Design and Development of Prototype IOT Controlled Forklift

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Abstract:
In industries loading and unloading of heavy loads manually is one among the foremost important task which is quite difficult, time-consuming and risky for humans. The paper illustrates the mechanical design of the prototype fork lift modeled as an industry based automated robot. It includes a DC motor which is been used with its controller to start the motion of the robot. This prototype industrial robot possesses three features and that they are: Path-Tracking, Avoiding Collision, Loading and Unloading heavy industrial goods. The autonomous robot is meant to start out its movement from a starting position, where goods are loaded. Then it follows a path of reference point drawn on white surface using line following sensor and unload goods by itself after reaching a destination place. Arduino Uno has been used to control the motion. Ultrasonic sensor has been attached with the robot to send the signal. It detects the presence of any obstacle that may appear in its path. Building an industrial robot with moderate Speed, good efficiency for loading and unloading purpose within a brief time to ease human suffering has been the focus of this paper.

Keywords **– Industrial automation, Robotic arm, Arduino, Ultrasonic sensor, Forklift, ANSYS**

1. Introduction

In general the forklift is often defined as a tool capable of lifting many kilograms of weight. A forklift may be a vehicle almost like a little truck that has two metal forks on the front to lift cargo. The forklift operator drives the forklift forward until the forks push under the cargo, and may then lift the cargo several feet within the air by operating the forks. The forks, also known as blades or tines, are usually made out of steel and may lift up to a couple of tons. Forklifts are either powered by gasoline, propane, or electricity. Electric forklifts rely on batteries to operate. Gasoline or propane forklifts are sometimes stronger or faster than electric forklifts, but they're harder to take care of and fuel is often costly. Electric forklifts are great for warehouse use because they are doing not give off noxious fumes like gas powered machines.

Forklifts are most frequently utilized in warehouses, but some are meant to be used outdoors. The vast majority of rough terrain forklifts operate gasoline, but some use diesel or gas. Rough terrain forklifts have the very best lifting capacity of all forklifts and heavy duty tyres (like those found on trucks), making it possible to drive them on uneven surfaces outdoors.

It is important for forklift operators to follow all safety precautions when employing a forklift. Drivers should take care to not exceed the forklift's weight capacity. Forklift operators also need to be ready to handle forklift's rear wheel steering. Driving a forklift is similar to driving a car in reverse, meaning that the driving force must constantly steer to stay it occupation a line.

The driver must remember of the forklift's ever-changing centre of gravity and avoid making any quick sharp turns or going too fast. It is advisable that anyone who operates a forklift be fully trained and licensed.

Various fields of technologies are included during this project work, because this technique

falls under the subject of mechatronics. The integration of electronic engineering, mechanical engineering and control technology is forming an important part during this design. The term mechatronics is employed to explain this integrated approach, therefore all above subjects are described during this project report in following chapters. Most systems that provide motion and force contain a mix of mechanical, electrical, and electronic Components. In fact, today most systems are mixed systems. The design of these mixed systems requires knowledge from all these fields. Warehouses are the storage elements of any industry. Storage quantity depends upon the assembly and demand of the content. In earlier days, warehouse services were managed with human also as machine efforts. Today, e-commerce industries have well advanced warehouse services with highly adopted computerized systems alongside human efforts. This needs human presence in warehouse along with continuous watch on system. We aren't far away from the time wherein the need are going to be to automated warehouses with robotic service and without on-field human involvement but with giving the control to humans.

Implementing an IOT controlled forklift vehicle and giving effective training will stop several of those accidents. Training can even stop or cut back the severity of accident associated. As the IOT controlled forklift can be controlled from a distant place having internet connectivity and will reduce the human effort.

2. Literature review

The event of robotic self-propelled vehicle meant to operate aboard human personnel, handling palletized materials at intervals existing, busy, and semi-structured out of doors storage facilities. Salvi Tushar et al. in his paper specified the objective of his work is to fabricate a Mechanical self-propelled vehicle for material handling in industries. In his paper a robotic vehicle is fictional that runs to hold material from one place to a different by victimization frequency technology. Nowadays to use self-propelled vehicle, it needs one spot guide to guide a self-propelled vehicle driver because of less visibility. This paper discusses the way to integrate radio frequency identification (RFID) technology into a self-propelled discusses the vehicle truck to create it wireless to extend visibility and human safety.

Avinash A. Kumar et al. in his work stated that Battery Operated fork carry is associated as an improved version of lifting and carrying the load that needs to be transferred from one place to a different. This advanced technology has brought a new revolution within the mechanical industries and most ordinarily utilized in serious engineering companies. These self-propelled vehicle vehicles had revolutionized ware-housing practices utilized in the middle of the twentieth century. For a protracted time, semi- automatic style of material handling systems being used. In semi automatic material handling, the system was manually controlled. The design of self-propelled vehicle has revolutionized warehouse work and it's practicable for one person to move many kilograms directly. This well maintained and safely operated self-propelled vehicle has made lifting and transporting consignment things terribly simply. The most purpose of this paper is to design and fabricate a self-propelled vehicle machine that is new and completely different from existing styles. This designed self-propelled vehicle uses a chargeable battery which implies it's supercharged fully by electricity. From the look of self-propelled vehicle, it will be all over that this machine is capable of lifting a load of a hundred kgs. The findings of this analysis show that the designed machine will be used in little scale industries.

Though the industries are well automated, automation is not well percolated among various Industrial warehouses. Various vehicles, machineries are used in warehouse service under human supervision. Abhay Bhujbal et al. have designed an IOT enabled robotic service for warehouse. Humans are prone to error while robots are prone to precession and response time. IoT enabled automated warehouse Service is a robotic solution for warehouse automation. Robotic structure incorporates the mechanical elements like chassis, wheels, etc. along with electronic elements like controlling unit, drivers, sensors, etc. The term IOT is an emerging technology which establishes the remote bridge between robot and warehouse operator and allows connecting the robot to the internet so as to command the robot. Robotic efforts will reduce the human efforts along with the efficient response time.

3. Methodology

This paper is aimed at providing a suitable solution for lifting loads with the implementation of automation such as IOT in the forklift. After understanding the current trends and advancement towards automatic system, we decided to work on this topic. The following are the sequential procedures adopted for completion of the work.

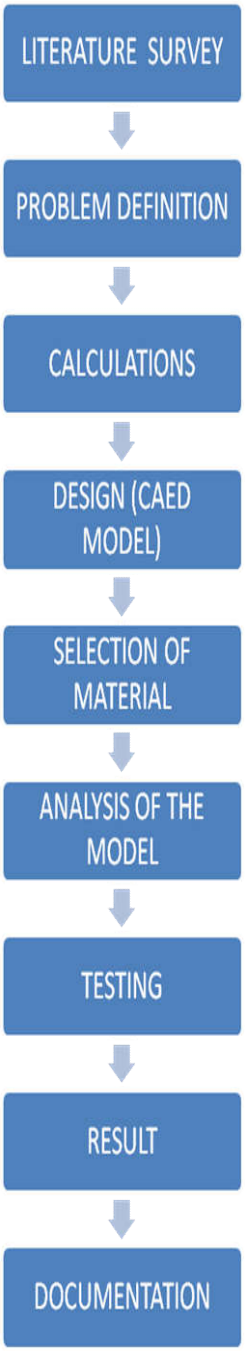


Figure1. Methodology flow chart

4. Design and Development

The CAD model was done using CATIA with the dimensions as shown in the figure 2, 3 and 4.

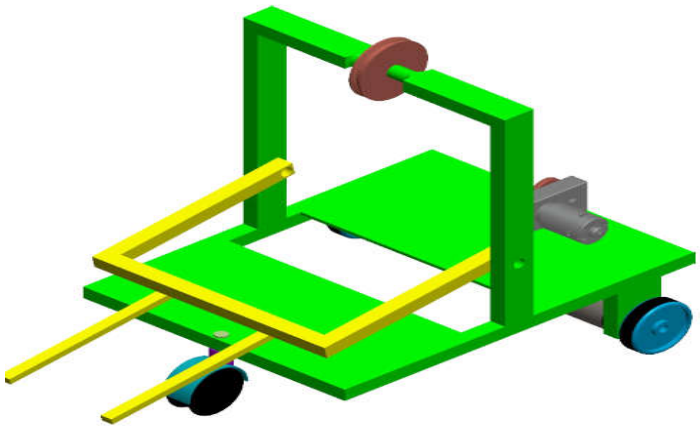


Figure2. CAD model of the conceptual design

The present work consists of 2 Dc motor which are mounted at rear and wheels are attached to them, the three wheeled design was chosen to provide a maneuverable forklift that could rotate on the spot, the chassis are made of mild steel. The main idea behind this prototype is to make that it follows a predetermined path ,so 6 infra red (IR) sensors are used , also we have used ultrasonic sensor which best serve the purpose of detecting and avoiding collision with the object.

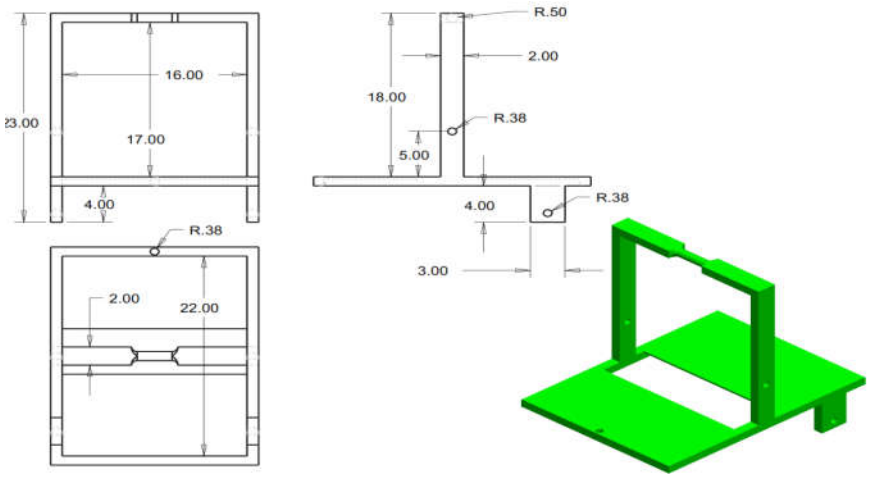


Figure3. Drawing of base with dimensions

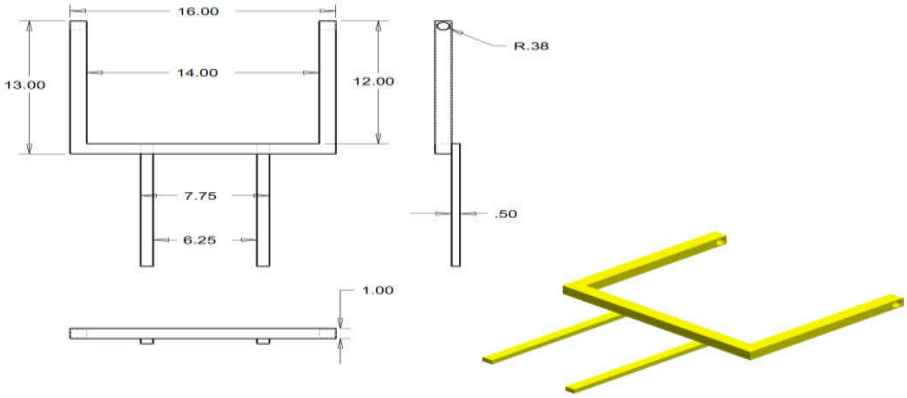


Figure4. Dimension of forklift

5. Components

5.1 Arduino Board

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform.

5.2 DC motor

For smaller prototype a 12v 1Amp DC motor is sufficient for lifting and a 24v motor with gear ratio 242:1 for the movement .It is slow but powerful with no load speed of 22rpm and rated torque of 20Ncm. The motor includes some terms and parameters for power loss and interruption whereas different terms are omitted from the model. It accounts for power loss in the winding resistance and time lag due to the energy storage in the magnetic field of the winding inductance.
There is no field power loss as a result of it's a static magnet field. The model doesn't embody power loss because of friction and different motion losses of physical phenomenon, eddy current, and wind age. The model additionally doesn't embody the interruption because of energy storage within the rotor inertia.

5.3 Motor Controller (H Bridge)

A motor controller may be a device or group of devices which will coordinate during a pre determined manner the performance of an electrical motor. A motor controller might include a manual or automatic means for starting and stopping the motor, selecting forward or reverse rotation, selecting and regulating the speed, regulating or limiting the torque, and protecting against overloads and electrical faults.

Figure5. 2A Dual motor controller

5.4 Line Following Sensor (Infrared sensor)

An infrared sensor is a device that emits so as to sense some aspects of the environment. An IR sensor can measure the warmth of an object also as detects the motion. Usually, within the spectrum, all the objects radiate some sort of thermal radiation. These sorts of radiations are invisible to our eyes, which will be detected by an infrared sensor. The emitter is just an IR LED (Light Emitting Diode) and therefore the detector is just an IR photodiode that's sensitive to IR light of an equivalent wavelength as that emitted by the IR LED. When IR light falls on the photodiode, the resistances and therefore the output voltages will change in proportion to the magnitude of the IR light received.

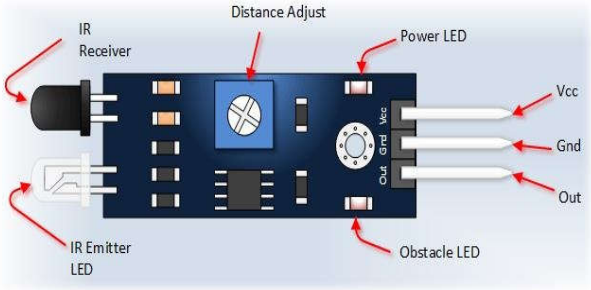


Figure6. IR sensor

5.5 Obstacle Detecting Sensor (Ultrasonic sensor)

An ultrasonic sensor is a device that measures the space of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and therefore the receiver (which encounters the sound after it's travelled to and from the target)

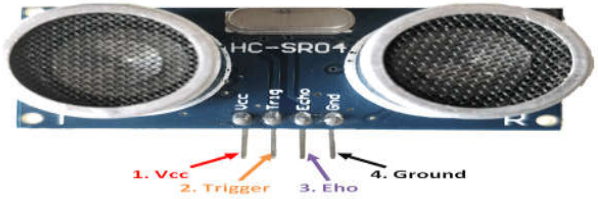


Figure8. Ultrasonic sensor

5.6 Servo Motor

A servo motor is an device which may push or rotate an object with great precision. If you would like to rotate and object at some specific angles or distance, then you employ servo motor. It is just made from simple motor which run through servo mechanism. If motor is employed is DC powered then it's called DC servo motor, and if its AC powered motor then it's called AC servo motor. We can get a very high torque servo motor in a small and light weight packages.
It consists of three parts:

- Controlled device
- Output sensor
- Feedback system

Figure8. Servo motor

6. Block Diagram

The Block Diagram is made to show how the control circuit has been implemented to allow the industrial robot to serve its purposes which are:
a) Path Tracking and Maneuvering.
b) Loading and Unloading of heavy goods.
c) Obstacle detection and avoiding obstacle.

In the block diagram Arrows are used to indicate sending and receiving of signals from different components that are used in the control circuit. These signals are classified as two types and they are: Input signal and Output signal. Inputs are distinguished from Outputs by the direction of arrows. Input signals are those which are represented as arrows that enter a block while output signals are represented by arrows leaving a block.

Digital Line Following Sensors that are assigned to detect the path read changes to the surroundings and output of sensor value (indicated as Signal A) is send to the Arduino Uno. Arduino Uno is the main and central block of the system which is programmed to make decisions depending on the output sensor value. These decisions are then send to Relays to take necessary actions. Signal B is that the output value of two sensors which go as input to the Arduino.
Depending on Signal A, Arduino transmit output to the Relay Switch (s1) which controls the only linear actuator for path tracking. Similarly, the output from the Relay Switch (s2) goes to two Linear Actuators for loading and unloading purpose after an output of Arduino goes to the input of that relay switch. Sufficient power source (5V) has been used to operate two Relays as well as to provide power to the Arduino. The following diagram shows actual negative feedback circuit of the system.

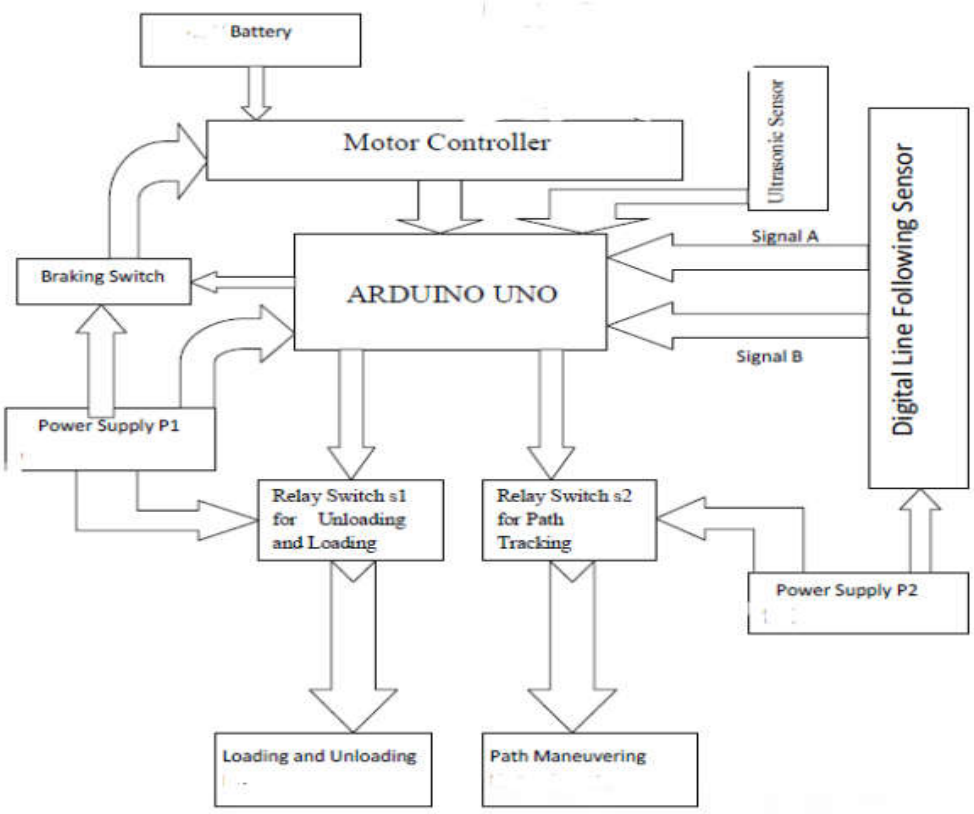


Figure9. Block diagram of the control circuit

7. FLOW CHART AND DESIGN CALCULATION

The flowchart shows in detail how the industrial robot is programmed to maneuver in the designed track for loading goods and unloading purpose. The black line has been specified in a predefined path such that the thick black line is drawn on the white surface.

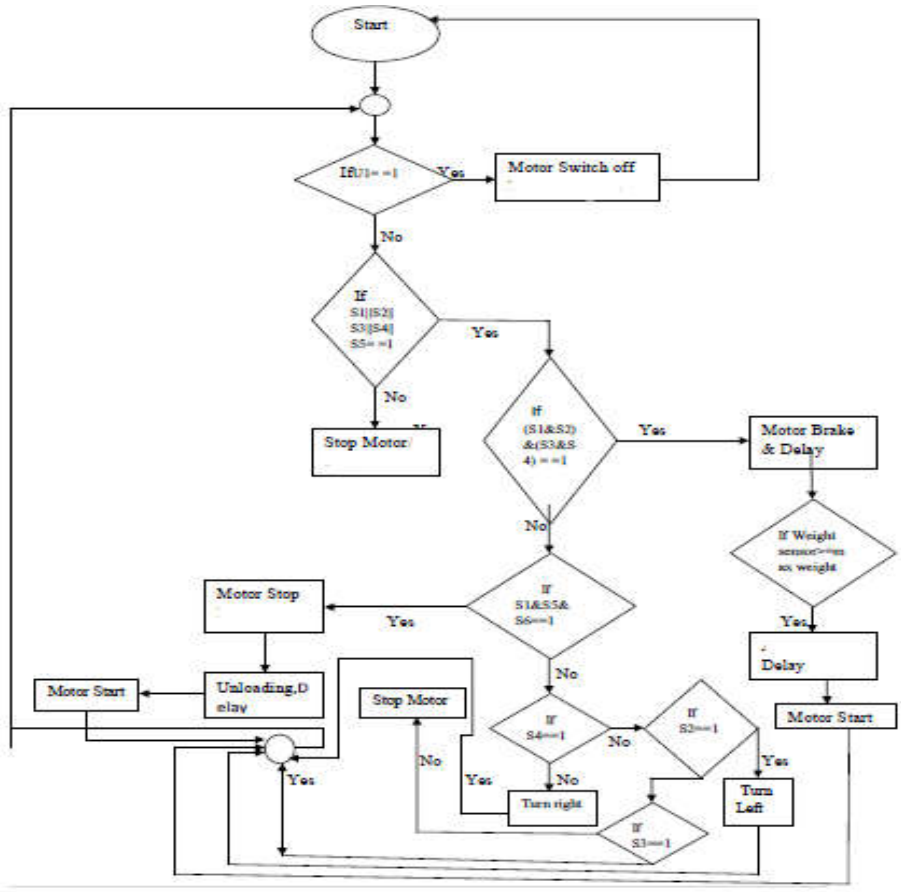


Figure10. Robotic maneuver flow chart

The design of forklift is derived as follows. Determine maximum load capacity, lifting height, forces acting on component. The material used for forklift is Mild Steel due to its properties like malleability as it can be pressed and hammered into various shape , ductility as it is versatile and can be bent easily and also due to factor that its very strong and is of low cost.

- Mass carrying (m) = 2 Kg
- Length of screw = 200 mm
- Factor of safety (FS)= 3
- Material = Mild steel {S_yt= 400N/〖mm〗^2,
- E=210 × 〖10〗^3 N/〖mm〗^2}

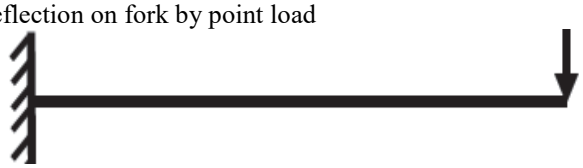
1. Total load in Newton –
Total Load (W) = Mass (m) × Acceleration due to gravity (g)…….(1)
= 19.62 N

2. Permissible compressive stress (σ_c)-

σ_c = S_yt/FS…… (2)
=133.33 N/〖mm〗^2

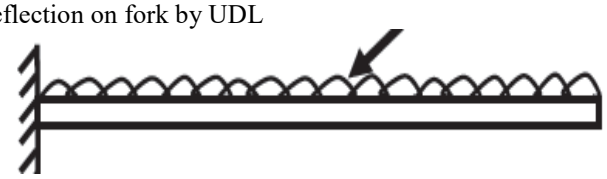
Design of Fork

Case 1:- By considering fork as a cantilever beam with point loading.
Deflection on fork by point load



W=3kg
By point load,
$Mx=-W\times L$……(3)
= -0.367Nm
Deflection,
$ymax=WL3/3EI$……(4)
$= 2.5344 \times 10-3\ mm$

Case 2:- By considering fork as a cantilever beam with uniform distributed load
Deflection on fork by UDL



Now
$Mx=-W\times L2/2$……(5)
= -0.0022Nm
Deflection,
$ymax=WL4/8EI$……(6)
$= 0.0188\ mm$

8. Analysis of the forklift

The software used in this paper for the analysis is ANSYS, various stress analysis has been done with the application of different loads. Static structural analysis provides a better understanding of the forklift under various stress condition.

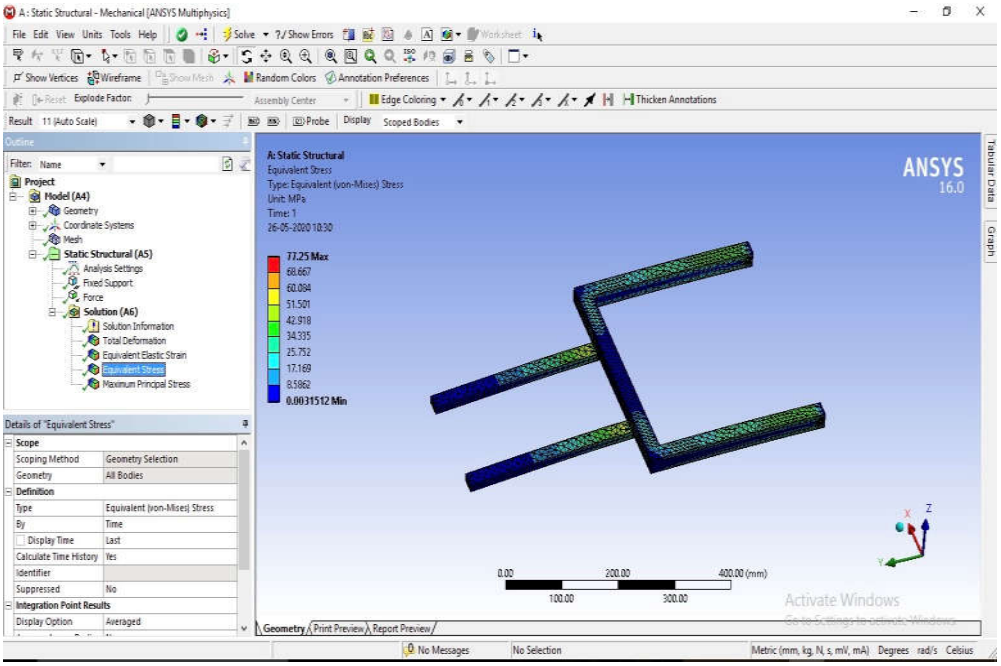


Figure11. Maximum principle stress

In the stability analysis is used to ensure that the forklift meets the safety requirements of its operations. The mass property calculations tool is used which gives us the volume, mass, centre of mass, principal moments, axes of inertia and other properties of the model. The above properties of the model are calculated by assigning material properties to each individual component as each having its own function and performance.

Also, the mass properties for both the fork have been calculated in order to ensure safety for the operator during its lifting as well as placing movement. In order to ensure safety of the forklift under static condition, the forklift is usually designed so that center of gravity will remain within the zone and has been checked in our design for stability in the forklift. We also performed those measurements to ensure the stability of our forklift under resting and loading conditions.

9. Result

The load weight, load distribution size and shape of the forklift plays an important role during the movement of the vehicle while in operation. So, in order to study the stability of this vehicle in terms of stress, deformation and load , stress and deformation have been plotted below.

load=500N

stress	deformation
77.25	3.23
68.184	2.87
60.084	2.513
51.501	2.154
42.918	1.791
35.335	1.4362
25.752	1.0771
17.169	0.7181
8.5862	0.35
0.0031	0

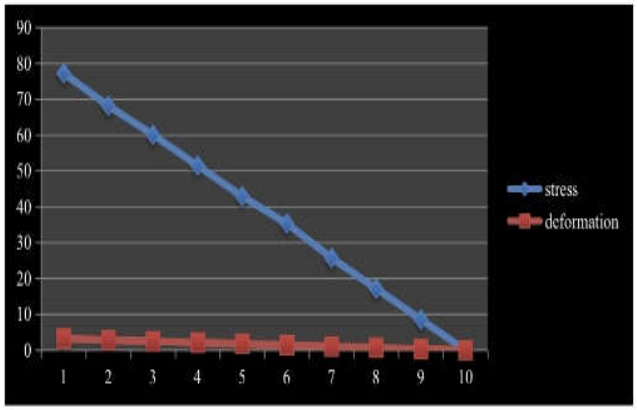


Figure12. Stress v/s deformation

load	stress
1100	159.92
1000	145.38
900	130.84
800	116.31
700	101.77
600	87.229
500	77.25
400	54.608
300	43.614
200	29.078

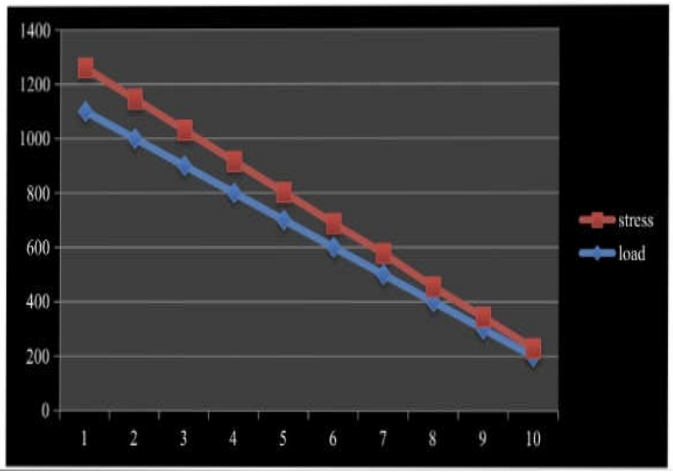


Figure13. Stress v/s load

From Figure 13 it is observed that as the stress on forklift increases the deformation also increases. As well as the stress increases uniformly and the graph is nearly parallel to load parameter. Similarly, from Figure 14 it is observed that the forklift deformation is linear in nature and the stress is directly proportional to the deformation or vice versa.

deformation	stress
7.109	159.92
6.426	145.38
5.8166	130.84
5.1703	116.31
4.524	101.77
3.877	87.229
3.2314	77.25
2.5852	54.608
1.938	43.614
1.2926	29.078

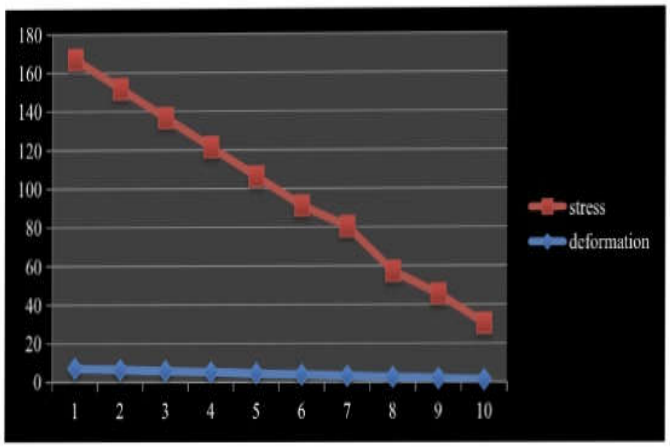


Figure14. Deformation v/s Stress

10. Conclusion

We have designed and developed an IOT controlled forklift which is completely autonomous. With the advancement of automation in industry, a forklift which does not involve human control can be a boon to the present industries. The use of IOT and its components decreases the error made by humans and provide a better safety. The prototype model has also been analyzed using ANSYS under various load condition, which helped in understanding the deformation obtained in different areas of forklift.

The main objective of the paper was to understand the need of automation in industries such as warehouse and how it can be implemented by decreasing the death rates due to human error and by increasing the efficiency of work performed.

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