Clean Energy Fund Project 16-92201-007 Final Report

SUMMARY

The project was initiated for the purpose of transforming the scrap carbon fiber from Washington's aerospace industry into useful products in the clean energy space and beyond, and specifically to support capital equipment purchase and install to be able to research, develop, and manufacture new products with the scrap materials.

The project performance location is in the Composite Manufacturing Campus of Port of Port Angeles, in a purpose-finished building set-up with utilities and services specific to advanced composite processing. Locations for most of the CEF2 equipment were pre-identified and in this manner we were able to minimize the costs of equipment movement and electrical and plumbing service attachments.

The primary supply relationship for scrap carbon fiber pre-preg materials is Toray Composite Materials America (Tacoma, Wa), and their waste (previously all sent to landfill) consists of mainly aerospace scrap from production rejects, trim from every roll of carbon fiber prepreg they make, and a smaller amount of scrap from their intermittent runs of sporting goods grade carbon fiber prepreg in that facility. This resulted in equipment requirements for maximum flexibility in processing as will be noted. The installed CEF2 equipment in CRTC was complemented by metal tool-making equipment, scrap prepreg storage freezers, other presses and ovens, automated fabric table-cutting system, tubular products roll-wrapping equipment, and design and engineering software and hardware.

Primary capacity from this equipment included high-rate production of compression molded composite parts, capability to transform different types of scrap into useful production feedstock, large panel manufacturing capabilities, and component cut and trim, and finish capabilities. Report will describe each item in detail along with the equipment parameters and capabilities.

Long lead times for equipment and issues in low facility overhead clearances were the main stumbling blocks encountered. In addition, we did not recognize early on what issues would be encountered in dust and particulate collection from handling of the scrap materials. Several iterations and designs needed to be done to properly address this and resolution of these has resulted in an excellent working environment.

The CEF2 enabled equipment is and has been used to support several new product developments and contract research. Two of CRTC's developments are completely unique in the advanced composite field, with much promise for advancing novel and high-impact clean-energy applications and benefits. The two are in: a) combined wood-carbon fiber Advanced Cross Laminated Timber (ACLT) for small cost-effective passive-house construction; and b) recycled carbon fiber cable for use in marine aquaculture and large-scale ocean farming. CRTC has also developed products for consumer and business-to-business sale in advanced sporting goods (archery, pickleball, and rowing); prosthetics; architectural wood-carbon fiber paneling; and park benches.

EQUIPMENT AND CAPABILITIES SUPPORTED BY PROJECT

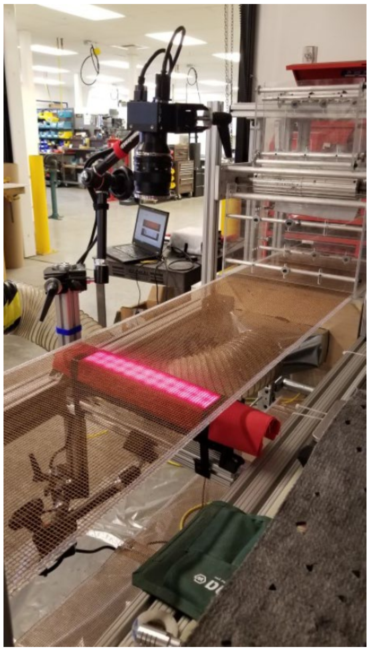
The following is a summary of the specific major items of equipment and their capabilities and applications:

1. ***Equipment for Chopping and Placement of Carbon Fiber Scrap***: a custom developed chopper was necessary to create useful “preforms” from the incoming scrap materials. As can be envisioned the scrap can be in any of several formats, and not consistent from batch to batch received by CRTC. In order to effectively use some of the scrap materials, we had to be able to chop it into small pieces (approximately 1-inch by ¼-inch and smaller) and create a flat sheet of random prepreg chips that could be formed over a compression molding tool. Nothing existed like this currently and it was designed and developed in-house from the ground up.

   The chopper system consists of a feed creel with fiber take-off from the as-supplied scrap spool. We also had to develop an alternative feed system that allowed the scrap materials to be unwound from the existing paper-backed format, and then re-wound onto a proper feeder spool. This was specifically to handle scrap materials such as edge-trim that had a large band of backing paper as compared to the thinner band of actual prepreg.

   The carbon fiber feeds into a guillotine or rotary chopping head that operates at temperatures below 0 degrees in order to keep the resins from heating, becoming liquified, and gumming up the machine Localized chillers are placed in strategic locations in the chopper to accomplish this. The chop materials are distributed onto a moving belt that has in-line pre-heat and we have developed in-line pre-consolidation as research has shown this benefits final production articles. The complete chopper has been used for multiple applications including contract R&D for IACMI, Boeing, and Toray, and production of bench, pickleball, and sporting goods parts.

   The chopper took quite a bit more effort and much longer than anticipated to develop and build. This is primarily because we were custom manufacturing it and designing the various components based on process development that was ongoing with our various feedstock materials. Several iterations of different chopper heads needed to be tried and improved, and each station of the system had to be prototyped, tested, then improved and reduced to continuous operation practice.



2. ***Hi-Temperature Oven:*** A Wisconsin Oven that is 20’ x 10’ x 8’ and capable of 500°F operation for curing large composite panels was procured and installed. The installation was our largest challenge, as the oven fit into the building and space with (literally) 1/8” clearance under the previously installed HVAC services. The oven has been utilized on a daily basis for production of benches, post-curing of compression molded components, and for large flat panels for architectural use. CRTC later modified the oven to accept high-pressure gas to enable bladder molding inside the oven for large finished components. Having this capability enabled CRTC to bid on and win the project to finish out the carbon fiber/wood panels for the Benaroya Octave 9 project (LMN Architects, Seattle Symphony) and we anticipate significant additional project work as a result of this once the architectural community learns more of the capabilities and levels of quality exhibited.

The key issue encountered with the oven has been quality of electric service, since the local service apparently has been causing fuses to burn out at much too high a rate. Several custom fixtures and racks for part cure have been made at CRTC over the last couple years, allowing more efficient loading and unloading as we typically cure overnight off the day's production.

3. ***Hi-Pressure Waterjet:*** A Flow high-pressure waterjet was procured with a 10' x 5' table area to enable trimming of our large panels. The 65,000 psi, garnet fed waterjet has been a critical item in development and production, used for cutting out the pickleball legs from compression molded plates, cutting out the individual orthotic springs from large plates, trimming and forming flat stock for bonding, and cutting strip sections for reinforcing the wood-carbon Advanced Cross Laminated Timber (ACLT) panels.

   The machine was provided to CRTC by Flow Company of Kent, WA, with significant no-cost upgrades and features. Installation was a major challenge as the hook-up of utilities and services was difficult to accommodate in the location necessary for best efficiency. Water treatment had to be added to our local feed water supply, and drain capacity was an issue for us. The system has been running also on a daily basis and is highly productive for the preparation of finished product. No major issues were faced in procurement and install, and Flow provided operator training at their facilities in Kent, WA to several CRTC staff.

4. ***Induction Heating for Rapid Processing System:*** A 2 x 100kW RocTool Induction Heating system was procured for the purposes of tool thermal control. Similar to the induction heating stoves, this system will only create heat in the top ¼ to ½ inches of the excited surface, eliminating costly and energy wasting effort of heating the complete block of tool steel. The process cycle thus uses much less heat to get to final temperature, and requires much less cooling to drop to a safe point for part release. The downside is that a very high-energy initial capacity is required for a short period of time, hence the

need for the two 100 kilowatt induction controls.

The presses below were modified to accommodate the integration of the RocTool, as it will now automatically interface with and control the press cycle. Rapid cycle times in the order of 1-2 minutes are possible. The system has not seen the amount of usage we envisioned for it, as the projects to date have not demanded the high production rates as yet, and the actual induction-controlled tooling is much higher cost than traditional tooling and clients have thus far been unwilling to pay the additional costs. Continuing interest in automotive and higher volumes of the orthotic springs should see this situation resolved in the future and we are investigating novel options for usage in the ACLT project.

5. ***Compression Molding Presses:***
Three high-capacity compression molding presses were procured for the purpose of forming final components, two are 200-ton, 650°F platen presses at 36" x 30" platen size, and one is a 300-ton, 650°F 60" x 30" hot-platen press. All were specified with interface controls to run external separate heater/cooler circuits for faster production rate capabilities. The press installation came with unique challenges, as cooling circuits and steam condensers needed to be added after the initial operations as we started to process at higher temperatures for new carbon composites being developed by Toray. Ventilation hoods and mold handling systems were needed. The presses are in daily operation and are used for the bench leg components, orthotic springs (highest volume use), legs for the pickleball nets, and panels for various other projects. Several contract R&D projects were engaged using their capabilities, including a unique carbon/nylon seatback for a BMW i3 trial that certainly pushed CRTC and the presses to our limits of what was feasible and capable (it was successful!)

The presses, in hindsight, should have been specified for 800 F operation, as we have had many calls for and requirement to process at higher temperatures for automotive and aerospace development projects. Our small (24" x 24" Grimco) press is capable of these temperatures, but having that option for the larger presses with higher compression pressures and tooling would have been extremely helpful. The second area we realized is a bottleneck is the need for additional "daylight" or full-opening space between the press platens for loading large tools. We learned that some of the tooling for hi-volume applications will have very deep cavities and thus we have some restrictions in tool design and application.

6. ***Mold and Tool Handling Systems:*** An electric forklift and several smaller hydraulic lift and moving systems were procured to be able to handle the mold bases, large tooling, and load/unload the three CNC machines and presses. Ultimately, the CRTC would like to automate handling of the tooling for the large compression molding presses as we are running multiple products in any given day and need to switch out tooling fairly often. The only issues we have seen with these systems is the capability to move larger equipment, and we had to contract several installations requiring larger capacities. This is a good trade-off as this approach meets 95% of our needs for typical daily handling. Several of these items were procured used for cost savings, and no issues have arisen in their operation.

7. ***5-Axis CNC Machining Center:*** A 5-axis DMS CNC Machining Center was procured in order to facilitate cutting out large tools, trim oversized components, and provide capability to rapidly make new parts internally (very typically the largest bottleneck and cost for companies providing prototypes to clients.) The machine required additional dust collection systems as machining both composites and wood patterns created large volumes of particulate dust, and the system needed to be capable of micron level filtration and movement of high volumes of air (due to the open nature of the machine bed.) The dust control ducts can be seen on the front of the machine, and the custom built curtain system can be seen overhead and surrounding the DMS to create proper down-draft and prevent blow-out of dust from the 10,000 rpm cutting spindle. The size selected based on budget availability was 10' x 5' x 4' machining envelope, with active cooling through the spindle for high-speed cutting and holding tolerances.

   The primary issue with the machine (aside from added dust control) was in alignment of the gantry and machine ways. We learned after the fact that this was an issue with DMS machines and once the warrantee and service approaches were exhausted with DMS we had to contract out for this effort. The re-alignment and finishing was successful and the machine is at full operational capability.

   The DMS has been used to make several iterations of the bench tooling, does routine trimming and finishing of bench and other components, fabricated the tooling for our test panels of wood-carbon fiber that led to the securing of Octave 9 interior finish panels, and provided the finishing stages for the first of our carbon fiber reinforced cross-laminated timber (CLT) panels. Future major applications will be in final trim and cut-outs of the Advanced CLT panels for housing panels, and we envision extensive use as we develop a model small home which will require approximately 60 ACLT panels to be manufactured and trimmed on the DMS.

8. ***Other Small Complementary RD&D Support Items:*** The sanding and finishing station, a small digital microscope/camera, 3-D printer, and materials handling items were also procured. Of these smaller complementary items, the most useful (by far) has been the 3-D printer. It has provided capability to rapidly develop and make all our pre-production injection molded plastic parts, made custom fitting and brackets for the chopper system, made custom trim and part holding fixtures, machine repair brackets, etc. We purchased a second identical unit and they are both in near daily operation. The digital microscope gave us major issues at first, but one of our interns resolved the issues and the machine is used to do quality checks of the molded carbon fiber plates, and to evaluate how different materials have processed as we experimentally determine process conditions for different incoming scrap batches.

LESSONS LEARNED

The primary lesson learned from the CEF2 experience was the high value in being able to express to other funding agencies and sources what the confidence and backing of the State meant. We should have, early on, taken more advantage of this with interactions with federal agencies and increased leverage potential. We received some grant funding from Department of Energy through their Institute for Advanced Composite Manufacturing Innovation, and could/should have leveraged the CEF2 contribution more. It would also have been beneficial for CRTC to spin-off a private, for-profit subsidiary earlier in our history, in order to secure equity investment and operating capital.

The next level lessons learned would be that we should have increased the size and capability of some of the equipment items, this especially applies to one of the presses and the 5-axis CNC and waterjet. Having a capability to move to a 12-foot by 6-foot processing area seems like a small increase over the 10-foot by 5-foot currently, however this would have moved the CRTC's internal capacity to match that of a typical unit of a Cross-Laminated Timber panel press and thus allowed for much greater additional collaboration opportunities with the several CLT manufacturers we are interacting with. We should of, in hindsight, trimmed back on the induction mold heating system and one of the compression molding presses, and applied those funds towards a slightly larger 5-axis DMS and Flow Waterjet. As it is, we can still process and be quite effective, and by using the bed areas carefully (and sometimes overlapping and extending outside of the machines), we have been able to accomplish most of what is required albeit at additional time and not as production-worthy an approach.

CONCLUSION

The Clean Energy Fund support has been a critical enabler of the CRTC to implement RD&D into new uses and application potential for scrap carbon fiber supplied to us by the Washington aerospace industry. Without this support we would have not have had the capability nor capacity to develop, market, and sell new products into several industry sectors. The cost-share support provided by the Port of Port Angeles was also crucial to the project, and further enabled the expansion of production capacity and hiring of new staff. The current team at CRTC – 13 production and 5 engineering and management is profoundly grateful for the opportunities afforded by the CEF program.