NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

June 13, 2013.

MATERIALS LABORATORY FACTUAL REPORT Report No. 13-022

A. ACCIDENT INFORMATION

Place : Atlanta, Georgia.
Date : January 13, 2013.
Vehicle: Cessna 560XL, N662QS.
NTSB No.: ERA13IA114.
Investigator: Dennis Diaz.

B. COMPONENTS EXAMINED

1. Elevator control pulleys (7).
2. Debris from pulley vicinity.

C. DOCUMENTS REVIEWED

1. Schatz Bearing Corporation drawing 3-3291-1. Caged pulley type ball bearing. ABMA[1] number PD5K.
2. Schatz Bearing Corporation drawing 3-3287-1. Caged pulley type ball bearing. ABMA number KP4K.

D. DETAILS OF THE EXAMINATION

Seven elevator control pulleys and debris removed from the vicinity of the pulleys in the aircraft's tail cone was received for examination and are illustrated and identified in Figure 1. Five pulleys were received in bags, sealed with duct tape, that were reportedly the bags that their replacements were received in and two new pulleys were received in sealed bags. The five duct taped bags were additionally identified with the aircraft registration number, N662QS, and with their location on the aircraft which consisted of their frame station (FS) number followed by their position, left (L) or right (R) where applicable. The five pulleys are identified in Figure 1 as "FS528.5-R", "FS528.5-L", FS449-R", FS449-L", FS 438" and the two new (exemplar) pulleys are identified as "EX-1" and "EX-2". The debris was received in the zip-closure bag illustrated in Figure 1.

Pulley FS528.5-R examination.

Pulley FS528.5-R was received in a bag with one white side and one clear side. The white side displayed the identifications "SPEC NO. MIL-DTL-7034/2 REV

[1] American Bearing Manufacturers Association.

A", "DESC. PULLEY, GROOVE, FLIGHT CONTROL, AIRCRAFT", "QUANTITY 1 EACH", "LOT NUMBER 22468", "LUBE MIL-PRF-81322", "LUBE DATE 03/2010", MADE IN USA", "RALMARK COMPANY-LARKSVILLE-PA USA" and "www.ralmark.com". The duct tape covered the identifications "RALMARK" and "MFR P/N MS20220-4". The clear side contained an adhesive label displaying "CPN: MS20220-4", "QTY: 1", "U/M: EA" and "PO#: PRIORITY: A3" with their associated bar codes. The label also displayed "ECCN#: EAR99", "CERTIFIED TO: MS20220-4", "DESC: PULLEY", "MFG: RALMARK", "LOT#: 22468", "CTRL#: 2010G10805", "COUNTRY OF ORIGIN: USA", "LOCATION: JET SPARES", and "ITEM NO.: 090185". The identifications "N662QS", "R/H" and "FS528.5" were written on the label in red ink.

Examination of the pulley revealed the identifications "RALMARK", "MS20220-4" AND "8M" printed on one side. The bearing could not be rotated by hand and radially oriented stains were observed emanating from the bearing on both sides. Both sides of the bearing are illustrated in Figure 2 with the retention sleeve, outer race, inner race, seal and retainer identified in the left image. The white arrow in both images indicates a relatively hard deposit on the seal and around the exposed outer diameter of the inner race that could be removed with a finger nail. The yellow arrow in both images indicates a deposit on the retainer that could be removed by wiping with a finger. The brown arrows in the left image indicate the radially oriented stains that were more prominent on that side of the pulley and the blue arrow indicates a deposit at the origin of the stains.

The examination also revealed a shiny surface in the root of the pulley groove. The shiny surface is illustrated in Figure 3 and contained between the two blue arrows. The yellow arrow indicates the root that displayed signs of use that was typical of the remainder of the pulley and can be compared with Figure 14.

The retaining rings and seals were removed from both sides of the bearing to reveal a smooth hard surface. The side of the bearing illustrated in the left image in Figure 2 is illustrated in Figure 4 with the outer race, the inner race, the retainer and the seal identified. The white arrow indicates the smooth hard surface and the blue arrow indicates the deposit similarly indicated in Figure 2. The yellow arrow indicates the deposit on the retainer, similarly indicated in Figure 2, which was wiped off to reveal the identifications "SCHATZ", USA" and "PD5K".

The bearing, with the retention sleeve, was pressed out of the pulley, the retention sleeve removed, the outer race of the bearing cut at opposing sides and one half of the outer race removed to reveal the bearing. The revealed bearing is illustrated in the left image in Figure 5 with the inner and outer races identified and a white arrow indicating one of the smooth hard surfaces previously noted. The yellow arrows indicate corroded balls that were firmly affixed in a cylinder of corrosion product. The removed outer race is illustrated in the right image in Figure 5 with yellow arrows indicating corroded impressions of the balls similarly indicated in the left image.

Pulley FS528.5-L examination.

Pulley FS528.5-L was received in a clear bag with an adhesive label displaying identifications similar to those on the pulley FS528-R label with exceptions being “LOT# 21941”, “CTRL# 2009L00925”, “ITEM# 081446” and “L/H” written in red ink.

Examination of the pulley revealed the identifications “RALMARK”, “MS20220-4” AND “8M” printed on one side. The pulley displayed stains, deposits on the bearing and a shiny area in the root of the groove. The bearing could not be rotated by hand. The identified side of the pulley is illustrated in Figure 6 with blue arrows indicating the relatively straight edges of a stained area. The brown arrow indicates a radially oriented stain emanating from the bearing and the purple arrow indicates an area of lighter staining.

Both sides of the bearing are illustrated in Figure 7 with the retention sleeve, outer race, inner race, seal and retainer identified in the left image. The green arrow in both images indicates a deposit on the edge of the outer race that could be removed by wiping with a finger and the yellow arrow in the right image indicates a deposit on the retainer. The brown arrow in both images indicates radially oriented stains emanating from the bearing and the blue arrow in the left image indicates a deposit at the stain origin.

The examination also revealed a shiny surface in the root of the pulley groove. The shiny surface is illustrated in Figure 8 and contained between the two blue arrows. The yellow arrow indicates the root that displayed signs of use that was typical of the remainder of the pulley and can be compared with Figure 14.

The retaining rings and seals were removed from both sides of the bearing to reveal a smooth hard surface similar to the bearing in pulley FS528.5-R illustrated in Figure 4. The deposit on the retainer, illustrated in Figure 7, was wiped off to reveal the identifications “SCHATZ”, USA” and “PD5K”.

The bearing, with the retention sleeve, was pressed out of the pulley, the retention sleeve removed, the outer race of the bearing cut at opposing sides and one half of the outer race removed to reveal the bearing. The revealed bearing is illustrated in the left image in Figure 9 with the inner and outer races identified and a white arrow indicating one of the smooth hard surfaces previously noted. The yellow arrows indicate corroded balls that were firmly affixed in a cylinder of corrosion product. The removed outer race is illustrated in the right image in Figure 9 with yellow arrows indicating corroded impressions of the balls similarly indicated in the left image.

Pulley FS449-R examination.

Pulley FS449-R was received in a bag similar to pulley FS528-R and displayed similar identifications. The identifications “N662QS”, “R/H” and “FSN449” were written on the label in red ink.

Examination of the pulley revealed that it was uniformly darker in color than the previously examined pulleys from FS528.5 and the exemplar pulleys. The pulley felt damp when handled and had a similar but stronger odor than the pulleys from FS528.5. The discoloration had almost obliterated the identifications but "RALMARK" and "MS20220-4" were still discernible. The bearing was found to rotate smoothly by hand and exhibited grease on both sides. Both sides of the bearing are illustrated in Figure 10 with yellow arrows indicating the grease. The discoloration of the pulley can be compared with a similar image of one of the exemplar pulleys illustrated later in Figure 13. The bearing, with the retention sleeve, was pressed out of the pulley and the retention sleeve removed. The retaining rings and seals were removed to reveal the bearing cage and grease on the cage. Grease was removed from the retainer to reveal the identifications "SCHATZ", USA" and "PD5K".

To identify the dampness on the pulley it was swabbed with a clean cotton swab to remove any residue or debris from the surface. The swab was then examined using an FTIR[2] to determine the identity of the residue. The spectra from the swab indicated the presence of water and a silicon-based product.

Pulley FS449-L examination.

Pulley FS449-L was received in a bag similar to pulley FS528-R and displayed similar identifications. The identifications "N662QS", "L/H" and "FSN449" were written on the label in red ink. The bag also contained a bolt, with locking wire in the head, and a washer.

Examination of the pulley revealed that it was uniformly darker in color, similar to pulley FS449-R. The pulley also felt damp when handled and had a similar odor. The discoloration had almost obliterated the identifications but "RALMARK", and "MS20220-4" were still discernible. The bearing was found to rotate smoothly by hand and exhibited grease on both sides. Both sides of the bearing are illustrated in Figure 11 with yellow arrows indicating the grease. The discoloration of the pulley can be compared with a similar image of one of the exemplar pulleys illustrated later in Figure 13. The bearing, with the retention sleeve, was pressed out of the pulley and the retention sleeve removed. The retaining rings and seals were removed to reveal the bearing cage and grease on the cage. Grease was removed from the retainer to reveal the identifications "SCHATZ", USA" and "PD5K".

To identify the dampness on the pulley it was swabbed with a clean cotton swab to remove any residue or debris from the surface. The swab was then examined using an FTIR to determine the identity of the residue. The spectra from the swab indicated the presence of water and a silicon-based product.

[2] Fourier-Transform Infrared Spectroscopy (FTIR) is a proven analytical technique for identifying unknown chemicals. The technique relies on the microscopic interaction of infrared light with chemical matter and produces a pattern of absorption features called a spectrum. The spectrum of each chemical is unique, and matching it with a library of spectra makes identification rapid.

Pulley FS438 examination.

Pulley FS438 was received in a bag with one white side and one clear side. The white side displayed the identifications “RALMARK”, MFG. P/N R24566-2600-4”, MFG. DWG NO. 8-2600 REV 000”, “CUSTOMER P/N CM3863-4”, “CUSTOMER STANDARD NO. CM3863 REV B”, “DESC. PULLEY-CONTROL SYSTEM, LOW FRICTION”, “QUANTITY 1 EACH”, LUBE MIL-PRF-81322”, “LOT NUMBER 17782”, “LUBE DATE 07/2006” and “MADE IN USA”. The clear side contained an adhesive label displaying “CPN: CM3863-4”, “QTY: 1”, “U/M: EA” and “PO#: PRIORITY: A3” with their associated bar codes. The label also displayed “CERTIFIED TO: CM3863-4”, “DESC: PULLEY”, “MFG: RALMARK”, “LOT#: 17782”, “CTRL#: 2006H03727”, “COUNTRY OF ORIGIN: USA”, “LOCATION: JET SPARES”, and “ITEM NO.: 6510”.

Examination of the pulley revealed that it was uniformly darker in color, similar to pulleys FS449-R and FS449-L and displayed a line of pale green paint on the outer edges of the groove. The pulley also felt damp when handled and had a similar odor. The discoloration had almost obliterated the identifications but “RALMARK”, and “CM3863-4” were still discernible. The bearing was found to rotate smoothly by hand and exhibited grease on both sides. Both sides of the bearing are illustrated in Figure 12 with yellow arrows indicating the grease. The white arrow in the left image indicates the bearing number, “KP4K”, and the blue arrow indicates the manufacturer, “SCHATZ”. The discoloration of the pulley can be compared with a similar image of one of the exemplar pulleys illustrated later in Figure 13. The bearing, with the retention sleeve, was pressed out of the pulley and the retention sleeve removed. The retaining rings and seals were removed to reveal that the bearing cage and the balls were covered in grease.

To identify the dampness on the pulley it was swabbed with a clean cotton swab to remove any residue or debris from the surface. The swab was then examined using an FTIR to determine the identity of the residue. The spectra from the swab indicated the presence of water and a silicon-based product.

Exemplar pulleys examination.

The exemplar pulley identified as “EX-1 was received in a bag with one white side and one clear side. The white and clear sides displayed identifications similar to those for pulley FS528.5 with the adhesive label displaying the exceptions “PRIORITY: B1”, “LOCATION: PROP SPARES”, “ITEM NO.: 087370” and the addition of “EFF DATE 03/01/10”. The white and clear bag was contained in a clear bag displaying a similar adhesive label.

The exemplar pulley identified as “EX-2 was received in a bag similar to pulley FS438. The white side displayed similar identification with the exceptions “LOT NUMBER 18440” and “LUBE DATE 12/2006”. The adhesive label on the clear

side displayed similar identification with the exceptions “LOT# 18440”, “CTRL#: 2007C021?[3]”, and “ITEM NO.: 090129” with the addition of “ECCN#: EAR99”.

Examination of the exemplar pulleys revealed that both bearings were clean and rotated smoothly by hand. For comparison with the bearings illustrated in Figures 2, 7, 10, 11 and 12, and with the pulley discoloration illustrated in figures 10, 11 and 12 both sides of the bearing in pulley “EX-1” are illustrated in Figure 13 with the retention sleeve, outer race, retainer, seal, and inner race identified in the left image. The blue and white arrows on the retainers indicate the manufacturer’s name, “SCHATZ”, and the bearing part number, “PD5K”. For comparison with the pulley grooves illustrated in Figures 3 and 8 the groove in exemplar pulley “EX-2” is illustrated in Figure 14 with a yellow arrow indicating the root of the groove and red arrows indicating the pale green painted outer edges also observed on pulley FS438.

Pulley information.

A search of the manufacturer’s web site revealed that the “-4” in the part number indicated that the pulley was non-metallic and manufactured from a laminated phenolic. The examinations revealed that the pulleys supplied for examination consisted of two types, part number MS20220-4, containing bearing number PD5K manufactured by Schatz[4], and part number CM3863-4 containing bearing number KP4K, also manufactured by Schatz. Schatz supplied drawings 3-3291-1 and 3-3287-1 (documents 1 and 2 respectively in section C) for bearings number PD5K and KP4K respectively. Examination of the drawings revealed that bearing PD5K was a double row ball bearing and KP4K was a single row ball bearing. For both bearings the inner and outer races, and the balls, were manufactured from an alloy steel with all external surfaces except the bearing bore being cadmium plated, the cage was a plain carbon steel, the seal was Teflon®[5] and the retainer was a stainless steel. The bearing was pre-lubricated with grease. Measurements revealed that the outer race outside diameter and the width and the inner race bore and width of all the bearings satisfied the requirements on their respective drawing.

Debris examination.

The debris in the zip-closure bag illustrated in Figure 1 consisted of lumps of an unknown material, beetles, a rivet shank, rivet pieces with a shank, a portion of a lip seal, a cotter pin, a portion of a nylon tie, a washer and a piece of twisted locking wire. The debris is illustrated in Figure 15 with the unknown lumps of material indicated by blue arrows and the other items identified. Examination of the lumps of material revealed a distinctly fibrous appearance. The lumps could be easily broken in two to reveal the typical fibrous interior illustrated in Figure 16 which consisted mostly of gray filaments with a uniform diameter. In Figure 16 the black arrow

[3] The ? indicates characters or numbers that were not discernible or missing.
[4] Schatz Bearing Corporation, Poughkeepsie, New York.
[5] Teflon® is a registered trademark of DuPont™.

indicates a black filament, the red arrows indicate red filaments and the orange arrow indicates an orange filament.

Derek Nash
Mechanical Engineer

Figure 1. The pulleys and debris received for examination.

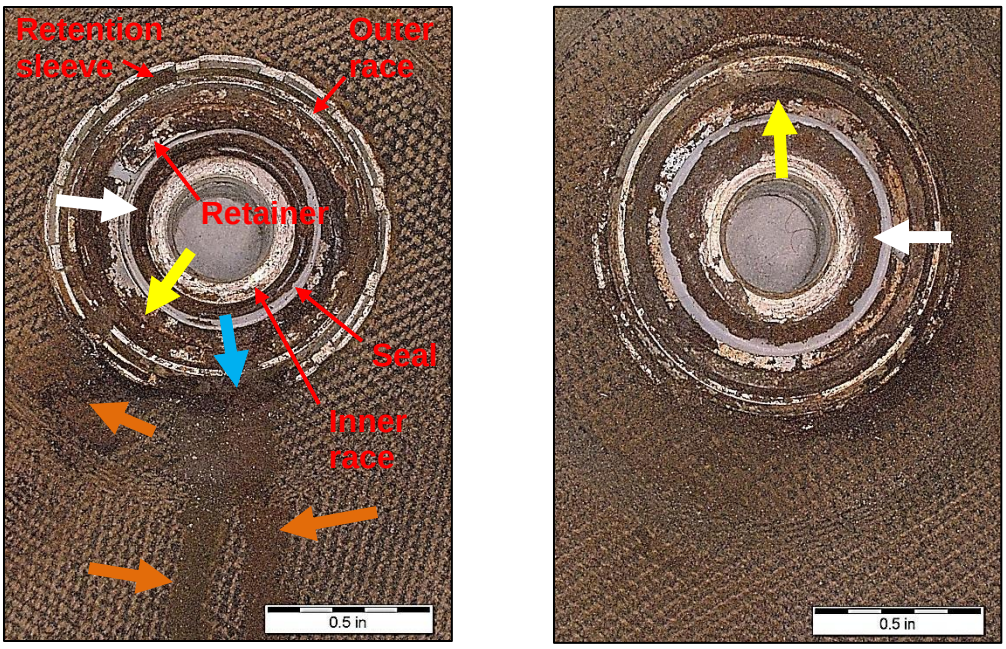

Figure 2. One side of the bearing in pulley FS528.5-R (left) and the other side (right).

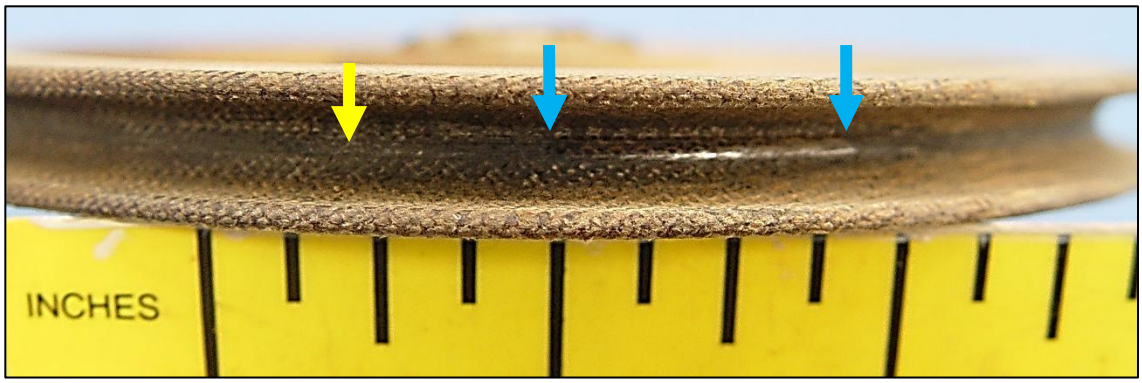

Figure 3. A portion of the groove in pulley FS528.5-R.

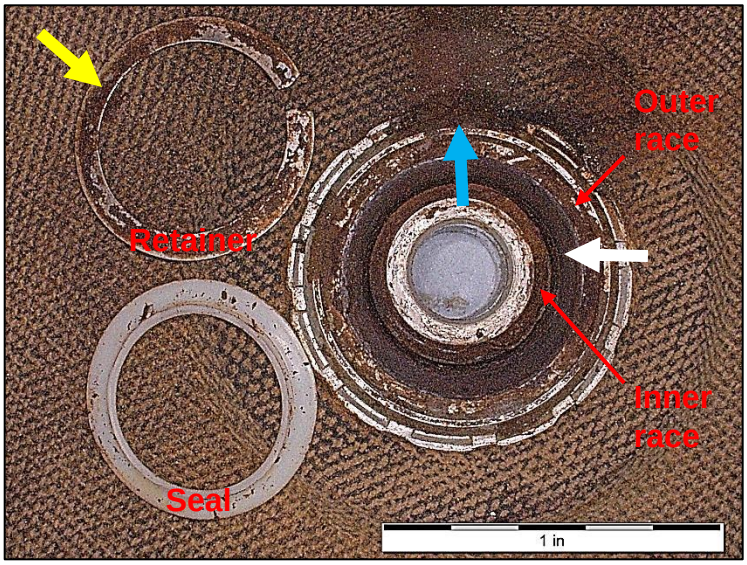

Figure 4. The bearing in pulley FS528.5-R partially disassembled.

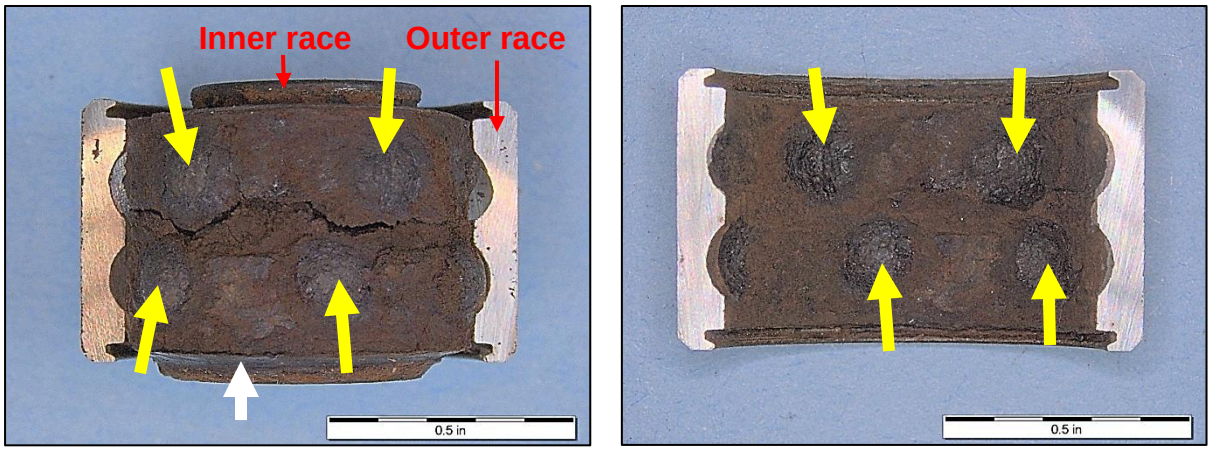

Figure 5. The exposed balls in pulley FS528.5-R bearing (left) and the inner surface of the outer race (right).

Figure 6. One side of pulley FS528.5-L.

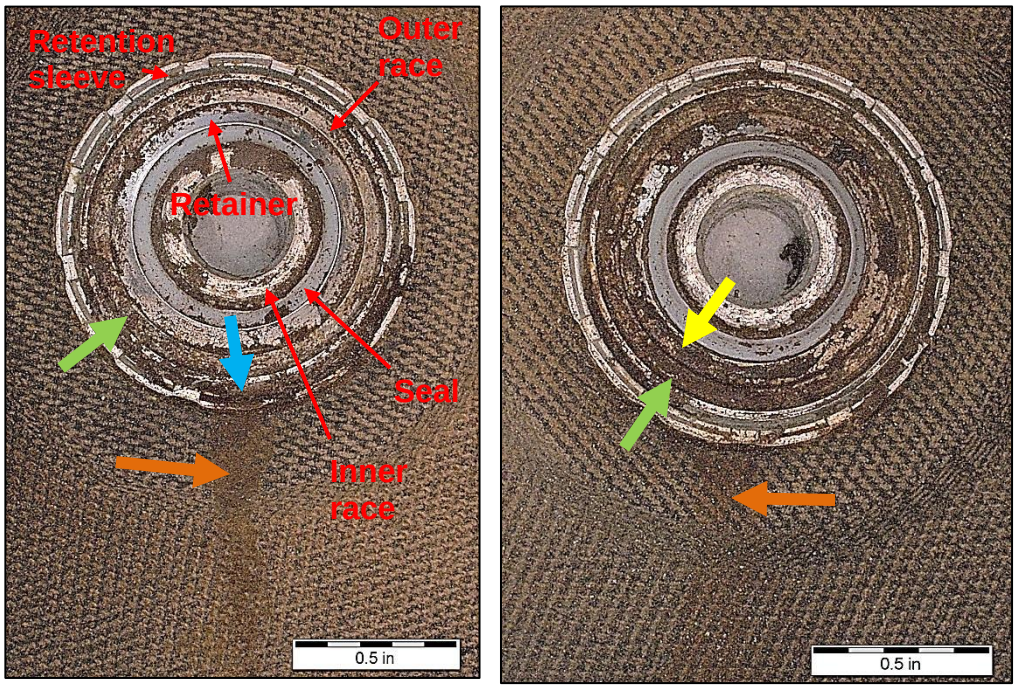

Figure 7. Pulley FS528.5-L bearing illustrated in Figure 6 (left) and the other side (right).

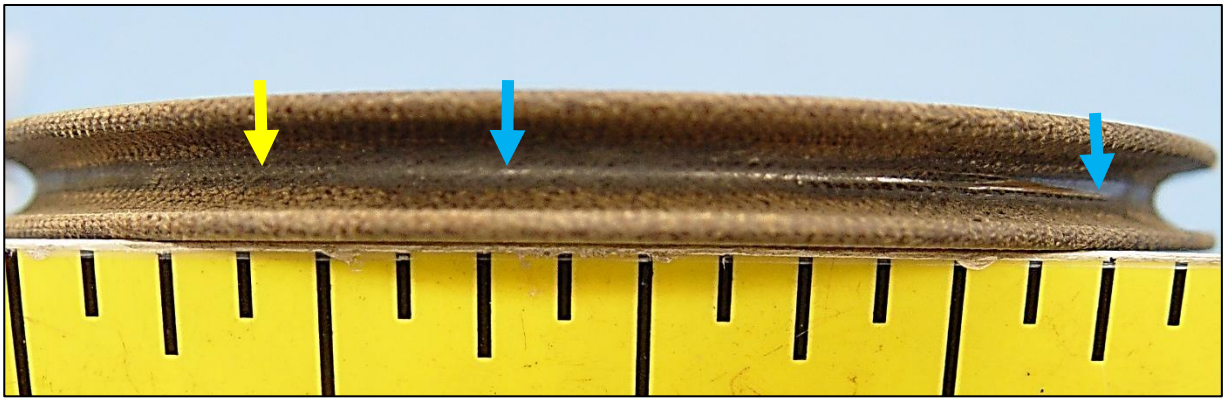

Figure 8. A portion of the groove in pulley FS528.5-L.

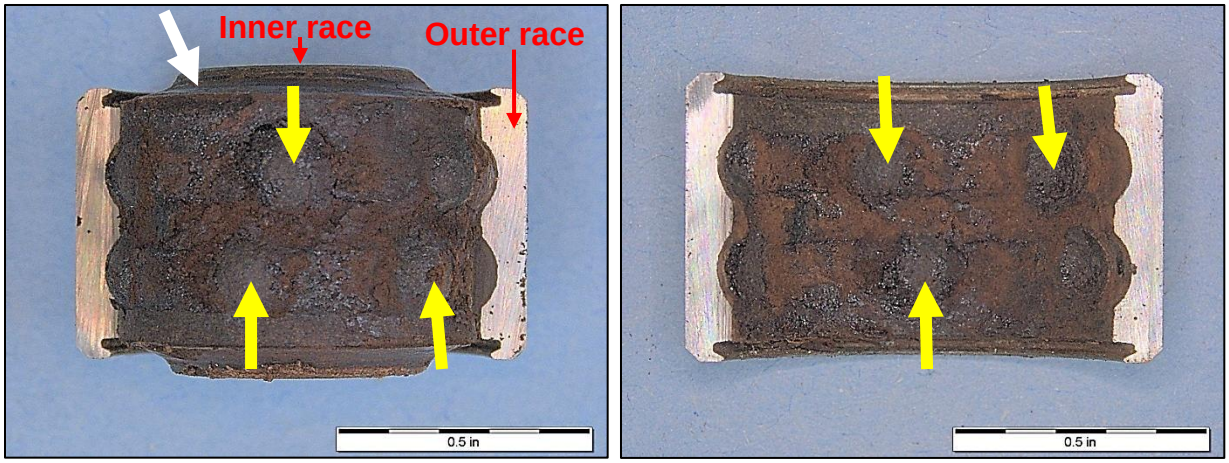

Figure 9. The exposed balls in pulley FS528.5-L bearing (left) and the inner surface of the outer race (right).

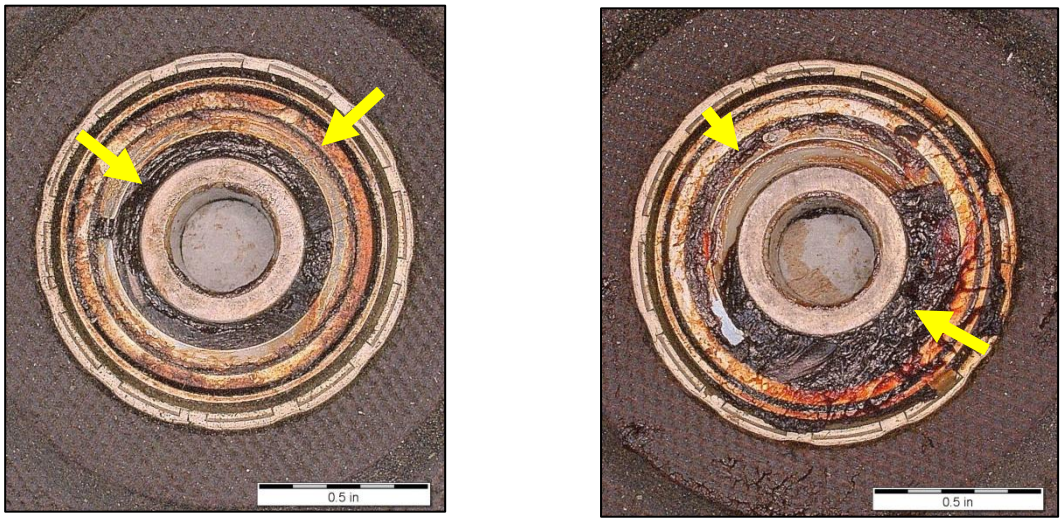

Figure 10. One side of the bearing in pulley FS449-R (left) and the other side (right).

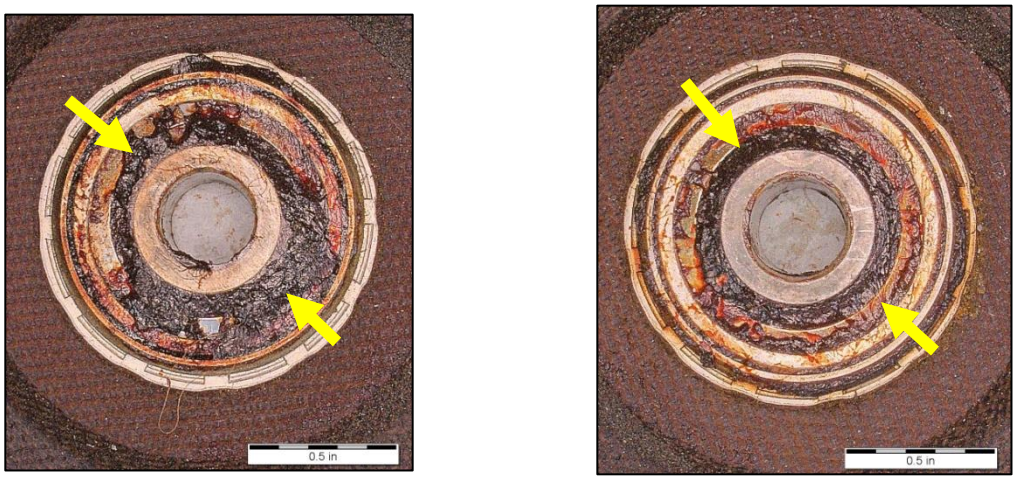

Figure 11. One side of the bearing in pulley FS499-L (left) and the other side (right).

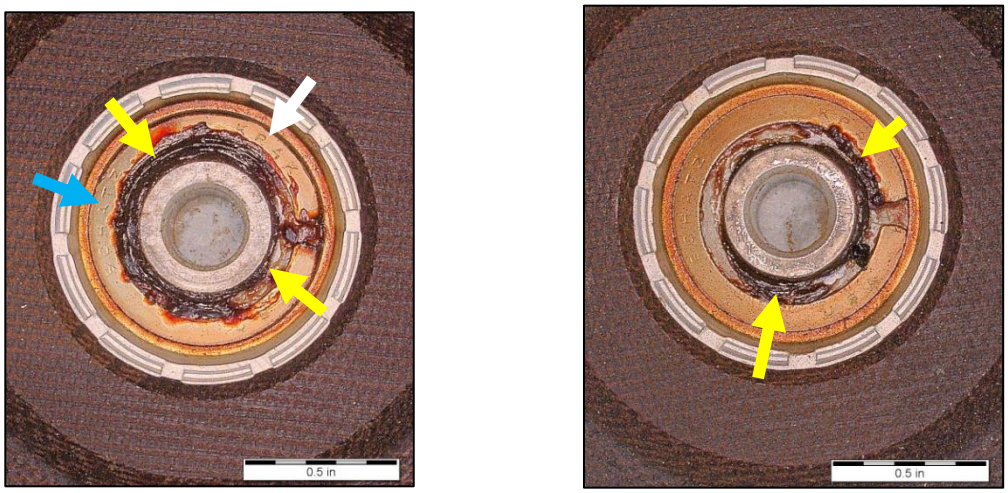

Figure 12. One side of the bearing in pulley FS438 (left) and the other side (right).

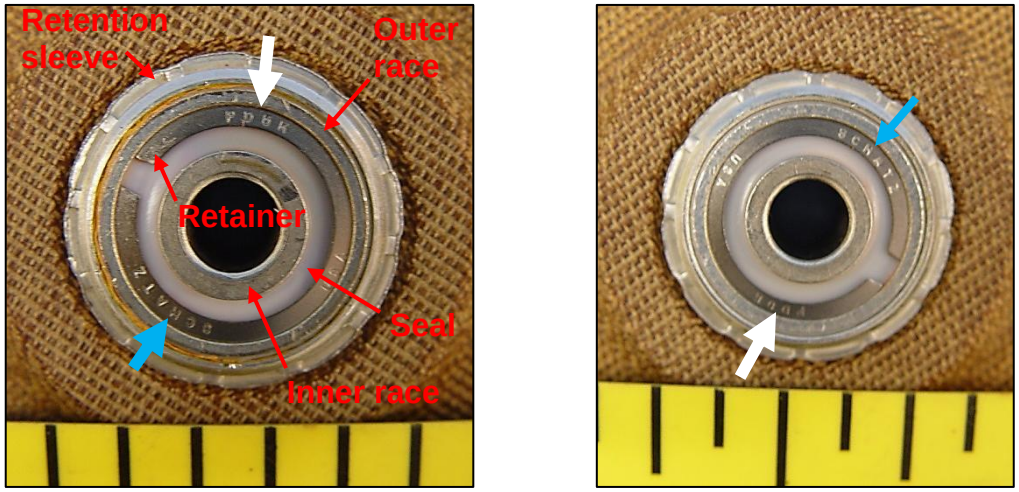

Figure 13. Both sides of the bearing in exemplar pulley EX-1.

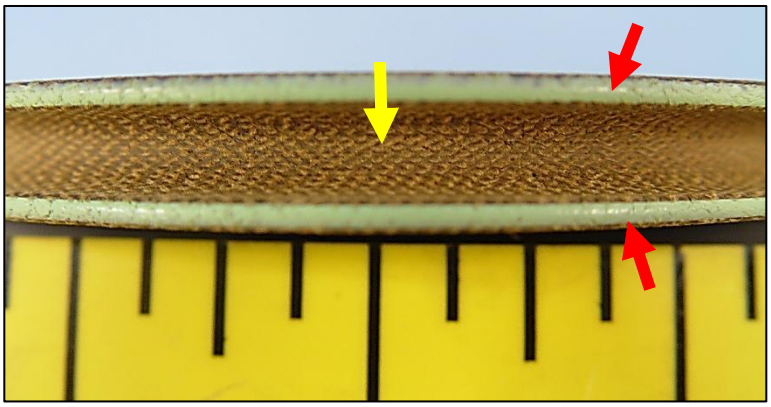

Figure 14. A portion of the groove in an exemplar pulley.

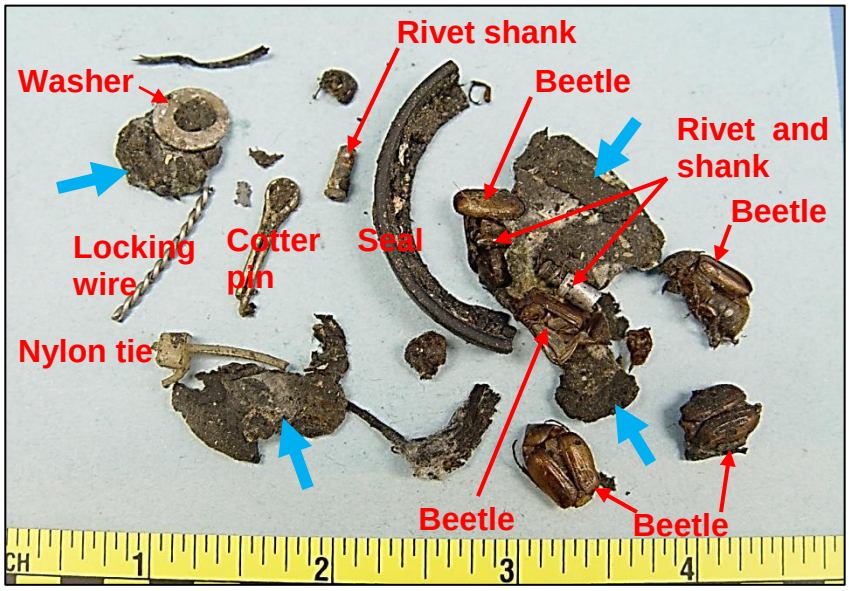

Figure 15. The debris contained in the bag identified in Figure 1.

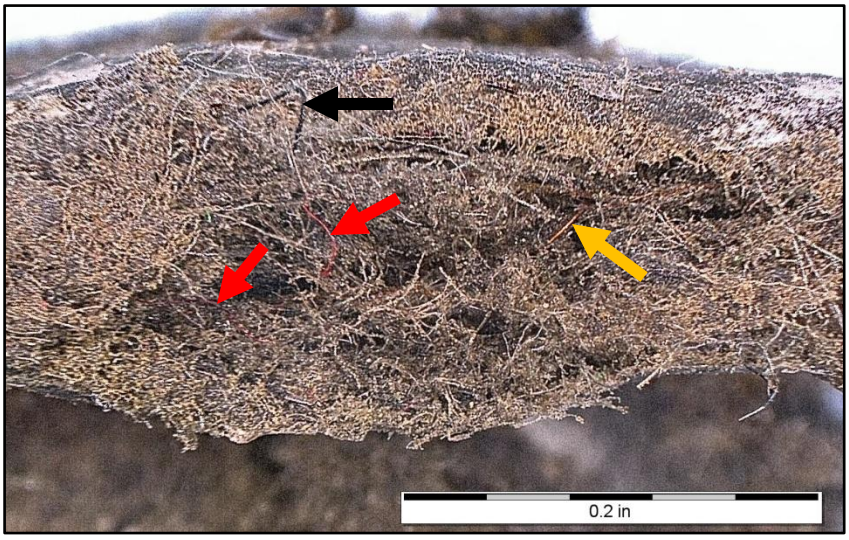

Figure 16. Typical inside of one of the debris pieces indicated by blue arrows in Figure 15.