

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594



October 13, 2015

MATERIALS LABORATORY FACTUAL REPORT

Report No. 15-082

A. ACCIDENT INFORMATION

Place : North Salt Lake, Utah
Date : December 2, 2014
Vehicle : Robinson R44 II
NTSB No. : WPR15FA051
Investigator : Andrew Swick, AS-WPR

B. COMPONENTS EXAMINED

Main rotor drive and control systems including sections of main rotor blade assemblies, main rotor hub assembly, pitch change links, swashplate assembly, mast assembly, and main rotor drive shaft piece.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted components is shown in figure 1 as placed on the corner of a black table with the components shown in their approximate positions relative to each other. The droop stops were fractured from the main rotor drive shaft. However, the original positions of the droop stops was determined using distinguishing witness marks around the attachment hole on the main rotor shaft with corresponding deformation of the red blade droop stop. Relative positions for the remaining components were determined based on blade labels, mating fractures, and/or witness marks.

The main rotor blades, pitch change links, yoke, and swashplate assembly as viewed from above is shown in figure 2. The pitch horns for the red and blue blades were fractured from the rest of the blade, and fracture features in both cases were matte gray and rough consistent with overstress fracture. The yoke was fractured through the arms at the counterweight side of the yoke, and the counterweights were missing. Fracture features in the yoke also showed rough matte gray features consistent with overstress fracture.

The pitch change link for the red blade was intact and remained attached to the red blade pitch horn as shown in figure 3. The lower end of the pitch change link was separated from the attachment point on the swashplate, and the attachment hardware was missing. The red blade pitch change link was bent slightly at two locations as indicated in figure 3; in the threads for of the upper end fitting and in the area of the length adjustment threads in the middle of the link. Thread impressions corresponding

to contact with the end fitting threads on the inside of the bend at the upper end of the pitch change link were observed as shown in the lower image in figure 3.

A close view of the swashplate at the red blade pitch change link attachment location is shown in figure 4. The attachment hole in the swashplate was intact and the surrounding area was generally free from contact damage. Closer views of the hole interior are shown in figures 5 and 6. At the outboard end of the hole as shown in figure 5, a discolored area with longitudinally-oriented sliding contact marks was observed on the lower side of the hole bore adjacent to the outboard edge (see unlabeled bracket in figure 5). The circumferential machining marks were disturbed or covered by material transfer in the area of sliding contact. At the inboard end of the hole, a series of parallel impressions oriented at a slight angle relative to the circumferential plane of the hole was observed adjacent to the inboard face on the upper side of the hole (see unlabeled bracket in figure 6). A lip of deformed material was present at the inboard edge of the series of parallel impressions, also indicated in figure 6.

As assembled, the attachment location for the red blade includes a NAS6605-31 attachment bolt that is installed through two counterweights, washers, a pitch change link rod end fitting, and the attachment hole in the swashplate all clamped together with a lock nut backed by a palnut. One counterweight is located at the inboard side of the swashplate attachment location, and the other counterweight and the rod end fitting are located at the outboard side of the swashplate attachment location. Therefore as installed, the hole bore at the attachment location in the swashplate should contact the grip (smooth portion) of the attachment bolt shank.

The pitch change link for the blue blade was fractured into 3 segments with the end fittings remaining attached to the pitch change horn at the upper end of the link and to the swashplate at the lower end of the link. The overall deformation associated with the fractures was in an "S" shape, consistent with compression buckling. Fracture features had rough matte gray features consistent with overstress fracture.

A close view of the swashplate at the blue blade pitch change attachment location is shown in figure 7. The pitch link remained attached to the swashplate, and an intact line of green torque paint was present on the lower side of the bolt, palnut, locknut, and washer as shown in figure 8. Thread impressions on the swashplate corresponding to contact with the pitch link end fitting on the upper side of the swashplate are indicated in figure 7.

Views of the hub, drive shaft, blade spindles, and droop stops are shown in figures 9 and 10. Heavy impact marks were observed on the lower side of each droop stop corresponding to contact with stop arms on the blade spindles. The stop arms on the blade spindles were also deformed downward consistent with heavy contact with the droop stops. Deformation corresponding to contact with the upper sides of the spindles was observed on the interior of the hub (see figure 10).

The main rotor drive shaft was fractured as shown in figures 9 and 10. The shaft at the fracture location was deformed into a “D” shape, and the fracture planes were on slant angles relative to the circumferential plane; features consistent with overstress fracture under bending loads.

Torque testing was conducted on the upper pitch change link attachment hardware for the red and blue blades and on the lower pitch change link attachment for the blue blade. At the start of each test, the head of the attachment bolt was placed in a vice, and the nuts were removed using a torque wrench. For each test, the palnut was removed first, and the peak torque required to start unthreading the palnut was measured. Next, the prevailing torque for the palnut was measured in the unthreading direction. After the palnut was removed, the position of the lock nut was marked relative to the bolt. The lock nut was then loosened up to approximately $\frac{1}{4}$ turn, and the peak and prevailing torques were measured. Next the lock nut was rotated back in the tightening direction until the nut returned to the marked position, and the peak torque was recorded. Then the nut was loosened again for at least one full turn while recording several measurements of prevailing torque which were averaged together.

Torque values for the palnut on the upper attachment locations were measured using a dial torque wrench with a 0 to 15 lb.-in. measurement range. Torque values for the palnut on the blue blade pitch change link lower attachment and all lock nuts were measured using a dial torque wrench with a 0 to 300 lb.-in. measurement range. Torque was applied with a torque adapter at the blue blade pitch change link lower attachment location due to the configuration of the nuts within the swashplate. The torque adapter was used with the 0 to 300 lb.-in. torque wrench; no torque adapter was available for use with the 0 to 15 lb.-in. torque wrench. All torque values listed in this report that were obtained using the torque adapter are calculated values that have been adjusted from the value read on the torque wrench dial to compensate for the added length associated with the torque adapter.

Results of the torque testing are listed in table 1. The return torque for the red blade upper attachment is listed as an approximate value. In this test, the washer and pitch horn were marked relative to the nut, and both turned with the nut. The pitch horn was returned to its approximate position to obtain the return torque measurement shown, but there is greater uncertainty with that measurement. The remaining return torque measurements were returned to marks that were made on the bolt threads protruding from the end of the nut.

At the blue blade pitch change link lower attachment location, the prevailing torque for the palnut at the blue blade pitch change link lower attachment location was not measured, and the prevailing torque in the lock nut was not achieved when loosening within $\frac{1}{4}$ turn. Initial attempts to apply the returning torque on the lock nut were unsuccessful, and the open-end torque adapter slipped from the nut at a torque of 135 lb.-in. The nut was then unthreaded to measure the second prevailing torque value. Subsequently, a box-end torque adapter was used to measure the prevailing torque in the tightening direction as well as the return torque to return the nut to the

marked position. The prevailing torque in the tightening direction was 9 lb.-in., and the return torque was 150 lb.-in., as listed in table 1.

According to the Robinson Helicopter Company Illustrated Parts Catalog¹ for the Robinson R44 series helicopters, the attachment bolts used at the upper and lower ends of the pitch change links are NAS6605 series bolts. According to the Robinson Helicopter Company Maintenance Manual for the R44 series helicopter, NAS6605 series bolts should be fastened to a dry torque value of 240 lb.-in. $\pm$ 24 lb.-in., and palnuts used on NAS6605 series bolts should be applied with a dry torque of 20 lb.-in. to 40 lb.-in.

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¹ Robinson Helicopter Company, Torrance, California.

Table 1. Pitch Link Attachment Torque Test Results

Pitch link attachment location	Nut	Breaking torque (lb.-in.)	Prevailing torque, first measurement (lb.-in.)	Return torque (lb.-in.)	Prevailing torque, second measurement average value (lb.-in.)
Red blade, upper	Palnut	8	5	---	---
Red blade, upper	Lock nut	90	30	~90	24
Blue blade, upper	Palnut	2	~0	---	---
Blue blade, upper	Lock nut	15	8	12	13
Blue blade, lower	Palnut	15	---	---	---
Blue blade, lower	Lock nut	108	---	150	5

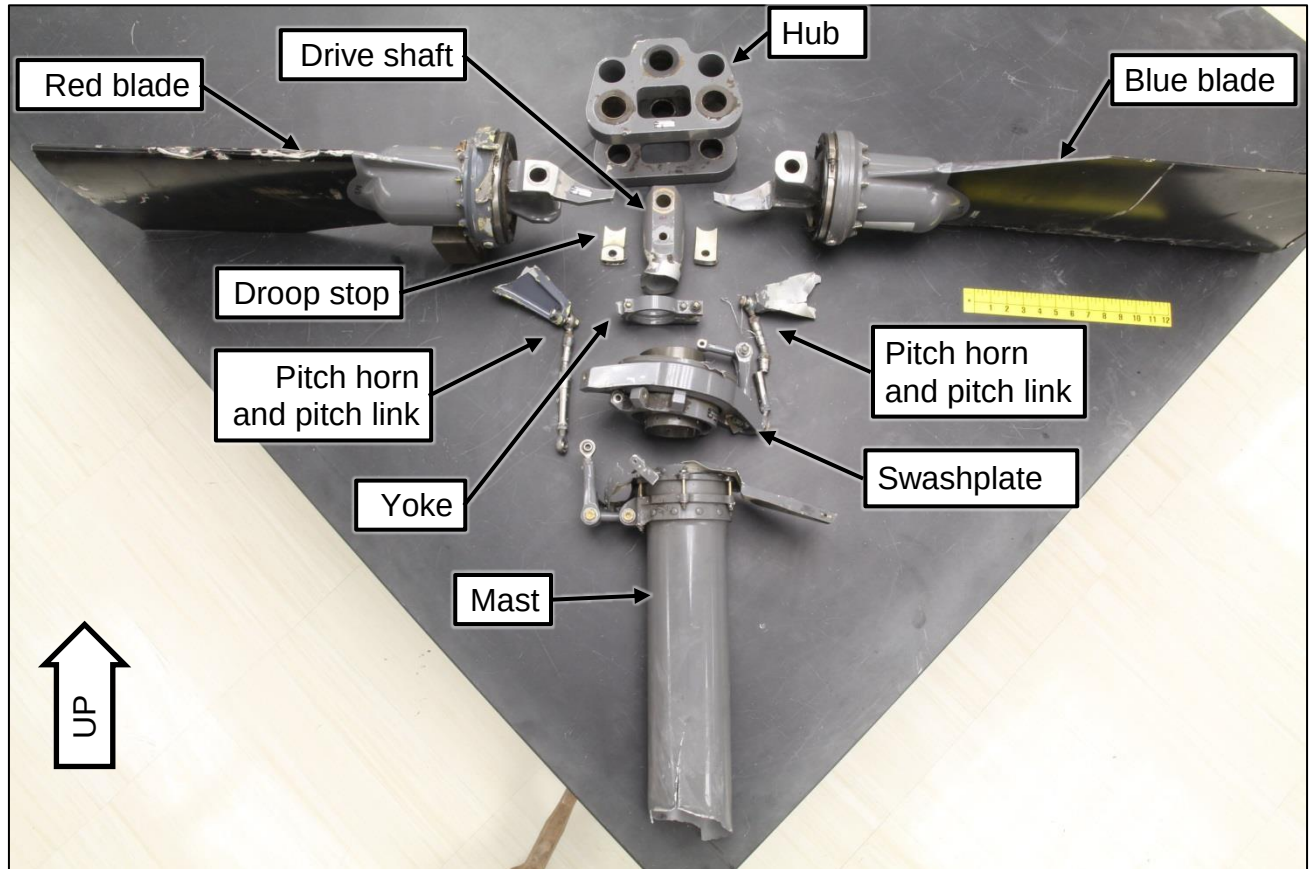


Figure 1. Overall view of the submitted components.

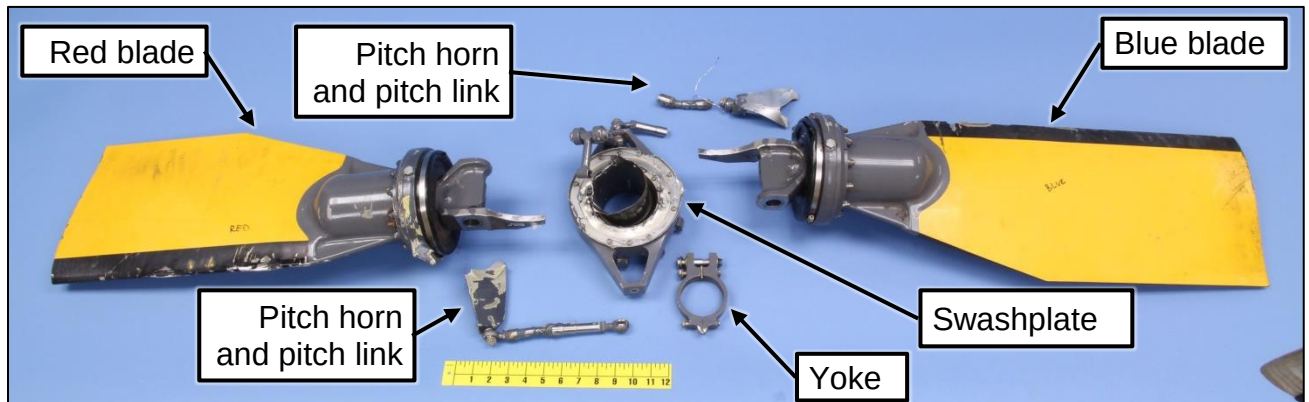


Figure 2. Overall view of the main rotor blade and swashplate assemblies with pitch links and counterweight yoke assembly.

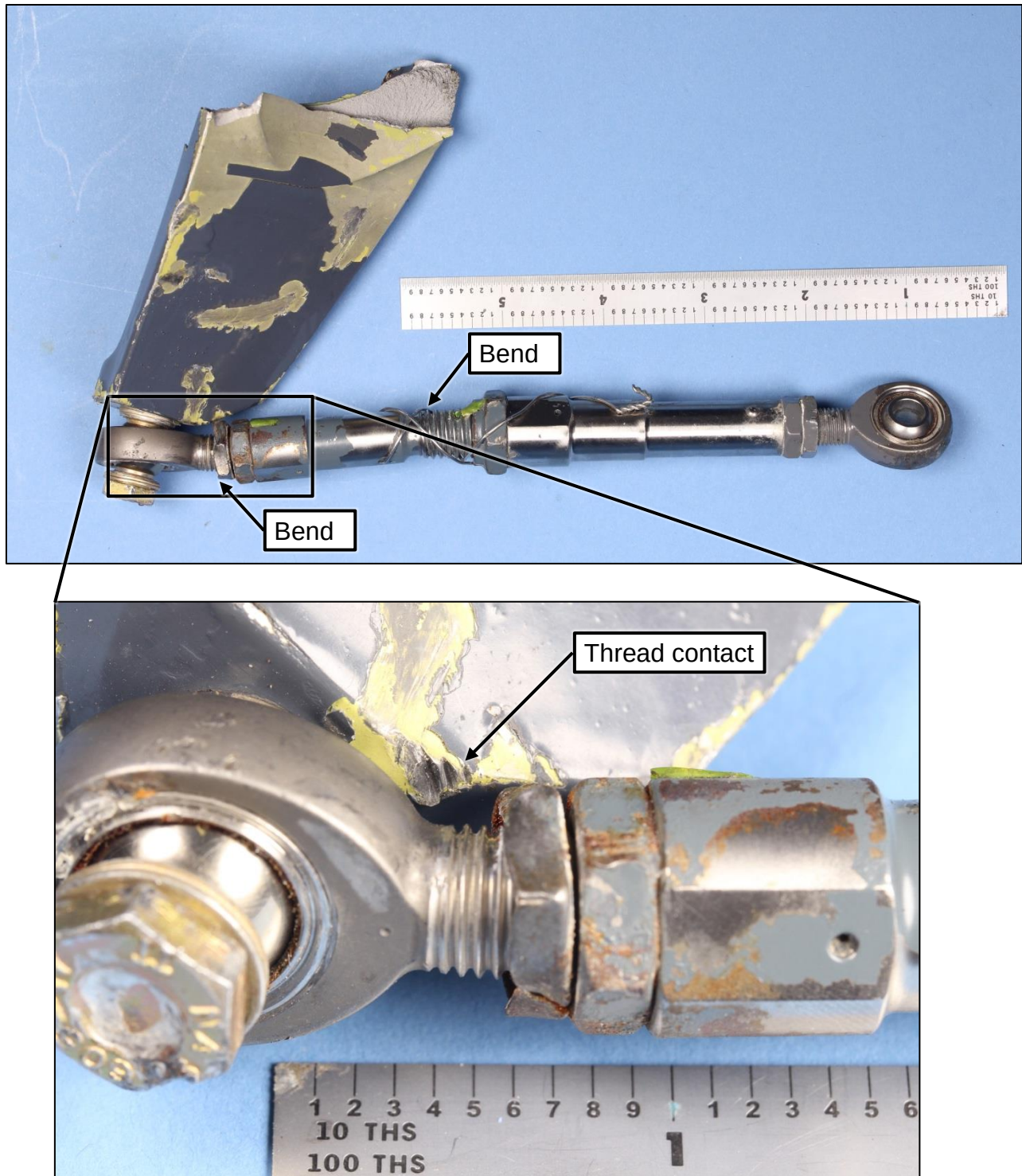


Figure 3. Views of the red blade pitch horn and pitch change link with a closer view of damage on the pitch horn corresponding to contact with the pitch change link end fitting threads.

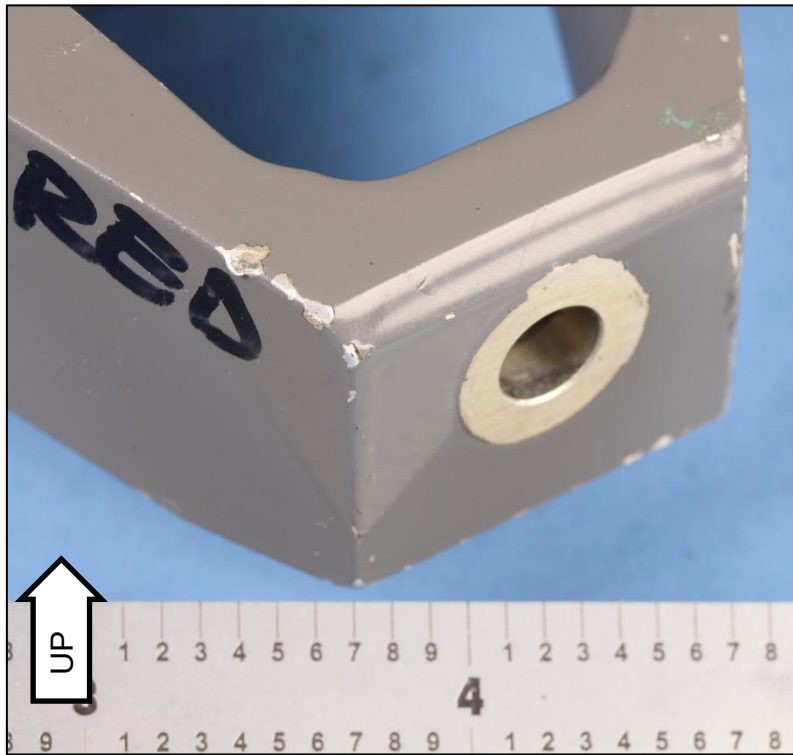


Figure 4. Swashplate showing the attachment location for the red blade pitch change link.

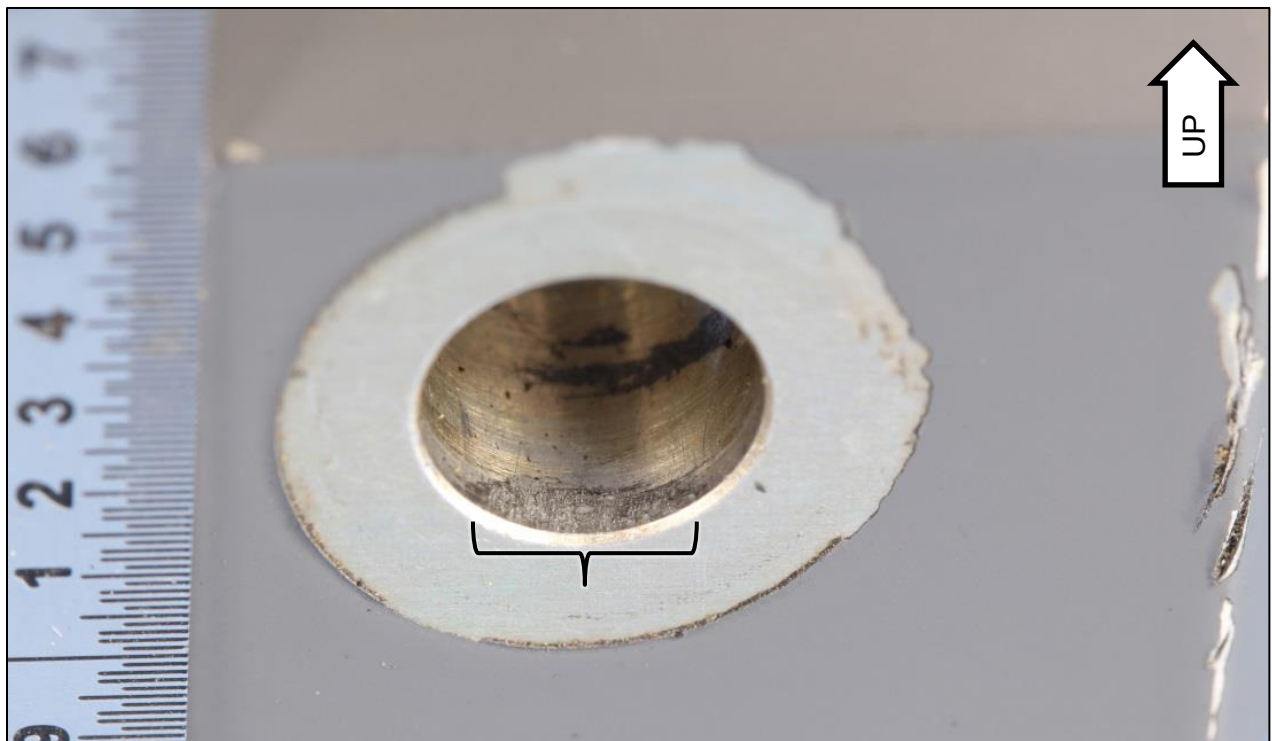


Figure 5. Close view of the hole in the swashplate for the red blade pitch change link attachment bolt. An unlabeled bracket indicates a discolored area where machining marks were disturbed and longitudinal sliding contact marks were observed.

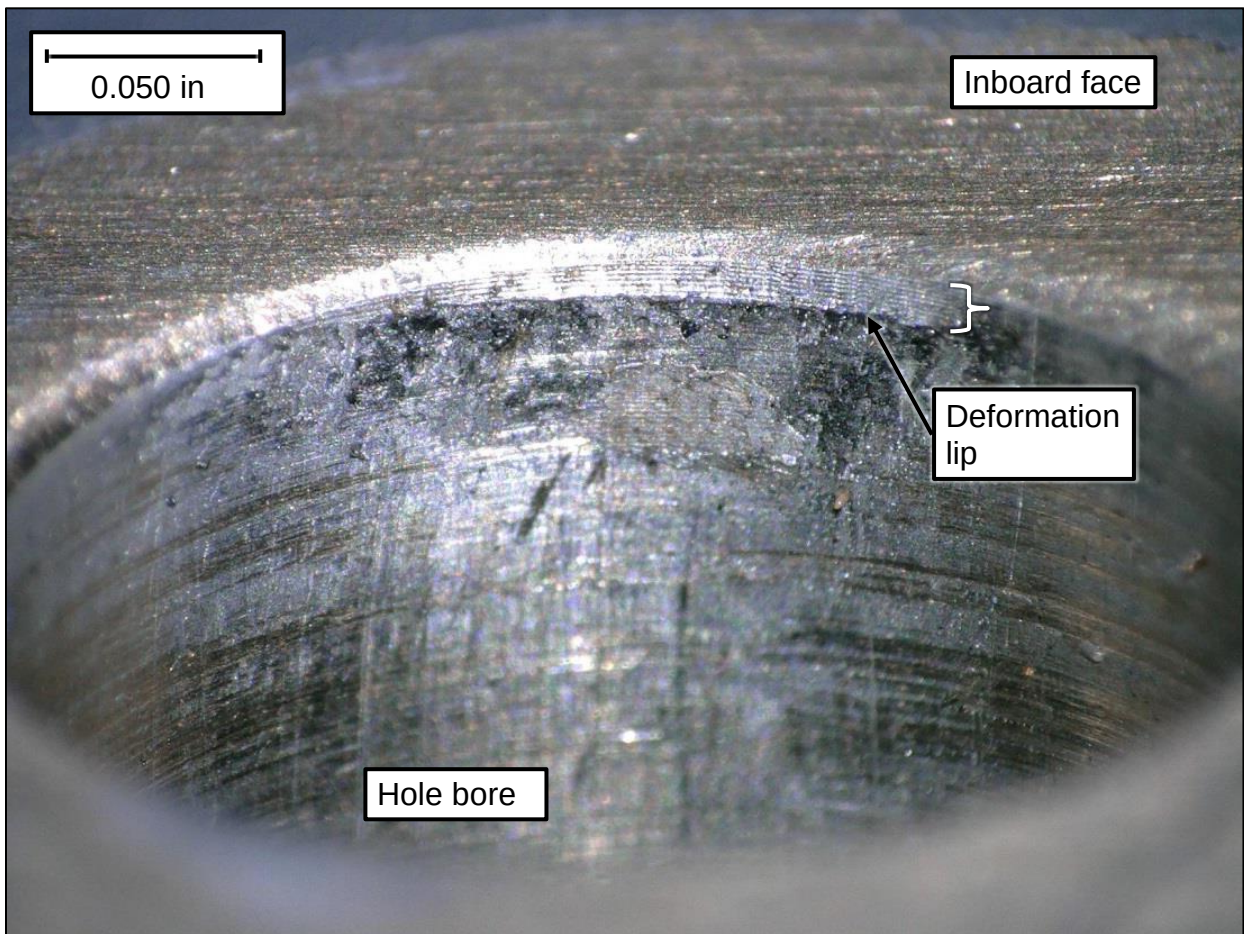


Figure 6. Image of the inboard end of the hole in the swashplate for the red blade pitch change link attachment bolt as viewed looking upward. An unlabeled bracket indicates a series of parallel impressions in the hole bore adjacent to the inboard face of the red blade pitch change link attachment location on the swashplate.

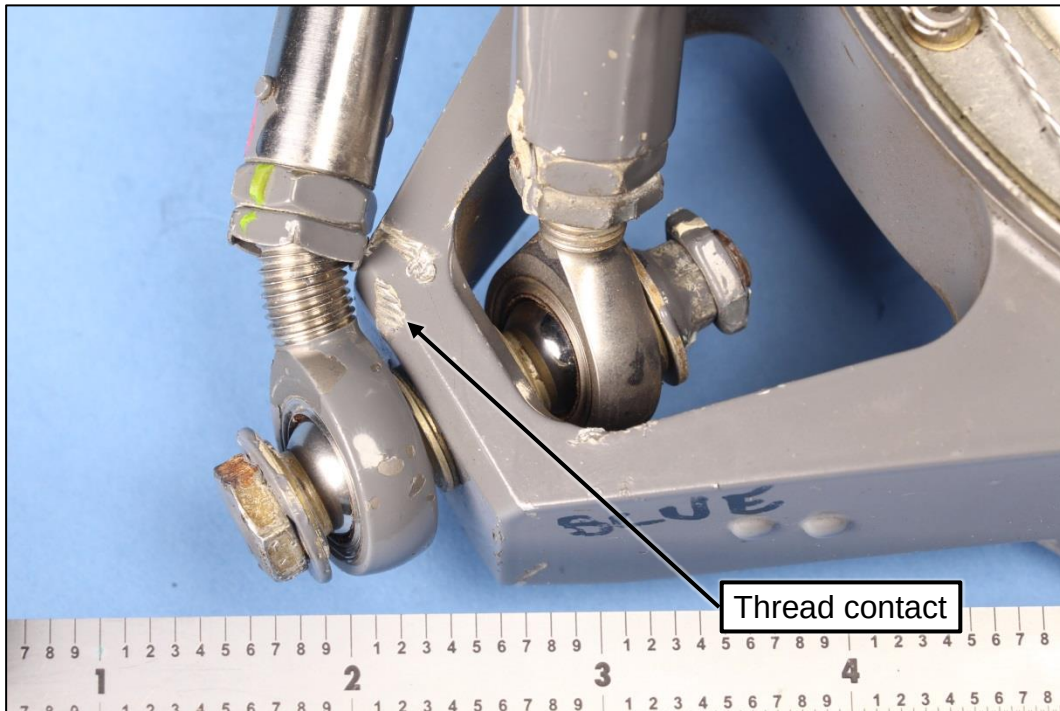


Figure 7. Swashplate at the blue blade pitch change link attachment location.

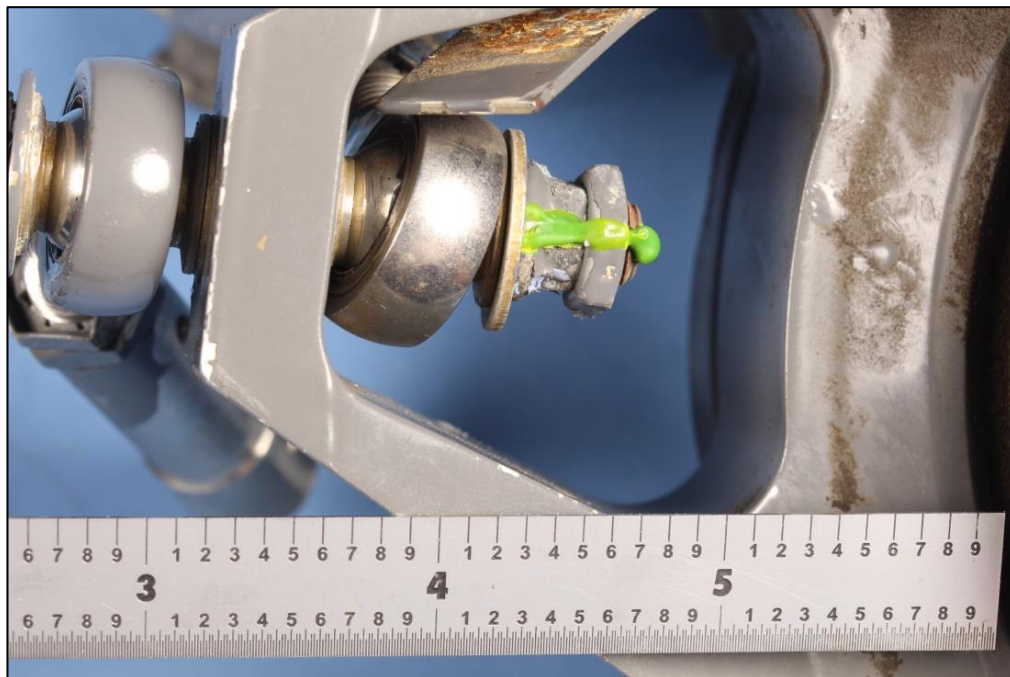


Figure 8. Underside of the swashplate showing a green line of torque seal on the bolt, nuts, and washer for the blue blade pitch change link attachment.

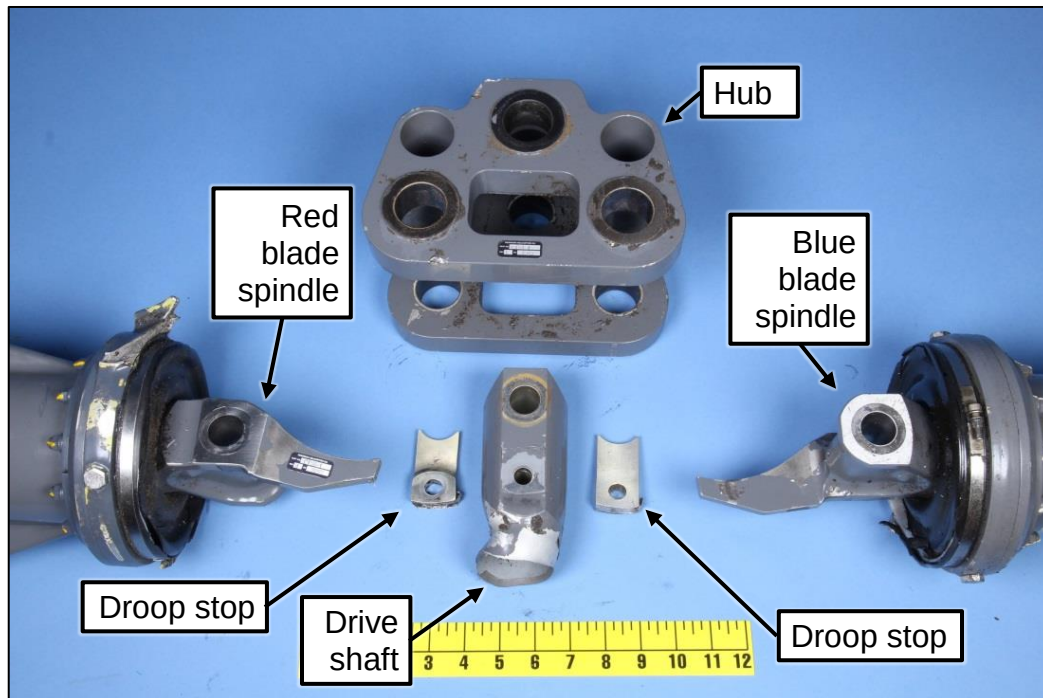


Figure 9. Overall view of the drive shaft, droop stops, hub, and blade spindles.

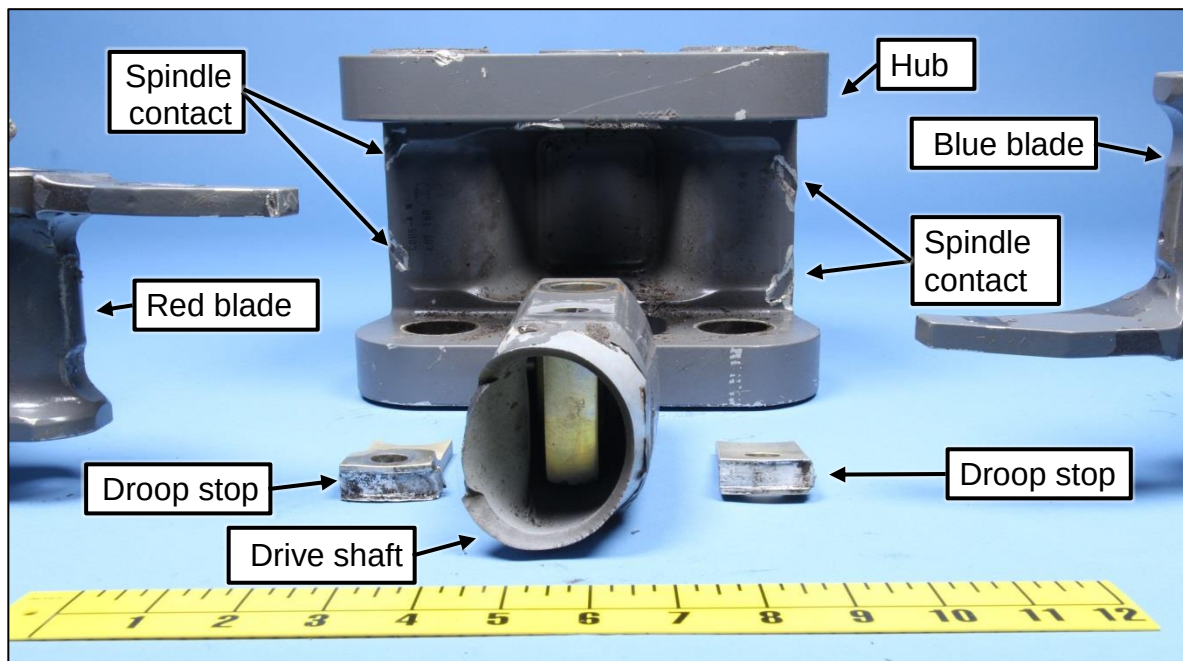


Figure 10. Components shown in figure 9 as viewed looking upward.