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Conference Paper · March 2021

DOI: 10.1109/ICACCS51430.2021.9441831

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2021 7th International Conference on Advanced Computing and Communication Systems (ICACCS)

Design and Modelling of Autonomous Mobile Robot for Material Handling

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***Abstract*— In the majority of the textile mills manual workers are used for locomotion from the process of Carding to Autoconer, the cottons are transported manually using trays and bins. To reduce the manual workers for transporting the processed cotton, a mobile robot is implemented in the textile mill. The main idea of this proposed work is to reduce manual human effort for transporting processed cotton between different process stages. The main objective of the project is to design and model an autonomous mobile robot for material handling in the textile industry. This reduces the workers for transportation of the cotton to the next process stage. These mobile robots are also used for warehouse goods movement. The workers who are manually transporting the processed cotton can be utilized in other fields. The mobile robot will be travelling by tracing the path of painted strips. Hence the production and efficiency of the mill increases significantly. Also, the workers are no longer required for transporting the processed cotton.**

***Keywords*— Autonomous mobile robot; Material Handling; Painted guide strips; Locomotion; Textile industry**

I. INTRODUCTION

The irony is that the way the textile industry handles materials in the factory haven't seen a fundamental shift over the decades. Previously, it was a workforce that is used to transport materials from one place to another. Then gradual development of technology like Automated Guided Vehicles (AGVs) happened, but a colossal scope of advancement is still available.

One of the critical challenges faced in the textile industry is that apart from the intense ongoing competition in this low-margin business, warehouse operators have to deal with difficulties in finding a human workforce who are willing to stay in the job for a longer run, always advertising for new workers, hiring them, and training them to incur a tremendous amount of money which further sues away the already formidable margin in the textile business.

Robotics offers a solution that would certainly transform the conventional material handling system. Gone are the days when the textile factory owners had to think of automation as expensive installations. Now they can get their material handling job done using small autonomous mobile robots.

Fig. 1. Process flow chart of the textile industry

Fig. 1 indicates the process flow of the textile industry. Here the implementation of the mobile robot is done in two stages which is from carding to comber and spinning to Autoconer. The mobile robot is used to transport the processed cotton from the above mentioned process station with the help of an autonomous mobile robot [1].

The objective of our project is to design and fabricate an autonomous mobile robot for Material Handling using photoelectric sensors with the help of painted strip guidance technology, thereby increasing productivity and reducing the workforce required for material handling.

II. METHODOLOGY

A. Working

The primary purpose of the project is material handling between two or more workstations [2]. Mobile robots use paint stripes for guidance. There are two colored painted strips. One strip leads to the workstation, and another leads to the charging station [3]. When power runs out, the mobile robot automatically goes to the charging station.

Fig. 2 shows the flow diagram of this proposed work. Photoelectric sensors are used to identify the color of the printed strip [4]. An ultrasonic transducer is used to ensure safety [5]. When an object comes near the mobile robot, it automatically stops. An analog to digital converter is used to convert the analog signal from the ultrasonic transducer to a digital signal so that the microprocessor can process it. A display is used as a human-machine interface in which the user can select the mobile robot's destination [6]. The microprocessor processes the data and gives the signal to the motor drives. The mobile robot has two motors drive systems. An emergency stop pushbutton is also there in the robot, which is placed at a reachable distance, which will stop the mobile robot immediately in case of emergency.

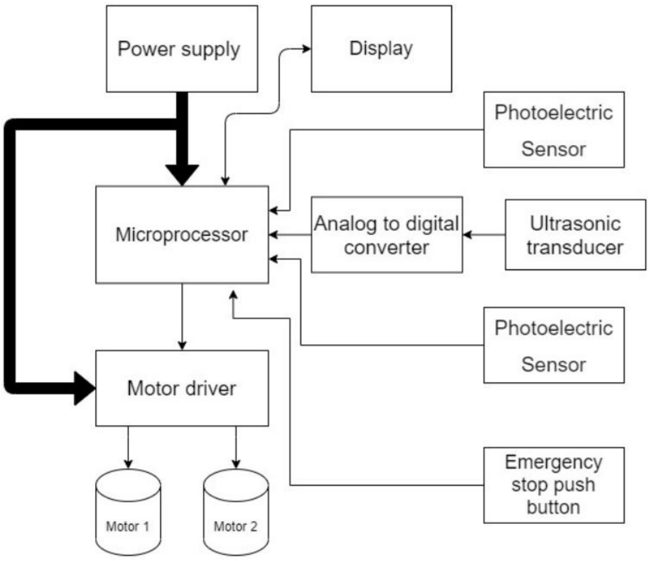

Fig. 2. Flow diagram

B. Components used

a) Geared DC motor

Geared DC motors are defined as an extension of the DC motor, which already had its insight details demystified. A geared DC motor has a gear assembly which is attached to the motor. The motor's speed is counted in terms of rotations of the shaft per minute and is termed as RPM. The gear assembly helps in increasing the torque and reducing speed. Using the correct combination of gears in a motor, its speed can be reduced to any further desirable configuration.

b) Li-Po battery

The battery used for this work were 11.1 volts as output voltage and capacity as 2000 mAh.

c) Ultrasonic sensor

An ultrasonic sensor is an electronic device used to measure the distance of a target object by emitting ultrasonic sound waves and converts the reflected sound into an electrical signal. The ultrasonic sensor is used for obstacle detection.

d) ARM controller

The primary advantages of using ARM microcontroller in this project is, the ARM processor is capable of multiprocessing many runtime programmes [7]. Since the ARM is tightly coupled memory the accessing of data and transferring is faster. The ARM processor uses memory management wisely and it is also secure. It uses thumb-2 technology which enables more reduction in memory space. It is a one cycle execution time. ARM processor pipelining can take many sets of instructions. It has a large number of registers.

e) Photoelectric sensor

A photoelectric sensor is a piece of equipment accustomed to discover the distance, absence, or presence of an object by implementing a light transmitter and a photoelectric receiver [8].

III. Design Calculation

The design calculations were made for the proposed model to know the significance of the mobile robot. In order to find the total accommodation of the tray which is to be carried by the mobile robot, its volume has been calculated,

A. Rectangular tray dimension

Length = 508 mm

Breadth = 406.4 mm

Height = 330.2 mm

Volume,

V = Length x Breath x Height

V = 508 x 406.4 x 330.2

$V = 68.17x10^6 mm^3$

B. Rectangular tray chassis dimension

Length = 558.8 mm

Breadth = 457.2 mm

Height = 400 mm

C. Bending moment and shear force calculations

The load applied on the mobile robot has its maximum bending moment and maximum stress calculations have been calculated.
Length of the beam = 560mm
The load applied here is a point load.
The total load = 40Kg = 393N
Q = Shear Force
M = Maximum Bending Moment
Consider it has simply supported beam
A&B are the two ends of the beam
Ra & Ra are the reaction forces acting on the roller support. Fig 3 shows the shear force and bending moment diagram for the proposed system.
The reaction forces acting on two ends of the beam,

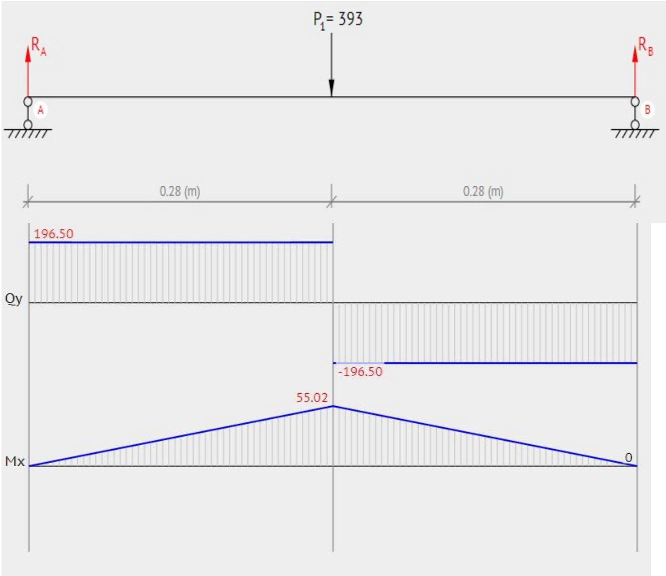

Fig. 3. Shear force and bending moment diagrams

Reaction force calculation:
Moment at point A:
Rb x 0.560 = 393 x 0.280
Rb = 196.5 N
Applying Equilibrium Equation (vertically):
↑ Ra + Rb = 220.08 N
Ra = 393 - 196.5
Ra = 196.5 N

Shear Force Calculation:
At point B, Bsf = +196.5
At point C, Csf = -393 + 196.5
= -196.5 N
At point A, Asf = +196.5 +196.5 -393
= 0 N

Bending moment calculation:
At point B, Bbm = 196.5 x 0
= 0 Nm
At point C, Cbm = (196.5 * 0.28)-(393*0)
= 55.02Nm
At point A, Abm =(196.5*0.56)-(393*0.28)+(196.5*0)
= 0Nm
Maximum Bending moment is 55.02Nm

In order to find the maximum bending stress of the material bending stress equation has been used,
Bending stress calculation:
M/I=σ/y=E/R
For rectangular tray,
M is the maximum bending moment
= 55.02 Nm
= 55.02 x 1000=55020Nmm
From PSG DDB, 5.127
B x H=60 x 60 (for L cross section)
y is the perpendicular distance from the centre of the beam
H/2 = 60/2 = 30m
σ is bending stress
I is the moment of inertia = 34.08cm^4 = 348000mm^4
E is the young's modulus
R is the Radius of curvature
Maximum bending stress σ:
= M/I x y
= 55020/348000*50
σ = 4.74N/mm^2
Maximum Bending stress is 4.74 N/mm^2
Factor of safety = 3
From PSG DDB 1.9
Yield stress for C10 material is 210 N/mm^2
Calculated value = 4.74N/mm^2
Standard value = 83.33N/mm^2
Since, the calculated value is less than the standard value, the design is safe.

In order to find the weight and thickness of the sheet for enclosure, bending stress equations has been used. Since the surface area of the sheet is rectangular, the moment of inertia is a rectangular cross section [9].
Bending stress:
Maximum bending moment =55.02 Nm =55020 N.mm
Bending stress equation,
M/I=σ/y=E/R
σ = M/I x y
I is moment of inertia for rectangular cross section,
= bh^3/12
b = 0.458m
From PSG DDB 1.9
Allowable stress for C07,
Factor of safety = 3
= 200/3 = 66.67N/mm^2
66.67 = 55.02/(458 x h^3/12) x h/2
h = 2mm
Volume, V = L x B x H
V =560 x 458 x 2
= 512960 mm^3
Weight = volume x density
Specific weight = 0.0785 N/cc
= 8.01 x10^{-6}kg/mm^3
Weight = 512960 x 8.01 *10^{-6}
= 4.1 Kg

D. Welding calculations

In order to find the weld size and weld rod selection with respect to the stress relation following calculations has been done, (parallel welding)
Welding calculations:
h = weld size
σ = p/hl
= p/A
σ = 393/120 x 5
= 0.655 N/mm^2
σ = p/hl
h = 393/0.655 x 120
= 5 mm
σ = p/0.707 x hl

$= 393/ (0.707 \times 5 \times 120)$
$= 0.926$ N/mm²
$\sigma = 0.926 \times 3$ Factor of safety = 3
$\sigma = 2.778$ N/mm²
Since the calculated tensile value is less than the actual value. Hence E60xx is used.

E. Screw calculations

For the enclosure of the mobile robot and for joining the components, screw calculations have been done [10], [11].

Screw dimensions:
$\tau = p/A$
$\tau = p/\pi d^2/4$
From PSG DDB 1.9, C07 material has been used
$\tau = 200$ N/mm²
$= 200/3=66.67$ N/mm²

$\pi d^2 = 393*4/66.67$
$= 52.46/\pi$
$d^2 = 19.152$
$d = 4.41 = 5$mm [M5] (coarse series)
Pitch = 0.8 mm
Pitch diameter = 4.48 mm
Depth of thread = 0.491 mm
Bolt = 4.019 mm
Nut = 4.134 mm

F. Motor calculations

For motor selection the following parameter power, torque and RPM has been calculated [12].

Torque calculation:
Force, $F = c \times w$
Where, c = coefficient of rolling friction
w = weight of the equipment
$F = 0.35 \times 393 = 137.55$N
Power, $P = F \times v$
v = linear velocity
v is assumed to be 3.5 m/min
$P = 137.55 \times 0.0584$
$= 8.033$ Watt
$= 9$ Watt
Torque
$P = 2\pi NT/60$
N = revolution per minute
N = distance/ $2\pi r$
r = radius of wheel = 25mm
$N = 3.5/ 2\pi \times 0.025$
N = 23 rpm
Therefore T,
$= 9 \times 60/(2\pi \times 23)$
T = 3.75Nm

IV. Modelling

Major motto of this autonomous mobile robot is to reduce the human workforce. Increase the reliability and be more suitable for repeated process continuously. Material handling can be done in a more safe and secured manner.

The proposed three-dimensional model design of the mobile robot has been done using Solidworks [13], [14], [15] and the model was shown in Fig 3.

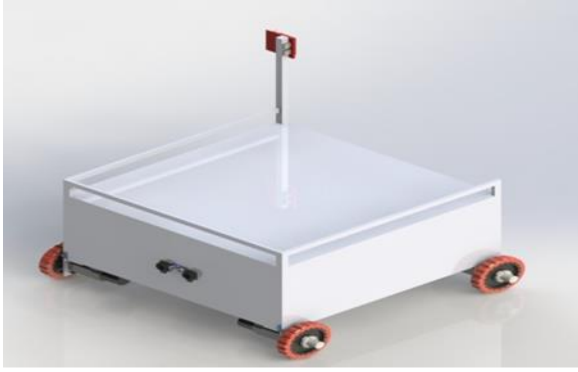

Fig. 4. Three-dimensional modelling of the proposed mobile robot

V. Conclusion

The working, calculations, design and three-dimensional model of the autonomous mobile robots for the textile mill for material handling of the processed cotton from the process stations were discussed in this paper. This proposed robot reduces labors for transporting the cotton from one station to the other and it is also safe and reliable.

Acknowledgment

The authors would like to thank Sree Jagathguru Textiles Private Limited, Tirupur, India and also thank Mr. K. Karunakaran for technical support and guidance.

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