CYCLING AND SUSTAINABILITY: DEVELOPMENT OF A RECYCLED CARBON FIBER (rCF) CRANKSET DEMONSTRATOR

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Introduction: Environmental integrity is paramount for the next generation of sports equipment, requiring proactive minimization of environmental impact at every stage of product development. The sport of cycling has been transformed by the popularization of carbon fiber reinforced polymer composite (CFRP) frames which can be made lighter, stronger, and more durable than metal frames. This paradigm shift towards CFRPs does not, however, come without an environmental cost. The significant environmental impact of virgin carbon fiber (vCF) manufacturing, immense volumes of CFRP waste, and increased demand for CFRPs have all fueled the urgent rise in sustainable solutions [1,2]. There is a considerable need to bring recycled carbon fiber reinforced polymer composites (rCFRPs) into high-volume composites manufacturing as a sustainable solution to address high volumes of carbon fiber waste, as well as to provide material with mechanical properties comparable to vCF to industries that continue to utilize it.

Bicycle manufacturers have already displayed intention of recycling their carbon fiber waste, among other environmentally conscientious initiatives [1,3]. It has been shown that rCf is comparable in strength and modulus to vCF given the proper recycling parameters; however, the recycled material's short fiber or non-woven form requires further optimization for high-volume manufacturing [2,4]. Additional research is thus necessary to provide insight into the long term reliability of a rCFRP structure for more practical applications [2,4]. The following work lays out how that can be accomplished within the context of cycling.

Project Outline: An original crankset design is under development for three material systems: aluminum, thermoplastic vCFRP, and thermoplastic rCFRP. Two forms of rCF are investigated: rCF non-woven mats, and rCF filled injection molding resin. Both forms of rCF were thermally recycled via commercial pyrolysis. Performance of the cranksets will ultimately be compared and validated in compliance with fatigue testing defined by the ISO 4210:8 safety standard.

All designs are being manufactured in-house, and additional mechanical testing will be done under load cases replicating that of a cyclist under varying riding conditions, including torque and bending load cases (Fig. 1). One of the main gaps in current rCFRP development is the long-term implementation in more strenuous applications. The mechanical testing and characterization during the service life of a rCFRP crankset will establish a platform to define the durability and fatigue limitations of a

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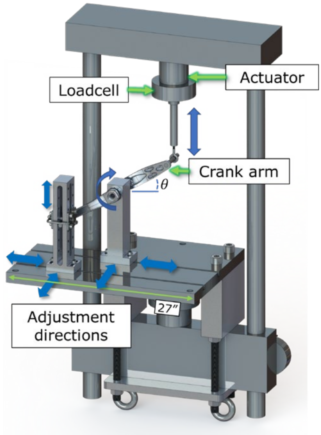

Fig. 1: Mechanical testing jig for crank arm performance validation.

geometrically complex rCFRP part in comparison to other material forms.

The mechanical testing results will then be compared to microstructural analysis of the rCFRP part as it relates to critical conditions in its service life. When evaluating performance, it is important to account for extreme crash conditions as well as long-term fatigue from regular use cases. Characterization will be done of fractured surfaces to study how reinforcement architectures, crystallization, and consolidation of the rCF affect the ultimate safety of the part. These results will direct new iterations of the design. Subsequent designs will also be guided by a predictive cost assessment for manufacturing, and a technical cost model of the entire manufacturing process is being developed to assess cost feasibility.

Conclusions: The project incorporates design work and CAE, metals and composites manufacturing, mechanical testing, microstructural analysis, predictive maintenance, and technical cost modeling to represent an entirely in-house product development process. This work aims to develop a feasible and reliable system to incorporate rCFRPS into cycling without sacrificing performance, as well as provide a demonstrator case to other industries regarding long-term reliability of an in-service rCFRP structure. The development of a rCFRP crankset ultimately aims to take advantage of the synergy between rapid prototyping and sports engineering to address complex sustainability issues in rCFRP manufacturing.

References

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