Study of testing Methods for Spur Gear

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Abstract: Spur gear is the simplest & widely used in power transmission system. A spur Gear is generally subjected to bending stress which causes teeth failure. However it is observed that performance of the spur gear is not satisfactory in certain applications and therefore it is required to test gear under such uncertain conditions so that exact nature of spur gear failure can be determined. For that purpose test like Loss-of-lubrication test, bending fatigue test, wear test and noise test conducted. In this paper, we briefly studied all tests.

Key Words: Loss-of-lubrication test, bending fatigue test, wear test, noise test.

Introduction:

Gearing is one of the most critical components in a mechanical power transmission system, and in most industrial rotating machinery. It is possible that gears will predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. In addition, the rapid shift in the industry from heavy industries such as shipbuilding to industries such as automobile manufacture and office automation tools will necessitate a refined application of gear technology.

1. Loss-of-Lubrication Test:

Prior to receiving airworthiness certification, extensive testing is required during the development of rotary wing aircraft drive systems. Many of these tests are conducted to demonstrate the drive system's ability to operate at extreme conditions, i.e.—beyond that called for in the normal to maximum power operating range. One of the most extreme tests is referred to as the "loss-of-lubrication" or "run dry" test.[1]

Failure of this test can lead to a partial redesign of the drive system or the addition of an emergency lubrication system. Either of these solutions can greatly increase the aircraft drive system cost and weight—and extend the schedule for obtaining airworthiness certification. Recent work at NASA Glenn Research Center (Cleveland, OH) focused on performing tests in a relevant aerospace environment in order to simulate the behavior of spur gears under loss-of-lubrication conditions. Recent testing has focused on newer aerospace gear steels and imbedding thermocouples in the shrouding to measure the air/oil temperatures flung off the gear teeth.

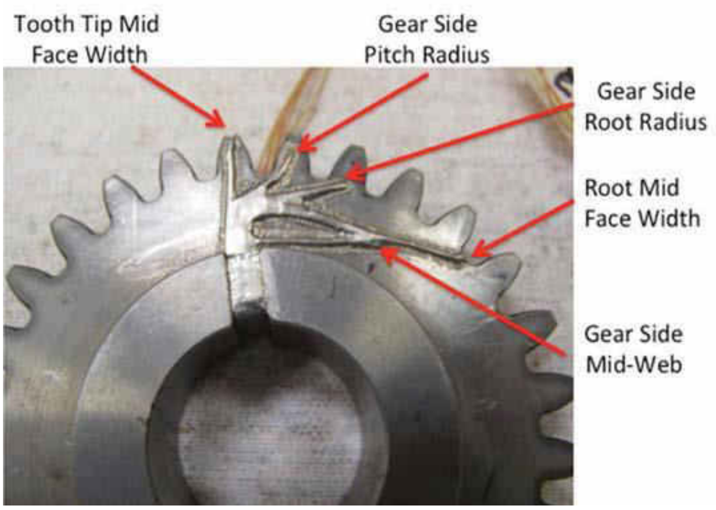

Figure1 Specimen before Test - [1-for ref.]

1.1 Testing Methodology:

Prior to the reported loss-of-lubrication testing, the gears were broken-in to allow normal run-in wear to occur. The gears were operated for at least 1 hour at ~50 percent maximum torque and at full facility speed (10,000 rpm). After this period the load was then increased to the maximum load and run for at least several more hours prior to conducting a loss-of-lubrication test. Most tests were run until the teeth failed to continue to carry torque (plastically deformed), or were stopped just prior to this condition. Test involves:

1. Warm-up of the test rig and steady-state operation of the test spur gears under normal lubricating conditions; in this phase the gears were jet- lubricated with an in-mesh spray bar.
2. Lubrication system shutdown.
3. Continued operation at constant speed and constant torque on the driven gear in loss-of-lubrication condition for 30 minutes.[1]

During all tests the static instrumentation and live video were carefully monitored. Data from all sensors were collected at 1 Hz and stored for post-processing.

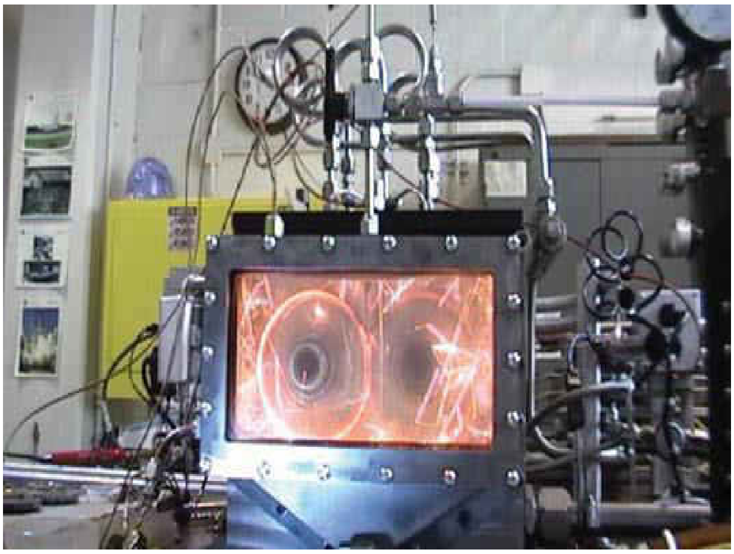

Fig.2: Loss-of-lubrication test [1]

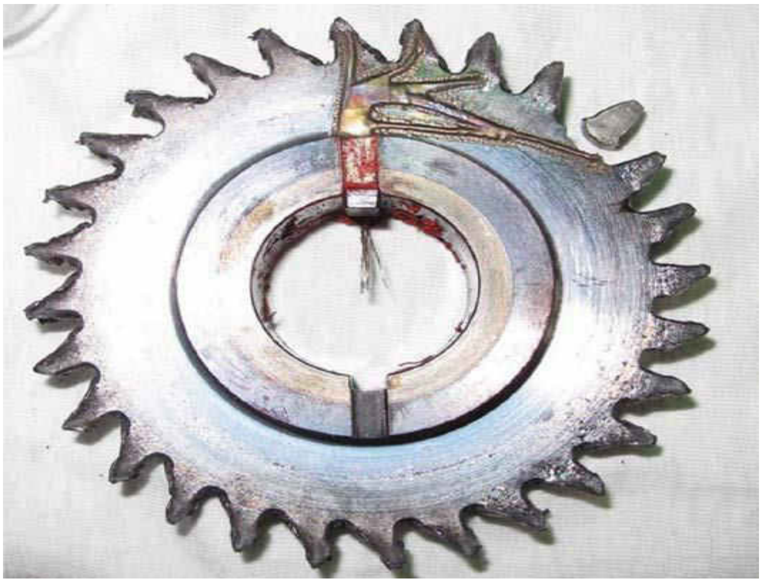

Figure 3: Instrumented spur gear post-loss-of-lubrication test condition. [1]

2. Bending Fatigue Test:

In certain space applications of gears, the level of loading applied to the gear mesh members can be large enough to cause a great deal of the gear's life to be used in a short number of cycles. The American Gear Manufacturer's Association (AGMA) standard for evaluating fatigue of gears states: "The use of this standard at bending stress levels above those permissible for 10^4 cycles requires careful analysis".[2] In the AGMA standard, the stress-life relationship for the cycle regime comprising 100 to 1000 cycles is depicted as a single value for the allowed bending stress. Thus, the problem is how to properly account for severe loads to estimate the fatigue lives of gear teeth. The standard's analysis techniques calculate a life at a given stress for 99 percent reliability at the component level. This means that a large population of components designed using the allowable stress values should experience crack initiation at a rate no greater than 1 per 100 for the given cycle count. To provide a credible estimate of fatigue life at 99 percent reliability, extensive experimental data is required to establish the load-life relationship the low-cycle fatigue ($<10^4$) regime.[2]

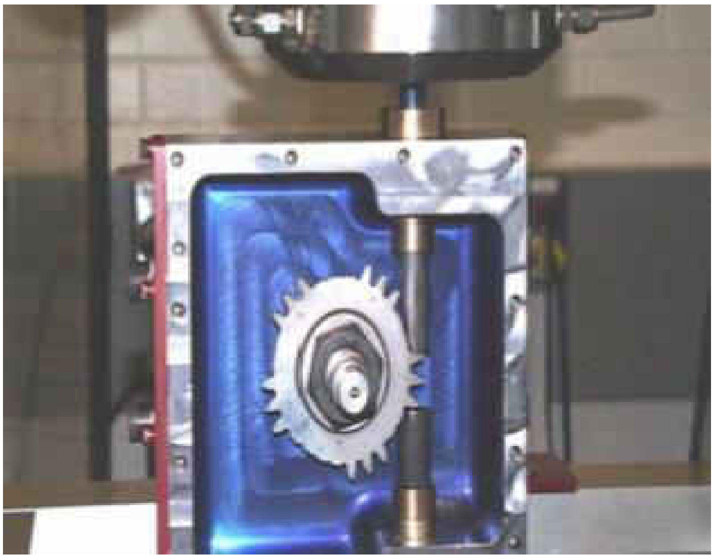

Figure 4: Test gear installed in test fixture [2]

2.1 Test Operation:

The single tooth bending tests of this study were conducted using unidirectional loading. Testing was done in load control. The gear was positioned to provide load on the test tooth at the theoretical highest point of single tooth contact for the case of the test gear mating with an identical gear at the standard center distance. The load is cycled from a small, minimum load to the maximum load desired for the given fatigue test. The load range was maintained a constant value throughout the test. Loading was cycled at 0.5 Hz using a sinusoidal waveform. For the testing conducted in this study crack initiation was assumed to occur when the loading rod stroke increased approximately 2 percent (~0.0002 in. change) relative to the stroke for the gear tooth at test initiation. At this point a crack had initiated with a size on the order of the case depth. The test was continued until the rod stroke was 0.010 in. greater than that achieved on the new gear tooth. At this point the crack size was visible on the side of the tooth and was approximately 30 to 50 percent of the distance across the tooth

Figure 5: Single tooth bending fatigue failure at the end of test. [2]

Five fatigue tests were done using gear teeth having dithering-induced surface damage on the active tooth profile. The fatigue crack location was at the usual position in the root and fillet, not at the dithering-induced damage location. For these five tests, the dithering-induced damage did not reduce the bending fatigue capability of the gear tooth.

3. Wear test:

There are several different methods for tribology testing, of which the pin-on-disk method probably is the most common for investigating wear. Depending on what is being investigated, different machines are used. When testing oils, a twin disc machine or a fourball machine may be used or any of several other alternatives. The FZG machine, developed for investigation of oils, is standardized according to DIN 51 354. By weighing the wheel before and after operation, material wear may be estimated. The origin of the wear debris, however, cannot be determined in this manner. The less the material that has worn off the better the oil. Extensive research to improve the FZG test is being carried out in Germany at the FZG, Faculty of Machine Engineering, TU Munich. Wear testing on an FZG back-to-back gear test rig but differs from the work of Höhn, whose work concerns classifying oils with respect to their wear resistance. The aim is to determine the wear distribution on a tooth surface with respect to time, and whether it can be predicted. If it can be predicted, the tooth could be designed to minimize the wear thus extending the fatigue limit. Figure (6) below shows a sketch of an FZG rig. According to Höhn, the main advantage of the FZG rig is that power is not taken from the system; therefore only a relatively small amount of input power is required to compensate for the losses in the system.

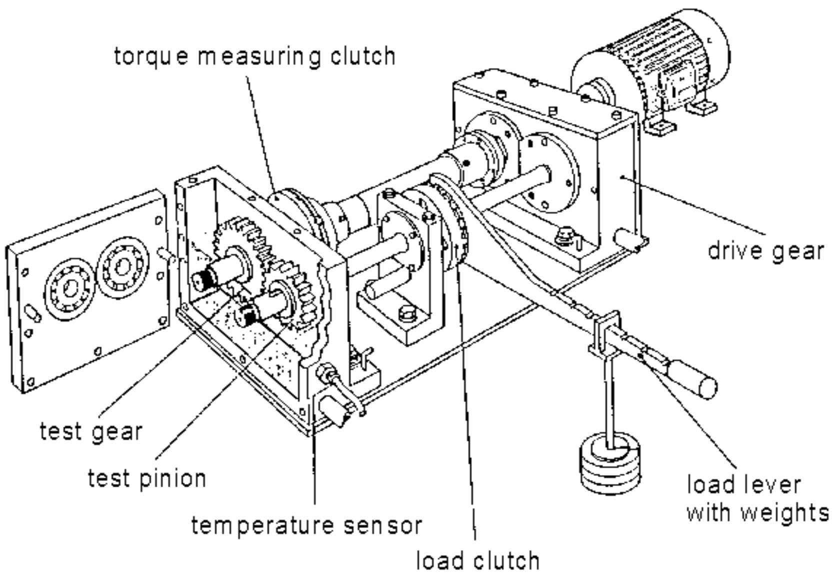

Figure 6: Sketch of FZG back-to-back

The controlled quantities in the basic FZG test are the rpm, oil temperature and quality including the level of filtering and load. Pre-tensioning the gears against each other by torsion of the load clutch controls the load. The drive gear counteracts the torsion and the shaft connected to the gear is very thick and therefore stiff. To permit wear monitoring, the FZG machine was periodically stopped according to a schedule with shorter intervals towards the beginning. At each halt the wheels were cleaned and degreased, and a mould of putty and aluminum was built around two gear spaces at three positions on each wheel.

A cold-curing resin with a methyl methacrylate base, supplied as powder and liquid, designed for taking accurate surface impressions, was poured into the mould. After hardening it was removed and examined using optic and stylus instrument. This method and material have been tested by Ohlsson and found satisfactory.[3] Typical measurement uncertainty for an integrating 3D-amplitude parameter is around 5%.

Another replica method was used by Andersson [4] on gear flanks where acetyl cellulose films are soaked in acetone and then put on the surface. After evaporation of the acetone the film can easily be removed and examined with various instruments. The form of a tooth is not preserved but the different features of the surface such as roughness and cracks can be investigated. Another feature appreciated is the semi-transparency of the films during examination with optical microscope. The main contributions and conclusions of this test are:

1. It has shown that it is possible to predict, with sufficient accuracy, the mild wear on gear tooth surfaces using phenomenological models.
2. The wear on gear tooth surfaces has both a negative and a positive impact on the performance and service life of a gear transmission.
3. The mild wear is very likely to act as a catalyst for surface fatigue.

4. The wear behavior of helical gears has been pointed out as well as some of its effects.

4. Noise Test:

To investigate noise emission from a vehicle gearbox and gear fault detection and diagnosis Essam Allam et al, Hui Li used the following procedure for investigation and the schematic representation of their test rig is shown in Fig.8, the gearbox was running at 200 RPM at 10 mm for 3 hours to make the gearbox settle dynamically and it reaches a stabilized temperature of 60°C. Input speed of 100 to 500 RPM with a torque of 2.5 to 15 Nm was used as test condition. Condenser 1/2- microphone with 4189A- 021 type preamplifier was placed in the center of the gearbox front casing used to measure the SPLs signals, Bruel and Kjaer (B and K) portable and multichannel PULSE type 3560-B-X05 was used to analyze the signal occurred. C. Brecher, conducted investigation on gear noise for that acceleration sensors are mounted close to the bearings and a free-field microphone is located close to the tooth mesh. The microphone was located close to the tooth mesh and acceleration sensors are mounted near the bearing. Fig.7. shows the schematic representation of the test rig used for this investigation. Åkerblom M uses a Mechanical power recirculation type test rig. Were two identical gear boxes were connected through a universal joint. One of the gear boxes was tilted with the aid of hydraulic cylinder for applying load. Accelerometers were mounted on the gearbox for vibration measurement. Microphones were used to measure the noise. The total setup was mounted over a concrete stage.[3] To conduct investigation on the resonance frequency behavior of spur gears Shuting Li used a power circulating test rig was used. Rubber couplings were used to avoid the effect of vibration signals from motor and shaft.

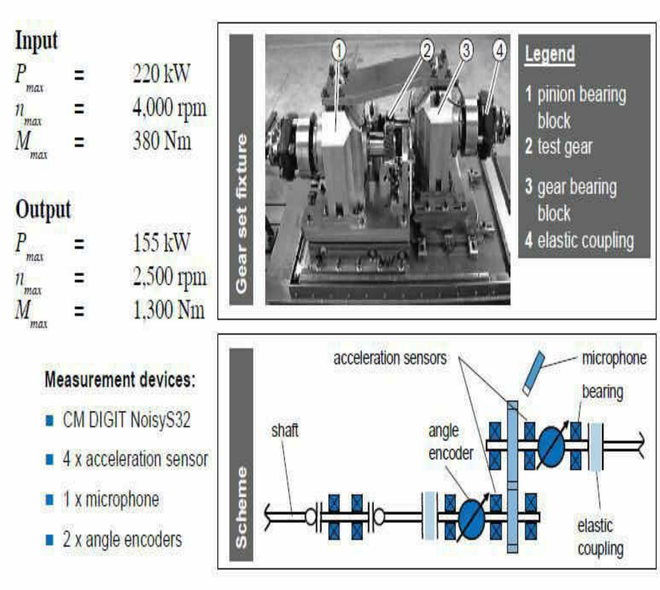

Fig. 7: Test rig for investigating gear noise [3]

References:

1. Robert F. Handschuh, Lucas J. Gargano, "Test Facility Simulation Results for Aerospace Loss-of-Lubrication of Spur Gears", NASA Glenn Research Center, 2015,pp 1-6.
2. Bradley Lerch, Christopher Burke, "Investigation of Low-Cycle Bending Fatigue of AISI 9310 Steel Spur Gears", QSS Group, Inc., Cleveland, Ohio,2007,pp 5-8.
3. A.P. Arun, A.P.Senthil kumar, B. Giriraj, Faizur rahaman, "*Gear Test Rig - A Review*", International Journal of Mechanical & Mechatronics Engineering IJMME-IJENS Vol:14 No:05,PSG College of Technology, Coimbatore,India.2014,pp2-7