Research Article

Usage of Additive Manufacturing Techniques in Producing Orthotic Insole

Ankit Gandhi[1], R. Vaishya[2], Anurag Gupta[3]

Abstract

Usage of 3 D printed objects has gained a huge interest in recent years. This has led to a variety of 3 D printed ready to use products in today's market. In this review paper, the usage and testing of 3 D printed orthotic insoles has been discussed in detail.

Thermoplastic Elastomers (TPE) and Thermoplastic polyurethane (TPU) are the most commonly used materials that are being used in customized printed orthotic insoles. Many 3D printers use these materials for the printing of customized orthotic insoles that are comfortable and assists the user in many foot disorders. After the product is produced it undergoes a series of testing for its mechanical and physical properties.

A total of 13 research papers were identified and 7 were selected based on the abstract and the title. Based on the assessment of the total articles, 4 papers fulfilled predetermined qualitative criteria and were selected for a detailed review. Effects of many parameters have been studied that affected the properties of orthotic insoles but the main affecting factor was the infill density. Although there are many more parameters which could be studied and more better results can be provided.

Introduction

The Thermoplastic Polyurethanes commonly known as TPU comprises of a two phase microstructure which consists of a hard and segment which are forming a two phase microstructure. The hard phase provides the base for its mechanical properties. It provides advantage in chemical resistance, abrasion, and blood and tissue compatibility. Thus, making it a very essential group of polyurethane group.

The Thermoplastic elastomers on the other hand are frequently used in harsh environmental conditions i.e. under high temperatures deviations and cyclic loading conditions.TPE is a new class of materials which can be studied more. So less information is available on this material.

In the recent years the sales of footwear in the market have rocketed, people choose the right footwear based on comfort , looks and quality. However, compatibility is not so well known for all types of interaction between people and equipment. Even though technology enhancements are thought to improve functioning of footwear, some of them are simply ornaments to enhance form rather than functional elements that protect people's feet. The interface

[1]Department of Production & Industrial Engineering, PEC University of technology, Chandigarh-160012, India, 296 Aggarsen Nagar Sri Ganganagar, Rajasthan- 335001.

[2]Assistant professor, Department of Production & Industrial Engineering, PEC University of technology, Chandigarh, 160012, India, #154, PEC University of technology, Chandigarh-160012, India.

[3]Department of Mechanical Engineering, KIET, Ghaziabad, U.P India.

Correspondence: Ankit Gandhi, Department of Production & Industrial Engineering, PEC University of technology, Chandigarh-160012, India, 296 Aggarsen Nagar Sri Ganganagar, Rajasthan- 335001.

E-mail Id: ankit.gandhi36@gmail.com

Orcid Id: http://orcid.org/0000-0002-8023-6253

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between the human and product has become an important parameter for the design of any product and if neglected it may result in some disorders, injury, pain or discomfort.

There is very vast range of product variety, but the reasons that make footwear very special is :

- Nearly all people use it
- Footwear are used by a person nearly all the time in a day except sleeping
- It covers the human feet, carry the body and mechanically they work together

Due to these factors and importance of comfort and to prevent injuries the concept of customized designed orthotic insoles has gained huge popularity in a short span of time. Orthotic insoles are generally used for extra comfort and to relief the foot pain, shin pain, heel pain and back pain. Often a biomechanical mal – alignment or lack of stability from the foot region can cause abnormal loads on the tissues of the foot and heel, shin, knee or back pain can develop as a result. Customized designed orthotic insoles are used to relieve plantar pressures.

Literature Review

The main objective found in the researches focused on the comfort and the life of the used orthotic insole while some laid stress on the prevention of injury and providing relief from knee, heel, and shin pain.

Two techniques of additive manufacturing were used in production of the orthotic insole namely:

- SLS (Selective Layer Sintering)
- FDM (Fused Deposition Modeling)

Selective Layer Sintering

SLS is the process in which the power source used is laser, targeted at specific areas of the model designed to produce a solid shape. This method was presented in the 8th Conference of the International Sports Engineering Association (ISEA) to produce the shoe spikes and sole for sprint shoes.

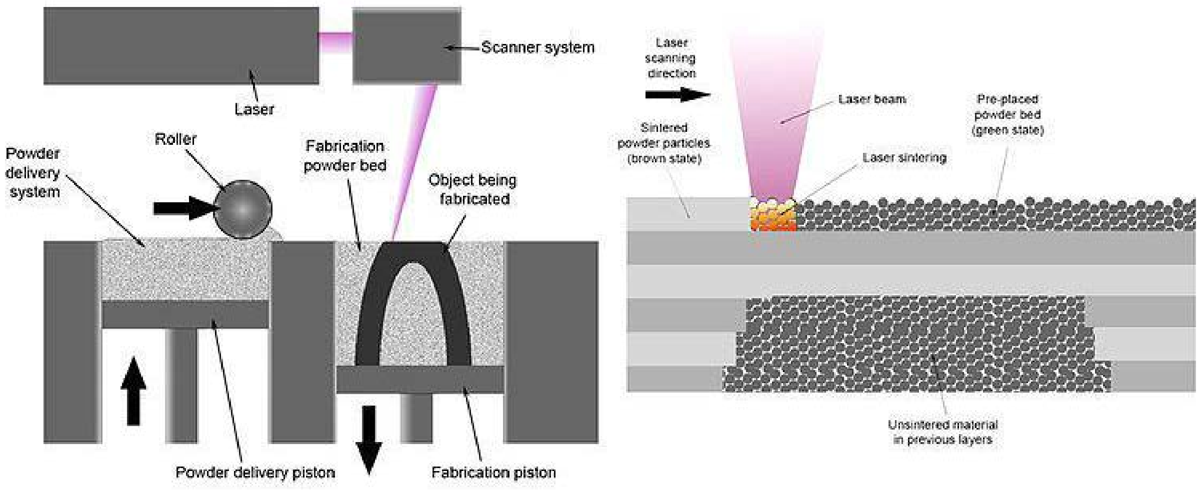

Figure.1 The process of SLS

The measured properly was the traction between the sole unit and the track surface by using the bespoke test fixture. The traction properties of different available SLS sole shoes were compared and studied. It was observed that during the start of a sprint race the horizontal force was applied on the shoes and the displacement was calculated on the application of the force. The test fixture was designed on the ASTM standard to test the traction characteristic of the athletic shoe – sport interface. The method of the test used was ASTM F 2333-04 and tight fit was created so that the force could be properly transmitted. The results found were satisfactory.

Another paper written by Sanjeev Kumar on SLS focused on the dimensional accuracy of the insole produced by process of SLS. The laser used was CO2 with a power wattage of 25-100 watt. The conclusions found were satisfactory.

Fused Deposition Modelling

It is the process of additive manufacturing in which the material is produces layer by layer and the raw material is supplied through coil in the thin wire form. It is relatively the conventional and oldest technique used in additive manufacturing. Many researches have been done in varying the different parameters and optimizing the results and the products obtained through FDM. Mostly taguchi techniques were used in the research papers written. Many flexible materials , TPE , TPU has been used in FDM. FDM is one of the RP processes that build part of any geometry by sequential deposition of material on a layer by layer basis. The process uses heated thermoplastic filaments which are extruded from the tip of the nozzle in a prescribed manner in a semi-molten state and solidify at chamber temperature.

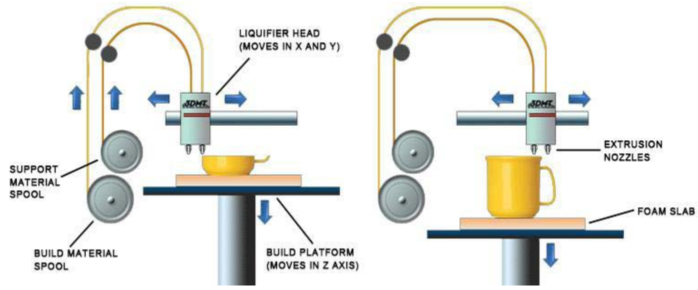

Figure 2.A schematic representation of FDM

In an another research more relevant to the title the infill density was considered as the parameter to be studied to compare the hardness and tensile strength of the test piece produced. Two different TPU were compared and results were published. The printer used in the production of the sample pieces was Flash forge 3 D printer.

The Flash forge 3D Printer is the easiest, fastest, and most affordable tool for making professional quality Models. The Flash forge sets a new standard in resolution and accuracy (true-to-life models) and builds volume (size of the model). Constructed with an industrial strength pressed steel frame, which has advantages for both form and function of the machine looks perfect in an office, lab, workbench, and even the living room and is durable enough to withstand high 3D printing speeds. The Flashforge Desktop 3D Printer is compatible with Mac, Windows, and Linux operating systems. MakerWare Desktop 3D Printer software is used as a communication medium between computer and Flashforge. MakerWare is free software that includes everything, including a lightning fast tool path engine and a brand new user friendly interface. Standard test specimens were prepared based on ISO 37 for tensile test.

Conclusions

It was found that the 3 D printed orthotic insoles is relatively new area for research and very less prominent conclusions have been found till date. Some of them will discuss in the following paragraphs in detail.

The SLS technology has been very rarely used in this area although some prominent results were concluded by some researches made using different composite materials. After the initial test trials were completed, the SLS B sprint shoe was excluded from further testing as there was visible fracture of several of the traction features. The results for the remaining three sprint shoes are presented as a mean of the four trials.

The graphical data in Fig. 3 shows the horizontal force recorded through displacement of these print shoes a distance of 100 mm at the various levels of normal loading. The results demonstrate that SLS A sprint shoe is able to generate traction forces consistent with the commercially available sprint shoes tested, across the levels of normal loading examined. At lower levels of normal load, the key concern was slipping of the sprint shoe relative to the track surface. The results, however, did not give evidence that SLS A sprint shoe would be more likely to slip during a sprint run than the commercially available sprint shoes.

The results from the SLS study are compiled in graphic form as shown:

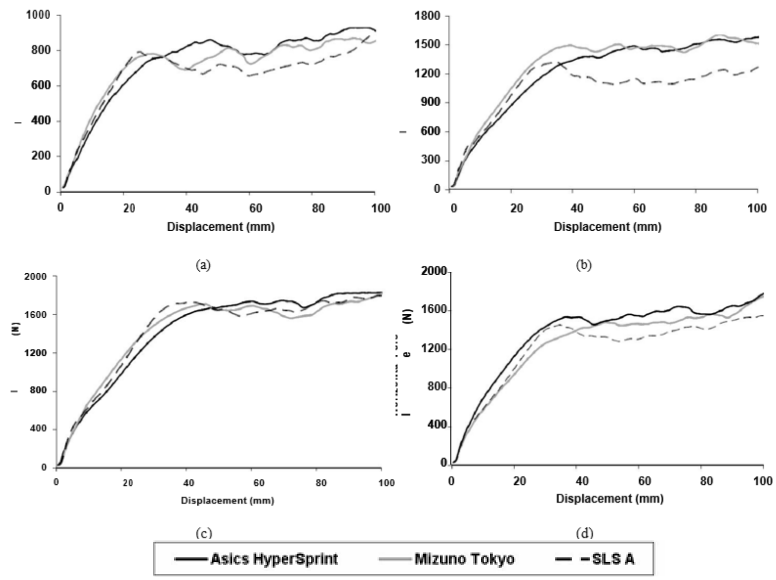

Figure 3.Results from SLS shoe spikes production

Another study in which FDM was used to compare the two different TPE for the production of orthotic insoles which showed the material Filaflex was far better than Ninjaflex for the insole material. The results were compared on the basis of hardness tests using Durometer which showed the better comfort material and tensile strength test was done using UTM. The samples and test results are shown below:

Figure 4.Tensile Samples

Figure 5.Hardness Samples

These samples were made using the Flash forge 3 D printer following the ISO 5893 and ISO 37. The results from this research made it clear that Filaflex is far better then ninjaflex for insole production. The results are given below:

Table 6.Tensile Test Results

Infill Percentage	Maximum Force (N)		Maximum Stress (MPa)		Break Force (N)		Break Displacement (mm)	
	FilaFlex	NinjaFlex	FilaFlex	NinjaFlex	Filaflex	NinjaFlex	Filaflex	NinjaFlex
10%	247.50	53.4406	30.94	6.68008	247.44	19.2656	360.10	60.4500
20%	224.38	58.0062	28.04	7.25078	224.24	23.3625	342.30	86.2320
30%	225.02	52.9562	28.13	6.61953	248.55	36.9469	361.46	27.5670
40%	231.72	57.0156	28.96	7.12695	241.44	40.3281	318.21	51.7710
50%	259.23	64.2969	32.40	8.03711	246.001	44.5063	316.48	52.7380
60%	249.19	74.1094	31.15	9.26367	249.06	46.6375	319.55	14.5160
70%	284.61	78.9031	35.58	9.86289	284.23	40.0281	319.38	38.8330
80%	275.41	64.6062	34.43	8.07578	261.28	27.6781	342.00	16.7710
90%	262.84	77.9656	32.86	9.74570	244.656	62.6750	352.00	56.4750
100%	241.11	105.556	26.76	13.1945	250.13	101.894	362.82	100.154

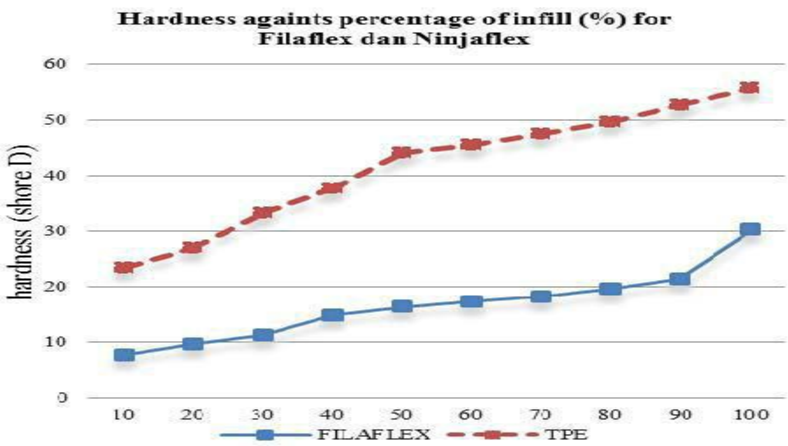

Figure 7.Hardness Test Result

It can also be concluded that no study was found relating to the specific area in an insole, further studies can be done on the flexural strength as the bending force is experienced by the insoles of the shoes.

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