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Design and Simulation of Double Deep ASRS for Engine Storage Line

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Abstract: **Storage system is a backbone for an industry with higher productivity. Storage of material may be in the form of raw materials, work-in process or finished product. Selection of storage system depends upon the available space, weight of items to be stored, method of storage operation etc. Manual storage system has been in use since many years. This not only increases handling time and causes fatigue for workers. But an ideal storage system should have low running cost, easy maintenance, and high throughput with least effort by workers. An Automated Storage and Retrieval System (ASRS) fulfil above mentioned characteristic of product and overcome the shortcomings of manual storage system. In addition, ASRS has high space utilisation, automation in storage system which leads to reduction in labour cost and running cost. Among various AS/RS, Double Deep AS/RS has undue advantage when less varieties of load to be handled with high throughput. In Double Deep ASRS items to be stored are placed one behind other. An ASRS is a system of conveyors, ASRS crane, racking structure and operating system for automation. The present work aims at designing a double deep ASRS for storage and retrieval of an automobile engine, determining the cycle time and overall capacity for ASRS and also finite element analysis of the designed ASRS to validate the design.**

Keywords: **Storage system, ASRS, FEA, Double Deep**

1. INTRODUCTION

ASRS provides better space utilisation and has longer life as compared to other storage system present in today's world. It can store palletized finished product, work in process and raw materials as well. ASRS has application in paper, paints, beverages and automobile industry. An ASRS consists of pick and place station, conveyor system, input-output station, a crane to transfer the pallet containing load and rack structure. Input-output stations may be connected to load/unload station by means of roller conveyor, belt conveyor, automated guided vehicle or forklift trucks. In ASRS, stacker crane is used to move parts from/to input output station from/to racks. Stacker crane is capable of three directional movements. The base carriageway at bottom moves on crane rail in X-direction. For Y-direction, wire drive system controls the telescopic fork movement. Movement of crane in X-Y axis simultaneously is called Tchebyshev movement. Telescopic fork which picks/places load in rack structure performs z-direction movement. These movements are controlled by means of electric motors. Designing of ASRS is a subject to unit load weight, dimensions and throughput.

2. LITERATURE SURVEY

Numerous works has been done regarding the study and design of the ASRS. Hausmen et al [1] has compared the two and three class based storage assignment, closest open location assignment and full turnover assignment. Comparison was done on the basis of cycle time. In his work a significant reduction in the cycle time of full turnover assignment was achieved and concluded that full turnover assignment is the most economic method of storage. Howard Zollinger [2] compared the VNA (very narrow aisle) with ASRS on the basis of various aspects ranging from cost, operating conditions, differences and similarities as well. In this study, it is noticed that ASRS has high initial installation cost but in long run it provides high return against VNA. During the study, the day with negligible inventory was ignored to arrive for correct result. Kees Jan Roodbergen et al [3] carried out a detailed literature survey on ASRS. They shown that most of studies covered so far are on only static problems. However, in the present changing world the study must contain dynamic problems and it should not be based on one or two factors. They also recommend development of simulation models where numerous design features and control problems are considered. Dimitrios Bargiotas, et al [4] developed a low cost ASRS for small and medium scale enterprise and this study proved that even in small and medium scale enterprise ASRS is most economical, for storage class based storage assignment systems were used. N. Meghelli Gaouar, et al [5] carried out work on the storage assignment by comparing class based storage method with heuristic approach. In class based storage method loads were divided into classes depending on priorities with load of maximum frequency nearer to dwell point which was I/O station. A technique called ABC analysis has been used for class based storage method. Heuristic approach consists of storage procedure and retrieval procedure. These results show the improvement in storage method by using class based storage system over heuristic method. Helen Heinrich et al., [6] carried out study on the application of AS/RS for the library storage other than manufacturing industries. This work has economically justified the installation of ASRS instead of expanding the existing storage system. An ASRS uses dedicated storage system for storing books. Ajinkya C. Dawale et al [7] worked on design and fabrication of ASRS system considering it as a robot system. This work basically concentrated about problems faced in store management of item in rack structure. This work also shows that installation of ASRS has high initial cost but in long run it is beneficial. Smita U Chakole [8] developed ASRS model for FMS laboratory. The prototype model of ASRS developed consists of the control hardware and software communicating over a field bus network. We-Min Chow [9] has made a comparison of manual conveyor and ASRS to choose material handling system. The comparison was carried out on different concerns such as from cost to speed.

3. AIM AND OBJECTIVE

Our aim is to design an ASRS crane and to determine the maximum storage capacity of rack structure as well as cycle time for storage and retrieval operations. The basic step is to first study the ASRS and its different load bearing members. The load acting on different members and stresses produced also needs to be studied. Dimensions of rack structure needs to be determined. Dimensions of rack structure helps in determining the total number of racks that is possible in available layout. Also the storage capacity will help in calculating the cycle time of ASRS.

4. ASRS SYSTEM

An ASRS consists of different components such as input/output station, conveyor system, load-unload station, ASRS crane, rack structure and storage module

4.1 Input output station (I/O station): Input-output station is the threshold of ASRS. It is the place from where items from different parts of industry enter the ASRS and vice-versa. The item arriving/leaving ASRS are controlled by means of AGV system.

4.2 Conveyor system: Conveyor system is the component which serves as bridge between the I/O and load unload station. Selection of conveyor system depends upon the weight of item it is transferring.

4.3 Load-unload station: Item coming from I/O by the means of conveyor system reaches load-unload station. From load unload station item is picked up by the ASRS and transferred to rack structure.

4.4 ASRS crane: ASRS crane performs the task of storage and retrieval of item into/from the rack structure. The ASRS crane should be capable of performing the three axes movement. The movement of crane is controlled with the aid of motor and individual motor responsible for motion in different direction. An ASRS crane is basically a vertical mast placed on base carriageway. The base carriageway contains wheels which move on rail section. The rail section at the bottom along with a guiding element at the top restrict the various moment that acts on the crane. The shuttle performs the storage and retrieval operation is lifted by means of rope system.

4.5 Rack structure: Rack structure is the frame work of rack and is made of steel. The rack structure serves as the temporary storage system of item in ASRS. The rack structure should be strong enough to bear the load of item that it has to store and also supports the roof.

4.6 Storage module: Storage module is the data storage device which holds the information about the stored or retrieved item such as rack number, time of storage etc. The storage module maintains database of stored items this is advantages over manual storage system.

5. DESIGN CALCULATIONS OF ASRS

In present design automobile engine is the item that will be stored. The ASRS crane will move with engine of weight 850 kg at speed of 60 m/min horizontally and will lift it at speed of 20 m/min.

5.1 Determination of degree of freedom of ASRS

Degree of freedom helps in determining the constrained motion that body can have in particular direction. According to Kutzback's criterion:

Degree of freedom (D_f) $= 3\,(N_l-1) - 2P_a$
$= 3 \times (4-1) - 2 \times 3 = 3$

Where, N_l = number of links
P_a = no of pairs having one degree of freedom

So, an ASRS crane has 3 DOF under working condition. As such the designed ASRS will have 3 linear motions along rotary motion have be constrained

5.2 Rack structure dimensions: Individual rack dimensions are determined by considering clearance allowances to dimension of the item.

The dimension of the engine including pallet is
$l \times b \times h$ = 1000mm ×700 mm ×1200 mm
where, l is length, b is breadth and h is height.

The height (H), length (L), and width (W) of rack structure is related by the relation:

L= my (l + x), W= u(b + y), H = mz (h + z) where, x y and z are allowances in length, width and height of palletized item. my, mz are respectively number of load compartments along the length and height of the aisle, u is the storage depth in number of unit loads.

5.3 Storage space capacity

In order to determining the storage space capacity following assumptions were made:-

- Random method of storage of loads in the ASRS i.e. racks in the storage aisle is equally likely to be selected
- Storage racks are of equal size
- The pickup and delivery station is located at the base and end of the aisle
- Constant horizontal and vertical speeds of the ASRS crane and
- Simultaneous horizontal and vertical travel of shuttle drive.

In randomized storage method, items are stored in random rack without any preference and their probability of retrieval is equal. Thus in long run randomized storage system have advantage over other storage method.

Storage capacity depends upon the number of bays is:
N_b = [{(available Bay length - Extra Space for maintenance)/ One bay size} + 1].
Similarly, for double deep number of banks $N_B = 4$, Number of levels $N_l = 5$,
The overall capacity of designed ASRS rack structure that, the number of pallets that ban be stacked at time in rack structure = $N_b \times N_B \times N_l$, found to be 460 engines at a time

5.4 Cycle time calculations

Let L_a be length of aisle, V_x be velocity of ASRS along aisle, H be height of rack structure, V_z velocity of lifting the item, T_{pd} be pick and drop time, W be the depth of rack structure, v_x be the velocity of shuttle.

Then, cycle time of single command cycle is
$T_{cs} = \text{Max}\ \{(\frac{L}{V_y}), (\frac{H}{V_z})\} +2\ T_{pd}$
Similarly cycle time for dual command cycle is
$T_{cd} = \text{Max}\ \{\left(1.5\frac{L}{V_y}\right), \left(1.5\ \frac{H}{V_z}\right)\} + 4\ T_{pd}$

Thus cycle time for single command cycle was found to be 64.6 sec/cycle while for dual command cycle it was 115.70 second/cycle.

6. FINITE ELEMENT ANALYSIS

Finite element analysis (FEA) of the ASRS crane was carried in order to validate the design. Analysis of whole FEA is cumbersome and time taking. Therefore, only load bearing part (as in Figure.1) of ASRS crane has been considered for FEA.

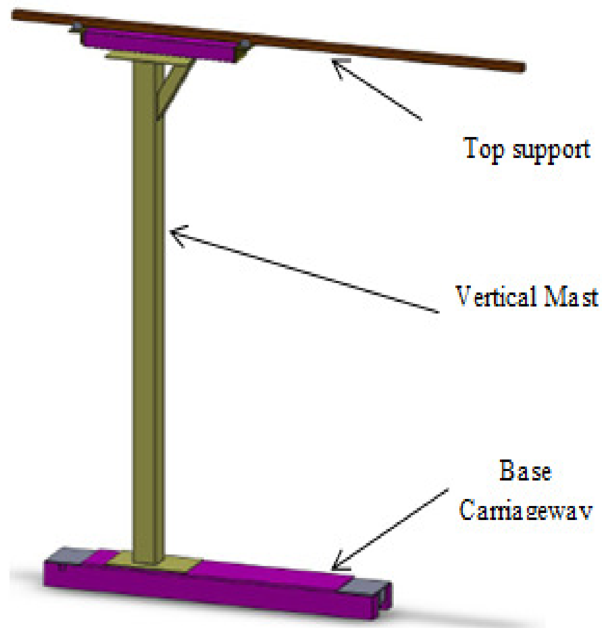

Fig. 1 FEA model

6.1 Meshing: For meshing ASRS, tetrahedral element has been used, due to complex geometry as well as due to size of ASRS crane. So, after meshing 636631 numbers of tetrahedral elements and 149659 numbers of nodes were generated.

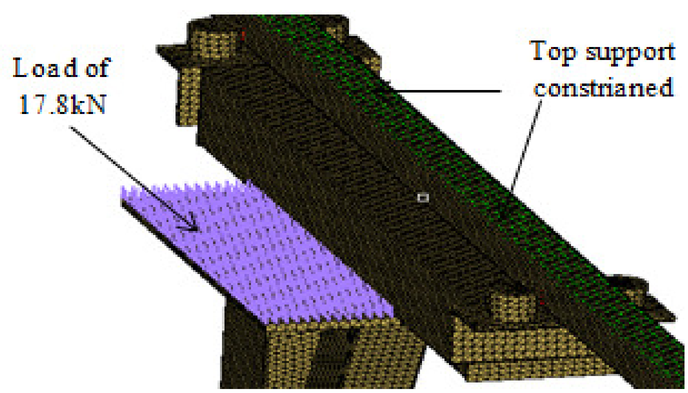

Fig. 2 Load and boundary conditions

6.2 Load and boundary condition: The load of 17.8 kN acts on the plate as shown in Figure.2. In present work top tube support and bottom wheel support has been given the zero degree of freedom. Boundary condition of top tube is also shown in Figure.2. Similarly, boundary condition of wheel support is shown in Figure.3.

7. RESULTS

The ASRS was designed for the automobile industry for temporary storage of engine. Figure.4 shows the 3 D model of ASRS designed to move the engine weighing 850kg. The rack structure size has been determined keeping the size of engine in mind. Similarly, based on the length of aisle, the overall capacity of rack structure, cycle time of ASRS for single as well as dual command cycle was determined and found to be 64.60 sec/cycle and 115.70 sec/cycle respectively. In order to validate the design, FEA analysis was carried out. In FEA displacement produced under loading condition was found to be 0.129 mm and the maximum stress developed was determined by Von-Mises stress to be 26.6 MPa and results of FEA is shown in Fig.5 and Fig.4 respectively. In ASRS the maximum permissible deflection is of 1mm, as rack number recognition is done by the means of sensors. Therefore, the designed ASRS is safe for the load of 850kg.

8. CONCLUSIONS

In present work an ASRS was designed by considering all design parameters. It was proved by FEA analysis that design is safe. Various design parameters were considered for selecting different components of ASRS. The data of the location of engine is stored in storage module. The system eliminates the manual work, which reduces the accident due to human error. It can be controlled by single man with prior training. An ASRS is one time investment and has high return in long run. Thus installation of ASRS is economic for company.

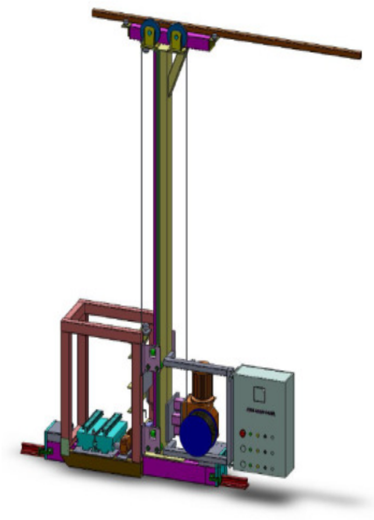

Fig. 4 3-D Model of ASRS crane

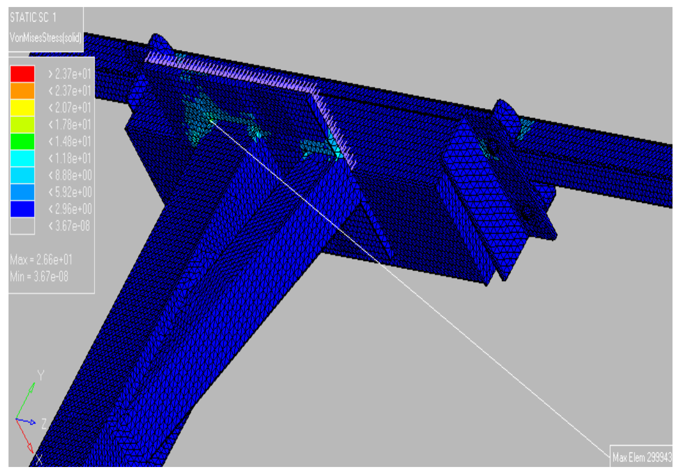

Fig. 5 Von Mises Stress

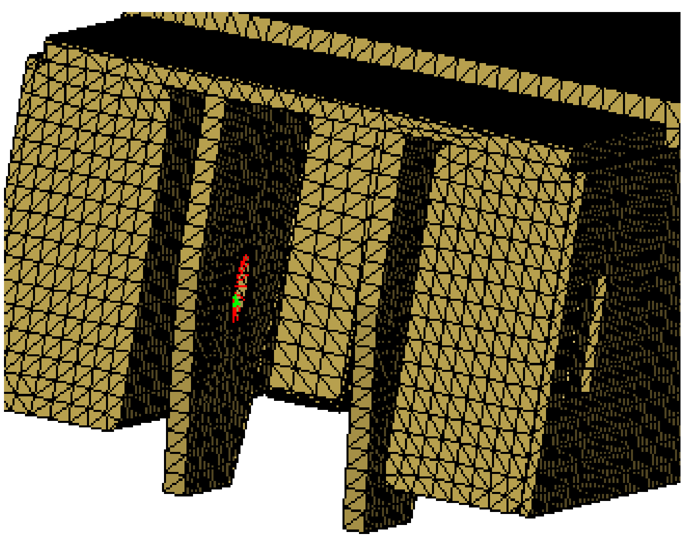

Fig. 3 Constrained wheel

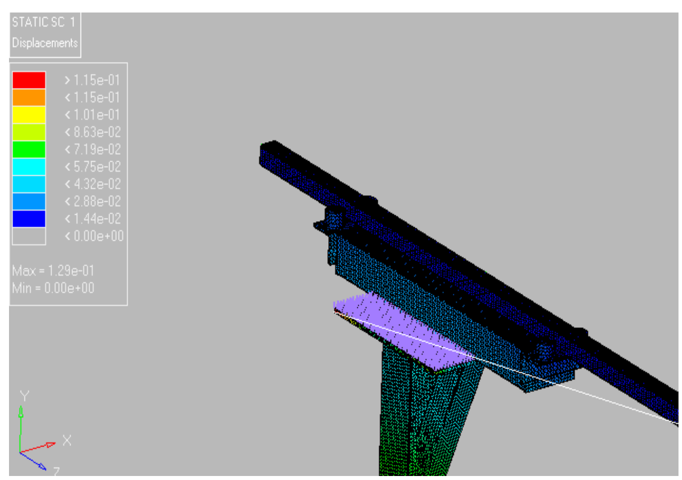

Fig. 6 Displacement

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