National Transportation Safety Board
Aviation Accident Final Report

Location:	Middletown, DE	**Accident Number:**	ERA12LA493
Date & Time:	08/01/2012, 0900 EDT	**Registration:**	N126GW
Aircraft:	SIKORSKY S-58JT	**Aircraft Damage:**	Substantial
Defining Event:	Miscellaneous/other	**Injuries:**	1 None
Flight Conducted Under:	Part 133: Rotorcraft Ext. Load		

Analysis

The pilot had flown two uneventful external load lifts to place 2,900-lb air conditioning units on a warehouse roof. The pilot reported that, during the third lift, he felt vibration in the pedals that became violent, and the helicopter then began to rotate about its vertical axis. The air conditioning unit touched down on the roof as the helicopter was spinning. The pilot could not stop the helicopter's rotation, so he released the cable attached to the air conditioning unit and then maneuvered the helicopter away from the warehouse. He then increased forward speed, turned right to line up with a street, and conducted a roll-on landing.

Examination of the helicopter revealed that the entire aft portion of one of the four tail rotor blades had separated just aft of the blade's spar where a bond line existed. Examination of the tail rotor blade revealed high-stress progressive crack growth features at the root end of the fracture, buckling deformation adjacent to the fracture, and bending deformation of the leading edge, all of which were consistent with the tail rotor blade fracturing due to dynamic instability in the tail rotor. The progressive crack growth features observed on the fracture surface were associated with relatively high stress and few cycles and likely occurred after the deformation associated with the buckling. In addition, all four tail rotor blades exhibited bending deformation, indicating that they all experienced loads that exceeded the allowable design loads, and the deformation pattern was consistent with an external input on the tail rotor assembly overloading all of the blades rather than a failure in the blade causing it to become unstable. The helicopter manufacturer confirmed that such damage can be caused by dynamic tail rotor instability and that such instability can be accompanied by tail rotor vibration, as was experienced during the accident flight.

Although dynamic tail rotor instability rarely occurs, it has been known to occur on the accident helicopter make and model. To improve tail rotor stability, the helicopter manufacturer had introduced two modifications to the tail rotor system, and both of these modifications had been installed on the accident helicopter. Even with the modifications, dynamic tail instability can occur, and high values of left pedal, improper tail rotor cable tension (too high or too low), bottoming of the tail rotor control system spring, higher rotor speed, or relative wind from the right forward quadrant could increase susceptibility. However, a review of the helicopter’s maintenance records did not reveal that any of the mechanical factors that could contribute to tail rotor instability existed, and wind was calm at the time of the accident. Additionally, after the damaged components were replaced, the helicopter was returned to service. The helicopter’s flight manual also contained guidance stressing that pilots should immediately decrease the tail rotor pitch after encountering pedal vibration. If the pilot had recognized that the pedal vibration was indicative of tail rotor instability and immediately taken the proper corrective actions in accordance with this guidance, the accident might have been prevented.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:
The pilot's failure to recognize that the helicopter was experiencing tail rotor dynamic instability and to take immediate corrective actions during an external load lift, which resulted in the failure of a tail rotor blade.

Findings

Aircraft	Tail rotor blade - Capability exceeded (Cause) Tail rotor blade - Failure (Cause)
Personnel issues	Incorrect action performance - Pilot (Cause)

Factual Information

HISTORY OF FLIGHT

On August 1, 2012, about 0900 eastern daylight time a Sikorsky S-58JT, N126GW, operated by Aircrane Inc., was substantially damaged when it incurred a failure of a tailrotor blade in Middletown, Delaware. The certificated commercial pilot was not injured. No flight plan had been filed for the local commercial flight conducted under Title14 Code of Federal Regulations (CFR) Part 133.

According to the 'Safety Officer," who was helping with the external load operation, placing air conditioning units on the roof of the warehouse, the helicopter flew in to the site around 0730. After gathering all of the personnel, she gave a safety briefing and gave instructions to them on how they were going to conduct the operation. She then split the personnel up into two 4 man crews and sent one of the crews off the roof to reduce the number of personnel they had in the way of the operation. Once she had done this, she gave the "High Sign" to start the operation. The first two lifts were good but, on the third lift, when the helicopter came up over the roof, it did not sound right, and was swerving with the air conditioning unit swinging below the helicopter. The helicopter than started spinning and she yelled for the people on the roof to move. Then while the helicopter was spinning and the nose dropping, the air conditioning unit landed on to the roof, and rolled upside down while it was still attached to the helicopter by the cable. She continued to yell for everyone to get away as the helicopter continued to spin with the nose dropping even after the air conditioner had fallen onto the roof. The pilot then released the cable, and the helicopter then began moving away from the building. A portion of a tail rotor blade then landed on the roof.

According to the "Guide Man" who was on the roof, after flying to the warehouse, the helicopter landed and was unloaded. The rigging was than attached to the helicopter. About 45 minutes later, He called for the helicopter and advised that they were ready on the roof. The helicopter lifted the first air conditioning unit and it was placed "dead on" to its mounting location. The second unit was then lifted and it also was "dead on." The helicopter then began lifting the third air conditioning unit, did a normal left turn but, he suddenly heard a high rotor rpm sound. The helicopter then turned into the wind and began spinning over the roof with the air conditioning unit about 12 feet off the roof. The air conditioning unit then touched down on the roof, but the helicopter was still spinning. He then began calling over the radio for the pilot to "break it loose". At this point the air conditioning unit was on the roof upside down, the helicopter then moved away from the building and landed.

According to the pilot, He flew the helicopter over from Summit Airport (EVY), Middletown, Delaware, and landed at the job site. They completed the "Safety Brief" for the area and personnel; and the extra people they did not need for the lift operation were moved off the roof.

The lifts consisted of 2,900 pound roof top air conditioning units. The first two lifts were uneventful. However, during the third lift, while over the curb about 12 feet above ground level, the pilot felt vibrations in the pedals for a moment. The vibrations became violent, which activated the emergency locator transmitter and the landing light.

The helicopter started to rotate about its vertical axis, and though he tried, he could not stop the rotation. He reduced power, then moved the aircraft from above the roof and jettisoned the cable. He then flew the helicopter away from the building, and cleared the roof. He then picked up forward speed, turned to the right to line up with a street, and did a roll on landing.

PERSONNEL INFORMATION

According to Federal Aviation Administration (FAA) records, the pilot held a commercial pilot certificate with ratings for helicopter and instrument-helicopter. He also held type ratings for the S-58 and S-61. His most recent FAA second-class medical certificate was issued on January 3, 2012. He reported that he had accrued 16,500 total hours of flight experience, of which, 7,000 hours were in the accident helicopter make and model.

ORGANIZATIONAL AND MANAGEMENT INFORMATION

Aircrane Inc. was established in 1993 as a construction helicopter operator, specializing in Heavy lift Aerial Crane Services or "External Loads."

At the time of the accident they held 14 CFR Part 133 (External Load), 14 CFR Part 135 (Air Taxi), and 14 CFR Part 137 (Agricultural Application) certificates.

AIRCRAFT INFORMATION

The commercial version of the S-58 helicopter was certificated by the FAA on August 2, 1956. The S-58 featured a 56 foot diameter, 4 bladed main rotor, and a 4 bladed tail rotor. Both main and tail rotor blades used the symmetrical NACA 0012 airfoil. The fuselage was all metal, and was equipped with conventional landing gear (main wheels in front, tail wheel in back).

According to FAA and maintenance records, the helicopter was manufactured in 1959. It was modified on July 7, 1971 with the removal of its radial engine and installation of a Pratt & Whitney Canada PT6T-3 Twin-Pac Turbine engine. A few years later, it was upgraded to a PT6T-6. Its last continuous airworthiness inspection was completed on July 31, 2012. At the time of the accident the helicopter had accrued 11,064.7 hours of operation.

METEOROLOGICAL INFORMATION

The recorded weather at New Castle Airport (ILG), Wilmington, Delaware, located 10 nautical miles northeast of the accident site, at 0851, included: calm winds, 8 miles visibility, clear skies, temperature 23 degrees C, dew point 22 degrees C, and an altimeter setting of 29.90 inches of mercury.

WRECKAGE AND IMPACT INFORMATION

Post accident examination of the helicopter by a Federal Aviation Administration (FAA) inspector revealed that the entire aft portion of one of the tail rotor blades was missing. Further examination revealed that it had separated at a point just aft of the broken tailrotor blade's spar where a bond line existed.

The separated aft portion of the broken tailrotor blade was later recovered from the roof of the warehouse by the operator. All four tailrotor blades including the seperated aft portion from the broken blade were then retained by the NTSB for further examination.

According to the operator after the accident, the yaw spring was inspected and returned to service on the accident helicopter.

The tail rotor assembly and intermediate gearboxes were scrapped along with the tail rotor drives. The chip detectors were inspected and found to be clean and the main rotor gearbox was inspected, and its chip plugs and screen were also found to be clean. The main rotor gearbox oil was changed, and a gear box penalty run of one hour was performed, the chip plugs and oil screen were then inspected again and were still found to be clean, and it was returned to service.

All of the hanger bearing supports, gearbox mounting flanges, and the pylon fittings then were subjected to a die penetrant inspection for cracking and no defects were noted.

All of the tail rotor drive shafts were scrapped and replaced with overhauled ones.

The pylon was also inspected for structural integrity and loose rivets and all of the inspection panels were opened on the helicopter and inspected with no defects being noted.

The helicopter was returned to service in October of 2012 and at the time of this report had been operating without incident.

TESTS AND RESEARCH

Tail Rotor Control System

The tail rotor was controlled through a hydraulically boosted cable system with push-pull rods which connected a rear fuselage bell crank to the rotor. The hydraulic servo operated on the tension difference between the two cables and, as the system was a boosting system with the power piston in series with one of the cables and not a fully powered system, the yaw pedals had a direct mechanical link to the rotor blade pitch change mechanism.

The cables were rigged to a specific tension and a spring inserted in one of the cables had as its main function the tuning of the rate of the whole tail rotor system to avoid unwanted resonances. The spring also maintained the tension over a wide range of ambient temperatures.

Tail Rotor Blades

The tail rotor blades were of aluminum alloy construction. The structural supporting member of the blade assembly consisted of a solid spar around which the skin was wrapped and bonded.

The skin was bonded together at the trailing edge and formed an integral part of the blade structure. An aluminum foil honeycomb core was sandwiched and bonded between the top and bottom skins and the trailing edge side of the spar to form structural support for the skin.

The tip of the blade was sealed by means of a riveted tip cap, and the root was sealed with cemented balsa filler.

The root end of the blade assembly was also reinforced by a strap which was wrapped and bonded to both sides and around the leading edge of the blade.

Review of the helicopter's maintenance manual revealed that the tail rotor blades had an unlimited life, provided that the following flight restrictions were complied with: 25 knots maximum sideward flight, minimum 10 seconds hovering turns (360 degrees), and minimum 88 percent Nr (main rotor rpm) on all taxi turns. Review of the maintenance records did not reveal however, whether the helicopter ever exceeded any of the specified flight restrictions nor could it be ascertained if a robust mechanism had ever been set up by the manufacturer or operators of the S58 that would capture these types of exceedances.

Examination of the Tail Rotor Blades

As part of the examination, the tail rotor blades were lettered from A to D in sequence in the direction of tail rotor rotation such that each blade trailed the next higher blade, and blade D trailed blade A. Blade A was fractured with most of the airfoil separated from the spar. Blades B, C, and D were intact.

All of the tail rotor blades were Sikorsky part number 1615-30100-045. According to component log cards, all blades were installed on June 28, 2011 at 162.3 hours prior to the accident. The component log cards stated that prior to installation on the accident helicopter, blade B was last removed from another helicopter in 1993 for painting, and blades C and D were last removed from another helicopter in 1990 for vibration troubleshooting. The prior installation history for blade A was not noted on the component log. At the time of failure, the component log stated blade A had a total time of 2,494.40 hours. The total times for blades B through D were unknown.

Data plates affixed to the inboard sides of the blades indicated the blades had been inspected and repaired at Sikorsky. Blades C and D were each marked inspected and repaired in May, 1979. Blades A and B were marked inspected and repaired in September, 1980, and in May, 1983, respectively. The data plate for blades A and C listed total times of 2,562.10 hours and 0.0 hours, respectively. The hours for blades B and D were marked unknown.

A stainless steel wear strip covered the leading edge along nearly the entire length of the airfoil back to approximately 1.44 inch from the leading edge. The wear strip is bonded to the skin with Scotch-Weld AF 30 structural adhesive film manufactured by 3M.

The intact areas of the blades were initially examined for paint condition, dents, and other anomalies. As shown in figures 1 and 2, the paint was eroded away from the leading edges of the blades. The paint erosion on blade A was less than that of the other blades.

A dent was observed on the outboard side of blade B at a location approximately 14.5 inches from the butt end of the blade and is indicated in figure 1. This dent, measuring approximately 1.75 inches in diameter, was the largest and deepest dent observed on the 4 blades. Smaller and shallower dents were observed on other areas of blade B and on blades A and D.

A slight bulge was observed on the inboard side of blade B near the trailing edge of the leading edge wear strip. The bulge was approximately 1 inch long and was located approximately 36.25 inches from the hub end of the blade.

Blade A was fractured into 2 pieces. One piece included the intact main spar, and the other piece which was recovered from the roof contained most of the airfoil. The spar was bent with the tip displaced toward the leading direction and outboard relative to the hub end.

The fracture in blade A intersected the hub end of the airfoil at a location approximately midway between the spar and the trailing edge. Along most of the length of the blade, the skin was fractured at the spar trailing edge on both the inboard and outboard sides of the blade. At the blade tip, a flange bonded to the trailing side of the spar was fractured and showed flat fracture features.

The tip cap on blade A was removed to facilitate examination of the fracture surfaces near the tip of the blade. When the tip cap was removed, it was noted that no lock wire was installed on the bolt attaching the tip weights. The fracture features of the flange at the blade tip were generally flat, and edges at the hub end of the flange piece attached to the spar were bent outward toward the tip.

The leading edge wear strip was intact and remained attached to the piece of the skin that wrapped around the leading edge spar. The trailing edges of the leading edge wear strip had a wave pattern deformation. The wear strip was disbonded from the pieces of the skin on the inboard and outboard sides of the separated trailing airfoil piece of the blade. The fracture was mostly an adhesive fracture at the interface between the skin on the trailing piece and the adhesive that remained bonded to the wear strip. Similar features were observed along the entire length of the blade where the skin was disbonded from the wear strip on both the inboard and outboard sides of the blade.

The adhesive was teal green in color and was impregnated with an open-weave fiber mesh. Portions of the adhesive appeared to be stained brown. Data sheets for Scotch-Weld AF 30, the leading edge wear strip adhesive specified in the engineering drawings for the blade assembly, state that Scotch-Weld AF 30 is an unsupported structural adhesive film. According to a technical representative for 3M, their unsupported adhesive films such as Scotch-Weld AF 30 do not have a fiber mesh.

The skin fractures were examined visually. The skin fractures were all on slant planes, consistent with ductile overstress fracture and closer examination of the blade surface in close proximity to one of the fractures near the root end of the airfoil revealed that the outboard skin was bent consistent with compression buckling. The surface adjacent to the fracture on the inboard side of the blade was relatively straight which was consistent with the tension side of a bending fracture.

Sections of the fracture surfaces at the blade tip and the root end of the airfoil were cut from the rest of the blade and examined using scanning electron microscopy (SEM). The flat fracture features of the flange attached to the aft side of the spar showed elongated dimples consistent with ductile overstress fracture from shear loading. The orientation of the dimples was consistent with a loading where the trailing piece of the airfoil was moving radially outward (away from the hub) relative to the spar.

Most of the SEM images of the fracture surface showed ductile dimple fracture features. However, portions of the fracture surface showed small regions of flat features with curving boundaries, features consistent with progressive crack growth.

At the inboard side of the fracture, evidence of progressive crack growth was also observed on the inboard side of the skin up to approximately 2.5 inches from the root end of the fracture. The progressive crack features were relatively small.

Evidence of progressive crack growth was also observed on both the inboard and outboard sides of the skin and strap and on the inboard side of the root end channel. None of the progressive crack regions extended through the thickness. Rubbed fracture features consistent with fracture surface recontact were observed across much of the fracture up to 4.3 inches from the root end of the fracture.

At the outboard side of the fracture, evidence of progressive crack growth was observed on the inboard sides of the skin and root end channel. The areas of progressive growth on the outboard side of the blade were only observed in the area of the root end channel. Overstress features with no evidence of progressive crack growth or fracture surface recontact were observed on the fracture surface at more than approximately 0.7 inches away from the root end of the fracture.

Blade B Disbond

A quarter was tapped on the inboard and outboard blade surfaces along the bonded area near the trailing edges of the leading edge wear strip on all three intact blades. Dull-sounding taps were detected in the area of blade B where the slight bulge was observed. No other areas with dull-sounding taps were detected on the remaining areas of the intact blades. Next, the tip portion of the blade including the bulge was cut from the remainder of the blade with a transverse cut using a band saw. Then, a transverse cut near the middle of the bulge was made using a liquid-cooled abrasive cut-off saw. Examination of the cut open bulge revealed a gap between the adhesive and skin.

Disassembly of Intact Blades

Blades B and D were partially disassembled to reveal construction of the leading edge strip and blade tip area. In blade B, a hand-held abrasive-wheel cut-off tool was used to grind a cut along the leading edge of the blade through the tip cap and the leading edge wear strip. Next, a flat-head screwdriver was inserted into the gap in the tip cap and twisted. The tip portion of the cap fractured open, exposing the underlying structure. Then, a utility knife was inserted under the tip end of the wear strip to separate it from the skin. Once enough of the wear strip was lifted to enable gripping with vice-grip pliers, vice-grip pliers were clamped to the lifted wear strip, and the strip was peeled toward the hub end of the blade piece. A similar procedure was repeated for the wear strip on the opposite side of the blade.

According to the engineering drawing, a rivet is inserted through the tip cap and spar near the leading edge of the tip cap. A hole was observed in the spar, but the rivet was missing as indicated in figure 13. No rivet holes were observed in the tip cap. A lock wire was observed installed on the tip weight attach bolts.

Examination of the adhesive revealed that it was greenish tan in color and included an embedded open fiber mesh. On the inboard side of the blade, approximately 50% of the area had adhesive that remained attached to the skin. The other 50% was mostly free of any visible adhesive. On the outboard side, most of the adhesive remained attached to the wear strip, and approximately 70% of the mating skin side of the fracture was completely free of any visible adhesive.

For blade D, the tip cap was removed by drilling out the rivets on each side of the blade. No rivet was present through the spar near the leading edge of the tip cap. A lock wire was observed on the tip cap bolts after the tip cap was removed.

Next, the inboard and outboard sides of the leading edge wear strip were peeled away from the skin using the same procedure used for blade B. The wear strip was cut and peeled along a length of approximately 9 inches from the tip end of the strip. The adhesive for the wear strip in blade D was teal green in color and was embedded with an open fiber mesh. After peeling, the adhesive remained mostly attached to the skin. However, bits of adhesive remained attached on the wear strip side of the fracture in a square pattern corresponding to fiber locations of the open fiber mesh.

Adhesive Identification

The adhesive for blades A, B, and D were analyzed using Fourier-transform infrared spectroscopy (FTIR), and the peaks were compared to a reference spectrum for Scotch-Weld AF 30 structural adhesive provided by 3M. The spectra for all three samples did not match the reference spectrum for Scotch-Weld AF 30, but the spectra had similarities consistent with being from a similar class or type of polymer.

Sikorsky Materials Engineering Examination

In order to garner more information about the tail rotor blades, at the request of the NTSB, Sikorsky Aircraft conducted an examination on all four tailrotor blades.

During the examination it was discovered that all four blades were modified with the longer, wider abrasion strip which was instituted in 1977.

The nameplate for the fractured blade, blade A, indicated that it had been modified in September 1980 at a total time of 2552.10 hours. The nameplate for blade B indicates that it had been repaired in May 1983 at total time unknown. It did not indicate that it was modified. The nameplate for blades C and D indicate that they had been modified in May of 1979 at a total time of 0.00 hours.

The abrasion strip bond was evaluated for blades A, B and D. The abrasion strip for blade C bond remained intact, so the bond could not be evaluated.

Blades A and B exhibited a mixed adhesive and cohesive failure of the adhesive, primarily at the blade surface. Blades A and B showed clear evidence of having flown with the original, shorter, narrower abrasion strip. Evidence for this included surface conductivity, which indicated that the anodize coating had been compromised, and a scuffed appearance. Scuffing of the surface prior to bonding was required by the repair procedure.

In addition, the trailing half of the blade B bond surface exhibited erosion damage that could not have occurred with the wider abrasion strip in place.

Blade D exhibited a mixed adhesive and cohesive failure of the adhesive primarily at the abrasion strip surface. The surface of blade D, where it was exposed exhibited an even gray color, was non-conductive, and did not appear to have been sanded. It appeared to have been fabricated new with the improved abrasion strip.

The blade B adhesive was tan rather than the robin's egg blue expected for the adhesive specified in the repair procedure and observed for blades A and D.

Fractured blade A exhibited a significant out-of-plane bending in the inboard direction. This was in addition to the edgewise bending that had been documented in the previous examination.

Examination of the other blades showed that they too exhibited out of-plane bending in the inboard direction.

The degree of bending was measured by placing a straight edge on the bolting surface and measuring the distance from the straight edge to the blade surface at sixteen inches from the inboard end of the spar.

The results were as follows:

- Blade A 1.40"
- Blade B 0.58"
- Blade C 0.32"
- Blade D 0.92"

Ground Rig Whirl Test Program

In 1976 Sikorsky Aircraft commenced a ground rig whirl test program to investigate the dynamic characteristics of the S-58T tail rotor.

These tests were conducted on the tail rotor test stand at Sikorsky Aircraft's facility at Stratford, Connecticut. The tests identified two modes of oscillation:

- A collective mode which involved control system collective properties and blade pitch and flap.

- Secondly, a forward whirl mode which involved control system cyclic properties and blade pitch and edgewise bending.

The onset of the collective mode vibration was found to be independent of blade pitch. Although it did lead to larger gearbox stresses than the whirl mode did it was not self-exciting. The collective mode required precise excitation both in terms of frequency and amplitude and Sikorsky stated that they knew of no such source of excitation on the S-58T.

The results of the whirl mode investigation were as follows:

The standard S-58T blade with the leading edge abrasion strip was tested. In a hover condition, 89 per cent NR and at an impressed pitch of 23 degrees non-harmonic oscillations occurred. At 93 percent NR the oscillations occurred at 21 degrees impressed pitch and at 100 per cent NR they occurred at 19 degrees. Analysis of the responses showed the rotating frequency to be nominally 1.5 x tail rotor speed (1.5/rev) and the mode to be a forward whirl.

Further tests were conducted using the whirl stand blower to simulate low speed forward flight, quartering winds and right side flight. Non-harmonic oscillations were again observed. The forward flight conditions were found to be the least damped while right side flight had a stabilizing influence. At 25 knots right side flight, no non-harmonic oscillations were observed up to the 500 HP test limit. The effect of wind velocity and angle of inflow to the rotor was believed to be associated with unsteady wake effects. In right side flight, the most damped condition; the rotor operated in a well-established wake and derived its damping from the air mass dynamics. As the wind quartered and approached the forward flight direction, the wake was disturbed with the result that its damping contribution was diminished. This effect was most pronounced at low forward flight speeds.

It was also found that ambient conditions had an effect on the whirl mode boundaries. Cold day (15°C) operation was found to be less damped than hot day (29°C) operation, and that the damping of the whirl mode decayed very gradually with pitch. For this reason, small changes in parameters or operating conditions could significantly affect the location of the boundaries.

The rate of growth of the amplitude of the non-harmonic oscillations as impressed pitch was increased was found to be a function of rotor speed. Thus, operation at the higher rotor speed, in addition to leading to earlier onset of non-harmonic response, also increased its rate of growth.

The fact that the whirl mode occurred on the test stand precipitated an investigation by Sikorsky of S-58 and S-58T flight test data to establish impressed pitch requirements for the flight conditions simulated on the test stand. These showed that impressed pitch requirements were below those at which the non-harmonic oscillations occurred.

In summarizing the whirl mode test results Sikorsky determined that at any operational rotor speed the blade pitch required to produce non-harmonic oscillation was outside the range used in normal operation of the S-58T. Sikorsky stated that the tests confirmed their previous opinion that operation at lower rotor speeds resulted in later onset of non-harmonic oscillation in terms of tail rotor blade pitch angle, and also in reduced loads. On this basis Sikorsky proposed, and the FAA approved, a reduction in operational main rotor speed from 100 per cent to 93 per cent.

Tail Rotor Instability

Tail rotor instability is extremely rare but has been known to occur on the S-58 and the S-61 and has been known colloquially as tail rotor 'buzz'. It is characterized by a medium frequency vibration originating in the area of the tail rotor and felt through the whole airframe and, in the case of the S-58, particularly through the yaw pedals.

Factors increasing the tail rotor's susceptibility to buzz are operation at high pitch angles, high rotor speed and the direction of the relative wind (the worst direction being from the right front side of the helicopter). Poor tail rotor condition (i.e. unbalanced or worn bearings) could also be a contributory factor. Depending on the particular conditions the buzz may simply become apparent as a momentary vibration which damps out without causing any damage. Conversely it may become divergent and result in serious damage to the tail rotor blades, possibly resulting in the stripping of blade pockets. If tail rotor pitch is decreased by the pilot immediately a buzz is detected, he may be able to prevent it from becoming divergent.

In approximately 1956, tail rotor oscillation was first noticed on the Sikorsky H34 (the military version of the piston engine S-58) which was in service in the United States Army and United States Navy. The symptoms were described as a vibration of the aircraft, fairly violent sometimes, clearly from the tail rotor, and felt by the pilot especially strongly through the yaw pedals. There was no apparent yaw and the only damage experienced was elongation of the tail rotor fairleads and heavy indentations on the flapping hinge nylon stops. As a result, a flight test program was carried out by Sikorsky but the condition was very difficult to reproduce.

According to Sikorsky, tail rotor gearbox failures had also been experienced on the S-58T and in one case had been positively associated with an observed tail rotor flutter and yaw pedal vibration. In other cases the failure was considered to be due either to an extreme combination of load, flight conditions and vibration leading to overstressing, or a bonding failure on a blade leading to the loss of a blade pocket and large out of balance forces. Modification and inspection procedures were introduced by Sikorsky in response to these failures and they conducted static load tests to determine the type of load required to produce gearbox failures with these characteristics. They concluded that this load was equivalent to that resulting from the loss of one blade pocket, or from a tail rotor vibration of sufficient magnitude and in such a direction as to duplicate the load vector that corresponds to the loss of one blade pocket.

Therefore, in order to eliminate the possibility of recurrence of the oscillation, over the S-58s life, various modifications designed to improve tail rotor dynamic stability were introduced including the issuance of Service Bulletin (SB) 58B15-18, which incorporated new stainless steel abrasion strips which covered the entire length of the tail rotor blade leading edges and which increased chordwise coverage, and SB 58B40-5, which required the installation of Sikorsky control rod assembly: P/N 58400-64010-101.

Both of these SBs were later included in FAA Airworthiness Directive 78-21-05, and the accident helicopter had both of these modifications installed.

Additionally, pilot guidance regarding tail rotor instability was also added to the S-58 flight manual to make pilots aware of the condition and to provide them with procedures to prevent it from becoming divergent stating:

"Abnormal tail rotor vibration may occur at low forward speed under conditions influenced by tail rotor pitch, tail rotor control system cable tension, rotor speed, relative wind speed, and direction. The vibration can be accompanied by a buzzing noise and by airframe or tail rotor vibration. High values of left rudder pedal, improper tail rotor cable tension (too high or too low) or bottoming of the tail rotor control system spring, higher rotor speed or relative wind from the right forward quadrant increase susceptibility."

A "WARNING" was also published in the manual stating "the vibration or noise should not be allowed to persist and immediate corrective action must be taken."

Furthermore, the guidance also directed that:

"Should unusual tail rotor or tail rotor pedal vibration or tail rotor noise be encountered, immediately reduce tail rotor pitch by moving the pedals toward the neutral position. This serves to reduce the tail rotor blade pitch and with fixed collective will turn the nose of the aircraft to the right. Lowering the collective might be employed when external clearance precludes turning right and when altitude permits a descent or landing.

ADDITIONAL INFORMATION

In 1970, Sikorsky had set up a production line to remanufacture S-58 helicopters to the S-58T configuration which included replacing the R-1820-84 Radial engine with a Pratt & Whitney Canada PT6T-3 Twin-Pac Turbine engine installation.

FAA approval for the modifications was received in April 1971. Sikorsky also produced kits which allowed S-58 helicopter operators to convert their helicopters to the S-58T Configuration.

An improved version of the S-58T, the S-58T Mark II, added a more powerful engine which improved one engine inoperative capabilities and installed a bifilar vibration absorber which reduced rotor induced vibration. The bifilar provided improved pilot and passenger comfort and reduced aircraft maintenance.

In 1981, Sikorsky sold the manufacturing rights, and support for the S-58/S-58T to California Helicopter International (California Helicopter Airways). This included all tooling, jigs, fixtures, drawings, and spares inventory. Sikorsky however, retained the type certificate and the responsibility for the manufacturing, repair, and overhaul of the main and tail rotor blades. Over the years though, as Sikorsky moved on to manufacture other helicopters; they ceased manufacturing, repair and overhaul of the main and tailrotor blades. As a result to maintain operational safety support, on May 6, 2015, Sikorsky transferred the type certificate for the S-58, as well as the S-55, and S-62 models to California Helicopter Airways.

History of Flight

Maneuvering-hover	Miscellaneous/other (Defining event) Sys/Comp malf/fail (non-power) Part(s) separation from AC
Autorotation	Off-field or emergency landing

Pilot Information

Certificate:	Commercial	**Age:**	65
Airplane Rating(s):	None	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	Seatbelt, Shoulder harness
Instrument Rating(s):	Helicopter	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 2 With Waivers/Limitations	**Last Medical Exam:**	01/03/2012
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	04/24/2012
Flight Time:	16500 hours (Total, all aircraft), 7000 hours (Total, this make and model), 16500 hours (Pilot In Command, all aircraft), 125 hours (Last 90 days, all aircraft), 50 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Manufacturer:	SIKORSKY	**Registration:**	N126GW
Model/Series:	S-58JT	**Aircraft Category:**	Helicopter
Year of Manufacture:		**Amateur Built:**	No
Airworthiness Certificate:	Normal	**Serial Number:**	581124
Landing Gear Type:	Tailwheel	**Seats:**	
Date/Type of Last Inspection:	07/31/2012, Continuous Airworthiness	**Certified Max Gross Wt.:**	12500 lbs
Time Since Last Inspection:		**Engines:**	1 Turbo Shaft
Airframe Total Time:	11064.7 Hours	**Engine Manufacturer:**	PWC
ELT:	C126 installed, activated, did not aid in locating accident	**Engine Model/Series:**	PT6T-6
Registered Owner:	AIRCRANE INC	**Rated Power:**	970 hp
Operator:	AIRCRANE INC	**Air Carrier Operating Certificate:**	Rotorcraft External Load (133)
Operator Does Business As:		**Operator Designator Code:**	A91L

Meteorological Information and Flight Plan

Observation Facility, Elevation:	ILG, 80 ft msl	**Observation Time:**	0851 EDT
Distance from Accident Site:	10 Nautical Miles	**Condition of Light:**	Day
Direction from Accident Site:	45°	**Conditions at Accident Site:**	Visual Conditions
Lowest Cloud Condition:	Clear	**Temperature/Dew Point:**	23°C / 22°C
Lowest Ceiling:	None	**Visibility**	8 Miles
Wind Speed/Gusts, Direction:	Calm	**Visibility (RVR):**	
Altimeter Setting:	29.9 inches Hg	**Visibility (RVV):**	
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Middletown, DE (None)	**Type of Flight Plan Filed:**	None
Destination:	Middletown, DE (None)	**Type of Clearance:**	None
Departure Time:	0830 EDT	**Type of Airspace:**	Class G

Airport Information

Airport:	Parking Lot (None)	**Runway Surface Type:**	Asphalt
Airport Elevation:	60 ft	**Runway Surface Condition:**	Dry
Runway Used:	N/A	**IFR Approach:**	None
Runway Length/Width:		**VFR Approach/Landing:**	Forced Landing

Wreckage and Impact Information

Crew Injuries:	1 None	**Aircraft Damage:**	Substantial
Passenger Injuries:	N/A	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 None		

Administrative Information

Investigator In Charge (IIC):	Todd G Gunther	**Adopted Date:**	08/11/2015
Additional Participating Persons:	David Moore; FAA/FSDO; Philadelphia, PA Christopher Lowenstein; Sikorsky Aircraft Corp.; Stratford, CT		
Publish Date:	08/11/2015		
Note:	The NTSB did not travel to the scene of this accident.		
Investigation Docket:	http://dms.ntsb.gov/pubdms/search/dockList.cfm?mKey=84540		