NASA
Technical Memorandum 87205

USAAVSCOM
Technical Report 86–C–3

Study of Journal Bearing Dynamics Using Three-Dimensional Motion Picture Graphics

(NASA-TM-87205) STUDY OF JOURNAL BEARING DYNAMICS USING 3-DIMENSIONAL MOTION PICTURE GRAPHICS (NASA) 8 p HC A02/MF A01 CSCL 20D

N86-18647

Unclas
G3/34 05375

David E. Brewe
Propulsion Directorate
U.S. Army Aviation Research and Technology Activity—AVSCOM
Lewis Research Center
Cleveland, Ohio

and

Donald J. Sosoka
Lewis Research Center
Cleveland, Ohio

Prepared for the
ASEE Engineering Design Graphics Division Midyear Meeting
West Lafayette, Indiana, November 24–26, 1985

STUDY OF JOURNAL BEARING DYNAMICS USING THREE-DIMENSIONAL MOTION PICTURE GRAPHICS

David E. Brewe
Propulsion Directorate
U.S. Army Aviation Research and Technology Activity - AVSCOM
Lewis Research Center
Cleveland, Ohio 44135

Donald J. Sosoka
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

E-2682

ABSTRACT

Computer-generated motion pictures of three-dimensional graphics are being used to analyze journal bearings under dynamically loaded conditions. The motion pictures simultaneously present the motion of the journal and the pressures predicted to develop within the fluid film of the bearing as they evolve in time. The correct prediction of these fluid film pressures can be complicated by the development of cavitation within the fluid. The numerical model that is used predicts the formation of the cavitation bubble and its growth, downstream movement, and subsequent collapse. A complete physical picture is created in the motion picture as the journal traverses through the entire dynamic cycle.

INTRODUCTION

Computer graphics is becoming increasingly valuable to the engineer. It can play a vital role in analyzing complex problems by providing quick insight and understanding to an otherwise overwhelming task. The ability to output data in the form of color, three-dimensional graphics to a motion picture device adds still greater versatility, especially for transient phenomena.

Computer motion pictures are being used at the NASA Lewis Research Center to study journal bearings subjected to dynamic loading. Under these conditions cavitation in the fluid film must be considered since it has an effect on load capacity, stiffness, damping, and power loss. Our particular concern thus far has been with the numerical modeling of the cavitation boundary conditions and the fluid film pressures as they evolve in time. The prescribed motion of a journal whirling in a circular path was chosen for the dynamic cycle so that comparisons could be made with concurrent experimental work. In this study each frame of the motion picture portrays the position of the journal relative to the housing at each instant in time. Accompanying each positional configuration is a three-dimensional pressure distribution that was determined from the numerical calculations. The formation, growth, and collapse of the bubble in response to the dynamic conditions are shown. A complete physical picture is created as the journal spins about its own axis and makes its journey through one complete orbit. In this way computer graphics makes it possible to obtain a more complete understanding of the complicated dynamics that may be encountered.

JOURNAL POSITION AND MOTION

The position of the journal relative to the housing is shown in the upper left corner in each frame of figure 1. The outline of the journal surface is represented by the dotted circle and its center by the smaller "+" symbol. The bearing housing inner surface is represented by the solid circle and its center by the larger "+" symbol.

The prescribed motion of the journal center was in a clockwise circular orbit about a point fixed in space relative to the bearing center. The journal spun in the counterclockwise direction about its own axis, which was considered parallel to the axis of the bearing housing. The net result for this motion was that the fluid entrainment velocity was in the counterclockwise direction. In this particular case a complete orbit took 66.7 ms.

THREE-DIMENSIONAL PRESSURE PROFILE

Accompanying each positional configuration of the journal and housing is a three-dimensional pressure distribution that was determined from the numerical calculations. This plot represents the pressures both axially and circumferentially within the clearance between the journal and the housing. A cylindrical representation has been transformed into a Cartesian representation by making a cut in the housing (journal) surface at the maximum film position and unwrapping it end to end. This position was determined by extending the line of centers through the largest clearance space. Note that the three-dimensional plot is in a moving coordinate system that is fixed to the minimum film position (located diametrically opposite the maximum film position). The positive pressures shown in the three-dimensional plots were generated in the fluid flow inlet (converging clearance) region adjacent to the minimum film line. In the direction of rotation the pressures became negative in the outlet (diverging clearance) region. The occurrence of vapor cavitation is made possible when these negative pressures lead to tensile stresses that exceed the tensile strength of the oil or the binding of the oil to the surface.

TRACKING PRESSURES THROUGH ONE CYCLE

The figure illustrates the pressure changes as they occurred throughout the entire orbit. Part (a) represents the position of the journal within the housing and the associated pressure distribution at the initial instant in time. The pressure buildup due to the combined squeezing and sliding motion of the journal is shown for the first half of the cycle in parts (a) to (d).

The onset of cavitation occurred between parts (c) and (d), 27 ms into the cycle. The extent of cavitation is shown by the outline of asterisks in the three-dimensional plot of part (d). The upstream and downstream menisci of the cavitation boundary are outlined in the diverging clearance region in the accompanying bearing configuration.

Graphically the menisci are represented by a pair of parenthetical symbols. The orientation, size, and position of the parentheses were based on the geometry of the journal and housing at a particular moment in time. During that part of the orbit in which cavitation was present, the orientation, size, and position were constantly changing and had to be redetermined to comply with the geometry changes and the extent of the bubble.

Proceeding from (d) to (e) shows the journal (near the minimum film line) separating from the bearing. The initial stages of separation created a suction effect, causing the pressure hump to dissipate and the vapor bubble to expand. As the journal continued to pull away from the housing, the side flow became dominant because of the increased clearance. This resulted in the collapse of the bubble. In this particular case the bubble drifted downstream and crossed the maximum film line (part (f)) before collapsing. Thus figure 1, and particularly the motion picture, created a complete physical picture of the fluid film behavior as the journal spun about its own axis and journeyed through one complete orbit.

CONCLUDING REMARKS

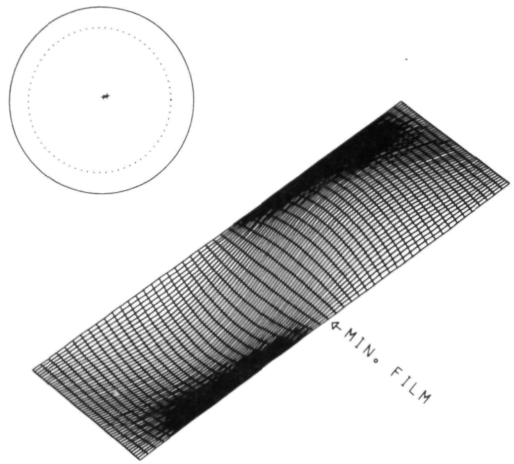
Three-dimensional graphics has been an extremely useful tool in analyzing journal bearings subjected to dynamic loading. Furthermore the capability to output the graphics to a motion picture device enables one to effectively and efficiently analyze transient phenomena resulting from dynamic loading. This motion picture afforded a visual recording of the motion simultaneous with the pressure map, which depicted the formation, growth, and subsequent collapse of the cavitation bubble. As a result a complete physical picture was created as the journal traversed the entire dynamic cycle.

APPENDIX - GRAPHICS SYSTEM OVERVIEW

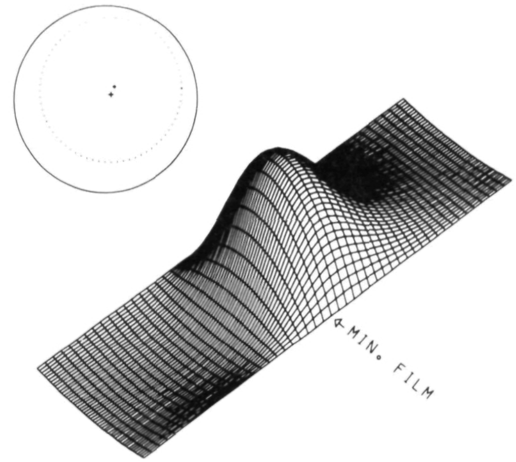
The computer graphics presented herein were generated by NASA Lewis' interactive three-dimensional graphics system known as GRAPH3D. This system, developed entirely in-house at NASA Lewis, is a large-scale, general-purpose graphics package based on the ACM Siggraph core specifications with several unique features added. Among these features are (1) a versatile interface that allows a user to create graphics either from Fortran or directly from command language; (2) one-command, device-to-device switching at any point; (3) alternative hidden-line, hidden-surface, or shaded renderings obtained with a single command and without reexecution of user code; and (4) a rich family of higher level primitives so that complex plots may be constructed in relatively few graphics calls or commands. In addition GRAPH3D makes available special tools to aid the scientific and engineering graphics application.

Currently GRAPH3D runs on a IBM 370/3033 operating IBM's TSS (Time Sharing System) and on an Amdahl 5840 running VM/CMS. At the moment more than a dozen different devices, ranging from an off-line Zeta pen-plotter to high-performance interactive terminals such as the IBM 5080 are supported. During prime hours GRAPH3D system usage averages 20 to 30 simultaneous users. Applications include standard two- and three-dimensional vector and point plots, contour plots, surface and solids modeling, continuous-color (psuedo image processing) data representation as well as interactive chart creation and plot enhancement for presentation and report generation.

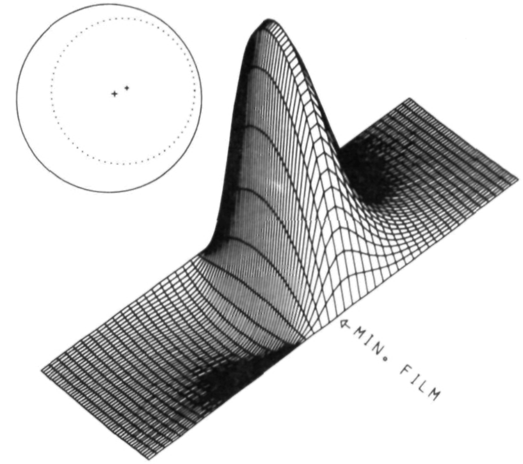
For the work presented herein four devices were primarily used. An Envision 230, a medium-resolution color raster device, was used as the primary development scope. The slides were obtained from negatives produced by a Matrix 3000 film recorder attached to a high-resolution Ramtek 9400 color raster workstation. Finally the color motion picture was generated on a Dicomed D48 recorder system. Approximately 390 CPU minutes were required to generate the graphics for the color motion picture.



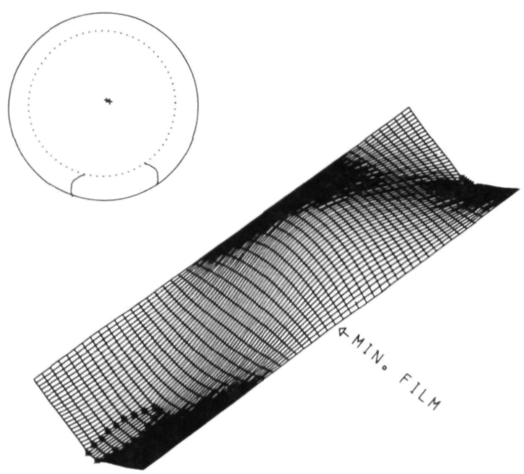
(a) Initial conditions (t = 0 ms).



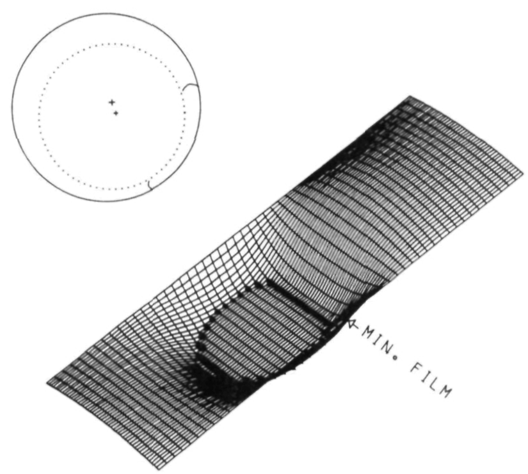
(b) Squeeze motion (t = 12.4 ms).



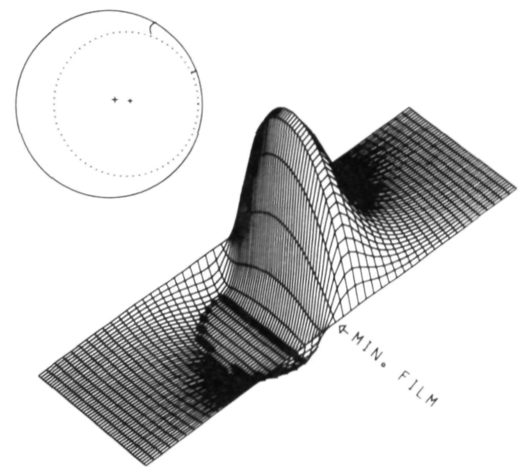
(c) Occurrence of peak load (t = 25.3 ms).



(f) Bubble collapse (t = 71.0 ms).



(e) Bubble expansion (t = 53.4 ms).



(d) Beginning of separation (t = 33.6 ms).

Figure 1. - Pressure distribution and bearing configuration for a full period of shaft whirl. Figures (a) to (f) viewed in clockwise order are consecutive in time.

1. Report No. NASA TM-87205 USAAVSCOM-TR-86-C-3	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle Study of Journal Bearing Dynamics Using Three-Dimensional Motion Picture Graphics	5. Report Date
	6. Performing Organization Code 505-63-81
7. Author(s) David E. Brewe and Donald J. Sosoka	8. Performing Organization Report No. E-2862
	10. Work Unit No.
9. Performing Organization Name and Address NASA Lewis Research Center and Propulsion Directorate, U.S. Army Aviation Research and Technology Activity - AVSCOM, Cleveland, Ohio 44135	11. Contract or Grant No.
	13. Type of Report and Period Covered Technical Memorandum
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546 and U.S. Army Aviation Systems Command, St. Louis, Mo. 63120	14. Sponsoring Agency Code

15. Supplementary Notes

David E. Brewe, Propulsion Directorate, U.S. Army Aviation Research and Technology Activity - AVSCOM; Donald J. Sosoka, Lewis Research Center. Prepared for the ASEE Engineering Design Graphics Division Midyear Meeting, West Lafayette, Indiana, November 24-26, 1985.

16. Abstract

Computer-generated motion pictures of three-dimensional graphics are being used to analyze journal bearings under dynamically loaded conditions. The motion-pictures simultaneously present the motion of the journal and the pressures predicted within the fluid film of the bearing as they evolve in time. The correct prediction of these fluid film pressures can be complicated by the development of cavitation within the fluid. The numerical model that is used predicts the formation of the cavitation bubble and its growth, downstream movement, and subsequent collapse. A complete physical picture is created in the motion picture as the journal traverses through the entire dynamic cycle.

17. Key Words (Suggested by Author(s)) Journal bearing; Dynamics; Graphics; Bearings; Motion pictures	18. Distribution Statement Unclassified - unlimited STAR Category 34

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages	22. Price*

*For sale by the National Technical Information Service, Springfield, Virginia 22161

National Aeronautics and
Space Administration

Lewis Research Center
Cleveland, Ohio 44135

NASA