



Rotorcraft gearbox regulations: LOL (not what you think)

The European Union’s CS-29 Amendment 7 places more stringent and rigorous testing requirements for certification of Category A type pressurized gearboxes under loss of lubrication conditions compared to the previous regulation.

For more than a decade, one of the most intensively researched subjects in aerospace engineering has been LOL. No, we are not talking about “laughing out loud.” We are talking about a rotorcraft gearbox loss of lubrication event.

An LOL event occurs when a pressurized lubrication system for a gearbox fails and endangers continued flight capability. All Category A type rotorcraft use pressurized lubrication systems. Under loss of lubrication, a gearbox is no longer capable of adequately lubricating rotating parts or dissipating heat. This combination leads to increased friction in the gears and bearings, and increased component surface temperatures. With increased surface temperatures, surface hardness can be lost resulting in the inability of the component to carry its designed loads. Thermal expansion in the components can also lead to the seizing of mated rotating parts. Continued operation of the gearbox causes the temperature to reach a critical level, resulting in its failure.

Many articles have been published on the subject. Some examples are:

- ▶ “Gearbox Loss of Lubrication: Myth, Art or Science?” [1]
- ▶ “Leonardo Strives for Greater Gearbox Loss of Lube Capability.” [2]
- ▶ “Evaluation for Loss of Lubrication Performance of Black Oxide, Superfinished, and As-Ground Surfaces for use in Rotorcraft Transmissions.” [3]
- ▶ “Oil-Out Endurance Under the Lens.” [4]
- ▶ “Surface finishing rotorcraft gearing.” [5]
- ▶ “AH-64 loss of lubrication study: Test of isotropic superfinished AH-64 (Apache) engine nose gearbox without black oxide coating.” [6]

These articles discuss historical certification testing for a gearbox under LOL conditions and its shortcomings. In the past, a gearbox met requirement if it could survive 30 minutes under inflight test conditions. However, the requirement was ambiguous and resulted in industry confusion. Longer flight missions employed in combat theaters or offshore services suggested the 30-minute duration rule was insufficient.

The articles listed above proposed several technologies to increase the LOL endurance limit such as:

- A:** Redundant (emergency) lubrication systems.
- B:** Superfinished gear flank finishes.
- C:** Adequate mated gear tolerance (backlash) to allow for thermal expansion.
- D:** High heat tolerant gear alloys.
- E:** Reservoirs within the gearbox that drip or mist lubricate gears and bearings after lubricant pump failure.



Figure 1: Left, an as-manufactured gear; right, the failed gear due to LOL gear (Aviation Investigation Report A09A0016).

During the period from 2013 to 2018, newer test methodologies trended toward more stringent, longer endurance limits for a rotorcraft gearbox under loss of lubrication. For example, in the 2018 Apache Technical Report cited above, an isotropic superfinished input gearbox achieved more than 60 minutes of successful inflight operation under LOL conditions without any indication of gear flank damage. Numerous other examples of recent loss of lubrication publications can be found in the journals. So, what prompted these intensive LOL investigations by the rotorcraft industry?

BACKGROUND

Unfortunately, in 2009, a helicopter crashed at sea in Newfoundland resulting in fatalities due to an LOL event. This caused the initiation of these investigations. The Canadian Government’s Investigation Report [7] of this incident was released in December 2010. Figure 1 pictures, on the right, the tail rotor take-off gear which failed due to this loss of lubricant incident.

Two subsequent incidents over the North Sea in 2012 involving LOL events resulted in the ditching of helicopters. Fortunately, these incidents did not result in fatalities. However, the ultimate outcome of these incidents was the convening of a group of government aerospace agencies and helicopter manufacturers to update loss of lubrication certification requirements. Previously, the loss of lubrication certification requirements had not been updated since 1988. Managed by EASA (European Union Aviation Safety Agency), this effort began in 2012.

INITIAL RECOMMENDATION

In November 2013, EASA released an initial Certification Memorandum, “Large Helicopter Main Gearbox Certification Requirements.” [8] A Certification Memorandum (CM) is non-binding guidance, in this case, related to loss of lubrication testing requirements. However, a CM is taken very seriously and normally is a pre-

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cursor to an updating of a Certification Specification. A Certification Specification (CS) is law within the European Union.

The intent of the CM was to assure a rotorcraft had continued inflight capability sufficient to safely land after the start of an LOL event. The CM recommended extending bench testing beyond 30 minutes to demonstrate such a capability. After its issuance, the updating to the CS for large rotorcraft continued in earnest.

FINAL RULE CHANGE

EASA managed the updating of the certification requirements for LOL from 2013 until 2019 under EASA RMT.0608 (RMT = a rulemaking task group). Following the guidance from the CM and over several years, this RMT took input from multiple government and industry sources. An approximate yearlong comment-resolution period to the proposed changes represented the final phase of the updating process. In July 2019, EASA released “Certification Specifications and Acceptable Means of Compliance for Large Rotorcraft, CS-29 Amendment 7.” [9]

RESULT

At first glance, this CS appears little changed from the previous regulation in regard to loss of lubrication. Amendment 7 reads at CS29.927(c) (1): “Confidence shall be established that the rotor drive system has an inflight operational endurance capability of at least 30 minutes following a failure of any one pressurized normal-use lubrication system.” However, reading the document carefully reveals it contains much more stringent and rigorous testing requirements related to LOL. The key wording above is “confidence shall be established.”

Today, the updated testing protocol in the CS clearly defines the minimum periods and load conditions that are to be used to simulate the most severe loss of lubrication failure mode of the normal-use pressurized lubrication system. Once the LOL test is initiated, the cycle begins with one minute at maximum continuous power followed by the minimum power needed for continued flight at maximum gross weight. The test ends with a 45-second out of ground effect (OGE) hover to simulate a landing. The CS further states “the test results must substantiate the maximum period of operation following loss of lubrication by means of an extended test duration, multiple test specimens, or another approach prescribed by the application and accepted by EASA, and must support the procedures published in the rotorcraft flight manual (RFM).” In other words, to establish the required confidence, the gearbox must demonstrate operational endurance of greater than 30 minutes. In addition, the expected endurance limit shall be documented in the RFM. In the explanations section of the CS (AMC 29.927(a), it is clearly defined

that the minimum acceptable performance shall “show a capability through testing of at least 36 minutes duration.”

Finally, the ambiguous phrase from the earlier specification edition “unless such failures are extremely remote” has been removed from the updated CS. This eliminates any certification without complete LOL testing.

To date, it appears that new pressurized Category A type gearboxes that achieve satisfactory operational inflight testing capability of 50 to 60 minutes represent achieving the required level of confidence. This might be why in 2018 the U.S. Army used the 60-minute test protocol cited in reference 6 for the Apache nose gearbox for its updated LOL test.

CONCLUSION

The European Union placed CS-29 Amendment 7 into law in July 2019. This specification places much more stringent and rigorous testing requirements for certification of Category A type pressurized gearboxes under LOL conditions compared to the previous regulation. The U.S. Army is updating ADS-50 Drives to match these testing requirements. Furthermore, the FAA is expected to update 14 CFR 29.927(c) to similarly match the requirements in CS-29 Amendment 7. Due to the updating of CS-29, future pressurized rotorcraft gearboxes will achieve a much safer LOL inflight capability. ☒

REFERENCES

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