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Design and Development of Multipurpose Automatic Material Handling Robot with implementation of Virtual Twin, Digital Manufacturing and Model based system engineering.

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Abstract – *This paper deals with the Design and development of multipurpose automatic material handling robot to overcome the logistic problem that often occurs in the warehouse automation, workplaces and make improvement to the facilities provided in the workplaces. Make efficient processes by enhancing material handling and inventory tracking and management process. Using system-thinking approach (MBSE), design and optimize the system and subsystem required for the automatic material handling robot considering interaction between systems, sub-systems and external environment within the workplace. Development of system to complement different functions of navigation, deployment, operational flexibility, responsiveness.*

Key Words: **System Engineering (MBSE), Factory flow simulation, Digital Manufacturing, Virtual reality, Logistics, Kinematic simulation, Wire harness, Process Planning.**

1. INTRODUCTION

This project emphasises use of logistic behaviour and complete digital manufacturing to implement these solutions in warehouse automation. An autonomous material handling robot is a system that uses on-board sensors and processors to move boxes without the need of human assistance or markers. It understands its surroundings, remembers its path, and dynamically plans its own path from one waypoint to another. The primary stakeholders or users would be manufacturing facilities, which requires material movement in and between different stations and lines. The potential target industry would be the logistics and supply chain (warehouse), where material movement activities, storage and retrieval after predominant work activities and in other workplaces where material movement activities are prevalent.

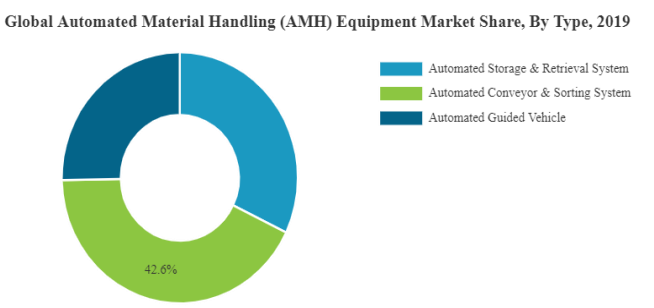

Fig -1: Global Material Handling Market Share Analysis

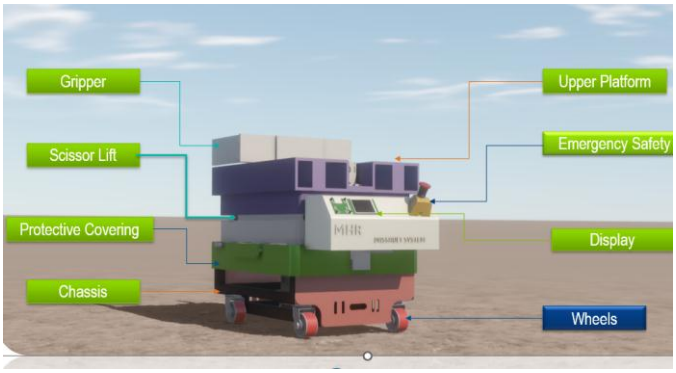

Fig -2: Multipurpose automatic material handling robot (MAMHR)

1.1 Actual model for MAMHR

We implemented the MBSE (model based system engineering) in order to build the complex product by distributing it into several sub-systems. We considered the scissor lift based model for current development. The scissor lift uplifts the complete gripper and object detection assembly at required height of racks in the warehouse environment. As box is detected using image processing and live video feed then the gripper starts reaching out near the box and held it firmly by linear actuator mechanism. While differential wheel drive maneuvering the complete system at required locations using path detection. The LIDAR,

ultrasonic sensor provides assistance to avoid collision with human and other co-operating MAMHR robot.

1.2 Linear Actuator and Gripper assembly

A linear actuator is an instrument that provides motion in a straight line, by using the circular motion of a electric motor. An actuator receives a control signal and respond to it by converting that signal into controllable mechanical energy.

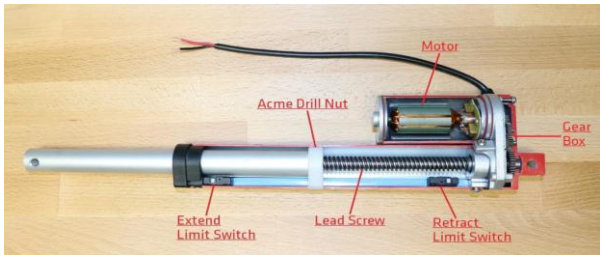

Fig -3: Linear Actuator with internal construction

1.3 Tools and Technology involved in Digital Manufacturing

In order to develop, test, implement and verify the new product we have utilized the digital technology in order to make the design industry ready before introducing it to physical prototyping. 3DExperience platform has provided us the tool called factory flow simulation in order to simulate the robot working in warehouse using virtual reality experience.

Fig -4: Factory Flow simulation of MAMHR

Fig -5: Virtual Reality of Warehouse Environment

Above images are showing the virtual reality experience of complete product and its working using 3DExperience platform. In order to get perfect validation we have implemented the digital manufacturing and digital twin by using process planning. Process planning helps to analyse complete manufacturing process virtually and provide scope of modifications and gives complete schedule for manufacturing of product. Along with physical dimensions the electronic system and wire harness design is a crucial part to validate all functionality using DYMOLA behaviour and Electrical CATIA. We had designed and demonstrated the complete electronic system design and its algorithms successfully using 3DExperience tools.

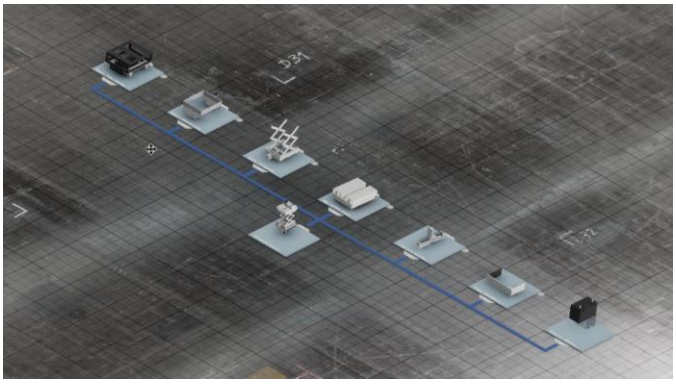

Fig -6: Digital Manufacturing & Heavy industry process planning

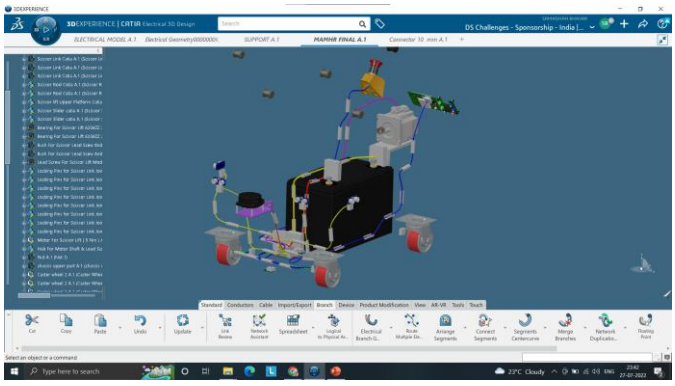

Fig -7: Electrical system and wire harness design

2. CALCULATION FOR SCISSOR LIFT

Scissor lift can be of standard dimension but in case of this model we have customize the dimensions according to required specifications. The Scissor lift upper and lower platform is of 600 x 500 x 70 (L * B * H) in mm. The scissor Links used are 8 in numbers to reach a height of 1.5-2m by using two linkages.

2.1 Calculation for dimensions of scissor links

Since we are using a mild steel for construction of scissor lift as it has greater durability, strength, easy and cheap availability. Dimensions of scissor link are 540 x 60 x 10 (L * B * H) in mm. For these dimensions of scissor link and lift the prototype model can lift a load of 5 to 7 kg using linear actuator assembly. According to lift height needed and weight to be lifted the dimensions of scissor links are calculated.

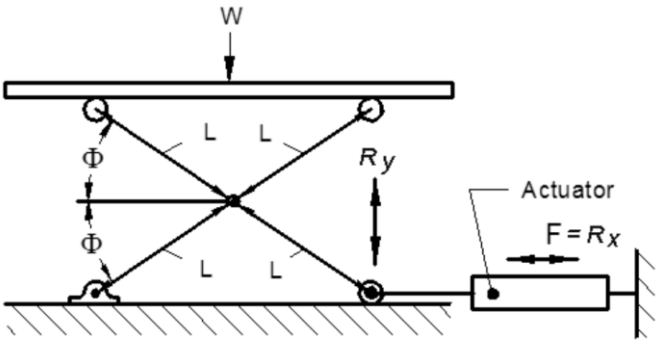

Fig -8: Scissor Lift with actuation

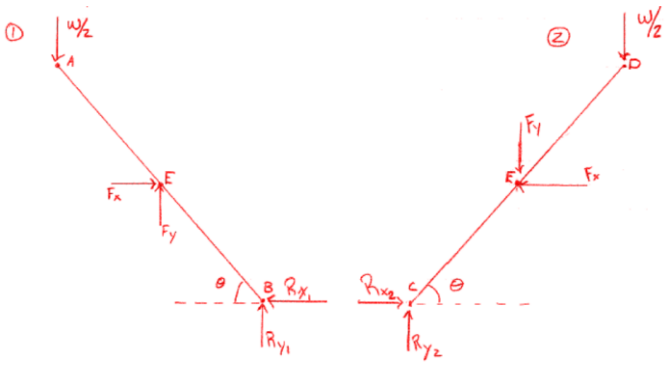

Fig -9: Forces acting on scissor links

2.1 Calculation of AGV dimensions

This product will be working in a warehouse automation where frequent operations are needed in close proximity space. In order to accommodate space issue, torque and maximum speed of vehicle and operational flexibility the dimensions of MHR robot is kept as 600 x 500 x 300 mm (L*B*H).

Table -1: MAMHR Specifications

General specifications of MAMHR	
AGV Dimensions	600*500*600 mm
Scissor lift Extended Height	2 to 2.5 m (possible)
Maximum AGV speed	2 m/s
Total Vehicle weight	40-50 kg
Wheel motor torque	45 Nm
Battery Backup	4.5-5 Hours in Dynamic operation

The above table shows generalized specifications of MAMHR. These specifications are suitable for AGV robot to work efficiently in warehouse working environment.

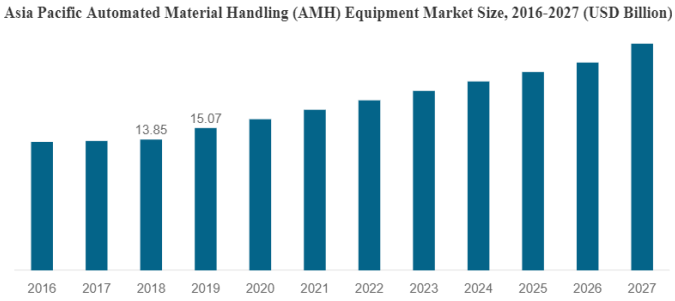

Chart -1: Material Handling robot market size

This chart shows how the equipment market size of the material handling robot is increasing day by day in a rapid manner. By considering the market scenario this product is helping out in order to automate material handling in warehouses.

Fig -10: Our MAMHR cad model for warehouse automation (image 1)

Fig -11: Our MAMHR cad model for warehouse automation (image 2)

These images show our cad model in a realistic world rendered using 3DExperience native application. These Rendered images illustrate virtual reality appearance of MAMHR robot in warehouse environment.

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3. CONCLUSIONS

As we know that the day-by-day demand and operations of E-commerce systems and increasing post pandemic. To tackle this increasing demand with higher output, operational flexibility, lesser human interaction and in cost effective manner. Hence the product we developed is the best solution for logistics and supply chain (warehouse) automation with least possible cost than other systems. This product involves plenty of research areas and future scopes and advancement as looking after the increasing demand.

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