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Transportation Research Concepts - attachment 1

Additional submitted attachment is included below.

Low cost mass production of light weight composite car wheels and monocoques

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This project has the potential to reduce US car accident fatalities by 15,000 and serious injury 80,000 annually, reduce car weight about 30% and save 20% energy car consumes.

1. Autos and eVTOLs require the cost-effective production of composites

eVTOLs require the use of carbon fiber composites because of their lightweight and strength. However, the mass adoption of eVTOLs will depend on the cost-effective production of composites.

Prioritizing safety is crucial in the adoption of eVTOLs. In addition to advanced sensor and control systems, there are two important safety measures to consider. Firstly, whole-eVTOL parachutes can be effective at heights as low as 333 feet. Secondly, carbon fiber Formula 1 racing car bodies can sustain collisions at speeds up to 180 miles per hour, equivalent to a free fall from a height of 1000 feet. With these two safety features, eVTOLs are much safer than helicopters, which lack these key safety measures.

After ensuring the safety of eVTOLs, the next major challenge for mass adoption is their cost. The cost of eVTOLs largely depends on the mass production cost of composites. Without low-cost mass production of composites, eVTOLs would be as expensive as Formula 1 racing cars and not affordable for regular middle-class families. The traditional prepreg composite method is difficult to scale for mass production and cost reduction.

2. Pioneer BMW just needs one more step to reach composites mass production

The BMW i3 composite car serves as a successful example of pioneering mass production of composites in family cars, having sold approximately 39,000 electric vehicles globally in 2019. Currently, it is at a level where it neither loses nor earns too much money for a composite family car.

BMW has already taken a step towards mass production of composites. If it continues to advance its technology pathway, it only needs one more step to fully automate its layup processes and achieve fully integrated production. With this advancement, a BMW i3 composite car body could be produced at 1/3 of its current cost, which would mean that BMW would truly have both feet firmly planted in the realm of fully adopting composites in mass production for family cars.

However, BMW has decided not to take the second step towards further automating its layup processes for composite production. As a result, the company has discontinued the production of the i3 composite car and has not introduced any new composite cars to the market.

3. **We developed an automated layup process to overcome the last technological hurdle**

We conducted research on mass production of composites concurrently with BMW, and successfully developed an automated layup process that BMW did not achieve. By combining our automated integrated production technology with BMW's composite technology, we believe that we can overcome the last technological hurdle and address the major challenges to achieve cost-effective mass production of composites in both the automotive and eVTOL industries.

Most composites are laminated, which involves laying up sheets to create the laminate. Therefore, the major production process for composite laminate is layup. The layup process, which is time and labor-intensive, serves as the bottleneck in the mass production of composites. **So, the high cost of composite products is primarily due to the labor-intensive layup process, rather than the high price of raw materials**. That is why composite products are typically priced at 10 to 20 times the cost of their raw materials. There is huge potential to reduce composite costs to a range of 2 to 3 times the raw material cost through our unique low-cost automated processes.

By improving efficiency by 10 times and reducing product and equipment costs by 80%, our robot automated and cost-effective composite production technology enables the production of composite car or two-seat eVTOL wheels and bodies in just 5 to 10 minutes, at a cost of $500 or $2500, respectively. The low-cost mass production of carbon fiber F1 racing car bodies for regular family cars and eVTOL aircraft is now feasible, making it affordable to protect both drivers and passengers. This has the potential to reduce US car accident fatalities by 15,000 annually, reduce car weight about 30% and save 20% energy car consumes.

When car bodies and chassis are constructed using metal sheets or films, they tend to lack the necessary strength to withstand collisions. To illustrate this point, consider an empty aluminum sheet beer can that can be easily squeezed by hand. Similarly, car bodies and chassis made from metal sheets are not strong enough in collisions. Based on the experiences of F1 racing cars, a composite car body can withstand collisions of up to 180 mph and is therefore considered a safe option. As a result, eVTOLs require the same level of safety and use composite car bodies similar to those found in F1 racing cars.

To produce a two-seat eVTOL at $50,000 and 50,000 to half a million units annually at lower affordable cost, following BMW's composite technology pathway, and using our further automated integrated production process is necessary.

This means that the cost of a two-seater eVTOL, such as Air One will be around $50,000. A reliable, low-cost eVTOL will likely surpass a half million in just a few years after launch, similar to the trajectory of Tesla cars after overcoming cost barriers.

A right technology pathway can save hundred million dollars investment and open a huge market.

Automation driving will likely be adopted earlier in eVTOLs than in cars, making eVTOL taxis cheaper than Uber cars because there is no pilot involved. As a result, it is anticipated that new "Tesla" and "Uber" companies will emerge from the eVTOL industry.

4. Car wheel is a crucial criterion for mass production of composites for cars and eVTOLs

Car wheels are load-bearing complex structures made of composites. The production of complex-structured composite car wheels is a crucial criterion for the automated mass production of composites.

If they can be fully automated in mass production, the manufacturing cost will be close to the cost of raw materials. A 17-pound wheel's raw material cost is about $130, with carbon fiber accounting for about $80 and resin for about $50. Therefore, a wheel's cost is around $300. If the sale price of a wheel is around $500, it will lead to the mass adoption of composite wheels.

However, the current market price for a composite wheel is about $2500, making it only suitable for sports cars.

Once the benchmark of $500 is achieved, the adoption of composites in car bodies and chassis will become widespread, marking the arrival of the composite car era.

If someone claims they can mass-produce composites for the auto industry or eVTOLs, ask them if they can produce a complex-structured composite car wheel near $500.

5. Motorcycle wheels are much easier to manufacture

Compared to car wheels, manufacturing composite motorcycle wheels is generally considered to be a simpler and less costly process. This is due to the smaller size and weight of motorcycle wheels, which requires less material and manufacturing time compared to car wheels. As a result, the investment required to manufacture composite motorcycle wheels is typically lower.

After the successful introduction of carbon fiber motorcycle wheels in the market, it is possible that manufacturers may expand their use of this material to create other automotive components. For example, carbon fiber could be used to create car wheels, car bodies, and even eVTOL bodies and wings.


6. Our pathway to adopt composite for autos and eVTOLs

Lightweight composites can save up to 30% of car weight and reduce fuel or battery usage by 20%. To adopt composites in cars, two conditions have to be met. Firstly, the manufacturing technologies for continuous fiber composites should match the efficiency and cost of plastic and aluminum injection molding, such as Tesla's Giga Press. If not, composites cannot replace aluminum and steel in cars. Secondly, once composite technologies are ready, it is necessary to convince car OEMs of their readiness.

The foundation of continuous fiber composite technology includes fast-curing resins or thermoplastics for quick production molding, and automatic layup laminate sheets for complex geometries, enabling efficient production with fewer car body parts.

Now, with the availability of fast-curing resin and thermoplastic materials, the molding time for composites can be reduced to within 3 minutes. The main technological challenge remaining is the skillful automation of laying up laminate sheets into complex geometries, which can also be achieved within 3 minutes. If the layup process can be shortened to 3 minutes as well, the entire composite manufacturing process would take approximately 3 minutes, comparable to injection molding.

Consequently, the cost of composites, which typically have products priced at 10 to 20 times the cost of their raw materials, could be reduced to a range of 2 to 3 times the raw material cost, similar to aluminum and steel.

Car wheels, with complex geometry and load-bearing function, serve as a crucial test to demonstrate the readiness of composite. If car wheels cannot be produced under $500, it indicates that composites are not yet prepared. Conversely, if car wheels can be manufactured under $500 and successfully integrated, it provides the best evidence to persuade car OEMs to use composites in family cars, similar to their utilization in F1 racing vehicles.

A good pathway to adopt composites in cars is to start by developing low-cost car wheels. If the composite car wheels are successful, they can serve as strong evidence to convince auto OEMs to use composites in their vehicles.

With our unique robotic layup process, composite car wheels can now be produced in just 3-5 minutes at a cost of $500. Furthermore, car or eVTOL aircraft bodies can be manufactured in 10 minutes, costing as low as $2500.

7. Budget

To build the pilot product for motorcycle wheels, a budget of $3.5 million has been allocated.

Similarly, a budget of $5.5 million has been allocated to develop the pilot product for car wheels.