



AEROSPACE INFORMATION REPORT

AIR6989™

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Micropitting of Bearings and Gears in Aviation

RATIONALE

Micropitting is a surface initiated fatigue wear process that can propagate to more severe wear that can result in bearing or gear failures. Mechanical system design has a major influence on micropitting and lubricant formulation has been shown to be a contributing factor in micropitting in other transportation sectors. The E34 committee identified the need to study micropitting and consider method(s) capable of screening formulations for micropitting propensity.

1. SCOPE

The intent of this SAE Aerospace Information Report (AIR) is to summarize and review the E34 committee's efforts to educate the aerospace propulsion lubrication community on the science of micropitting, its consequences, and the various tribology evaluation methods that can be employed under aviation related conditions to differentiate formulation related aggravating factors.

2. APPLICABLE DOCUMENTS

2.1 SAE Publications

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Telephone: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), Web address: <http://www.sae.org>.

AIR5433 Lubricating Characteristics and Typical Properties of Lubricants Used in Aviation Propulsion and Drive Systems

AS5780 Specification for Aero and Aero-Derived Gas Turbine Engine Lubricants

2.2 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-PRF-23699 Performance Specification Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, Nato Code Numbers: O-152, O-154, O-156, and O-167

2.3 SAE E34 Committee Meeting Presentation References

Indicated as reference numbers throughout body, full presentations can be found on the E34 Standard Works website.

¹ Surface Initiated Fatigue Rationale for Oil/Material Qualification Test, L. Wedeven, April 2003 meeting

² Some New Developments in Tribological Testing, A. Olver, April 2005 meeting

³ The PCS Disc Rig - Micropitting Test, S. Lee, April 2004 meeting

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Documents

Document Sharing Hub

- 4 The influence of Lubricant Additives on Micropitting, A. Olver, March 2013 meeting
- 5 Micropitting Perspective for Aero propulsion Components, L. Wedeven, March 2013 meeting
- 6 Traditional and Operational Micropitting, L. Wedeven, March 2017 meeting
- 7 Micropitting Damage in Gear Tech Contacts, A. Kadiric and P. Rycerz, September 2018 meeting
- 8 PCS Micro Pitting Rig - A Brief Overview, R. Baker, March 2013 meeting
- 9 New Test Methodologies for Screening of Micropitting in Aviation Industry, K. Topolovek Miklozic, March 2013 meeting
- 10 Micropitting Update, R. Baker, March 2017 meeting
- 11 Failure mode - Test Method - Influence Factors, K. Michaelis, October 2013 meeting
- 12 Micro-Pitting in Service and WAM_{mp} Simulation, L. Wedeven et al., October 2013 meeting
- 13 WAM_{mp} Micropitting Test Conditions, L. Wedeven et al., March 2014 meeting
- 14 WAM_{mp} TRL4 and Superficial Tribology Testing, L. Wedeven et al., March 2015 meeting
- 15 Wedeven Micropitting Investigation At Two Lambda Ratios, L. Wedeven et al., September 2019 meeting
- 16 WAM_{mp} Micropitting Update, L. Wedeven et al., September 2018 meeting
- 17 WAM_{mp} Micropitting Update, L. Wedeven et al., March 2021 meeting
- 18 SAE E34 Propulsion Lubrication Tribology Direction Survey, D. Stone and A. Dobbins, September 2020 meeting
- 19 Eastman Micropitting Results, R. Yungk, September 2018 meeting
- 20 ExxonMobil Micropitting Test Results, M. Douglass, September 2019 meeting

3. BACKGROUND

- 3.1 AIR5433 sponsored by E34 beginning 2005 defined micropitting as a “type of fatigue (that) is characterized by subsurface shallow spalling in the order of 0.0002 to 0.0005 inch (0.005 to 0.013 mm) depth which occurs where the surface finishes have many asperities greater than the lubricant film thickness.” While micropitting is defined and recognized as an important consideration for the aerospace community, AIR5433 does not propose methods for its evaluation as the AIR relates to oil formulation based on the effects of pressure-viscosity, load carrying, and traction coefficient.
- 3.2 AIR5433C describes important parameters that lead to micropitting in the description of mixed film lubrication. The point is made that micropitting is avoided when ample lubricant film thickness is maintained. When the lambda ratio ($\lambda = h/\sigma$; hydrodynamic film thickness/average surface roughness or height) is greater than 3, micropitting is mostly eliminated.
- 3.3 Vern Wedeven of Wedeven Associates¹, Andy Olver of Imperial College², and Steve Lee of QinetiQ³ presented to E34 the need for micropitting evaluation and proposed test method platforms in the 2003 to 2005 timeframe.
 - 3.3.1 Wedeven presented experimental data on HTS class aviation turbine oils with different boundary film capability correlating the oil with the higher traction with worse surface initiated fatigue (e.g., micropitting) damage.
 - 3.3.2 Olver also suggested that (anti-wear or extreme pressure) additives “caused micropitting by preventing ‘running in’” from his research into non-aviation lubricant formulations.

- 3.3.3 Lee presented on the feasibility of applying the PCS MPR machine for aviation turbine oil micropitting evaluation.
- 3.4 The notion raised by Wedeven and Olver that strong boundary film forming chemistry can promote micropitting was received by some OEM committee representatives as an indication that a micropitting screening test should be developed. This was especially important, as the U.S. Military had coincidentally proposed a MIL-PRF-23699 class of oils with higher load carrying capability (EE or Enhanced Ester class). A micropitting screening test was deemed a prudent industry tool to allow formulators to design lubricants with a balance of properties.
- 3.5 Wedeven provided some micropitting example images obtained through a survey of military hardware showing damage accumulation (Figures 1A and 1B). In these examples, film thickness was limited by the surface condition of the bearings inspected.

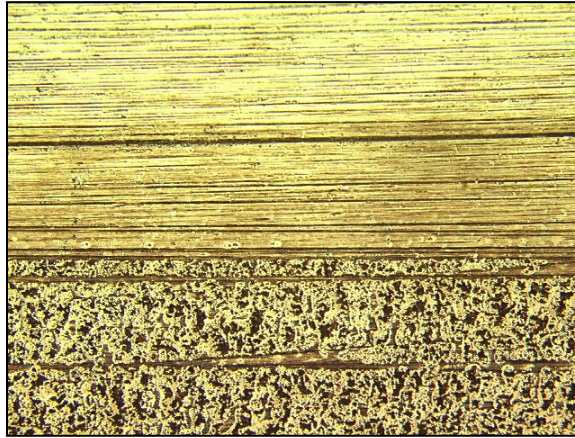


Figure 1A - Micropitting evidence caused by grinding features, 50x



Figure 1B - Micropitting evidence caused by surface imperfection, 50x

- 3.6 Micropitting became a focal point of the E34 tribology agenda in the 2013 timeframe after a number of OEM representatives supported the topic by inviting various independent test labs and academicians to make presentations to the committee.
- 3.6.1 Olver⁴ presented a series of experiments on two common aviation turbine oils with reduced or no anti-wear additive (tricresyl phosphate or TCP) demonstrating again that chemistry mattered. In these experiments, lower TCP contents gave rise to more severe micropitting. The experiments also highlighted differences in two fully formulated oils' micropitting behavior (Figures 2A and 2B).

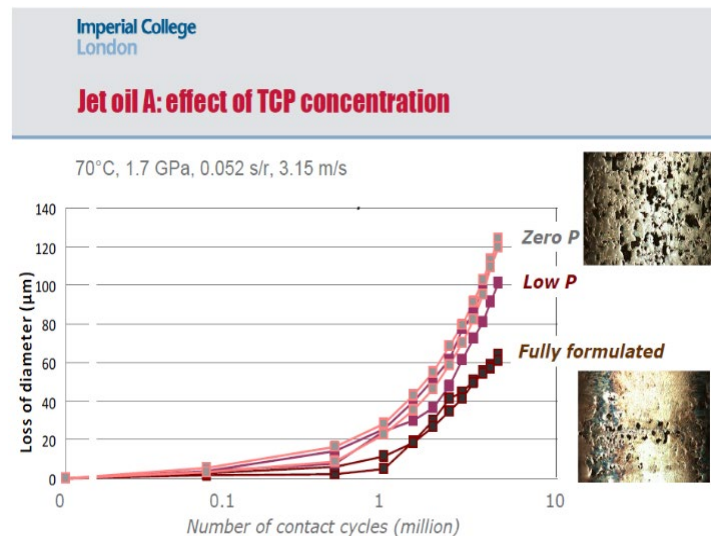


Figure 2A - Examples of two aviation turbine (jet) oil with varying phosphorus (P) drive trends in micropitting behavior in PCS MPR rig

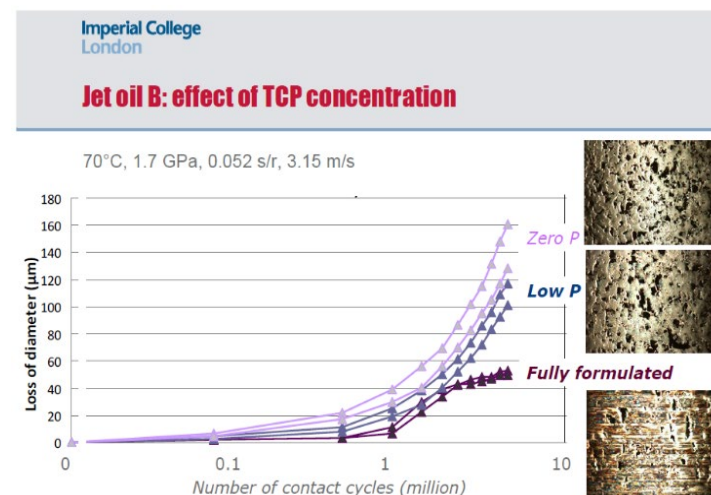


Figure 2B - Examples of two aviation turbine (jet) oil with varying phosphorus (P) drive trends in micropitting behavior in PCS MPR rig

- 3.6.2 Wedeven^{5,6} made the distinction between traditional micropitting (grey staining) and operational micropitting with examples of field hardware.
- 3.6.2.1 Traditional micropitting occurs if roughness features do not wear (e.g., good anti-wear performance) allowing the lambda ratio to remain vulnerably low.
- 3.6.2.2 Operational micropitting occurs when wear in high slip regions or surface damage (e.g., debris dents or assembly damage) impact surface geometry resulting in local high stresses.
- 3.6.2.3 Wedeven proposed that avoiding traditional micropitting benefits from less anti-wear capability while avoiding operational micropitting benefits from more anti-wear capability.
- 3.6.3 Amir Kadirci⁷ of Imperial College reinforced the fundamentals of micropitting as a rolling contact fatigue process that takes place at the asperity level that results in tiny cracks in a 2018 presentation.
- 3.6.3.1 Micropitting occurs under low film/low lambda ratio condition and high asperity stresses