Performative System
Linking Design and Developing System Based on Behavior of Material

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***Abstract*- The Paper describes understanding the material behavior of Acrylic, its different forms, and the properties that it evolves into when subjected to heat; calculate the deflections and resultant forms achieved. The research speculates design ideas for architectural outer skins, interiors or, for rapid prototyping incorporating high-end fabrication techniques and digital tools necessary for the simulation of the anticipated material behavior and its implementation into desired design or design form. The ultimate goal will be to develop a system or apparatus driven through computer-aided design (CAD) which shall be based on the understanding of material behavior through physical experiments. A digital part is preceded by physical experiments to attain desired shape or form. The design idea or form for various architectural skins and interior products can be verified using various analysis tools for quantitative data. The aim is also to entrench Acrylic (Thermoplastic) as one of the alternate building materials for architectural outer skins, facades as well as in interiors in a required or desired curved form.**

***Index Terms*- Acrylic, Digital Fabrication techniques, Material behavior, parametric design.**

I. INTRODUCTION

Architecture is both the procedure and the product of planning, designing, and constructing buildings or any other structures. On the other hand parametric design is a process based on algorithmic thinking and calculations that indorses the set of parameters and rules that, together, define, encrypt and rectify the relationship between design objective and design response.
Parametric design can be defined as an archetype in design where the relationship between various elements are used to manipulate and apprise the design of complex geometries and structures which include complex surface geometries, form based on material behavior and doubly curved forms. All the complex geometries and forms can be achieved through different techniques and material but when it comes to doubly curved forms; it is difficult to achieve the exact configuration of required form through the techniques used for other geometries. This becomes a hindrance for the designers to use the exact configuration for their respective design ideas.

To overcome such problem and to provide an easy better, economical and sustainable approach to acquire double curvature, a system has to be proposed.

Why acrylic?

Acrylic is a thermosetting plastic which possess strong intermolecular bonding and therefore once the plastic is set into finished shape under the certain combined action of heat and pressure, reheating will not soften it. Excessive heat may result in its decomposition. During the application of heat and pressure the material first becomes plastic and flows to take the shape of the mold cavity. Subsequently under the action of heat, irreversible chemical change takes place.

$$\text{Thermoplastic} \xrightarrow{\text{Heat}} \text{Softens} \xrightarrow{\text{Cool}} \text{Hard}$$

Advantages of Acrylic as a building material:

a. Good design flexibility, i.e. they can be molded to desired form
b. Good thermal insulating properties
c. Non-crystalline in nature
d. Non-conductor of heat and electricity
e. It has relatively low softening temperature
f. Exhibit viscoelastic behavior
g. Cost is relatively low when compared with massive metals and other material
h. It shows direct end usability, i.e. they do not need much finishing after being molded.

II. OBJECTIVE

Complex freeform designs and forms are the most prominent trend in computation aided design and parametric architecture. Today, design and fabrication of such structures are based on digital technologies, which have been developed in other industries as well.

The development of a system which has an adaptive mold for production of precast elements, which can have a given double curved form, is the only objective, a system for producing curved panels where repetition is low, and creativity is high. The Mold can give any form and is with the wealth of possible material applications, providing architects and designers with unheard of possibilities in innovative ideas. Working on a configurable mold that can assume complex shapes based on CAD computations will give the architects and designers the freedom to have desired curved forms.

III. METHODOLOGY

Acrylic as a material is known for its flexibility, optical clarity and versatility. A series of experiments were performed to test the variation regarding the heating patterns, with fixed and changing parameters to show its transformation into a double curved surface. This was followed by a series of experiments to examine the reaction of the material to dual heat intensities. Further on, the reaction of the material was also tested with slits and varying geometries. The sheets were also experimented when supported on points of varying heights using an apparatus designed specifically to accommodate these changing parameters. Through the research it was observed that the flexibility of the material when subject to heat would lead to rigidity. The series of experiments gave rise to a variety of interesting forms with varying properties in terms of its horizontal/ vertical strength and curvature.

IV. APPARATUS

Physical experiments were carried on an Apparatus comprising of a 50x50 centimeter wooden board with a grid of 5x5 centimeter, threading bolts with a maximum adjustable height of 8cm and minimum height of 1 cm on each point on the grid. In addition to that, there is an allowance for the sheets to be hung using Thread bolts fixed on all four sides. Acrylic sheets were supported using points in accordance to the grid. The apparatus allows for a variation in heights of various points. Acrylic sheets were also hung using support from threading bolts fixed across all four corners of the sheet.

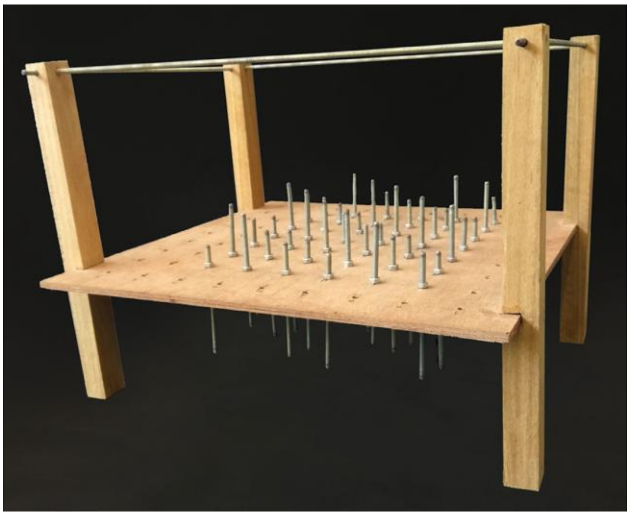

Figure 1, Apparatus used for Physical experiments

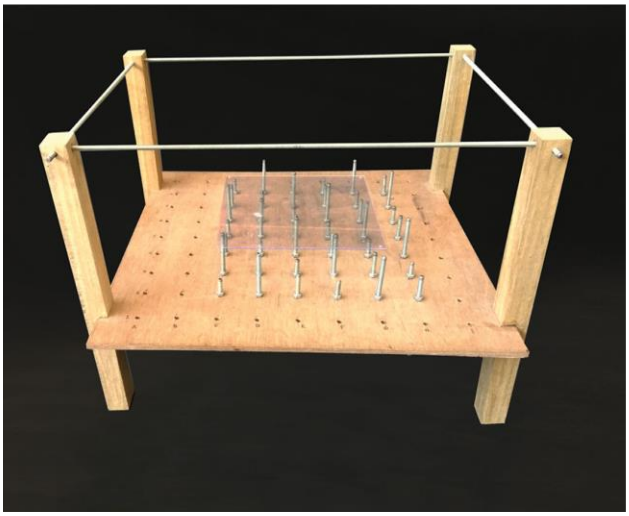

Figure 2, Acrylic sheet on Apparatus

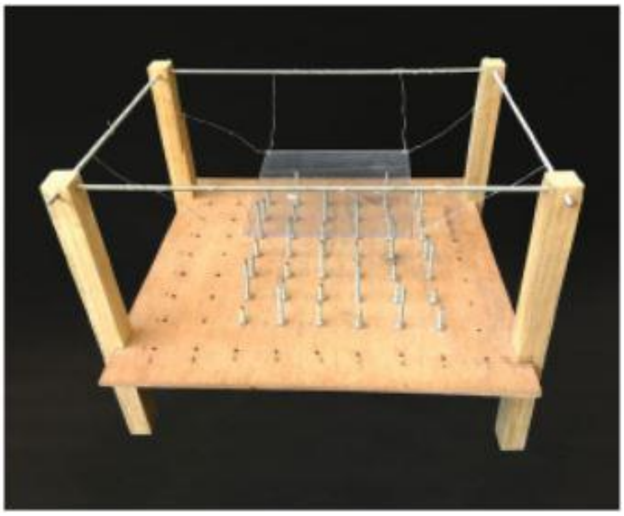

Figure 3, Acrylic sheet hung on Apparatus

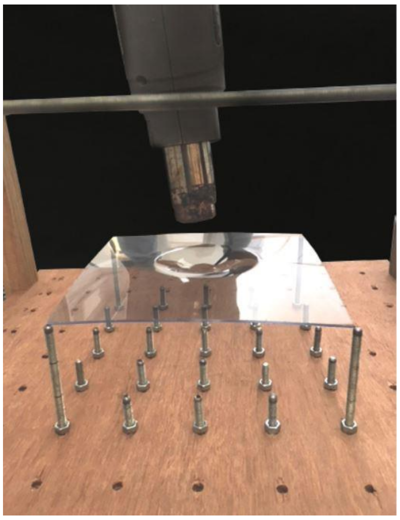

Figure 4, Acrylic sheet placed on points subjected to heat centrally.

A heat gun was used as source of heat to carry all the experiments. Acrylic sheets were subjected to heat using heat gun following either circular or linear heating pattern.

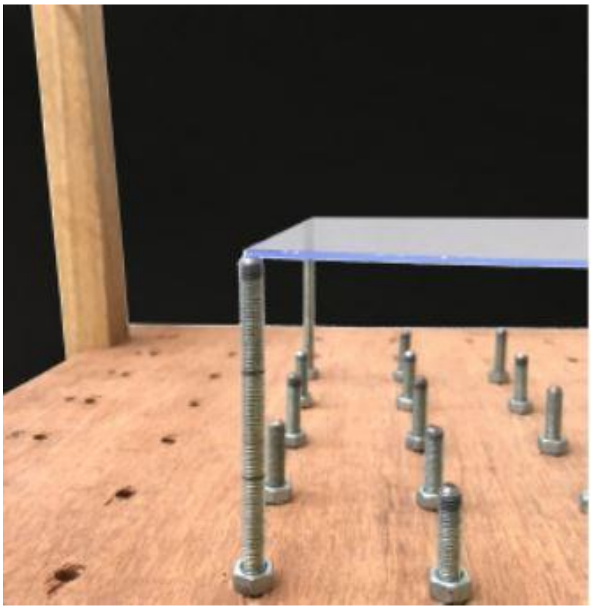

Figure 5, Experimentation using points

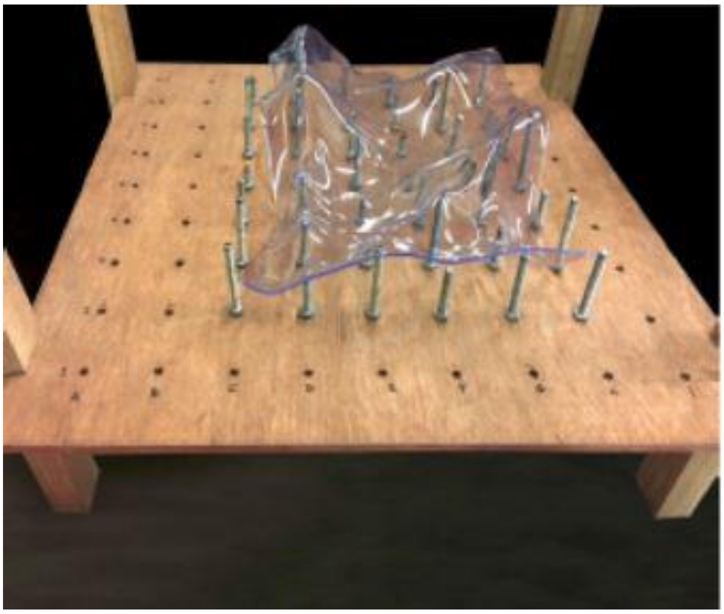

Figure 6, Resultant form after sheet being subjected to heat

V. EXPERIMENT

Stage 1: Experimenting with different heat pattern-

A series of experiments performed using apparatus with certain objects using singular and multiple points with difference in heating pattern.

Experiment 1:

- Acrylic sheet hung
- Heating pattern - Diagonal
- Heating duration – 4 minutes 22 seconds

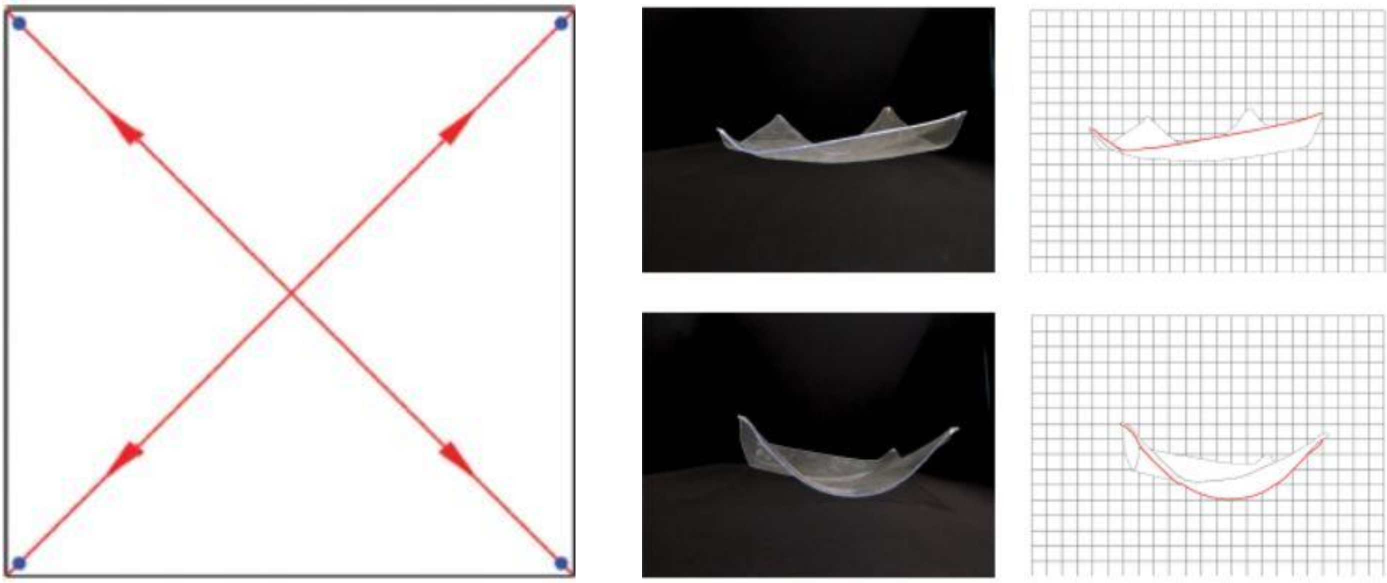

Figure 7, Acrylic sheet placed on points subjected to heat diagonally.

Experiment 2:

- Acrylic sheet hung
- Heating pattern – Linear
- Heating duration-4 minutes 35 seconds.

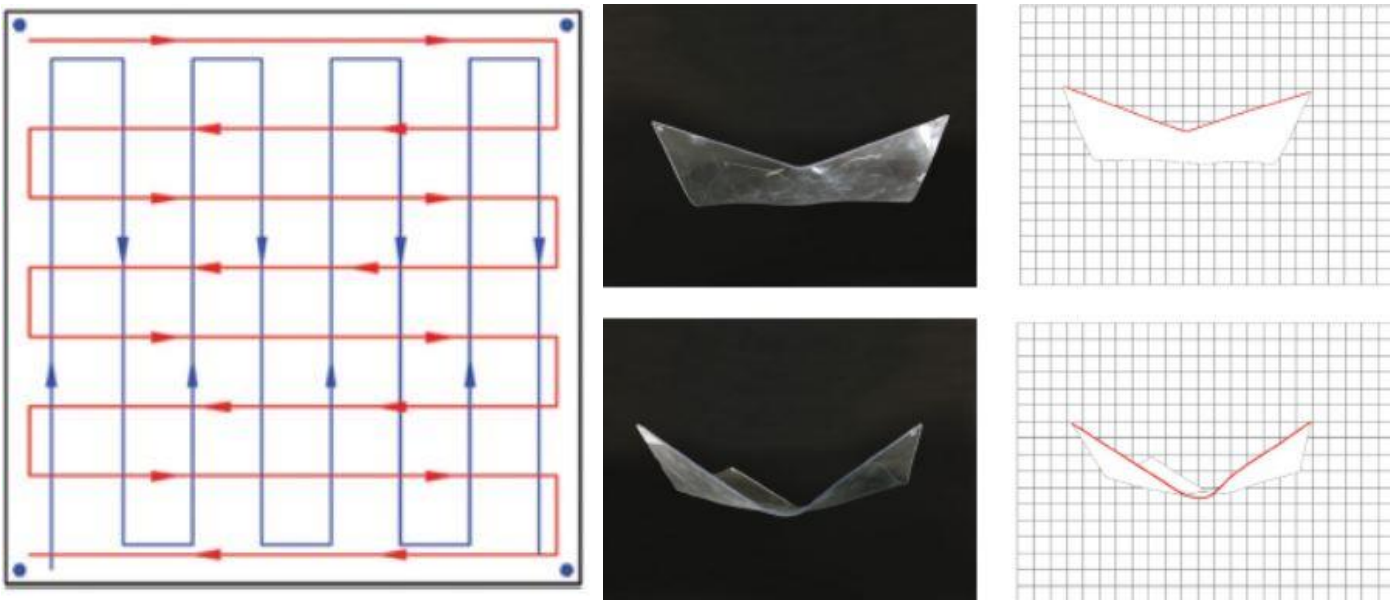

Figure 8, Acrylic sheet placed on points subjected to heat linearly.

Experiment 3:

- Acrylic sheet hung
- Heating pattern – Radial
- Heating duration – 4 minutes 35 seconds

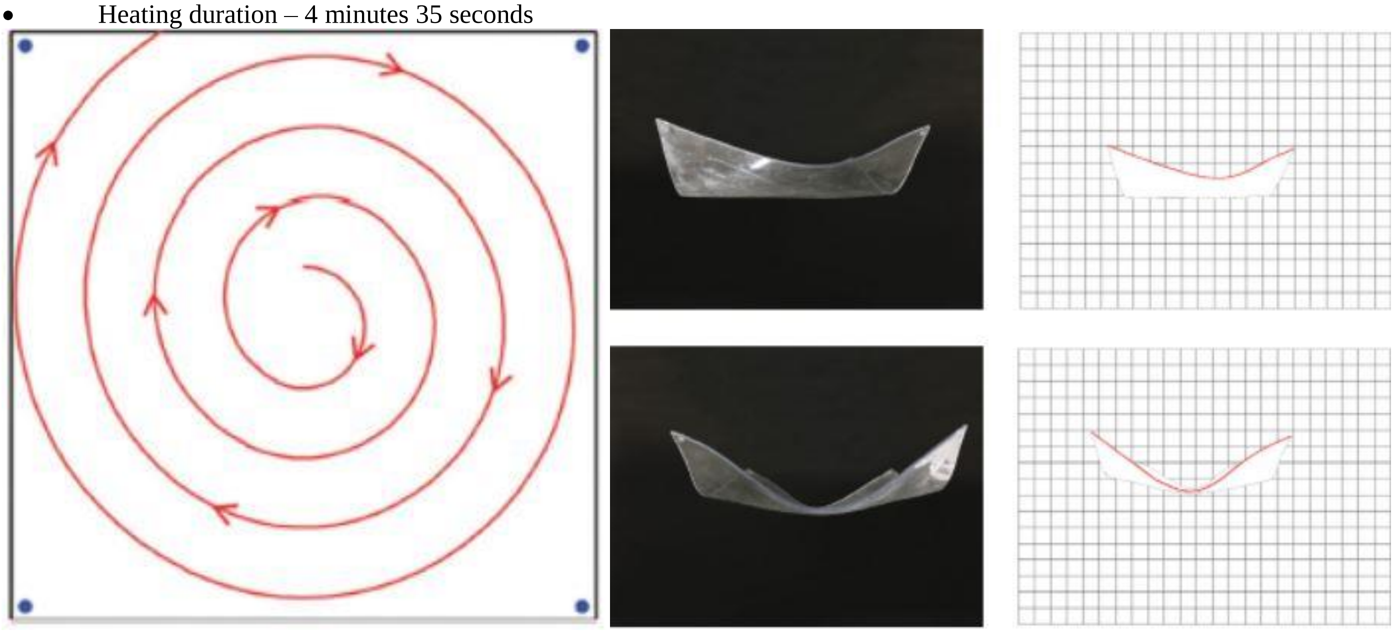

Figure 9, Acrylic sheet placed on points subjected to heat radially.

Stage 2: Experimenting with slits and points-

A series of experiments performed using apparatus with Patterns/Slits on acrylic sheet and then subjecting it to heat.

Experiment 1:

- Acrylic sheet placed on points
- Heating pattern - Linear
- Heating duration – 3 minutes 44 seconds

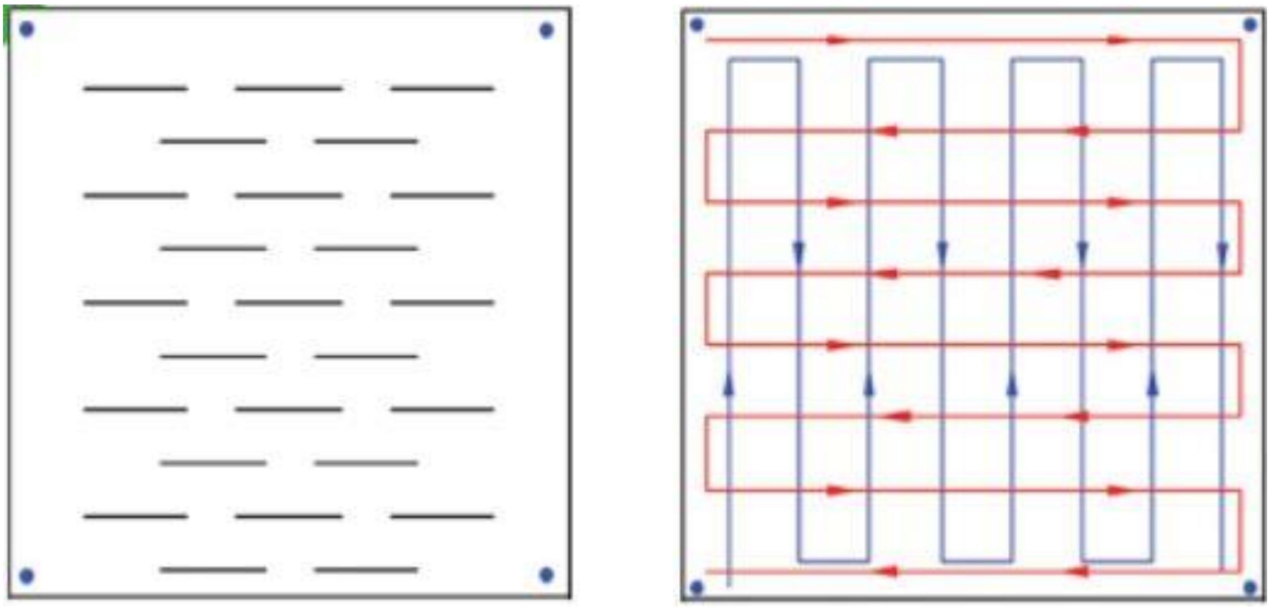

Figure 10(a) Acrylic sheet placed on points subjected to heat linearly.

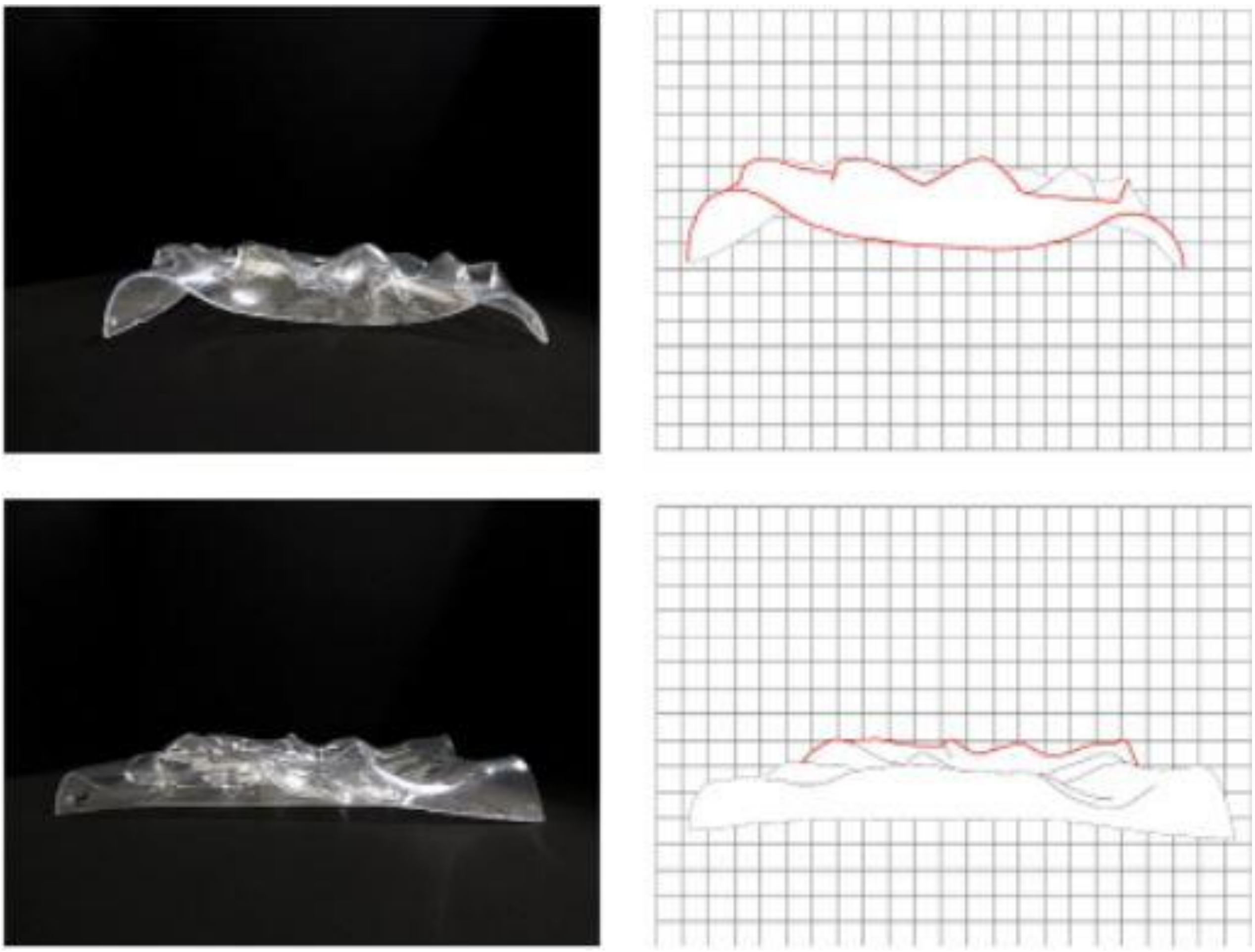

Figure 10(b) Acrylic sheet placed on points subjected to heat linearly.

Stage 3: Experimenting with Variation in points-

Experiment performed using apparatus with acrylic sheet placed on points of different height and then subjecting it to heat. There are three variations of points-

- Point at a height of 11 cm
- Point at a height of 6.5 cm
- Point at a height of 3.5 cm

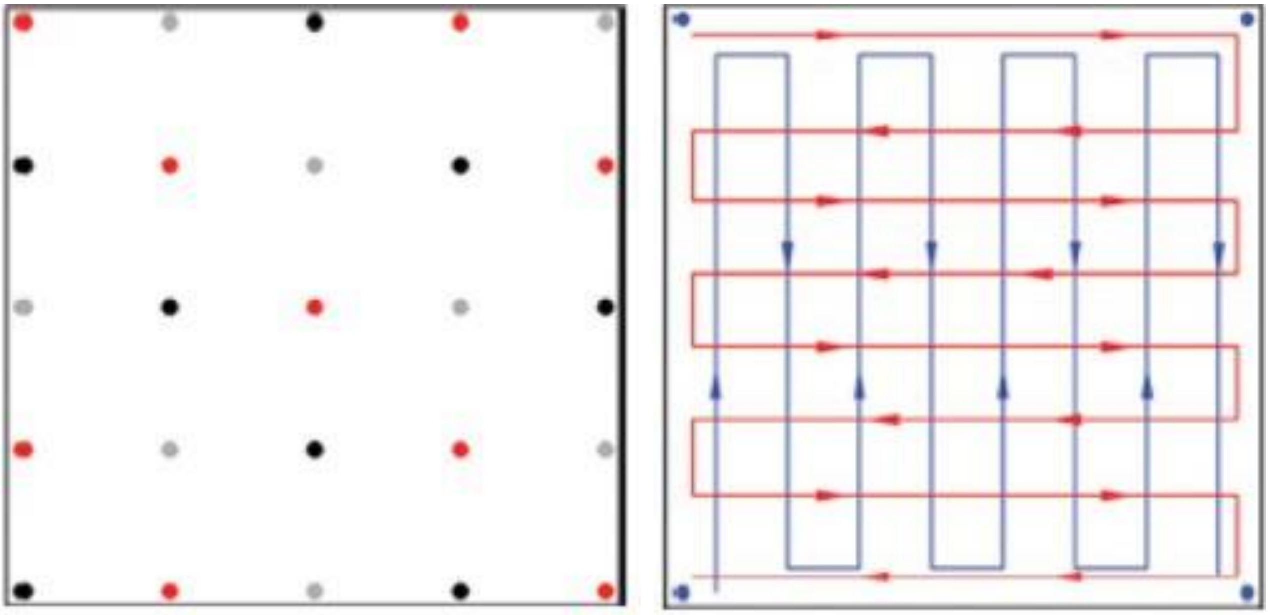

Figure 11(a) Acrylic sheet placed on points with different heights subjected to heat linearly.

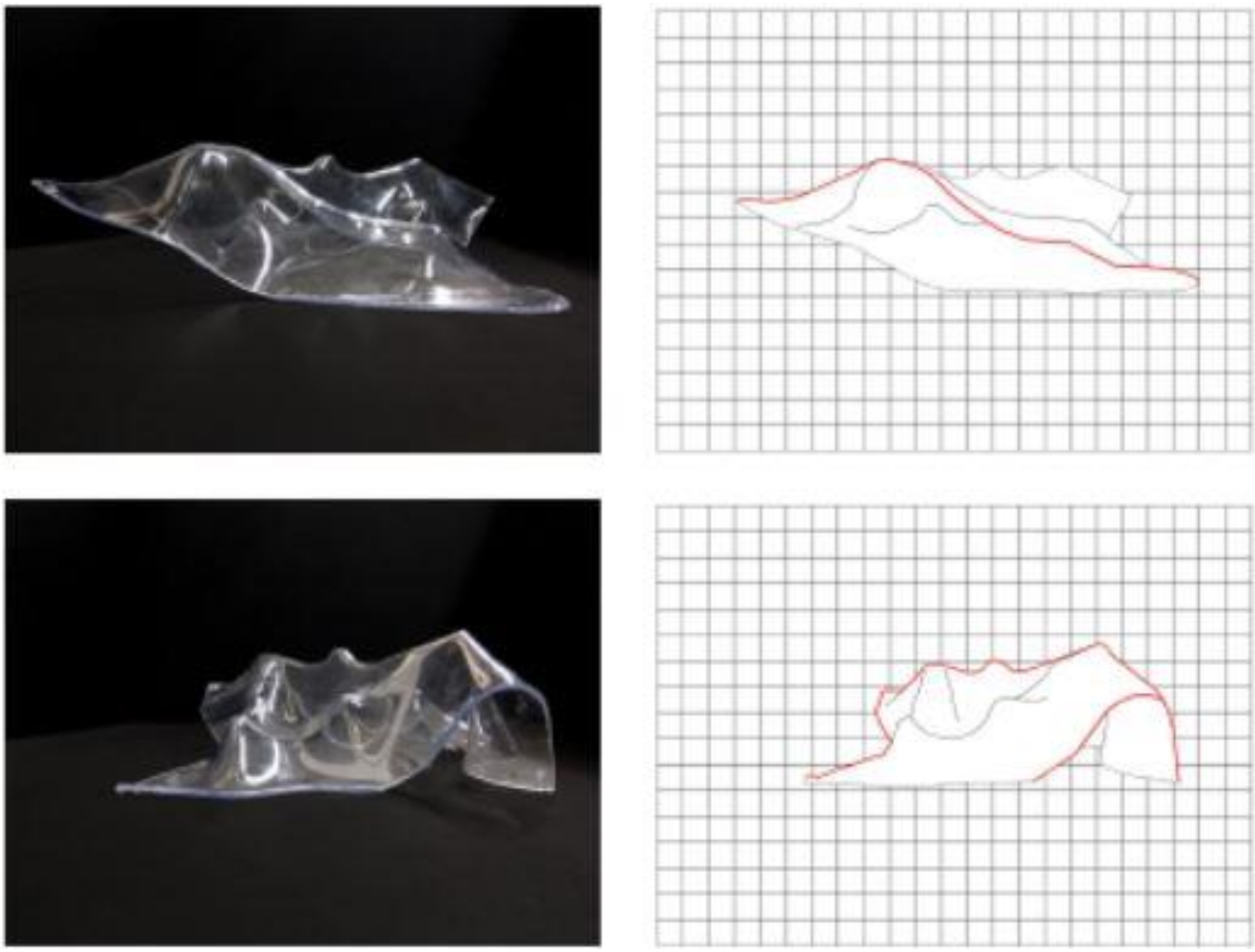

Figure 11(b) Acrylic sheet placed on points with different heights subjected to heat linearly.

Stage 4: Inferences from physical models-

- Change in curvature
- Edges are more curved after subjecting to heat
- Sheet with slits have openings which when heated resulted in ridges which added to its relative strength.
- Doubly curved forms achieved.

Though doubly curved forms were achieved, but their manipulation was not possible with the manually operated heat gun and apparatus. To achieve desired doubly curved form with acrylic, a computer aided system/apparatus needs to be designed which results into desirable forms.

Inferences from physical models would be translated to design ideas into Computation aided software which further can be used as outer architectural skins, facades, interior designing elements.

VI. CONCLUSION

Through the series of experiments, it was deduced that Acrylic as a material evolves and achieves a fixed form along with rigidity when subjected to heat. It was ascertained that the strength of the material was vastly influenced by the double curved surfaces in the form. Certain relationships between the heating patterns, heat intensity, slits and variation in heights of points provided with a qualitative understanding of the properties of the material. Experiments were carried out to achieve certain properties within the material even though a fixed algorithm couldn't be devised to achieve a certain form. Further on, this project would provide with an opportunity to devise better ways of taking the learnings forward overcoming the limitations that come about in the case of scaling up. The future scope of this research paper would be designing apparatus driven by software inputs resulting into doubly curved surfaces.

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