Docket #: S17-103

Double-Double Composite Laminates for Versatile Manufacturing

Stanford researchers led by Stephen Tsai are advancing a new, much simplified design approach for composite laminates – termed "double-double" – that can replace conventional laminates for lighter, tougher, and lower cost airplane structures among other uses. Whereas legacy quad laminates have remained static since their development in the 1960s and are becoming so complex that have added time and cost in their use. They are no longer optimal. **Double-double laminates simplify optimization, leading to new structures with unmatched low weight and cost.** As a result, the double-double composite structures can be designed and produced with tapers to save weight, to have ply drops on the exterior surface to remove defects from the interior, and 1-axis layup of multi-axial tape and fabric —in a customizable manner—meet requirements of many applications, from heavily loaded aircraft wings to sports products.

Replacing legacy quad laminates with this technology opens up new frontiers. For example, it is possible to manufacture a fuselage, and wings in large pieces of structure, with fast layup, cured outside autoclave, with no fasteners, and easy to inspect and maintain. As other non-limiting examples, for rockets, pressure vessels, other structural forms including grid/skin as a special double-double, can also be designed and produced with ease, confidence and quality that can compete with metals



A 21st century composite airplane in Otto Aviation's Celera 500L with extensive application of double-double (Image credit: the inventors)

Related Technology

Stanford docket S19-225 - Manufacturing of Composite Grid/Core/Skin Structures
This invention describes a rib-stiffened, composite grid skin structure design, which is ultra-lightweight, stiff, strong, and easier and less expensive to manufacture.

Stage of Development

In addition to the progress summarized here, tools are available to help in the design of specific shapes while taking advantage of all the great features of double-double composites. In additional to Otto, there are three ongoing programs with major aerospace companies having components designed and prototype produced and tested per double-double technology to be completed before summer 2021.

Applications

- To improve performance and quality, and reduce weight and cost of composites structures
- Aerospace/automotive components

Advantages

- Double-double is a highly engineered fabric with 2 sets of angles of thin plies so multiple sheets can be stacked to form a homogeneous laminate like a piece of aluminum. (Quad cannot be made into multiaxial because it is too thick.)
- This laminate can be easily tapered to save weight and cost.
- A homogenized laminate with thin plies are delamination resistant and designed just like metals.
- Reduced minimum gage requirement opens up applications for components/devices not possible with thick sub-laminates in quad.

Publications

- Bruno Vermes, Stephen W. Tsai, Aniello Riccio, Francesco Di Caprio, Surajit Roy, Application of the Tsai's modulus and double-double concepts to the definition of a new affordable design approach for composite laminates, Composite Structures, Volume 259, 2021,113246, ISSN 0263-8223.
- Tsai, Stephen W. "Double–Double: New Family of Composite Laminates." *AIAA Journal* 59.11 (2021): 4293-4305.

Patents

- Published Application: 20210114336
- Issued: 11,446,897 (USA)

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