

CAD METHOD FOR SHOE SOLES FORMED IN MOULDS

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Abstract. This paper presents a 3D design method for obtaining footwear soles using PowerSHAPE-e software of Delcam system. Computer-aided design used in this paper highlights several important advantages that include: design increased quality; soles three dimensional viewing, which can lead to immediate decisions, regarding the acceptance of newly developed models; it can be appreciated the complexity of mould cavities execution, without the need of making prototypes; the outlines of construction templates are accurately obtained for the mould cavities and for all size numbers; there can easily be done calculations for determining the soles volume for the entire size number volumes, with implications on estimating polymer blend consumption and so on.

1. INTRODUCTION

The CAD/CAM kind design systems have been largely developed including the domain of footwear uppers and footwear soles. Among the high performance systems used in the design of footwear soles and moulds for shoe soles, we may mention: Delcam Shoe Solution (3D), Delcam PowerSHAPE-e (2D and 3D), Padsy II (2D) and Padsy III (3D), Shoemaster System (2D and 3D), Lectra System (2D and 3D), Parmel System (2D), ATOS II System (3D) [1, 2, 5]. These systems are equipped with colour graphical displays, plotters, digitizers, terminals and other peripheral equipment needed for computer assisted activities.

The footwear soles are produced as flat footwear soles, as partially spatialized footwear soles and as spatialized footwear soles. The complexity of footwear soles design and of mould cavities increases with the spatialization degree [1, 2, 5]. The Delcam Shoe Solutions and Delcam PowerSHAPE-e applications provide the user with the needed tools for designing the most complex footwear soles and footwear moulds.

In this paper is presented a method [4] developed by the authors, for the 3D design of the footwear soles which are formed in moulds, using the PowerSHAPE-e 2010 R2 application.

2. 3D DESIGN METHOD FOR FOOTWEAR FLAT SHOE SOLES

The flat sole is the easiest kind of sole to design from the geometrical point of view. A set of steps is followed to design the flat footwear soles.

Step 1. Copying the shoe last.

The bottom of the shoe last is copied as a patten using one of the known methods. This pattern represents the shoe last insole.

Step 2. Inputting the insole outline, drawing the main axis and positioning the basic foot anatomical points.

The insole outline is drawn as a Bezier curve using the **Create a Bezier Curve** tool under the **Curve** function. The inputted outline is presented [4] in figure 1.

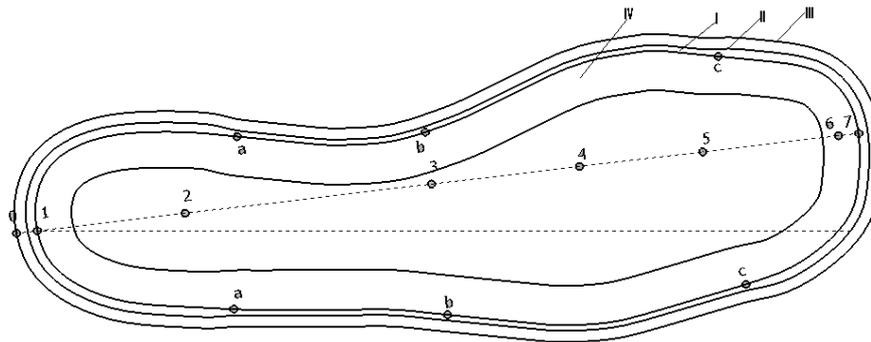


Figure 1. Drawing the footwear sole flat contours
I-insole contour; II-sole interior contour; III-sole exterior contour; IV-gluing surface of the sole with the upper

After inputting the insole outline, the two axes are drawn: the insole axis and the shankpiece axis. These axes are drawn using the **Create a single line** tool in the **Line** function as simple lines, by specifying the coordinates.

The main anatomical points are positioned on the insole axis represented by the segment 1-7 in the figure 1. Their coordinates are calculated according to the foot length L_p . The value of the foot length is equal with the footwear last size number in centimeters. The reference points used for the footwear sole design are: 0 – rear foot curvature amplitude; 2 – heel center; 3 – middle of the foot arch; 4 – center of metatarsophalangeal articulations I-V and 5 – extremity of toe V. The positions of these points, respectively the length of the segments relative to the point 1, are calculated with the following relations: $0-1=0.025 \cdot L_p$; $0-2=0.18 \cdot L_p$; $0-3=0.48 \cdot L_p$; $0-4=0.66 \cdot L_p$; $0-5=0.81 \cdot L_p$; $0-6=L_p$. The length of the segment 6-7, represents the length of the footwear last tip whose size is variable and depends on the tip shape [3].

The position of the points will be marked by circles which are drawn using the **Create a full arc** tool in the **Arc** function. The radius value will be filled in the **Radius** field. The **Name** field is filled automatically with a number generated in the order of creation. However, each circle name can be manually set.

The posterior extreme point 0 is obtained by extending the insole axis in the rear zone. In order to accomplish this, a work-plane is positioned with its origin in point 1 and its ox axis overlapping the insole axis. To create this work-plane follow this procedure: select the **Workplane** function and then the **Create a single workplane** tool and position the new work-plane with its origin in the point 1; reposition this plane's ox axis along the insole axis; open the insole axis parameters editor; select the newly created work-plane as the value of the **Workspace** field; fill the 1-0 segment inverted length in the **X** field of the start point. This procedure is presented [4] in figure 2.

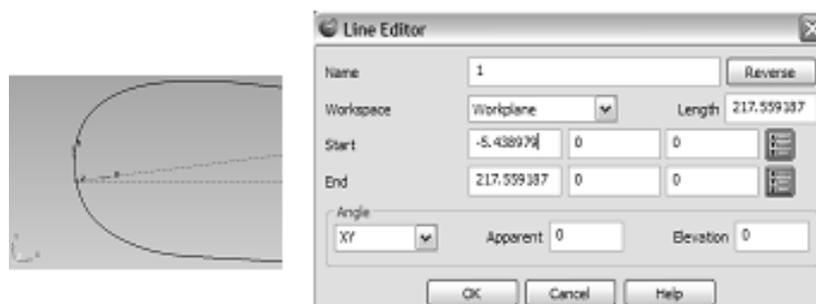


Figure 2. The insole axis parameter editor

To position the points 2, 3, 4, 5 on the insole axis follow this procedure: select the circle drawing tool; open the position dialog box; select the **Along** tab; select the insole axis by clicking next to the start point; fill in the **Proportion** field with the corresponding proportion (e.g.: 0.18 for the point 2); click on **Apply** and then on **OK**.

The position of the point 6 will be determined using the **Line** function and drawing an added line whose length will be equal with the foot length. After positioning the point 6 the added line should be erased using the option **Delete**.

The **Horizontal text** tool in the **Annotation** function is used in order to label the points.

Step 3. Drawing the footwear sole interior contour.

The sole interior contour is obtained by adding the thickness of the upper parts to the insole contour [3]. This thickness varies along the insole perimeter depending on the number and the thickness of the layers. From the thickness variation point of view, the zones a-1-a, a-b, b-c and c-7-c are distinguished on the insole contour, presented in figure 1. The positioning of the points that separates these zones is accomplished by constructing a set of added lines as Bezier curves. The curves will be drawn both in the inside direction and outside direction using the point 1 as start point. The **Create a full arc** tool in the **Arc** function is used to draw the circles that will mark the points. Open the position dialog box, select the **Along** tab, select the added curve by clicking next to the start point and then fill the value in **Distance** mode. This will position the circle center at the desired position along the added curve. This procedure is presented [4] in figure 3.

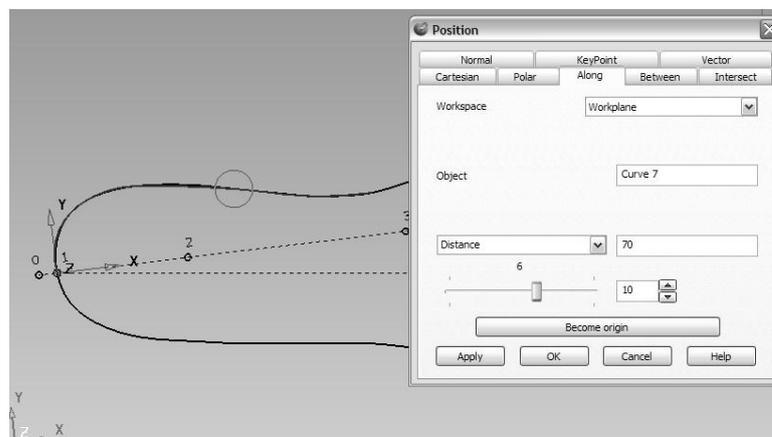


Figure 3. The positioning dialog. The Along option.

The distance at which will be positioned the sole interior contour in relation with the insole contour is variable. To draw this contour, the **Variable offset** tool in **general edit options** is used. In the **Offset** window associated with this tool, the set of points for each zone is selected individually. If the transition from one zone to the other is not smooth, the curve should be fine-tuned to obtain a smooth curve. The sole interior contour so drawn is presented in figure 1.

Step 4. Drawing the footwear sole exterior contour.

The sole exterior contour, presented in figure 1, is drawn at a constant distance in relation with the interior contour. This distance varies depending on the footwear sole model between 0 and 8 mm. The **Offset items** tool in the **general edit options** is used to draw this curve. Select the sole interior contour and then select the **Offset items** tool. The offset value is specified in the associated window. In order to keep the sole interior contour the **Keep original** button must be activated.

Step 5. Defining the footwear sole gluing surface.

The gluing surface is the area where the upper and sole are assembled by gluing. This surface is continuous, without weight removal cavities and its width is of 14-15 mm.

The exterior of the gluing surface is delimited by the sole interior contour. The interior limit of the gluing surface is obtained by offsetting inwards the sole interior contour at a distance equal with the gluing surface width. The tool used is **Offset items** in the **general edit options**. After selecting the sole interior contour click the **Offset items** tool and then specify the offset distance and activate the **keep original**.

Step 6. Creating the solid that defines the volume occupied by the upper in the sole volume.

In order to assemble by gluing the footwear upper with the sole a cavity in the sole volume is needed. This cavity represents the volume occupied by the lasted upper in the sole volume. To accomplish this, an extrusion solid is created starting from the interior contour of the sole. This solid enters in the sole volume on a distance equal with the cavity height. This volume will be removed from the sole volume. Select the sole interior contour and using the **Create one or more solid extrusions** tool from the **Solid** function the solid is created [4] like in figure 4. The solid extrusion height will be specified in the parameter editor for this solid in the **Negative Length** field. The **Length** occupied by the solid above the sole will be established big enough to allow an easy selection of the solid.



Figure 4. The solid that defines the interior cavity of the sole

1- sole exterior contour; 2- the volume of the solid created above the sole; 3- the volume of the solid created inside the sole

Step 7. Creating the solid that defines the sole volume. Obtaining the sole cavity.

The thickness of the sole is obtained by summing the heel height, the sole cavity height and the sole thickness in the front sole zone.

Initially, the sole will be defined as a monolith solid, obtained by extruding in negative direction the exterior contour on a distance equal with the sole thickness. In order to accomplish this, the sole exterior contour is selected, the solid is created using the **Create one or more solid extrusions** tool in the **Solid** function and the value of the sole thickness is filled in the **Negative Length** field. The field **Length** is filled with the zero value because the sole will be delimited above by the XOY plane of the coordinate system associated to the work-plane. The sole cavity height is obtained by eliminating the solid that defines the cavity from the solid that defines the total sole volume. To operate on the solid that defines the sole, this solid must be activated by checking the option **Active**.

The tool used for solid removal is **Remove the selected solid, surface or symbol from the active solid** in the function **Feature**. This operation is presented in [4] figure 5.

Feature function. The sequence of operations that led to the definition of the heel shape and volume is presented [4] in figure 6.

Step 9. Obtaining the sole weight removal cavities.

A fast and precise method of drawing the weight removal cavities consists in using an auxiliary construction [4], as in the example presented in figure 7.a. Using the compound curve tool, each individual weight removal cavity contour is drawn as in figure 7.b. The auxiliary solids are created by extrusion using this contours as in figure 7.c, solids which will be removed from the sole solid. The extrusion is done in negative direction on a length equal with the depth of the weight removal cavities. The weight removal cavities in figure 7.d were obtained by removing the auxiliary solids from the sole volume using the **Remove the selected solid, surface or symbol from the active solid** tool in the **Feature** function.

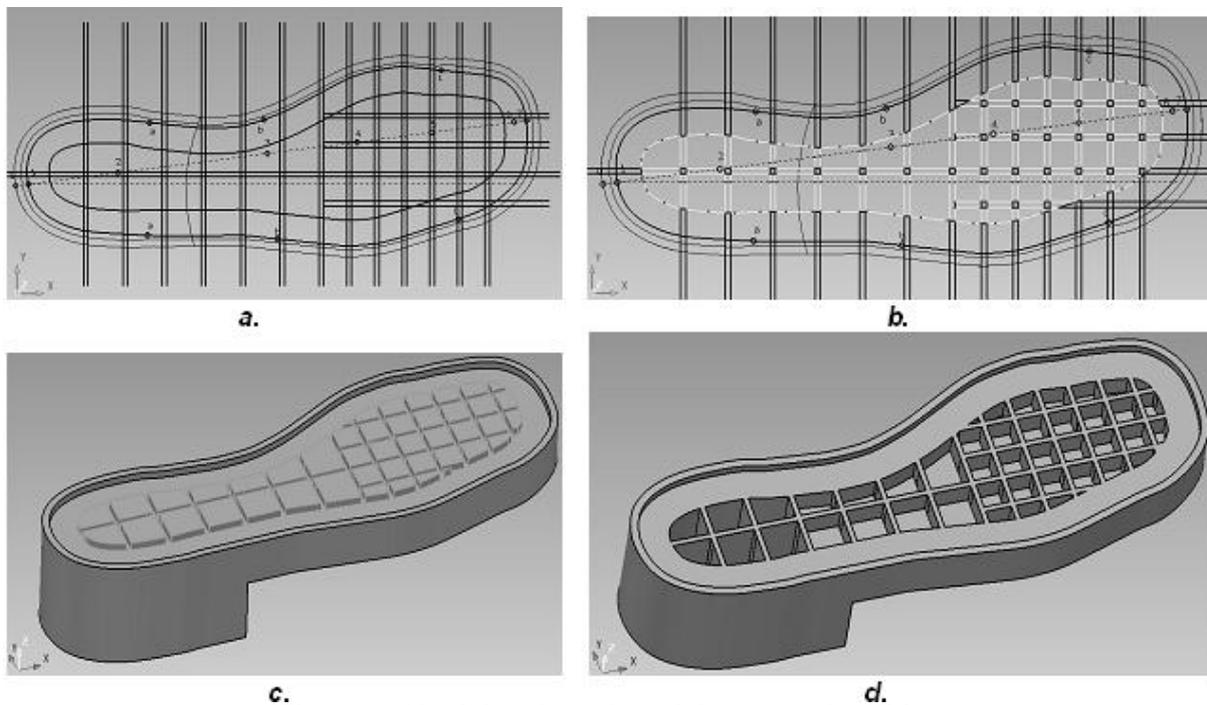


Figure 7. Obtaining the sole weight removal cavities

a- drawing the auxiliary construction; b- weight removal cavities contours; c- creating the auxiliary solids; d- creating the weight removal cavities

Step 10. Obtaining the anti-skid relief

The work method [4] is similar to that used to obtain the weight removal cavities. On the surface of the solid on which the anti-skid relief will be made, an auxiliary network is drawn which will be used to obtain the contours of the auxiliary solids that will be removed from the sole volume. Because the surface of the heel and the surface of the sole are situated on different levels an auxiliary network will be drawn for each of this two zones. For each of the two surfaces a work-plane will be associated as in figure 8. The tool used for the creation of the work-planes is **Create a single workplane**.

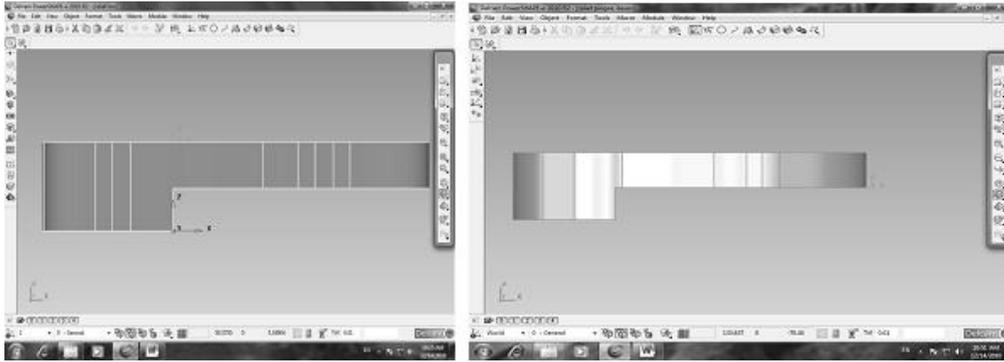


Figure 8. Positioning the work-planes for heel and for front sole

In order to draw the anti-skid relief design the **Create a single line** tool from the **Line** function and **Curve** function will be used. In figure 9 is presented the auxiliary network design.

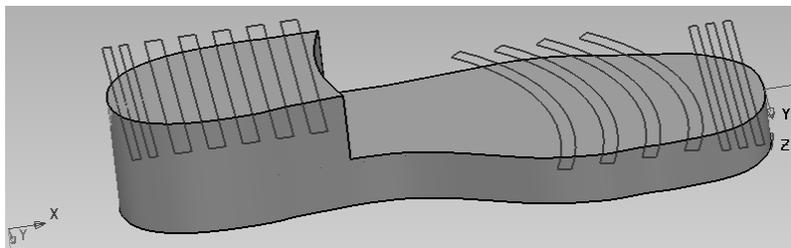


Figure 9. Drawing the anti-skid relief design

Finally the drawings are used to obtain the composite curves using the **Create a Composite Curve by tracing** tool. The composite curves are used to obtain the auxiliary solids as in figure 10, using the **Create one or more solid extrusion** tool in the **Solid** function.

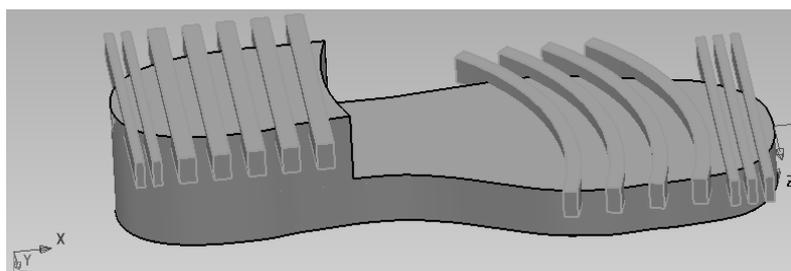


Figure 10. Obtaining the auxiliary solids from the composite curves

The anti-skid relief, represented in figure 11, will be obtained by removing or adding the auxiliary solids volume to the sole volume using the **Remove/Add the selected solid, surface or symbol to the active solid** tool in the **Feature** function.

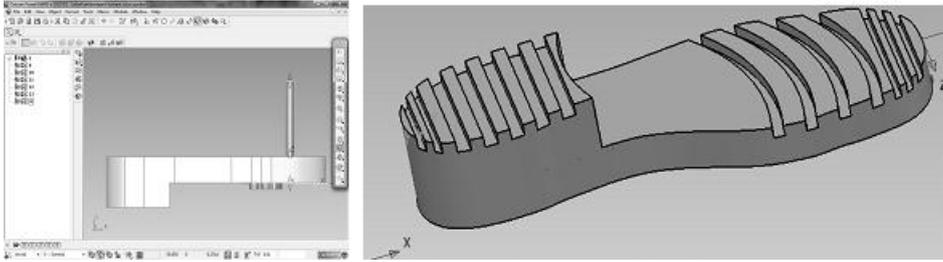


Figure 11. Obtaining the anti-skid relief

The Delcam PowerSHAPE-e application provides a complete and intuitive environment for computer aided design. Unlike other CAD environments, in PowerSHAPE-e the surfaces and 3D solids are created with a minimum effort. The method presented in this paper is approachable to any category of designers with basic skills in CAD systems.

CONCLUSIONS

- The CAD/CAM systems developed by the big software companies are remarkable but most of them can be used under commercial licence. The Delcam PowerSHAPE-e 2010 R2 application, which was used for the development of the method presented in this paper, doesn't need a commercial licence. It can be downloaded free of charge from the developer company website.
- The developed method for the soles and mould design is suitable for both beginner and advanced designers. The hybrid modelling in PowerSHAPE-e, combines perfectly the solid and surface modelling, providing the necessary flexibility to develop complex shapes like the footwear soles and mould cavities.
- The developed method allows the inputting of the 3D last contour, the 3D sole design, inexhaustible diversification possibilities of the soles, the three-dimensional visualization of the sole models, obtaining the patterns or casts needed for the execution of the mould nests, determining the polymer blends volume needed to obtain the soles, etc.
- This method can be used in advanced mould design where the soles are formed.

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