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Studies on Development of Soft Robotic Bending Actuator using Natural Rubber

D. Deepak*, Muhammad Ameen, Rohit Jagan and Kashish Kumar

Department of Mechanical and Manufacturing Engineering, Manipal Institute of Technology, Manipal University, Manipal - 576104, Karnataka, India;
deepak.d@manipal.edu, muhammadameen.to@gmail.com, rohitjagan47@gmail.com, kashish1493@gmail.com

Abstract

Objectives: This article investigates the usage of natural rubber in raw form as an alternative to commercial elastomeric for manufacturing the soft robotic actuator. **Methods:** Soft actuator is fabricated with pure latex as well as with formic acid as additive. The mold surface was coated with releasing agent and the latex is carefully poured into the mold. Curing was made at room temperature for 2 days and post curing is done at 80 °C for two hours. **Findings:** The actuator made using natural latex without acid exhibited higher shrinkage. Whereas, the actuator treated with formic acid confirms the dimensional stability and comparatively lesser pores. Hence the natural latex with suitable additives can be used in the manufacture of soft actuators for robots. However, there is need of further investigation for establishing optimum combinations of the additives with natural rubber to obtain the desired properties in the actuator. **Application:** The developments in the proposed field of soft actuator reduce the cost of end effectors which find applications in medical as well as in engineering domain.

Keywords: Actuator, Elastic Material, Latex, 3-D Printing, Soft Robots, Soft Hand

1. Introduction

Soft robotics is an active field of research in robot technology, which uses soft material in complete body of the robot[1]. A new class of robot are developed using soft material which is deformable and having variable stiffness. These are expected to interact with more safely and deal with uncertain and dynamic task[2]. The increased use of robots in day to day life for complex and highly diversified tasks in the production environment necessitates interaction of industrial robots and human with great flexibility and sensitivity[3]. The conventional robots are made using hard material, which in case of a malfunction may lead to irreparable damages, whereas use of soft actuators can prevent such serious damages. The field soft robots are emerged by the inspiration of nature itself, such as octopus arm, elephant trunks and earthworm. Since primitive type of muscles fails to reproduce passive characteristics of biological muscles[4], the development of soft robots has gained popularity. Animal kingdom is a classic example of biological soft actuator in which biological movements are driven by skeletal muscles. Complex movements of the muscle shows that muscles are powerful, versatile and flexible[5]. Depending on structural implementation and contraction dynamics[6,7], the muscle can operate in different modes. Developing such artificial muscle is the most challenging in the field of biomedical science[8,9]. There are similar challenges in soft robotics for the design of actuators as well as in achieving response with external environment[10]. Since the conventional materials exhibits stiffness and brittleness, soft robots require novel materials for the development of robotic components. The cost of the matrix materials used for robots are high, hence there is a

* Author for correspondence

need to explore low cost materials. In considering of this, a soft actuator is developed with natural latex and results are discussed in this article.

2. Methodology

2.1 Material

Latex is a yellowish or white opaque secretion of plants like Heave tree. When the latex in the liquid form is exposed to air, heat or some chemicals, small globules of rubber substance coagulates. The globules of rubber lump get separated from the watery portion of the latex, thus forming an elastic material which is in the solid form. To enhance its resilience, strength and resistance to temperatures, the rubber is cured with certain additives such as formic acid. Table 1 shows the general properties of formic acid. The product thus vulcanized can be stretched to up to eight times its initial length and regain its original shape. Natural rubber is proven to be more elastic and resilient than synthetic rubber. Figure 1 shows the latex extraction process.

Figure 1. The latex extraction process from the tree.

Table 1. Properties of formic acid

PROPERTIES	VALUE
Melting point	8.4 °C
Boiling point	100.8 °C
Density	1.220 g/ml
Solubility in water	Miscible

2.2 Design of the Bending Actuator

Elastic material of any closed cross sectional shape with uniform wall thickness when supplied with compressed air creates internal pressure. This results in expansion of the material both along its axis and also in radial direction. If the thickness of the actuator wall is varying around its cross section, the actuator bends in curvilinear path along the side having higher thickness. Because of the unequal thickness, wall expansion is more towards thinner side compared to thicker side[11]. A thick rib on the actuator provides strength on the surface and prevents the actuator from bulging out at a single point and also transfer load evenly towards the sides of the actuators. Figure 2 shows the computer aided model generated to make the mold which is used in fabrication of the actuator. The molds were printed using rapid prototyping.

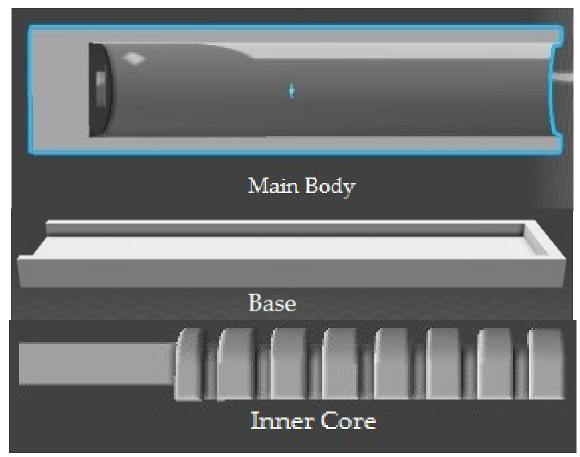


Figure 2. Molds for fabricating actuator.

2.3 Manufacturing of Soft Robot

Soft actuator is fabricated with pure latex as well as with formic acid as additives. Figure 3 shows the molding process of the actuator. Initially the mold surfaces are coated with releasing agent which helps for ease the removal of the actuator from the mold after curing process. The latex is carefully poured into the mold and it is kept for curing at room temperature for 2 days. Natural latex has 70% of water and 30% latex, which vary from place to place, age of the tree, climate. During the curing process, the excess amount of water present in latex extracted is expelled out in the form of foam or water as shown in Figure 4. After initial curing the actuators are removed from the mold and kept under sunlight for post curing, where the excess water evaporates. During the post curing process, the color of the actuator changes to brown. Finally the actuators were cured in oven for two hours at 80^{o} C in free hanging conditions.

Figure 3. The molding process.

3. Results and Discussion

Figure 5 shows the actuator molded using latex without using additive. Figure 5 shows the closer view of the texture of the actuator. These figures shows that the actuator molded with natural latex shows large number of pores which are formed due to expulsion of water during the curing process. Also, due to un-even shrinkage during the curing process the required shape is not replicated on the actuator. Hence an additive called formic acid is included with the latex and the actuator is molded. Formic acid is available in the form of colorless liquid having a highly penetrating odor.

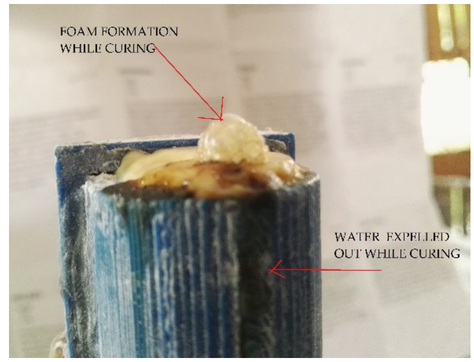
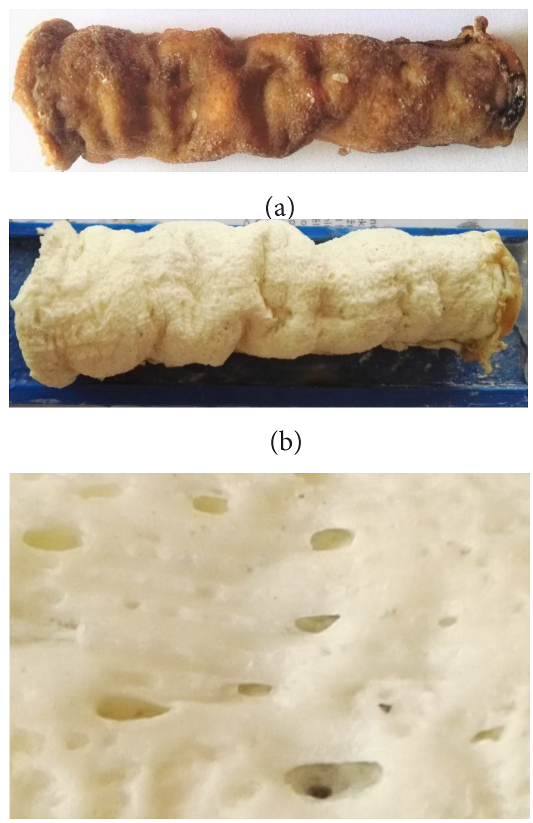


Figure 4. Foam formation on the molded part.



(c)

Figure 5. The actuator (a) cured with sunlight exposure and in oven (b) Curing inside room (c) Pores formed while curing.

Figure 6. Cured actuator with additive.

Figure 6 shows the molded actuator. It is seen that the actuator thus manufactured confirmed the size and shape after the curing process. The surface did not show any pores as found on the actuator made without additive. By stretching both the samples, it is found that the elasticity of actuator with additive has increased considerably compared to actuator without additive. The wall thickness of the actuator molded with the formic acid has decreased compared to the one without acid due to the dilution of the natural latex with water before the acid treatment.

4. Conclusion

Following conclusions were made based on the experimental work. The actuator molded using natural latex without acid exhibited higher shrinkage as well as porous holes and did not confirm to shape of the mold. The actuator treated with formic acid additive confirms the dimensional stability during the molding and comparatively pores produced were reduced. Elasticity of the actuator made with additive is found to be improved compared to actuator made with pure latex. It is concluded that natural latex with suitable additives can be used in the manufacture of soft actuators for robots.

5. Acknowledgement

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