

# Design of A Novel Instrumentation for Measurement of Blood Flow While Gripping a Handle

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**Abstract-** The purpose of this study was to design a prehensile device which could be coupled with a Laser Doppler Flowmetry (LDF) system to simultaneously measure components of grip force, push force and blood flow on the inside of the hand surface. This device will enable physicians, researchers, and designers of hand-held equipment to study blood circulation in the hand under different grip forces, and hand-push loading conditions.

## I- INTRODUCTION

A Secondary Raynaud-like disease sometimes referred to as "white finger" affects blood flow in the fingers and the inside surface of the hand. This disease is often a direct result of using vibrating hand tools [1]. Blood flow on the open hand surface can be measured with conventional Laser Doppler Flow (LDF) techniques. The Laser Doppler technique is a well-established noninvasive method of monitoring micro vascular blood flow. This method has been used in a variety of research and clinical studies [2]. It has been difficult, however, to measure blood flow on the inside surface of the hand, fingers, and fingertips while gripping an object such as a tool handle. The purpose of this study was to design a prehensile device which could be coupled with an LDF system to simultaneously measure components of grip force, push force, and blood flow on the inside hand surface. The system is capable of measuring blood flow at either specific anatomical locations or over the entire inside surface of the hand, including fingers and finger tips. Measurement of blood flow can be made while a wide range of grip forces are applied to the handle. This device may be used in ergonomic studies in designing better handles and gripping devices in order to reduce hand disease and increase worker productivity and comfort.

## II- METHOD AND MATERIALS

A commercial Laser Doppler Flowmetry system (Moor LDI) is utilized as the laser source (2 to 3 mW

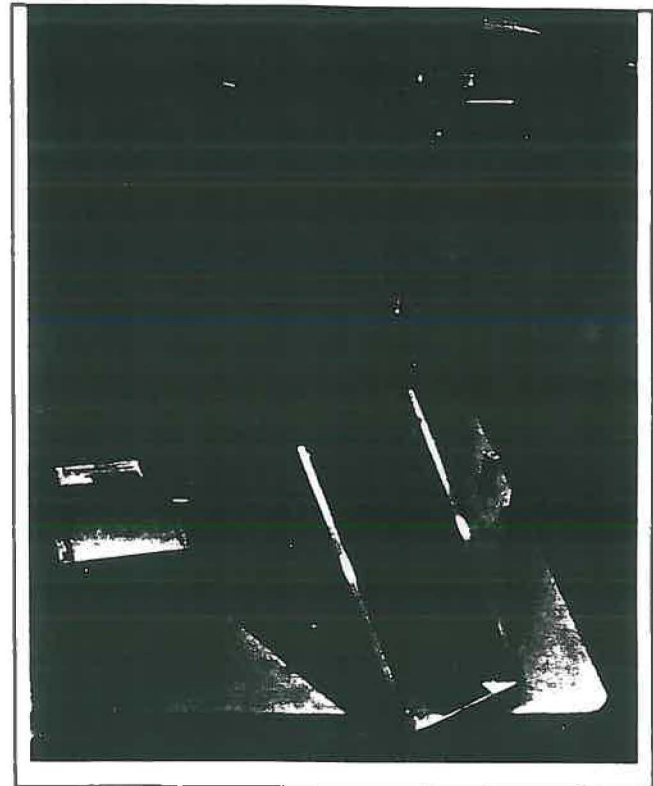


Fig1- Presentation of the hand-gripper blood flow attachment device

helium-neon) for this instrument. The laser beam is transmitted to the center of the optical input port from the top of the device, which is aligned with the Z-axis of the cylindrical housing (Fig 1). This housing is covered with two pieces of transparent semi-cylindrical lexan, which transmits the forces exerted during the grip. One of the pieces is stationary and the other through a base with four stainless steel rods that slide freely inside eight frictionless bearings is attached to a load cell (S shaped with a maximum capacity of 450 Newtons ) The design is such that the finger force is conveyed by the stationary piece while the movable piece conveys the force exerted by the palm of the hand. A cylindrical handle, 46 mm in diameter, was chosen based on

the recommendation of previously related studies [6]. A mirror was positioned at angle of 45° within the handle housing to reflect the incoming laser beam through the cylindrical lexan wall surface. When the handle is grasped, the laser beam passes through the inside wall surface and is directed toward the inside surface of the hand. Some losses of the laser beam are associated with the index of refraction and cleanliness of the lexan wall surface. During operation the laser beam is randomly scattered from the handle structure, hand tissue, and moving blood cells within the tissue. Light refracted from static tissues remains unchanged in frequency, while light scattered by moving blood cells undergoes a frequency shift according to the Doppler principle [3,4]. The collected scattered light from the tissue surface hits the 45-degree-mirror and reaches the photodetector where it is analyzed. Two stepper motors control the 45-degree mirror. One rotates the mirror 360 degrees and the other moves the mirror along the z-axis. The stepper motor movements are operated via computer and enable the laser beam to freely scan at any desired point of the gripped hand's palm and fingers. Laser Doppler flowmeters are not able to measure flow in absolute units (mm<sup>3</sup>/sec). Arbitrary units are used for flux, which is the product of the concentration of moving red blood cells and the mean velocity of the red blood cells. This technique gives a continuous measure of erythrocyte motion in the outermost layer of the tissue under study. In this experiment the signal collected from the photodetector is processed through a 15kHz bandwidth filter. The results are sent to a computer for digital processing and data collection. The blood flow reading is the result of digital analysis of this signal.

The Laser Doppler flowmeter system is calibrated before each study against a standard reference (Brownian motion of polystyrene micro spheres in water). Calibration is performed using a modified version of the Moor model [5].

### III-RESULTS

A representative example of handgrip testing at various grip forces has performed on several subjects is depicted in Fig 2. These results show that blood flow decreases with increasing grip force. When the grip force reaches a certain value the blood flow stops. This value differs between subjects.

### VI- ACKNOWLEDGMENT

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### V-References

- [1] Ulf Mattson, Anne-Lene Krogstad, Gron Pegniouis, Mikael Elam and Mat Jontell "Assessment of erythematic and skin perfusion by digital image analysis and scanner laser Doppler", *Skin Research and Technology*, 1997; b3: 53-59.
- [2] Markus Farkkila, Ilmari Pyykko, "Blood flow in contralateral hand during vibration and hand grip contractions of lumberjacks", *Scand. J. Work Environ Health*, 5 (1979) 368-374.
- [3] Seyed Mohammad Mirbod, Hideyo Yoshida, Marjan Jamali, Kazuhisa Miyashita, Haruko Takada, Roich inaba and Hirotooshi Iwata, "Finger skin temperature and laser-doppler finger blood flow in subjects exposed to hand-arm vibration", *Industrial Health*, 1998, 36. 171-178.
- [4] A. M. Seifalian, G. Stansby, A. Jackson, K. Howell and G. Hamilton, "Comparison of laser Doppler perfusion imaging, laser Doppler flowmetry, and thermographic imaging for assessment of Blood flow in human skin." *Eur J. Vasc Surg* 8, 65-69 (1994).
- [5] N.J. Barnett, G. Dougherry and S.J. Pettinger, "Comparative study of two laser Doppler blood flowmeters", *Journal of Medical Engineering & Technology*, Volume 14, Number 6 (November/December 1990), pages 243-249.
- [6] W. Karwowski, W.S Marras "Occupational Ergonomics Handbook", CRC Press 1998, page 469.

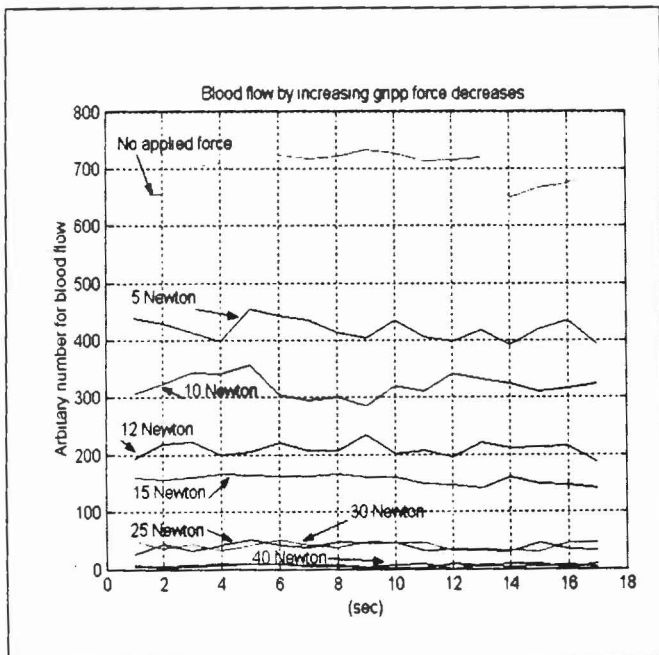


Fig 2 – Effect of grip force on blood flow.

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