

# Design and Development of Customized Insole using 3d Printer

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**ABSTRACT:** Designs with adjustable gradient modules have become necessary for applications with special demands such as diabetic insole in which the contact stress between the foot and insole is a critical factor for the ulcer development. However, since the adjustment of elastic modulus on certain regions of the insole is hardly achieved through material selection, a porous structural unit with varying porosity becomes a feasible way.

Therefore, a porous structural unit associated with adjustable effective modulus and porosity can be employed to construct such insoles by 3D printing manufacturing technology. This study provides a generalized foundation of porous structural design and adjustable gradient in application of diabetic and customized insole, which can be equally applied to their designs with similar demands.

This study results in an insole which can reduce pressure in the plantar region by applying a support in the arch region on the foot. This study provides a methodology to produce a customized insole using a 3D printer.

## I. INTRODUCTION

The foot is the most inferior part of the human body. The foot makes human capable of walking, and also perform countless other activities.

The foot's complex structure involves more than 100 tendons, ligaments and muscles. They move nearly three dozen joints while bones provide solid base structure. According to the structure of the foot is analogous to that of the hand, but because the foot carries more weight, it is stronger and less active. By wearing ill-fitting shoes that are not biomechanically friendly, there might be a large possibility for the onset of foot problems.

In order to avoid these cases, a customized insole is designed to reduce the abnormal

pressures, off-load the pressures equally in the plantar region and to prevent the formation of the plantar ulcers. Most of these ulcers are developed due to the loss of sensation leading to peripheral neuropathy.

According to a case study, the third leading cause of death is diabetes which is next to heart disease and cancer, approximately 15% of patients with diabetes will develop foot ulceration during the life time. Lower extremity amputations are mostly preceded by a foot ulcer.

The abnormal pressures acting in the foot affects the nerves in the foot which results in foot ulcer, loss of sensation in foot. To avoid such cases, these customized insoles are used. These insoles are made individually for a patient's own specific dimensions and needs, instead of following standard dimensions.

## 3D printer

A 3D printer is a computer aided manufacturing device that creates three-dimensional objects. Like a traditional printer, a 3D printer receives digital data from a computer as input. However, instead of printing the output on paper, a 3D printer builds a three dimensional model out of a custom material.

3D printers use a process called additive manufacturing to form physical objects layer by layer until the model is complete. This is different than subtractive manufacturing, in which a machine reshapes or removes material from an existing mold. Since 3D printers create models from scratch, they are more efficient and produce less waste than subtractive manufacturing devices. The process of printing a 3D model varies depending on the material used to create the object. For example, when building a plastic model, a 3D printer may heat and fuse the layers of plastic together using a process called fused deposition modeling. When creating a metallic object, a 3D printer may use a

process called direct metal laser sintering. This method forms thin layers of metal from metallic powder using a high powered laser. While 3D printing has been possible since the 1980s, it has been primarily used for large scale industrial purposes. However, in recent years, 3D printers have become much cheaper and are now available to the consumer market. As the technology becomes more widespread, 3D printers may become a viable means for people to create their own home products and replacement parts.

### Plantar pressure data collection

Feet provide the primary surface of interaction with the environment during locomotion. Thus, it is important to diagnose foot problems at an early stage for injury prevention, risk management and general wellbeing. One approach to measuring foot health, widely used in various applications, is examining foot plantar pressure characteristics.

Thus an accurate and reliable foot plantar pressure measuring device is used, as shown in fig 1.1.



Fig 1.1 Plantar pressure measuring device

### Ch 2 .....

The beginning of 3D printing is related to studies of photography, sculpting, and Landscape design, which took place in America. Much of the technology was not being developed until the mid-1980s. During this period, 3D printing was known as “RAPIDPROTOTYPING”. Chuck Hull, of 3D Systems Corporation, manufactured the first usable 3D printer. Later in the 80’s, selective laser sintering technology was synthesized by Dr. Deckard at the university of texas during the commencement of project being done by defense advanced research projects agency. In the 1990s, the technology was further improvised with the advancement of a method that uses UV light to solidify photopolymer, a highly viscous liquid material. In the 20th century, 3D printers were very expensive and were used to print a few numbers of products. Most of the printers were owned by

scientists and electronics groupies for research and display. However advancements in the area of 3D printing have allowed for the design of products to no longer be limited by complex shapes or colors.

## II. THERMO PLASTIC POLYURETHANE

Thermoplastic polyurethane (TPU) is an elastomer that is fully thermoplastic. Like all thermoplastic elastomers, TPU is elastic and melt-processable. Further, it can be processed on extrusion as well as injection, blow and compression molding equipment.

It is a common material used for manufacturing slippers, shoes and insoles, as shown in fig 2.1.



Fig 2.1 Thermo plastic polyurethane

### Porous structure

A porous medium or a porous material is a material containing pores (voids). The pores are typically filled with a fluid (liquid or gas). The skeletal material is usually a solid, but structures like foams are often also usefully analyzed using concept of porous media. As shown in fig 2.2

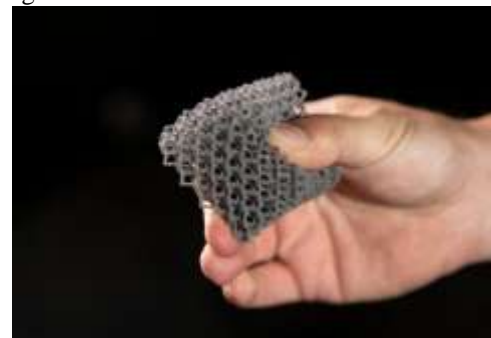


Fig 2.2 picture of porous structure

### Pressure data analysis

The technique used to measure the pressure in foot is called pedobarography. It is the

study of pressure fields acting between the plantar surface of the foot and a supporting surface. Used most often for biomechanical analysis of gait and posture, pedobarography is employed in a wide range of applications including sports biomechanics and gait biometrics. As shown in fig 2.3.



**Fig 2.3 Pedobarography method**

**Ch 3** .....  
 The aim of this chapter is to describe various materials used and methodology used to make different parts. The conceptualization, designing, pressure data analysis are dealt in this chapter. The characteristics of various components and their specifications along with their dimensions were taken into account.

**Methodology flowchart**

- Conceptual development of model
- Collection of materials
- Fabrication
- Testing and evaluation

**Conceptual design**

The conceptual design of both customized insoles was done with the SOLIDWORKS 3D modelling software. The conceptual design provides an idea of proposed design. The conceptual design is shown in the figures 3.1 & 3.2.



**Fig. 3.1 Conceptual design of left insole**



**Fig 3.2 Conceptual design of right insole**

**Components**

The components of the customized insole are listed below,

- i. 3D printer
- ii. Thermo plastic polyurethane

**III. 3D PRINTER**

The 3D printer is used to print the designed insole using the filament material. Some of the specification of 3D printer is listed below, as shown in table 3.1.

<b>Printed technology</b>	Fused filament fabrication
<b>Built volume</b>	11.2Lx6.0Wx6.1H in[28.5x15.3x15.5cm]
<b>Positioning precision</b>	XY: 11 microns [0.0004in]: Z: 2.5 microns [0.0118in]
<b>Filament diameter</b>	1.75 mm [0.069in]
<b>Nozzle diameter</b>	0.4mm [0.015in]

**Table 3.1 3D printer specifications**

**Pressure data analysis for test subject**

It is a type of data analysis which is used to determine the pressure acting in the foot while walking. This pressure data analysis requires a plantar pressure scanner.

The pressures from the pressure data test varies from 1 to 30. i.e, 1 being the minimum pressure till 30 and above 30 being the maximum pressure. The pressure data analysis for the given insole is shown in the figs, 3.3, 3.4 and 3.5.

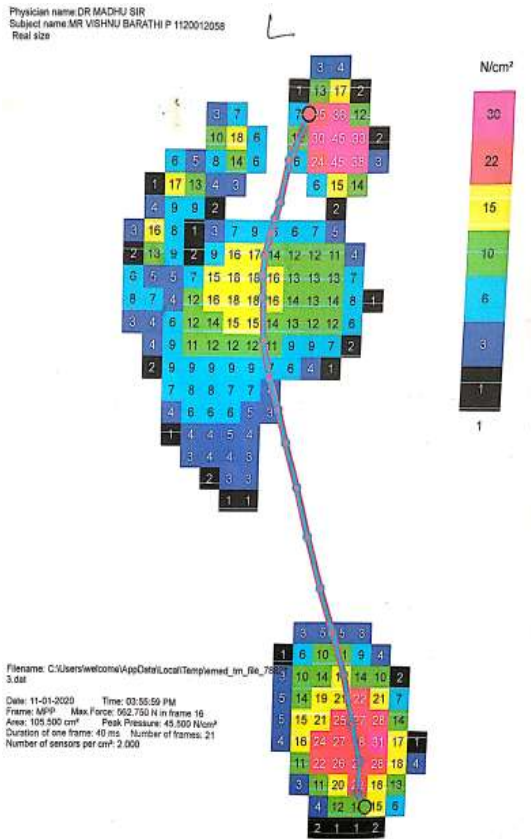


Fig 3.3 Pressure data analysis

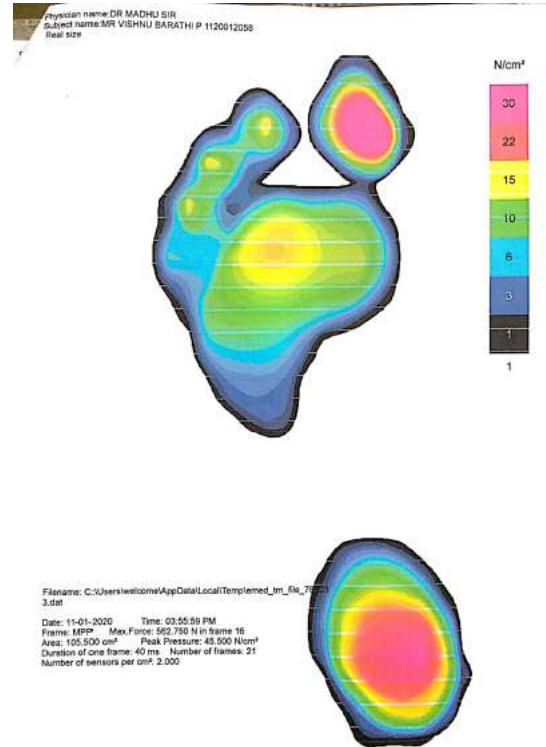


Fig 3.5 Pressure data analysis



Fig 3.4 Pressure data analysis

#### IV. POROUS STRUCTURE

Initially porous structure is designed for the insole so as to reduce the abnormal pressure that is acting in different parts of the foot. The porous structure is made in hexagonal units and is made in such a way that the thickness varies for each pressure points.

#### Ch 4 .....

In this chapter the various working, operational parameters, cost estimation, optimum settings and are all discussed and studied for further improvements.

#### Fabricated prototype

The fabricated prototype is given in figure 4.1. The design of the customized insole was done using Solid works modelling software and fabricated using 3D printer. The TPU material available in the market was purchased based on the requirement.



**Fig.4.1 Customized insole**

**Procedure**

A 3D model of customized insole is created using Solidworks software under the requirements of our test subject's feet measurements and pressure data analysis result.

The step by step procedure is explained below.

**3D-Modeling:** 3D-Printing begins with creating the 3D model with CAD software. The model will be designed with 3D modeling software SolidWorks and saved in a standard file format (.STL).

**Thermo plastic polyurethane:** TPU is the base material which is used to fabricate the insole, which requires certain temperature condition while 3D printing i.e., platform temperature as 70 celsius and extruder temperature as 220 celsius

**Part modeling:** A part was modelled using SolidWorks for the dimensions. Then the model in .STL format was sliced in to layer and the numerical tool paths were generated using slicer software.

**Control software and interface**

The control software and interfaces used to interact with the 3D printer must smoothly control all parameters like nozzle point, bed, extrusion, 3 axis movements, etc...The interface should be as simple and user-friendly as possible. We have many open source software for the purpose. But we used makerbot replicator 2x as our 3D printer. Therefore, we used makerbot software for fabricating.

**Makerbot software**

Makerbot software has a graphical and control interface that ensures compatibility. For proper handling, it was necessary to establish the parameters to manipulate the prototype, where the most important are: speed, position of rest, arm

length, print area, and maximum print height. Therefore, this software is simple, user friendly and feature rich for experimenting with the 3D printer.

The 3D design that needs to be fabricated is saved as a STL file and transferred to makerbot software after which certain platform and extruder speed adjustments are made, finally temperature is fixed according to the melting point of TPU. As shown in fig 4.2.



**Fig.4.2 Makerbot software**

**V. DISCUSSION ON VARIOUS FACTORS**

**Test subject**

Our test subject is basically a highfoot person, so the prototype is made for the requirements of high foot persons but with specific measurements and pressure effects of our test subject.

**Arch**

The extra arch region that is fabricated in the insole is made in such a way that it reduces planter pressure in the fore foot and hind foot region, which specifically does not cause any side effect.

**Porous structure units**

The porous structure pattern is fabricated in between the upper and lower layer of the insole, which is made in fore foot and hind foot region where the test subject has high planter pressure.

**Ch 5 .....**

The abnormal pressures acting in the foot affects the nerves in the foot which results in foot ulcer, loss of sensation in foot. To avoid such cases, these customized insoles are used. These insoles are made individually for a patient's own specific dimensions and needs, instead of following standard dimensions.

**VI. SUMMARY**

The customized insole for foot is apparently a simple way to adjust the abnormal

pressure in the foot. Although there are many possible ways than an insole for plantar pressure in foot, but it may still prove as a possible solution and eventually be cheaper in the near future.

**Learning from the project**

- Studied about biological aspects such as human foot, diabetes and machines that are used for measuring the pressure in foot.
- Designing a human foot in solidworks.
- Studied about the working of 3D printer.
- Knowledge about the softwares that are involved in using a 3D printer.
- Dealing with associates –Communication.
- Discipline, Punctuality, Dedication, Commitment and Time management.

This project work has provided us an excellent opportunity and experience, to use our limited knowledge. We gained a lot of practical knowledge regarding, planning, designing and 3D printing while doing this project work.

We are proud that we have completed the work with the limited time successfully. We have done to our ability and skill making maximum use of available facilities.

**Cost estimation**

S.No	Component/Work	Quantity	Cost
1	Material- Thermoplastic polyurethane(800g)	1	4000
2	Pressure data analysis	1	500
3	Kypton tape	1	650
4	3D printer cost for insole	2	6000
	Total		11,150

**Table 4.1 Cost estimation**

**VII. RESULT**

After various analysis like pressure analysis tests for bare foot and many tests that are obtained from trial and error method on printed insoles. A proper insole is designed for specific dimensional conditions and it evidently reduced the pressure in the foot. Hence a perfectly recorded trail involves,

- No abnormal peak pressures.
- No abnormality in pressure regions and contact area.
- Reduced using the designed customized insole Consistency in the peak pressure’s values.
- Considerations made on both the foot.

From this analysis possible peak pressure in the foot and corresponding regions such as size and shape of the foot for insole dimensioning can be.

**VIII. CONCLUSION**

The results from the pressure analysis test for bare foot and various other test insoles showed an improvement in decreased pressure in the foot region compared to bare foot. From this analysis possible peak pressure in the foot and corresponding regions such as size and shape of the foot for insole dimensioning can be reduced using the designed customized insole.

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