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Design and Fabrication of Self-Weighted Material Handling (SWMH) Equipment

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ABSTRACT
In this study, a Self-Weighted Material Handling (SWMH) equipment is designed, constructed and evaluated its performance. Most of the material handling system using in industry is requires external energy or manpower to operate it. In this work, a spring operated SWMH system is developed and this system does not need external energy or manpower to operate which reduce the material handling cost as well as production cost. At first design of various mechanical parts, a details drawing is done using SOLIDWORKS software. All designed elements are fabricated and assembled for final SWMH system. After constructed the system, a performance test is performed in various loading condition. The performance test results show that maximum 75.5 kg weight is covered the about 4 m distance. The calculated and experimental results show the 1.92% error due to ignore the frictional loses during calculation.

Keywords: Material handling, Spring, Gear, Mechanical Design, Industry

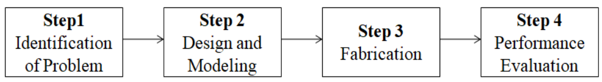
1. Introduction

Material handling is the movement, security, storage, and control of materials and products throughout manufacturing, production, assembling, warehousing, appropriation, utilization, and removal. Now a days, material handling's accomplished with the assistance of various types of conveyance, instrument or contraption which basically functioned by electricity, one the other hand small industries employ human resources. An appropriate material handling system can reduce the overall cost of the production process. In a manufacturing company, material handling may represent for 25% of all employees, 35% of all organization space, 77% of creation time, and 55% of the cost of complete item [1]. From a health and safety perspective, a material handling system could be unsafe from manual occupation. Therefore, proper material handling system can ensure the safety of employees and improve the production procedure with enhancing process flexibility [2]. Another examination found that out of absolute production time fall, 12.45% could be added to material handling [3]. This study additionally emphasizes the heavy use of equipment such as trolleys for the swift material handling. For selecting appropriate material handling equipment, Kumar et al. [4] proposed a design that can be reduced the overall production cost. In their model, they applied the Fuzzy Analytic Hierarchy Process (FAHP) to achieve the proper solution. Self-operating material handling equipment may have heavy weight conveying limit, high dependability, and low maintenance [5]. Vaibhav Thete et al. design a self-operated material handling trolley. Such equipment can diminish the energy utilization and reliance on human resources prompting significant production costs [6]. Kulak et al. revealed that efficient material handling equipment could be reduced by 30% to 75% assembly system activities cost [7]. Khurmi et al. found that spring-operated material handling devices have tremendous burden conveying limit, huge covering territory, improved structure, simple maintenance, and highly reliable quality of activity [8].

For this reason, with this such background, it is concluded that the appropriate material handling equipment stands as the most wanted system to reduce production costs and ensure workers' safety. Therefore, in this study, self-weighted material handling (SWMH) equipment is designed and fabricated. The performance of this equipment is evaluated by using various loading conditions. This machine's primary function is to move products from one place to another without any external power or human resources help. The primary goal of developing the machine is mainly to save energy consumption and minimize other material handling equipment costs.

2. Methodology

In this study SWMH equipment is designed and fabricated by following steps.



Identification of problem: An automated material handling equipment need huge electrical energy we need more human effort and need of more electrical energy. For saving the electrical energy consumption, SWMH equipments can be a promising and alternative solution rather than automated one. Therefore, in this study a self weighted material handling (SWMH) equipment is designed and fabricated.

Design and Modeling: Mechanical parts are design such as spring, shaft & gear and a 3D model is designed using SOLIDWORKS software.

Fabrication: All the designed elements are manufactured and assembled.

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Performances Evaluation: The performance of this equipment is evaluated by using various loading conditions.

3. Design and Modeling

3.1 Components Used in this SWMH equipment

Spring: One of the most important components for this equipment is spring. Four springs are used in this SWMH equipment. Each spring are 1.26-inch mean diameter and 0.118-inch wire diameter and spring material is Cr-V Steel VSQ(s); ASTM A232. Maximum loading capacity at solid height is 24.04 Kg.

Gear: Another most important component of this system is gear. Gear is a very simple machine which has the ability of changing torque, direction and speed of the power source which creates mechanical advantages. Gear material chosen AISI C1020 as rolled with number of teeth Np = 18, Outer diameter D_p = 1.25 inch and n_p =116.73 rpm.

Rack and Pinion: This linear gear is known as rack and it is used in this equipment to control the linear motion.

Base: Base is made by cast iron in where all components are mounted.

Tray: Tray is the top portion of this equipment where the load is put on it. It is made by wood.

Inner pipe and Outer pipe: The outer pipe is for the main support of the tray. It also carries the springs. The outer pipe is designed as the requirement of placing the springs. The inner pipe is attached with the tray. It is placed over the springs into the outer pipe. The inner pipe is solid pipe but the outer pipe is hollow. Inner pipe is designed solid because the load needs to fully apply on the spring. But if the pipe becomes hollow, the load may not be appropriately applied on the spring. The outer and inner pipe is made with mild steel.

Chain Drive System**:** The chain drive is attached to the wheel which is help to move the trolley forward and backward.

Bearing and Shaft: These are used to transmit power**.**

Wheels: Four wheels of 4-inch diameter are used in this equipment.

3.2 3D Modeling

At first a 3D model is developed using SOLIDWORKS software shown in figure 1. The specification of different components is shown in Table 1.

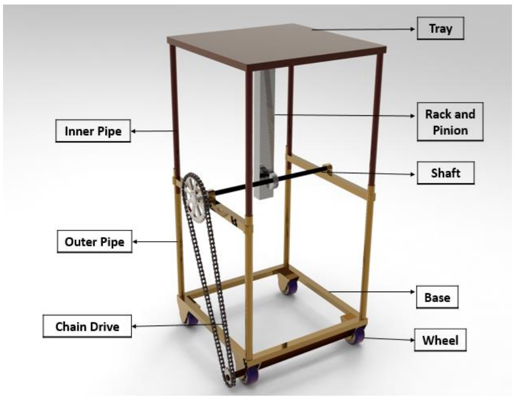

Fig.1 3D view of Self-Weighted Material Handling Equipment designed by SOLIDWORKS

Table 1 Specification of the different components of SWMH Equipment

Parts Name	Specifications
Spring	Free length=13″, Mean diameter= 1.26″, Wear diameter = 0.118″
Gear	Outer diameter =1.25″, Teeth Number= 18
Rack	Length= 18″
Tray	Length= 20″, Width=20″
Base	Length= 20″, Width=20″
Inner pipe	Diameter=0.97″, Height=24″
Outer pipe	Diameter=1.69″, Height=24″
Shaft	Length=26″, Diameter= 0.9″
Wheel	Diameter=4″

4. Fabrication

After manufacture all designed component assembled. The final fabricated SWMH equipment is shown in figure 12. The load is put on the top of the system and calculated the distance traveled.

Fig.2 Constructed material handling system (two different views)

5. Working Principle

The working principle of the self-weighted material handling (SWMH) equipment is given below:

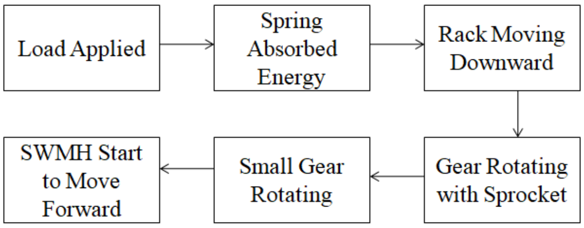

Fig.3 Block diagram of Forward Motion

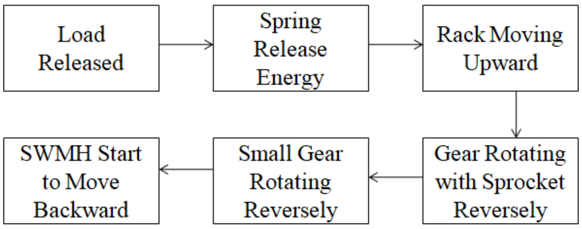

Fig.4 Block diagram of Backward Motion

The working principle of the SWMH Equipment is given below:

(i) This machine is operated by the weight of the product which is carried by it. When there placed the load on the tray, it forced the tray downward.
(ii) When the tray starts moving downward, the rack also moves to the same direction as it is attached with the tray.
(iii) As the tray come to downward, the spring absorbs the potential energy of the load. For this reason, the springs start compressed into the pipe and the rack come downward at a fixed speed.
(iv) The rack is mounted with the pinion gear which main work is to convert the linier motion into the rotary motion. The gear is attached with a shaft. The shaft is attached with bearing at both side and there is also a sprocket of chain drive system. As the shaft rotates because of the gear, the sprocket is also rotating at the same direction.
(v) When the sprocket starts rotating, the pinion which is another part of the chain drive system also rotates.
(vi) There is a shaft that attached with the pinion and front two wheels. So, when the pinion rotates, the shaft also rotates along with the wheels. That's why the total system starts moving forward.
(vii) When the material reached to its destination, the product will take from the machine. When the load is released from the material handling system, the potential energy is also become releases which are stored into the compressed spring.
(viii) The springs start to move its initial position. And when it moves upward, the rack and tray also start moving upward.
(ix) As the rack is attached with the gear, so the gear starts rotating reversely than previous.
(x) When the gear rotates reversely, the full chain drive starts rotating in backward motion. So, the full material handling system moves backward to its initial position.

6. Theoretical Distance Calculation

Here,
Calculated rpm= 116.73 (For 75 Kg load)
The periphery of the gear= 2*3.1416*1.25/2 = 3.927″
For every revolution, the gear travelled 3.927″
The length of the rack that gear traveled= (13-3.186) ″ = 9.814″
So, the total revolution of the gear=9.814/3.927 =2.5 rev
The sprocket revolution is same as the gear. Though the gear ratio of chain drive is 4, so the small gears' revolution= 4*2.5 = 10 rev
The wheels are also revolute as the second gear.
The wheel diameter is 4″
So, the wheel periphery = 4*3.1416= 12.57 inch
So, the traveled distance = (wheel periphery*revolution of wheel) + length of the base
= (12.57*10) + 24
= 149.7 inch
= 380.24 cm
= 3.802 m

7. Results and Discussion

A performance test of fabricated SWMH equipment has been carried out by loading different weight top on the system. At first traveling surface is cleaned carefully and lubricated all wheel to avoid the possible frictional losses. The load is put on the top of the system and calculated the forward distance covered by the system. Similarly, unloading and calculated the backward distance covered by the system. Data is taken for different loading and maximum loading is 75.5 kg. Travel distance for various loading and unloading conditions is shown in Table 2, Fig. 5. From these results the backward distance covered is slightly less than the forward distance. The reason is to the power losses of spring during unloading conditions. When the system needs to move backward, the spring needs an extra push so that it can rotate the pinion. And as there are other external frictions, it loses some power.

Table 2 Travel distance for various loading and unloading conditions

Weight, kg	Travel Distance (Loading), m	Travel Distance (Unloading), m
62	3.29	3.13
66.5	3.46	3.25
71	3.61	3.44
75.5	3.73	3.51

As the whole system depends on spring, it is the main part of this system. Springs are always into the outer pipe and working. This makes tiredness into the spring which impacts directly into the spring's efficiency. It also happens while the system did not use for long time. So, it needs to oil regularly and need to bring springs out after a several time. When any kind of load need to put on this system, it must be remained the path clear. If the system has the load on it and cannot move to its path then the system may fail to do its job. When the system reached the station with the load, it needs to unload as soon as possible. Long time weight keeping may hamper the spring and causes of deformation of the spring which can totally fails the system. However, the calculated and experimental results show the 1.92% error (Fig. 6). This is because of in calculation purposes we ignore the frictional loses. Therefore, this SWMH equipment is almost functioning very well and satisfying the main objectives of this study. This equipment performance is also compared with those obtained by Vaibhav Thete [6] and Kalpesh Borse [9]. It is observed that the equipment can carry a maximum 30 kg load over the distance of 1.35 m, whereas, in this study, it can carry a maximum 75 kg load over 3.73 m distance. After considering all of these, the equipment might be applied to transport the material over short distances (3 to 4 m) such as in assembly lines of engine block, loading and unloading of brick field or in packaging industry etc.

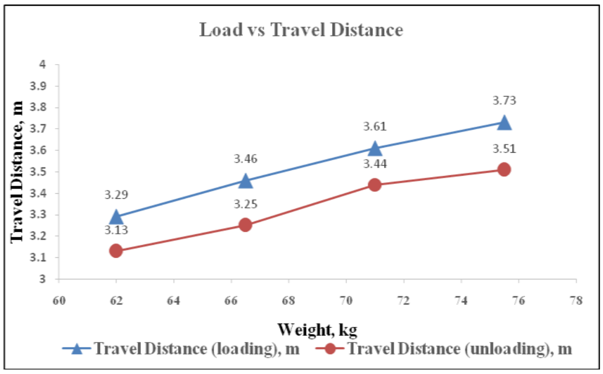

Fig.5 Loading Unloading vs Travel distance curve

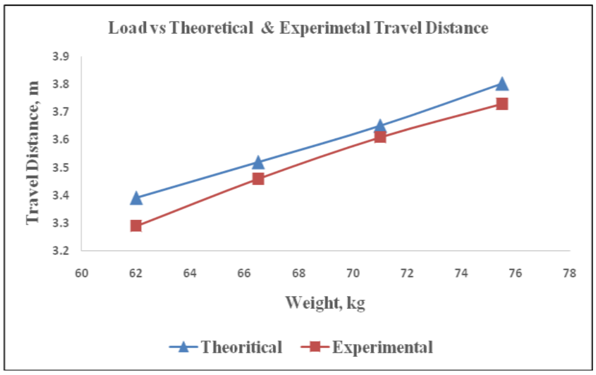

Fig.6 Comparison of theoretical and experimental results

8. Conclusion

In this study, a Self-Weighted Material Handling System is designed, constructed and the performance test is carried out. The following conclusions can be figured out:

(i) The designed material handling system constructed successfully and evaluated its performance.
(ii) The results show that, the backward distance covered is less than the forward distance. The reason is to the power losses of spring during unloading conditions.
(iii) The calculated and experimental results show the 1.92% error due to ignore the frictional loses during calculation.

Additionally, this material handling system is environment friendly as there is no use of external power source.

9. References

[1] Tompkins, J. A., White, Y. A., Bozer, J. M., & Tanchoco, A., Facilities Planning. 4th edition, New York: Wiley, 2003.

[2] S. Sujono and R. S. Lashkari, A multi-objective model of operation allocation and material handling system selection in FMS design, *International Journal of Production Economics*, Volume 105(1), pp.116-133, 2007.

[3] S. O. Okpighe, The Impact of Materials Handling Management on Production and Time Loss in a Tyre Manufacturing Company: A Case Study., *International Journal of Innovative Science, Engineering & Technology*, Volume 2(9), pp11-18, 2015.

[4] Kumar, S. and Raj, T., Selection of material handling equipment for flexible manufacturing system using FAHP. *Int. Jr. Recent Adv. Mech. Eng. (IJMECH)*, 5(1), 2016.

[5] Kadam, M., Kesarkar, K., Narvekar, S., Gurav, P., Chaudhari, T. and Koshti, V., Design and Development of Weight Operated Material Handling Device. *Journal of Modern Mechanical Systems and Machining*, *1*(2), 2018.

[6] Thete, V., Patil, R., Sarange, R., Shinde, T. and Awate, S., Design and development of a material handling trolley operated by self-weight of the job. In *AIP Conference Proceedings* (Vol. 2018, No. 1, p. 020001). AIP Publishing LLC, 2018.

[7] Kulak, O. A decision support system for fuzzy multi-attribute selection of material handling equipments. Expert systems with applications, 29(2), pp.310-319, 2005.

[8] Khurmi, R.S. and Gupta, J.K., A textbook of machine design, Eurasia, 2005.

[9] Kalpesh Borse, Jasmeen Shaikh, Gayatri Pawar, Mr.M.K.Holkar, Weight operated material handling device, *International Journal of Advance Research in Science and Technology*, 7(7), pp. 21-24, 2018.