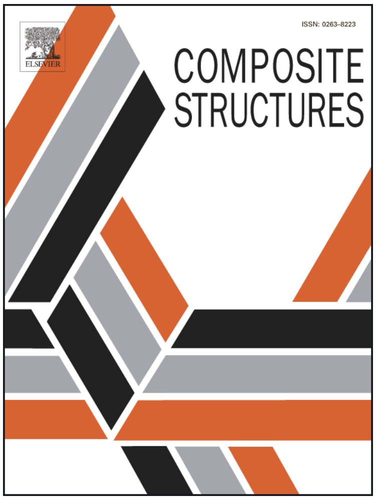

Optimized Design for Projectile Impact Survivability of a Carbon Fiber Composite Drive shaft

T.C. Henry, B.T. Mills

PII: S0263-8223(18)32793-4
DOI: https://doi.org/10.1016/j.compstruct.2018.09.049
Reference: COST 10195

To appear in: *Composite Structures*

Received Date: 3 August 2018
Revised Date: 31 August 2018
Accepted Date: 18 September 2018

Please cite this article as: Henry, T.C., Mills, B.T., Optimized Design for Projectile Impact Survivability of a Carbon Fiber Composite Drive shaft, *Composite Structures* (2018), doi: https://doi.org/10.1016/j.compstruct.2018.09.049

Title: Optimized Design for Projectile Impact Survivability of a Carbon Fiber Composite Drive shaft

Authors: Henry TC[1*], Mills BT[2]

Affiliations: [1]Vehicle Technology Directorate, US-ARL, Aberdeen Proving Ground, USA; [2]Suvivability/Lethality Analysis Directorate, US-ARL, Aberdeen Proving Ground, USA

Abstract:

Helicopter power transmission systems consist of aluminum drive shafts which are connected together with flexible couplers to accommodate misalignment and hanger bearings to secure each drive shaft to the airframe. The development of carbon fiber composites have resulted in designs which reduce the weight of the system as well as eliminate parts which can be integrated into the composite material itself. The reduction in weight and parts provide transmissions which are more maintenance cost conscious as downtime related to manual part inspection for defects and damage is reduced. One barrier to fielding composite systems is impact qualification to ensure passing of survival standards. Some certainty that a design will not increase the vulnerability of a vehicle must exist and this paper provides an impact study for flexible composite drive shafts and performs a design analysis on tradeoffs between weight, and residual strength. 16 drive shafts with two different thicknesses and the optimized lamination $[\pm 45_6/\pm 40_2]$ were manufactured and impacted with either 7.62 or 12.7 mm projectiles while under 252 N-m of torque.

Keywords: Impact behavior, drive shaft, optimization, laminated composite, woven fabric composite

Introduction:

Tail rotor transmission and cross shafting in helicopters fielded today operate with a series of hollow aluminum drive shafts connected with flexible couplers for accommodating misalignments and hanger bearings mounting the system to the frame. The drive shafts, couplers, and bearings have been a target of design improvements as composite material technologies have matriculated [1-5]. The multi-objective space for flexible composite power transmission faces a few challenges (1) strength and stiffness of the lamina, (2) viscoelastic damping-induced heat generation, (3) lateral and torsional dynamic stability, (4) and impact performance. Optimization literature has advanced the state-of-the-art for designing to most of these criteria reducing the system weight and part count with impact requirements remaining as a pass or fail determined after the design.

Laminate strength depends on the material system, method of manufacture, and fiber orientation of each lamina. Research has been conducted on replacing the metal drive shaft by using either braiding or filament winding, common composite cylinder manufacturing methods for automotive power transmission [6-11] as well as pressure vessels [12-14]. Typically braiding [15,16] can be used in a matched molding resin transfer process for higher dimensional tolerance through the thickness and lower void content than filament winding which only has molding for the interior surface but is more cost effective in time and capital. These processes introduce a weaving texture to the composite [17] which decreases fiber direction stiffness and strength as at each fiber crossover there is a through-the-thickness misalignment to the fiber. Material property inputs for woven composites take into account the misalignment [18-24] when conducting a structural analysis [25]. The strength and stiffness for a particular part can be well predicted by quantifying the degree of misalignment and representing the macrostructure with a representative volume element. A multi-objective analysis will determine a laminate sequence which does not have any lamina stress which exceeds the strength in any direction taking into account misalignment.

The flexible couplers of the transmission are present to ensure that the aluminum drive shafts do not experience fatigue as the fuselage flexes under aerodynamic forces. The polymer of the coupler experiences