potential weight savings of say 100 pounds or increased PCP, which could bring up to a 1% increase in fuel economy.

Reviewer 2:
The reviewer described the project focus as being on elevating the performance of ICE components to allow more efficient operating conditions.

Reviewer 3:
Improved material properties, the reviewer pointed out, can enable more efficient diesel engines, leading to reduced petroleum consumption. Just as important, in this reviewer's opinion, improving ferrous metal models can speed the development of new alloys for further engine development.

Reviewer 4:
The project is exploring, developing and implementing ICME, alloy development and characterization techniques, yielding materials that will have improved properties, the reviewer observed, thus leading to improved strength capable of handling increased demands in engine environments with minimal additional costs.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The work speed seemed reasonable to this reviewer.

Reviewer 2:
The complexity of the remaining work is considerable, the reviewer said, but the program has demonstrated a distinct level of competence in the work carried out thus far. It is reasonable to assume, the reviewer concluded, that the program will progress as planned.

Reviewer 3:
The project appeared to this reviewer to be well funded and progress to date in the reviewer's opinion has been excellent with roughly half the DOE funds expended to date. The reviewer called attention to a note in the slide intended solely for reviewers indicating that there is insufficient budget and planning to reconstruct the 3-D primary solidification front. It appeared to the reviewer (Future Plans) that it is proposed to achieve this using x-ray radiography and/or computed tomography. If the task involves hardware development as well as unique data processing, the reviewer believed it is probably outside the scope of this project but that it would be a useful component of a follow-on project.

Integrated Computational Materials Engineering Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications: Mei Li (Ford Motor Company) - pm060

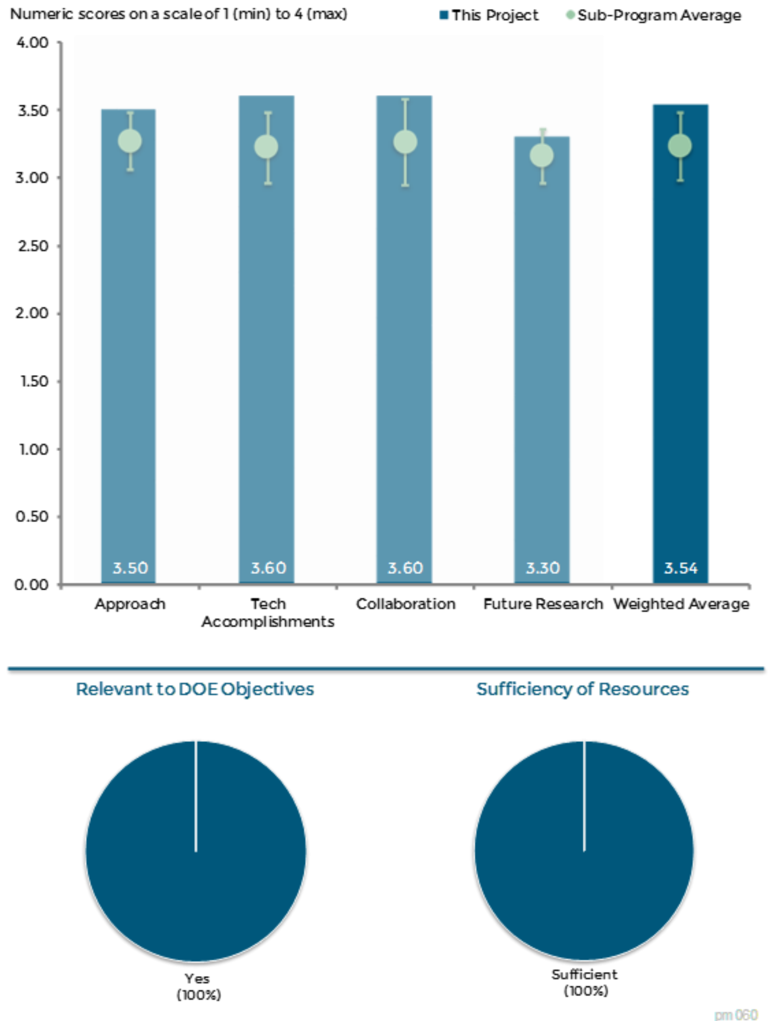


Figure 7-10 Integrated Computational Materials Engineering Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications: Mei Li (Ford Motor Company) – Propulsion Materials

Presenter

Mei Li, Ford Motor Company.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

This is a great team and approach, the reviewer said, and the project is well planned and strongly focused on meeting the program objectives.

Reviewer 2:

The approach is specifically targeted at overcoming existing barriers, the reviewer affirmed, and focused on developing higher-performance (stronger) and more cost-effective alloys to address high temperatures. The project, the reviewer added, is also developing the design data and modeling tools necessary for success.

Reviewer 3:

Terming the technical challenge significant given the high diffusion rates of essentially all the possible element combinations, the reviewer was happy to see the use of ICME tools and experiments quickly to select a possible route to accomplish the objective.

Reviewer 4:

There appeared to this reviewer to be a good understanding of ICME regarding the tools or their deployment on an industrial scale, but in-depth characterization of some of the observed microstructures (specifically, the secondary precipitation phase), the reviewer noted, was not presented. Perhaps, the reviewer speculated, this development is in the intellectual property (IP) regime, so this omission was intentional. But one of the real benefits of ICME, the reviewer pointed out, is feeding existing microstructural evolution back into the modeling loop in order to optimize subsequent simulations or experimental matrices. The reviewer would have been very interested in seeing this approach outlined in detail.

Reviewer 5:
The project team considered the basic strengthening mechanisms in Al alloys and explained the shortcoming of the current alloys, the reviewer summarized. The approach is well planned, the reviewer went on, however, strength in Al alloys is derived from precipitation hardening and the major barrier for high-temperature stability is the coarsening of precipitates. It is necessary to identify precipitates which are stable at high temperatures (~300°C) if the strength has to remain stable, the reviewer cautioned. The project, the reviewer said, is working on some of the precipitates, which may be stable at these temperatures but this aspect was not reviewed in detail.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
This project seemed to this reviewer to have made a lot of progress toward development of alloys that would improve over those currently in use.

Reviewer 2:
The reviewer noted great progress toward achieving the material goals and deemed this work very encouraging.

Reviewer 3:
During the past year, the reviewer noted, project has appeared to build on its previous successes and has seen greater high-temperature performance due to improved materials selection and production processes, as well as having continued to move forward with data analysis process modeling. The reviewer's concern is that there still appears to be a great deal of work left to do before project completion in early 2016.

Reviewer 4:
Noting that the project is reported to be about 70% complete and scheduled for completion in February 2016, the reviewer cited substantial progress made in alloy design, casting process modeling and heat treatments, yielding increasingly higher yield strengths. However, the reviewer would have liked to see more discussion of progress on the gap analysis (Task 3) and a more complete description of the models employed.

Reviewer 5:
The presentation, the reviewer observed, concentrated on alloy development and heat treatment in coupon-level testing and the presenter explained that the ICME efforts are also ongoing. The reviewer noted that the analysis indicates the properties of the new alloy seem to meet expectations. While the complete heat treatment cycle was not provided, the reviewer assumed the high- temperature stability of precipitates had been considered and recalled that the presenter also indicated that variable cooling rates and their effect on precipitation were considered for the model.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
Noting that the project includes Alcoa, Nemak, Magma and the University of Michigan, all with specific duties under the project to supplement the work of an OEM (Ford as Project Lead/PI), the reviewer added that the project is also taking advantage of significant facilities available among the project participants.

Reviewer 2:
Collaboration seemed productive to this reviewer, given the fatigue results, microstructural assessment, and ICME tools.

Reviewer 3:
The reviewer cited an impressive team that shows a clear path to commercialize any resulting materials and to understand the costs of finished parts from any new materials.

Reviewer 4:
The collaboration was clearly described in the presentation, the reviewer noted, adding that the team has solid contributors in all aspects of the project.

Reviewer 5:
The roster of project collaborators covers the full spectrum of the supply chain, with material and service providers as well as Tier 1 suppliers and an OEM involved, the reviewer said.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The plan for future work is a reasonable progression from past and current work, according to this reviewer.

Reviewer 2:
The proposed future direction seems useful, in the estimation of this reviewer.

Reviewer 3:
There is a great deal of work left to accomplish in the eight months remaining in the project, the reviewer pointed out, including some steps that clearly require previous steps be completed first. The reviewer cited the PI’s apparent confidence that all required activities can be completed on time. However, the reviewer drew attention to the identification of a prototyping effort considered an important addition to the project, one which may result in a six- to eight-month extension. Accordingly, the reviewer said, it would not be surprising if the completion dates for some required activities were similarly extended. The reviewer concluded by noting the PI’s having indicated that future work in this area will be focused on ever-increasing engine temperature operational environments.

Reviewer 4:
The reviewer heard little discussion of how the model gap analysis is being done, although the task is listed in the future plans. This gap analysis, the reviewer said, is a key output for DOE.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
The project is clearly focused on higher-performance materials for challenging operating environments, to improve engine efficiency, the reviewer summarized.

Reviewer 2:
The reviewer predicted that higher efficiency engines will be achievable with the success of this project.

Reviewer 3:
If the project continues to be successful, particularly in meeting the cost goals, the reviewer offered, this can result in design options for much more efficient spark-ignition engines. Depending on the results, the reviewer projected, this might also provide options for much lighter passenger car diesel engines, which would be a major contribution to meeting the DOE petroleum displacement goals.

Reviewer 4:
The reviewer summarized the project work as providing progress and leadership on implementation of ICME principles, advancing heat treatments that enable modification of precipitation microstructure, and as having developed new testing procedures (for thermomechanical and thermal fatigue) and explored new Al alloys.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

At this time, resources appear sufficient, in the opinion of this reviewer, who added that this will require continued monitoring if additional efforts identified are added to the project's scope, resulting in an extension.

Reviewer 2:

To this reviewer, the time to fully explore the cost of alloy replacement seemed short. However, the reviewer said an estimate would be satisfactory to justify the potential use of these new alloys.

Reviewer 3:

The reviewer cited the PI’s expressed confidence that sufficient resources are available to complete all tasks, but cautioned that there may be a shortfall in resources as the project winds up, as it was unclear to the reviewer that all tasks can be completed on schedule and within budget.

Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines FOA 648-3a: Mike Walker (General Motors) - pm061

Presenter

Mike Walker, General Motors.

Reviewer Sample Size

A total of six reviewers evaluated this project.

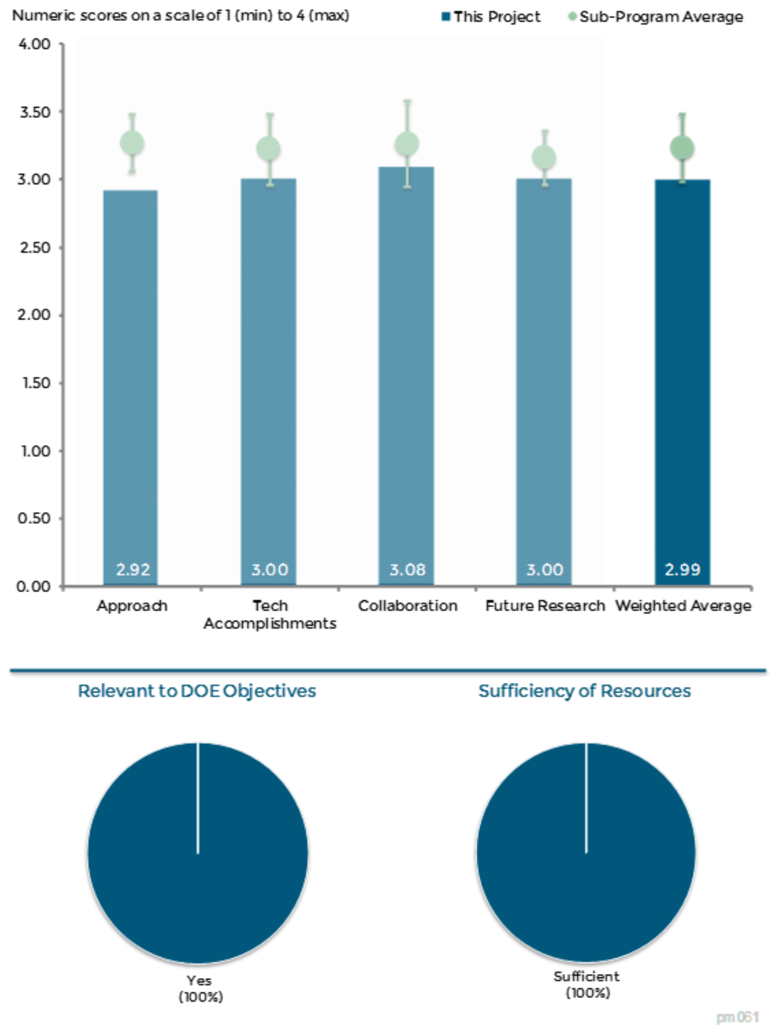


Figure 7-11 Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines FOA 648-3a: Mike Walker (General Motors) – Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

Saying the material temperature is given by its thermal conductivity, the reviewer called for the thermal conductivity to come into the evaluation process at an earlier stage and in a more systematic way, adding that there also seemed to be a need for better tools for thermal conductivity predictions.

Reviewer 2:

The approach seemed to this reviewer to be to evaluate minor changes to the existing chemistry based on the effect on the same classes of resulting precipitate phases. The reviewer thought a wholesale increase in strength properties using this approach seemed unlikely, particularly when the phases that form (omega, theta, beta) are not stable phases to begin with. The reviewer speculated that the modified chemistries being evaluated may be hiding some more transformational approach due to IP issues. The program can certainly be successful, the reviewer said, provided the target is not set excessively high, and the knowledge gained from this type of study is important to future ICME development.

Reviewer 3:

The reviewer described the research in this project as a combination of requirements development driven by metallurgical experts, modeling for alloy composition and properties, castings, advanced materials evaluation and model validation.

Reviewer 4:

Noting that consideration had been given to precipitate stability at 300°C, the reviewer also observed that alloying elements were chosen to provide stable microstructure at 300°C. Alloy selection was conducted in the previous year and characterization was the focus for Year 2, the reviewer noted in conclusion.

Reviewer 5:
The reviewer considered that this project is doing very good work, but found it unclear what the mechanism is for using all the developed information to improve the predictive models. Nonetheless, the reviewer saw clear indications of model improvement initiatives.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
Calling the approach fundamentally right in view of the available modeling capabilities, the reviewer noted that how much better the engine becomes depends on how good thermal conductivity is. The reviewer also observed that very little information was given on concept alloys, which if successful, will not be available on the market.

Reviewer 2:
Noting that alloy characterization is closely tied to the model development, the reviewer said good understanding of alloy interactions had been achieved even though the required strength has not. The reviewer also pointed to the project team's having identified some of the gaps in the ICME approach.

Reviewer 3:
Although microstructural characterization and the relationship of microstructure to thermomechanical processing was evident to the reviewer, who commented that the use of TEM micrographs in the presentation comparing evolution but shown at different scales/orientations (Slide 9) as not informative. The reviewer said density functional theory (DFT) calculations should cover a much wider composition space than was presented, but acknowledged that that might have resulted from IP considerations.

Reviewer 4:
The modeling teams appear to have made good progress in model development and development of initial alloy designs, the reviewer said, and castings and validation steps had also been completed. While opining that results are moving in a positive direction, the reviewer perceived that key targets had not yet been achieved.

Reviewer 5:
The modeling discussed appeared to the reviewer to be focused on single material characteristics, which the reviewer cautioned can lead to sub-optimization. The strength versus ductility tradeoff did not appear to the reviewer to be adequately predicted from the modeling efforts. Noting that cost constraints were mentioned, the reviewer saw no discussion of the cost assessment process.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
Calling the project collaborators a good team, the reviewer found it particularly refreshing to see recyclability considered in the development process.

Reviewer 2:
GM, the reviewer said, has developed a strong team of collaborators making use of industrial and academic expertise for modeling and materials characterization.

Reviewer 3:
The team is composed of competent members, the reviewer said, but found their individual responsibilities unclear. Identifying Northwestern and QuesTek as the major collaborators, the reviewer described them as related in a number of respects, despite their being listed as two distinct entities. The range of computational and characterization results indicated to the reviewer that multiple contributors are providing input.

Reviewer 4:
The reviewer expressed the opinion that an Al producer would have strengthened the team and, if successful, would have supported commercialization.

Reviewer 5:
Despite the absence of a material provider on the team, it possesses enough expertise to develop new alloy compositions, in the view of this reviewer.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The simulation approach allows a wide selection in the first step, thus minimizing the risk of failure, according to the reviewer, who noted that the approach nevertheless will inevitably require several loops.

Reviewer 2:
To this reviewer, it seemed that the proposed future research was to refine the existing approach. Although it may prove successful, the reviewer allowed, inclusion of other potential alloying elements – not necessarily the more expensive variety such as scandium or silver mentioned in the presentation – would likely have a much more beneficial effect.

Reviewer 3:
The reviewer believed the future work list looked like a concerted exploratory material development push. It was not clear to the reviewer, however, what the plan is to evaluate and meet the team's go/no-go milestone.

Reviewer 4:
To the reviewer, the planned future work represented a logical progression for the project. Parametric studies, DFT analysis and multiple castings with evaluation, the reviewer predicted, will yield a substantial amount of useful data. However, it was not clear to the reviewer that the sample space will be sufficiently covered to permit identification of the right mix of materials and processing to meet project goals.

Reviewer 5:
Noting that the strength of Al alloys is derived from precipitation hardening and that the major barrier to high-temperature stability is the coarsening of precipitates, the reviewer said it is necessary to identify precipitates which are stable at high temperatures (~300°C) if the strength is to remain stable. In the reviewer's opinion, the project did not review this and appears not to plan to evaluate it in future work.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
Lower weight and/or higher loading will significantly support fuel economy improvements, the reviewer said.

Reviewer 2:
The goal of the program is to allow the more widespread deployment of lightweight materials in more demanding environments, the reviewer observed, adding that both serve to increase ICE efficiency.

Reviewer 3:
The reviewer described the project effort as working toward developing Al with higher strength properties through a combination of modeling, experiment, characterization and validation.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The program appears to have spent roughly a third of the funds as the halfway point nears, the reviewer observed. Based on the reported time extension and the delays associated with program startups, the reviewer believed the project funding level appeared to be tracking with progress.

Reviewer 2:

Calling the per-year resources reasonable, the reviewer cautioned that several loops should be expected, making a long project duration vital for success.

Reviewer 3:

Resources appeared sufficient to this reviewer, who found it unclear what had caused the delay in Budget Period 2 and how that affected the overall project goals.

High-Performance Cast Aluminum Alloys for Next Generation Passenger Vehicle Engines 2012 FOA 648 Topic 3a: Amit Shyam (Oak Ridge National Laboratory) - pm062

Presenter

Amit Shyam, Oak Ridge National Laboratory.

Reviewer Sample Size

A total of six reviewers evaluated this project.

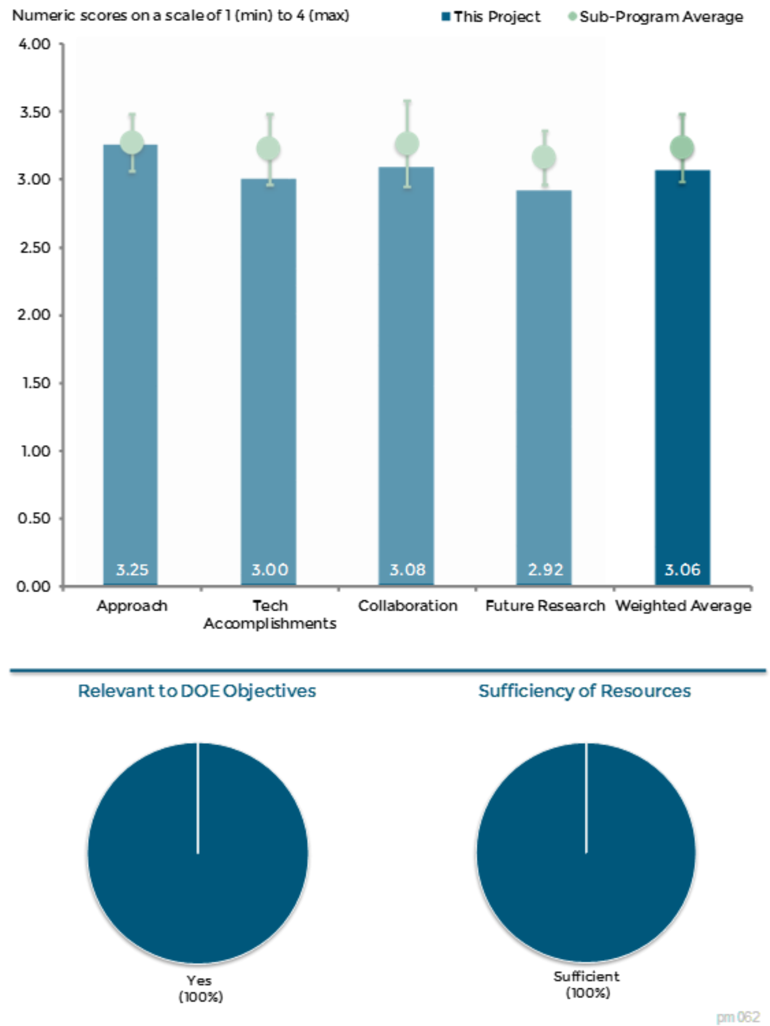


Figure 7-12 High-Performance Cast Aluminum Alloys for Next Generation Passenger Vehicle Engines 2012 FOA 648 Topic 3a: Amit Shyam (Oak Ridge National Laboratory) – Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer characterized the approach as a good program plan and a focus on assessment and integration of models.

Reviewer 2:

The team is certainly competent, the reviewer said, however the goals are somewhat convoluted. The reviewer saw the obvious goal as producing an alloy with higher capabilities, but was unclear as to how the ICME tools are being incorporated into subsequent heats. The characterization work the reviewer found impressive, but asked how it was being leveraged. Likewise, the reviewer queried whether there is specific distribution of theta phase, for instance, that is expected to prove more stable through nucleation strategies such as heat treatments or composition changes. How the microstructural evolution is being modeled, the reviewer continued. Based on what has been learned in the project, the reviewer believed that redefining the goals using microstructural terms rather than final properties would be very interesting.

Reviewer 3:

The reviewer characterized the approach as involving an iterative, coordinated effort of property development from ICME modeling geared toward surpassing limitations of properties and processing in the Gap Analysis. The approach, the reviewer added, includes engine testing, cost analysis and commercialization planning.

Reviewer 4:

The reviewer noted simply that the project is still in an early phase.

Reviewer 5:
Noting that down-selection is based on microstructure, the reviewer pointed out that composition is unknown, and that using only customized heat treatment may not insufficient or lead to an incorrect conclusion.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
In the opinion of this reviewer, this ORNL work is focused more on assessment of the ICME toolset than solely on developing a target material. This, the reviewer said is more likely to provide the detailed gap assessments that will result in long-term achievement of the DOE goals for the materials area.

Reviewer 2:
The reviewer noted progress in model development used for the preliminary design of new alloy compositions.

Reviewer 3:
The reviewer reiterated that the project is still in an early phase.

Reviewer 4:
A better understanding of the intricate balance of properties in the alloys of interest is being gained, the reviewer said, but the down-selection process seemed to the reviewer to need a more definite set of criteria.

Reviewer 5:
Reiterating that strength of Al alloys is derived from precipitation hardening and that the major barrier to high-temperature stability is coarsening of precipitates, the reviewer underlined the necessity of identifying precipitates which are stable at high temperatures (i.e., approximately 300°C) if the strength is to remain stable. The project has carried out analysis based on this approach, the reviewer said, but this has not resulted in an economical alloy; rather the alloy has proved expensive due to the alloy additions. Although justification was provided for concentrating on 30 micron dendrite arm spacing, the reviewer agreed, there was no plan provided for the contingency of larger-than-planned grain size.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
A good project team, the reviewer said.

Reviewer 2:
Following establishment of the CRADA, the collaboration team is complete, the reviewer noted, appearing to provide all the necessary expertise for successful implementation of the tasks.

Reviewer 3:
To this reviewer, it seemed that the industrial partners were largely slated for consultation rather than hands-on contributions. Castings, the reviewer noted, are still being produced using lab-based conditions, although Nemak is supplying master alloys. Thus the reviewer assumed that complementary analyses show casting results from ORNL heats are similar to industrial castings.

Reviewer 4:
Collaboration seems heavily focused on Fiat Chrysler Automobiles (FCA) and Nemak, the reviewer observed, but the roles of the other participants are less clear.

Reviewer 5:
The team has interaction with many partners who can adequately address the technical issue, the reviewer stated.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The plan for future work is logical, the reviewer said, and should lead to sufficient information development to determine if the approach can converge on materials that meet project targets.

Reviewer 2:
The plan looked very good to the reviewer, who believed it did not include enough time for loops and remarked the lack of heat conductivity feedback in the development loop

Reviewer 3:
The proposed future research is the critical step, in this reviewer's estimation - proving that the basis for improved alloys is adequate. It will be incumbent upon the PI, the reviewer went on, to provide ample evidence that this is the case, although the planned full-scale trial may help in that regard.

Reviewer 4:
The reviewer did not find the flow chart of future work helpful, because there seemed to the reviewer to be no exit or end to the work.

Reviewer 5:
The number of new alloys proposed seemed large (25) to this reviewer, who predicted that this would reduce the scope of characterization.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
There is huge fuel economy improvement potential in stronger materials, the reviewer asserted.

Reviewer 2:
Light-weighting is certainly an issue, in the reviewer's opinion. This program, the reviewer said, seeks to make use of advanced, lightweight materials more cost-effective, which will naturally result in a larger fraction of lightweight materials being deployed.

Reviewer 3:
The project directly addresses the need to produce Al alloys capable of higher- temperature strength and fatigue properties using the ICME principles, conventional experimental techniques and model validation, the reviewer stated.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The target is difficult to reach, the reviewer stated, but time is probably more limiting than money.

Reviewer 2:
Resources appeared ample to this reviewer for the ongoing and planned future work.

Reviewer 3:
The program, the reviewer said, is presented as being 38% complete. Noting that of the $3.5 million DOE share, $2.1 million will be spent at the end of FY 2015, the reviewer doubted that the burn rate could sustain the program through FY 2017, as stated. How the cost share from the industrial partners fits in, the reviewer

conceded, may explain this, although the commitment seemed vague when presented as approximately $2000 K.

Alloy Development for High-Performance Cast Crankshafts: Rich Huff (Caterpillar, Inc.) - pm065

Presenter

Rich Huff, Caterpillar, Inc.

Reviewer Sample Size

A total of seven reviewers evaluated this project.

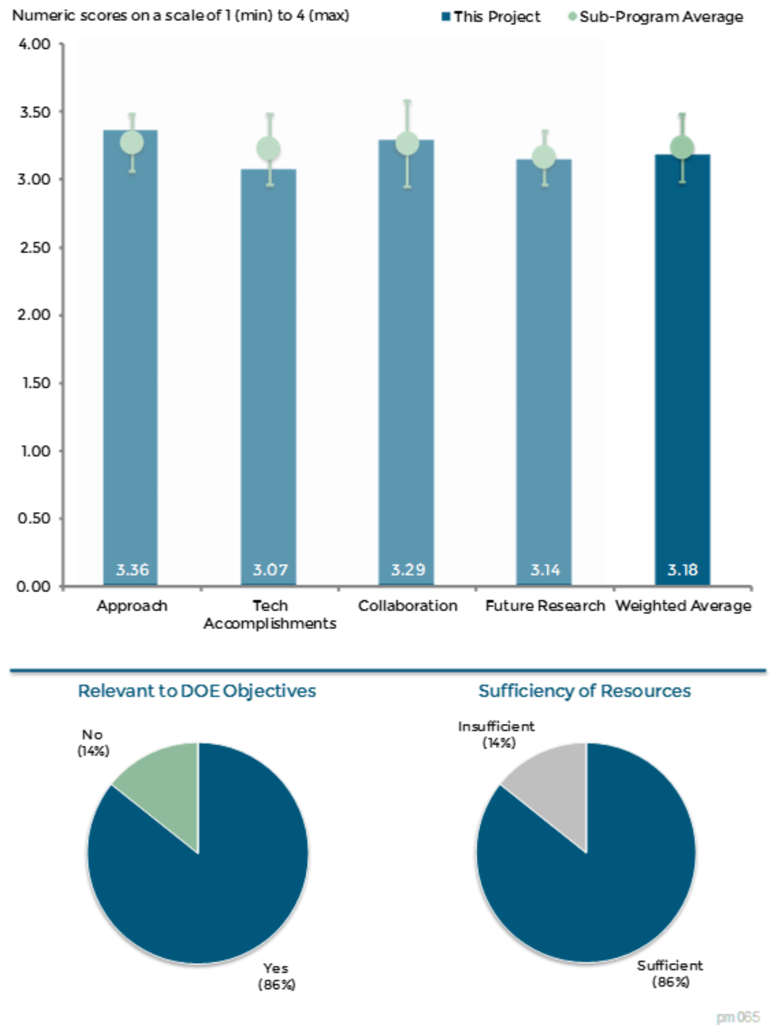


Figure 7-13 Alloy Development for High-Performance Cast Crankshafts: Rich Huff (Caterpillar, Inc.) – Propulsion Materials

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed, feasible, and integrated with other efforts.

Reviewer 1:

The reviewer praised a good start to the project and modeling, adding that the overall project appeared well designed and appropriately focused.

Reviewer 2:

This, the reviewer averred, is a well-planned project with a good distribution of tasks and milestones. The approach the reviewer considered clear and logical, addressing key DOE interests. The reviewer also praised the system and materials design graphics as very useful for setting the stage for the work to be performed.

Reviewer 3:

The program to date shows a great deal of competence with regard to the analysis of cooling rates and their effects on final properties of interest, in this reviewer's view. The reviewer also found the comprehensive systems design chart a powerful visual aid. The reviewer praised the ICME roadmap as also more complete and highly informative by comparison to those shown in other presentations.

Reviewer 4:

The multi-disciplinary approach is very good and considers many variables including structure, alloy composition and heat treatment, in the view of this reviewer.

Reviewer 5:

The approach appeared sound to the reviewer, who thought, however, that it would have been preferable to see a commercial foundry involved from the beginning as a cost-share partner, along with the university, for an effort as challenging as steel casting. Nevertheless, the reviewer said, it appeared that progress was being made in identifying potential foundries.

Reviewer 6:
The project relevance was described, the reviewer agreed, but no quantifications or examples were given.

Reviewer 7:
In the presentation, the reviewer said, the design approach was clear, showing that the model predictions showed some discrepancy with the data. Are there any plan to understand this gap, the reviewer wondered.

Question 2: Technical Accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made, measured against performance indicators and demonstrated progress towards DOE goals.

Reviewer 1:
The initial milestones associated with requirements for end product, materials and processes have been completed, the reviewer said, and the systems and materials design charts allow verification of progress on tasks. The reviewer observed that model development is driving the alloy design and the casting process.

Reviewer 2:
Terming the modeling and predictive work reasonable for this point in the project, the reviewer noted a good beginning for the experimental program.

Reviewer 3:
The ICME prediction has identified many alloy variations for testing and development, the reviewer said.

Reviewer 4:
How individual analyses would be carried out based on altering (and optimizing) compositions was not entirely clear to the reviewer, who noted that the program is nearing the halfway point. Specific identification of properties of interest may provide a relatively straightforward final evaluation based on yield strength (YS) and UTS (and, presumably, fatigue), the reviewer said, but to be effective, the looping of information back into the ICME modeling flow will require analysis of considerably more factors than strength levels.

Reviewer 5:
The advantages are described, the reviewer noted, but no quantifications or examples were given.

Reviewer 6:
Progress has been limited, the reviewer observed, with only hardness data from cast alloys thus far. However, the reviewer acknowledged, it is very early in the project.

Question 3: Collaboration and coordination with other institutions.

Reviewer 1:
The team is diverse and individual responsibilities were presented with a level of detail this reviewer found particularly satisfying. Employment of Argonne National Laboratory's Advanced Photon Source and associated results were not addressed at this point in the program, according to the reviewer.

Reviewer 2:
This is a good project team, the reviewer said, the combination of Caterpillar and GM crankshaft requirements and objectives strengthening the project. The reviewer asked if the cost targets will be assessed for each company, or for just one.

Reviewer 3:
Caterpillar has assembled a very well-coordinated team of collaborators, in this reviewer's view, and the initial collaborative effort with General Motors on performance needs is a good driver for the project.

Reviewer 4:
Collaborations appear sound to the reviewer, who insisted that a foundry partner is essential in a project with a limited budget.

Reviewer 5:
Though praising a good team set-up, the reviewer found it difficult to understand from the presentation who in the team did what.

Reviewer 6:
Noting that two OEMs are involved in the development work, the reviewer added that their respective cost structures may differ based on their production volumes. The 110% cost increase for both was not explained to this reviewer’s satisfaction.

Question 4: Proposed future research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology, and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
Deeming the main barriers well identified, the reviewer could see no alternative development pathways.

Reviewer 2:
There is a clear plan for future efforts, the reviewer said, leading to an ICME-driven, and experimentally validated crankshaft prototype.

Reviewer 3:
The reviewer discerned a distinct level of complexity remaining in the program, specifically regarding the analysis of different compositions and leveraging this analysis with the comprehensive process analysis modeling and evaluation. This effort, the reviewer said, will be the true measure of the progress and ultimate success of the overall program.

Reviewer 4:
Steel cleanliness will be a major challenge for such a fatigue-driven component, the reviewer predicted. It would be better, the reviewer continued, if next year's review includes a strategy for increasing the cleanliness and quality of the casting process. Likewise, the reviewer expressed a desire to see work proposed on characterizing casting defects as a function of alloy composition, pouring conditions and local cooling rates.

Reviewer 5:
Casting is the challenge, as the component must be produced with minimum defects, the reviewer stated. The solidification modeling, the reviewer continued, can be a useful tool in identifying the optimum (vertical or horizontal) casting process.

Reviewer 6:
The reviewer considered that the expected use of the results of this research is to facilitate redesign of the casting process. Lots of integration tools are available, the reviewer noted, but how to improve the efficiency of integration and reliability – which will lead to robust analysis –is the key. The reviewer expressed a desire to see additional effort on that side to facilitate a functionally excellent approach.

Question 5: Relevance: Does this project support the overall DOE objectives of petroleum displacement? Why or why not?

Reviewer 1:
Cast crankshafts offer the potential for weight savings in vehicles, the reviewer noted.

Reviewer 2:
The PI presented a compelling set of benefits for the reduction in weight of the major rotating components (specifically the crankshaft), the reviewer said, and for the associated trickle-down effects regarding subsequent lightening of other components (such as the block that must contain the considerable rotation-based stresses).

Reviewer 3:
Yes, the reviewer said, but the weight saving target is not well motivated and can be questioned.

Reviewer 4:
The benefit of this project to improving engine efficiency was unclear to the reviewer. The underlying goal seemed to the reviewer to be reducing the cost of higher-performance crankshafts. This clearly benefits the partner engine companies, the reviewer acknowledged, because success would allow them to replace forged crank with lower-cost cast cranks. If this cost reduction results in turn in greater penetration of higher peak cylinder pressure and higher- efficiency engines, this project will contribute to the DOE objective, the reviewer concluded.

Question 6: Resources: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It appeared to this reviewer that both the three-year project duration and funding resources are less than ideal for developing a highly fatigue-resistant, cast steel crankshaft, because both materials and processing development are required.

Reviewer 2:
This project, the reviewer predicted, will either work or not work and spending more would not help much.

Reviewer 3:
From a budget standpoint, the reviewer noted, the program is still in its infancy, with relatively little of the overall program funding having been spent thus far. Presumably, the reviewer speculated, the remaining budget is sufficient to cover the remaining scope.

Reviewer 4:
Resources appear to be sufficient, in the opinion of this reviewer.

Acronyms and Abbreviations

3D	Three dimensional
Al	Aluminum
AMR	Annual Merit Review
ANL	Argonne National Laboratory
C	Carbon
CF	Carbon fiber
CFD	Computational Fluid Dynamics
CGI	Compacted graphite iron
CRADA	Cooperative Research and Development Agreement
CTE	Coefficient of thermal expansion
Cu	Copper
DFT	Density functional theory
DOC	Diesel oxidation catalyst
DOE	Department of Energy
EDT	Electric Drive Technologies
EGR	Exhaust Gas Recirculation
EM	Electric motor
EV	Electric Vehicle
FCA	Fiat Chrysler Automobiles
FEM	Finite element modeling
FSP	Friction Stir Processing
FY	Fiscal Year
HD	Heavy-Duty
ICE	Internal combustion engine
ICME	Integrated Computational Materials Engineering
IP	Intellectual Property
K	Potassium

LD	Light-duty
Mg	Magnesium
MPa	Megapascal
Na	Sodium
Ni	Nickel
NOx	Oxides of Nitrogen
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturer
ORNL	Oak Ridge National Laboratory
Pa	Pascal
PCP	Peak cylinder pressures
PE	Power electronics
PI	Principal Investigator
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
RS	Rapidly solidified
SAE	Society of Automotive Engineers
Si	Silicon
TEM	Transmission electron microscope
UTS	Ultimate tensile strength
VTO	Vehicle Technologies Office