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Design and analysis of a 3d-printed first aid armband for first responders

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ABSTRACT

A first aid kit is a collection of medical supplies used to provide immediate treatment during emergencies, with its contents varying according to the experience and requirements of the user. An alarm clock is a clock that is designed to alert an individual or group of individuals at a specified time. The primary function of these clocks is to awaken people from their night's sleep or short naps; they are sometimes used for other reminders as well. The main drawback to a regular alarm clock is the snooze button. A person will constantly wake up to click the snooze button on his alarm. This leads to disturbed sleep and according to recent studies at the University of Survey in the UK found that hitting the snooze button in the morning can affect cognitive functions throughout the day. This paper aims to prevent the constant application of snooze button and wake a person up from sleep only once after continuous sleep.

KEY WORDS

3D printing; Wearable medical device; First aid armband; Additive manufacturing; Emergency response equipment

ARTICLE HISTORY

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Introduction

First aid responders play a critical role in saving lives during roadside and on-site emergencies. Delays in administering first aid can significantly increase the risk of severe injury or loss of life; therefore, responders must not only reach the accident scene quickly but also apply medical assistance without delay. The purpose of this project is to develop a cost-effective, 3D-printed first aid armband that is reliable, versatile, and easy to use, enabling first responders to provide immediate medical support without diverting their attention from the patient. This Arduino based Real time clock is a digital clock to display real time using a RTC IC DS1307 which works on I2C protocol. Real time clock means it runs even after power failure. When power is reconnected, it displays the real time irrespective to the time and duration it was in off state. In this project we have used a 16x2 LCD module to display the time in - (hour, minute, seconds, date, month and year) format. An Alarm option is also added and we can set up the alarm time. Once alarm time it saved in internal EEPROM of arduino, it remains saved even after reset or electricity failure. Real time clocks are commonly used in our computers, houses, offices and electronics device for keeping them updated with real time. Therefore the major components used in this project are: Arduino Uno R3 ATmega 328P,Real Time Clock (RTC DS1307), LCD Display, 9V Battery, Battery plug, 12 K Potentiometer, standard bread board, 5V Buzzer, 3 push buttons and jumper wire kit.

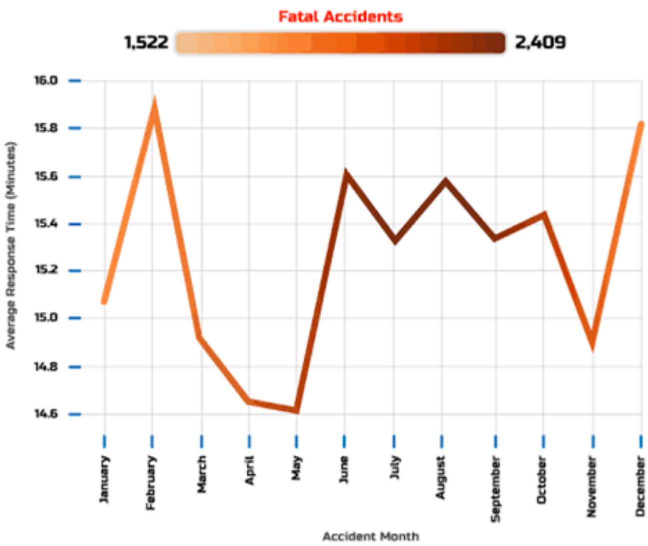

Figure 1. Average emergency response time and fatalities.

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Literature Review

The advancement of additive manufacturing and wearable medical technologies has created new opportunities for developing compact, efficient, and user-centric emergency medical devices. Traditional first aid kits, while effective, often require responders to divert their attention away from patients to retrieve necessary equipment, potentially delaying critical care. Recent studies lay emphasis on speed of accessibility, portability and ergonomic nature of emergency medical support systems. The choice of materials has been an important factor in the design of wearable first aid devices. Krache and Debbah examined mechanical and thermal behavior of PC /ABS blends, which are advantageous in the usage areas that need strength, impact resistance, and thermal stability [1]. On the same note, ABS plastics have gained popularity in additive production because of their strength, simplicity in production, and low cost, making them good wearable case and medical accessories [2]. The research on the topic of fused deposition modeling (FDM) also demonstrates that the process parameters have a substantial impact on the mechanical behavior of the printed parts, which is why the optimal design is extremely important to secure the high reliability of the performance [3,4]. Additive manufacturing has received much research in terms of its adaptability to produce complex and highly customized products. Gibson et al. and Ngo et al. have conducted reviews of the additive manufacturing technologies, materials and applications in detail and noted their increasing use in the biomedical and wearable devices [5,6]. Gokhare et al. also have conducted a review of different 3D printing operations, which supports the appropriateness of additive manufacturing in rapid prototyping and low-volume medical requirements [3]. The benefits of sustainability and less material waste related to 3D printing have also been noted among the main ones, focusing on emergency and healthcare applications. The use of additive manufacturing in healthcare and wearable medical devices has been on a tremendous pace in the recent years [7]. The evolution of 3D-printed biomedical devices and polymeric biomaterials with specialization and patient design was discussed by Mamo and Zhu [8,9]. According to design studies on wearable products, ergonomics, comfort and accessibility are critical towards ensuring that there is effective user interaction, especially during emergency situations [10]. Kulkarni et al., showed the way in which miniaturized 3D-printed devices could improve the portability and functionality which is required by the wearable first aid solutions [11]. Research on emergency medical response reveals that time is critical in the saving of lives. A high correlation between the response time of emergency medical services and the survival of patients has been established by Blanchard et al., which insists on the importance of the timely and continuous provision of first aid [12]. The authors of this paper, Khan and the World Health Organization, have recognized the need to have efficient emergency tools and rapid response equipment to reduce mortality and enhance patient outcomes [13,14]. The findings can help to create wearable first aid devices that reduce the response time and enhance access to vital medical resources. Smart and wearable technologies have also been discussed lately in the context of rescue and first aid operations. Zenkert et al. introduced a wearable with superior sensing and intelligent functions which can be used to help rescue workers and Amin and Khondoker examined the design and testing of wearable medical gadgets produced via additive manufacturing [15,16]. Chan et al. also noted this emerging enthusiasm of smart wearable systems in emergency healthcare and how they can be used to increase the efficiency and situational awareness of responders [17].

Problem Description

Conventional first aid kits are typically bulky and require first responders to pause treatment and search through compartments to access essential medical supplies [18]. An alarm clock is made in such a way that a person can set an alarm for a particular time and the alarm will make a sound to wake the person up. In most alarms two features are present to switch of the alarm, the snooze feature and the switch off feature. People who are unable to wake up timely will set multiple alarms and once the alarm rings in the morning, the will repeatedly hit the snooze button provided. This habit of snoozing leads to disruption in REM cycle sleep. This can lead loss of productivity at place of work and also health hazards. We have tried to develop a mat alarm using RTC DS 1307 (real time clock) and Arduino coding, that will prevent a person from using the snooze button at all. Another alternative to the mat alarm as a prototype would be to not provide any snooze feature at all.

METHODOLOGY

Modern developments in the 3D printing process allows us to effectively make the base structure of the armband [19]. Furthermore, the arm band shall be held in place with the use of Velcro and straps, this will help ensure a comfortable fit on the arm and help us to adjust the size and fit of the armband depending on the shape and size of the users arm. The arm band also has pockets, which will have any cloth-based materials used as a cover so as to keep the equipment from falling out of the pockets while the user is in motion.
Basic steps of the design are listed below:

Step 1: Design a basic Solidworks model.

Step 2: Use bonded, non-penetrating or shrink fit depending on the type of lock required for the part.

Step 3: Run Solidworks simulation to test whether the armband can carry the necessary weight of the equipment without any breakage.

Step 4: Apply equally distributed load to the pockets to simulate the weight of the first aid equipment. Use true to scale measures.

Step 5: Find the maximum possible weight of equipment that can be added to each pocket of the armband based on stress and displacement of the pockets.

Step 6: Make the necessary changes to the design based on the results of the simulation.

Modelling

The isometric view of the developed SolidWorks model of the armband is presented in figure 2.

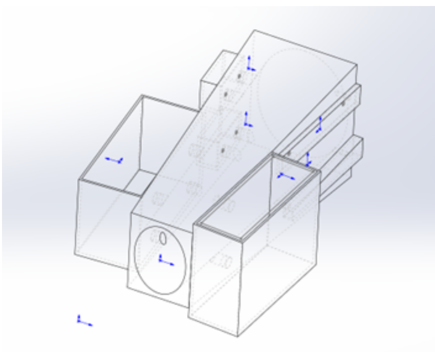

Figure 2. Isometric view of the armband.

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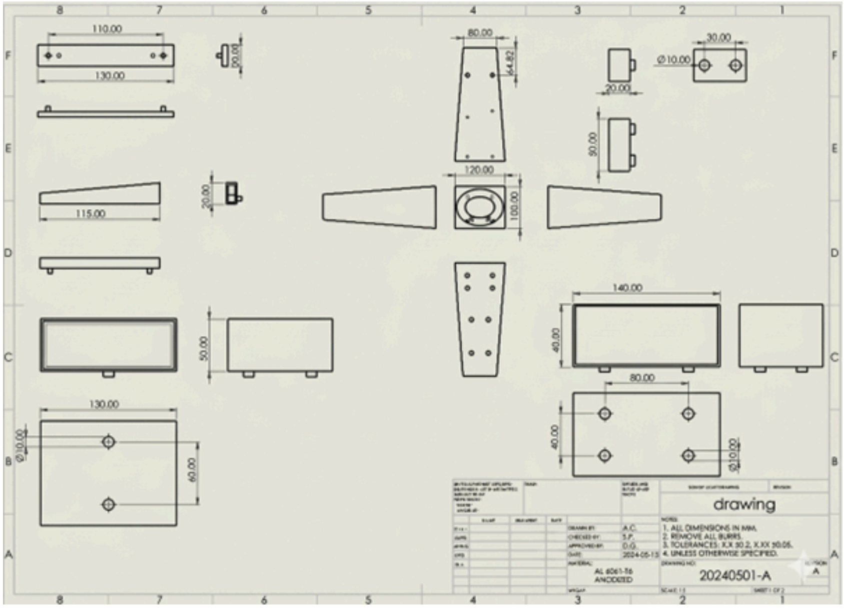

Figure 3. Armband schematic layout.

Material Selection

Based on the comparative analysis presented in the table, ABS was selected as the preferred 3D printing material for the armband. ABS offer a favorable balance of low production cost, good dimensional accuracy, structural strength, and long service life, making it well suited for wearable emergency equipment [20].

Table 1 . Material selection criteria.

Material	Pros	Cons	Cost per Kg
PLA	• Low cost • Stiff and good strength • Good dimensional accuracy • Good shelf life	• Can deform because of heat • Can ooze and may need cooling fans • Filament can get brittle and break • Not suitable for outdoor exposure	20-50
ABS	• Very sturdy • High melting point • Long lifespan • Good dimensional accuracy and detail	• Requires cooling while printing • Requires ventilation while 3D printing • Deforms when not being printed on a heated surface	18-20
ABS	• Tough and partially flexible • High impact resistance • No unpleasant odour • Good abrasion resistance	• Prone to warping • Air-tight storage required to prevent water absorption • Improperly dried filaments can cause printing defects • Not suitable for humid environments	20-23
Carbon Fiber Filling	• Increased strength and stiffness • Very good dimensional stability • Lightweight	• Abrasive and requires hardened steel nozzle • Increased oozing while printing • Increased brittleness of filament • Higher tendency to clog	50-120

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One of the primary challenges associated with printing ABS is the release of fumes during the heating process; therefore, adequate and continuous ventilation is required during fabrication to ensure safe operating conditions. From a sustainability perspective, ABS is easily recyclable and can be reused, contributing to its environmental friendliness.

Results and Discussions

The arm has a middle base part that the user will wear, this part can be cut into two halves or produced in two halves. These two halves will be held together using a simple locking mechanism and velcro straps.

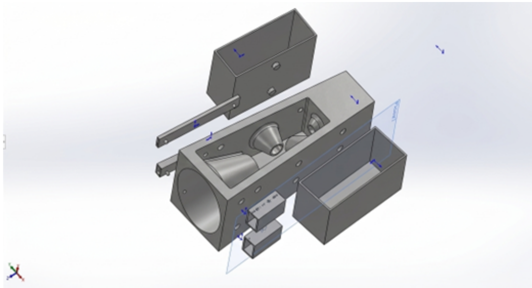

Figure 4. Explorative view of the entire arm assembly.

The basic model shown here also displays the two detachable and interchangeable pockets at the front end of the arm; a scalpel slot and a scissor slot on the left hand side over the forearm, and two pockets for band-aids, alcohol free cleaning pads and antiseptic pads on the right hand side on the inner side of the arm.

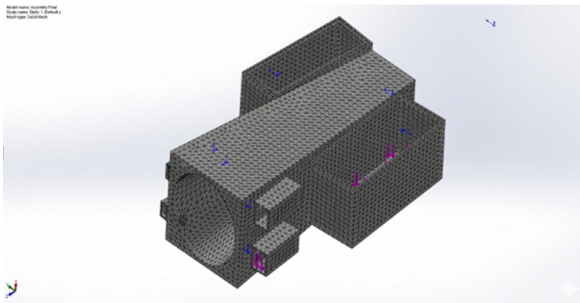

Figure 5. Meshing after boundary condition.

The load distribution of the armband was evaluated by calculating the weight of the equipment assigned to each individual pocket. The central base structure of the armband was fixed as the anchor, and the corresponding loads were applied to all the pockets to simulate real operating conditions. The resulting structural response and load effects obtained from this analysis are presented below.

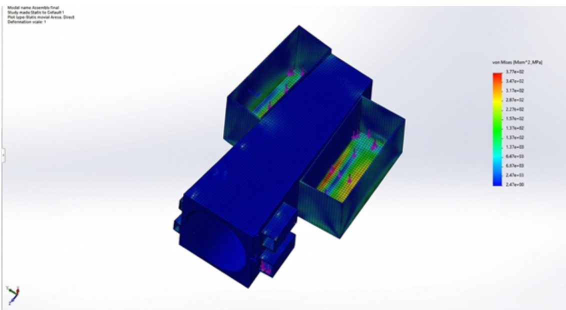

Figure 6. Stress analysis.

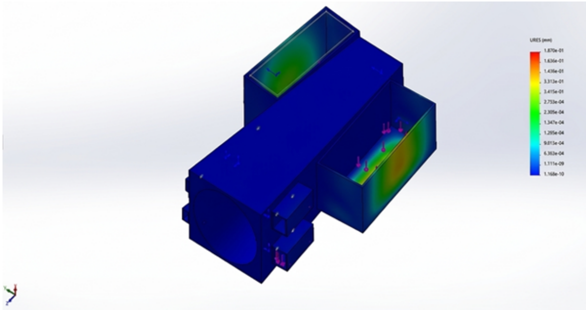

Figure 7. Displacement analysis.

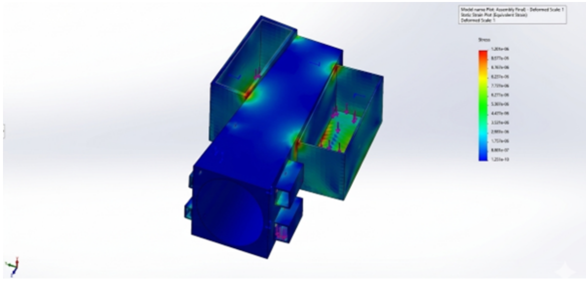

Figure 8. Strain analysis.

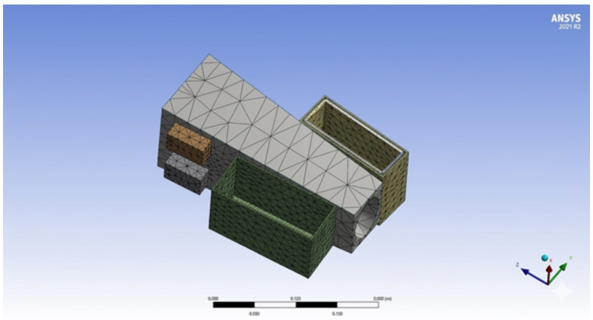

Figure 9. Meshing.

Simulation

In additive manufacturing, the digital part model is first sliced into multiple layers, where a smaller layer thickness is selected to achieve improved surface finish and dimensional accuracy. Afterwards, parameters like shell or wall thickness are chosen, and the larger its value, the higher the surface strength and structural durability. The infill density is then defined to allow the optimum internal strength and minimum material consumption.

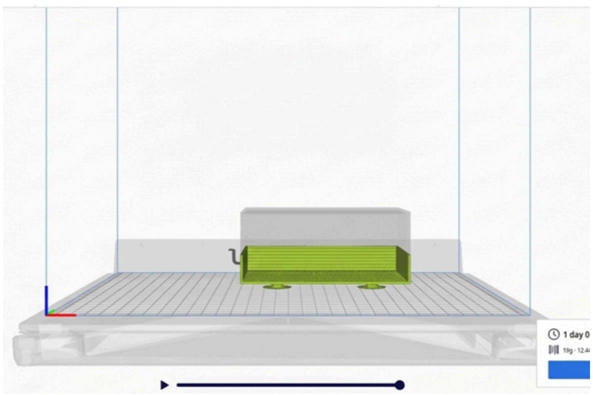

Figure 10. Big box slot.

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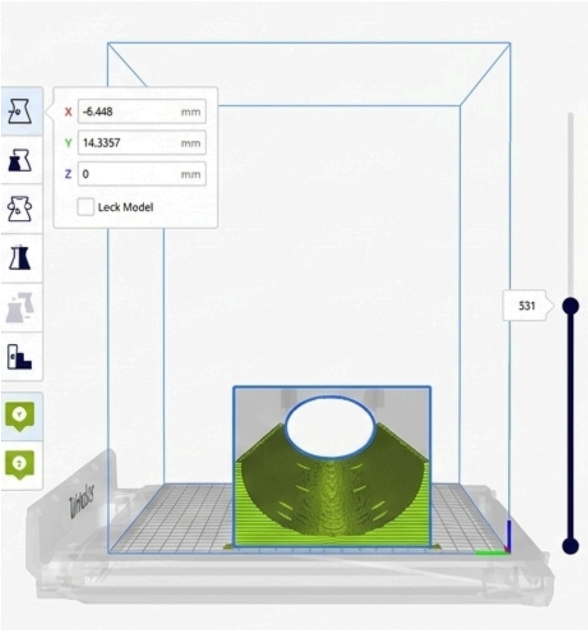

Figure 11. Main arm base.

Conclusions

The given design of the first aid armband is able to combine functionality, ergonomics and structural reliability in a small wearable product. It can be made in two distinct halves with one half functioning as a base and the other as a top part to be worn on the arm which is highly comfortable and will fit easily once simply connected to hold the halves together with a locking mechanism and Velcro straps so that it is easy to use and can be adjusted to suit other users. The armband has a modular design, which means that the device can be customized with detachable, interchangeable pockets depending on the emergency needs. The designated location of practical components like the scalpel and the scissor slots on the front part of the forearm and storage compartments of band-aids, antiseptic pads, and cleaning wipes on the inside arm make everything very convenient and easy to access in addition to keeping a user comfortable and steady. Armband analysis: Structural analysis of the armband was done by fixing the central base as an anchor and putting realistic loads based on the weight of the equipment in each pocket. The findings are used to show that the armband is able to sustain the operational loads safely without structural integrity or comfort to the wearer. The design validates the need of a wearable and lightweight first aid solution, which will increase the accessibility and efficiency of first responders. The load optimized and modular design has an excellent basis to be improved in the future, such as the optimization of materials, further integration with medical instruments, and mass production with additive manufacturing methods.

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