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Development of Automated Storage and Retrieval System (ASRS) for Flexible Manufacturing System (FMS)

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Abstract: Automated Storage and Retrieval System (ASRS) is an integrated, computer-controlled, and automated material handling machine for depositing, storing and retrieving loads. The operation elements of ASRS are loading, unloading, storing, retrieving, sorting, and order-picking. The storage retrieval equipment consists of a special mechanism responsible for transferring the products from input / output to a point in the shelves, a system for reading and executing an order, and a system for updating the records of the manufacturing system's database. In this research study, the design and development of ASRS for Flexible Manufacturing System (FMS) was investigated. The study activities involved the investigation on ASRS features and operating procedures, and the evaluation of related hardware, software and communication modules. The research project explored the choices of several hardware and software modules offered in current market, and presented the most suitable one for the manufacturing process. This research also presented the ASRS design considerations and the limitations faced by designers during the process of project development and implementation. At the end, a final prototype of fully-developed ASRS was tested and presented.

Keywords: Automated Storage and Retrieval System; ASRS; Flexible Manufacturing System; FMS; storing and retrieving system; loading and unloading system.

1.0 INTRODUCTION

The Automated Storage and Retrieval System (ASRS) is an integrated automated system which operates under computer-controlled system. It is one of the systems involved in Flexible Manufacturing System (FMS) which can be found in many warehouses, production, automation, and distribution industry. The ASRS is basically used to store or retrieve the loads in the storage or out of storage. The computer will determine where in the storage area the item can be retrieved from and schedule the retrieval operation. As the items are stored into or retrieved from the racks, the computer updates the inventory system accordingly. The ASRS can be used either as a standalone unit or in integrated workstations as a system.

Along with ASRS, other components of FMS includes the Automated Guided Vehicle (AGV), CAD/CAM system, Image Processing / Recognition System, Enterprise Resource Planning (ERP), Digital Manufacturing Interactive Solution (DMIS), Factory Visualization System, Computer Numerical Control (CNC) machines, Central Supervisory Control (CSC), and the Job Shop Scheduling (JSS), as shown in Fig. 1. Together, these FMS components, forms an arrangement of machines interconnected by a transport system, and being controlled by a main computer system. It consists of a group of processing workstations (i.e. CNC machine cells) which interconnected by an automated material handling and storage system (i.e. AGV, ASRS, robot, conveyor) and controlled by an integrated computer system (i.e. CSC). The computer system can be considered as a central system which controls both machines and transport system, by handling the communication between hardware and software components using programming language and network infrastructure, which coordinates the activities of the workstations and material handling system like traffic control, shuttle, production and system performance monitoring and reporting.

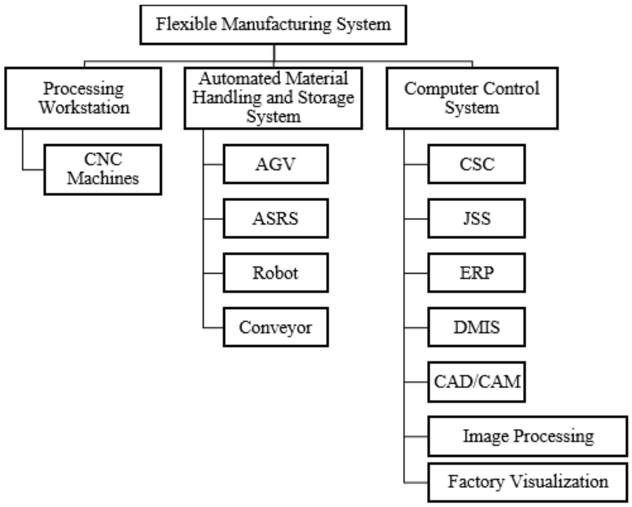

Fig. 1: Components of FMS

The main goal of a Flexible Manufacturing System is to manufacture with flexibility that allows the system to react upon slightly or greatly changes, whether it is predicted or unpredicted by offering the speed needed to change with market conditions quickly, but not sacrifice any quality.

In this study, only the development of ASRS will be discussed. ASRS have many benefits including savings in labour costs, improve material flow and inventory control, improve throughput level, high floor-space utilization, and increase safety and stock rotation. The efficient operation of ASRS requires planning of physical storage specifications such as height, length, width of storage structure and storage opening; and operating characteristics of ASRS such as horizontal and vertical velocity, acceleration rate, number of machines and control strategy.

The operation elements of ASRS are loading, unloading, storing, retrieving, sorting, and order-picking. The storage retrieval equipment consists of a special mechanism responsible for transferring the items from input/output point to a point in the shelves, a system for recording and arranging the items, a system for reading and executing an order, a system for locating and retrieving the items through an advanced type of recognition device (i.e. barcode and RFID), and a system for packing and shipping the items and updating the records of the inventory manufacturing system [1].

The system operates under computerized control system which determines where in the storage area the item should be retrieved from, and schedules the retrieval process, directs it to loading/unloading station, and directs the AGV to transfer the item to the destination. For storing process, the load will be placed at loading/unloading station of the system, the information for inventory is entered into computer, thus the ASRS moves the load to the storage area, determines the suitable location for the item, and stores the load. The inventory is then updated accordingly for the items stored into, or retrieved from the racks.

The principle in ASRS control system is positioning the arm within and acceptable tolerance at a storage compartment in the rack structure to deposit or retrieve a load. The location of materials stored in the system must be determined to direct the arm to a particular storage compartment. Using identification scheme, each unit of material stored in the system can be referenced to a particular location in the aisle. The record of these locations is called as the item location file. The transaction will be recorded into the file for each time a transaction is made. The CSC will determine the required location and guide the arm to its destination.

Fig. 2 and Fig. 3 below show the flowchart of storing and retrieving activities. Basically, the power light turns on once the START button is pressed. Then, the ASRS waits for any command/instruction from the computer. Upon receiving the instruction, the stacker crane moves from its origin to the new location provided by the computer. As in Fig. 2, the computer instructs the ASRS to store the item from conveyor to cell m, while in Fig. 3, the computer instructs the ASRS to retrieve the item from cell n to conveyor. The stacker crane will remain at its last position after completing the task.

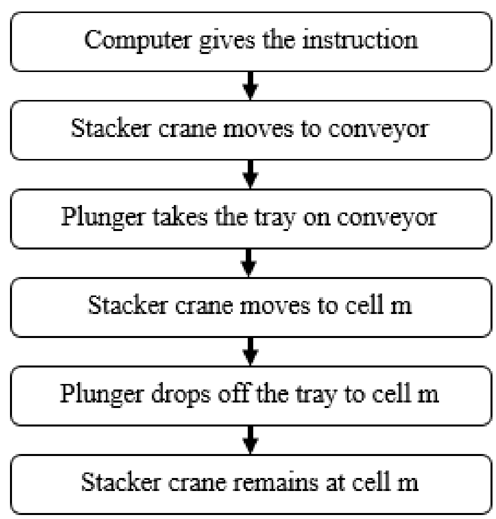

Fig. 2: To store the item from conveyor to cell m

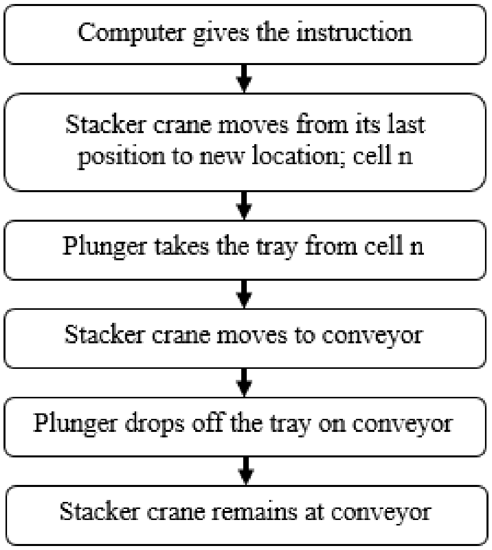

Fig. 3: To retrieve the item from cell n and bring it to conveyor

The alarm and warning light turn on if there is any fatal or error occur, such as the motor is not functioning, and the item drops from plunger. Once the OFF button is pressed, the stacker crane moves to its origin and the power light turns off.

2.0 BACKGROUND

In manufacturing industries nowadays, the automated material handling and storage system as ASRS plays an important role for storing and retrieving products and parts as to cope with aggressive global competition and rapid market changes. It is highly demanded in large industries such as automotive factories and mass production companies to aid the inventory management system in the warehouse and huge storage area due to the time consumption and dramatic cost reduction factors [1]. It was originally introduced in the 1950s to eliminate walking that accounted for 70% of manual storage and retrieval period. Characterized by high accuracy, speed and safety, this automated system can effectively reduce the labour cost, improve material management, and system throughput [2], depends on the control system and physical design of the ASRS.

Being an important part in Flexible Manufacturing System, the ASRS, which can help on solving the storage problems for raw material and finished products, are used in the manufacturing process. But, how to make the ASRS more and more effective is worth considering [3]. With the development of technology, the microcontroller and other electronics modules such as sensors and actuators, the designers capable to control the movement and rotation of the motor while the PIC programming language aid the ASRS movement based on its condition and position of each parts [1].

A microcontroller which acts as the brain of the system, controls all the working operations, is designed as an embedded system which contains a processor, peripherals, and memory. It is embedded in other systems such as automobiles, appliances, medical equipment, and other control systems. The switches, relays, liquid-crystal displays, LEDs, motors, and sensors are the typical input and output devices connected to microcontroller. The compilers and assemblers are used to convert the high-level language and assembler language codes into a suitable machine code to store in the microcontroller memory. There are many types of microcontrollers such as ARM, Atmel AVR, Intel 8051, and PIC.

For this research project, the microcontroller chip that has been used is PIC18F46K80, manufactured by Microchip. The PIC18F46K80 is a high performance of 8-bit MCU, has low power consumption and low sleep current for low power application, 1.8V to 5.5V operating voltage for automotive, elevator control, building control, and industrial application. The PIC18F46K80 family is ideal for any applications which requires cost-effective, low power CAN solutions with high performance and robust peripheral set [4].

3.0 ASRS DESIGN BY ANALYSIS

The research project for development of ASRS focused on concept and working operations of storage and retrieval system. Therefore, both hardware and software aspects are first being identified, before designing, developing and implementing the system.

A. Design Approaches

This sequence shows on how the project development and implementation were carried out.

- System requirement analysis
- ASRS concept design
- Electrical and electronic engineering design
- Programming of microcontrollers and ASRS cell system integration
- Hardware and software integration
- Functional ASRS cell integrated with conveyor
- Functional test and optimization
- Testing and commissioning
- Documentation of system specifications and user manual

In the planning process, the time consumption and the use of resources have been considered to ensure the project flows smoothly and problem-free. The mechanical part such as frame, storage rack, and location of the motor

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presented in CAD software for clear view of 3D design. The electrical system consists of power supply, microcontroller, electronic modules, and sensors. The logic controller and data management system is carefully planned to ensure the system can fulfill the task given [1].

B. Design Specifications

The system developed is equipped with a 2-axes (X, Y) load handling device (or also known as stacker crane), and 20 storage cells in 4x5 array which can store up to 20 items. The stationary storage racks is developed rather than the movable racks since the system can be considered as a small system. The racks are configured in a single deep storage. Fig. 4 shows the storage rack of the developed ASRS.

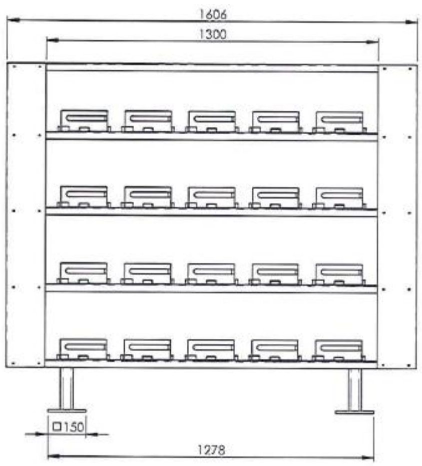

Fig. 4: Storage rack

The storage rack is configured as a class-based which divided into 3 divisions; raw material, semi-finished products, and finished products [5]. The cell number 1 until cell 6 are assigned for raw material, cell 7 until cell 12 are for semi-finished products, and cell 13 until cell 18 are for finished products. The other two cells, cell 19 and 20 are reserved cells for any extra items. Each cell has its coordinate of (x, y) to ease the localization process during storing and retrieving activities, as in Fig. 5. The system features included are the location of initial position of the linear motion guide actuator or stacker crane, location of loading and unloading conveyor, and the movement of linear motion guide actuator.

	(5,4) Cell 20	(4,4) Cell 19	(3,4) Cell 18	(2,4) Cell 17	(1,4) Cell 16
	(5,3) Cell 15	(4,3) Cell 14	(3,3) Cell 13	(2,3) Cell 12	(1,3) Cell 11
(6,5) Conveyor	(5,2) Cell 10	(4,2) Cell 9	(3,2) Cell 8	(2,2) Cell 7	(1,2) Cell 6
	(5,1) Cell 5	(4,1) Cell 4	(3,1) Cell 3	(2,1) Cell 2	(1,1) Cell 1

Fig. 5: Storage cell configuration

Table 1 illustrates the general system specifications for the developed ASRS.

Table 1: ASRS system specifications

General Specification	Description
No. of levels	4
No. of bays per level	5
Total number of bays	4 x 5 = 20
Clearance between levels	150 mm
Size of bay	200 mm x 366 mm
Conveyor motor	25 watts induction motor
Communication system	Wireless communication
Mechanical structures	• Floor-mounted storage unit • 20 cells in an 4x5 array
Home	Home position on each axis
Actuators	• Vertical movement: NX series of NX640MS-3 AC servo motor • Horizontal movement: NX series of NX640AS-3 AC servo motor
Safety features	• Emergency switch • Magnetic brake during power fail
Path control	Linear
Speed control	Manually set on motors driver, NXD75S
Microcontroller	PIC18F46K80

C. Development Boards

There are two types of development boards for ASRS; common board and target board (or also can be called as master-slave board). The common board which can be considered as a heart of ASRS, consists of a PIC18F46K80 microcontroller, MCP2551 CAN transceiver, FTDR230 USB-to-USART converter, power supply circuit, In-Circuit Serial Programming (ICSP) connector, and so on, is attached on the top of each target boards. The block diagram of common board is illustrated in Fig. 6.

There are three target boards needed for ASRS. The target board 1 (TB1) is programmed to act as a master, controlling hardware modules such as limit sensors for

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storage racks and support system, light indicators, emergency switch, and conveyor, while the target board 2 (TB2) and target board 3 (TB3) are programmed as slaves, respectively controlling the speed and movement of two AC servo motors; NX640MS-3 and NX640AS-3, as shown in Fig. 7. The TB1 communicates with TB2 and TB3 via CAN transceiver. It receives the command / instruction from computer system, then spreads the command to TB2 and TB3. Once the task is done, the TB2 and TB3 will update their status to TB1, so that TB1 can inform the computer system.

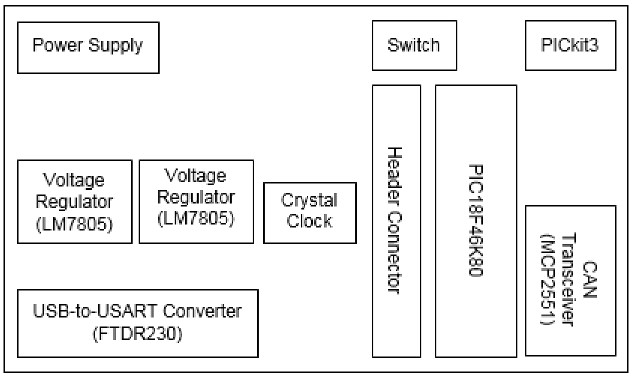

Fig. 6: Block diagram of common board

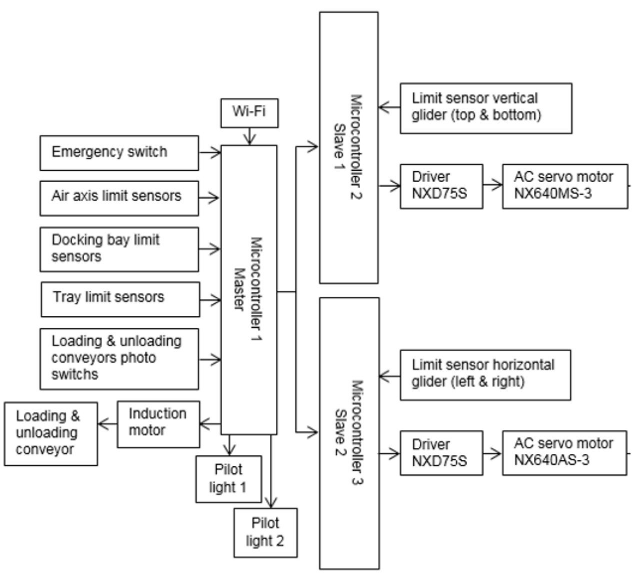

Fig. 7: Block diagram of target boards

The input/output and communication signals involved in microcontroller boards are shown in Table 2.

Table 2: Input / output and communication signals

Signal	Description
Input	• Limit sensors • Photoelectric switch sensors • START and STOP buttons
Output	• Standard type three phase servo motor with electromagnetic brake • Standard type three phase servo motor • Induction motor • Linear motion guide actuator • Pneumatic axis cylinder actuator • Pilot light • LED
Communication	• CAN transceiver • Serial Wi-Fi

For this ASRS, two AC servo motors are used to move the intelligent linear motion guide actuator; the NX640MS-3 to move the actuator vertically, while the NX640AS-3 to move the actuator horizontally. The NX640MS-3 is provided with a power off activated electromagnetic brake. This brake will hold the load in linear motion guide actuator in its position to prevent it from moving or dropping if the power supply is accidentally cut off due to a power failure or any other unexpected event. Both of servo motors use the same driver; NXD75S.

The schematic circuit for TB2 and TB3 are identically to each other although they are used for different motors; TB2 for vertical movement, and TB3 for horizontal movement. They have their own microcontroller because of the limitation on input/output (I/O) pins, whereas one PIC18F46K80 has 44 pins, and one motor consists of 36 pins. These two motors are used due to their high responsive and accurate positioning feature, which a vital element in ASRS working principle as well. It may also control the rotation angle and rotation speed precisely. Besides, they are tuning-free and has driver package which easily operated to achieve the smooth operation in high-inertia loads and belt-drive applications.

4.0 RESULTS AND DISCUSSION

This section discusses the results of the development of hardware and software of Automated Storage and Retrieval System.

A. Testing and Commissioning

This section shows the Printed Circuit Board (PCB) for microcontroller boards and system developed. Fig. 8 and 9 show the PCB board for target board 1, 2, and 3. The design for target boards 2 and 3 are same to each other but controls different motors; target board 2 is for NX640MS-3 motor, while target board 3 is for NX640AS-3 motor.

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Fig. 8: PCB board for target board 1

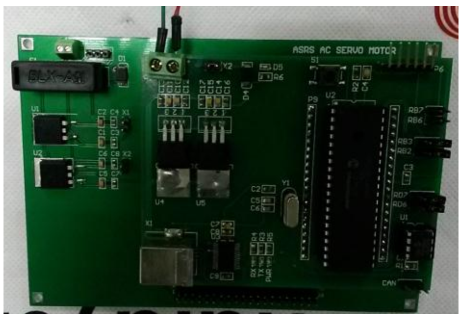

Fig. 9: PCB board for target board 2 and target board 3

Table 3 below shows the software and test specifications that have been done before integrated with other modules.

Table 3: Software and test specifications

Software	Test specifications
CAN driver	The data can be transmitted and received by the tested boards (3 target boards)
USART driver at 115200 b/s at 64MHz	The board can be accessed via USB terminal by PC
I2C DAC	The output voltage can be controlled by varying the variable resistor
Buzzer	The buzzer can be activated or deactivated via hyperterminal
LED indicator	The LED can be activated or deactivated via hyperterminal
Proximity sensor	The present status of the switches are displayed correctly on hyperterminal
Emergency switch	The system halts / stops and produces the warning sound (beep)
Reset switch	The system presume its work from idle condition

Fig. 10 and Fig. 11 show how the data transmitting and receiving is being tested via Wi-Fi.

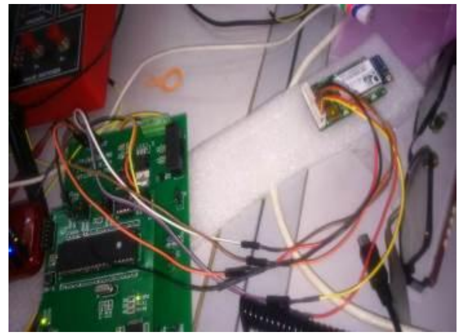

Fig. 10: Test data transmitting and receiving via Wi-Fi

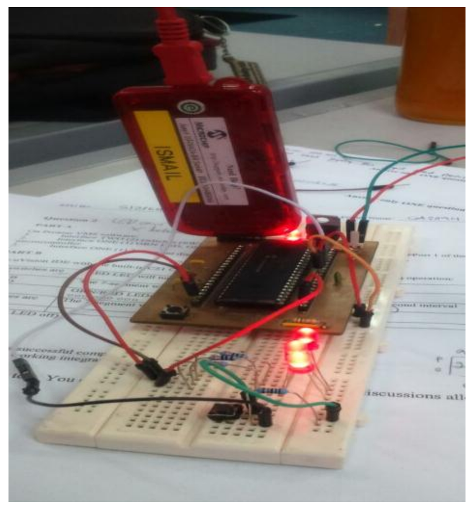

Fig. 11: LED is turned on and off via hyperterminal

B. Functional ASRS Cell Integrated with Conveyor

The ASRS that has been developed is shown in Fig. 12 and Fig. 13, as in front-view and side-view respectively. As we can see there are 20 storage cells, loading and unloading conveyor beside the storage rack, and control panel.

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Fig. 12: Front-view of ASRS

Figure 13: Side-view of ASRS

There is a limit sensor EE-SPY402 attached at each of cells to detect the presence of object, to identify the maximum limit for tray, or to provide a reference point for incremental motions, as shown in Fig. 14.

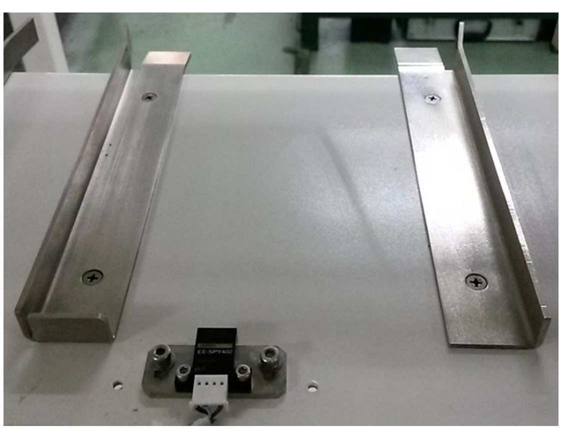

Fig. 14: Limit sensor

There are two pairs of photoelectric switch sensor at the front and end of the conveyor; HPJ-R11, HPJ-E11, HPJ-R21, and HPJ-E21, as shown in Fig. 15. These sensors are used to detect the distance, absence, or presence of the object on the cell conveyor, and to limit the range of object movement on conveyor.

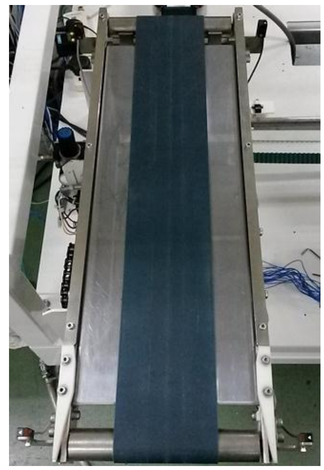

Fig. 15: Loading and unloading conveyor

Fig. 16 shows the tray contains a raw material located in one storage cell.

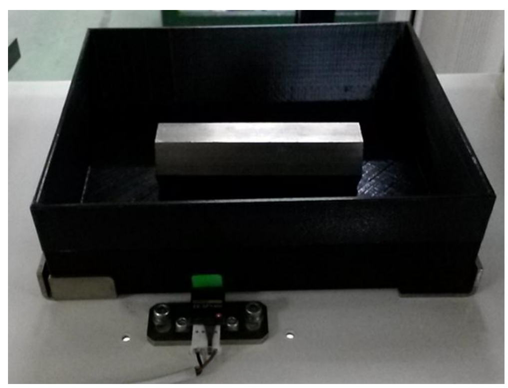

Fig. 16: A tray contains a raw material

5.0 CONCLUSION

Automated Storage and Retrieval System offers significant space savings, smaller footprint and smarter, and smart inventory system which is being updated accordingly throughout its working operation. This ASRS development and implementation deal with integrating both mechanical elements and electrical knowledge. The mechanical elements of this ASRS development provide tools for the ASRS to fulfill its robotics tasks, while

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electrical elements deal with the control of the movements on each object.

The success in moving the linear motion guide actuator to the right cell with accurate position and placing the object to the right destination show that, this project achieved its objective. The team has definitely benefited from this research project including gaining technical skills, knowledge of designing and developing the system, and know more about the common machines used in industry. The scope of this research project to develop and implement the storage and retrieval system can be further improved. The future work shall implement the barcode scanning system for real-time identification and verification of part-carrying activities.

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