

NATIONAL TRANSPORTATION SAFETY BOARD

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



February 18, 2020

MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-008

A. ACCIDENT INFORMATION

Place : Foley, Alabama
Date : September 1, 2019
Vehicle : Cirrus SR22, N878SR
NTSB No. : ERA19LA264
Investigator : Lynn Spencer

B. COMPONENTS EXAMINED

Fractured camshaft gear from a Teledyne Continental Motors IO-550-N engine.

C. DETAILS OF THE EXAMINATION

Figure 1 shows a photograph of the as-received camshaft gear. The camshaft gear contains outer teeth and an internal spline at the core. Visual examination of the camshaft gear revealed a total of eleven outer teeth were fractured, in the areas indicated by arrows "G1" through "G11" in figure 1. Five fractured teeth were submitted as shown in figure 1. The forward face of the camshaft gear was marked Teledyne Continental Motors "P/N 631845 J", and "G87". The same face also was marked with a character that appeared similar to a capital "M", where the size of the character "M" was slightly larger than the size of the characters for the part number. The area within the "M" contained the characters "TK" and "5", see figure 2. The opposite face of the gear was marked with the characters "RAM 24".

For the purpose of this report, a fractured tooth has an inner and an outer mating fracture face. The camshaft gear and teeth fragments were ultrasonic cleaned with Alconox, a commercial detergent. Detailed binocular microscope examination of the camshaft gear revealed all the outer gear teeth on one side exhibited a worn pattern, whereas, those on the opposite side exhibited no evidence of a worn pattern, see figure 3. In summary, the outer faces of teeth "G1" through "G3" in figure 3 contained evidence of fatigue cracking and the remaining faces of the fractures exhibited severe mechanical damage that obliterated the fracture features. Details of the fatigue cracking are documented in the following sections of the report.

Fractured Gear Tooth "G3"

Binocular microscope examination fractured gear tooth "G3" revealed the inner face of the fracture contained a fatigue crack that emanated from the root radius on each side of the tooth in the areas indicated by arrows "03" and "04" in figure 3. Figure 4 shows a photograph of the inner face of the tooth fracture. The fatigue crack origin areas indicated

by arrows "03" and "04" in figure 3 corresponded to those indicated by brackets with the same respective numbers in figure 4. Fatigue propagation was toward the core of the tooth in the general direction indicated by arrows in figure 4 and terminated in the areas indicated by dashed lines in figure 4. The areas outside of the fatigue crack region exhibited a rough texture consistent with overstress separation. The mating fracture face (not shown in this report) showed fracture features that were similar to those on the inner face of the fracture.

Fractured Gear Tooth "G2"

The outer face of fractured gear tooth "G2" contained evidence of fatigue cracking that emanated from the root radius on the worn side of the tooth in the area indicated by arrow "O2" in figures 3 and 5. Fatigue crack propagation was through a major portion of the tooth. The mating fracture face (inner fracture face) was not a mirror image of the outer fracture face, indicating a fragment of the tooth separated from the camshaft gear. The fragment was not submitted.

Fractured Gear Tooth "G1"

The outer face of fractured gear tooth "G1" in figure 6 showed evidence of fatigue cracking that emanated from the worn side of the tooth. The origin of the fatigue crack showed evidence of severe mechanical damage that obliterated the fracture features in the general area of the fatigue origin. Fatigue crack propagation was through a major portion of the tooth. The mating fracture face (inner face of the fracture) in figure 7 was not a mirror image of the outer face of the fracture, indicating a fragment of the tooth from the inner face of the fracture had separated. The fragment was not submitted.

Fractured Gear Teeth "G4" through "G11"

The fracture faces of gear teeth "G4" through "G11" in figure 1 showed evidence of severe mechanical damage that obliterated the fracture features.

Width of the Gear at the Outer Teeth

The Teledyne Continental Motors engineering drawing for the cam gear P/N 631845 specified the width of the outer gear teeth is to be between 0.43 inch and 0.45 inch. The width of the outer gear teeth measured approximately 0.44 inches, within the width specified for the outer gear teeth.

Case Hardened by Nitriding

The Teledyne Continental Motors engineering drawing for the camshaft gear P/N 631845 specified the outer surface of the gear teeth are to be hardened by the nitride process. A radial-circumferential cross section was made through fractured tooth "G3" that intersected the fatigue origin on both sides of the tooth (section not shown in this report). The section was polished and etched with 2% Nital reagent. Examination of the cross section revealed the core contained a microstructure of tempered martensite, normally expected for a hardened and tempered high strength low alloy steel. A darker etching zone, typical of a nitride layer, extended all around and adjacent to the outer surface of the gear tooth. The

nitride layer extended approximately 0.026 inch below the surface, which is typical for a nitride layer. The outermost portion of the nitride layer contained a uniform white layer, typical of an iron nitride white layer. The thickness of the iron nitride white nitride layer measured approximately 0.0006 inch.

Elemental Composition

The same engineering drawing indicated the camshaft gear is to be made from AMS 4140 steel, per specification AMS6382, titled "Steel, Bars, Forgings, and Rings 0.95Cr-0.20Mo (0.38-0.43C) (SEA 4140) Annealed". An isolated area on the forward face of the camshaft gear was cleaned with grit paper and this isolated area was analyzed with a handheld Olympus VANTA XRF alloy analyzer. The alloy analyzer identified the alloy as 4140 steel. Table 1 shows the major elements that were identified and the percentage of each element that was detected. The elements identified and the percentage for each element was consistent with 4140 steel.

Service Bulletin

Continental Motors Aircraft Engines Critical Service Bulletin CSB05-8D was issued to eliminate the possibility of camshaft gear tooth fracture, resulting in power loss or in-flight shutdown, and to inspect and remove from service P/Ns 631845, 655430, 655516, or 656031 and replace with camshaft gear, P/N 656818. According to CSB05-8D, the fractured camshaft gear involved in this accident ERA19LA264 is P/N 631845 and must be (should have been) replaced with P/N 656818.

Frank Zakar
Senior Metallurgist

Table 1. Composition for 4140 Steel (Weight %)		
Element	Specified	Measured
Manganese	0.75-1.00	0.799
Phosphorus (max)	0.35	0.14
Sulfur (max)	0.40	0.015
Silicon	0.15-0.30	0.19
Chromium	0.80-1.10	0.925
Molybdenum	0.15-0.25	0.195
Nickel		0.13
Copper		0.145
Tin		0.074
Zinc		0.086
Carbon	0.38-0.43	Not measured
Iron		Remaining

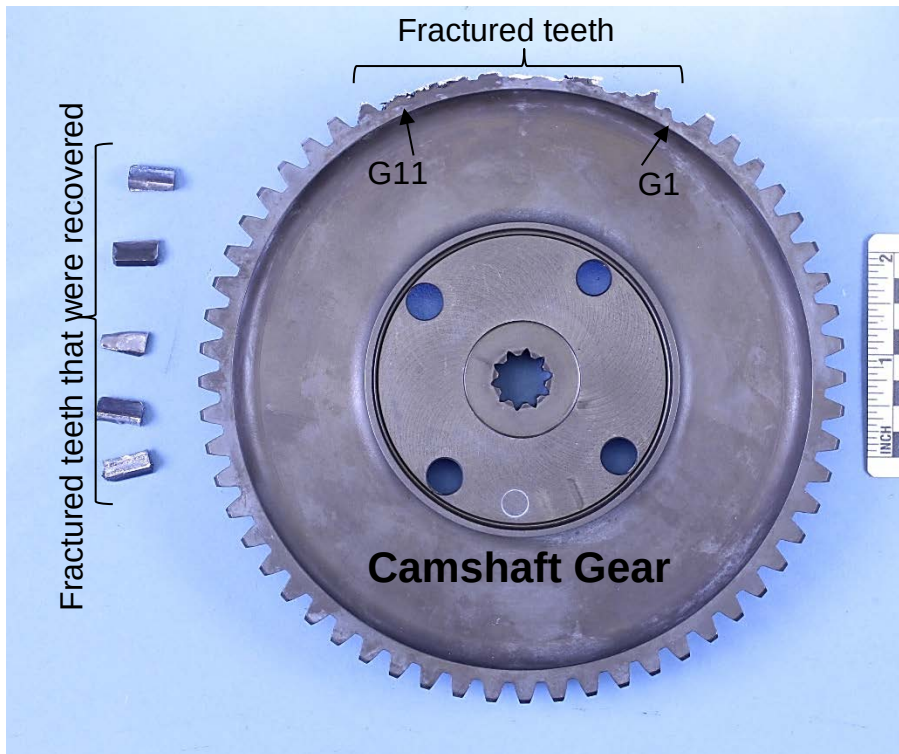


Figure 1. Photograph of the as-received camshaft gear showing the forward face and the location of eleven fractured teeth, indicated by arrows "G1" through "G11", and five fractured teeth that were recovered.



Figure 2. Photograph of the part number "631845" found on the forward face of the camshaft gear.

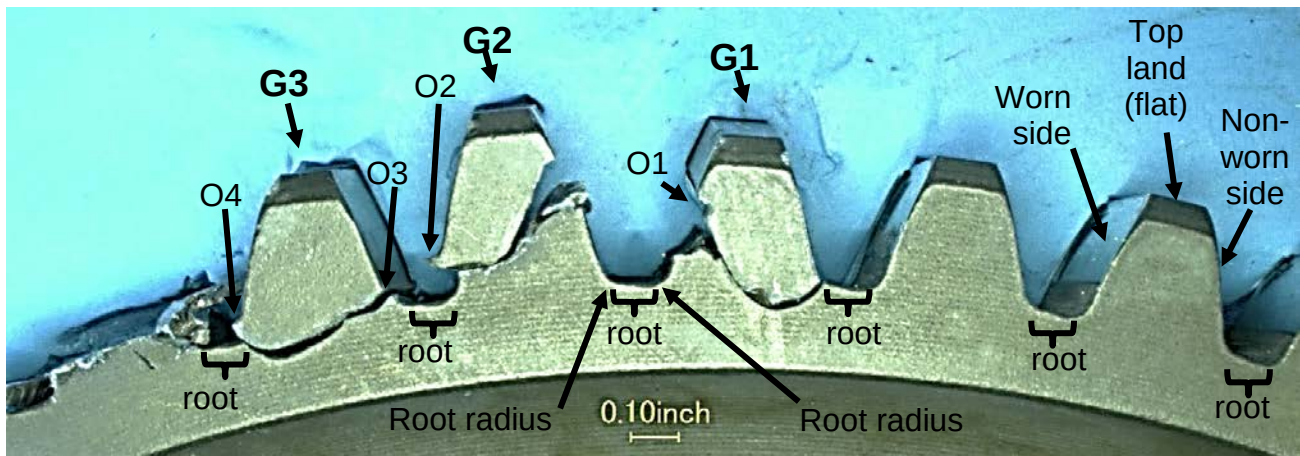


Figure 3. Photograph of a portion of the camshaft showing the forward face and fractured teeth indicated by arrows "G1" through "G3" positioned next to their respective mating fracture faces. Fatigue crack origin areas are indicated by arrows "O1" through "O4".

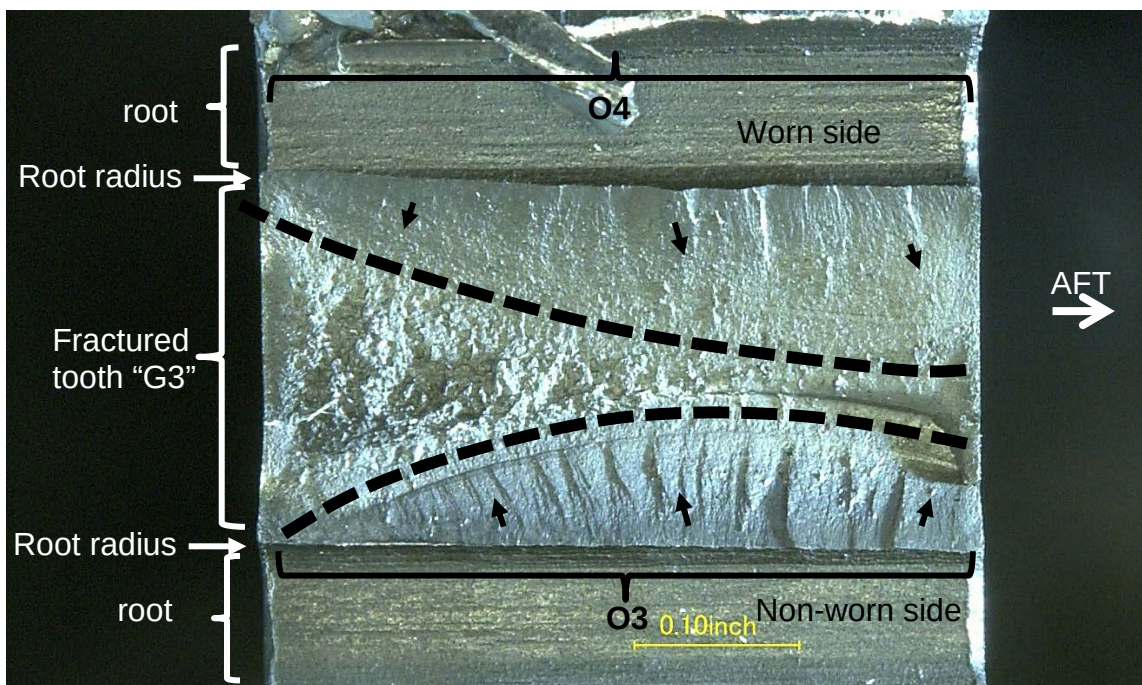


Figure 4. Close-up photograph the inner fracture face of tooth "G3". A fatigue crack emanated from the root radius on each side of the tooth in the areas indicated by brackets "O3" and "O4".

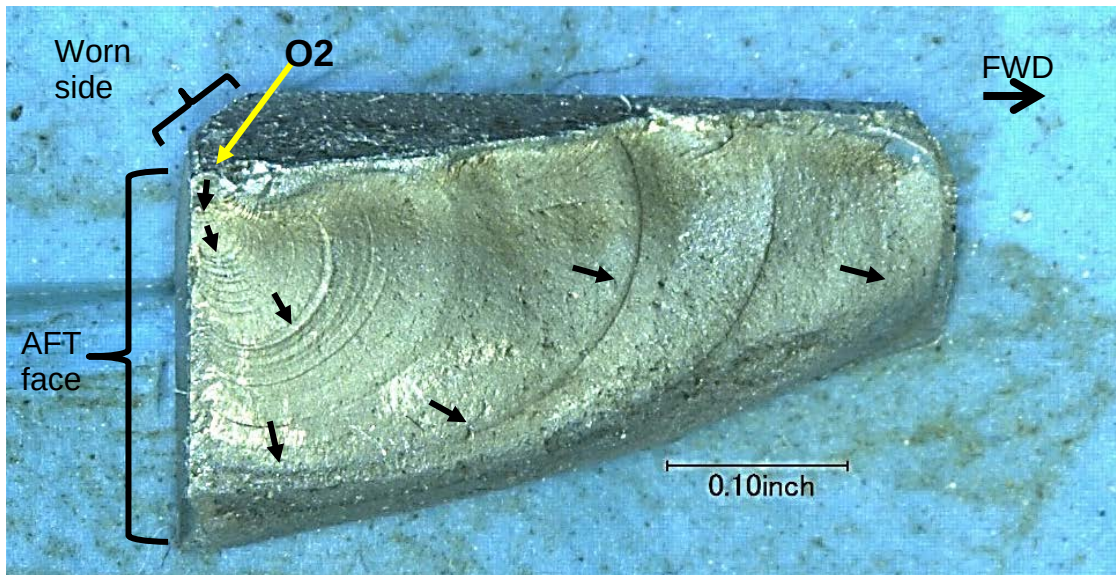


Figure 5. Close-up photograph of the outer fracture face of tooth "G2". A fatigue crack emanated from the worn side near the forward face in the area indicated by arrow "O2". Fatigue origin arrowed "O2" in this figure corresponded to fatigue origin arrowed "O2" in figure 3.

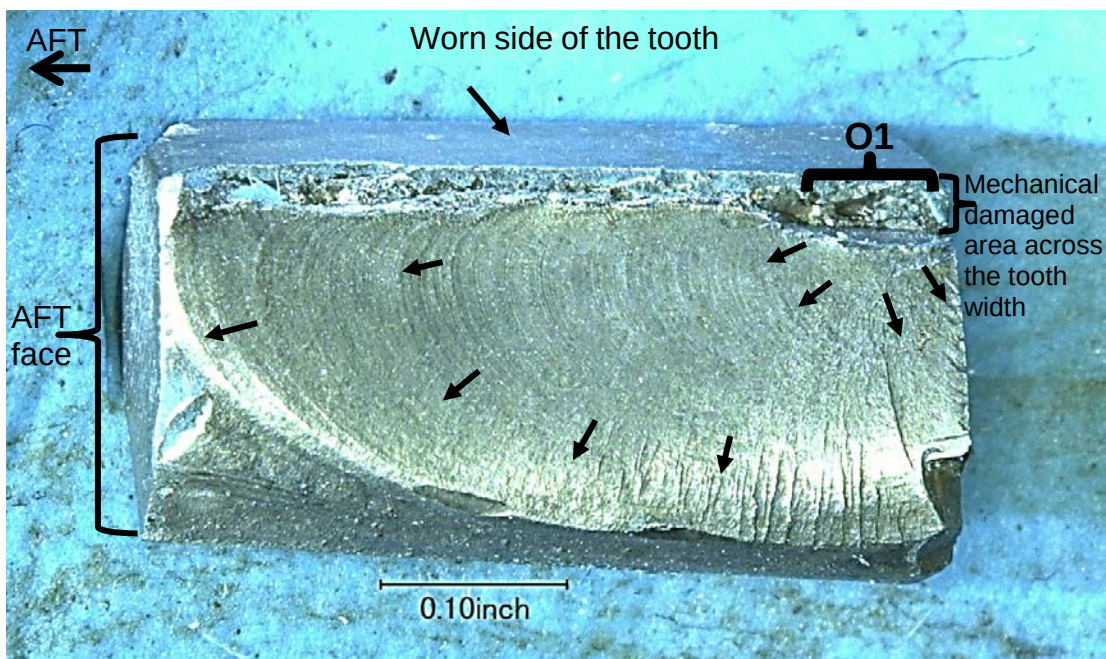


Figure 6. Close-up photograph of the outer fracture face of tooth "G1". A fatigue crack emanated from the worn side of the tooth in the area indicated by bracket "O1". Fatigue origin indicated by bracket "O1" in this figure corresponded to fatigue origin arrowed "O1" in figure 3.

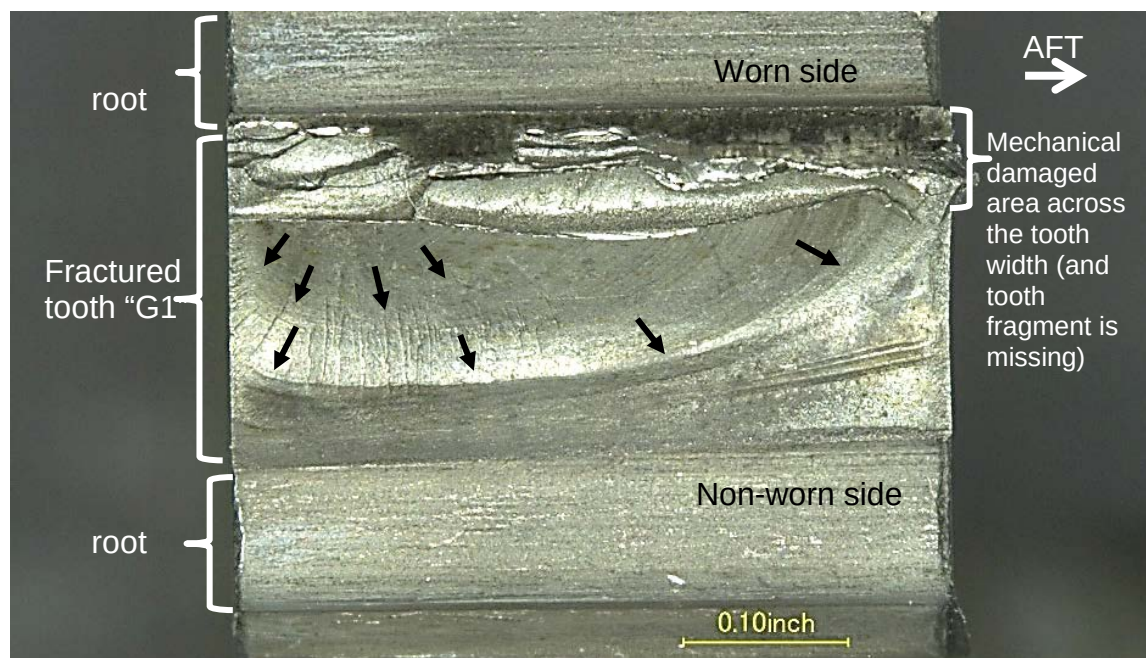


Figure 7. Close-up photograph of the inner fracture face of gear tooth "G1" (it mates with the fracture face in figure 6). A tooth fragment is missing from the origin of the fatigue crack. Fatigue crack propagation was in the general direction indicated by arrows.