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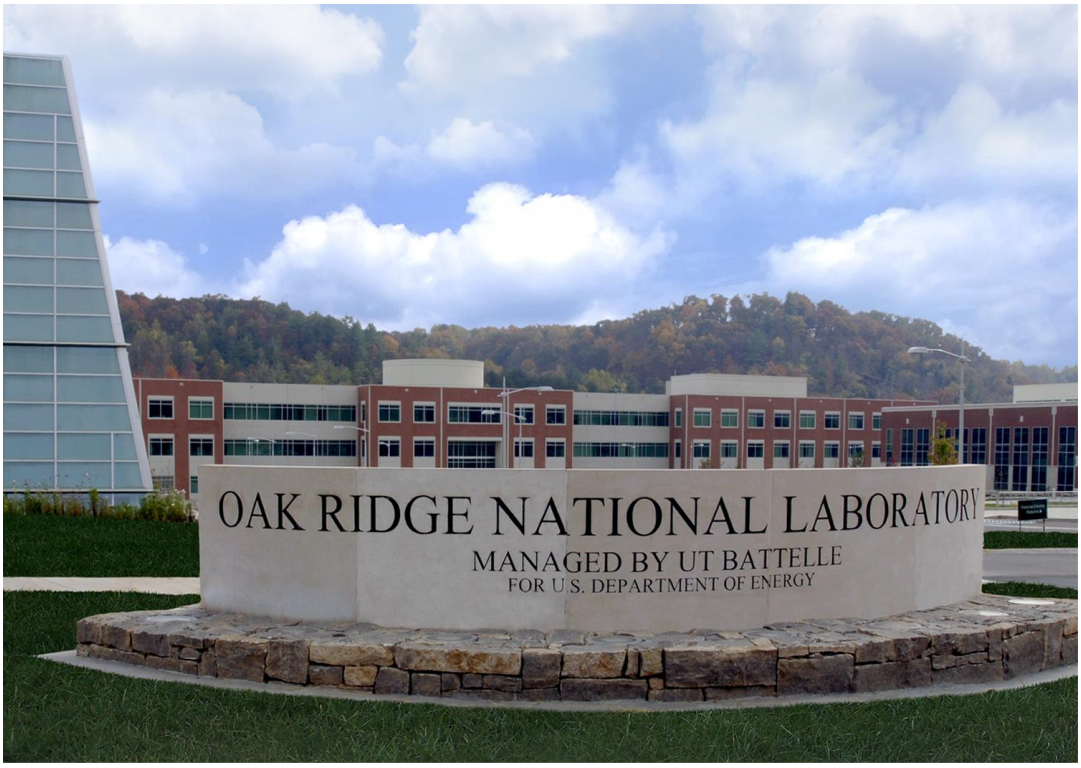
Carbon Fiber Composite Materials for Automotive Applications



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Carbon Fiber Composite Materials for Automotive Applications
VW CRADA Final Report

ABSTRACT

Volkswagen (VW) is internationally recognized for quantity and quality of world-wide vehicle production and the Oak Ridge National Laboratory (ORNL) is internationally recognized in materials research and development. With automotive production ramping up in the recently constructed VW Group of America facility in Chattanooga, Tennessee, ORNL and VW initiated discussions in 2012 concerning opportunities for collaboration around ORNL's carbon fiber and composites programs. ORNL is conducting an internationally recognized program to develop and implement lower cost carbon fibers and composites for automotive and other "energy missions" for the US Department of Energy. Significant effort is ongoing in selecting, developing, and evaluating alternative precursors, developing and demonstrating advanced conversion techniques, and developing and tailoring surface treatment, sizings, and formatting fiber for specific composite matrices and end-use applications. ORNL already had North America's most comprehensive suite of tools for carbon fiber research and development and established a semi-production demonstration line referred to as the Carbon Fiber Technology Facility (CFTF) to facilitate implementation of low cost carbon fiber (LCCF) approaches in early 2013.

ORNL and VW agreed to collaborate in a formal Cooperative Research and Development Agreement (NFE-12-03992) specifically focused on evaluating applicability of low cost carbon fiber products for potential vehicle components. The goal of the work outlined in this report was to develop and qualify uses for carbon fiber-reinforced structures in connection with civilian ground transportation. Significant progress was achieved in evaluating and understanding lignin-based precursor materials; however, availability of carbon fiber converted from lignin precursor combined with logistical issues associated with the Visa limitations for the VW participant resulted in significantly shortening of the collaboration period and development of the targeted application(s). Alternatively, objectives of this work have been refined and are now largely being pursued through the involvement of ORNL and VW participation in the more recently established Innovation for Advanced Composites Manufacturing Innovation (IACMI) where composite materials applications are being demonstrated in a much larger scope.

BACKGROUND AND OBJECTIVES

ORNL is conducting an internationally recognized program to develop and implement lower cost carbon fibers and composites for automotive and other "energy missions" for the US Department of Energy. Significant effort is ongoing in selecting, developing, and evaluating alternative precursors, developing and demonstrating advanced conversion techniques, and developing and tailoring surface treatment, sizings, and formatting fiber for specific composite matrices and end-use applications. In discussions with ORNL on collaboration opportunities, VW expressed interest in learning how to incorporate low cost carbon fiber into composite materials for future vehicle platforms. The purpose of this CRADA is for ORNL and Volkswagen to jointly evaluate multiple carbon fiber composite material options on applicability to Volkswagen's cost/performance specifications. The larger goal of this program was to develop and qualify uses for carbon fiber-reinforced structures in connection with civilian ground transportation. Work performed under this CRADA and VW's activities to implement the resulting technology in civilian transportation applications are likely to enhance the domestic skills base and lead to further domestic development of the technology by Participant or others, including VW's domestic subcontractors. In addition, use of this technology is likely to lead to safe, more efficient, and less expensive transportation solutions for U.S. consumers. If the technology developed under this CRADA is

successfully implemented, new and different uses for the technology could be developed and qualified for a variety of applications. To the extent these uses are manufactured in the U.S., the work performed under this CRADA could have a positive impact on the U.S. balance of payments in terms of product exports.

The project was structured under a Cooperative Research and Development Agreement (CRADA) as defined by Stevenson-Wydler Innovation Act of 1980 with VW providing both funds for ORNL participation as well as in-kind support exceeding the projected costs of ORNL. The plan of action developed by ORNL and VW was for a VW employee to work alongside ORNL researchers in researching composites processes and evaluating carbon fiber and composite properties, assisting with ongoing work as applicable and in conducting experiments specifically related to the processes and applications of interest to Volkswagen. The VW employee planned to work with ORNL composites researchers to evaluate how various carbon fiber products, product forms, and fiber architectures can be combined with specific resin systems and utilized in various processes that will allow meeting final product property and economic requirements. Potential considerations included multi-dimensional weaving, braiding, the ORNL P4-based preforming process, etc. It was anticipated that the processing work will require some engineering and/or developmental work in collaboration with ORNL composites personnel as well as significant interaction with outside processing experts. We will likely obtain various samples for preliminary testing and evaluation. It is also anticipated that utilization of ORNL low cost carbon fiber will likely require at least some modification of surface treatment, sizing, and/or product formatting to tailor the material to specific process requirements and resin compatibility.

Ideally, the culmination of this activity would be the production of representative material samples that are fully evaluated through testing at ORNL. Although it is desirable that an actual demonstration part can be produced and evaluated, considering the likely tooling cost it is anticipated that this demonstration will most likely be in the form of flat plaques or relatively simple geometry parts where existing tooling can be utilized to minimize cost to Volkswagen.

The original scope of work was defined as having the following interrelated tasks:

1. Volkswagen Application Product Requirements Definition and Tradeoffs
2. Preliminary Resin Transfer Molding Processing Trials and Fiber/Resin Compatibility Assessment
3. Carbon Fiber Product Form Manufacturing and Composite Process Optimization
4. Demonstration Article Manufacturing and Testing
5. Final Reporting and Publications

BENEFITS TO DOE MISSIONS

The goal of this program was to develop and qualify uses for carbon fiber-reinforced structures in connection with civilian ground transportation. In performing work under this CRADA, VW is fully funding activities such that neither ORNL nor VW are using any US Government funds. VW has a substantial existing and potential manufacturing base in the United States. Accordingly, if technology developed under this CRADA is used to manufacture VWs future products, VW agreed that the largest possible portion of those products will be designed, manufactured, and sold in the United States, resulting in both direct and indirect investment in U.S.-based plants and equipment.

Work performed under this CRADA and VW's activities to implement the resulting technology in civilian

transportation applications would likely to enhance the domestic skills base and lead to further domestic development of the technology by VW or others, including VW's domestic subcontractors. In addition, use of this technology is likely to lead to safe, more efficient, and less expensive transportation solutions for U.S. consumers. If the technology developed under this CRADA is successfully implemented, new and different uses for the technology could be developed and qualified for a variety of applications. To the extent these uses are manufactured in the U.S., the work performed under this CRADA could have a positive impact on the U.S. balance of payments in terms of product exports and may also lead to U.S.-based job creation.

WORK PERFORMED

Early in the collaboration, VW expressed desire to focus on LCCF variants produced from lignin precursor. Lignin, currently available as a bi-product from the production of paper, offers a number of potentially attractive benefits for large-scale implementation in the production of carbon fiber. Lignin represents a substantial portion of plant matter along with cellulose and hemi-cellulose. While the cellulose products are separated out and utilized in value added applications such as paper, lignin has traditionally had limited applications value and frequently the large excess quantities of lignin from pulp and paper product streams has been burned such that the lignin worth was defined from heat values. Although somewhat difficult, lignin can be melt spun into fiber versus polyacrylonitrile, or PAN-based, precursor currently must be solution spun. Over the last decade, interest in developing and implementing bio-refineries for fuel and raw material production potentially offers the opportunity to introduce new processes that provide lignin feedstocks tailored to cleanliness and tight variability control needs of carbon fiber precursors in going forward. The combination of large quantities of a low cost, renewable feedstock that can be specifically tailored to carbon fiber production via a lower cost spinning process are the primary drivers for interest in lignin precursor as recognized by VW, ORNL, and the larger community interested in lower cost carbon fiber.

As alluded to previously, the ORNL approach to carbon fiber development is very comprehensive in considering selecting, developing, and evaluating alternative precursors, developing and demonstrating advanced conversion techniques, and developing and tailoring surface treatment, sizings, and formatting fiber for specific composite matrices and end-use applications. The VW approach to material and product development is comprehensive as well requiring a thorough understanding of the complete product stream. The purpose of the collaboration was to expose both organization to both interest and needs of each other. Volkswagen agreed to provide an employee to work alongside ORNL researchers in researching composites processes and evaluating carbon fiber and composite properties, assisting with ongoing work as applicable, and in conducting experiments specifically related to the processes and applications of interest to Volkswagen. The Volkswagen employee responsibilities included working with ORNL composites researchers to evaluate how various carbon fiber products, product forms, and fiber architectures can be combined with specific resin systems and utilized in various processes that will allow meeting final product property and economic requirements. The employee identified by Volkswagen represented their central materials R&D organization in Wolfsburg.

In executing the project plan, VW and ORNL jointly participated in extensive characterization of carbon fiber, characterization of lignin materials as precursor for carbon fiber, assisted in development of liquid molding processes for making composite panels for lignin-based carbon fiber mats, developed a process for making thermoplastic composite samples, and conducted theoretical work on the reaction mechanism for lignin transformation into carbon fiber. During this time period, the VW employee also served as the Volkswagen representative in the Oak Ridge Carbon Fiber Composites Consortium. Beyond the collaborative work, he also extended his personal knowledge and the corporate awareness of Volkswagen by assessing the U.S. carbon fiber markets by visiting and interacting with key players in carbon fiber

production and carbon fiber equipment development and attended a variety of well-established technical conferences.

Significant progress was achieved in evaluating and understanding lignin-based precursor materials; however, availability of carbon fiber converted from lignin precursor combined with logistical issues associated with the Visa limitations for the VW participant resulted in significantly shortening of the collaboration period and development of the targeted application(s). As a result of this work along with other background and responsibilities both before and after working alongside ORNL, the VW employee made presentations at a couple of US Society of Plastic Engineers Automotive Composites Conference & Exhibitions (ACCE). This ACCE event is considered by many to be the world's leading automotive composites forum. Related work was also published by VW in the Journal of Materials Research and Technology.

SUBJECT INVENTIONS

No subject inventions were created during the course of these project activities.

COMMERCIALIZATION POSSIBILITIES

Significant progress was achieved in evaluating and understanding lignin-based precursor materials; however, availability of carbon fiber converted from lignin precursor combined with logistical issues associated with the Visa limitations for the VW participant resulted in significantly shortening of the collaboration period and development of the targeted application(s). Alternatively, objectives of this work have been refined and are now largely being pursued through the involvement of ORNL and VW participation in the more recently established Innovation for Advanced Composites Manufacturing Innovation (IACMI) where composite materials applications are being demonstrated in a much larger scope. It is likely that specific commercialization possibilities will be identified and implemented as a result of this much larger follow-on effort through IACMI.

PLANS FOR FUTURE COLLABORATION

As previously identified, ORNL and VW are both actively involved in a much larger follow-on initiative sponsored by the Department of Energy through the even larger National Network for Manufacturing Innovation. Specific objectives in the IACMI initiative mirror objectives of this CRADA, but on a much larger scale. At the time of this report, VW and ORNL are collaborating on recently launched efforts along with other team members.

CONCLUSIONS

Although efforts on this project have been terminated prior to achievement of the larger planned goals, the project did provide useful information to VW, ORNL, and the broader community interested in lignin-based lower cost carbon fiber. The project provided opportunities for early ORNL/VW collaboration as

VW moved major manufacturing facilities into the region close to ORNL and helped to kindle interest for follow-on ORNL/VW collaboration in the larger and likely more impactful IACMI program.