International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 06 | June 2019 www.irjet.net p-ISSN: 2395-0072

Behaviour of Stimulus Responsive Material in 4-D Printing Technology

Pratik Dhotre[1], Amit Chavan[2], Venkatesh Chatne[3], Sumedh Chatse[4]

[1,2,3,4]*Final Year Student, Mechanical Engineering, JSPM's ICOER Wagholi, Pune, Maharashtra, India*

Abstract – *The attraction towards 4D printing is since 2013 when the idea was firstly introduced. The idea is mainly based on 3D printing technology. But for 4D printing additional stimulus and stimulus responsive materials required. As we see in 3D printing the printed object from 3D printer is rigid it will not change its shape and size but in 4D printing with the help of smart materials change in shape and size will occurs after some time of instant. Therefore the objective of this paper was to find the mathematical relation between change in shape and size with respective to stimulus and time.*

Key Words: 4D Printing technology, stimulus, smart materials.

1. INTRODUCTION

Recent research using 3D printing to create active structures has added an exciting new dimension to 3D printing technology. After being printed these active composite materials can change their shape over time which has been termed as 4D printing. 4D printing is a targeted revolution of the 3D printed structure & was initially defined as '4D printing = 3D printing + time' where the shape, property, or functionality of a 3D printed structure can change as a function of time. It is capable of achieving self-assembly, multi-functionality, and self-repair. It is printer independent & predictable.

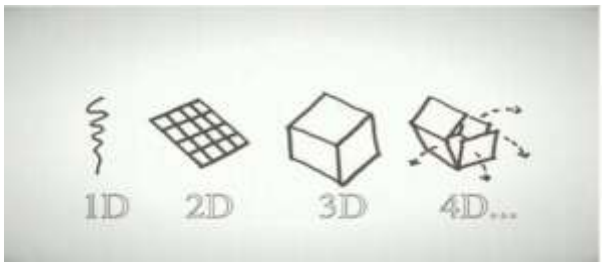

Fig-1: Concept of 4D printing

1.1 Problem Definition

In 4D printing when we apply external energy such as light, heat or any other external stimuli component changes its shape with respect to time when we remove stimulus component regains its original shape. When time comes to zero the shape can't change.

1.2 4D Printing Bases

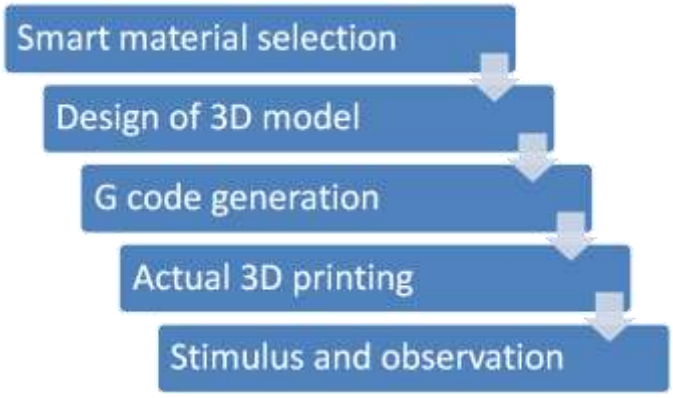

Chart-1: Steps involved in 4D printing

1.2.1 Stimulus responsive materials (SM)

Smart material is a combination of two or more material having different young modulus means that smart material consist of one layer of active material and one layer of passive material. In these paper we take PLA (polylactic acid) as active material and paper membrane as passive material.

1.2.2 Design of 3D model

first of all we draw rough skecth of strip model having dimensions (90*1.6*0.12) on sheet. By using **CATIA V5** software we made 3D model of strip.

1.2.3 G-Code Generation

After completion of 3D model, STL file format loaded on **CURA 15.04.3** software. By giving appropriate parameter such as fill density, print speed, printing temperature, bed temperature, support type, platform adhesion type, filament diameter and flow, nozzle size etc.

1.2.4 3D Printing

3D printing facility: Usually, a 4D printed structure is created by combining several materials in the appropriate distribution into a single, one-time printed structure. The differences in material properties, such as swelling ratio and thermal expansion coefficient, will lead to the desired shape shifting behavior. Therefore, 3D printing is necessary for the fabrication of multi-material structures with simple

geometry. **We used CREALITY CR10S 3D printer for 3D printing**. The printer was run under the following condition printing resolution was set to 100 mm; nozzle temperature was adjusted to 205 _C; bed temperature was considered as 60 _C, and printing speed was tuned to 50 mm/s . PLA is a shape memory polymer having a Tg (glass transition temperature) of60C.

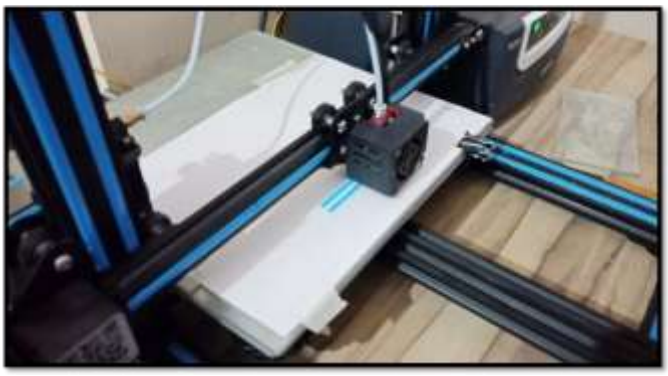

Fig-2: 3D Printing of strip

1.2.5 Stimulus and observation

Stimulus is required to trigger the alterations of shape/property/functionality of a 4D printed structure. The stimuli that researchers have used in 4D printing thus far include water, heat , a combination of heat and light, and a combination of water and heat. The selection of the stimulus depends on the requirements of the specific application, which also determines the types of smart materials employed in the 4D printed structure.

In these experiment we used warm water and hot plate as stimulus, after completion of 3D model we can apply stimulus means these 3D printed strip drop in warm water or keep on hot plate. Actuation of strip occur when stimulus apply to strip means it changes its shape and size in these case contraction of strip occurs.

TIME	TEMPERATURE	STRAIN
0	60	0
50	70	0.0012
100	80	0.0023
150	90	0.0045

Table-1: Observation table

2. Objectives

- To find mathematical relation between time, temperature and change in shape and size.
- To design and developed 3D solid model of PLA strip in CATIA V5.
- To slice the developed 3D solid model of smart PLA strip using CURA 5.04.3 software.
- To generate G code file by applying various machining parameters to CURA .
- Actual 3D printing of developed smart PLA strip using 3D printing machine by FDM.
- To actuate smart PLA strip as per the prediction using stimulus like hot water etc.
- To plot 3 dimensional surface graph.

3. Results

1] Mathematical relation between time, temperature and strain is represented by 3-dimensonal surface curve.

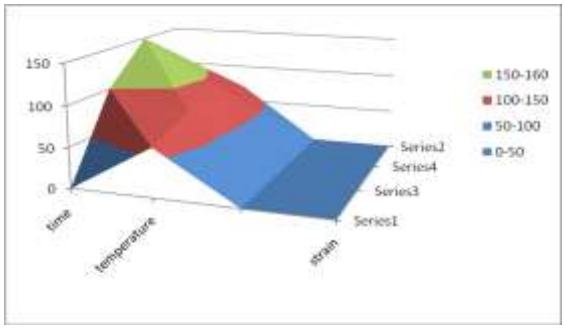

Chart-2: surface chart between time, temperature and strain

2] Relation between time and temperature

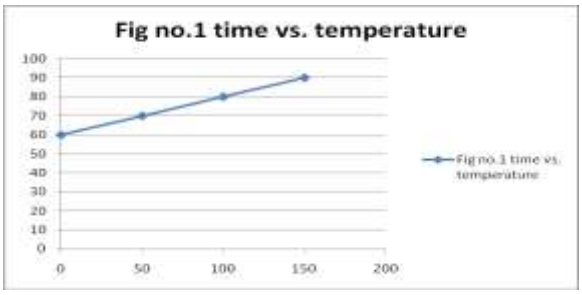

Chart-3: time vs temperature

3] Relation between strain and time

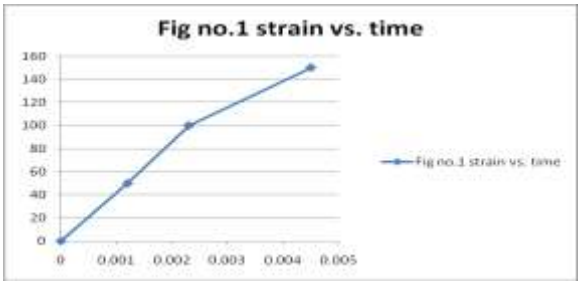

Chart-4: strain vs time

4] Relation between temperature and strain

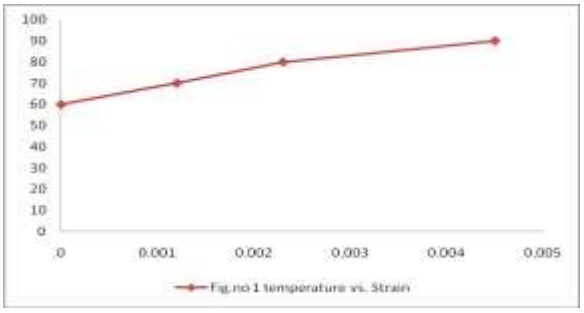

Chart-5: temperature vs strain

4. Conclusion

We studied that stimulus responsive materials change its shape and size with respective to time. when we apply stimulus in this case we use hot water as stimulus for actuation of strip. It started change in shape and size when its temperature greater than its glass transient temperature (T_g), because when temperature is lesser than glass transient temperature the structure of material is straight linked. When temperature increases above glass transient temperature structure of material changes from straight linked to cross linked hence shape and size of material changes**.**

5. Future scope

- Shoes which can transform themselves according to the use required.
- Buildings that could assemble and disassemble themselves.
- Printing bio components that can be implanted to human body.
- In aero plane wings which transform themselves according to the flow of air for better lift.
- Smart valves, connections and sensors for infrastructure lines that can fundamentally respond to control-flow.

ACKNOWLEDGEMENT

I take this opportunity to express my gratitude and indebtedness to my guide **Dr. Sarje S.H.** Head of Department, Mechanical Engineering, JSPM's ICOER who has been constant source of guide and inspiration in preparing this paper.

I also thanks to **Mr. Amol Patil** helped me in completing this Paper work successfully.

I also thankful to Everyone who helped me to completing the paper work and those who have directly or indirectly helped for completion of this Report.

REFERENCES

[1] Momeni, F., M.MehdiHassani.N, S., Liu, X., & Ni, J. (2017). A review of 4D printing. Materials & Design
[2] Tibbits, Skylar (2014-01-01). "4D Printing: Multi-Material Shape Change". Architectural Design.
[3] Germain sossou, fredericdemoly,samuelgomes "Design for 4D printing: rapidly exploring the design space around smart material"
[4] Ramesh, Sai Kiran reddy, Usha , Niranjan kumar naulakha, adithyakumar. "Advancements in the research of 4d printing-a review".
[5] Quan Zhang, Kai Zhang & Gengkai Hu, " Smart three-dimensional lightweight structure triggered from a thin composite sheet via 3D printing technique".

BIOGRAPHIES

Mr. Pratik krushnrao dhotre
BE Mechanical
JSPM's ICOER, Pune

Mr. Amit suresh chavan
BE Mechanical
JSPM's ICOER, Pune

Mr. Venkatesh ganesh chatne
BE Mechanical
JSPM's ICOER, Pune

Mr. Sumedh baban chatse
BE Mechanical
JSPM's ICOER, Pune