



VAN HORN AVIATION, L.L.C.
Tempe, Arizona

REPORT No. 206BT-STR-508
STRUCTURAL TEST REPORT
EVALUATION OF N90326 CRASH DAMAGE TO 2062200 TAIL
ROTOR BLADES

July 18, 2023

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REVISIONS

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Acronyms

CF – centrifugal force
 FAA – Federal Aviation Administration
 IPS – inches per second
 LEF – load enhancement factor
 MSAD – monitor safety/analyze data
 RPM – revolutions per minute
 VHA – Van Horn Aviation, LLC
 VHR – Van Horn Repair, LLC

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References

1. National Transportation Safety Board Aviation Investigation Preliminary Report WPR22LA221
2. Van Horn Aviation Drawing 2062200 Blade Assembly, Revision J
3. Van Horn Aviation Structural Test Report 206BT-STR-507 Non-Visible Damage, Revision N/C

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1. Scope

The following report presents a visual evaluation of damage to 2062200-301 Tail Rotor Blades with serial numbers C548 & C549 installed on Bell 206 JetRanger tail number N90326, which was involved in an accident near Stockton, CA on June 17, 2022 (Reference 1).

2. Introduction

The referenced 2062200-301 blades were sent to Van Horn Aviation for examination after a hard landing in which the pilot reported a vibration, hearing a bang, and a loss of yaw control. The helicopter came to rest in an orchard after contacting a tree. It landed flat but was spinning to the right and rolled onto its left side. Blade C548 was primarily intact and still attached to the tail rotor hub. Blade C549 was fractured into multiple pieces of which only the root fitting was still attached to the hub (Figure 3). According to the pilot, he recovered two additional fragments approximately 2000 ft from the main wreckage. Both blades, including the separated fragments of C549, are shown in Figure 5.

2062200-301 Tail Rotor Blades are constructed primarily of uni-directional carbon fiber epoxy over a structural closed-cell foam core in a sandwich structure configuration (Reference 2). The carbon fiber direction is primarily aligned with the long axis of the blade (0 deg); however, the outermost skin plies include one ply each at positive and negative 45 deg angles for in-plane shear and torsional stiffness. The entire laminate wraps continuously around the leading edge with the upper and lower surface plies connected at the trailing edge by a wedge-shaped, uni-directional trailing edge strip. The root end attachment is comprised of a titanium fitting bonded to the inner surface of the composite with stainless steel spherical bearings for pitch motion. The tip end is closed off with a GEE-F fiberglass block and the leading edge has an electroformed nickel abrasion strip to protect the carbon from erosion (see Figure 1 & Figure 2).

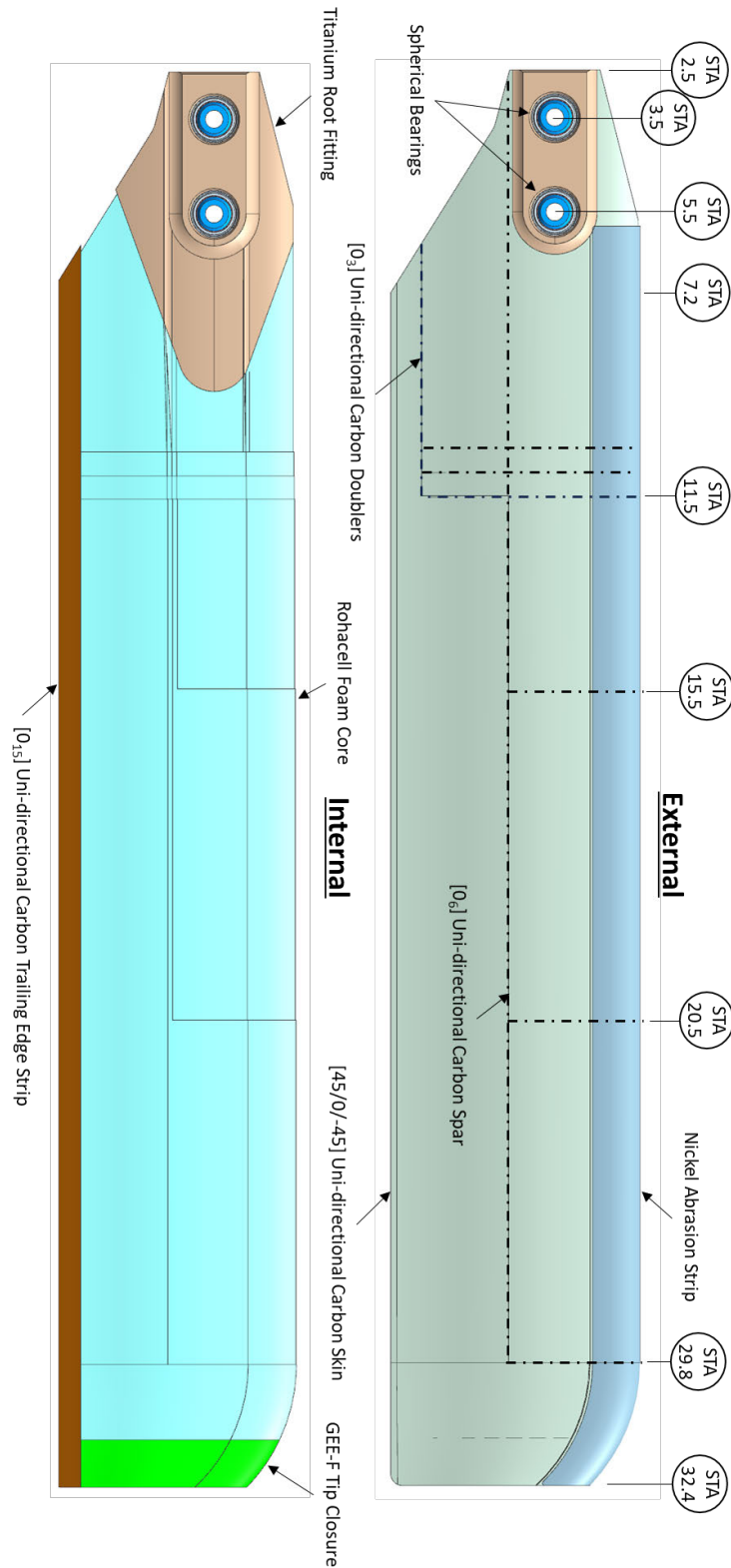


Figure 1 - 2062200-301 Tail Rotor Blade Construction

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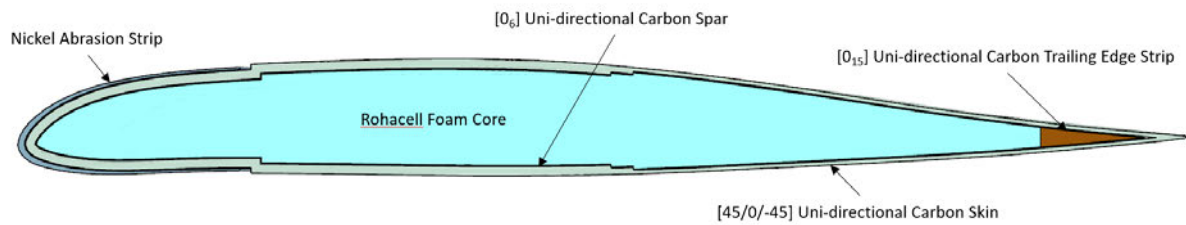


Figure 2 - 2062200-301 Tail Rotor Blade Cross-Section



Figure 3 - C548 & C549 As Found at the Site

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Figure 4 – Overall View of Blades C548 & C549 Upper Surfaces

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Figure 5 – Overall View of Blades C548 & C549 Lower Surfaces

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3. Examination

3.1 Blade S/N C548

Multiple images of blade C548's upper and lower surfaces are shown in Figure 6 & Figure 7, respectively. As mentioned, this blade was largely intact, which is to say that most of the structure was still in one contiguous piece. However, this blade did exhibit two primary fracture planes, one at the root end (Figure 8) and the other near mid-span (Figure 9). The root end fracture is characterized primarily by a nose-down rotation about the blade axis. This resulted in delaminations within the uni-directional carbon as well as some epoxy matrix cohesive failure adjacent to the titanium root fitting. Translaminar shear failures in the upper and lower laminates propagated outboard along approximately straight lines from the aft corner of the root fitting. On the lower surface, this crack extended 6.5" outboard, moved forward along the 45 deg laminate direction until reaching the aft edge of the spar plies, and then continued another 3.5" outboard before arresting. In this area there is also extensive core peel failure, initially adjacent to the upper skin at the root end but shifting to the lower skin immediately outboard of the root fitting. Of note, the upper laminate at the inboard end was delaminated from the root fitting and deflected so significantly that it came to rest on the outside of the pitch horn balance ring (Figure 8). This is noteworthy because only a tremendous overload such as from an impact event could have forced the laminate passed the ring to the outside.

The mid-span fracture predominantly follows a 45 deg angle from leading to trailing edge. The lower surface (Figure 7) exhibits multiple parallel translaminar fractures following the 45 deg ply with nearly chordwise fractures through the abrasion and trailing edge strips. Of interest, some of the carbon laminate attached to the outboard side of the abrasion strip crack was forced past the lower surface of the inboard portion of the abrasion strip. Similarly, some of the inboard portion of the trailing edge strip was forced past the lower surface of the outboard laminate. On the upper surface (Figure 6), more extensive damage is seen including portions of the upper skin & spar missing and multiple core fractures. At the leading edge there are multiple scrapes and material transfer marks as well as a second smaller crack and a dent approximately 2" inboard of the main fracture (Figure 9). Immediately outboard of the fracture the abrasion strip is buckled on the upper surface and delaminated along its aft edge extending approximately 2 inches outboard. The residual strength and stiffness of the blade allows the tip to move easily upward and rotate nose down along the 45 deg fracture indicating this was the direction of deformation which caused the failure. Such a bending deformation would have put the lower surface in tension and the upper surface in compression. This is consistent with the buckling observed in the abrasion strip as well as the more extensive laminate and core damage observed on the upper surface. The missing laminate likely peeled away from the core, buckled, and fractured at either ends of the buckle which led to its departure.

The tip end of the blade exhibits relatively little external damage, however, scrapes and material transfer extending in an aftward direction are apparent on the abrasion strip (Figure

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10). In addition, there is an approximately 2” crack visible in the paint on the lower surface (Figure 11). A tap test reveals extensive voiding throughout the tip region and tactile pressure finds the surface to be squishy and produce crunching sounds. This is consistent with internal core failure and separation from the overlying laminate. The paint crack and extensive internal core failure is commonly seen in impacts to the aft body of the blade (Reference 3). Moreover, an impact at the crack site would induce a tip-up, nose-down moment and therefore could potentially have caused the mid-span and/or root end fractures.			

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Figure 6 – C548 Upper Surface Montage

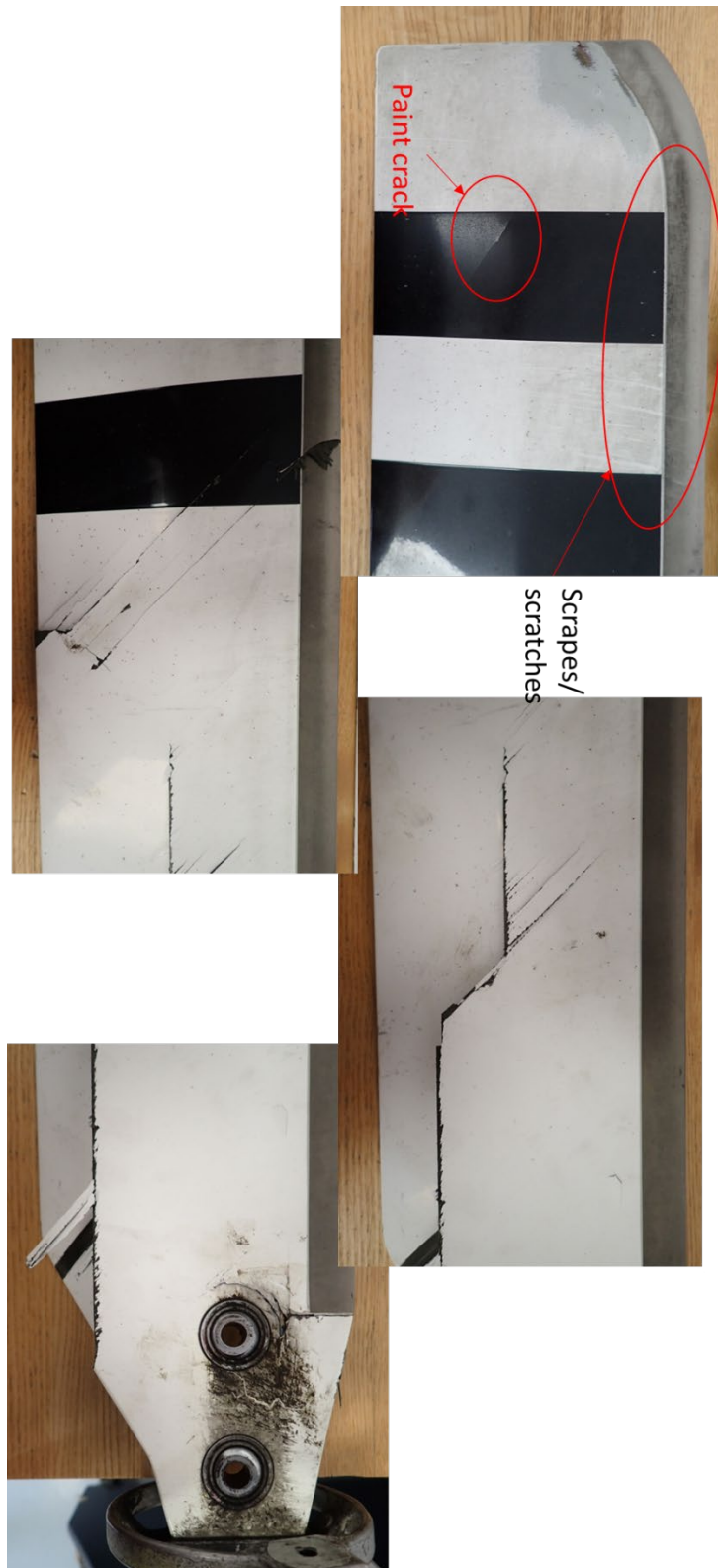


Figure 7 – C548 Lower Surface Montage

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Figure 8 – C548 Root End Fracture

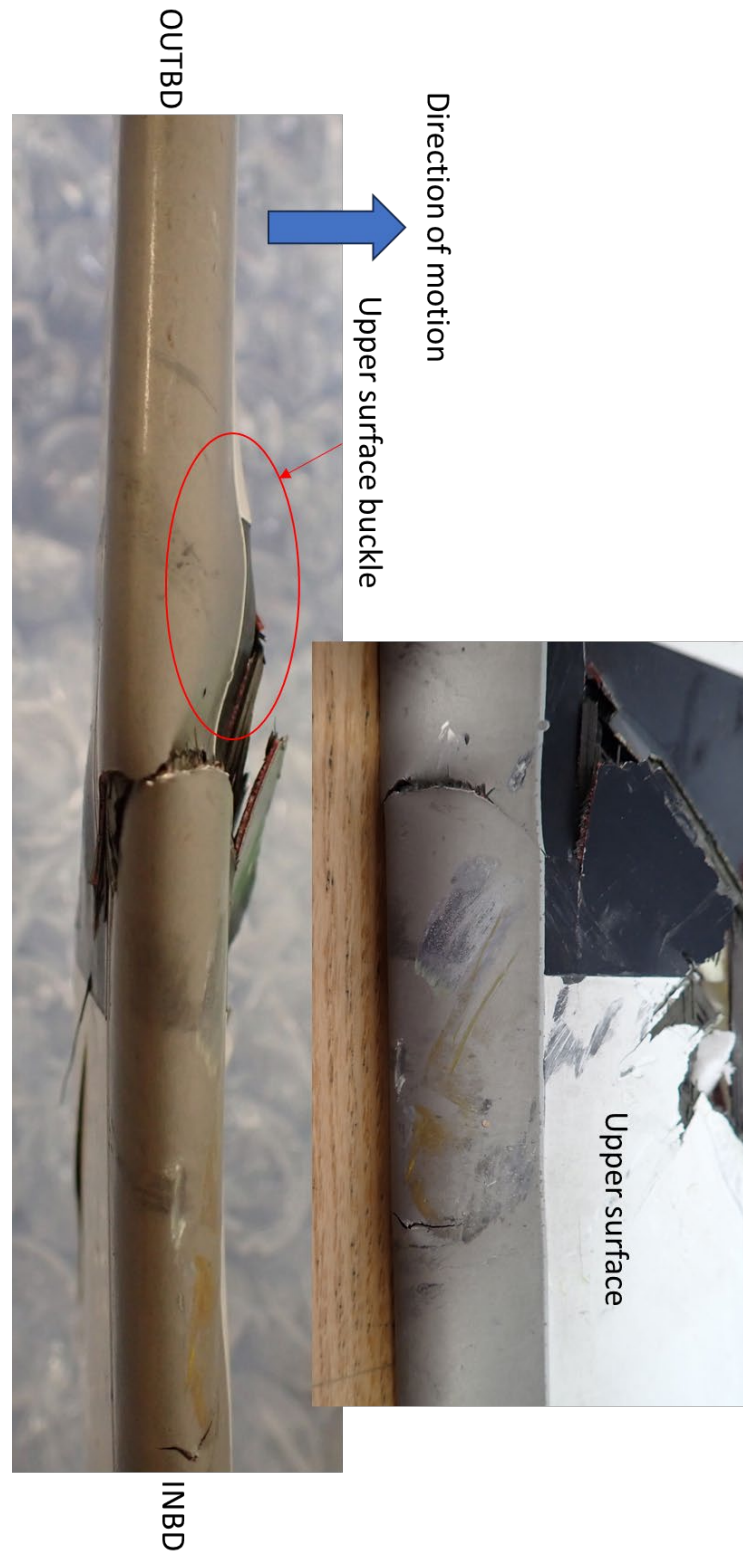


Figure 9 – C548 Mid-Span Fracture

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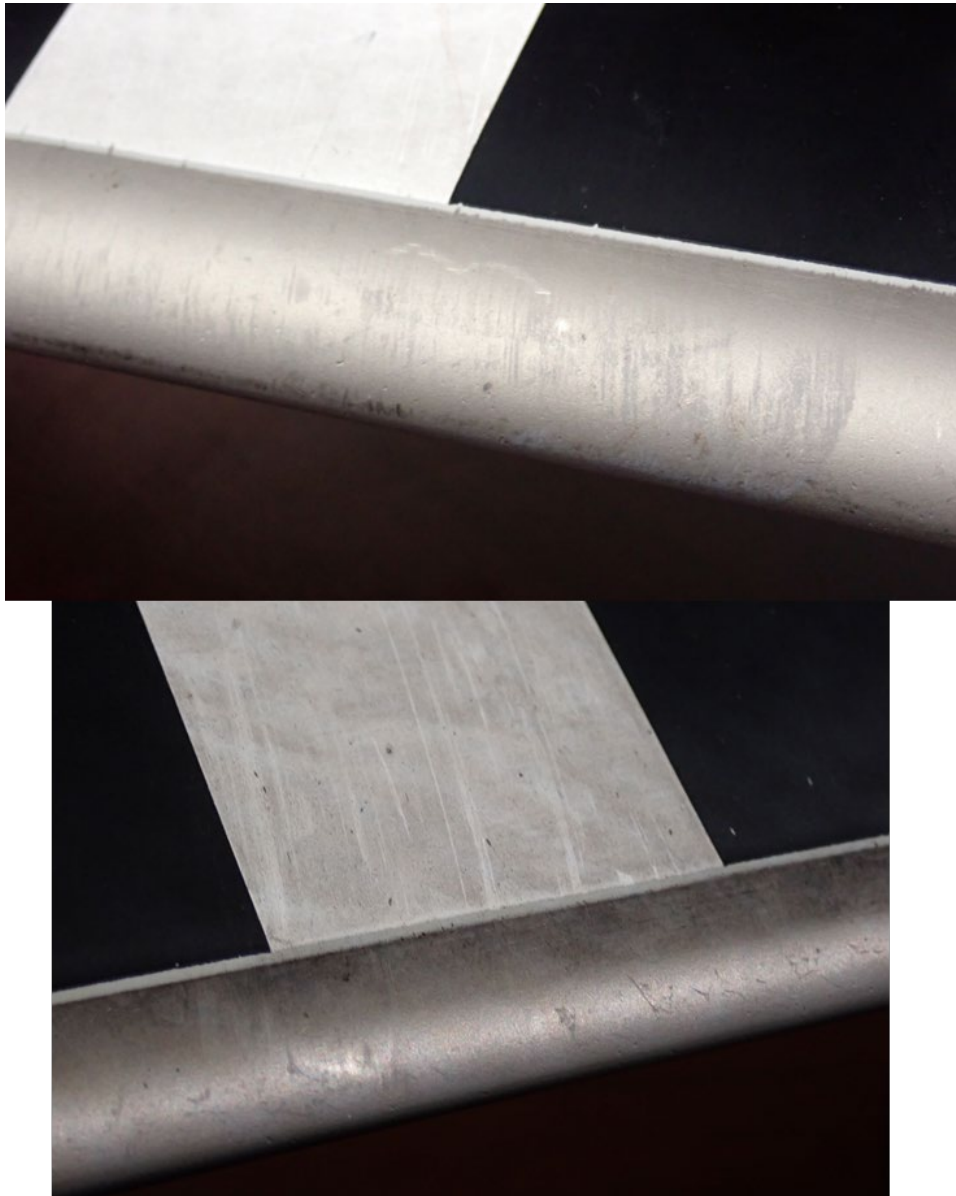


Figure 10 – C548 Abrasions on Upper & Lower Tip Leading Edge

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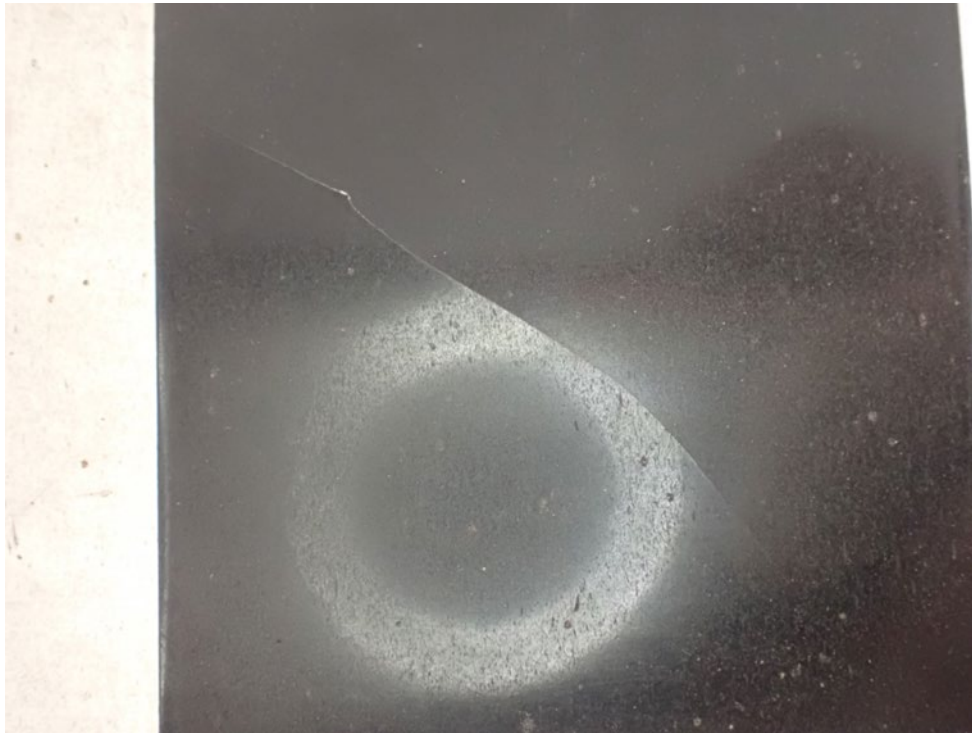


Figure 11 – C548 Crack on Tip Lower Surface

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3.2 Blade S/N C549

As previously mentioned, only the root fitting portion of blade C549 was still attached to the helicopter. A large lower skin fragment (“fragment 1”) as well as a trailing edge piece (“fragment 2”) were found separated from the root fitting (Figure 12 & Figure 13). However, nearly all the core, most of the upper laminate, and the entire swept tip portion were not recovered. Both recovered fragments have portions of laminate which interface to the root fitting as well as each other. Multiple images of the assembled blade C549’s upper and lower surfaces are shown in Figure 14 & Figure 15, respectively. Of note, both fragments interface primarily with the lower surface of the root fitting, except for that portion of fragment 1 which includes the abrasion strip that wraps around the leading edge and mates with a small portion of the upper surface of the root fitting. The separations at the root fitting are characterized by interlaminar failures primarily between the 0 deg fibers of the spar (Figure 16), however some delaminations within the outer +45/0/-45 deg skin plies are also evident. Figure 17 shows a buckle in the abrasion strip on the upper surface of fragment 1 which mates with the outboard end of the root fitting. The V-shape of the buckled region indicates a deflection primarily in the aftward direction.

The mid-span fracture (Figure 18) shares similarities with that seen on blade C548 albeit somewhat less severe. The abrasion strip is cracked in 3 places on the lower surface and with only one wrapping around slightly onto the upper surface. There are also several delaminations in the 45 deg plies immediately aft of the cracks on the lower surface. The residual strength in the laminate permits motion most easily in the tip up direction, again indicating this was the direction of deflection at failure. The lower surface outboard of this cracking shows an extensive network of fine paint cracks or crazing (Figure 19) which is typically associated with wide area impacts on the aft body of the rotor blade (Reference 3).

The tip fracture removed the last 2” of the tip of the blade (Figure 15). This constitutes the entire swept tip portion of the blade. This is readily apparent since none of the white paint outboard of the last black stripe is visible. In this area the abrasion strip shows substantial denting, folding, and debonding/delamination along its aft edge as well as discoloration from foreign materials. The abrasions strip is significantly deformed aftward starting just outboard of the inboard edge of the black paint stripe (Figure 20). This extensive amount of deformation to the abrasion strip is indicative of a high energy impact on the leading edge and almost certainly while the blades were turning. The carbon material aft of the abrasion strip exhibits translaminar fracture mostly along a plane at rotor station 29.8 which corresponds with the outboard termination of the spar plies. Many of the cut ends of the spar plies are visible. On the lower surface, a portion of the skin separated along the fibers of the 45 deg ply. Finally, a foreign material, possibly compacted soil, was found embedded behind the abrasion strip at the tip end of the blade.



Figure 12 - C549 Fragments Upper Surface



Figure 13 - C549 Fragments Lower Surface

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Figure 14 – C549 Upper Surface Montage



Figure 15 - C549 Lower Surface Montage

Upper Surface



Lower Surface



Figure 16 - C549 Root Fracture

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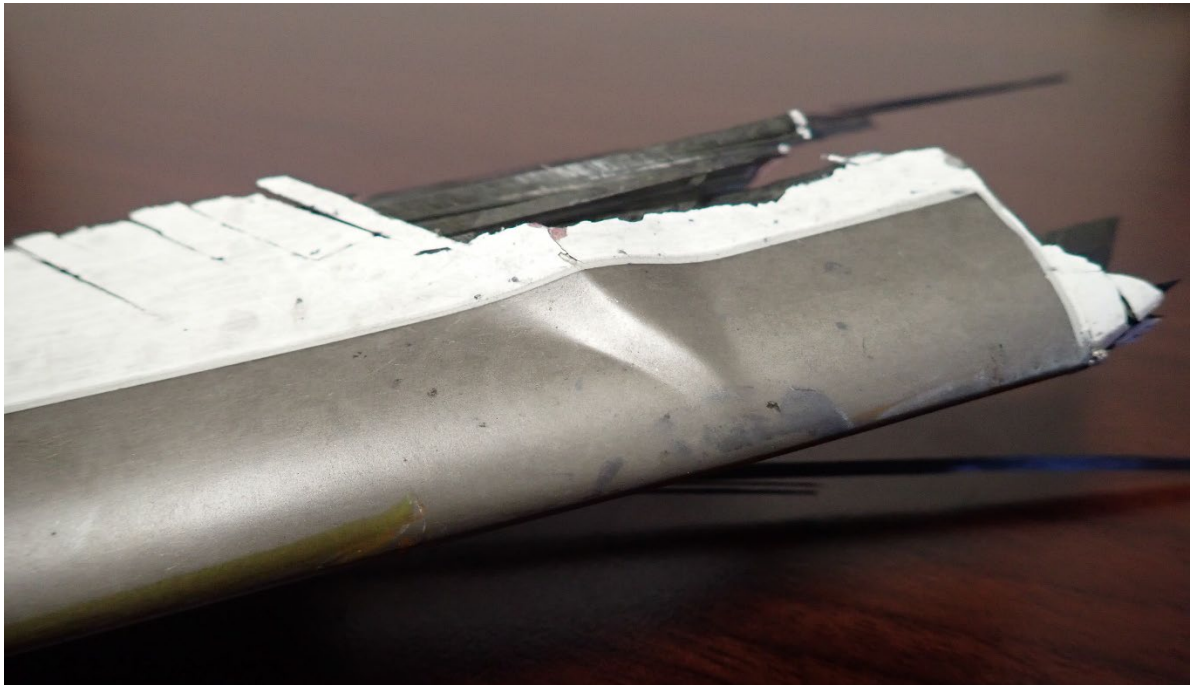


Figure 17 – C549 Fragment 1 Abrasion Strip Buckle



Figure 18 - C549 Mid-Span Fracture

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Figure 19 – C549 Fine Paint Cracks on the Lower Surface Near the Tip End

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Figure 20 - C549 Tip Fracture

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4. Conclusions

