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Design and Fabrication of Automatic Storage and Retrieval System

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***Abstract-** The paper summarizes design and fabrication of a cost effective single aisle Automatic storage and retrieval system whose database regarding the status of storage location (either filled or empty) is stored in its own operating system. This system can be efficiently used in material handling or store management.*

Material handling can be defined as movement of raw-material, semi-finished goods, finished articles through various stages of productions and finally storage of finished product in warehouse. Material handling forms main aspect to be considered in production processes in industries. Starting from the time raw material enters the factory and goes out the factory gate in form of finished product, it is handled at all stages in between, no matter it is in stores or on the shop floor. It has been estimated that the average material handling cost is roughly 40% - 50% of total production cost. Our project aims to ease the efforts in store management. The store of industry comprises of many parts or components which are required at the time of assembly of any product or regular inspection in which it is required to change a particular part or component of product. At this stage it becomes difficult to search a particular part or component in the store. This can be made easy by allotting the part or component, with a specific number which can be detected by sensor in robot's end effectors and further made available to user, with a help of conveyor. It will also reduce total handling time. It becomes easier, cleaner and safer method of material handling. It will also decrease fatigue incurred by workers, by reducing their physical work. Hence this project proves useful in store management.

Keywords-material handling, robotic end effector, single asile, conyeyor.

I. INTRODUCTION

Figure illustrates the traditional method of material handling, it clearly signifies that the process of material handling is non-value-adding process. It will definitely increase cost of product as direct labor is involved here and also loss probability of damage is maximum.

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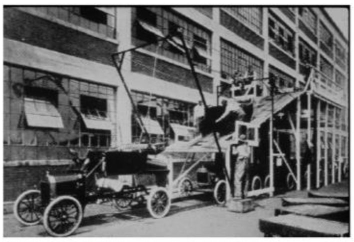

Figure Material Handling in Early Automotive Assembly

In Present work scenario, all this work is carried out by the use of man power. Physical power of labor is used to carry out this process, which definitely leads to fatigue. At particular stage this will reduce the speed and efficiency of work carried out. This results in slow down of each and every process.

A. Limitation of present available system for material handling and store manangement.

1. Some industries also used semi-mechanized material handling system, which uses fork lift trucks, overhead cranes or transportable vehicles which move in store for retrieval or storage, but Accidents are observed maximum while performing this operations.
2. Material Damage is maximum.
3. Rate of labour injury is high.
4. Cost of product increase as handling charge is added.
5. Proper database is not prepared of products available in store house, which may cause expiry of products.

B. Aims and objective of the project.

Our final aim is to design and fabricate a motion control robot used for material handling and store management of a factory. At basic stage it is required to study types of robot and the one we will be using must be selected. Secondly robot anatomy must be overviewed which includes study of links, joints, end effectors, sensor, power supply and various controllers used in robot. Further we will go through various terms used for robot such as DOF, work volume, accuracy, control system, spatial resolution, etc. Our design process will start calculating link length of robot, number of links used, its degree of freedom, motor we will be using to drive system successfully. Also we must carry out the study of micro controllers and software which will govern the system. Fabrication of store rack which consists of many compartments must be done where we will place parts or component which will be retrieved. Each compartment must be given specific number. The dimension of robot links must be also decided considering the size of stand. The weight of part to be handled must also be considered because it increases the rigidness of prototype and also power required to drive the mechanism. The sensor must also be selected considering further use.

Actuator must also be studied and used. Thus the design and fabrication of system which will prove beneficial in many industries will be completed. This will for sure encourage the productivity which will further cause to reduction in cost of component manufactured or stored.

II. CONSTRUCTION AND WORKING OF THE SYSTEM

A. The system consists of a mainly 5 components

1. Storage structure (ply rack).
2. Storage and retrieval machine. (S/R machine)
3. Storage modules
4. Pick and deposit stations
5. Control system (programmed with .NET software corresponding to this project)

1. Storage structure:

Storage structure is the rack framework typically made of fabricated steel, which supports the load contained in ASRS. The structure must possess sufficient strength and rigidity that it does not deflect significantly due to load in storage or other forces on framework. The individual storage compartment in the structure must be designed to accept and hold the storage modules used to contain the stored materials. The rack structure may also be used to support the roof and sliding of the building in which ASRS system resides. Another function of the storage structure is to support the aisle hardware required to align the S/R machine with respect to storage compartment of ASRS. The hardware includes the guide rails at the top and bottom of structures well as end stop and other features required for safe operation of ASRS.

2. Storage and Retrieval Machine:

The S/R machine is used to accomplish storage transaction, delivering load from input station into storage and retrieving loads from storage and delivering them to output station. To perform this transaction the S/R machine must be capable of horizontal and vertical travel to align its carriage (which carries load) with the storage compartment in the rack structure. In many cases the S/R machine consists of a rigid mast on which is mounted a rail system for vertical motion of carriage. Wheels are attached at the base of mast to permit horizontal travel along the rail system that runs the length of the aisle. A parallel rail at the top of the storage structure is used to maintain alignment of mast and carriage with respect to rack structure.

The carriage includes a shuttle mechanism to move loads into and from their storage compartment. The design of the shuttle system must also permit loads to be transferred from S/R machine to pick and deposit (P&D) station or other material handling interface with ASRS. The carriage and shuttle are positioned and actuated automatically in the usual ASRS. Man-on-board S/R machine are equipped for human operator to ride on carriage.

To accomplish the desired motion of S/R machine, three drive systems are required: horizontal movement of mast, vertical movement of the carriage and shuttle transfer between the carriage and storage compartment. Modern S/R machines are available with horizontal speeds up to 200 m/min along the aisle and vertical or lift speeds up to around 50m/min. These speeds determine the time required for carriage to travel from the P&D station to particular location in the storage aisle. Acceleration and deceleration have a more significant impact on travel time over short distance. The shuttle transfer is accomplished by any of several mechanisms, including forks (for pallet loads) and friction devices for flat bottom tote bins. In the original design the S/R machine is located at the bottom right corner of the system as its initial position however the efficiency can be further improved by keeping the S/R machine at central bottom position.

3. Storage modules:

The storage modules are the unit load containers of the stored material. These includes pallets, steel wire baskets and containers, plastic tote bins and special drawers (used in mini load system). These modules are generally made to a standard base size that can be handled automatically by carriage shuttle of the S/R machine. The standard size is also designed to fit in storage compartments rack structure.

3. Pick and deposit stations:

The pick and deposit station is where loads are transferred into and out of ASRS. They are generally located at the end of aisles for access by the external handling system that brings loads to ASRS and takes loads away. Pickup station and deposit station may be located at opposite ends of storage aisle or combined at same location. This depends on origination point of incoming loads and the destination of output loads. A P&D station must be designed to be compactable with both the S/R machine shuttle and external handling system. Common methods to handle loads at the P&D station include manual load/unload, forklift truck, conveyor (e.g. roller) and AGV's.

4. Control system

The principle ASRS control problem is positioning the S/R machine within an acceptable tolerance at storage compartment in the rack structure to deposit or retrieve a load. The locations of the materials stored in the system must be determined to direct the S/R machine to particular storage compartment. Within a given aisle in the ASRS each compartment is identified by its horizontal and vertical position and whether it is on the right side or left side of aisle. A scheme based on alpha-numeric codes can be used for this purpose. Using this location identification scheme, each unit of material stored in the system can be referred to a particular location in the aisle. The record of these location is called the 'item location file'. Each time a storage transaction is completed the transition must b recorded into item file location.

Given a specified storage compartment to go to, the S/R machine must be controlled to move to that location and position the shuttle for load transfer. One positioning method uses a counting procedure in which the number of bays and levels are counted in the direction of travel(horizontally and vertically) to determine position. An alternative method is numerical identification procedure in which each compartment is provided with the reflective target with binary coded location identifications on its face. Optical scanner are used to read the target and position the shuttle for depositing or retrieving a load.

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Computer control and programmable logic controllers are used to determine the required location and guide the S/R machine to its destination. Computer control permits the physical operation of the ASRS to be integrated with the supporting information and record-keeping system. Storage transaction can be entered in real-time, inventory records can be facilitated with other factory computer system. These automatic controls can be superseded or supplemented by manual controls when required under emergency conditions or man-on-board operation of the machine.

B. Design calculation of AS/R system.

1. *Calculating Individual Storage Space Dimensions*

Let l, b and h be the length, width and height of the unit load. The length (L), width (W)
and height (H) of the rack structure of the AS/RS aisle are related to the unit load dimensions and number of compartments as follows :

L = ny (l + x)
W= u (b + y)
H = nz (h + z)

Where,ny and nz are respectively number of load compartments along the length and height of the aisle
x, y, and z are allowances designed into each storage compartment to provide clearance for the unit load.
u is storage depth in number of unit loads.
Note-All the dimensions of rack structure are in ‘mm’.
The total storage capacity of one storage aisle is expressed as follows :
Capacity per aisle = 2 x ny x nz
Constant ‘2’ is multiplied because loads are contained on both sides of the aisle.

2. Estimating Storage Spaces Number

Dedicated and randomized storage policies are used to determine the number of storage spaces in AS/RS. In dedicated storage policy, a particular set of storage slots is allocated to a specific product. Hence the sum of the maximum inventory levels for the entire products match with the number of slots required to store the product. In case of randomized storage policy, any compartment in the storage aisle is equally probable to be selected for transaction. Likewise, there is equal chance of each unit of particular product to be retrieved when a retrieval operation is performed. Thus, in a long run, maximum of the aggregate inventory level of all the products is taken into account for determining the storage space number. Estimation of AS/RS Throughput and the Number of S/R Machines System throughput is defined as hourly rate of S/R transactions (number of loads stored and number of loads retrieved) that an automated storage system can perform. A dual command cycle is used to increase the throughput, since it reduces travel time per transaction.

Following are the factors that influence system throughput :

- Velocity of S/R machine
- Single and dual command cycles
- System utilization per hour
- Arrangement of stored items
- Speed of AS/RS control system
- Speed and efficiency of the material handling equipments

The number of S/R machines can be determined as follows:

Number of S/R machines = S/R machine capacity in cycles per hour/System Throughput.

Estimating the Size Parameters of the Storage and Retrieval System, System length, width and height are vital to estimate the size of AS/RS. For this purpose, it is required to determine following parameters:

- Number of Rows and the Number of Bays in Each Row of a System
- Number of S/R machines used to store and retrieve materials depends primarily on the system throughput and the cycle time. S/R machines are used for one or more aisles. Each aisle has two rows. Therefore, the number of rows in case of one S/R machine per aisle is :

Number of rows in the system = 2 * Number of S/R machines in the system.

- Number of storage spaces persystemheight
- .Number of rows per S/R machine Number of S/R machines
- Number of storage space required
- Number of Bays

Number of storage spaces per system height = Storage space height/System height desired
The variation in the desired system height is in between 30 to 90 ft.57Automated Storage/Retrieval Systems
Estimation of Bay Width, System Width, Rack Length, System Length, Bay Depth and Aisle Unit
The length of a single storage space is added to the centre-to-centre rack support width to calculate bay width. Thus we get,
Bay width = Length of storage space + Centre-to-centre rack support width
= L + x + x1
where x1 is the centre-to-centre rack support width
Rack length = bay width * number of bays
System length = rack length + clearance for (S/R machine run-out + P/D area)
Bay depth = width of the individual storage space + bay side support allowance
= u (b + z) + x2
where x2 is the bay side support allowance.
Aisle unit = Aisle width + (2 * Bay depth)
System width = Aisle unit × Desired number of aisle

3. Kinematic synthesis-Number synthesis

Number synthesis deals with deciding number of links we will be using considering its degree of freedom. There are several methods suggested to assist number synthesis, one of which is suggested by R.C. Johnson and towlighand consist of following procedure

The determination of that must be satisfied for selection of suitable “associate linkage”. These rules are derived by observing the specific design application.

1. The application of suitable associate linkage to the synthesis of different type of devices.

We have finalized the type of robot we are going to use i.e. Articulate robot. It’s a four bar mechanism, with 3 joints.

First of all we will

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4. Calculate degree of freedom of system.

Degree of freedom can be defined as number of independent input required to determine the position of all links of mechanism with respect to groundor Minimum parameters required to completely define position of link in space with respect to fixed link.

DOF= 3 (n-1) – 2f

Where,

n= number of links

f= number of joints

comparing our system we have 4 links and 3 joints

DOF = 3 (4-1) – 2 x 3= 3

5. Selection of motor

Force (Newton)

F=m x a where m= mass(kg) and a=acceleration(m/s2)

Motor torque(Newton-meters)

T=F x d where F=force (Newton) and d= moment arm(meters)

Power (Watts)

P = I x V where I = current (amps) and V = voltage (volts)

P = T x ω T = torque (Newton-meters)

ω = angular velocity (radian/second)

Unit Conversion

Length (1 in = 0.0254 m)

Velocity (1 RPM = 0.105 rad/sec)

Torque (1 in-lb = 0.112985 N-m)

Power (1 HP = 745.7 W)

Example related to our project.

The following is the specification of motor we will be using to lift a 1-kg load using a 0.5-m lever arm.

12V DC motor

10 rpm

3000RPM base motor

6mm shaft diameter with internal hole

125gm weight

Stall torque 22kgcm

No-load current = 60 mA(Max), Load current = 300 mA(Max)

Solution

we will Convert Stall Torque fromkgcm to Nm

22 kgcm = 22 x 9.8 x 10^-2 = 2.15 Nm

now,

Calculate the Force required to lift the 1-kg load

F = m x a = 1 kg x 9.81 m/s2 = 9.81 N

Calculate the Torque required to lift the Force with the lever arm

T = F x d = 9.81 N x 0.15 m = 1.471 N-m

Hence We can perform the lift with this set-up, because the stall torque is greater than the torque required for the lift. The length of the lever arm is also allowable.

The selection of motor is also perfect.

6. Dimension Synthesis

Dimension synthesis deals with calculation of link length and its arguments with respect to fixed support.

There are many methods of dimension synthesis. Here we will be using freudenstein's equation with chebeshev's spacing.

Link length AB=0.2m

Link length BC= 0.225 m

Link length CD= 0.15m

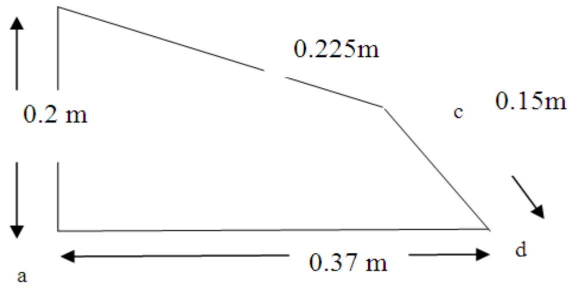
Link length CD=0.375m

Argument of AB with respect to horizontal is = 90

Argument of BC with respect to horizontal is = 30

Argument of DC with respect to horizontal is = 150

Argument of AD with respect to horizontal is = 180



7. Dynamic Analysis Of Mechanism

Velocity= l x ώ

Where l= length of link

ώ = angular velocity of link = (2π x N)/60

As N=10rpm for each motor

Therefore ώ = (2 x 3.14) / 60 = 1.046

Vab = velocity of link AB = 0.2 x 1.046 = 0.21 m/s

Vbc = velocity of link BC = 0.225 x 1.046 = 0.2355 m/s

Vdc = velocity of link DC = 0.15 x 1..46 = 0.157 m/s

Now acceleration

a_r = Radial acceleration = $ώ^2$ x link length

a_t = tangential acceleration = α x link length

where α = angular acceleration,

therefore,

a_{rab} = radial acc of link AB = 1.046^2 x 0.2 = 0.219 m/s^2

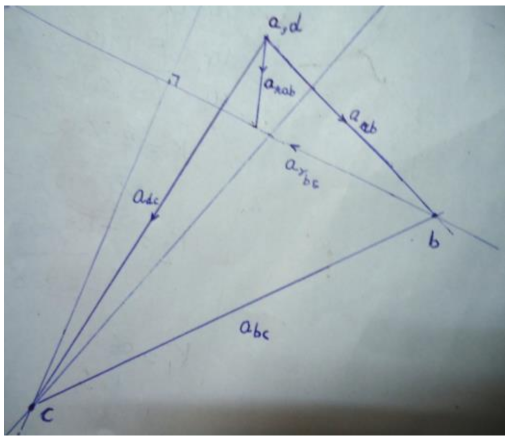
a_{rbc} = radial acc of link BC = 1.046^2 x 0.225 = 0.246 m/s^2

a_{rdc} = radial acc of link DC = 1.046^2 x 0.15 = 0.164 m/s^2

now we know

a = acceleration = α * link length

we want the value of α i.e. angular acceleration and value of a_t is obtained from acceleration polygon



Acceleration polygon

a_{ab}= acceleration of link AB =2.8m/s^2

a_{bc}= acceleration of link BC = 4.7m/s^2

a_{dc}= acceleration of link DC = 2.65m/s^2

therefore

$α_{ab}$ = angular acceleration of link AB = a_{tab} / length of AB = 2.85/ 0.2 =14.25rad/s^2

similarly

$α_{bc}$ = 4.7 /0.225 =20.88 rad/s^2

$α_{dc}$ = 2.6/0.15 = 17.33 rad/s^2

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III. RESULTS AND DISCUSSION

This chapter deals with the results and discussions of the present state of work. The experimental data has been converted into the interpretable form. It is now necessary to analyze this data to draw some logical conclusion. Obtain results are now useful to interpret its significance and effects. Keeping this in mind following study have been made.We have discussed various problems in an industry for material handling and store management. We also overviewed the traditional method used in industries for store management which causes lots of problem in respect of labor, cost, safety, etc. and hence selection for design of ASRS was taken into interest. We have studied classification of material handling process. We also overviewed types of machines use in industry for store management. Various types of ASRS used with its detail description was also studied with its policies. Storage and interleaving rules are also covered in this thesis. Current types of ASRS and their uses have been also enlighten. We then selected the R/S system we will be using. Storage structure size, spacing, capacity, load size determination, estimation of storage space is also computed. We also carried out its kinematic dimensioning with calculation of DOF.

IV. ADVANTAGES OF AS/R SYSTEM

1. High stock with limited space.
2. Reducing labor costs
3. Easy Provision for Expansion
4. Easy and fast maintenance
5. Easy and appropriate inventory control
6. Pleasant and convenient work environment
7. Easy management of inventory as FIFO.
8. Faster and more reliable operation
9. Protection of storage goods
10. Prevention of safety accident
11. Immediate identifying of the ware
12. Immediate price, feature information of the wares
13. This computer can be equipped by a bank card reader, which can be used for paying.
14. The whole shopping process can flow without human service
15. More capability than standard inventory control
16. The S/R machine does not take breaks
17. Reduced training time
18. Higher inventory security
19. Less product damage
20. Uses less square footage
21. Higher return on investment
22. Eliminates machine operators
23. Change of end effecter can be made to perform many other operations by the system.

V. DIS-ADVANTAGE OF AS/R SYSTEM.

1. A steady, high volume supply of consumables (i.e. vials, microplates, pipette tips, solvent, etc.) is necessary.
2. The cost of purchasing, storing and disposing of consumables may be significant enough to dictate the use of methodologies that minimize their use, such as reformatting of samples using washable pipetting components or non-contact technologies, such as ultrasonic droplet ejection.
3. Weighing: The bottleneck for any dry compound collection is often the dispensing and weighing of samples. Automated techniques exist for this operation, but none span all the different potential physical characteristics posed by solid samples. Thus some degree of manual intervention is almost always going to be required. Strict attention must be given to eliminating the exposure of individuals to these dry compounds during such a weighing process.
4. Centralized vs. decentralized: The debate over the merits of a large, centralized sample collection vs. multiple, decentralized collections is ongoing. Many companies have decided to have both, with a single, large collection providing samples to smaller, decentralized facilities on a “campaign” basis. In this scenario, the decentralized facilities have a smaller capacity and are highly focused on providing the samples in a format and throughput consistent with their specific downstream needs
5. Sample identification: The use of some form of Automatic Identification technology is essential for sample identification. Two or three - dimensional bar coding are the most common methods. Radio Frequency ID tags (RFID) are also a viable choice, although likely more expensive. Any label technology must be capable of staying adhered to the vessel and remaining readable under the storage conditions, i.e. very cold, potential frost (see Bar code labels). A choice must be made between a ID strategy in which the identifier is simply a pointer to information in a data base, or one in which the identifier actually contains information about the sample (see Automatic Identification - strategy).
6. Support and maintenance: A large, fully automated AS/RS is an industrial scale system and operation. Each installation of such a system involves some degree of customization, so none of these systems can be considered to be commercial-off-the-shelf (COTS). Successful installation and operation of such systems is made much more likely by the presence of in-house laboratory automation specialists. Although the system is almost certainly to be provided and integrated by a commercial entity, internal resources are essential for all the aspects of managing a highly custom laboratory automation project.
7. Changing requirements: Such large, industrial operations take much time to put into place. The R&D process supported by these large systems change and evolve constantly, sometimes rapidly, not only in terms of science, but also organizationally. Therefore one must carefully weigh the timelines of implementing such a system vs. the potential timelines of change within the organization.
8. Changing viewpoints on stability: Over the history of compound collections, opinions and information about sample stability has evolved, and will likely continue to evolve as more long-term data is obtained. This may cause an evolution in the desired storage conditions or format, which may necessitate system modification.

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VI. COMPARISON BETWEEN ASRS AND OTHER MECHANIZED SYSTEM

Basis	Other system	ASRS
Operator vs. Automatic	Operator can provide Flexibility	Operator-less operation
Training	Higher training	Reduced training
Effective machine usage	Operators require breaks	Automatic machines don't take breaks
Product damage	More due to human error	Less with proper load screening built into system
Floor space		Generally requires less than others
Expansion	Can add fifth tunnel and ninth & tenth machines	Can lengthen aisles up to the throughput of each of four machines
Security		Secure by safety fence and Gates
Inventory Control		Standard PC based supervisory control provides more features than bar code equipment system
Maintenance	With good preventive maintenance has low maintenance	With good preventive maintenance has low maintenance
Reliability	Generally high reliability, but VNA hydraulics and batteries tend to have more failures	Generally high reliability with AS/RS electric drives and PLC having fewer failures

VII. CONCLUSION

In the present work all the details of proposed machine have been found considering all the design parameters. The present machine is robust in construction. Various design parameters are taken into consideration in designing of this system. Cost of machine may be high but proves beneficial in coming years and can definitely make profit out of firm.

The machine can be operated by any common man. This system proves very useful in large scale industries where one process is related on other and store management of unfinished goods is made. We presented the main problems that can arise in store management, which can be successfully solved by the application of system. This system eliminates manual work, hence reduces the labor cost, and finally leads to reduction in final cost of product. The product is handled carefully which reduces its probability of breakage. Proper database is maintained for the products available in warehouse which avoids detonation of product. The manual accidents are also avoided. The mechanized system require humans to operate them personally, whereas this system can be operated by any communication channel, so no need to drive them in person. In case of emergency we can retrieve the precious goods out of store house. Many factors do favor ASRS, proving it beneficial in industries in many ways. The use of this system is cost effective also, if used for specific purpose. Travelling through brief description we can clearly conclude that ASRS is beneficial in industries. It has an broad implementation and use.

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