CORRELATION OF LUNG CRACKLES WITH SURFACE DEFORMATION USING HOLOGRAPHIC INTERFEROMETRY

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INTRODUCTION

The primary function of the lung, i.e. gas exchange, occurs in peripheral units termed alveoli. Diagnosis of lung dysfunction is therefore dependent on techniques to evaluate the status of the peripheral airways. Since these airways and alveoli are very small, it is difficult to determine directly how they function or how the function is changing due to disease. Yet this understanding is critical to the design of instrumentation to detect early changes in lung function due to disease.

An interesting hypothesis describing one aspect of small airway function has been proposed by Frazer (1) as gas trapping due to the formation of menisci in the airways. An additional study (2) proposes that the breaking and possibly the formation of these menisci could generate lung sounds, i.e. crackles. These lung sounds were recorded by placing a microphone at the trachea of an excised rat lung. The lung was degassed and then inflated and deflated. At points along the path of inflation, lung sounds were recorded . However, determination of the origin of the sounds was not attempted due to the difficulties induced by contacting the lung surface with a microphone.

The purpose of this paper is to describe a non-contacting, whole field technique to monitor and describe the movements of the lung surface during inflation - deflation cycles.

HOLOGRAPHIC INTERFEROMETRY

Holographic interferometry is a full field, non-contacting and non-destructive technique that measures deformations of an object with a sensitivity in the order of the wavelength of light. A laser beam is split, with one beam reflected from an object and the other used as a reference beam. Both beams combine to produce a hologram of the object on a photographic plate. The process utilizes the concepts of interference, i.e. the two wave amplitudes will add at the points where the difference in optical path lengths over the exposure period is zero or a whole number of wavelengths and will subtract at other points.

To detect the deformation of an object over an interval of time, an initial hologram of the object is recorded in its undeformed state. After the object is deformed, a second hologram is recorded and allowed to interfere with the first hologram. The interference fringes produced are indicative of the deformation experienced by the object.

EXPERIMENTAL METHOD

The intact lungs and heart were excised from Long Evans male rats weighing about 300 gm. The lungs were degassed twice by exposure to a vacuum of 28 in of Hg. A stainless steel 20 gauge needle was inserted into the trachea and mounted in the holographic exposure unit. As the lung was inflated and deflated, volume was maintained by a Harvard Model 901 Infusion / Withdrawal pump modified to produce a 0 to 5 volt signal proportional to volume. A Setra Model 239E monitored pressure. Values of pressure and volume were acquired by a Keithley Series 500 data acquisition system interfaced to an IBM PC.

Holograms were produced with a 0.5 watt Argon laser and recorded on Agfa-Gevaert 10E56 holographic plates. These plates were chosen because of their high sensitivity in the 514.5 nm wavelength region of the Argon laser.

These techniques have been described in more detail by Pathak and Stanley (3)

RESULTS

Double exposure holograms were recorded at four points in the inflation-deflation cycle. Two holograms during the inflation phase indicated considerable surface activity and correlated well with the lungs sounds as shown in (2). Holograms taken during the deflation phase were distinctly different indicating a less chaotic state.

Work is continuing to determine if the resulting fringe patterns can be associated with regions of gross deformation of the lung or if the patterns are the result of sound waves propagating through the lung parenchyma.

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PREFACE

The 1989 Advances in Bioengineering contains papers sponsored by the Bioengineering Division of the American Society of Mechanical Engineers which are being presented at the 1989 Winter Annual Meeting in San Francisco. This years Winter Annual Meeting feature is "Mechanical Engineering in Biomedical and Bioprocess Technology." There are a total of thirty-one sessions sponsored by the Bioengineering Division. Two panels, one on microsensors and the other on bioengineering and bioprocessing research in space, have been organized. Several of the sessions are sponsored jointly by the Heat Transfer Division, the Design Division, the Applied Mechanics Division, the Non-Destructive Evaluation Program, the Acoustics Division, and the Bioprocessing Program. Unlike previous years, the majority of papers are contributed papers.

A four session symposium on "Crash Worthiness and Occupant Protection" is printed in a separate volume. The symposium on Hyperthermia and Emerging Horizons in Bioheat Heat Transfer is also published in a separate volume. Papers which are part of jointly sponsored sessions with the Non-Destructive Evaluation Program and the Bioprocessing Program are printed in separate bound volumes as part of other symposia.

The Advances in Bioengineering contains papers from a seven session symposium on "Advances in Medical Devices and Instrumentation," and covers diverse topics such as biofluid devices and instrumentation, devices used in heat transfer, application of CAD-CAM in design of medical devices in medicine and sports, and microsensors. Eleven sessions deal with applied mechanics. The applied mechanics topics include a joint mechanics symposium, sessions on the spine and on interface biomechanics. The fluid mechanics sessions deal with physiological fluid mechanics through valves and ventricles and with rheology and fluid flow. Papers from the sessions on bioengineering in space, rehabilitation engineering and on the use of ultrasound in medicine are also included. This year we have established a student paper competition. The finalists from that competition are listed in this volume. An award for the best student paper will be presented at the Bioengineering Awards Dinner.

The Bioengineering Division Honors Committee has chosen Professor Robert M. Nerem as the recipient of 1989 Herbert R. Lissner Biomedical Engineering Award. A tribute to Professor Nerem appears in the front of this issue. The award, which honors outstanding contributions to the field of Bioengineering, will be presented at the Bioengineering Awards Dinner.

Boris Rubinsky

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I would like to express my sincere appreciation to Gerald Miller, the 1988 Bioengineering Program Chairman and Albert King, the 1989 Bioengineering Division Chairman for their guidance and assistance in program development. The help from Robert Spilker who handled the review of all the papers in Applied Mechanics is gratefully acknowledged. Scott Hubbard has put a tremendous effort in developing excellent sessions on the research in bioengineering in NASA. Kent Udell has developed the panel on microsensors. Tom Khalil developed the Symposium on Crashworthiness and Occupant Protection. K. K. Shung developed the Symposium on Ultrasound Applications in Medicine. I would like to acknowledge Gerald Miller, Malcolm Pope, Art Erdman and Diane Rekow, John McGrath and Tom Diller, Ray Vanderby Jr., Mohamed Hefzy and Avinash Patwardhan, Jack Lewis and Edward Grood for their review of the papers submitted for the sessions on fluid mechanics, rehabilitation engineering, instrumentation and design, heat transfer, joint mechanics, interface mechanics and the student paper competition respectively.

The assistance of the ASME staff, in particular the outstanding work of Julie Trunzo Lee, was integral to the development of this program. I would also like to acknowledge the support of the Mechanical Engineering Department at the University of California at Berkeley for making resources available to develop this program. In particular, I would like to express by appreciation to Mary Anne Peters for her tremendous help and responsible work during the most critical stage of this project, the assembly of the text.

Boris Rubinsky