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Anti-Decubitus Air Pump for Air Mattress System

R.Krishnakumar[1], S.Padmaja[2], K.Soundarya[3], T.Subasri[4]
Department of Electrical & Electronics Engineering,
Sri Ramakrishna Engineering College, Coimbatore, Tamil Nadu, India.

Abstract:- **This paper is proposed to improve the efficiency of the air pump for Air Mattress system. The Air Mattress System comprises of Compressor, Stepper Motor, Speed controller. The air from the atmosphere is filtered through filter and then injected to compressor where obtained high pressure air is pumped into air passage valve. The air passage and control dial valve is designed as per inflation and deflation of air in air mattress. Alternating pressure is obtained by system by replacing the plastic gear by speed control drive. The speed of the stepper motor is controlled by PIC microcontroller. The System is tested and simulated with the help of PROTEUS/MP Lab.**

Alternating pressure is obtained by changing the direction of control dial valve at slow rate. This slow rate is achieved by controlling the speed of the motor at 1/10 rev per min. To avoid the friction, spring load is used between motor block and control dial valve. The proposed method improves durability of the whole

Keywords:- *PIC microcontroller, Stepper Motor, Control Dial Valve, Vibrating Armature Compressor , Air Mattress.*

I. INTRODUCTION

Pressure Ulcers (PUs) are one of the most common medical Problems in hospitalized immobile patients and elderly patients in nursing homes. PU occurs due to cell necrosis which tends to develop when a soft tissue is broken by a prominence bone or a hard surface for a long period of time. Currently available techniques and or protocols designed to prevent pressure ulcers are mainly based on the improvement of the skin- support interface and on a postural and behavioral education. The pressure ulcers are caused by unrelieved pressure and shearing forces on soft tissue overlaying bony prominence when patient lying on hospital bed. These two forces can interrupt the blood circulation to underlying tissues. This results in oxygen depletion in soft tissues and muscles. Pressure Ulcers (PUs) are difficult to cure, treat and are a major cost factor in the health care system. Classical treatment aimed at reducing pressure ulcer incidence are: assess pressure ulcer risk upon admission for all patients in all care environments: acute care, long term care and home care, reassess risk daily through skin inspection, manage moisture by keeping the patient dry, optimize nutrition, minimize pressure through use of pressurerelieving surfaces, turn every 2 hours. Classical treatment involves extended period of bed rest that is believed to cause further deterioration of the patient's general condition. A decubitus ulcer arises when the pressure applied on soft tissues in correspondence to bony prominence exceed 32 mmHg (pressure that causes capillaries closure) and the occlusion of the vessels occurs. If this occlusion is prolonged, it can lead to ischemia of the tissues as a consequence of thrombosis of the vessels. The shear stresses, provoking a stress with vessels slant, promote their occlusion in a shorter time. Elderly patients are at higher risk in the development of ulcers due to body changes associated with ageing process, such as loss of subcutaneous adipose tissue, skin dehydration and thinning, reduction immune system response, obesity, diabetes and other illness. General Factors as the alteration of neurological and mental conditions, the use of drugs, the habit to assume unhealthy body positions, and, in general, the reduction of mobility, are other additional risk factors. The existing system consists of a synchronous motor with gear mechanism. In order to avoid the wear and tear problem caused by the plastic gears and to improve the reliability of the whole system, the mechanical part is replaced by speed control driver. Thus the proposed system has a stepper motor along with PIC microcontroller which avoids the usage of gear box in the system.

II. UNDERSTANDING PRESSURE ULCER

Pressure ulcers, sometimes called bed sores or decubitus (lying in bed) ulcers, are typically located in the areas where the body has less protective covering on weight bearing points. Those areas are typically heels, elbows, shoulders and the sacral regions in the supine, semirecumbent and seated positions. Ankles, knees, hips and ears are additional areas of concern in the lateral position. When blood pressure inside the dermis is blocked or above 32mm/Hg, capillaries begin to close. Without the nutrients in the blood and the removal of waste products, the area begins to break down. The first sign is redness and warmth to the touch. In severe stages, extensive tissue destruction can lead to tissue necrosis (death), and damage for supporting muscle and bone.

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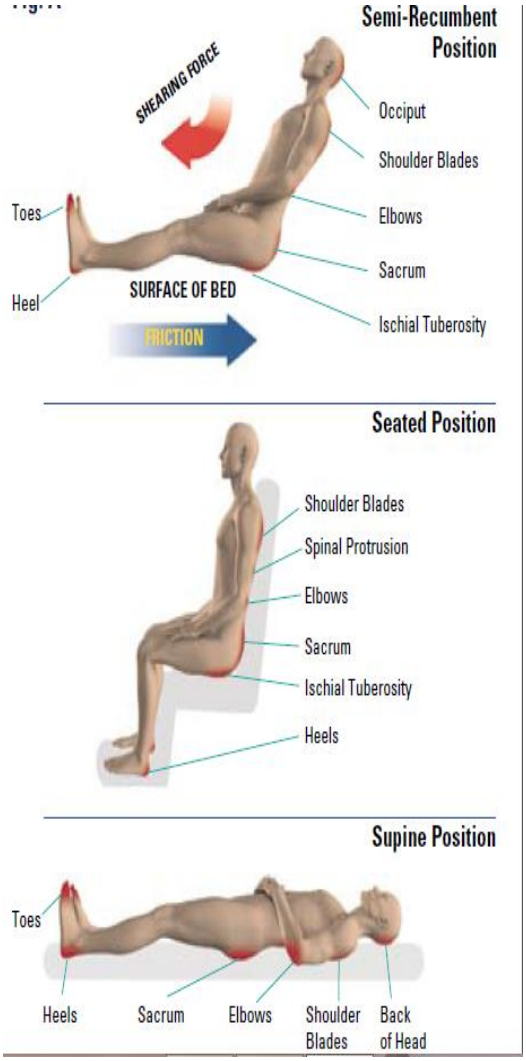

Fig. 1 Pressure ulcer points based on positioning

A. Risk Factors

- Patient is immobile or inactive
  The lack of movement results in loss of blood flow to the skin.
- Body size and shape Very thin or very obese patients are at a higher risk. Very thin people lack cushioning between the skin and bony prominences such as heels and elbows. Overweight patients have fewer blood vessels to the skin and require body movement to get the blood flow to the susceptible areas.
- Skin condition and hygiene regimens Thinning skin, which naturally occurs with age, as well as with the use of some medications, may make the patient more susceptible.
- Nutrition A balanced diet and proper calorie consumption are important in maintaining skin thickness and elasticity.
- Incontinence and infection Urine and fecal matter or increases in body temperature and subsequent perspiration can cause maceration (the skin to soften). The skin is therefore more susceptible to tearing.
- Circulation Edema or swelling due to poor blood circulation makes the susceptible areas less resistant to pressure.

B. Stages of Pressure Ulcer

- *Pre-Stage*

Suspected Deep Tissue Injury-Localized area of discolored (purple or maroon)intact skin or blood-filled blister due to damage of underlying soft tissue from pressure and or shear. The tissue may be painful, firm, mushy, warmer or cooler compared to adjacent tissue.

Stage 1: Non-blanchable erythema of intact skin.(Skin that does not turn white when depressed)

Stage 2: Partial thickness skin loss involving epidermis, dermis or both.

Stage 3: Full thickness skin loss involving damage or necrosis of subcutaneous tissue that may extend down to, but not through, underlying fascia.

Stage 4: Full thickness skin loss with extensive destruction, tissue necrosis or damage to muscle, bone or supporting Structures.

Unstageable: Full thickness tissue loss in which the base of the ulcer is covered by slough(yellow, tan, grey, green or brown and or Escher) (tan, brown or black) in the wound bed.

III. EXISTING SYSTEM

The existing system consists of vibrating Armature Compressor, AC Motor with gear arrangement, Air passage control dial valve, and Air Mattress. The compressor absorbs the air from atmosphere and increases the pressure of the air. The output air from the compressor is in the range of 10 LPM (Liters Per Minute). The main purpose of the control dial valve is to change the direction of the air by rotating in clockwise direction. The rotation of the dial valve depends on the rotation of the AC synchronous motor. The speed of the motor is maintained at 0.1rpm. The speed of the motor is controlled by a gear mechanism. The air from the compressor is injected into the air mattress through the dial valve.

The mattress is provided with two cells A and B . A cell is inflated for the period of 5minutes and at the same time B cell is deflated, thus the process continuous alternatively. The control dial valve is designed in such a manner that it produces alternate pressure inside the mattress. The serious problem associated with existing system is the usage of gear inside the motor. The gear used is mainly made up of plastic which causes wear and tear problems. The efficiency of the entire pump system is reduced because of the plastic gear. The

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system has to work 24/7, but the gear mechanism is not effective as it doesn't maintain the speed.

IV. PROPOSED SYSTEM

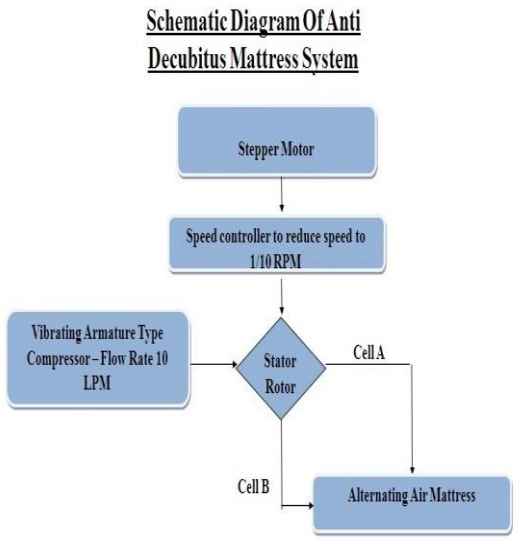

Fig 2:- Schematic Diagram

The existing system uses AC synchronous motor. The speed control of the motor is achieved by gear mechanism. The gear used in the system is made up of plastic, it results in poor performance. To overcome the above issue, a stepper motor with electronic speed controller is used. It improves the system efficiency and durability

- *Block Diagram*
- *Complete System Block Diagram*

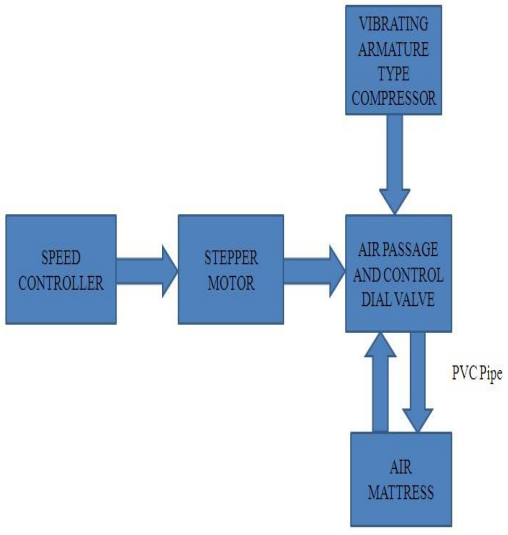

Fig 3:- Block diagram of complete system

The stepper motor is in connection with L293d Motor driver IC which receives the signal from the PIC microcontroller. As per the signal received from the controller unit, the speed of the motor is controlled. The low current signal from the controller is converted into high current signal by the driver IC and then applied to the motor. The motor runs at 0.1 RPM and the control dial valve changes its rotation according to the motor, simultaneously compressor produce the air as the output at the rate of 10LPA.The air supply is maintained inside the cells, as the cells inflate and deflate alternatively in a sequential manner. Thus the alternating pressure is achieved.

- *Speed Control of Stepper Motor*

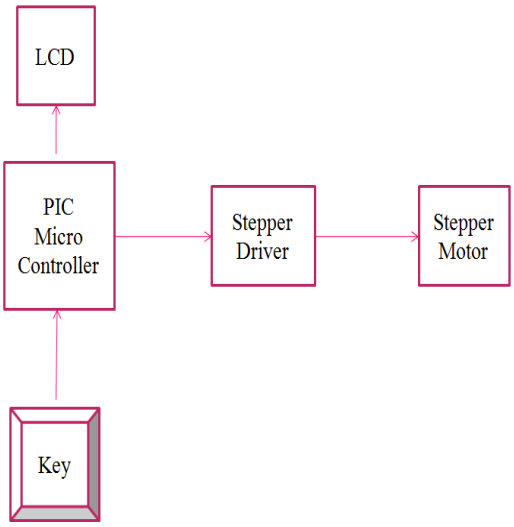

Fig 4:- Block diagram of control circuit

The LCD is additionally used to display the speed and step angle. By this way, if any fault occurs in motor it can be easily rectified. It is mainly used in testing purpose. PIC microcontroller is chosen to add and access additional features in future.

V. HARDWARE IMPLEMENTATION

Our project is mainly focused on improving the efficiency of the pump for air mattress system, it includes the following components which acts as the main parts of the proposed system:

- PIC Microcontroller
- Air Mattress
- Vibrating Armature Compressor
- Control Dial Valve
- L293D Motor Driver
- Stepper Motor
- Step down Transformer

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A. PIC microcontroller

A microcontroller is a computer control system on a single chip. It has many electronic circuits built into it, which can decode written instructions and convert them to electrical signals. The microcontroller will then step through these instructions and execute them one by one. As an example of this a microcontroller could be used to sense the light intensity output from LDR and can control the motor speed through relay. Microcontrollers are now changing electronic designs. Instead of hard wiring a number of logic gates together to perform some function we now use instructions to wire the gates electronically. The list of these instructions given to the microcontroller is called a program. There are different types of microcontroller, this research focus only on the PIC16F877A Microcontroller. PIC microcontroller offer different kinds of memories. PIC 16F877A has different types of memories such as EEPROM, EPROM, FLASH, etc. FLASH is the most recently developed technology. So, that data is retained even when the power is switched off. Easy Programming and Erasing are other features of PIC 16F877A. Some of the core features of PIC 16F877 are,

- High-Performance RISC CPU
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC – 20MHz clock input DC – 200 ns instruction cycle
- Up to 368 x 8 bytes of Data Memory(RAM)
- Up to 256 x 8 bytes of EEPROM data memory
- Interrupt capability

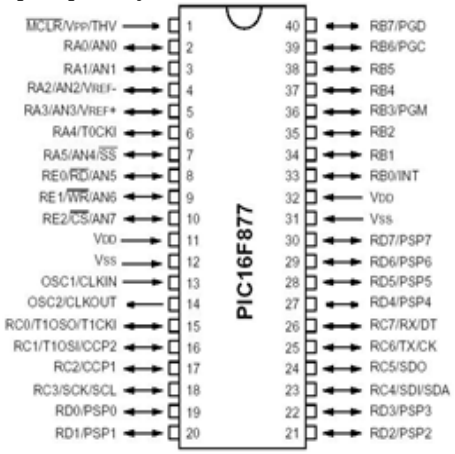

Fig 5:- PIC microcontroller

B. Air Mattress

The advanced technology pump inflates and deflates the air cells of air mattress alternatively for patient relief by causing little movements to the patient's body. Variable pressure settings provide patient comfort. The specifications of the air mattress are listed below:

- Dimensions without flaps: 200*90*7 CM
- Flaps length:50+50CM
- Cell height:7 CM/2.7"
- Mattress material: EN71 Medical Grade PVC
- Material thickness:0.35 MM
- Cold resistant:30 deg C
- Number of cells: 130
- Weight support: 100 kg

Fig 6:- Air Mattress

C. Vibrating Armature Compressor

A vibrating armature compressor uses atmospheric air as its input and produces output air with flow rate of 10 Liters Per Minute. The air form the atmosphere is filtered using a carbon filter and the air is allowed to pass inside the compressor.

Inside the compressor there is a coil with E stack arrangement which is excited with the help of power supply. The E stack arrangement comprises of 28 stacks with attached bellows .The electromagnetic field makes the bellow to change the pressure of the air inside the compressor. The pressure range of the compressed air is 15-20K Pa.

Fig 7:- Vibrating Armature Compressor

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The specifications are,

- Air flow rate – 10 LPM
- Current – 30 m A (approx)
- Voltage – 220 V 50 Hz AC
- Power – 4 W
- Pressure – 15- 20 K Pa

D. Control Dial Valve

Control dial valve is the heart of the entire system, which decides the flow of air into the cells of the mattress. The inflation and deflation of the cells A and B is based on the direction of the control dial valve. There are two main parts involved in control dial valve, they are called as stator and rotor .The dimensions of the control dial valve are:

- Rotor diameter: 40mm
- Stator tube length: 1.5m
- Stator diameter: 40mm
- Inner diameter: 3mm

➢ *Stator*

The stator is fixed one which is fixed to shaft of the stepper motor by the attached spring load. The stator is connected to air mattress through the inlet tube of length 1.5m.The air is flow from the compressor to the air mattress.

Fig 8:- Stator of Control Dial Valve

➢ *Rotor*

The rotor is placed above the stator with the help of shaft and small connector. The rotor changes the direction of flow of air into the air mattress (i.e., flow of air in each cell for 6 minutes alternatively) as the motor rotates continuously. The rotor is designed to achieve the above process.

Fig 9:- Rotor of Control Dial Valve

E. L293d Motor Driver

L293D is a typical motor driver or motor driver IC which allows motor to drive on either direction. L293D is a 16 pin IC which can control a set of two motors simultaneously in any direction. It means the IC can control two motor with a single L293D IC. Dual H-bridge motor driver integrated circuit (IC).

There are two enable pins on l293d. pin1 and pin 9, for being able to drive the high. For driving the motor with H-bridge the pin 9 should be high.

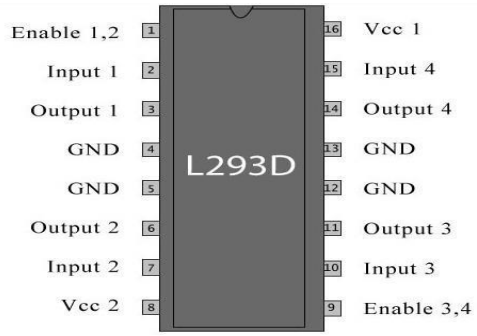

Fig 10:- L293D Motor Driver

If anyone of the either pin 1or pin 9 goes low then the motor in the corresponding section will suspend working. It simply act as a switch.

F. Step down transformer

A step down transformer is a type of transformer (static device), which converts a high voltage at the primary side to a low voltage at the secondary side.

Fig 11:- Step down Transformer

In terms of the coil windings, the primary winding of a step down transformer has more turns than the secondary winding. The ratings of the step down transformer are listed below:

- Primary voltage: 0-220v
- Secondary voltage: 0-15v
- Current ratings:1Amps

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- Frequency: 50 Hz

G. Stepper Motor

Stepper motor consists of a permanent magnetic rotating shaft, called the rotor, and electromagnets on the stationary portion that surrounds the motor, called the stator. A bipolar stepper motor has one winding per stator phase. A two phase bipolar stepper motor will have 4 leads, there is no common lead like in a unipolar stepper motor. Hence there is no natural reversal of current direction through the winding

Fig 12:- Bipolar stepper Motor

In order to drive a bipolar stepper motor there is a need of a driver IC with an internal H bridge circuit. This is because, in order to reverse the polarity of stator poles, the current needs to be reversed. The specifications of the bipolar stepper motor are as follows:

- STEP ANGLE : 1.8 DEG
- HOLDING TORQUE: 22 NCM
- RATED CURRENT PER PHASE: 1.33 AMPS
- Voltage :2.8 v
- Phase resistance: 2.1 ohms
- Inductance: 2.5 mH
- Shaft length: 24 mm
- Shaft diameter: 5 mm

VI. SIMULATION RESULT

The simulation of the project is done by using Proteus software and MP lab. The hex file is loaded into the PIC micro controller. the simulation circuit uses PIC microcontroller, L293d IC, stepper motor, LCD display. The speed of the motor is controlled as per the signal obtained from the micro controller. As the motor requires a high current, the driver IC converts the low current signal from the microcontroller into high current signal, the output is obtained.

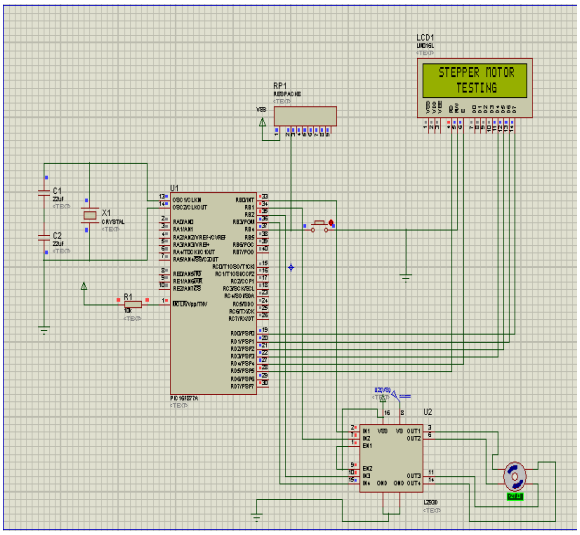

Fig 13:- speed control of stepper motor

VII. CONCLUSION

In this project, the system uses stepper motor instead of geared motor which increase the efficiency of the system. The future scope of the project is to monitor the pressure of air inside the mattress using sensors. Four different aspects can be monitored using the pressure sensors. A specific limit is set in the pressure sensor. An alarm is used to indicate the change in the pressure level inside the mattress. IOT can make the system smarter. The information about the pressure can passed as a message to the care taker of the patients. It improves the safety of the system.

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