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Structural Failure of Piper Part Number 40622 Rudder Posts Made of 1025 Carbon Steel

Introduction

The National Transportation Safety Board (NTSB) is providing the following information to urge the Federal Aviation Administration (FAA) to take action on the safety recommendation in this report. This recommendation is derived from the NTSB's investigations of two accidents involving airplanes, designed and built by Piper Aircraft Inc. (Piper), that sustained substantial damage when their rudders structurally failed in flight.¹

For both accident investigations, the NTSB's findings indicate that the rudder post fractured above the upper hinge and the top portion of the rudder folded over the upper tail brace wires, resulting in diminished control of the airplane. The NTSB has determined that the rudders were consistent with Piper part number 40622 and that the rudder posts were made of American Iron and Steel Institute (AISI) 1025 carbon steel and likely fractured due to fatigue. Additional support for this recommendation is derived from the examination of similarly fractured rudder posts. The NTSB is issuing one recommendation to the FAA.

¹ Visit [ntsb.gov](https://www.nts.gov) to find additional information in the [public docket](#) for these NTSB accident investigations (case numbers ANC20LA059 and ANC21LA064). Use the [CAROL Query](#) to search safety recommendations and investigations.

Factual Information

Related Investigations

The following are brief summaries of the two accidents supporting this recommendation. In both cases, the airplanes were being operated as Title 14 *Code of Federal Regulations* Part 91 flights.

- **ANC20LA059, Anchorage, Alaska.** On June 8, 2020, about 0945 Alaska daylight time, a float-equipped Piper PA-12 airplane, N3188M, sustained substantial damage when its rudder structurally failed in flight about 8 miles north of Anchorage, Alaska.² The flight instructor and private pilot receiving instruction were not injured.

While on a left crosswind leg after takeoff from a lake, the airplane yawed abruptly to the right and the pilot indicated that the controls “felt strange.” The flight instructor assumed control of the airplane and noticed drastically diminished control about the vertical axis. In addition, significant downward elevator pressure (forward control yoke) was required. In an effort to aid in directional control, the water rudders were deployed. Uncertain that he could make a 180° turn due to the poor directional control, the flight instructor elected to return to the airport from which they had departed and landed without further incident.

- **ANC21LA064, Anchorage, Alaska.** On July 23, 2021, about 1510 Alaska daylight time, a float-equipped Piper PA-14 airplane, N4206H, sustained substantial damage when its rudder structurally failed in flight about 15 miles southeast of Anchorage, Alaska.³ The commercial pilot was not injured.

The pilot reported that while in level cruise flight, frequent left and right rudder inputs were required to keep the inclinometer centered, similar to a light turbulence encounter.⁴ The airplane then began to experience a constant yaw, with elevator adjustments required to maintain level flight. He stated that the oscillation then stopped and a “a very large right rudder input” was required to maintain the course heading. He was able to land the airplane without further incident.

² Piper no longer owns the PA-12 type certificate. It now belongs to the FS 2003 Corporation.

³ Piper no longer owns the PA-14 type certificate. It now belongs to the FS 2002 Corporation.

⁴ An *inclinometer* measures an object’s angles of slope, elevation, or depression in relation to gravity’s direction.

Through examination of the rudders involved in these accidents, the NTSB has determined (1) the rudders were consistent with Piper part number 40622, and (2) the rudder posts were made of AISI 1025 carbon steel.⁵ The NTSB has also determined that in both accidents, the airplane's rudder post fractured above the upper hinge, and the top portion of the rudder folded over the upper tail brace wires (see figures 1 and 2).



Figure 1. Photograph showing the fractured rudder post from N3188M (case number ANC20LA059).

⁵ No part number was marked or stamped on either rudder; however, both rudders met the material requirements and dimensions that correspond to the part number 40622 rudder.



Figure 2. Photograph showing the fractured rudder post on N4206H (case number ANC21LA064).

Additional Examinations

Concerned that the structural failure of these rudder posts was indicative of a wider safety issue, the NTSB examined three additional similarly fractured rudders. The NTSB obtained two rudders from a repair facility, and the third was provided in response to an airworthiness concern sheet the FAA issued in September 2020 (the rudder had been found and reported during an inspection).⁶ The NTSB found that the three additional rudders were also consistent with Piper part number 40622, had posts made of AISI 1025 steel, and had fractured above the upper hinge.

⁶ Following the June 2020 Anchorage accident, the FAA issued the airworthiness concern sheet with the intent of collecting additional information about structural failures of other part number 40622 rudder posts from owners and operators of Piper models J-SA, J-5B, J-5C, J-5D, AE-1, HE-1, PA-12, PA-12S, PA-14, PA-16, PA-18, L-21, PA-20, and PA-22. As stated in the airworthiness concern sheet, at the time of its issuance, the FAA had not "made a determination on what type of corrective action (if any) should be taken. The resolution of this airworthiness concern could involve Airworthiness Directive...action or a Special Airworthiness Information Bulletin..., or the FAA could determine that no action is needed at this time." The airworthiness concern sheet is available in the [public docket](#) for NTSB case number ANC20LA059.

Our evaluation showed that the peak stresses on the nominal rudder post approach the endurance limit of AISI 1025 steel.⁷ All five of the rudders the NTSB evaluated had an aftermarket beacon or strobe installed on the top of the rudder post. The additional surface area and mass of a beacon or strobe would likely increase the stresses even further (see the following table for more information about each rudder examined and its associated airplane).

Table. Five Piper rudders examined and associated airplane information.

Rudder Source	Airplane Model	Airplane Engine Rating	Airplane Landing Gear	Airplane Year Built*
ANC20LA059 Rudder	PA-12	160 Horsepower	Float	1947
ANC21LA064 Rudder	PA-14	160 Horsepower	Float	1948
Repair Facility Rudder	PA-12	150 Horsepower	Wheel/Ski	1946-1948
Repair Facility Rudder	PA-12	180 Horsepower	Wheel	1946-1948
Airworthiness Concern Sheet Rudder	PA-18	160 Horsepower	Wheel	1969

*The NTSB does not know the exact date of manufacture for the two PA-12 airplanes from which rudders were obtained from repair facilities; however, the PA-12 was in production from 1946-1948.

Further NTSB examination identified evidence of a progressive fracture mechanism such as fatigue on each of the rudder posts, including fatigue fracture features on three of the rudder posts. The fracture surfaces on the other two rudder posts were too damaged to identify the specific fracture mechanism. Corrosion, scratches, or surface roughness features were found on all five of the rudder posts. The fracture origin areas were damaged, but corrosion pits or scratches on the exterior surface were associated with fatigue origin areas on two of the examined rudder posts.

Rudder Post Material

According to engineering drawings, the rudder post for part number 40622 was originally manufactured from 0.875-inch diameter, 0.035-inch wall thickness AISI 1025 carbon steel tube. A Piper engineering change order dated June 3, 1974, showed that the specified material for the rudder post was changed to normalized AISI 4130 low-alloy steel tube with the same dimensions. The material change was incorporated into the part number 40622 engineering drawing in June 1974.

⁷ The *endurance limit* is defined as the stress below which a material can endure an infinite number of repeated load cycles without failure.

FAA Advisory Circular 23-27

FAA Advisory Circular (AC) 23-27, "[Parts and Materials Substitution for Vintage Aircraft](#)," published in May 2009, states that AISI 4130 low-alloy steel may be substituted for AISI 1020 or AISI 1025 carbon steel, including for structural posts on applicable aircraft.⁸ The AC clarifies that this is because AISI 4130 low-alloy steel is more widely available and generally has more desirable material properties, such as higher tensile ultimate strength, yield strength, and fatigue strength.

Analysis

The five Piper rudders examined were all older part number 40622 rudders. The June 1974 engineering change order changed the material for the rudder posts on this part from AISI 1025 carbon steel to stronger normalized AISI 4130 low-alloy steel. According to AC 23-27, AISI 4130 low-alloy steel (or other industry standard 4130 low-alloy steel) may be substituted for AISI 1020 or AISI 1025 carbon steel when replacing parts on older airplanes.⁹

The vintage PA-12, PA-14, and PA-18 airplane model types from which these rudders were obtained complied with the static load conditions required by the regulations in place at the time they were certified in the 1940s.¹⁰ However, in service, the loading conditions on many parts of these airplanes' structures, including the rudders, are not static and contain dynamic alternating or repeated (fatigue) loads. To assess the implications of this, the NTSB conducted a structural load analysis for three of the rudders and found that the bending stresses on the rudder post from certification gust and maneuver loads are significantly closer to the endurance limit for rudder posts made of AISI 1025 carbon steel than they are for those made of AISI 4130 low-alloy steel.¹¹

The NTSB also identified corrosion, scratches, or surface roughness features on each of the examined rudder posts. These types of surface anomalies would result in a stress concentration that could cause the stress in a rudder post to exceed the endurance limit for AISI 1025 carbon steel. Hence, an AISI 1025 carbon steel rudder

⁸ AC 23-27 provides guidance on parts and material substitutions for old or out-of-production general aviation aircraft. For more information, see appendix 2, "Material Substitutions" in the AC.

⁹ AISI is no longer directly involved in the development or maintenance of standard steels.

¹⁰ Piper models PA-12, PA-14, and PA-18 were certified in 1947, 1948, and 1949, respectively.

¹¹ (a) See the "Structures Group Chairman's Rudder Loads Study" in the [public docket](#) for case numbers ANC20LA059. (b) No scatter factor was applied. A *scatter factor* is a statistical method used to account for uncertainties and variations in structural performance relative to experimental test data.

post exposed to loads approaching certification gust and maneuver limits would be more likely to fail due to fatigue from stress-concentrating surface features that are present under normal service conditions.

Although the five rudder posts that we examined had beacons or strobes installed that increased the posts' susceptibility of failure, our analysis shows that, even without the additional stress of these components, in-service stresses likely exceed the endurance limit for AISI 1025 carbon steel rudder posts that have corrosion, scratches, or surface roughness features. As a result of the loads study and materials laboratory examinations, the NTSB concludes that it is likely that each of the five recently examined Piper part number 40622 rudder posts, all made of AISI 1025 carbon steel, fractured due to fatigue. The NTSB also concludes that posts made of AISI 1025 carbon steel in Piper part number 40622 rudders are susceptible to fatigue cracking under normal service conditions.

Comparable findings about the structural failure of the five fractured Piper rudder posts suggest a possible broader problem. In both recent accidents, the fractured rudder posts also led to diminished control of the airplane, demonstrating a compounding unacceptable flight risk.¹² The NTSB is concerned that the failure of a primary flight control, like a rudder, could also lead to the loss of an airplane and the loss of life.

Further, AC 23-27 only addresses permissible material substitution for such rudder posts when replacement is needed; it's unknown how many rudder posts in the fleet may have already been replaced as allowed in the AC. Accordingly, the NTSB is concerned that general aviation pilots may be unaware of the safety risks associated with the continued use of rudder posts constructed from AISI 1025 carbon steel and that related rudder post failures that don't result in an accident or incident may be underreported.

Therefore, the NTSB concludes that recently documented structural failures of Piper part number 40622 rudders equipped with a post made of AISI 1025 carbon steel indicate a serious hazard to flight safety that warrants action. Therefore, the NTSB recommends that the FAA issue an airworthiness directive that describes the safety risk associated with the continued use of Piper part number 40622 rudders equipped with a post made of AISI 1025 carbon steel and that requires owners and

¹² The NTSB determined the probable cause for both accidents to be "the fatigue fracture of the American Iron and Steel Institute (AISI) 1025 carbon steel rudder post, which resulted in structural failure of the rudder. Contributing to the fatigue failure was the post's susceptibility to fatigue cracking under normal service conditions."

operators to address the unsafe condition, such as by replacing them with rudders equipped with a post made of AISI 4130 low-alloy steel or its equivalent.

Conclusions

Findings

It is likely that each of the five recently examined Piper Aircraft Inc. part number 40622 rudder posts, all made of American Iron and Steel Institute 1025 carbon steel, fractured due to fatigue.

Posts made of American Iron and Steel Institute 1025 carbon steel in Piper Aircraft Inc. part number 40622 rudders are susceptible to fatigue cracking under normal service conditions.

Recently documented structural failures of Piper Aircraft Inc. part number 40622 rudders equipped with a post made of American Iron and Steel Institute 1025 carbon steel indicate a serious hazard to flight safety that warrants action.

Recommendation

As a result of this report, the National Transportation Safety Board makes the following safety recommendation:

New Recommendation

To the Federal Aviation Administration:

Issue an airworthiness directive that describes the safety risk associated with the continued use of Piper Aircraft Inc. part number 40622 rudders equipped with a post made of American Iron and Steel Institute (AISI) 1025 carbon steel and that requires owners and operators to address the unsafe condition, such as by replacing them with rudders equipped with a post made of AISI 4130 low-alloy steel or its equivalent. (A-22-3)

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