Print ISSN : 0022-2755
Journal of Mines, Metals and Fuels
Contents available at: www.informaticsjournals.com/index.php/jmmf

Design Optimization and Implementation of an Automated Storage and Retrieval System

Sowmya C[1], Karibasavaraja D[2*], Ramesh M R[3], Sharnappa Joladarashi[4] and Aishwarya M V[5]

[1]*Assistant Professor, Department of Industrial & Production Engineering, JSS S&TU, Mysuru, India.*
**E-mail: sowmyac@sjce.ac.in*
[2]*Assistant Professor, Department of Industrial & Production Engineering, SJCE, JSS S&TU, Mysuru, India.*
[3]*Associate Professor, Dept. of Mechanical Engineering NITK, Surathkal, India.*
[4]*Associate Professor, Dept. of Mechanical Engineering NITK, Surathkal, India.*
[5]*Under Graduate, Department of Industrial & Production Engineering, SJCE, JSS S&TU, Mysuru, India*

Abstract

This research article suggests a system for automated storage and retrieval. The AS/RS is an advanced material handling equipment that utilizes the concept of high density material storage with an automatically controlled stacker for material handling. Designing an affordable Automated Storage and Retrieval System, which is utilized extensively in the manufacturing assembly production process and movement of the component, is a challenge for the majority of companies. The selection of storage system mainly depends on physical dimensions, required space and storage volume capacity. This paper aims to develop a customized AS/RS system that is low cost and thus reduces worker fatigue caused by heavy lifting. In addition, to create a secure system to prevent unauthorized access by personnel to the racks. The optimized results of the present work shall be presented here.

Keywords: *Actuator, EM Plate, Electromagnet, Reed switch, Work Station AS/RS.*

1.0 Introduction

Material handling is the process of storing, moving, controlling and protecting material which may include raw materials, finished goods, in-process inventory, consumables, spare parts etc. There are several material handling principles, and one of them is the automation principle, which deals with using electromechanical, electrical, and computer-based systems to operate and regulate production and service activities. It suggests the linking of several mechanical systems that can be controlled by programmed instructions. The main objective of automated material handling systems is to be a replacement to human labour by efficient handling, utilization of space and reducing the handling time. As observed in the research of Corina and Gabriela in 2011, Automated Storage and Retrieval Systems is a cutting-edge material handling tool that uses the concepts of high-density storage of goods with a computer-controlled stacker crane handling the item.

The research work in this paper is dedicated for automation to be integrated into a storage racking system for the automatic placing and retrieving of items stored according to their indexing or part numbers. It is required by the customer to give a low cost, flexible, automated material handling system which can be cost effective to be used by manufacturers.

According to the literature survey, some details are provided about the existing solutions for the research

**Corresponding Author*

problem considered, ranging from products sold by leading MHS manufacturers to field work and research methodologies conducted to tackle the efficiency, flexibility and affordability of such existing systems.

Pop et. al[1] have examined two types of automation used in handling: automated storage/retrieval and automated return/sorting system. It has chosen a portable shelving storage system that travels over rails set into the floor for the warehouse AS system. Items that have been returned enter the Book Return Sorting System, a network of connected modules that recognizes each item and determines where it should go. In their paper, Jitendra S. Patil and Prof. P. R. Attar[2] conducted research on the market's current racking systems based on a variety of configurations, including manual and powered ones. These configurations include flow racks, drive-in and drive-through racking, adjustable pallet racking, and powered mobile racking. In their research, T Ajay et al[3]. created a unique unit-load AS/RS system. The unit-load technique is appropriate when many components are stocked up but there are few discrete standard types available. Implementing the Particle Swarm Optimization technique decreased the system's lead time for transferring operations like loading and unloading of the components and improved overall performance. Matthew William James Crosbie[4] investigates the industrial pallet racking system performance in comparison to the FEM code for a specific manufacturer. During the course of this activity, almost 2000 tests were completed. This characteristic test data was then used to build a strategy.In their study titled, Tian Liu et al[5]. examined a split-platform system that includes platforms lifts that may move independently in both horizontal and vertical directions. The prototype that was made, the specifics of which are further explored in their work, was substantially influenced by the design of this rack.In their study, Azadehet.et. al[6]. examine novel automated types of material handling systems, including robotic mobile fulfilment systems, shuttle-based S/R systems, and compact storage systems. F. Azadivar[7] has described a warehouse with two different types of storage areas in this study. Because items may be stored in and retrieved from random access areas immediately, it has been discovered that they are more effective overall.

Table 1: Configurations of the prototype developed

Overall dimensions	1100 mm × 810 mm × 450 mm
Supply voltage	230V AC
Maximum load capacity	9 kgs
Space occupied	0.5274m^3
Number of shelves	6
Maximum crate dimensions	300 mm × 200 mm × 100 mm

2.0 Methodology of the Present Work

The Automated Storage and Retrieval System are developed based on digital type prototype and the experimentation work conducted to build an actual working prototype to test the mechanism idea selected.

2.1 Automated Storage and Retrieval System Configuration

The basic information related to the prototype configuration of the AS/RS system developed is shown in Table 1. These parameters are specific to the developed mockup model and provide a general idea of its capacity.

2.2 Design Process

In this design processare carried out the material selection, electronic components, constructional features of prototype model with working process, shape of the frame and rack, redesign the bracket and mountings.

2.2.1 Material selection

The design decision was made to construct the fixed and moveable frames with extrusions that were easily accessible in the market since aluminium looked perfect for the existing requirements. They also enabled ease of construction and included V-grooves for the wheels to roll over, as indicated in the Table 2. The linear actuator bundle included a steel lead screw mounted on an aluminium extrusion with a C-shaped cross section. The same method was used to order the bundle of rubber wheel and steel gantry plate. A hollow stainless steel tube was opted for the central arm. The electromagnetic plate was made in a stainless steel plate, again, due to load bearing reasons. The shelving on the inside was made using stainless steel tubes that can carry a significant amount of weight. The structure was powder coated to prevent rusting and give a good aesthetic finish. Aluminium plates were cut and fastened on the racks to form the shelves. The guide rod on the opposite side of the actuator was selected as stainless steel to avoid rusting and provide a smooth sliding surface along with rigidity. All custom made brackets and mountings were machined in aluminium. In some places, aluminium sheets of 0.45-1 mm thickness were used as a mounting strip.

2.2.2 Electronic Components Selection

The Table 3 gives the details of part list and specification of electronic components. The two linebundles came with Nema 23 stepper motor which necessitated the use of TB6600 stepper motor driver. An SMPS was required to convert 230V AC to 24V AC. This output voltage was stepped down with the help of variable DC transformers to power up the motor

Table 2: Material Selection of various components of the assembly

Part	Material
Static frame	Aluminium
Movable frame	Aluminium
Linear actuator	Aluminium - stainless steel
Gantry	Stainless steel - rubber
Central arm	Stainless steel
Electromagnetic plate	Stainless steel
Shelving structure	Stainless steel (powder coated)
Shelving plates	Aluminium
Guide rod	Stainless steel
Custom made brackets and mountings	Aluminium

Table 3: Electronic components selection

Part Name	Specification
SMPS	230V AC-24V DC
Nema 23 stepper motor	21 kgcm torque
TB6600 motor driver	9-24V DC
DC Transformer	24V DC-12V DC
Arduino Uno	-
Reed switch	3.3V DC normally closed (NC)
Hall sensor	-
Ring magnet	30mm DIA
DC geared motor	12V 200 Rpm
Neodynium magnets	-
Electromagnets	12V DC

drivers. The vertical axis motor was replaced with a 12V 200 RPM DC motor with an L298N motor driver to run it. A Hall sensor and a ring magnet mounted on the coupling helped to formulate a make shift encoder. The Arduino Uno microcontroller was chosen to power all of these components.

2.2.3 Constructional Features with Working Process

The static frame is made up of assembling 12 aluminium extrusions called V-Slots together to form a rectangular prismatic structure. It acts as a firm riding surface for the moving parts and binds the moving parts and the circuitry together. The shelving system has cantilever shelves on both sides at a 262 mm pitch with space in the middle for the movement of crates. This fits inside the static frame and is fixed. The shelving is built using iron beams of different cross sections and fastening the shelves on them. The movable frame has parts which enable it to move vertically and horizontally just to get it into the correct position over the storage crates. The movement is provided by actuators with lead screws, powered by high torque motors that augment the load bearing capacity of the arm. 4 gantry sub-assemblies are attached to the frame and 3 of these are attached to the lead screw actuators to help mount the frame and the central arm. One end of the arm is fixed to the gantry of the linear actuator which accounts for horizontal movement and the other end to a gantry which slides on a simple V-Slot. The electromagnetic plate has 2 electromagnets fitted to it. This plate is responsible for sticking to the storage crates and moving it to and fro along with the movable frame. The circuitry mainly involves components to convert the alternating current from the power source to direct current which is utilised by other components like microcontrollers, motors drivers, sensors and transformers. They together provide for the overall mechanism of the storage system.

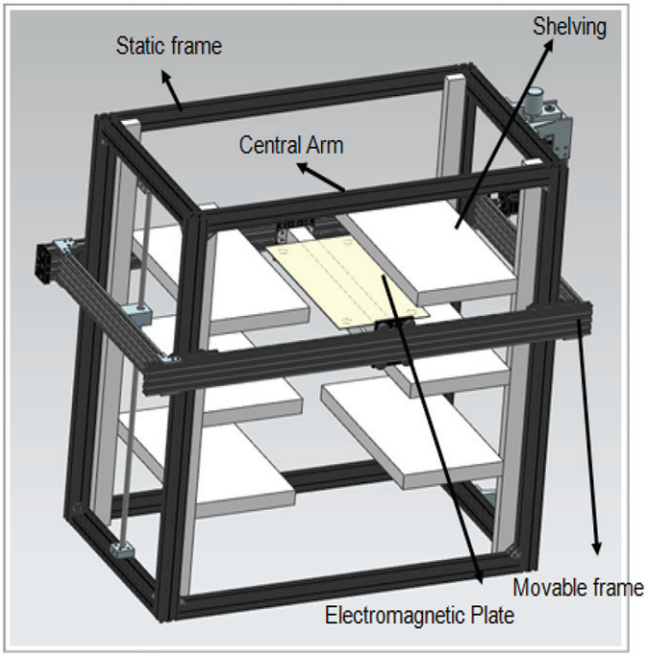


Figure 1: Construction of the prototype model

2.2.4 Selecting the Overall Shape of the Frame and the Rack

As shown in the figure below, many rack shapes were considered, keeping in mind the overall mechanism and the cubic space requirements of each shape. Finally the structure of cantilever shelves on both sides was selected because it occupied the least floor space. The rack was designed to be made of stainless-steel tubes with square and rectangular cross sections on which sheets could be fastened to make the shelving.

2.2.5 Custom Re-designing of Brackets and Mountings

In many assembly aspects, there was a requirement for brackets that could fasten two components together to restrict an relative motion. Since such brackets were not readily available in the market, they had to be custom designed and fabricated with the help of CNC machines. The following parts had to be redesigned is as shown in Figure 2. This includes assembling brackets for V-lots, linear actuators, end caps, couplings, fixing and mounting brackets. Some mountings had to be done with the help of aluminum sheets and were used in placed where reed switches and magnets were applied.

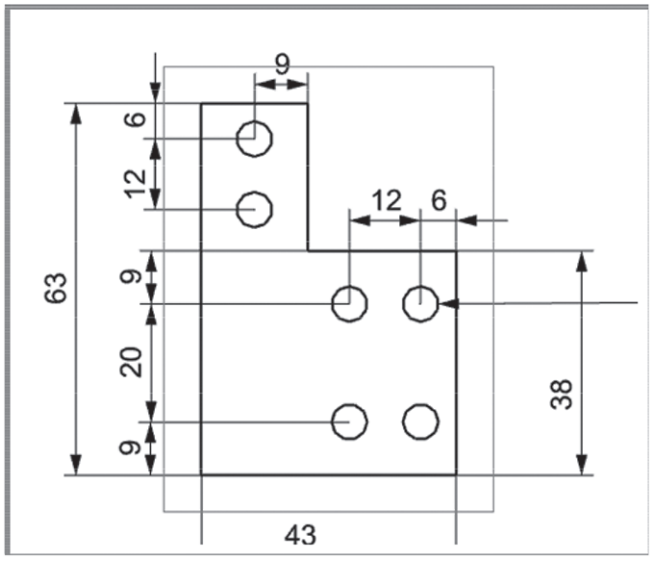


Figure 2.1: 80 × 20 Vslotassembling bracket

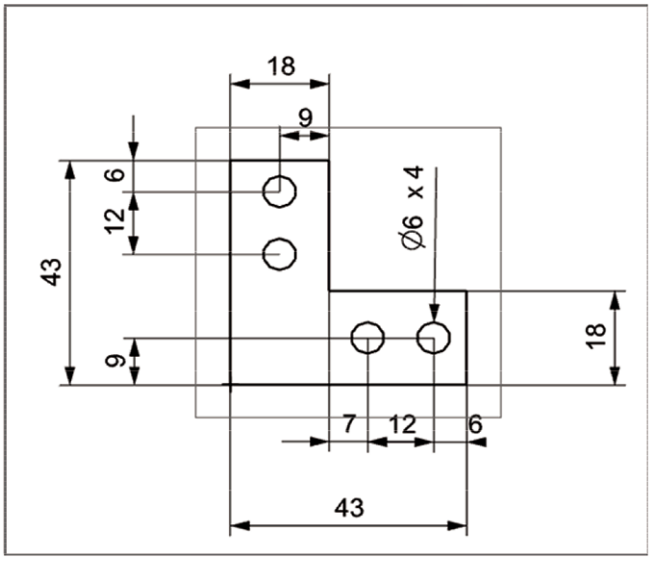


Figure 2.2: 80 × 20 Vslot to Linear actuator assembling bracket

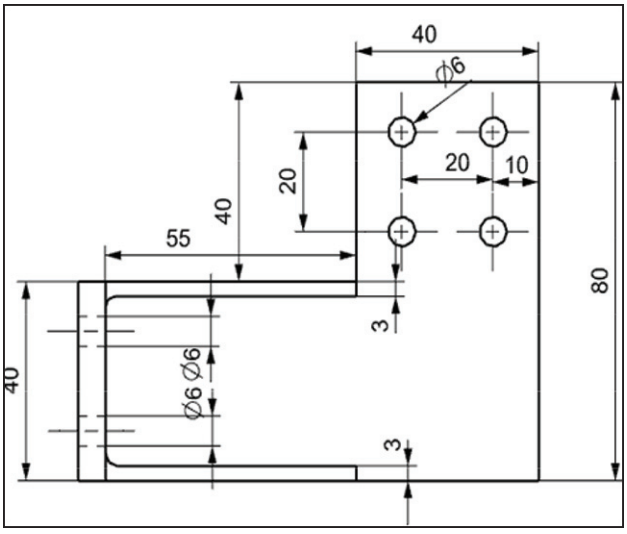


Figure 2.3: Linear actuator to static frame fixing bracket

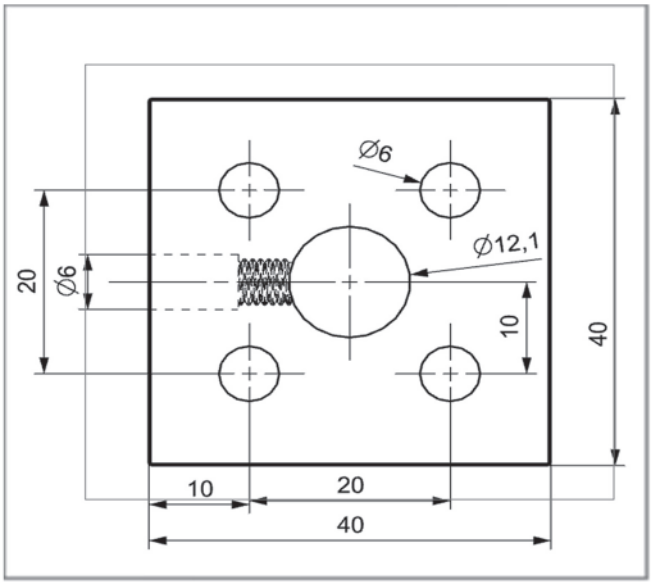


Figure 2.4: Guide rod to Vslot fixing brackets

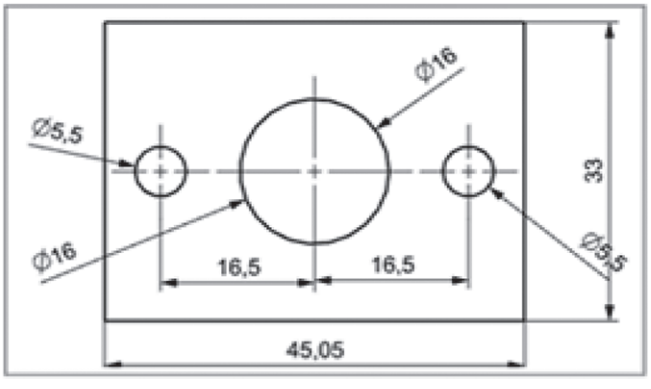


Figure 2.5: End cap for guide rod coupling to Vslot mounting bracket

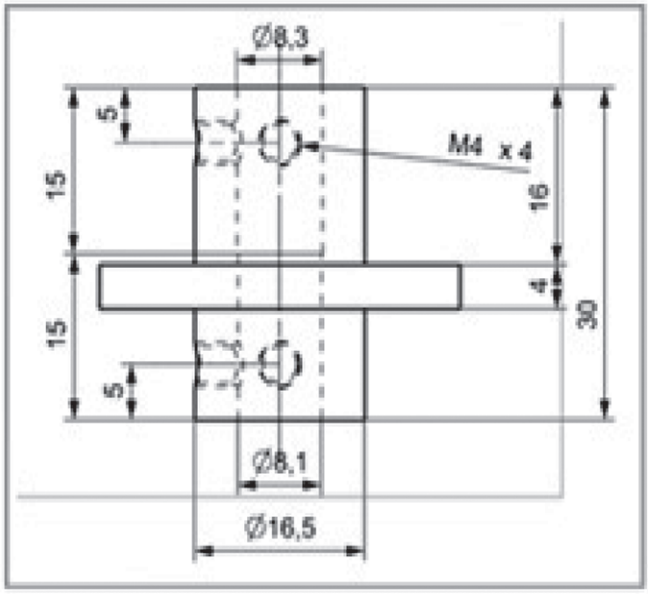
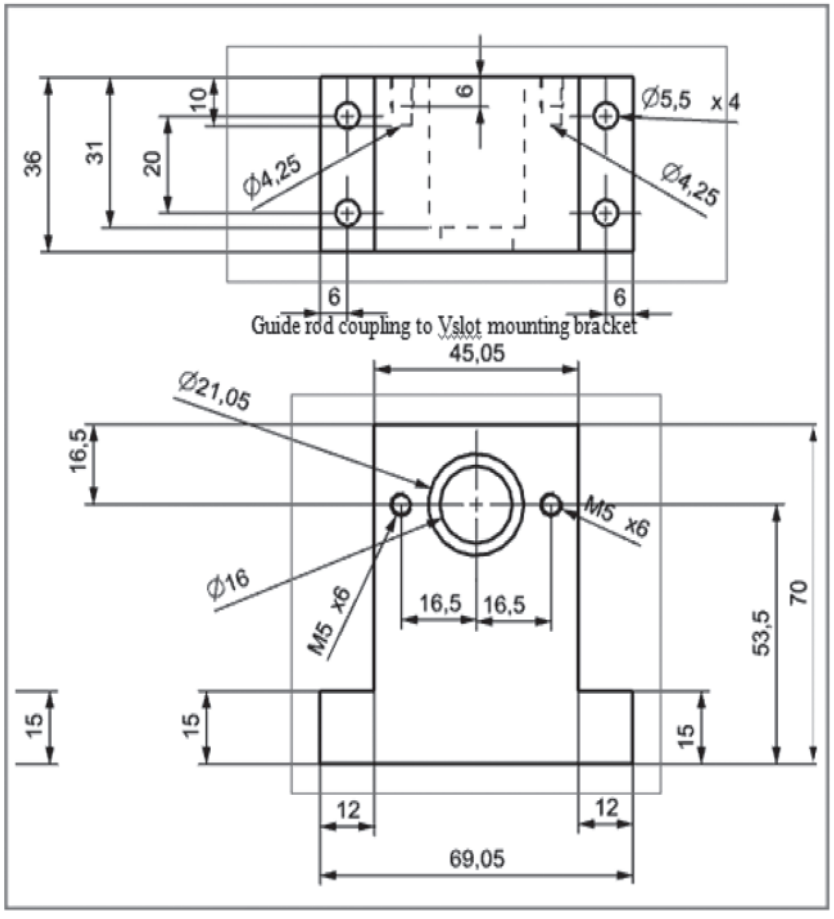


Figure 2.6: Coupling for DC motor of linear actuator



Linear actuator motor mounting bracket

2.3 Mechanism Flowchart

The mechanism to store or retrieve items can be summarized into a series of steps while combining the decision-making process. These steps can be graphically represented in the form of a flowchart as shown in Figure 3.

3.0 Results and Discussion

The experimental work discussed in this paper can be summarized based on 3 categories: space, capacity and cost. The space occupied by this prototype sums up to 0.5247m^3 of floor space (1100 × 810 mm × 530 mm) in the industrial environment and has 6 racks available for storage with 2 additional spaces on the floor as an extra utility.

Though the combined capacity of the electromagnets is 16 kgs, the maximum load that can be lifted by this system is limited to 10 kg, determined experimentally, which is due to the actual weight of the frame while considering the eccentric load applied on the motor. If the motor and the lead screw can be changed for a more robust application along with the electromagnets, it can support much higher loads to suit the industrial capacity. Some load calculations were made after the assembly as follows:

Motor torque for a 200 rpm rated motor:

$$T = 9550 \times 1000 \times \frac{N}{n} \text{ in N-mm}$$

where,

T - Motor torque

N - Power rating of the motor in KW

$N = V \times I$

V - Voltage to the motor

I - Current required by the motor

n - speed of the motor in rpm

$\Rightarrow N = 12 \times 1.5 = 18W = 18\times10^{-3}kW$

$$\Rightarrow T = 9550\times1000\times\frac{18\times10^{-3}}{200}$$

$\Rightarrow T = 859.5$ Nmm $= 0.8595$ Nm

The motor has a torque rating of 0.8595 Nm.

However, when the motor was supplied with its rated voltage which was 12V, the speed was slightly lesser than the one specified. The following graph was plotted to measure the speeds at different supply voltages:

When the height and number of shelves are extrapolated to match the models available in the market today, it can be implied that this system can provide a 50-60% decrease in the cost required to build a

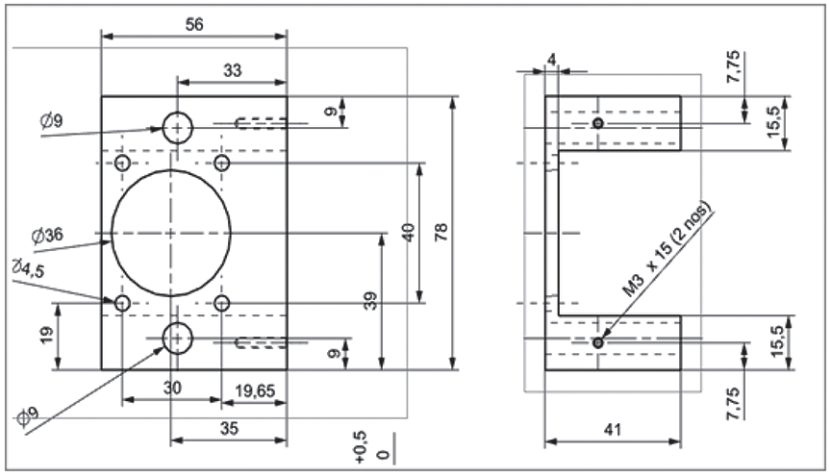


Figure 2: Drawings of custom re-designed brackets

working prototype. Though the system may not be able to be on par with the efficiencies in load capacity and lead times of the existing solutions, it is still affordable for many applications. The calculation and analysis of the time taken to store or retrieve items along with its optimization are beyond the scope of this research due to the design limitations of the prototype. The prototype was built as a proof of concept for the mechanism intended to solve the material handling problem and cannot be directly implemented as product in the real world without making a number of changes to the assembly and design parameters. It is constructed to match the digital prototype made and simulated in NX to study the workability of the mechanism conceived as shown in the Figure 5.

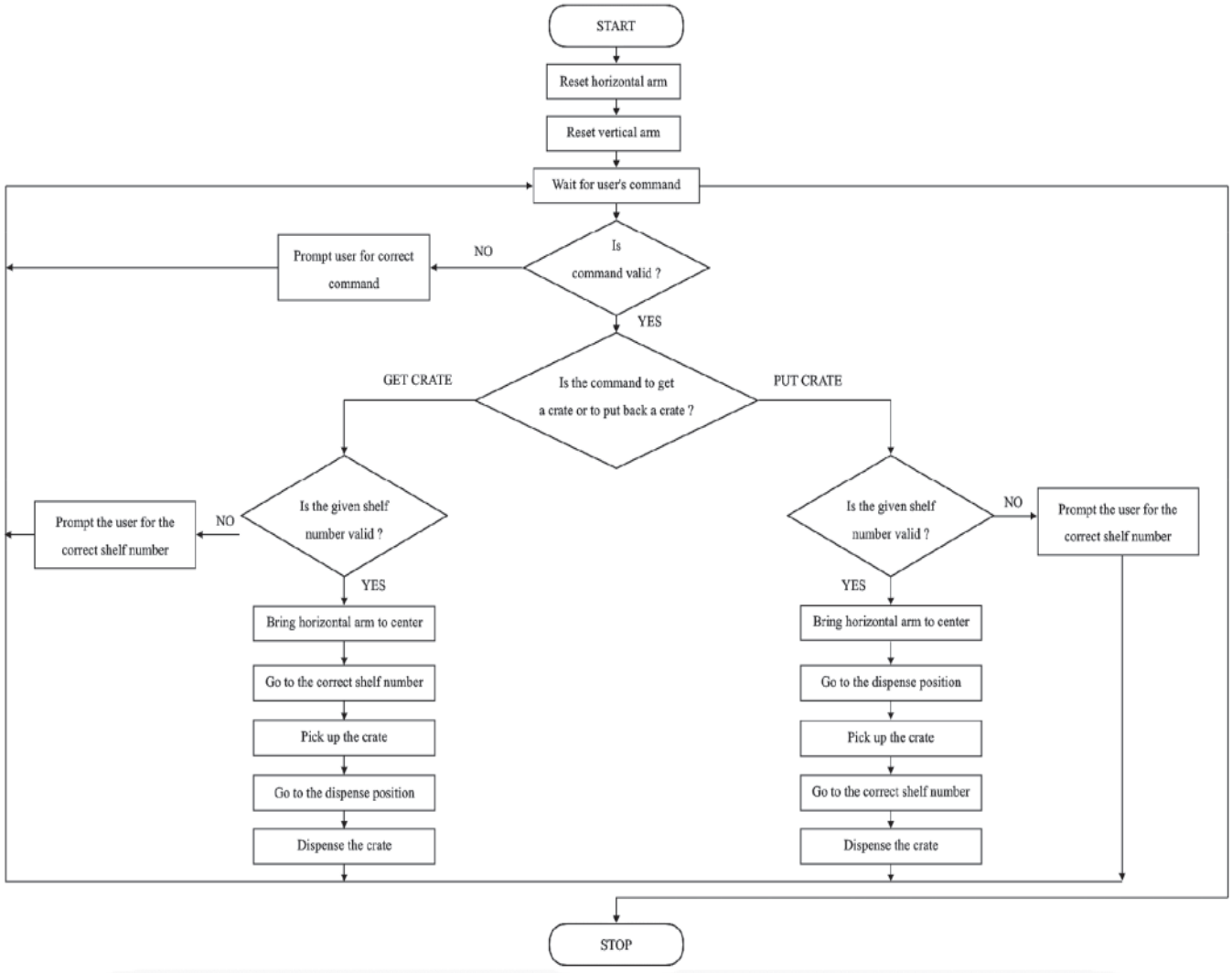


Figure 3: Mechanism of flow chart

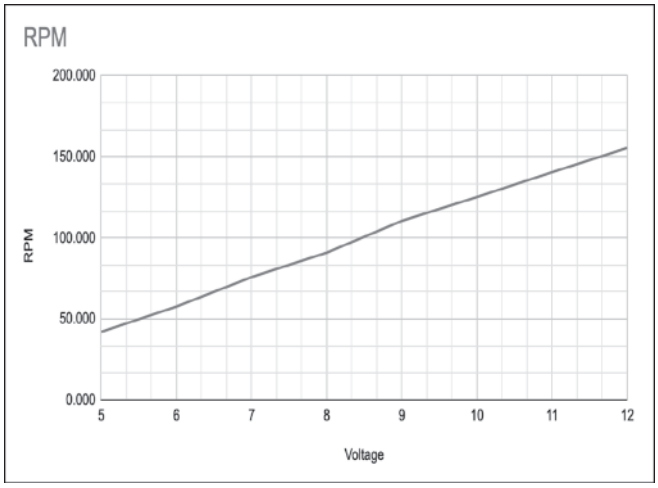


Figure 4: Speeds of the vertical axis motor at different voltages

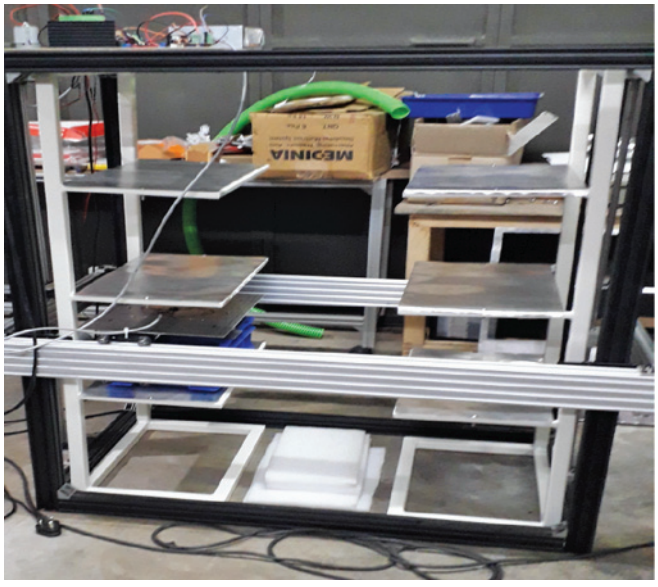


Figure 5: Actual AS/RS prototype model

4.0. Conclusion

The experimentation conducted throughout this prototyping process which began from an idea to find an economical alternative to the material handling systems existing concluded after testing the prototype for the mechanism post assembly. The journey of building the mock up gave rise to various design and assembly challenges which were tackled stage by stage, with some modifications to the design and introduction of better components. At each step of the design process, it was imperative to think of better methods that can optimally solve the issue at hand while meeting the cost constraints. The main objective of cost reduction was met as the prototype was built in 50-60% deprecated expenses. The main design change made was the magnetic lifting mechanism, unlike the mechanical alternatives available in the market. The prototype was tested to lift a maximum load of 10 kg, the increase of which requires a motor with a higher torque capacity. Though the process was not able to exactly meet all the objectives intended in the design phase, it can serve as a starting point for the product development process for the same manufacturing problem. This can lead to the development of a material handling system with shorter lead times, higher efficiency and reduced costs whose target audience may be considered as small scale industries.

5.0 Acknowledgements

The authors of this paper would like to thank Mr. Venkatesha MN, the Managing Director of Divya Engineering Works Pvt. Ltd and all its staff for their endless support throughout the project. We also acknowledge the enormous contribution of Mr. Nagendra R Setty, Founder and CEO, Ideas Unlimited Mysuru Pvt. Ltd for his enlightening guidance and resourcefulness. The staff of Ideas Unlimited Mysuru, namely Anusha B, Nagprasad VS, Karthik GN, Aditya and Devaiah need to be thanked for their assistance in making this project a succesful one by offering a part of their skillsets. We would finally like to thank Mr. Nakul Tirumalai and Mr. AbhiramMadenur, alumni of SJCE Mysuru for sharing with us their valuable ideas.

6.0 References

[1] Pop, Corina & Mailat, Gabriela. (2011): Automated material handling systems (AMHS) in libraries and archives: automated storage/retrieval and return/ sorting systems 190-193.

[2] Jitendra S. Patil, Prof. P. R. Attar (2016): Storage Racking System for efficient warehousing, VJTI, Mumbai, India. *International Research Journal of Engineering and Technology* (IRJET) Volume: 03 Issue: 11. e-ISSN: 2395 -0056.

[3] Roodbergen, Kees Jan & Vis, Iris. (2009). A survey of literature on automated storage and retrieval systems. *European Journal of Operational Research.* 194. 343-362. 10.1016/j.ejor.2008.01.038.

[4] T Ajay, A Vinoth and J Daniel Glad Stephen (2020). Design optimization and development of an Automated Storage and Retrieval System. OP Conf. Ser.: Mater. Sci. Eng. 912 032031.

[5] Matthew William James Crosbie (1998): The Design and Analysis of Static Pallet Racking Systems.

Sheffield Hallam University. Published by Pro Quest LLC (2017). 789, East Eisenhower Parkway P.O. Box 1346 Ann Arbor, Ml 48106-1346

[6] Liu, Tian and Gong, Yeming and De Koster, René. (2018): Travel time models for split-platform automated storage and retrieval systems. *International Journal of Production Economics*. 197. 10.1016/j.ijpe.2017.12.021.

[7] Azadeh, Kaveh and De Koster, René and Roy, Debjit. (2019): Robotized and Automated Warehouse Systems: Review and Recent Developments. *Transportation Science*. 53. 10.1287/trsc.2018.0873.

[8] F. Azadivar (1989): Optimum allocation of resources between the random access and rack storage spaces in an automated warehousing system, International *Journal of Production Research*, 27:1, 119-131, DOI: 10.1080/00207548908942534

[9] Granlund, A. (2014): Facilitating automation development in internal logistics systems (Doctoral dissertation, Mälardalen University).

[10] S. C Sharma, (2016): Plant Layout And Materials Handling, Third Edition, Khanna Publishers, 4575/15, Onkar House, Ground Floor, Darya Ganj, 110002 Delhi, India.