Design and Fabrication of Battery Operated Semi-Automatic Forklift Vehicle

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Abstract— The Automatic Forklift System (AFS) is designed to make the process of stocking warehouses safer and more efficient. This machine is self-drive by the used of battery power and the lifting mechanism is also run on the battery power with the help of lead screw mechanism. Available here are a wide choice of fork which can either lift or pull load by means of a lead screw. There are two main differences with lead screw devices, some are designed to lift and pull and some are designed just to pull. The main factor that decides if a lead screw machine can be used to lift, pull or both is the factor of safety that it required and the unit is built to; to lift a load there is a FOS (factor of safety) requirement of 5:1, whereas to pull a load requirement on only 3:1 FOS. Options are available for manual, electric, pneumatic or hydraulic cable pulling and lifting devices. All of which have their own unique features and specifications which can make one more suitable than another.

Key words: Forklift, battery, lead screw, ball bearings, pinion

I. INTRODUCTION

A forklift is a powered industrial truck used to lift and move materials over short distances. The forklift was developed in the early 20th century by various companies, including Clark, which made transmissions, and Yale & Towne Manufacturing, which made hoists. Since World War II, the use and development of the forklift truck have greatly expanded worldwide. Forklifts have become an indispensable piece of equipment in manufacturing and warehousing. In 2013, the top 20 manufacturers worldwide posted sales of $30.4 billion, with 944,405 machines sold. The Automatic Forklift System (AFS) is designed to make the process of stocking efficient while decreasing unnecessary work-related spending. A one-sixth scale model forklift is being used to demonstrate the feasibility of the project. An operator will control the system at a safe distance away from the forklift, such as in a separate control room, decreasing the risk of work related injuries with a handheld user interface.

The Automatic Forklift System is capable of the following operations: receiving commands from the operator, navigating through the modeled warehouse, retrieving and placing pallets at desired locations. This device the lead screw fork lift has been developed to today itself the needs of small and medium scale industries, who are normally man powered with very minimum of skilled labors. In most of the industries the materials are lifted by using high impact man power and more amount of skilled labors.

To avoid all such disadvantages. This, fork lift has been designed in such a way that it can be used to lift the material very smoothly without any impact force. The operation is made be simple that even an unskilled labor can handle. It is movable from one place to other place easily by a proper wheel arrangement. Material handling is a specialized activity for a modern manufacturing concern. It has been estimated that about 60-70% of the cost production is spent in material handling activities.

II. CONSTRUCTION

The following are the main component of the project

A. Liftting Trolley:

This trolley is made by the M.S. Material for loading and unloading and for lifting and transporting the material from one place to the place in the industry.

B. D.C. Battery:

The battery is an essential part of the system. It is use for smooth & efficient operation of unit.

1) Types of Battery

1) Non rechargeable
2) Rechargeable

2) Rechargeable

Batteries are further classified into two types

1) Dry
2) Wet

– Dry Rechargeable Battery

These batteries are very small in size; they are also called as pencil cells. This battery consists of Nickel cadmium material for electricity generation. It has an output voltage of 12v and an output current of 500 ma. It is used mobile phone, pagers, electronic pocket diaries etc.

– Wet Rechargeable Batteries

These batteries consist of lead electrodes and Sulphuric acid for power generation. The lead electrodes are immersed in conc. Sulphuric acid in porous partition. These batteries are mostly used in automobiles.

Lead acid battery is also an example of wet batteries. This consists of lead acid medium for current generation. These materials are placed in a sealer casing. These are comparatively compact and are mostly use in emergency light solar lanterns etc.

3) Types of Rechargeable Batteries

– Sealed lead acid battery
– Sulphuric acid battery
– Dry cadmium nickel battery
– Sulphuric Acid Battery

It consists of lead electrodes immersed in Sulphuric acid in porous segment. It requires proper care and regular addition of distilled water is required mostly it is used in automobiles it is quite expensive.

– Sealed LED ACID Battery

These batteries are similar in construction as that of sulphuric acid battery. The main thing is that is does not require addition of distilled water. It is generally used in solar lanterns emergency light etc.

– Dry Nickel Cadmium Cell

Fig. 1: Dry Nickel Cadmium Cell

These cells consist of NICKEL and CADMIUM. It is dry and is very small in size as compared to other batteries. It is generally used in toys mobile, horn, pagers and in walkie-talkies.

4) Specification of Battery used

– Max output voltage:- 12V
– Max output current :- 2Am
– Type of current: - D.C.
– Charging rate :-2.5v@2A

C. D.C. Motor:

DC Geared Motor, 12V, 150 RPM, Torque up to 1.5 Kg-cm
This DC Motor with Metal Gear Head is generally used in various robotics applications; it has following electrical and mechanical specifications.

1) Specifications:

Motor type: DC with Gear box, Metal Gears
Shaft Type: Circular 6mm Dia. With internal hole for coupling
Maximum Torque: ~1.5Kg-cm at 12V=0.14715N-m
RPM: 150rpm at 12V
Weight: 130Gms
Max Load Current: ~330mA at 12v

Fig. 2: DC Geared Motor

D. DP/DT Switch:

In electrical engineering, a switch is an electrical component that can break an electrical circuit, interrupting the current or diverting it from one conductor to another. The mechanism of a switch may be operated directly by a human operator to control a circuit (for example, a light switch or a keyboard button), may be operated by a moving object such as a door-operated switch, or may be operated by some sensing element for pressure, temperature or flow. A relay is a switch that is operated by electricity. Switches are made to handle a wide range of voltages and currents; very large switches may be used to isolate high-voltage circuits in electrical substations.

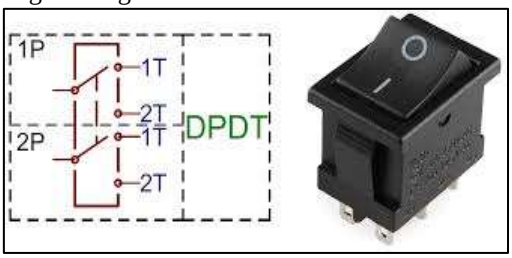

Fig. 3: DP/DT Switch

E. Lead Screw:

A leadscrew (or lead screw), also known as a power screw or translation screw, is a screw used as a linkage in a machine, to translate turning motion into linear motion. Because of the large area of sliding contact between their male and female members, Screw threads have larger frictional energy losses compared to other linkages.

They are not typically used to carry high power, but more for intermittent use in low power actuator and positioner mechanisms. Common applications are linear actuators, machine slides (such as in machine tools), vises, presses, and jacks. Leadscrews are manufactured in the same way as other thread forms (they may be rolled, cut, or ground).

A lead screw is sometimes used with a split nut also called half nut which allows the nut to be disengaged from the threads and moved axially, independently of the screw's rotation, when needed (such as in single-point threading on a manual lathe).

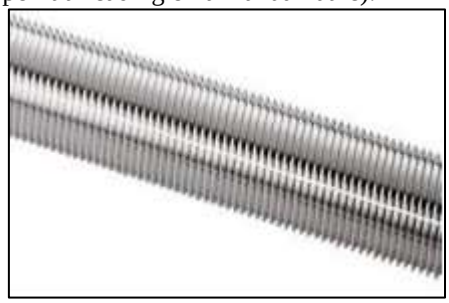

Fig. 1: Lead Screw

F. BALL BEARING:

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races.

The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly. As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other.

Ball bearings tend to have lower load capacity for their size than other kinds of rolling-element bearings due to the smaller contact area between the balls and races. However, they can tolerate some misalignment of the inner and outer races.

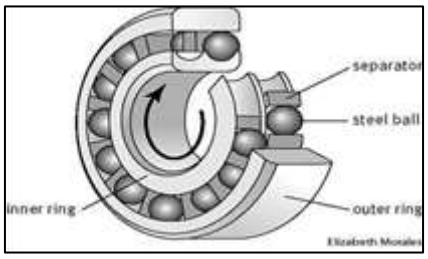

Fig. 5: Ball Bearing

G. Guide Bar:

This is supporting bar help for sliding the hole mechanism from top to bottom and vice versa. It is bright bar.

Fig. 6: Guide Bar

H. Pinion:

A pinion is a round gear used in several applications:

Usually the smaller gear in a gear drive train, although in the first commercially successful stream locomotive (the Salamanca), the pinion was rather large. In many cases, such as remote controlled toys, the pinion is also the drive gear. The smaller gear that drives in a 90-degree angle towards a crown gear in a differential drive. The small front sprocket on a chain driven motorcycle. The round gear that engages and drives a rack in a rack and pinion mechanism and against a rack in rack railway. In the case radio-controlled cars with an engine(i.e. nitro) this pinion gear can be referred to as a clutch bell when it is paired with a centrifugal clutch.

Fig. 7: Pinion

III. WORKING

This project is assembled as per our concept and design. In this project we used the two DC motor. First motor is used for moving the project from one place to another i.e. to transport the material from one place to another place. For moving the project we operate the DP/DT switch. This switch rotate the DC motor in clockwise and anticlockwise due to this the machine is move in reverse and forward direction and move the material from one place to another place.

The second DC motor is used for lifting and lowering the material from one place to another place through the lead screw . For lifting and lowering the material firstly we put the material on the tray. According to the requirement we rotate the DC Motor through the DP/DT Switch in clockwise or anticlockwise through the lead screw rotation. This lead screw is connected to the D.C. Motor through the pinion arrangement.

Fig. 8: Battery Operated Forklift after Assembly

IV. CALCULATION

A. System Design

Design

1) Motor

Specification of motor

Voltage = 12 volt

Power = 60 watt

Speed = 150 rpm

$$p = \frac{2\pi NT}{60}$$

$$T = \frac{60 \times p}{2\pi N} = \frac{60 \times 60}{2\pi \times 150} = 3.81\,Nm$$

a) Design of Input shaft

Material selection

Designation	Ultimate strength(U.S.) N/mm^2	Working strength N/mm^2
EN_{24}	900	700

According to ASME Std code values and shear stress may be calculated from following relation. F.S actual <F.S small Input shaft is under torsional load.

b) Design of slide screw

Basic Dimensions for square threads

(Ref:Pg. No. 5.69, PSG-Design Data)

Nominal Dia.	Major Dia.(bolt)	Major Dia.(nut)	Minor Dia.	Pitch	Area of core
16	16	16.5	10	3	78.5

Given motor specification
P = 60 watt, N =500 rpm

$$p = \frac{2\pi NT}{60},\quad T = \frac{60 \times p}{2\pi N} = \frac{60 \times 60}{2\pi \times 500} = 1.14\,Nm$$

Transmission ratio of the gear arrangement is to be 1:55

$$T_d = 55 \times 1.14 = 62.7 \cong 63\,Nm \ldots\ldots\ldots .(a)$$

Material Combination	Coefficient of friction(starting)	Coefficient of friction(running)
Soft steel-Bronze	0.10	0.08

d =Nominal/outer diameter = 16mm
d_c =core/inner diameter = 10mm
d_m = mean diameter= 13mm
W = Axial load
θ = friction angle
α = Helix angle
Torque during starting the movement of lead screw

$$Td = w \times \tan(\alpha + \theta) \times \frac{d}{2} \ldots\ldots\ldots(b)$$

Check lead screw design by formula

$$T = W \times (\frac{dm}{2}) \tan(\alpha + \theta)$$

Helix angle

$$\alpha = \tan^{-1}(\frac{1}{\pi dm}) = 4.2$$

$$\mu_s = 0.11,\quad \mu_s = 0.08$$

$$F.S.Max = 0.18 \times U.S = 0.18 \times 900 = 162\ N/mm^2$$

$$F.S_{\max} = 0.3 \times Y.S = 0.3 \times 700 = 210\ N/mm^2$$

Considering the maximum value of all above two calculated value

$$\therefore F.S_{\max} = 162\ N/mm^2$$

As shaft is provided with keyway its strength is reduced, allowable stress is reduced by 25%

$$\therefore F.S_{\max} = 121.5\ N/mm^2$$

This is the stress which can be induced in shaft material for safe operation
Assuming 100% load

$$T_{design} = 2 \times T = 2 \times 3.81 = 7.62\,Nm$$

Check for torsional shaft failure of shaft, put d=16mm

$$T_d = \frac{\pi}{16} \times F.S_{actual} \times d^3$$

$$F.S_{actual} = \frac{7.62 \times 10^3 \times 16}{\pi \times 16}$$

$$F.S_{actual} = 9.47$$

$$T = W \times (\frac{13}{2}) \tan(4.2 + 5.71)$$

$$63 = W \times 1.13$$

$$W = 55.75 \cong 60\,KN\ (starting\ )$$

$$T = W \times \frac{13}{2} \times \tan(4.2 + 4.57)$$

$$T = W \times 1.002$$

$$63 = W \times 1.002$$

$$W = 62.87 \cong 65\,KN\ (running\ )$$

Maximum weight of system component on the side=200N i.e 20Kg
Material selection for screw

Designation	Tensile strength	Yield strength
EN_9	600	380

$$F_{act} = \frac{w}{\pi/4 \times dc^2} = \frac{200}{\pi/4 \times 10^2} = 2.54$$

As $F_{cact} < F_{call}$
Screw is safe in compression
M_t is torque required at screw to move slide=800Nm
Torsional shear stress

$$T = \frac{\pi}{16} \times F_{sact} \times dc^3$$

$$0.8 \times 10^3 = \frac{\pi}{16} \times F_{sact} \times 10^3$$

$$F_{sact} = 4\ N/mm^2$$

$$F_{sact} < F_{sall}$$

Screw is safe in torsion
Bearing pressure

$$p_b = \frac{W}{N} = \frac{W}{\pi/4(d^2 - d_o^2) \times n}$$

Application of screw	Material	Safe bearing pressure	Rubbing speed
Screw jack	Screw/nut steel bolt	11-17N/mm^2	Low speed

$$n = \frac{800}{\frac{\pi}{4}(d^2 - dc^2) \times P_b} = 0.59$$

$$n = 1$$

Selecting length of nut=13(n=2)
Shear stress due to axial load

$$F_{act} = \frac{W}{\pi tndc} = \frac{800}{\pi \times 2 \times 10 \times 3} = 4.24\ N/mm^2$$

T=thread width=P/2
As $F_{sact} < F_{sall}$ screw thread are safer in shear.

B. Design of nut

Material selection

Material	Allowable tensile stress N/mm^2	Allowable shear area N/mm
Phospher	400	210

$$F_{bearing} = \frac{W}{\frac{\pi}{4}(d^2 - d_o^2) \times n} = \frac{800}{\frac{\pi}{4}(16^2 - 10^2) \times 1}$$

Normally recommended that ratio of diameter of nut to core diameter (dc)
L_n= length of nut
P= pitch

$$n = \frac{L_n}{p}$$

$$L_n = nP = 1 \times 6 = 6$$

$$L_n = 1.2 \times 10 = 12$$

Shear stress due to axial load

$$F_{snut(act)} = \frac{W \times p}{L_n \times n \times dc} = \frac{800 \times 2}{13 \times 1 \times 10}$$

$F_{sact} < F_{sall}$ hence the nut is safe.

As the calculated length of nut is 12 which is less than selected length nut 13. Hence the length of nut is safe.

V. CONCLUSION

The project work "Battery operated forklift" is aimed to control through lead screw. The main advantage of using this technology is to increase the safety of operator by operating the forklift from certain distance. This increases the efficiency of the productivity, because human errors due to the poor visibility can be minimized. The system is designed and developed successfully, for the demonstration purpose prototype model (mini model) is constructed.. After going through these collected data and statistics from various journals as well as research papers; we came to conclusion that remote controlled fork lift is the only way to stop such industrial issues like labour cost, hazardous material handling. Our project has a simple electrical heart and a simple mechanical body. It can be modified into any high class application. Considering the project time and all the necessary steps, we concluded this project is the right one. Since just a simple modification in its mechanical arm and movement way, we can convert into any robot that can perform a special type of work. We can use our human brain but the hands and legs of a robot, and thereby nullifying the chances of accident.

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