Designing a Compliant Self-Sanitizing Glove Device to Curb COVID-19 Spread

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Abstract
Currently, there are millions of global confirmed cases of COVID-19 outbreak, rendering religious gatherings such as Hajj and Umrah or hospital to be a risk because a single individual can infect hundreds. The number of COVID-19 infections increased rapidly. Lack of a vaccine calls for implementing quick and easy safety steps to curb exposing the masses. This paper suggests developing a compliant self-sanitizing glove technique to prevent the virus spread via touch. Conducting the spray-compliant mechanism design simulation involves making the gloves from a polymer, a low-risk substance. The device contains the sanitizer, and pressure application sprays the liquid, thus creating a compliant spraying device. The device has two major components, the middle section, and the joints. The middle section is the reservoir, while the disposal units are at the ends. The kinematics synthesis equation derived from the Pseudo-Rigid-Body method is used in modeling the compliant device. Testing of the modeling strategy to design the spray device was conducted successfully. The details enable the user to recreate the compliant spray device by inserting the total required length (Lf) to produce the necessary measurements. The self-sanitizing glove is still a new idea, and other clothing items can also use the spray mechanism to promote a hygienic and cleaner surrounding. The gloves have a self-sanitizing ability, including sanitizing the surfaces they contact. Therefore, increased use of gloves can help in infection prevention by providing quick sanitization and hygienic surroundings.

Keywords: *Pandemic, Coronavirus; Self-sanitizing device, Compliant mechanisms, 3D Printed Manufacturing.*

1. Introduction

This research aims at offering solutions to curb the spread of coronavirus outbreaks. The coronavirus spread is currently a pandemic with a global impact. The outbreak has significantly impacted world economies, whose effect hurt humanity. Cases of COVID-19 had surpassed 34 million by the end of September 2020, with only 8 million active cases and deaths crossing over one million worldwide [1, 2]. There will be catastrophic damages if the spread persists, and it will take many years to normalize the consequences. Therefore, it is necessary to develop solutions to help curb the spread.

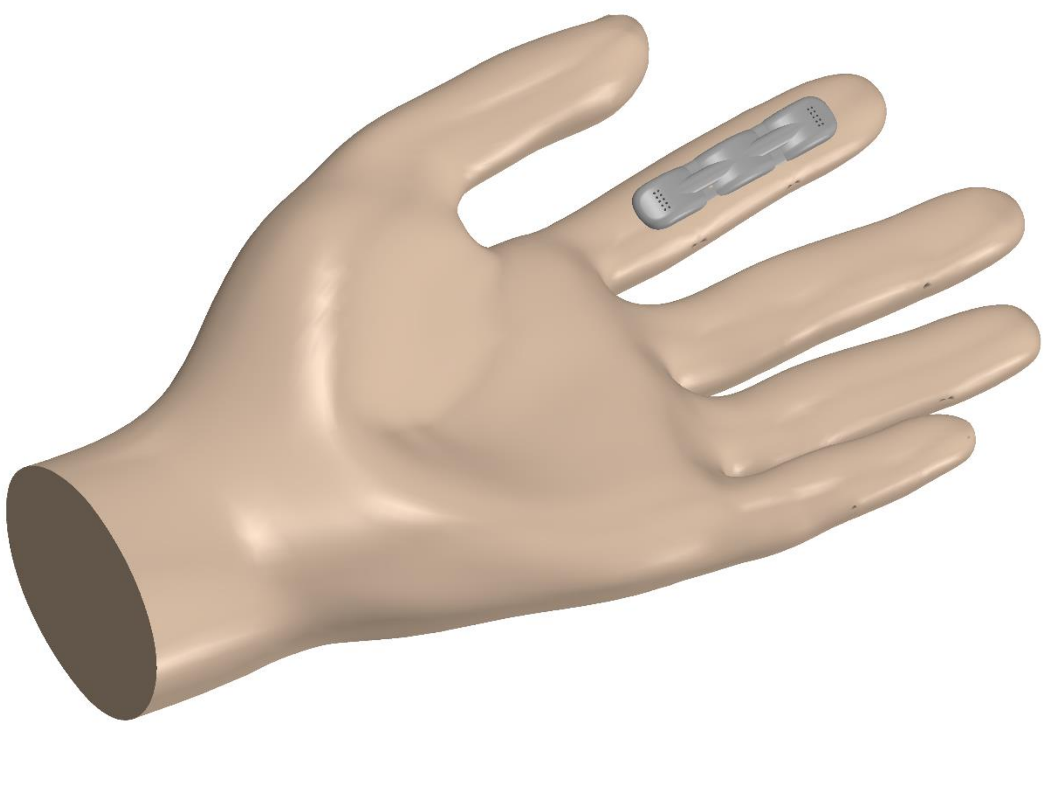
It has been proven that coronavirus spread quickly through our hands [3, 4]. It may take 14 days for symptoms to appear in a single infection case, while the infected case continues their normal activities within the incubation period. This provides a footprint for the virus in every case visit [5, 6]. This means that there are high chances that any surface the case touches will have the virus, meaning that the infection rate will be increased in people touching the same surfaces sanitizing all surfaces in the infected areas is critical in minimizing the virus spread [7,8]. The suggested idea is to develop self-sanitizing gloves which allows the sanitization of every surface touched by a user [9]. This will bar the user from spreading the virus to their face (the most vulnerable area for infection) or other places and surfaces. Besides, it disinfects every object and surface it contacts.

This research will develop self-sanitizing gloves which will prevent the spread of the virus while disinfecting the areas it touches. The self-sanitizing glove will protect the user since it self-sanitizes when a user touches a place. Besides, it will disinfect many infected surfaces thereby eliminating the virus. Increased use of self-sanitizing gloves will eventually reduce infection rates since users will repeatedly sanitize more surfaces.

While this project's needs seem to only apply to this pandemic, many clients desire such a solution. Besides COVID-19, doctors, nurses, administrators, staff, patients, and visitors in hospitals are at risk of many contagious illnesses. Security and police should also be protected since they are in the frontline of catching the disease. Additionally, Hajj and Umrah are the most crucial periods since many people worldwide gather, bringing numerous diseases that require control.

Methodology and materials

A polymer material that does not allow the virus to live on it for long is used to make the glove. It is advisable to use materials made from monolithic processes (single part) like PLA (polylactic acid), Hysoll 9361, and polydimethylsiloxane (PDMS). A compliant spray device containing the sanitizer is placed on the palm-side of the glove [11], as Figure 1 shows.



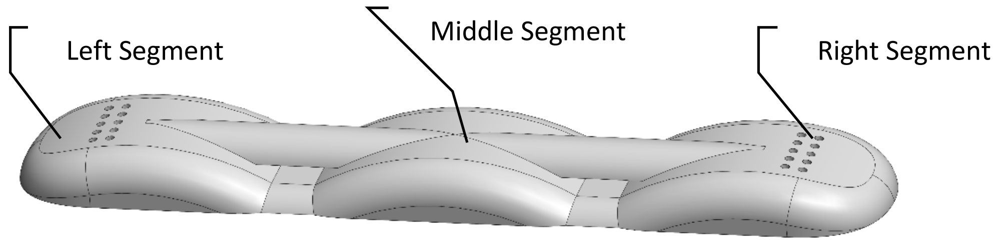


Figure 2: A flat configuration of the compliant spray device. This arrangement stores the sanitizer in the middle section.

Figure 1: diagrammatic representation the self-sanitizing glove. The spray mechanism is embedded on the glove fingers as an evidence of the idea.

The compliant spray device releases the sanitizer every time the hand holds something. The device has various parts (left, middle, and right). The disposal units are in the right and left sections which produce the sanitizer. The middle section contains the sanitizer. Small tubes connect to the middle section for refilling the sanitizer when necessary. Figure 2 shows the schematics of the compliant spray device.

1.1. Designing the spray device:

The whole spray device should fully comply with manufacturing benefits. A 3D printer can fabricate it as one piece from an elastic substance like a stereolithography (STL) 3D printer [12]. It is usually cheaper to print small-sized objects in 3D than large-sized objects. High process dimensional precision and intricate details can be used to make the spray device. Components of SLA provide a very fine finish. SLA products are available, produce transparent, elastic, and moldable resins. Object size increase leads to an exponential price increase. These are resistant to sanitizers will little alcohol. Therefore, they are suitable for storage container fabrication [13]. A casting process with the conventional method can be used in its fabrication. However, the weight may increase with cast section and lower the elasticity and the smooth surface of the spray mechanism.

The spray nozzle is at the left and right segments, where it releases the sanitizer (from the middle section during compression). The nozzle working is similar to a conventional one, only that it is within the section and made from a similar material that needs no assembly, as Figure 4 shows.

The nozzle occupies the middle of the right and left parts and lies 45 degrees from the floor plane, springing sideways, as Figure 4 shows. This ensures that the spray device targets the touched object and covers the most area. Figure 5 elaborates how the 45^0 oriented nozzles will cover more area at 90^0 and 180^0.

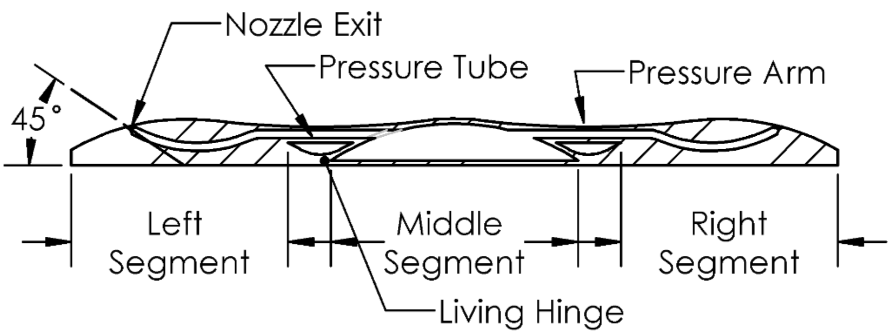


Figure 4: A cross-section of the spray compliant device exposing the device's interior components, the location of the pressure arm, and the angle of nozzle sprout.

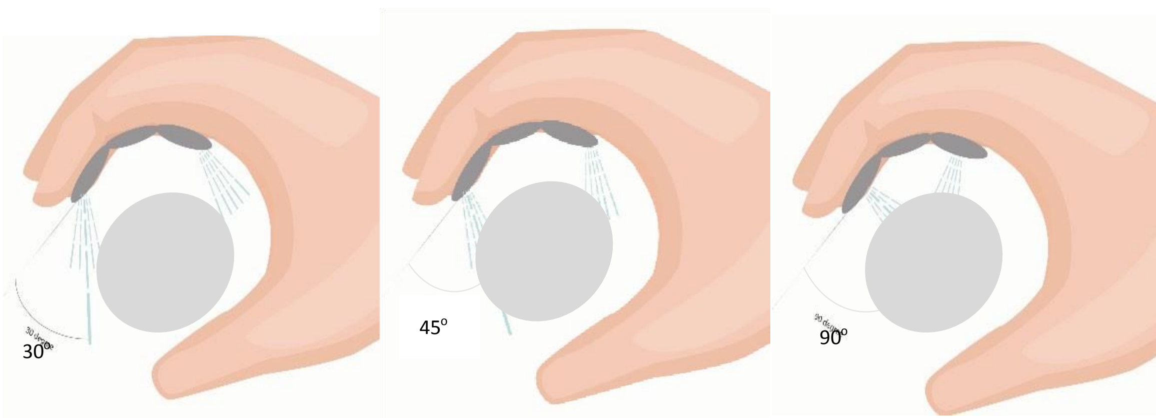


Figure 5: Angle of the nozzle from the base of the spray device. The angle lies at 30°, 45°, and 90° to show the total coverage when an object is gripped.

Findings and Discussion

The following two factors cover the critical concepts of the spray compliant device:

1- The Middle section (sanitizer storage)

The middle section has the liquid ingredient only, with no pressurization. When the joint connection compresses it, the liquid flows through the nozzle tube (pressure arm) to the nozzle, as Figure 6 illustrates. This arrangement compresses the central section forcing the fluid inside the spray nozzles in the left and right sections. The device works to elevate the middle segment pressure, forcing the liquid to be sprayed. An increase in pressure means that the device will regain its original shape (flat shape), creating low pressure within the middle space, refilling the storage from the gloves' main reservoirs.

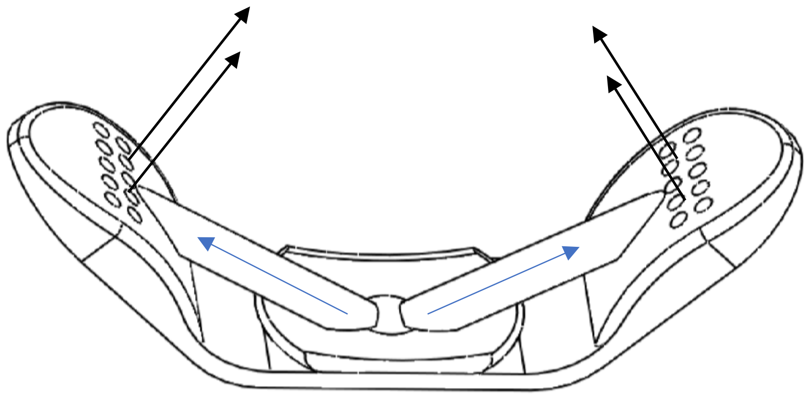


Figure 6: Deformed configuration of the compliant spray device with spout out direction.

A small tube connects to the central part to refill the device when the liquid volume reduces. The pipe is configured to only allow a unidirectional fluid flow to the middle section. The glove material hides the tube. The tube is connected with the middle section with the primary storage positioned atop the side of the glove, as shown in Figure 7. Depending on the drip position, 0.75mL to 3ML of the sanitizer is released. This can be sufficient for medium and large-sized sanitizer.

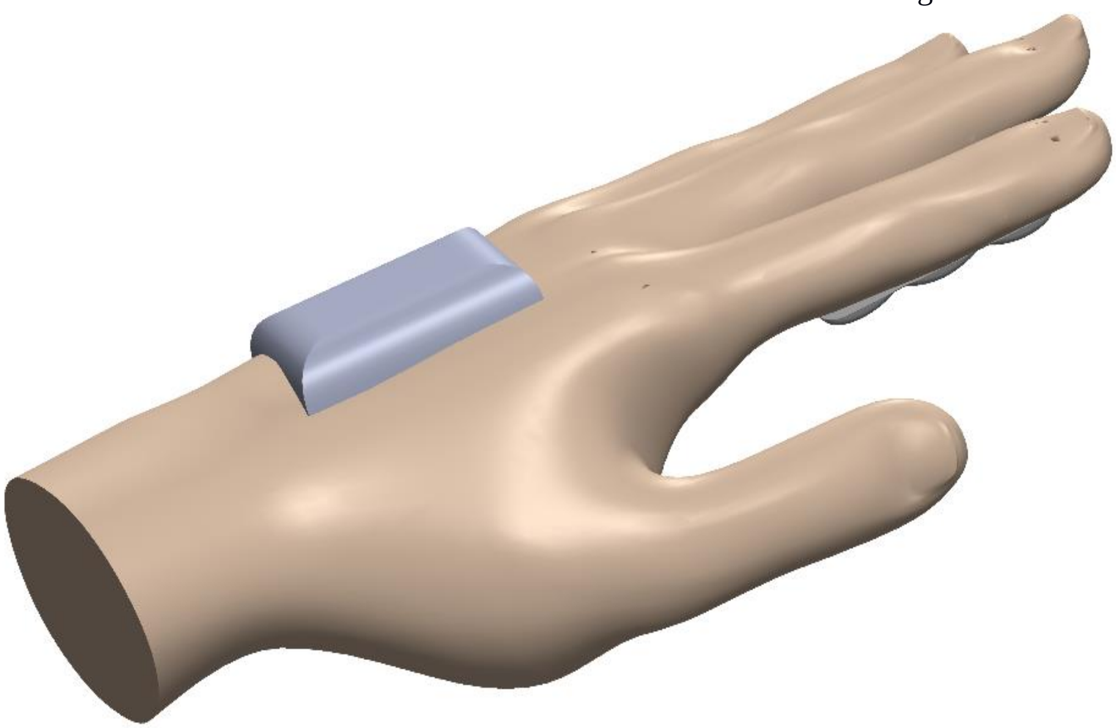


Figure 7: Hand schematic showing the location of primary storage.

2- The connecting links of middle and left sections and right to middle parts. The left and right links joining the sections are compliant connections within the spray device. The compliant device has two critical components, the pressure arm and a small-pivot flexural, shown in Figure 8.

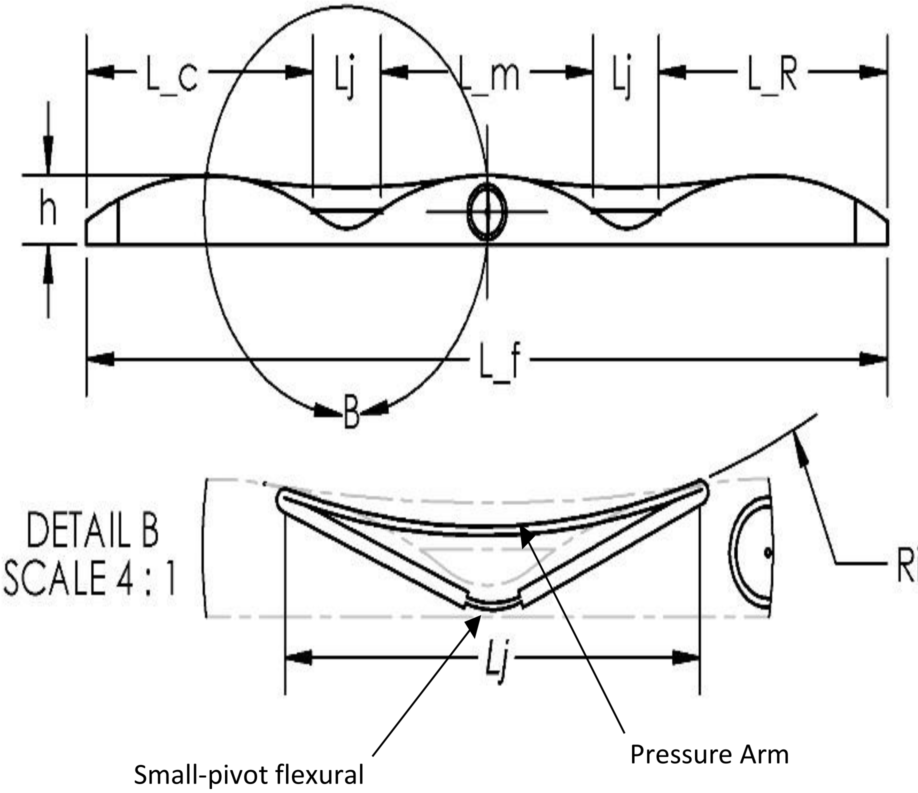


Figure 8: A magnification of the left and middle sections. Illustration B shows the joint skeleton of the device.

The pressure arm is an elastic hollow semicircular cross-section connection joint dominating the stiffness attributes of the spraying device. The blank cross-section allows the fluid to flow from the center to the nozzle when compressing the middle part. During the movement of the left and the right segments, the pressure arm's stiffness compress the middle section pushing out the liquid within it. When the pressure arm's compression on the middle section touches the base, it buckles if the load increases persistently. The pressure arm occupies the right end, with a load increase at the opposite end.

The joints linking the left and the right parts can be designed as fully compliant device with a pressure arm and a small-pivot flexural as one mechanism shown in Figure 9. The Pseudo-Rigid-Body Model can model the fully compliant mechanism as a slider system based on the symmetry of the fully compliant mechanism [14, 15]. The pressure tube link's stiffness is designed as torsional springs placed at the joints. The initial curve characteristic of the link guided the deflection trajectory.

The Pseudo-rigid-body model (PRBM) approach is used to model the pressure arm and the small-pivot flexural. Howell initially developed the PRBM to estimate compliant beams' large deflections. There may be different PRBM in different loading types and conditions. The arm of the pressure joint is a pined-pined beam having clutch force at the ends.

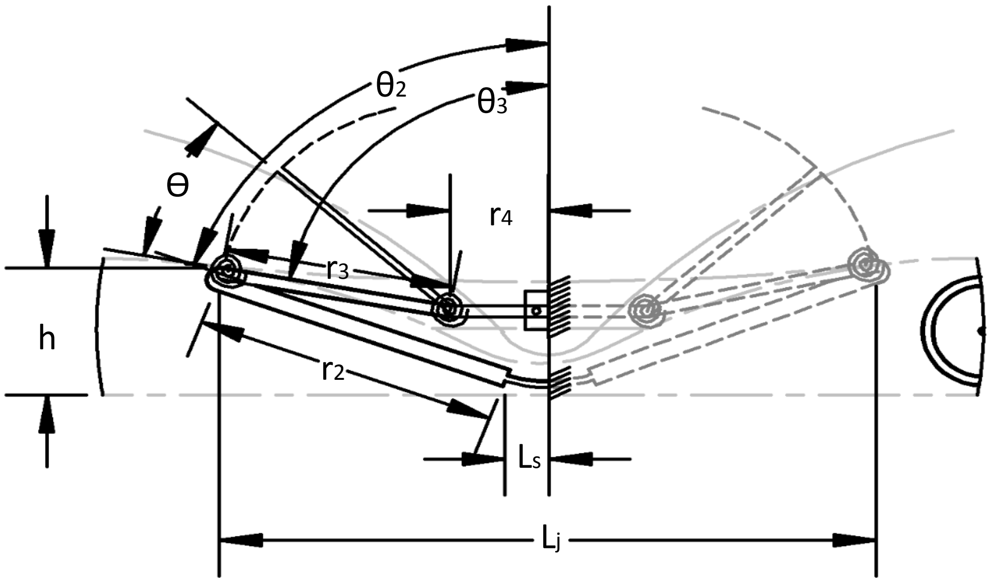


Figure 9: The fully compliant device in which the configuration shows a slider system. The middle of the fully compliant device is considered the base on which the slider vertically slides.

The kinematics process of the device is called a rigid-body replacement synthesis, in which the design approach estimates the compliant joints to be two fixed joints linked with torsional springs. The material properties determine the stiffness coefficient of the torsional spring k, is given at the computed area, showing the resistance of joint deflection. The angle of pseudo-rigid-link deflection is known as the pseudo-rigid-body angle (Θ). This PRBM accounts for the properties of homogenous substance. The joint length of the fully compliant device is regarded as a function of the finger length (Lf). The pseudo-rigid body formulas (1-14) represent this model:

$$L_c = L_R = L_m = 0.3\ L_f \tag{1}$$

$$L_j = 0.05\ L_f \tag{2}$$

$$h = 0.1\ L_f \tag{3}$$

$$r_2 = \sqrt{h^2 + \left(\frac{L_c + L_j}{2}\right)^2} \tag{4}$$

$$r_3 = \frac{L_c + L_j}{2} \tag{5}$$

$$r_4 = \frac{L_j}{2} \qquad 6$$

$$r_1 = r_3 \cos\theta_3 + r_2 \cos\theta_3 \qquad 7$$

$$\theta_3 = \text{asin}\left(\frac{r_4 - r_3 \sin\theta_2}{r_3}\right) \qquad 8$$

$$\theta_{2o} = \frac{\pi}{2} - \text{acos}\left(\frac{h}{r_2}\right) \qquad 9$$

$$F\, a \sin\theta_2 = K_2\big((1+H)(\theta_2 - \theta_{2o}) - (1+2H)(\theta_3 - \theta_{3o})\big) - K_1(\theta_2 - \theta_{2o}) \qquad 10$$

$$K_2 = \frac{2\gamma k_\Theta E\, I_3}{r_3} \qquad 11$$

$$K_1 = \frac{E\, I_s}{L_s}, L_s = \frac{0.15 L_j}{2}, I_s = \frac{w t^3}{12} \qquad 12$$

$$H = \frac{r_2 \cos\theta_2}{r_3 \cos\theta_3} \qquad 13$$

Where $a = r2$, $k\theta$ is a rigidity coefficient equaling Howell's proposed 2.65, *t* is the small pivot flexural diameter equaling 10% width. The spray mechanism's width *w* equals 10% of the spray device's total length. The movement degree of the left segment after touching the floor is vertex angle θ_2, which deflect from the finger movement. Formula 10 guides the mechanism. Formula 14 gives the average gripping strength [16], which can be approximated depending on gender and user age. Equation (10) gives the geometry schematic, which defines the pressure arm's dimensions depending on cross-section *I*3's moment of inertia:

$$I_3 = \frac{9\,\pi^2 - 64}{72\pi}\; R_o^4(1-\boldsymbol{\xi}) + 2R_o^2\boldsymbol{\xi}(1-\boldsymbol{\xi}) \qquad 14$$

Where Ro of Eq. (14) is the external radius as shown in figure 10 and $\boldsymbol{\xi}$ is the ratio between the internal area Ri and the external radius Ro. The ratio has an examination range between 90% to 60% of Ro. The effects of ratio change over the inertia moment for various cross-sections are shown in Figure 10. The experiment of analyzing various cross-sections on a range aims to determine the cross-section offering higher pressure arm stiffness and to what degree.

From Figure 10, moment of inertia of the semicircular cross-section is higher, producing a high tension spring rigidity. It additionally shows that a higher *I* with a higher *I* ratio is preserved at the semicircular cross-section. It also shows that is a maximum at = 73, which will be a constant ratio $\boldsymbol{\xi} = \frac{R_i}{R_o}$**.**

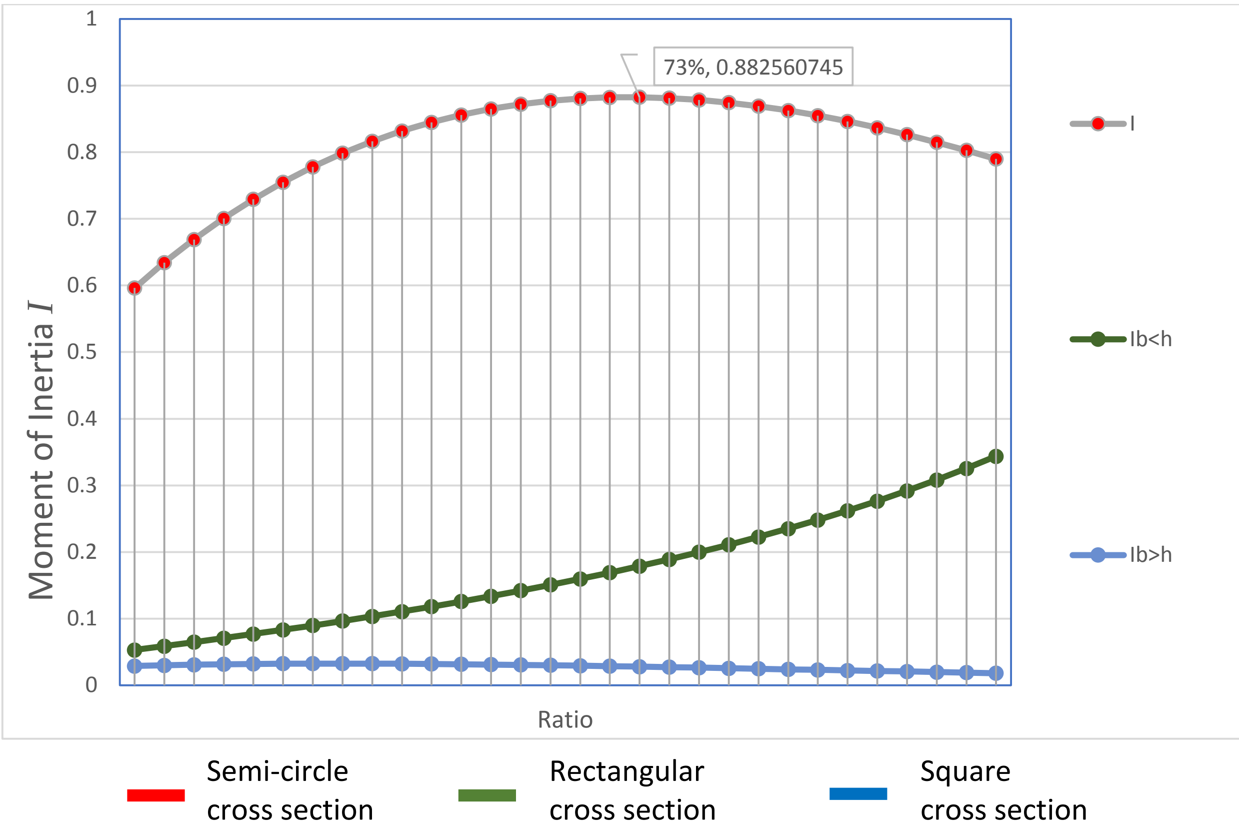


Figure 10: Graphs showing the association between the inertia moment of various blank cross-sections with ratio ranges of the inner and outer measurements.

The grip force of individual fingers is the load acting on the right and the left sections. The load should exceed the acting pressure force within the tube for spraying to happen. Bernoulli equations (15) can be used to calculate the pressure force [17], where the orifice diameter (nozzle exit, *Re*) is the required spray mechanism:

$$q = A_2 \left[\frac{2(p_1 - p_2)}{\rho\left(1 - \left(\frac{A_2}{A_1}\right)^2\right)} \right]^{\frac{1}{2}} \qquad 15$$

Where *q* is the internal pressure arm flow rate, *p2, and A2*, *p1 and A2* are the pressure and the orifice's and the pressure arm's cross-section area, respectively. Bernoulli equation can be used to find the orifice radius depending on the ratio (β) of the orifice radius (*Re*) to the internal radius of the pressure arm (*Ro*).

$$\beta = \frac{R_e}{R_o} \qquad 16$$

The typical value of the ratio (β) in Eq. (16) ranges between 0.3 and 0.75 determined by the required speed of exit [16]. The exit speed should not exceed the range to guarantee spraying by the device. Therefore, the ratio (β) is set at 0.4. Since different light finger movement gipping positions quickly activate the compliant device, there is little load on joints and assembly. The compliant device has good endurance strength due to little induced stress. Therefore, it can have a long life [18]. It can be used in numerous places regardless of a reduction of the sanitizing liquid or a particular position grip. It is economical to produce the compliant device since it can be produced using a 3D printer. The overall production cost of a single compliant mechanism glove set-up amounts to USD 75, while in mass production, 10000 pieces may cost USD 15 to 20 and 1000000 pieces USD 2 to 3 and so on.

Conclusion

This invention can produce self-sanitizing gloves that curb the virus spread. The self-sanitizing glove protects the user since it sanitizes itself when the user touches an object. Besides, the glove will eliminate the virus from a lot of infected places in the region. This research offers a step-by-step process of developing spray compliant device. By providing the total desired length (Lf) to determine the necessary framework, the requirements allow the user to recreate the design of the spray compliant device.

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Conflict of Interest

The authors declare that there is no potential conflict of interest concerning research, authorship, and/or publication of this article.

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