VOL. 16, NO. 2, JANUARY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

REVERSE ENGINEERING (RE) FOR DESIGNINGINSOLE SHOE ORTHOTICS LEADING AN ACCURATE DIMENSIONAL SIZE FOR PATIENTS WITH A DEFORMED FOOT

P.W. Anggoro[1], A. Wicaksono[1], J. Jamari[2] and A. P. Bayuseno[2]
[1]Department of Industrial Engineering, Faculty of Industrial Technology, University of Atma Jaya Yogyakarta, Jl. Babarsari, Yogyakarta, Indonesia
[2]Department of Mechanical Engineering, Faculty of Engineering, Diponegoro University, Jl. Prof. Soedarto, Tembalang, Semarang, Indonesia
E-Mail: pauluswisnuanggoro@ymail.com

ABSTRACT

Computer-aided design (CAD) was implemented in the study to make a precise dimensional insole design according to the foot shape of patients with foot deformity. The insole design was performed byscanning the feet using a 3D handy scanner to provide the physical foot model in the form of a solid 3Dmesh model, that was converted in the CBS-modelling. Evidently, the obtained insole design fits the contours of the patient's feet. This research proved that the reverse engineering RE technology provided data of an accurate insole design, which could be manufactured on a CNC machine.

Keywords: CAD; Insole design; patients with foot deformities; RE; CBS-modeling.

INTRODUCTION

Computer-aided design (CAD) is an attractive technique that is capable of generating the geometrical shapes of components or products with the help of computers to produce graphic shapes (line, surface, and solid modeling) (Ye *et al*., 2008). Additionally, CAD can be used to analyze and optimize designs, especially in determining the optimal dimensional products. Currently, CAD technology has become essential for supporting the process of designing and developing considerable new products for fulfilling the market demand so that the products can compete with domestic and foreign ones (Anggoro *et al.,* 2018). Specifically, the shoe industry relying on CAD technology can increase production rapidly following the increasing customer need. Practically, for designing shoes may include four components, namely insoles, outsoles, upper shoe, and shoe last. Good and proper shoe fit with human foot shape are desirable for shoe design, which must refer to the physical body and the mechanical functionality of the human foot. Correspondingly, the design of shoes with comfort must bring to the concern on the material selection and structure of the shoes.

Generally, the anatomy of the foot has very complex structures with many interdependent parts. The normal human foot has an identical shape, but some people have a foot deformity. Correspondingly, the shoe design reflecting to the functions of the feet for supporting the weight of the body and providing movement has become a great concern. During standing, walking, and running, the weight of the body would be distributed between the footpath and the heels. For this reason, the shoes should be designed to fit precisely with parts of the foot, which may have a variety of foot sizes and geometry due to foot disorders (John *et al*., 2008).

Further, foot disorders refer to musculoskeletal problems, whereas many of them are simple disorders that can be treated with easy treatment (Julieanne and Freeman, 2013). Also, leg disorders with many types require different treatments. One of the foot disorders may involve pediatric foot disorders. These disorders can affect the bones, tendons, and leg muscles (Farzin *et al*., 2013) resulting in a variety of foot shapes, in that one is flatfoot. For the treatment of this deformity, the selection of the right form of shoes is needed (Anggoro *et al.,* 2017). This disorder is a condition of foot shape changes that affect bones, tendons, and muscles (Farzin *et al.,* 2013). Correspondingly, these disorders could be treated depending on the foot characteristic of each patient. In fact, shoes also have another use as a medical treatment device instead of being used as footwear. For this use, shoes need insoles that frequent contact with the base surface of having a period of reflection and interconnecting with the organs of the physical structure, while the design of customized shoes required accurate foot data points. Due to the limitation of these data points, the patients have often difficulty in finding orthotic shoes that are fitted and comfort (Anggoro, *et al*., 2018; 2019 and Anthony *et al*., 2020).

At present, there is a growing concern in designing precisely for the components of the insole and shoe last with soft materials (Anggoro *et al*., 2019a, 2019b; Anthony *et al*., 2020; Miguel *et al*., 2011 and Sambhav *et al.,* 2011). Here rubber, foam, or plastic is common materials for making a curve-shaped insole fitting with the shape of the foot surface.

Instead of flatfoot, metatalsalgia or high heels are a common disorder causing pain in the foot in the metatarsal area or behind the big toe. The main cause of this disorder may correspond to the inappropriate footwear and be the use of high heels, and the age of the patient. The disorder causes the patient experience pain during walking or moving. Treatment for this disorder has been proposed to wear an insole with a special form so that the pressure on the metatarsal part could be decreased. In this case, enlarging the insole at the back of the finger could be performed in addition to provide the deeper curves on the back of the finger. Moreover, the disorder resulting from the leg height difference requires the insoles for balancing the foot during walking or standing.

Accordingly, the manufacture of shoes for patients with foot disorders is mainly focused on the appropriate design of shoe insole because this part is in direct contact with the feet playing a role in comfort. In this event, there are needs of adaptation between the insole and the foot shape of the patients to minimize trauma and better comfort. For this purpose, CAD technology is available for designing and developing shoe insoles by providing more accurate foot data points compared to a conventional design (Mandolini *et al.,* 2015; Telfer and Woodburn, 2010).

From making shoes with comfort, namely shoe fit and shoe size allowance depend on providing the accuracy of foot data points. These data points are then converted into data of the 3D CAD for the manufacturing process of customized shoe insoles (Steven *et al.,* 2006; Kemal *et al*., 2016; Ali *et al.,* 2016). It is very common to perform the design of insole with finite element analysis and the use of 3D printing technology for yielding the prototype insole form. Conversely, the process of insole design could be based on the scanned data of foot shape which is presented in data points in the format of STL (stereo lithography) and subsequently converted into 3D CAD models. In such a methodology, the scanned data points are processed further for the design optimization stage using computer-aided engineering (CAE) or manufacturing optimization using computer-aided manufacturing (CAM). Eventually, the manufacturing of the insoles can be processed using a CNC machine or a 3D printer. However, only very few reports have been published in the literature for designing and manufacturing stages in customized shoe insoles based on the 3D CAD methodology.

In this work, the stages of the insole design process for both patients with foot deformity using the reverse engineering (RE) method are presented. The reverse innovative design (RID) was successfully implemented in previous work (Anggoro *et al.,* 2018; 2019; Beniere *et al.,* 2013) and such methodology was employed to reduce insole dimension errors that occurred from the scanning stage and the insole design process in CAD. Here, the RID methodology was applied to forming a solid part of the insoles so that any changes in the geometry could be made. Afterward, the auto surfacing process was then done using solid modeling using curve-based modeling (CBS modeling). The results are expected to add knowledge of designing and manufacturing customized shoe insoles based on CAD technology.

METHODOLOGY

In fact, the complexity and accuracy of the previous design of the orthotic insole shoes with conventional foam box methods made the process taking a long time for printing material resulting in an inaccurate dimension (Anggoro *et al.*, 2019). These inaccurate results caused the insole design formed to be not optimal and uncomfortable when applied in treating cases of foot deformity. For this cause, the initial step of the design was addressed to reduce these weaknesses by scanning the patient's feet as a physical model using a scanning tool with precise scanning tolerance.

On this subject, two patients with foot deformities were examined, namely high heel and different foot height (Figure-1). Both patients were female, age between 50-60 years. The collection of data was conducted with the help of a 3D scan tool with a Handy Scan 700 model. The data collected in the study included in the shape of foot for both patients with foot disorders. The type of collecting data was a surface mesh consisting of point cloud resulting from the tools used (Figure-1 (b) and 1 (f)). After obtaining the scanned data, the analysis of the scanning results was carried out using NetFabb software (optimization software for helping in the design optimization and automatic data repair) to help and reduce the scanned defects including hollow mesh, stacked mesh, and unneeded mesh. These NetFabb results are presented in Table-1. However, NetFabb results have sometimes the uncertain perfect model which could be repaired manually with the help of CAD software, in which Power Shape has a mesh editing feature (Table-2).

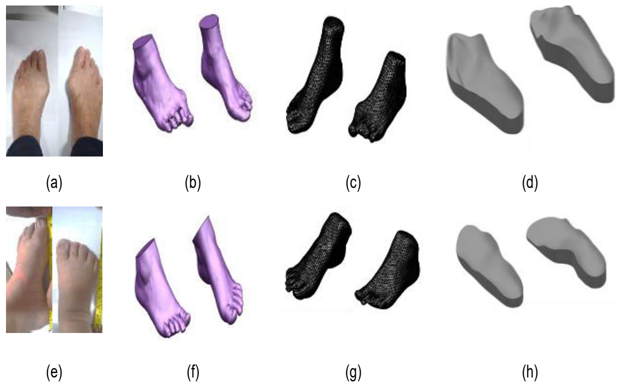

Figure-1. The legs of both patients with foot deformities: (a) the physical model of the high heel patient; (b) 3D mesh high heel feet; (c) 3D solid patient's High heel foot; (d) 3D CAD models of orthotic insole shoes for patients with high heels; (e) physical model of different height legs; (f) 3D mesh feet of different heights; (g) 3D solid patient legs of different heights; (h) 3D CAD models of orthotic insole shoes for patients with different heights

The improved results of this process yielded the foot in the form of a solid model. The subsequent smooth processing was performed because the patient's 3D foot scans data has a mesh structure. In fact, this structure was difficult to analyze because its shape has no exact size. Subsequently, changes were made by changing the shape of the mesh into a solid form because the solid shape made it easier to do both in terms of size analysis. The forming process was done by simplifying the foot shape. During the course of the study, fingers in the part of the foot shape were very complex. For solving this problem, the simplification process was performed for not changing the shape of the foot contour into the insole shape reference. From the simplification results, a conversion was made to

VOL. 16, NO. 2, JANUARY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

form a solid foot by changing the mesh into a solid surface. On the other hand, the solid surfaces have often cavities, in that conversion of solid shapes by filling cavities were performed to make the foot having volume (Figure-2 and Table-1).

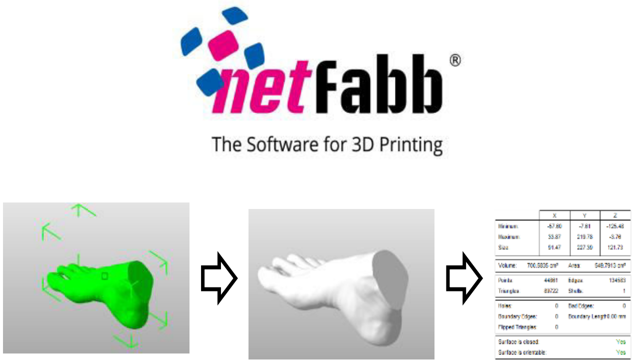

Figure-2. Optimization of 3D solid foot meshes from netFabb.

After the 3D solid model was fixed to be formed, the orthotic insole shoe model was generated using the CBS-modeling method (Figure-3). These results were then analyzed for the changes in the dimensions of the physical model, the results of scanning and insole to see how much error formed from differences in size that occurred (Table-2 and Table-3). The greater error generated between 3D solid insole and foot geometry indicates that the scanning tool used was not compatible.

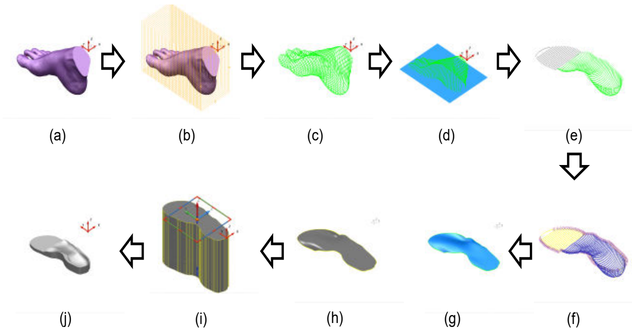

Figure-3. A CBS Modelling process in PowerShape2019i: (a) Mesh 3D Importing; (b) oblique processing; (c) foot wireframe; (d) Cutting wireframe; (e) Repoint wireframe curve; (f) repaint wire frame curve; (g) surface generating; (h) surface to solid process; (i) input the thickness size; (j) 3D solid of orthotic insole shoes

In general, the methodology adopted in this study can be presented in the flowchart (Figure-4):

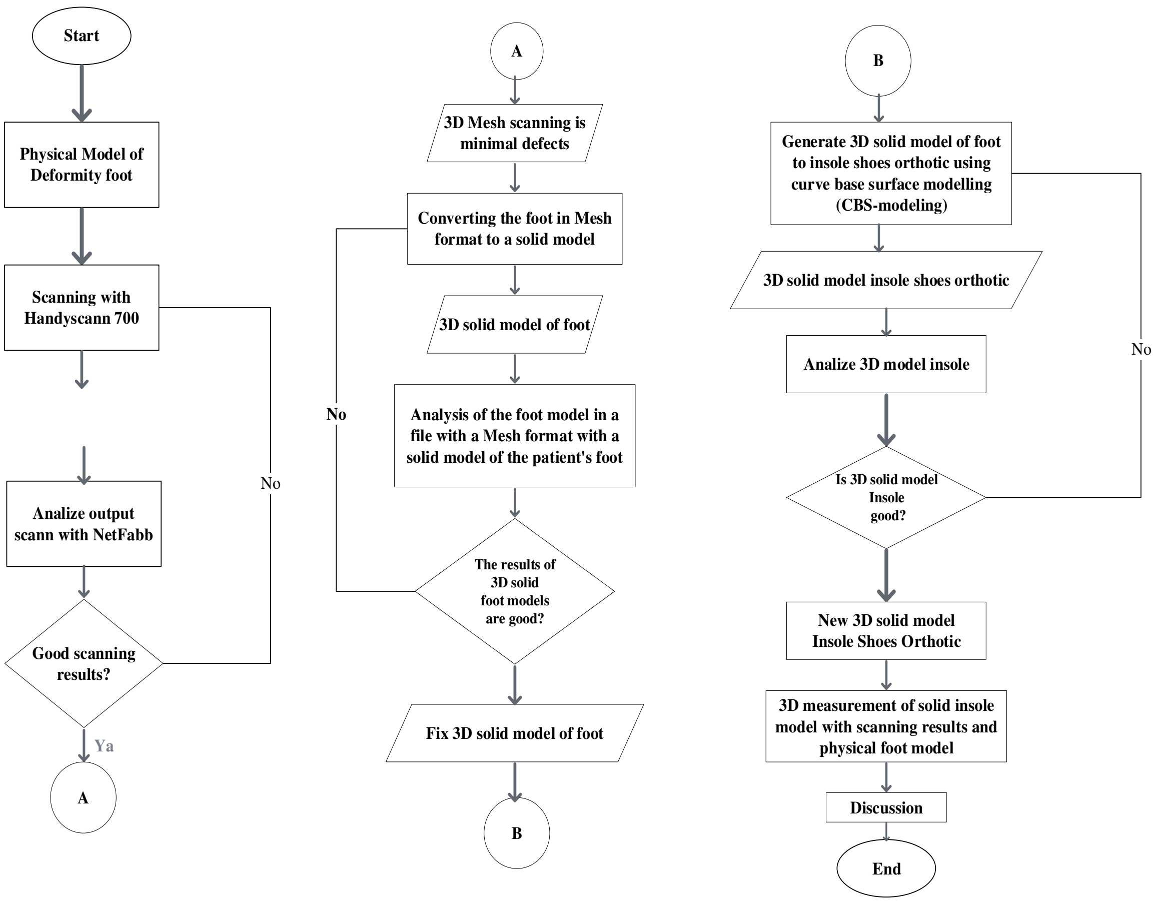

Figure-4. Flowchart reverse engineering research methodology for deformity patients.

Table-2. Colour mapping analysis and verification of scanning from 3D mesh to 3D CAD model of insole shoes orthotic.

Patient	Foot	Sample point	Point calculates	Point interpolated	Mean deviation	Error range	Standard deviation
					Mm	mm	mm
High Heels	Left	44,691	12,947	31,744	0.5202	-8.50585 to 3.1241	0.722
	Right	44,691	12,947	31,744	0.7695	-8.5687 to 3.0996	0.9022
Different High	Left	45,083	12,507	32,576	0.5057	-6.1708 to 4.2135	0.6717
	Right	46,332	12,791	33,541	0.5094	-7.2931 to 4.2901	0.7352

Table-3. Deviation of mesh feet, solid feet, and orthotic insole.

Type of patients	Notation	Left Foot			Right Foot			Mean Error	
		3D mesh foot	3D solid foot	3D Insole	3D mesh foot	3D solid foot	3D Insole	Mesh foot with Insole	solid foot with insole
		(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
High Heels	A	87.25	88.92	87.94	86.06	85.77	88.27	0.450	-0.240
	B	57.18	57.39	59.71	62.79	62.9	63.09	1.415	1.255
	C	47.21	46.27	48.56	45.46	45.7	46.11	1.000	1.350
	D	209.48	209.72	210.12	213.66	212.76	213.53	0.255	0.585
Different Foot	A	87.59	86.9	88.36	86.31	85.84	87.64	1.050	1.630
	B	56.72	57.48	56.12	68.88	68.66	68.62	-0.430	-0.700
	C	49.67	49.15	49.63	51.54	51.34	51.97	0.195	0.555
	D	218.99	218.31	220.1	220.24	219.15	221.13	1.000	1.885

RESULTS AND DISCUSSIONS

The data were collected by 3D scanning method on all feet of patients with foot deformities. The scanning process was performed using the range scanners method. On such a methodology, the light was focused on a small point on the object. Correspondingly, the reflected light from the object was captured by the camera or so called optical triangulation. From these results, three dimensional dots were formed and interconnected to form surfaces similar to the scanned objects (Brian, 1999). In this work, an approach according to the range scanner theory was adopted using the handy-scan, which has 7 lasers as a scanner with an accuracy of 0.03 millimeters. This tool was also equipped with vxelements software that can convert scanned points into surfaces. The results of scanning and verification data are presented in Figure-1 (b) and Table-1.

Correspondingly, the physical model of both patients, as well as the output of the scanning process, including verification of the solid mesh and re output of the 3d cad model of the patient's foot, fit into orthotic insole shoes are shown in Figure-1. Scanning output in the form of 3d mesh (Figures 1b and 1f) and the 3d solid mesh foot optimization process was performed using netfabb to check whether the solid formed has defects or holes so that it affected later in the next design process (Figure-2). From the results of verification using netfabb, the surface formed as a result of the scanning process in both patients was verified and processed further to the next stage (Table-1). Apparently, these results were also appropriate and in agreement with the result of the previous study (Anggoro *et al.*, 2019) regarding patients with diabetes mellitus.

However, the mesh resulting from the scanning process still had high defects which were subsequently repaired and validated on the mesh. With the help of validation software, the mesh could be repaired, whereas some defects found in the mesh could be minimized or removed without changing the basic structure of the scanned object. In the process of repairing the mesh, the software detected defects found in the object and then performed the repair, according to defects that occur such as hole filling, overlapping, and gap fitting. From the results of this improvement, a new mesh was formed. Accordingly, the process of mesh repair with nettfab provided the advantage of the repaired shape of the object to be unchanged, and the results of the repair were obvious. Apparently, the repaired features found in nettfab included, the default repair and simple repair. The validation process in netfabb software was to measure the entire mesh. In addition to the size of the validation process, all categories of defects occurring in the mesh were examined by displaying defects that were found in the mesh. The analysis provided the mesh standard. This analysis also examined the entire object and provided all the object information. There is some information displayed in the standard analysis as presented in Table-1. It shows the coordinates of objects at the reference point zero at netfabb. The letters x, y, z represents the axis. The minimum column refers to the position of the object away from the reference point in the direction opposite the axis. Conversely, the maximum column presents the position of the object away from the reference point in the direction of the axis. Accordingly, the size column is the difference between the maximum and minimum coordinates or indicates the size of the object.

Further, the volume column presents the volume of the object measured in cm^3 and the area row shows the total surface area of the object, measured in cm^2. The next column refers to the mesh information contained in the object, in which the first show points and triangles and second show edged and shells. Points are the number of points on the mesh that show the ends of the triangles in the mesh. The triangle shows that many triangles are composed of a mesh and are the basic form of a mesh which can be called a triangle. Edges relate to the connections between points, so the number of edges multiples three of the points because of the triangular shape formed. The shell indicates the number of shells contained in the mesh, while mesh form is composed of triangles or triangle forms cavities in the object because of that there is a calculation of the shell or hollow mesh section of the object. The fourth table indicates the defects in the mesh. Some of the defects analyzed in the standard analysis provided holes, boundary edges, flipped triangles, bad edges, boundary lengths. The mesh analysis process carried out with netfabb has the advantage that the shape of the fixed object did not change shape, and the results of the repair are almost invisible to the visual. After going through the process of improvement and validation, the mesh can be exported from netfabb software in a format as needed in this study by using the stl. format.

In fact, the evaluation of the foot scan data in the form of mesh confirmed that a complex shape and a high level of defects could be still observed during the course of study. Consequently, the mesh form may result in a high probability of error when processed in CAD and CAE software. In such CAE software, the mesh quality is desirable and the higher the mesh quality would provide a more precise result (Gao *et al.,* 2010). However, the process of generating a mesh in CAE requires time, in that the higher the quality of the mesh made the longer time required. After 3D foot mesh was obtained in the STL format, verification of the 3D foot mesh was focused on the fit of the physical model of the disc foot. As reported by (Anggoro *et al*., 2018), VX element 5 can be used to get mesh lab results that are fit and precise, while in this work software was used to simplify the shape of the patient's foot deformity scanning results so that the design optimization process can be performed on computer-aided engineering (CAE) or manufacturing optimization in computer-aided manufacturing (CAM).

Correspondingly, a software (meshlab) was used for processing the mesh. This software uses an open-source system so that it can be easily obtained. Specifically, it has capabilities in processing mesh such as editing, cleaning, healing, inspecting, and processing raw data enabling this software to process mesh foot data. Conversely, the mesh reconstruction used the Poisson method, in that the mesh points could be reconstructed and reorganized using the Poisson approach so that new mesh points were formed according to the parameters set. These parameters showed the standard values that are common in the reconstruction process by the Poisson method. The initial step in the process of simplifying the mesh started with the process of importing data mesh into the software as shown in Figure-5 and the results can be presented in Figure-1 (c) and Figure-1 (g).

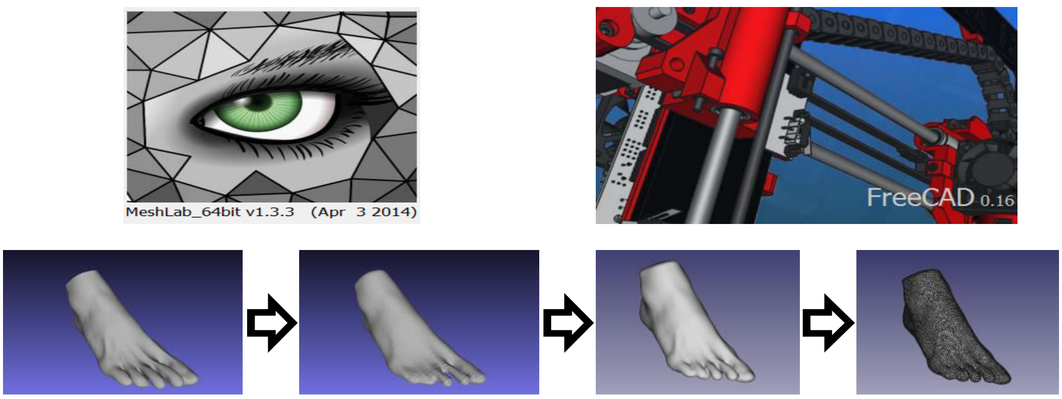

Figure-5. Meshlab-Poisson method using freecad.

The obtained color map was then evaluated by comparing the 3D cad surface with the 3D mesh STL format with the same orientation. A comparative analysis was also performed on the VX element 5 and power shape 2017 features. The sample points on the two images were compared, calculated for the gap between the dots, and displayed in shades of red to blue. By using VX element 5 software, 3D scannings to capture data directly (in real-time) from the 3D scanner of handy scan and data could be displayed on the computer screen. Principally, this software involves modules from element VX, VX inspect, and VX models. The VX element 5 could retrieve data and perform 3D scanning to check whether the mesh processing of 3D solid models fits the foot. Table-2

ARPN Journal of Engineering and Applied Sciences

presents the results of the color mapping and the verification analysis results of the scanning of the 3D mesh (Table-1) into a 3D CAD model conducted using the 2017 power shape software. As shown in Table-2, the average deviation that occurred on the two legs of patients is less than 1 mm (0.6213 mm for high heel patients and 0.5076 for patients with the differing height of the legs). These results indicated that the change in structure from mesh to solid shape did not affect the size or shape because the deviation was still below one millimeter, so it could be concluded that the scanning process with the handy scan can produce a 3D mesh leg with precision and fit to the real shape of the scanned physical model of the foot. After the 3D solid foot mesh model fits (Figure-1 (c) and (g)), then the model was processed to the stage of making 3D CAD drawings of orthotic insole shoe models (Figure-1 (d) - 1 (h)) with the help of powershape 2017 CAD software. The insole design method was implemented similar to that of previous work (Ye *et al.*, 2008; Anggoro *et al.*, 2018; 2019), in that the curve base surface modeling (CBS-modeling) was selected in this study. Such methodology, including several stages, namely: mesh importing and preprocesses; rewiring; repoint, built and verify 3D surface to solid foot with a solid doctor; 3D solid model foot from mesh; oblique processing; foot wireframe; wire support; repoint wireframe curve; wire reconstruction; surface generating; surface curve editing and 3d solid orthotic insole shoes for patients with foot deformities. In general, the detailed description of this stage is presented in Figure-3. Further finding of this work was the insole geometry fitting with the patient’s foot based on the scanning data. Moreover, the accurate data would be value for engineers whether the scanning based on CBS-modeling images can be further optimized or not. As demonstrated in the study, the difference in size (deviation) produced between 3D foot mesh and 3D CAD models were less than 3 mm at each magnification in the x and y axis (Anggoro *et al.*, 2018). For this result, the design form seems to have the correct geometry with high precision and to fit with the shape of the patient's feet. Accordingly, the resulting design could be further processed in manufacturing with subtractive manufacturing technology or adaptive manufacturing for yielding the insole products that match the shape of the patient's foot.

In fact, the overall measurement of the insole found the difficulty on several points measured and the resulting data influenced the suitability of the insole with the feet (Anggoro *et al.*, 2016; 2019). The suitability between mesh insole and feet could be verified by measurement, which can compare the data to know the deviations between the insole and feet. The deviation in the first measurement of between the insole and the mesh foot could be determined so that the compatibility between the insole and the mesh foot was known. Likewise, the second measurement of the insole with 3D solid CAD legs was performed to determine the compatibility between the shape of the solid foot and insole. The solid feet need a measurement because the solid feet could be a change from the mesh followed by changing shape. Here, the solid feet data are needed for the manufacturing process as the basis for making shoe lasts or analysis, such as CAE so that compatibility between the insole and solid feet could be obtained. Output deviationsand dimensional differences can be presented in Figure-6 and Table-3.

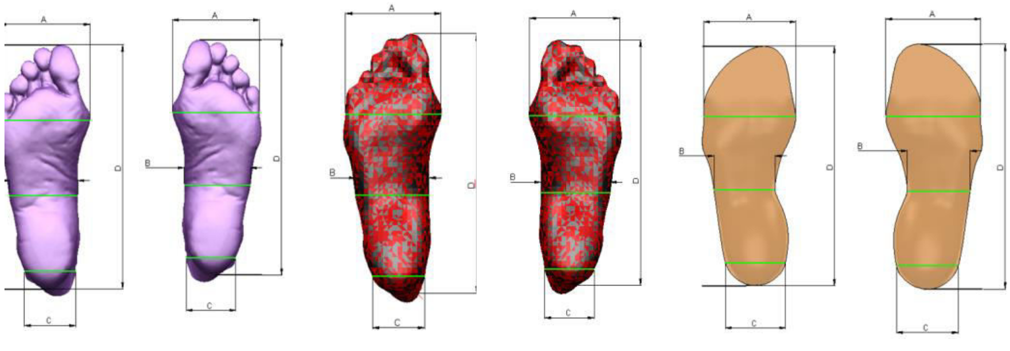

Figure-6. Description right foot size in the top view: (a) 3d leg mesh; (b) 3d solid fit feet; (c) 3d model orthotic insole shoes

Table-3 shows the difference in size between feet and insole (mesh foot with the insole and solid foot with insole) with mean error values ranging from -0.430 to 1,885 mm (less than 3 mm). Apparently, the 3d cad insole model has precise geometry and fits with the contours of the feet of both patients. The subsequent manufacturing process using a cnc machine would obtain a pair of insoles that are really comfortable to use by patients in this paper. In the future, this re-based insole design method can also be applied to patients with other foot deformities, such as diabetes with amputation cases; club foot from birth; foot disorders due to traumatic factors due to accidents or amputation processes that really need orthotic shoes in accordance with the shape of the patient's feet.

CONCLUSIONS

t can be concluded that the RE methodology used for the experiments with a scanning tool with a tolerance of less than 0.03 mm provided data of a more precise and accurate physical model of the foot's patient with deformed legs. The results of the design of insole and 3D solid foot could be further used for manufacturing insole and 3D solid foot into the last shoe using a CNC machine. Thusthe orthotic shoes could be made according to the patient's request. A significant finding in this work demonstrated that the use of cad-based re technology could be applied for patients with more complex and detailed foot contours for answering the challenges of the orthotic shoe industry, orthotic and prosthetic doctors and engineers in solving practical solutions in cases of foot deformities.

ACKNOWLEDGEMENT

This work was supported by the research grant for the years of 2019-2021, funded by Directorate General Strengthening Research and Development, the Ministry of Research, Technology and Higher Education (DIKTI) Indonesia.

REFERENCES

Ali S., Abbas M., Sasan A., Babak K. 2016. Studying Maximum Plantar Stress per Insole Design Using Foot CT-Scan Images of Hyperelastic Soft Tissues. Journal of Applied Bionic and Biomechanics. 6: 1-6.

Anggoro P W., Saputra E., Tauviqirrahman M., J Jamari, Bayuseno A.P. 2017. A 3D dimensional finite element analysis of the insole shoe orthotic for foot deformities. International Journal of Applied Engineering Research. 12(15): 5254-5260.

Anggoro P.W., Bawono B., Tauviqirrahman M., Jamari J., Bayuseno A.P. and Avellina M M. 2018. Computer Aided Reverse Engineering System in the design and production of customized orthotic shoe insoles for patients with diabetes. Cogent Engineering. 5(1): 1-20.

Anggoro PW., Bawono B., Tauviqirrahman M., Jamari J., Bayuseno A P., Wicaksono A. 2019a. Reverse Innovative Design of Insole shoe orthotics for diabetic patients. Journal of Engineering and Applied Sciences. 14(1): 106-113.

Anggoro PW., Tauviqirrahman M., Jamari J., Bayuseno AP., Wibowo J., Saputro YD. 2019b. Optimal Design and Fabrication of Shoe Lasts for Ankle Foot Orthotics for Patients with Diabetes. International Journal of Manufacturing, Materials, and Mechanical Engineering. 9(2): 68-88.

Anggoro PW, Bawono B., Andreyas W., Jamari J., Bayuseno A.P. 2016. Parameter optimization of strategies at CNC end milling machine Roland modela MDX - 40R Cam against surface roughness made insoles shoe orthotic EVA rubber foam. International Journal of Mechanical and Mechatronics Engineering. 16 (4): 96-102.

Anthony A A., Anggoro PW., Yuniarto B.,Bawono B., Bayuseno AP., Jamari J. 2020. Semi Reverse Innovative Design of Insole shoes orthotic for patient with club foot. The 1st International Biomedical Instrumentation and Technology Conference (IBITech), 23-24th October, 2019, Yogyakarta, Bali (Proceeding IEEE Xplore). pp. 127-135.

Beniere R., Subsol G., Gilles G., Breton F., Puech W. 2013. A Comprehensive Process of Reverse engineering from 3D *Mesh*es to CAD Models. Journal of Computer Aided Design. 45: 1382-1393.

Brian C. 1999. From Range Scans to 3D Models. University of Washington.

Creaform. Portable 3D Scanners: Handyscan 3D. Acces internet on Nopember, 29, 2016, http://www.creaform3d.com/en/metrology-solutions/portable-3d-scanner-handyscan-3d#

Farzin H., Reza M., Maryam M. and Ladan A. 2013. Pediatric Flexible Flatfoot; Clinical Aspect and Algorithmic Approach. Journal of Clinical Approach. 23: 247-260.

Gao S., Zhao H., Wei Lin., Yang F., Chen X. 2010. Feature suppression-based CAD mesh model simplification. Journal of Computer Aided Design, 42: 1178-1188.

John S., Emily R., David M. 2008. Pediatric Foot Deformities: An Overview. Access internet on June, 8, 2017, https://www.hss.edu/conditions_pediatric-foot-deformities-overview.asp

Julieanne P., Freeman M. 2013. Overview of Foot Deformity Management in Childern with Cerebral Palsy. Journal of Child Orthop. 7: 373-377.

Kemal S., Faruk O., Yunus Z. 2016. Design and Production of Subject Specific Insole Using Reverse Engineering and 3D Printing Technology. Journal of Engineering Science Invention. 5: 11-15.

Mandolini M., Vitali MC, Macchione A., Raffaeli R., Germani, M. 2015. A CAD Tool to Design Bespoke Insoles for Severe Orthopaedic Treatments. Computer-Aided Design and Applications. 12(6):700-709.

Miguel D., Michele G., Marco M., Maura M., Enrique M., Roberto R. 2011. Shoes Customization Design Tools for the Diabetic Foot. Computer-Aided Design and Applications. 8(5): 693-711.

Production of the manufacturing industry in Indonesia in the first quarter of the year 2019, acces internet on July 2019, https://economy.okezone.com/read/2019/05/04/320/2051437/produksi-industri-manufaktur-naik-4-45-di-kuartal-i-2019

Sambhav K., Tandon P., Dhande SG. 2011. Computer Aided Design and Development of Customized Shoe Last. Computer-Aided Design and Applications. 8(6): 819-826.

Steven G., Ahmet E., Marc P., Sachin B., Peter R. 2006. Reduction of Plantar Heel Pressures: Insole Design Using Finite Element Analysis. Journal of Biomechanics. 39: 2363-2370.

Telfer S., Woodburn J. 2010. The use of 3D surface scanning for the measurement and assessment of the human foot. Journal of Foot and Ankle Research. 3(19): 1-9.

Ye X., Liu H., Chen L., Chen Z., Pan X., Zhang S. 2008. Reverse innovative design - an integrated product design methodology. Computer Aided Design. 40(7): 812-827.

VOL. 16, NO. 2, JANUARY 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Table-1. Output validation Mesh of foot from NetFabb.

Patient	Foot	Coordinate									Volume	Area	Points	Triangle	Edges	Shells	Holes	Boundary Edges	Flipped Triangle	Bad Edges	Note	
		X			Y			Z														
		Min	Max	Size	Min	Max	Size	Min	Max	Size	cm^3	cm^2									Surface Closed	Surface is Oriented
		mm	mm	mm	mm	mm	mm	mm	mm	mm												
High Heels	Left	-43.5	45.4	88.9	-64.3	155.4	219.7	-133.6	0.4	134.0	706.9	557.4	44,691	89,378	134,067	1	0	0	0	0	yes	yes
	Right	-48.6	44.0	92.6	-51.2	161.7	213.0	-124.5	-13.0	111.5	630.9	510.6	41,422	82,856	124,284	1	0	0	0	0	yes	yes
Different High	Left	-65.8	27.8	93.6	-44.7	176.5	221.2	-124.6	-8.5	116.2	737.5	563.2	45,083	90,162	135,243	1	0	0	0	0	yes	yes
	Right	-42.7	49.8	92.5	-49.9	174.1	224.0	-126.6	-9.7	116.9	752.7	569.5	46,332	926,644	138,996	1	0	0	0	0	yes	yes