ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 8, August 2021

Design and Development of Anti-bedsore Air Mattress

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***Abstract*--- An Anti-Bedsore Air Mattress is a prototype designed to help the patients who have limitation in movements and cure bedsore or pressure ulcers found in comatose patients. The objective of this prototype is to develop a user-friendly and low-cost air mattress with use of automation in the medical field. The mattress would help the patients to change the body positions after a certain interval of time by inflation and deflation of airbags and without any external help. This paper highlights the findings, methodology and results of this prototype.**

***Index Terms*— Air Mattress, Bedsores, Pressure Ulcers**

I. INTRODUCTION

Bedsores additionally referred to as pressure ulcers and posture ulcers are injuries to skin and underlying tissue ensuing from prolonged pressure on the skin. Bedsores most frequently develop on skin that covers bony areas of the body, like the heels, ankles, hips and tailbone. Patients most in danger of bedsores have medical conditions that limit their ability to alter positions or cause them to spend most of their time in a bed or chair. The problem faced by nurses or caretakers of the patients is that, it becomes difficult to physically move the patients. This prototype addresses this problem by the provision of airbags which can be inflated and deflated at various positions; hence increasing the quality of blood circulation throughout the body. The literature review shows that the similar products available in the market are either expensive, difficult to use or bulky in size.

II. OBJECTIVES

1) Designing an anti-bed sore mattress for patients who have limitation in movements and are bed ridden for a long time
2) The mattress would help the patients to change the body positions after a certain interval of time suggested by medical practitioners without any external help.

III. LITERATURE

A. Pressure Ulcers:

Pressure ulcers are a sort of injury that breaks down the skin and underneath the tissue once a part of skin is placed under constant pressure for some period inflicting tissue ischemia, halt of nutrition and oxygen provided to the tissues and eventually tissue necrosis. Constant pressure leading to 'distortion or deformation damage' is maybe the accurate description of a pressure ulcer[1].

Pressure ulcers will develop once an oversized quantity of pressure is applied to a locality of skin over a short amount. They can conjointly occur once less pressure is applied over an extended amount of time. The majority of people affected with pressure sores are those having health conditions (mental or physical) that encourage immobility, particularly those that are confined to bed or chair for prolonged periods of time [1]. Several other health conditions that influence blood supply and capillary perfusion, such as type-2 diabetes, can make a person more vulnerable to pressure ulcers. Age is also a factor that the majority (approximately two-third) of pressure ulcers occurs in old age people (60-80 years of age). To put it more simply, any individual, with or without a medical condition, who is incapable of avoiding prolonged periods of an uninterrupted compression, is at a risk of pressure ulcers. Majority of the patients affected with pressure ulcers frequently develop it over a bony prominence. Table 1 describes the various direct and indirect causes of pressure ulcers found in comatose patients [2].

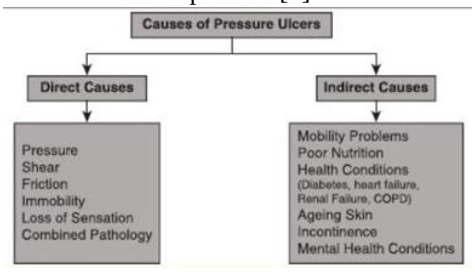

Table 1: Causes of Pressure Ulcers.

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International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

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Healthcare professionals use various grading systems to describe the severity of pressure ulcers in patients. Pressure sores are categorized into four stages Table 2 corresponding to the depth of damage [2].

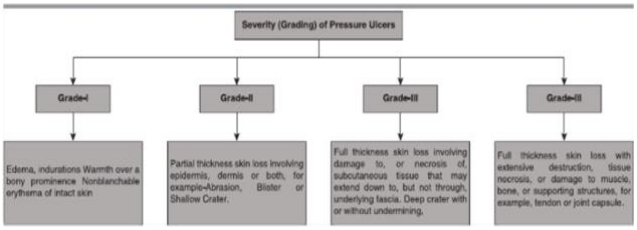

Table 2: Grades of Pressure Ulcers

Treatment: The affected area needs thorough cleanup and dressing. The limb should be elevated to enhance the venous and lymphatic drainage, and therefore the part should get some rest from the load bearing, pressure and friction. However, since the total range of motion and active physical therapy of joints do improve circulation, even non-weight bearing physical therapy is fascinating. This movement may be achieved using air mattresses to well elevate the patient's body and scale back the pressure on the body parts[3].

Products available in the market:

3) Air Mattress: An air mattress, additionally called an airbed or a blow-up bed, is an inflatable mattress manufactured from polyvinyl chloride (PVC) or textile-reinforced urethane plastic or rubber. The deflated mattress will be compacted and carried or kept in a very small space.

Fig.1: Air Mattress

4) Fouler Bed with Air Mattress: A fouler bed or hospital cot is a bed specially designed for hospitalized patients or others in need of some form of health care. These beds have special features both for the comfort and well-being of the patient and for the convenience of health care workers. Common features embrace adjustable height for the whole bed, the head, and also the feet, adjustable side rails, and electronic buttons to control each the bed and different nearby electronic devices.

Fig.2: Fouler Bed with Air Mattress

5) *Water Bed:* A waterbed, water mattress, or flotation mattress is a bed or mattress filled with water. Waterbeds meant for medical therapies appear in numerous reports through the nineteenth century.

Fig.3: Water Bed

IV. DESIGN METHODOLOGY

The design of the air mattress consists of two factors of research that is research about other mattress in the market and the average height of the human body. The average height of a person to be around 5.7 ft. Beds available in hospitals and old age homes are around 6 ft, finalizing the height of our mattress to be 6 ft. according to literature and site visit the pressure points of sleeping body were identified. When a patient turns on either side, around 1.25 ft to 1.5 ft, of mattress was enough for the patient to feel comfortable. This gave the idea about breath of mattress required and it was about 3 ft. To break the contact between the pressure points of the body parts and the mattress, it was decided to split the bags horizontally into three parts to achieve the three main positions. In consultation with medical practitioners and nurses as well as referring some literature it was concluded that the angle of air bags should be 30^0 and 45^0 [4]. The automation will be achieved using Arduino MEGA 2560 board. The code is written in such a way that the user can easily actuate any valve and inflate/deflate any airbag as per the necessity.

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Bed Dimensions	•Height of an average person •Movements Required
Component Research	•Pneumatic Components •Power Units •Electric Components •Material for Airbag and Adhesive Products •Joints and Hoses
Mechanical Design	•Calculation of angles of airbags •Designing as per dimensions and angles using Fusion 360 •Analysis of Components
Code for Automation	•Tinkercad Software
Testing	•Material Testing •Component Testing •Code Testing •Time Required
Component Finalization	•Pneumatic Components •Electric Components •Power Unit •Joints and Hoses
Final Prototype	•Combining the mechanical design, electrical

Table: Design Methodology

V. COMPONENT SELECTION

A. 2/2 Solenoid Operating Valves:

The 2/2-way pneumatic solenoid valve has 2-way 2 position. The 2 position suggests that there are 2 operating positions, namely, the solenoid valve has 2 state of switching on and off the air path. The 2 way implies that there are two port connecting the solenoid valve to the pipeline and it's internally piloted.

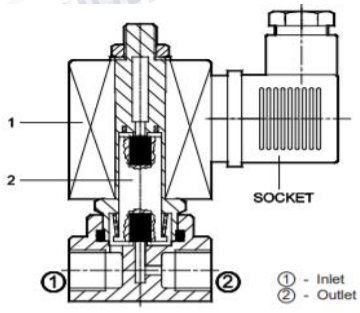

Fig.4: Cross-Sectional View of Janatics 2/2 Valve

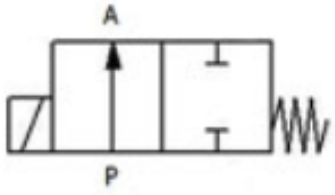

Fig.5: Circuit Diagram of 2/2 Valves.

B. Power Unit: Industrial Compressor:

An air compressor turns power (gasoline or an electrical motor) into potential energy. This P.E. is stored in a tank and forces air into the tank making positive pressure. Usually a hose is connected to the tank and so when opened with a valve or switch, air is shot out of the hose at high speeds. Motor: 2hp single phase.

C. Arduino MEGA 2560:

The Arduino Mega 2560 is a microcontroller board supported the ATmega2560. It's fifty four digital input/output pins (of that fifteen are often used as PWM outputs), sixteen analog inputs, four UARTs (hardware serial ports), a sixteen MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

D. Switched Mode Power Supple (SMPS):

The Switched Mode Power Supply (SMPS) circuit is designed for obtaining the regulated DC output voltage from an unregulated DC or AC voltage. There are four main types of SMPS such as DC to DC Converter, AC to DC Converter.

E. 16 Channel Relay Board:

A 5V 16-Channel Relay interface board is selected for this application. Each one of the individual relays needs 15-20mA Driver Current. The board features indication light-emitting diode for Relay output status and therefore the standard interface which will be controlled directly by several of widely used microcontrollers like Arduino etc. The 5V electromechanical relay module with AC contacts capacity of 250V that additionally embrace light coupling protection (optocoupler) for isolation of control circuitry.

F. Keypad: Keypads permit users to input data while a program is running. A 12-button keypad has 3 columns and 4 rows. Pressing a button can short one of the row outputs to at least one of the column outputs. From this data, the Arduino will verify that button was pressed.

G. Pneumatic Joints and Hoses:

H. Pneumatic fittings offer the essential link between tubes, hoses and different parts in a pneumatic system. The

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

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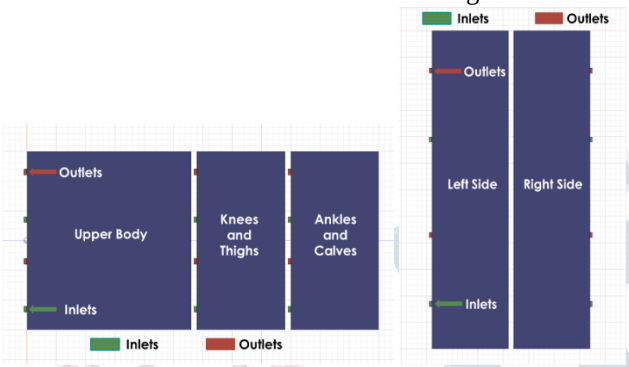
tube is connected to the fitting by a straightforward push ensuring leak proof affiliation. Hose is fabricated in layer of elastomer or synthetic rubber, which allows operation at high pressure and conveys controlled air to different devices.

VI. MECHANICAL DESIGN

To achieve both comfort and movement in the body 5 main positions were finalized. Turning the patients onto either sides of the body contribute as 2 main positions i.e. left air bag and right air bag (Mattress 2). The other 3 positons will be achieved through another air mattress with horizontal sectioning and will be kept above the left and right section air mattress (Mattress 1). The figures given below indicate the sections for both the mattresses and the positions of various inlet and outlet valves for each airbag.



(a) (b)

Fig.6: Mattress 1 and Mattress 2 – Sections and ports

VII. ANALYSIS

CAE Analysis was performed on all the 5 airbags individually, using the ANSYS software. Each airbag was subjected to 10bar air pressure through the inlet ports. The outlet ports were kept open to simulate the one touch fittings used in the prototype. Some air inside the airbag come out of the outlet one touch fitting into the hose but is not let out of the system because the outlet valve is shut. Similar result can be seen in the analysis solution. It can be seen in the velocity streamline analysis that air coming from the inlet port, reaches all corners and edges of each airbag respectively.

A. Upper Body Movement Airbag:

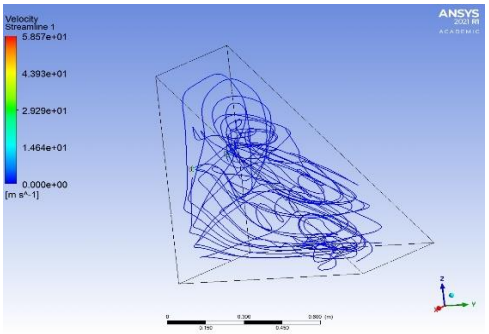


Fig. 7: Upper Body Movement Airbag Analysis

B. Knee and Ankle Movement Airbags:

Both the airbags have similar dimensions and hence the analysis solution obtained is same.

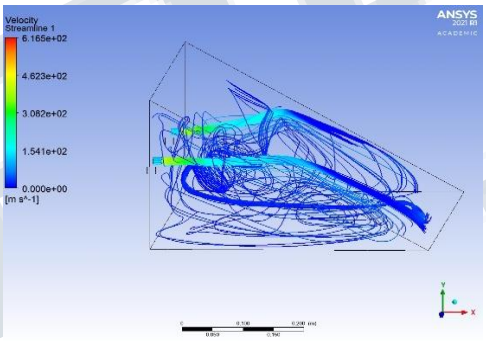


Fig.8: Knee and Ankle Movement Airbag Analysis

C. Full Body Left and Full Body Right Side Movement Airbags:

Both the airbags have similar dimensions and hence the analysis solution obtained is same.

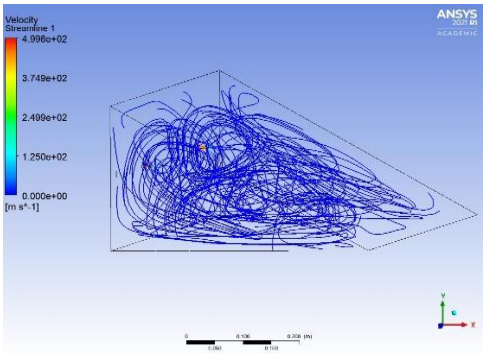


Fig.9: Full body Left and Full Body Right Side Movement Airbags Analysis

VIII. RESULT TABLE

The airbags of the required dimensions were manufactured and they were tested for the effects of different pressure inputs. Since the five airbags have different functions, they

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

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are subject to different loads. Therefore, each bag takes different amount of time to fill completely with respect to different pressure settings. The graph below shows the difference in time required versus the pressure setting.

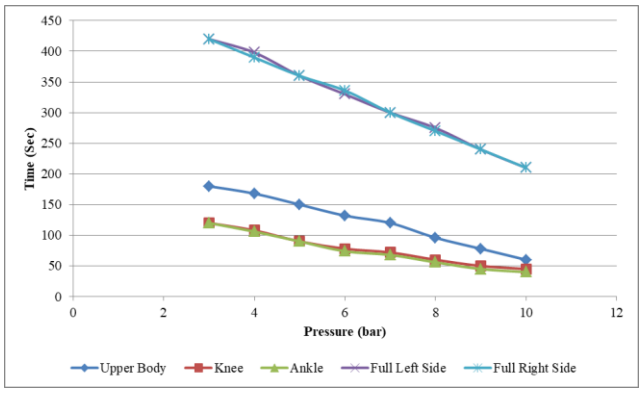

Table: Pressure VS Time for each airbag

IX. LIMITATIONS OF THE PROTOTYPE

1) When the outlet valve is opened during deflation process, the airbags deflate by the force of self-weight itself. Hence it takes a longer time to deflate than required. The quick-exhaust valves available in the market provide extremely fast exhaust and that much speed will be harmful to the patient and might cause sever accidents.
2) The industrial compressor provides the required 10 bar air pressure but it also produces a lot of noise. The industrial compressor cannot be kept next to the patient bed. The possible solution to this is to dedicate a room for the compressor and provide a pipeline from the compressor to the bed.

X. FUTURE SCOPE OF RESEARCH

The limitations of this study can be overcome by the following ways:

1) Finding an efficient solution to the deflation process which will exhaust the air faster but safer
2) Controlling the noise production of the compressor by a silencer
3) The compressor can be replaced with a different power unit provided the cost doesn't increase drastically and the required sir pressure is attained.

XI. CONCLUSION

The Anti-Bedsore Air Mattress is a successful designed and prototyped in terms of achieving the necessary movements, cost, and ease of use. This prototype helps in circulation of blood throughout the body and relieving the pressure on the pressure points found in the human body when the patient is in supine position. This prototype promises an effective future in the industry. Various applications of this air mattress are:

1) Giving periodic movement to patients who are in coma
2) Giving periodic movements to patients who are bed-ridden at home without leaving the bed
3) Nurses can easily move fragile old age patients without the risk of harming the patient's already weak muscles and bones.
4) This product can be used by physiotherapist to train patients who have had a serious injury (e.g. leg fractures) so that the patients can slowly yet easily resume walking.

XII. ACKNOWLEDGMENT

We are thankful to Mr. Tushar Wadhavkar from Tapas Elder Care for providing us the opportunity to design this prototype and help us make a valuable contribution to the medical field. We are also thankful to Mr. Pushpashil Salunkhe from PMS Robotics for providing us with the necessary equipment needed during the manufacturing and testing period.

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