PENNSTATE

1855

(814) 865-2569
Fax: (814) 865-7092

Department of Aerospace Engineering
College of Engineering

The Pennsylvania State University
233 Hammond Building
University Park, PA 16802-1401

DKM-9603

January 11, 1996

Defense Technical Information Center
Building 5, Cameron Station
Alexandria, VA 22304-6145

SUBJECT: ONR Grant No.: N00014-93-1-0374
"Basic Research on the Physics of Noise Production by Centrifugal Pumps," PI's D.K. McLaughlin and D.E. Thompson.

Greetings:

Attached please find two copies of the Yearly Summary of Research 1994-95 for the above noted ONR Research Grant. Should their be any question regarding this submission, please let me know.

Sincerely,

Dennis K McLaughlin

Dennis K. McLaughlin
Prof. and Head
Department of Aerospace Engineering

DKM/ahs
Attachments
c: D.E. Thompson
L.P. Purtell

Basic Research on the Physics of Noise Production by Centrifugal Pumps

Principal Investigators: D. K. McLaughlin and D. E. Thompson

Department of Aerospace Engineering
and the Applied Research Laboratory
Penn State University
University Park, PA 16802

YEARLY SUMMARY OF RESEARCH 1994-95

ONR GRANT NO: N00014-93-1-0374
R&T PROJECT NO: 4322902
Scientific Officer: Dr. L. P. Purtell

1. Research Goals

The goal of this research is to develop an understanding of the fundamental aspects of the production of noise in centrifugal turbomachinery. Previous investigations at Penn State have revealed two noise production mechanisms. Additional research was initiated to further enhance the understanding of the basic fluid dynamic properties associated with these noise production phenomena and to transfer these experimental results into reliable computational modeling capability.

To work toward achieving the goal to develop deeper understanding of the noise production processes, experiments were undertaken as follows:

Multi-sensor microphone measurements were performed in the discharge area of the centrifugal impeller. Some continued hot-wire and surface pressure measurements accompanied these acoustic measurements. The microphone measurements were conditioned using an advanced processing technique to extract the portion of the acoustic signals that is directly attributable to the large-scale instabilities identified and quantified in earlier work.

These measurements provide information that is needed to develop the understanding of the noise production mechanisms.

2. Accomplishments of Last Year

Experimental Program

As part of the experimental program, extensive multiple-sensor microphone measurements were made in the discharge area of the centrifugal impeller. The practice of component isolation was continued so that the impeller discharged to the open anechoic room (the volute exhaust was removed as in almost all previous measurements). Additionally, the microphones were positioned to the side of the direct flowfield to minimize windage effects. The microphone signals were processed using more sophisticated acquisition and processing techniques than any previous centrifugal turbomachinery aeroacoustic studies. Specifically, the acoustic measurements were ensemble averaged based on a condition of maximum pressure induced by the large scale instability on a pressure transducer mounted on one or two impeller blades. In doing so, a pressure pattern around the periphery of the impeller is established that is synchronized with the instability. Having established this synchronized pattern, phase relationships between these conditioned components of multiple microphone signals are used to characterize the noise at all of the dominant frequencies of the large scale flow field instabilities.

Computational Modeling

To further the understanding of the turbomachinery noise phenomenon, an analytic model was developed to predict the acoustic signals. This model uses trailing edge noise theory to predict acoustic time signals from measured surface pressure spectra on the impeller blades. The close correspondence between measured and predicted acoustic signals suggests that a basic understanding of the dominant noise sources is being developed (for broadband spectral components).

From this analysis two types of noise produced by the interaction of the blades with modes of the coherent large scale instability are elucidated. One type is a tone produced at the same frequency as an identified component of the large scale velocity field instability (as measured in the near wall region of the impeller, near the discharge tip). The modes responsible for these tones are primary modes with azimuthal mode orders equal to integer multiples of the number of blades. The other type is tones produced by non-primary modes present not at the instability frequencies, but at frequencies generated by an interaction between the flow field fluctuating components (at instability mode frequencies) and the shaft rate frequency. From this work, it is believed that significant progress has been made in the understanding of broadband spectral components of the noise generated by centrifugal impellers. The results of this work should lead to the development of techniques to reduce noise levels in this class of turbomachines.

3. Response to Navy Requirements

The phenomenon of the interaction of the large scale instability with the impeller trailing edges was previously unknown. The analytical tool developed can be used in centrifugal pump and fan design to minimize noise. Although not currently planned, transition of the technology to a 6.2 program to demonstrate the methods on typical centrifugal turbomachinery would be straightforward.

4. Future Research

At the present time continuing funding, past last October, 1995 has not been provided. ONR has, on the other hand, provided an augmentation grant through the AASERT program

(Grant No. N00014-95-1-0877). In this program two major activities will be undertaken: 1) Measure the input flowfield parameters more precisely that are the input to the newly developed acoustic model. This will allow a much more rigorous validation of the developed mode. 2) Adapt the water facility to examine the fundamental issue of scaling these turbomachinery aeroacoustic measurements between air and water measurements.

OFFICE OF NAVAL RESEARCH
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT
01 October 1994 through 30 September 1995

R & T Number:	4322902
Contract/Grant Title:	N00014-93-1-0374
Program Officer:	Purtell
Principal Investigators:	McLaughlin and Thompson
Mailing Address:	233 Hammond Bldg., University Park, PA 16802
Phone Number:	(814) 865-2569
FAX Number:	(814) 865-7092
E-Mail Address:	

a. Number of Papers Submitted to Referred Journal but not yet published: 2 in preparation

b. Number of Papers Published in Referred Journals (List Attached): 2

c. Number of Books or Chapters Submitted but not yet Published: 0

d. Number of Books or Chapters Published (List Attached): 0

e. Number of Printed Technical Reports & Non-Referred Papers (List Attached): 1

f. Number of Patents Filed: 0

g. Number of Patents Granted (List Attached): 0

h. Number of Invited Presentations at Workshops or Professional Society Meeting (List Attached): 0

i. Number of Presentations at Workshops or Professional Society Meetings (List Attached): 2

j. Providing the following information will assist with statistical purposes.

PI/CO-PI:	TOTAL	2	Grad Students:	TOTAL	2
	Female	0		Female	0
	Minority	0		Minority	0

Post Doc:	TOTAL	0
	Female	0
	Minority	0

TECHNOLOGY TRANSFER

The method of spectral decomposition developed and employed in the present research for separating a measured acoustic spectrum into an aeroacoustic source spectra and an acoustic transmission spectra has been modified and applied by ARL Penn State to measured propulsor unsteady force spectra. In this case, the measured spectrum is separated into a hydrodynamic source spectrum and a structural response (vibration) spectrum. The new method has been applied successfully to an ARPA/ONR sponsored test program conducted at the LCC jointly by ARL Penn State and CDNSWC personnel and most recently in the NSSN program.

Additionally the method described above has also been adopted by the following organizations: 1) United Technologies Research Center (R.H. Schlinker), 2) AT&T Bell Labs, computer cooling fan quieting, (P.H. Bent), and 3) Purdue University Herrick Laboratories (L. Mongeau), 4) Ingersoll-Rand, pump quieting work, 5) Allison Engine Company, turbine engine quieting (P. Tramm), 6) CDNSWC - ANN, pump quieting.

LIST OF PUBLICATIONS/REPORTS/PATENTS/GRADUATES

1. Papers Published in Referred Journals:

   Mongeau, L., D. E. Thompson, and D. K. McLaughlin, **"Method For Characterizing Aerodynamic Sound Sources in Turbomachines,"** *Journal of Sound and Vibration, Vol. 181, No. 3, 1995.*

   Dorney, D. J., Davis, R. L. and McLaughlin, D. K., **"Numerical Simulations of Flows in Centrifugal Turbomachinery."** *AIAA Journal of Propulsion and Power,* Vol. 11, No. 5, 1995.

2. Books (and sections thereof) Published:

   None

3. Technical Report, Non-Refereed Papers:

   Tetu, L.G., D.E. Thompson, and D.K. McLaughlin, **"Noise Produced By Large Scale Instability Modes in Centrifugal Turbomachinery,"** in Proceedings of the ASME '95 International Mechanical Engineering Congress and Exposition (IMECE), Symposium on Turbomachinery Noise, San Francisco, CA, November 12-15, 1995.

4. Presentations:

   Tetu, L.G., D.E. Thompson, and D.K. McLaughlin, **"Noise Produced By Large Scale Instability Modes in Centrifugal Turbomachinery,"** Presented at the ASME '95 International Mechanical Engineering Congress and Exposition (IMECE), Symposium on Turbomachinery Noise, San Francisco, CA, November 12-15, 1995.

   Tetu, L.G., D.K. McLaughlin, and D.E. Thompson, **"Experiments on the Noise Production of Centrifugal Turbomachinery,"** Presented at the Office of Naval Research Turbulence Review, Washington, DC, October 23-25, 1995.

5. Patents Granted:

   None

6. Degrees Granted (name, date, degree):

   No degrees granted this past year.

OTHER SPONSORED RESEARCH

(Include title, sponsors's name, dollar amount and start and end dates for the award)

"Rotor/Casing Interaction," D. E. Thompson, ONR, FY 92 - $90K, FY 93 - $250K., FY 94 - $80K.

"Rotor Unsteady Response," D. E. Thompson, ONR, FY 93 - $315K, FY 95 - $250K.

"The Aeroacoustics of Supersonic Jets," D. K. McLaughlin and P. J. Morris, NASA Langley, $186,505, April 1, 1992 - March 31, 1995.

"Mixing Enhancement in Supersonic Shear Layers," D. K. McLaughlin, L. N. Long and P. J. Morris, NASA Lewis Research Center, $99,992, April 28, 1993 - April 30, 1995.

FUNDING BALANCE

All funds have been expended.

Date: 8/20/95 Time: 7:03:03PM

Page: 1 Document Name: untitled

```
--      1   OF      1
-- 1 -  AD NUMBER: A298944
-- 2 -  FIELDS AND GROUPS: 20/1, 20/4, 13/7, 13/11
-- 5 -  CORPORATE AUTHOR: PENNSYLVANIA STATE UNIV  UNIVERSITY PARK APPLIED
--      RESEARCH LAB
-- 6 -  UNCLASSIFIED TITLE:    BASIC RESEARCH ON THE PHYSICS OF NOISE
--      PRODUCTION BY CENTRIFUGAL PUMPS.
-- 9 -  DESCRIPTIVE NOTE: SUMMARY OF RESEARCH 1993-1994,
--10 -  PERSONAL AUTHORS: MCLAUGHLIN, D. K.; THOMPSON, D. E.
--11 -  REPORT DATE:      AUG   , 1994
--12 -  PAGINATION:      10P   MEDIA COST:  $  6.00
--15 -  CONTRACT NUMBER:  N00014-93-1-0374
--18 -  MONITOR ACRONYM:  XB
--19 -  MONITOR SERIES:   ONR
--20 -  REPORT CLASSIFICATION:  UNCLASSIFIED
--33 -  LIMITATION CODES:  1
```