# VIRTUAL PERFORMING OF THE SHOE LAST MODEL ABLE FOR CNC MACHINING

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**Abstract:** For the 3D virtual model of the shoe last it is necessary to take a lot of points from the spatial surface, which are needed to transform in a cloud of points to be used by the CNC machine. To be able this kind of performing we need a milling machine with minimum 3 axis or 5 axis.

**Keywords:** model 3D, shoe last, CNC, cloud of points, virtual surface.

## 1. INTRODUCTION

To do the shoe last we must have a model of the surface. For the shape of shoe last we can use a virtual surface, is performed by the milling machine. Milling machine can be programmable using CNC devices. For the points coordinates of a shoe last surface we use a comparative clock to measurement the coordinates on axis x, z and rotate angle φ.The shoe last 3D model can be obtain from palpation with a comparative clock and this model is created from a cloud of points, like in figure 1.

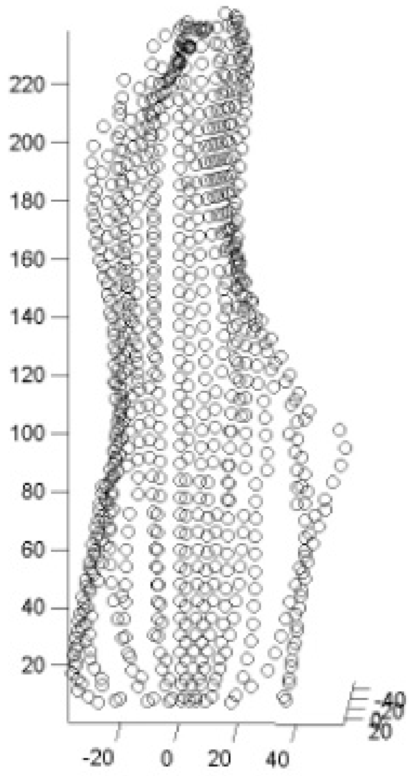


**Fig. 1.The cloud of points obtain from palpation.**

## 2. EXPERIMENTAL METHOD

Techniques for creating a custom last vary greatly. In some cases modern digitizing equipment, computer numerically controlled (CNC) milling machines, computer aided design (CAD) software, and computer aided manufacturing (CAM) software is used to create the last. It was determined that the primary source for skilled labor requirement was the last design software, often taking an operator an hour per custom last to design. Methods were also developed for creating tool paths to guide CNC milling machines to create the lasts.

Traditionally, lasts would be made and modified by hand with tools such as chisels. With a CAD program however, a model of the last can be modified as necessary before actually manufacturing. Last models are created by modifying the geometry of existing lasts. Thus the use of CAD packages for last modification did not take hold until digitizing solutions such as the laser scanner became available. Most modern CAD programs are able to manipulate lasts by scaling and transformation. However, the tools required to adjust a last to closely fit a foot are less common. For this reason, specialized CAD systems have been developed to provide modern last makers with powerful last modification tools.

To create the physical last, computer aided manufacturing (CAM) packages are used to convert the CAD model into numerically controlled (NC) code that will operate computer numerically controlled (CNC) milling machines. The specialized CAD systems mentioned above often incorporate a CAM system to provide a more streamlined solution.

The shoe last can be positioned between the handy devices on the milling machine 3 axis. Those devices are specific for the shoe last. In the back side of the shoe last there are two wholes in the heel zone, the back device is holding by the universal device. In front of the shoe last there is a pin which permitted the shoe last rotating.

We use a comparative clock on the milling machine, that has a rod for palpation. It is proceeding at palpation of the shoe last surface in several points after a trace which is defined a spiral trajectory.

Such that:

-at x axe: it moves with 0.30 mm (0.30; 0.60; 0.90; 1.20….)

-at y axe: we are reading the movement from y- (-0.11; 3.35; 12.14; 16.52…)

-it is rotate with an angle φ : 18; 36; 72; 90….

By laser scanning an object, a series of points (point cloud) are obtained. This raw data is not a convenient form for manipulating the data. The data can be converted into a more manageable format called stereo lithography (STL). This is essentially an array of triangles that as a group closely approximate a surface. An alternative to a mesh is a surface. A surface is described by a single equation and in general is a more robust description of geometry and superior for simplifying computations. A limitation that created a challenge for representing the last with a surface is that surfaces in Rhinoceros 3D have 4 sides. One way around this is to „trim" the surface; however a trimmed surface is somewhat more difficult to work with. Two different methods were attempted for capturing the geometry of the last with a surface. The first was to wrap the last with a surface placing a hole on either end and a seam along the side (Figure 2). This method proved to be unproductive as the density of control points greatly varied from near the ends to the middle. Thus to obtain a minimum control point density near the middle of the last, a drastically larger and impractical number of control points would be created at the ends. Therefore a compromise had to be made to keep the computations of reasonable simplicity. This resulted in an unacceptably low number of control points near the sharp edges at the top and bottom of the shoe last and thus rounded edges where sharp edges were desired.

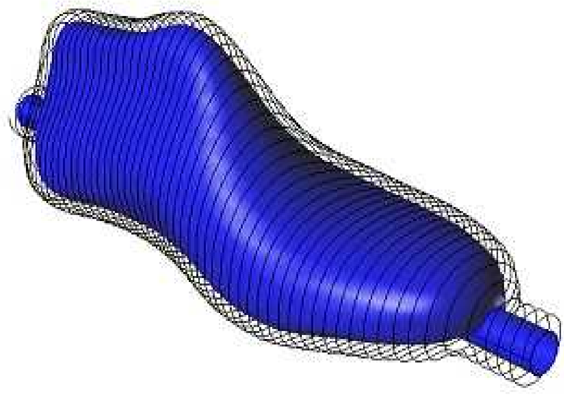

**Fig.2. Offset Mesh Tool path**

The second technique attempted was to create three separate surfaces for the top, bottom, and body of the last where the top and bottom were trimmed surfaces (Fig.3.). This was beneficial as perfectly sharp edges could be created for the top and bottom edges as well as relatively even spacing of control points. The primary disadvantage of this method was that many of the operations used for modifying the last would also cause minor edge separation. Though various operations could be used to reconnect the surfaces, it became apparent this was an inadequate solution. Besides the disadvantages of working with surfaces discussed above, they also add one more step to the last modification process therefore further complicating the problem. For this and the above reasons, it was decided to work with the last in the form of a mesh. Similarly, the foot is represented by a mesh.

**Fig.3.From Left to Right: Mesh, Single Surface, Three Surface Last**

## 3. BONDING SURFACE

The combination of parts in different ways, resulting in a new form, is often performed by technician's business forms. In this sense, the need to implement in a 3D feature Shoelast that allows the same type of operation based surface models. It is, therefore, the implementation the operation of gluing surfaces.
The examination of existing business systems, earlier concluded that the functionality of glue surfaces in the vast majority of them, merely juxtapose the two surfaces, deforming the edges of border adjacent to match. Aim was something more ambitious is not only to juxtapose two parts of surface form (hitting the edges border), but to transform them into a single surface may be subject to other operations modeling.
From literature for this type of operation is something scarce, however, some authors have investigated on the problem. The fact that they used distinct processes of Shoelast implemented in 3D the generation of surface (eg triangulation for a Delaunay triangle mesh that approximates the surface), restricted to adapt their algorithms to Shoelast 3D. It was therefore possible to find a satisfactory solution in the literature investigated.
For example, we can discusses the problem of loss of higher-order continuity between surfaces glued, especially in collage preceded by operations blending between the respective borders of each surface necklace.

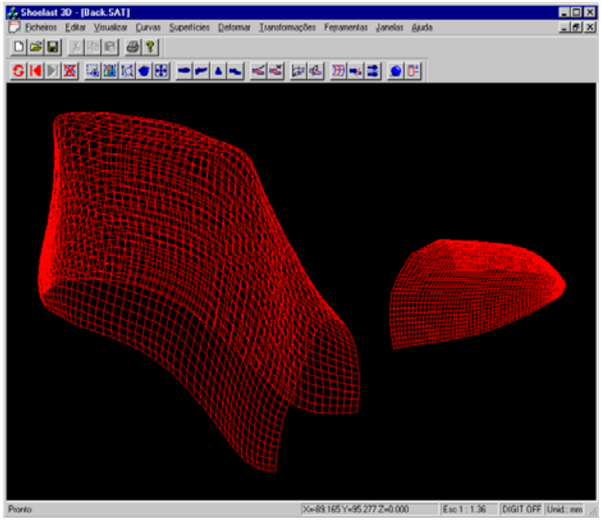

**Fig.4.Two pieces of surface, belonging to forms different, it is intended to paste.**

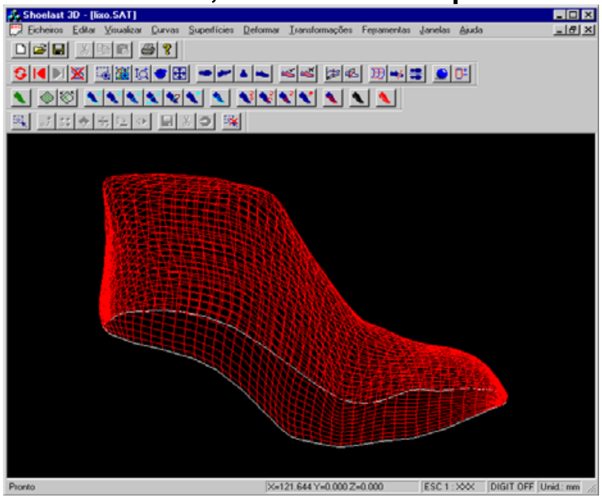

**Fig.5.Surface resulting glue.**

It was then developed an algorithmic process capable of solving the problem of bonding surfaces form.
The solution implemented is based on a constructive process:
1. The two Surfaces are positioned correctly in space, using auxiliary operations rotation, translation and scaling;
2. Hit in the two border edges, whereby surfaces will be glued, using operations strain on one (or both) surfaces;

3. In each of the areas are calculated curves corresponding to a fixed parameter, which interpolate generating a new surface (Fig. 5).
Step 2, proved somewhat time consuming and not always the result end was satisfactory. This sense, it was solutions that automatically deform one of the areas, taking into account the geometry (vectors tangents) on the border of another. Thus, they are calculated vectors tangent to the surface at points along the border of the surface is not deformed. Based these vectors are calculated the ideal points to boundary of another surface (the warp). Curve defined by these new points to set the force deformation apply at the border of the surface to deform. Has been achieved thus implementing an algorithm to automate the process of deformation to adjust surfaces in the glue.
In step 3, the number of curves is calculated for each area depends on the spacing parametric used. After some tests we obtained a value spacing that allows you to create the new surface approaching precisely those that gave rise. Surface you get presents, of course, continue higher order.

In my researches I made the measurements on a shoe last with a CNC milling machine, in the laboratory of university. The next figure is one of the experience.

**Fig.6. Working in laboratory**

**Fig.7. How is positioned the shoe last in CNC milling machine**

## 3. CONCLUSIONS

The cloud of points which was obtained give us the virtual surface of the shoe last, the goal of this researches. A script was written within a commercial CAD program to automate the last production process from foot measuring to last modification to tool path planning. The algorithms were also designed to provide orthopedic advantages over existing programs in an attempt to minimize the possibility of requiring rework.

## REFERENCES

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