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Technical paper

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CREATING CURVED MESHES BY HEAT-FORMING 3D-PRINTED PARTS

ABSTRACT: This research investigates the creation of curved mesh structures through heat-forming of 3D-printed parts, producing dome-like shapes using only a 3D printer and manual pressing. Compared to conventional 3D modeling methods, this approach is faster, reduces material waste by eliminating support structures, and can achieve a smoother surface finish through deformation of planar meshes. The study used PLA mesh wafers with hexagonal infill patterns at 20% and 40% densities, printed in thicknesses of 1 mm and 2 mm. All other printing parameters remained unchanged. Before forming, the samples were heated on the heated bed of an enclosed 3D printer. The wafers were shaped using a one-piece PET-G mould with a hemispherical profile raised 10 mm above the base. Vertical guides were incorporated to improve alignment during the forming process. The formed parts closely matched the intended geometry, with only minor imperfections caused by twisting during manual pressing. While further improvements in guidance and pressing stability are needed, the results demonstrate that heat forming is a viable method for producing curved mesh structures. As a proof of concept, the research confirms that complex dome-like forms can be successfully created using simple equipment and a low-cost manufacturing process.

KEYWORDS: 3D-printing, heat-forming, infill, PLA, meshing

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IZRADA ZAKRIVLJENIH MREŽASTIH STRUKTURA TERMIČKIM OBLIKOVANJEM 3D ŠTAMPANIH DELOVA

REZIME: Ovo istraživanje ispituje mogućnost izrade zakrivljenih mrežastih struktura termičkim oblikovanjem 3D štampanih delova, pri čemu se kupolasti oblici dobijaju korišćenjem samo 3D štampača i ručnog presovanja. U poređenju sa konvencionalnim metodama 3D modelovanja, ovaj pristup je brži, smanjuje količinu otpadnog materijala eliminisanjem potpornih struktura i omogućava postizanje glađe završne obrade površine deformacijom ravnih mrežastih struktura. U istraživanju su korišćeni PLA mrežasti uzorci sa heksagonalnom mrežom ispune gustine 20% i 40%, štampani u debljinama od 1 mm i 2 mm. Svi ostali parametri štampe ostali su nepromenjeni. Pre oblikovanja, uzorci su zagrevani na grejnoj podlozi zatvorenog 3D štampača. Oblikovanje je vršeno pomoću jednodelnog kalupa napravljenog od PET-G materijala, sa hemisferičnim profilom izdignutim 10 mm iznad osnove. U kalup su ugrađene vertikalne vođice radi boljeg poravnanja tokom procesa oblikovanja. Dobijeni delovi su u velikoj meri odgovarali predviđenoj geometriji, uz manje nepravilnosti izazvane uvijanjem tokom ručnog presovanja. Iako su potrebna dodatna unapređenja u vođenju i stabilnosti presovanja, rezultati pokazuju da je termičko oblikovanje efikasna metoda za izradu zakrivljenih mrežastih struktura. Kao dokaz koncepta, istraživanje potvrđuje da se složeni kupolasti oblici mogu uspešno proizvesti jednostavnom opremom i ekonomičnim proizvodnim postupkom.

KLJUČNE REČI: 3D štampa, termičko oblikovanje, ispuna, PLA, mrežasta struktura

INTRODUCTION

Fused deposition modelling (FDM) has seen rapid advancements in the availability, reliability, printing speed and precision of printers, different slicing techniques, as well as a widening of the range of applications of printed goods. The proliferation of so-called print farms has positioned 3D-printed parts in use cases outside of just one-off designs or prototype refinement and made it an integral part of a lot of small- to medium-sized production runs. The ability to create geometrical shapes which were unimaginable due to technological limitations allows engineers to create more use-appropriate parts with optimized geometries and allows midcycle optimization of the design without having to stop production to retool and remould.

The limitations of FDM 3D printing with polymers are well known and documented. Some practical limitations in assembled mechanisms can be overcome with the combined use of off-the-shelf industrial parts and their implementation using various fitment means, as was done by Palić et al. (2025), Vasić et al. (2025) and Jovanović Pešić et al. (2025). Over the years, some limitations have been mitigated to a certain extent through clever use of slicer settings; however, some feature shapes still lend themselves better to parts produced by conventional injection moulding.

One such feature is a protruding or dome-shaped mesh. Conventionally, this process would require support material, which would be difficult to remove from thin meshes, and it would also make the outer and inner surfaces of the domed mesh rigid because layered deposition is planar. This would create not only aesthetic issues but also structural ones, since the ridges would be stress concentration points, especially for shallower domes. Vapour polishing, as presented by Mathew et al. (2023), could be a solution for the aesthetic problem for specific materials, but due to the thin mesh structure having little material, it would create new problems with potential geometrical distortion. Maity et al. (2023) further advanced non-planar printing techniques, enabling improved surface quality on curved layers with geometries extending along the X-, Y-, and Z-axes. This approach is particularly advantageous for components such as aerofoils, where surface quality can have a direct impact on functional performance. Beyond improving surface finish, non-planar printing has also demonstrated the potential to increase the printable overhang angle without requiring additional support structures. This capability was demonstrated by Vele and Achten (2023) using unconventional printing materials, specifically through experiments involving clay, while Wüthrich et al. (2021) investigated the use of PLA filaments. Another potential solution for the ridging issue was presented by Lalegani Dezaki et al. (2020), Alinaghypour et al. (2026) and Antonelli et al. (2025); however, this can only be applied to solid models and would not work well with thin mesh structures. This means that the best solution for this type of problem would be to avoid producing the dome using conventional means.

Printing out of plane has been done before and has its limitations, as has been shown by Hrib et al. (2023), where the authors propose a new approach to the 3D printing process by using a robotic arm to ensure more than 3 degrees of freedom and deposition paths with spatial orientation. They proposed two types of working: nonplanar with the tip normal to the working plane and nonplanar with the tip normal to the trajectory. This approach, however, is costly and requires additional equipment most do not have. Other research in the field of non-planar slicing, such as Li et al. (2025), Yao et al. (2024) and Li et al. (2026), shows the possibility of using the slicer to instruct the printhead to use a path which follows the shape; however, for meshed domes, this could be problematic as the bottom side of the

structure needs to be hollow and bridging in this manner would lead to incorrect geometry. The use of a support structure has its limitations in this regard as well, since there needs to be clearance for the nozzle geometry, resulting in geometries with smooth curves but shallow depth.

This research focuses on the creation of an easy-to-create and accessible way to make meshed domes using just an FDM 3D printer. The idea is to show the benefits and limitations of the chosen process and, through experimental results, provide guidelines for implementing this method in practice. This process can be useful in the auto industry in the prototyping phase for producing meshes for air intakes, speaker covers, etc., as well as in the customization and repair sectors for creating replacement parts which are unavailable due to being discontinued.

PROBLEM FORMULATION

For the purposes of this research, two options were considered for mesh generation. One was to have four different models with the desired meshes designed into features of a part file, which would be converted into .STL files for slicing, in which case the mesh would be considered by the slicer as walls. This approach was ultimately not accepted due to the difficulty in giving a precise percentage of mesh coverage and a messy toolpath in the slicer. Another option was to use the slicer's ability to create infill meshes and remove the top and bottom layers, making the inner circle an exact percentage infill with clean paths and precise thicknesses. This approach meant that in order to make the outer rim of the design sturdy, the wall line count would need to go up in order to not have the rim be hollow and lose rigidity. Ultimately, this was the method which was chosen, as the preparation was easier and faster to do, as well as easy to control.

The geometry of all wafers followed the same formula with identical inner and outer diameters and used a formula for determining the lip height so the total part height would be $a_1 = 2,5b$. Two mesh densities of 20% and 40% were selected, as well as two thicknesses of $b=1$ mm and $b=2$ mm. The four samples were created from two-part files, which were both full cross-section circular discs with a lip, as shown in the dimension sketch in Figure 1a. The part files created in Autodesk Inventor were then saved as .STL files and opened in Bambu Studio V2.5.0.66, where slicer options for meshing were set to 20% and 40%, respectively, and a wall-count number of 10 with top and bottom layers set to 0mm. This is illustrated in Figure 1b, where the sliced preview is given for the 20% infill $b=2$ mm model. Finally, all four parts were printed using a Bambu Lab H2S AMS Combo using AzureFilm white PLA filament, with all other slicer settings set to their default values. Figure 1c shows an example of the resulting mesh.

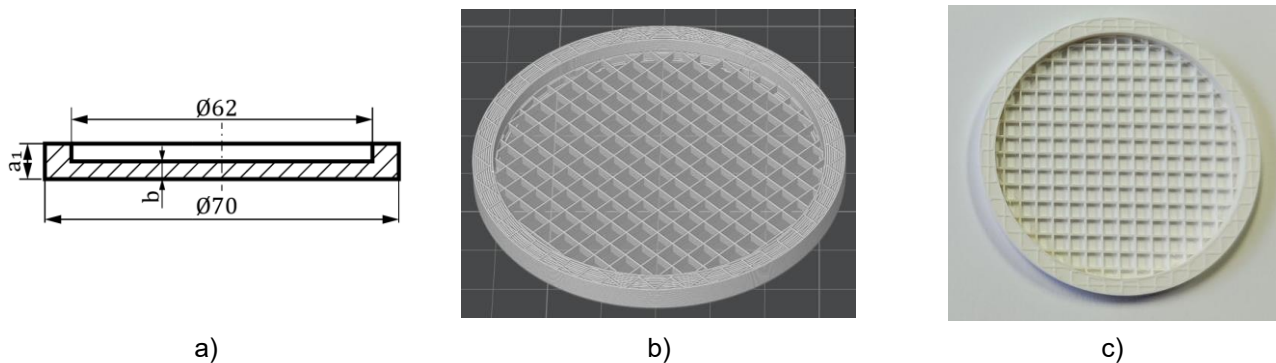


Figure 1 Mesh example: a) dimensions of 3D models, b) sliced part and c) final printed part before moulding

This process was repeated for all four models, with printing taking roughly 12 to 20 minutes for each mesh. All models were printed using 0.16 mm resolution.

MOULD DESIGN

To create a dome-like shape with the printed mesh wafers, a mould was designed to guide and shape the 2D meshes into the desired form. The mould was chosen with a dome height of 10mm, which, accounting for some spring-back, was expected to increase the part height by roughly 9mm. Since little literature is available for specific spring-back rates of meshed 3D-printed parts, the authors relied on previous experience with thermoforming PLA. The mould was designed in Autodesk Inventor using the dimensions shown in Figure 2a, and the model (Figure 2b) was sliced and printed in purple DevilDesign PET-G with a 0.2 mm (Figure 2c) resolution since the surface finish of the dome was expected not to have an impact on the moulding process, as the ridging would not be able to imprint onto the meshes given the low temperature of forming, small forces being applied and lack of pressure on the meshed surface itself. The tension of the material stretching over the dome ensured a smooth inner surface of the moulded parts.

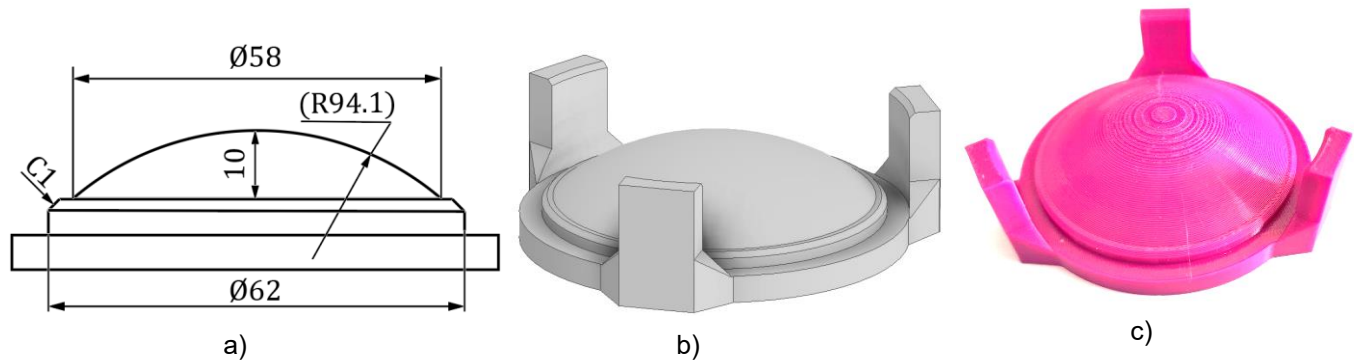


Figure 2 Mould design a) dimensions, b) 3D model and c) final printed part

The mould's inner diameter is Ø58 to allow room for a gradual bend on the bottom side, avoiding stress concentration and making pressing easier. This creates a smoother geometric transition, as illustrated in Figure 4, which shows half the cross-section. The mould also has a chamfer of 1mm around the Ø62 diameter in order to more easily centre the rim onto the mould once it reaches that level.

RESULTUS

The moulding process was found through trial and error. It was found that using the print bed preheated to 100 °C was sufficient to make the parts mouldable after only 15 seconds. The enclosed bed of the Bambu Lab H2S AMS Combo, used to print all the parts, was also used to heat the parts for moulding. Parts were moulded one at a time by preheating the print bed. Once the bed reached 100 °C a mesh was placed, flat side down, on the print bed along with the mould. After 15 seconds, the wafer was flipped and pressed onto the mould by hand down to the limiting surface and held there until the parts were cooled, which was roughly 30 seconds. After that, the parts were removed from the mould and left to cool to room temperature. The process was repeated for all four examples. Figure 3 shows the resulting meshes.

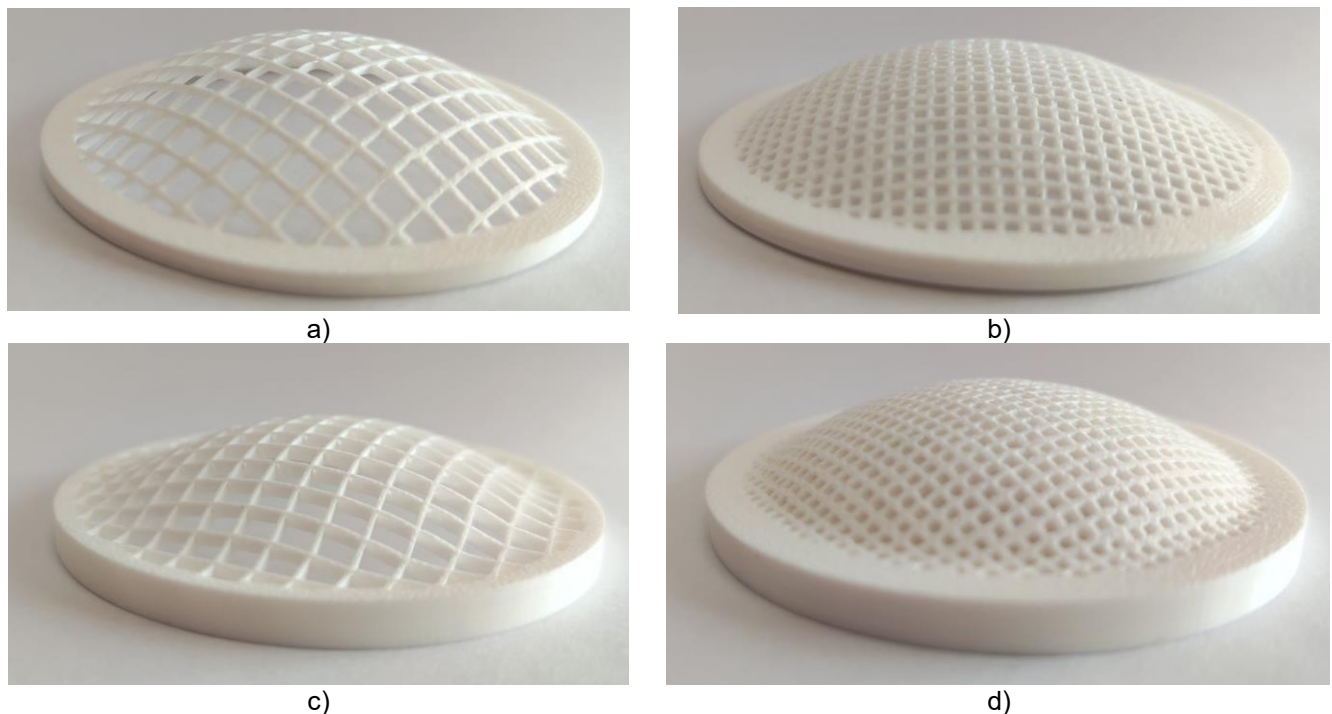


Figure 3 Moulded parts a) 20%, b=1mm, b) 40%, b=1mm, c) 20%, b=2mm and d) 40%, b=2mm

The created meshes showed some spring-back, as expected, and slight shrinkage in the inner diameter. Figure 4 illustrates the dimensions which were examined after the moulded parts had cooled.

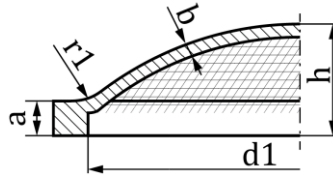


Figure 4 Type the title of the Figure here

Table 1 provides the dimensions of the moulded meshes according to Figure 4. Measurements were done using Vernier callipers and a radius gauge.

Table 1 Resulting geometry dimensions

Dimension	20%, b=1 mm	40%, b=1 mm	20%, b=2 mm	40%, b=2 mm
d1	61	60.2	61.1	61.2
r1	8	15	14.5	7.5
a	2.6	2.8	4.8	4.9
h	13	13	13.8	14.2

CONCLUSIONS

This paper focused on the practical application of hot-forming by hand-pressing grid-type meshes into a specific dome shape using only the available means provided by the 3D printer and geometry slicer. The proposed method successfully formed round grid meshes with 20% and 40% infill into a dome 10 mm tall using grids of 1 and 2 mm thickness. All models started as round Ø70 mm plates with 1- and 2-mm-thick Ø62 mm inbored circles and a 1.5x-taller lip around the part. Parts were sliced in Bambu Studio V2.5.0.66 with the specified infills, and the top and bottom layers were removed to create a see-through mesh in the middle and thick walls using a high wall line count. Parts were printed in PLA and later moulded inside the Bambu Lab H2S AMS Combo. The forming tool was printed on the same printer using PET-G to ensure there is no deformation of the mould during the short heating time. The wafers were hand-pressed after 15 seconds at 100 °C on the print bed and held in place for 30 seconds before being removed from the mould. The achieved results demonstrate little noticeable difference in part geometry compared to the ideal shape they were intended to be moulded into. There was a decrease of ~1 mm in the 20% mesh and 40% mesh diameter of the 1 mm thick model, as well as the 2 mm 20% mesh model, while the 40% mesh with 2 mm thickness decreased by less than 0.5 mm.

It should be noted that since this technique is intended for hand pressing, there will inevitably be some twist in the resulting shape unless the design incorporates some form of guide, either through the addition of a notch, or some other shape, or just by forming shapes which are not completely round. In this research, minor warping due to a small twist during the forming process had resulted in the geometry being skewed by less than 0.5 mm, which did not significantly impact the structure, nor is it easily visible to the naked eye. The models have also slightly warped out of the circle plane after cooling, with a height variation of less than 0.5 mm, which is insignificant but noteworthy.

This experiment proves that simple shapes can be easily hot-formed with just an enclosed 3D printer and a controlled process. The application of these types of formed meshes is possible in a wide range of use cases. Future research will focus on more experimentation using different thicknesses, mesh infills and mould radii, as well as mould depth, in order to map out the results and show the limits of feasibility using this method of mesh forming. Another thing which will be interesting to test is the strength under load of formed meshes compared to flat meshes, since the shape should have better stress distribution, but it is still unclear how much of an impact the internal stresses of the forming process and the deformation itself have on the strength of the part.

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