

# Strain Measurements on a Prosthetic Socket to Improve Ventilated Socket Design

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## Abstract

Artificial limb prostheses are devices that facilitate patients in performing everyday functions. The existing problem within the socket is the excessive rise in temperature and humidity. A solution is the design of a ventilated socket that contains mesh to allow air to circulate within the socket. However, an issue with this modified socket may be the compromised strength of the prosthetic socket, which could lead to mechanical failure.

The project conducted was to examine strain levels on the socket. It was determined after compression testing that the highest regions of strains were the lateral proximal and the medial distal regions of the socket. In the future, these measurements can be used to perform a stress analysis to assist clinicians in designing ventilated sockets avoiding mechanical failures.

## Background

### Transfemoral Amputation

- ❖ The residual limb is amputated above the knee.
- ❖ Problems associated with transfemoral amputation are the loss of body surface area and reflex sweating.

### Complications

- ❖ The existing problem is an excessive increase in temperature within the socket. This causes skin irritation on the residual limb, which leads to bacterial and fungal infections. This results in down time where the patient has to remove the socket to heal (Fig. 1) [1].



Fig. 1: Infection of hair follicles on the residual limb [1].

### Ventilated Socket

- ❖ The ventilated socket has a cutout with a nylon mesh to prevent window edema. This design allows air to circulate within the socket (Fig. 2).



Fig. 2: Socket with cutout (no mesh).

- ❖ To investigate the mechanical integrity of the socket, an artificial residual limb was produced to be used in compression testing where strains on the socket surface were measured.

## Methods

### Potting the Femur

- ❖ This femur was potted for easy attachment to the tensile tester.
- ❖ The femur was potted by lining an aluminum box with clay, filling the box with a mixture of automotive epoxy and resin, and placing the head of the femur into the box at 12° of anteversion (Fig. 3).

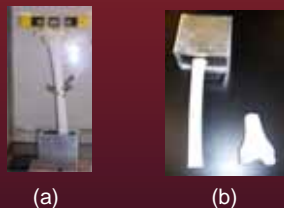


Fig. 3: (a) Set up of hardening stage and (b) the final product.

### Production of Mock Residual Limb

- ❖ Mixed 10:1 ratio of fast curing silicone and catalyst and poured the mixture into a transparent socket acting as a mold (Fig. 4).



Fig. 4: (a) Set up and (b) finished product of the mock residual limb.

### Compression Testing

- ❖ Eight rosette strain gages were adhered to the outer socket using a standard procedure from Vishay (Fig. 5 a,b).

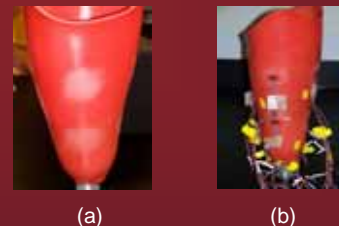


Fig. 5: View of (a) the prepared surface and (b) the adhered strain gages on the socket

- ❖ The pre-attached strain gage wires were connected to the signal conditioning systems, which were switch and balance units and a P3 strain indicator.
- ❖ Strain gages were connected to an internal quarter bridge circuit

- ❖ Compressive load of 100 lb applied using the tensile tester once the socket and the mock residual limb were attached (Fig. 6).
- ❖ Principal strains and maximum shear strains were calculated using Mohr's circle.



Fig. 6: Tensile tester with the mock residual limb along with the prosthetic socket attached.

## Results

### Strain Analysis ( $\mu\epsilon$ )

Region	$\epsilon_{max}$	$\epsilon_{min}$	$\gamma_{max}$
Anterior proximal	195	-22	217
Anterior distal	196	-47	243
Lateral proximal	961	-361	1322
Lateral distal	117	21	97
Posterior proximal	195	-89	284
Posterior distal	525	-1135	1660
Medial proximal	33	-226	259
Medial distal	-22	-208	186

- ❖ Highest strain occurs in the lateral proximal and posterior distal regions

## Future Work

- ❖ Establish repeatability of the strain measurements
- ❖ Investigate alternate procedures for the manufacture of the mock residual limb
- ❖ Determine material properties required for stress analysis of the socket

## Reference

[1] S. William Levy, *Skin Problems of the Amputee*, St. Louis: Warren H. Green, 1983.

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