RESEARCHERID
THOMSON REUTERS

[Umesh* *et al.*, 6(9): September, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DESIGN AND FABRICATION OF A LIGHT WEIGHT ALUMINIUM GANTRY CRANE

Gandi Umesh*,Guguloth Ravi, Thurai Sai Sharath.

* Department of Mechanical Engineering, Swarana Bharathi Institute of Science & Technology, Khammam, India.

DOI: 10.5281/zenodo.996010

ABSTRACT

Nowadays mostly in shipbuilding, gantry cranes are needed in many areas. With evolving technology the sizes of the structures are growing too. Generally in the construction of these structures gantry cranes are preferred for lifting heavy loads. In this study Main Component of gantry crane is beam which transfers load to structural member. Gantry crane beam is designed with CREO parametric 2.0. And Analysis is performed with finite element method. The working load acting on the beam is 5000N. In the analysis of the beam construction the self-weight of the beam working loads static and dynamic loads arising due to the crane movement are considered. The beam is modeled as a three dimensional design and the analysis of the construction is performed using finite element method with the help of an analyses program. The analysis is performed for three cases. In the first case the analysis is performed by considering only self-weight of the beam. In the second case the analysis performed under the influence of working load (while two trolleys on the beam are in various positions) and in the third case, both the working loads static and dynamic loads. In this study, the stress values obtained from the analysis are examined and the results obtained from theoretical calculations are compared with the results obtained with the finite element method. As a result, using finite element method in the analysis is appropriate and this method provides great convenience in the calculations..

KEYWORDS: Aluminum Gantry crane, beam, Design and analysis, CREO parametric 2.0, Finite element method static and dynamic loads.

INTRODUCTION

Background

Portable lifting equipment is a large component of any mechanical shop. This can be achieved through the use of forklifts, chain lifts, etc. While motor-powered equipment is expensive and requires maintenance and fuel, manually operated lifts are inexpensive and do not require much or any maintenance. Ease of maneuverability is a big issue for most shops along with variable terrain.

Justification

The plan for this project is to design and build a light weight aluminum crane with a chain hoist that can be broken down and easily moved to different job sites and have a 2 ton lifting capacity. Using materials that are already available will cut down on costs and allow for more money to be put into a higher quality hoist. The caster wheels will be a high strength solid rubber wheel so there are no problems with flat tires while it still has the ability to be maneuvered in more hostile terrains such as soft soil and gravel driveways. They will also have to have a higher load rating than the 2 ton rated capacity to account for the extra weight of the frame, hoist, and trolley. Building a custom hoist will allow for plenty of customization and personal additions to the basic overhead hoist design such as racks for tools, parts, and other items could be useful in the work area.

Objectives

The design will consist of a breakdown of the materials used to find the maximum bending moment in the center of the wide flange beam for the maximum holding capacity. The casters will possibly be the limiting factor on the design since they generally have low load ratings and are expensive and hard to find for load ratings above 1500 lbs. A simple cost analysis will be done also to compare the price of purchasing a frame, buying materials to build one, and using what is available to build a gantry hoist. Shipping has a very high importance about travelling of people and transportation of commercial goods around the world. In the construction phase of the ships, many massive parts might be necessary for construction and need to be moved. Mostly in shipyards and in many other places gantry cranes are preferred to transport massive parts.

Aluminum Gantry Crane Overview

These Span co All Aluminum Gantries quickly assemble and disassemble, making them popular with contractors who need highly mobile lift equipment that they can carry in their service trucks. Just one or two workers can typically move a disassembled crane up stairways, in to roofs, or in other challenging locations. Once on location, the gantry cranes are rapidly assembled, ready to lift, and able to precisely position heavy objects, such as bulky HVAC units. Because they are corrosion resistant, aluminum gantries are also ideal for refrigerated areas, clean rooms, and other controlled environments, making them increasingly popular with HVAC contractors.

Features Of Span co Aluminum Gantry Cranes

Crane Height Adjustments: Adjusts in six-inch increments, using spring-loaded steel locking pins that automatically engage when height positioning holes are reached. Adjust heights for specific lifts, uneven floors, or to move through doorways.

Adjustable Spans: Allows crane to be shortened for transport down narrow aisles.

Heavy-Duty Casters: Four-position, swivel-lock casters with mold on polyurethane wheels for excellent floor protection.

Options for Span co Aluminum Gantry Cranes

Pneumatic Tires: Either single or dual. Perfect for soft roofs.

Alternative Caster Styles & Wheel Brakes: Available upon request.

Height Adjustment Winch-Hoist Kits: Includes two LUG-ALL™ cable winch-hoists to quickly and easily change I-beam height. Gantry crane is the development of overhead crane. It is used to load and unload bulk loads in freight yard outdoor and in stock ground in harbor. Metal structure of the gantry crane is just like gantry frame; two supporting legs are installed below main girder and can move along ground track. There are cantilever beams at each end of the main girder. Gantry crane is widely used in the port and freight yard, featuring high site utilization, big work range, wide adaptability and good generality.

LITERATURE REVIEW

LK Goodwin CO. is a material handling Equipment Company that sells many types of hoist's and cranes for certain applications. Looking through their list of portable hoists, a 2 ton has a cost around $2500 for a non - adjusting height crane and would have an equivalent rating to the one being designed. These hoists come with casters but the trolley and chain hoist must be purchased separately. Below is an example of a basic portable gantry hoist design

Figure 1: Basic "A" frame gantry hoist (LK Goodwin 2012)

This design is relatively easy to assemble while it is lying down but would most likely require two people to stand up. Using two people to stand up the hoist after assembly seems to be an unavoidable factor in the design. The Cal Poly Rose Float club has a gantry hoist (3 ton Capacity) which was quickly examined to get a different idea of how the column and frame could be designed. After looking at the frame it was easy to see that the legs were designed poorly; they were built with 3"X6"X3/16" rectangular tube which is strong but the "A" frame design means the legs will start deflect due to the resolving bending moment and the rectangular tube was oriented to bend about its weaker axis seen in Figure 2. This also allows for someone to be underneath the frame when it could potentially fail making it a severe safety hazard.

The hoist beam is an S15X42.9 and spans around 26ft without support of the compression flange making its Lb value 26ft as shown in Figure 2. Adding support (drawn in Figure 2) would reduce the travel of the trolley slightly but would improve the overall safety of the design by reducing the beam's Lb value. This is a very long length to span without supporting the compression flange and using the AISC Steel Manual page 3-82 the beam's Lp=4.41ft and Lr=16.8ft. Since Lb > Lr the critical force Fcr was calculated and found to be 15,100 lbs which means the 3 ton capacity is allowable.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Figure 2: Rose Float "A" frame gantry hoist

Figure 3: Rose Float gantry hoist, no support of the compression flange

Grainger has a large selection of casters with a wide range of load bearing capacities. Grainger Item # 1NVT6 is a swivel caster with a rating of 1650lbs/caster making it a possible choice for this design. Using four casters would be able to hold 6600lbs which would satisfy the assumed 2 ton desired load capacity.

Figure 4: Caster wheel 1650 lbs capacity (Grainger 2012)

They run about $66/caster which seems typical for casters above 1500lbs. The caster wheels will be the limiting factor for this hoist and they will determine the load capacity that will be printed on the side. The trolley chosen was a JET 2 ton manual trolley; this trolley is meant for beams from 4-8 in width. The hoist is designed for 4000 lbs so the 2 ton trolley will meet the capacity required for the design and will be compatible with the hoist since they are the same brand.

Figure 5: Jet 2-ton trolley (CPO Jet Tools 2013)

The AISC Steel manual will be the book used to help calculate the maximum load the beam available can handle and how much the beam will deflect with the assumed load on it. The compression flange is the main factor to design around when using a beam whether it is an "S" or "I" beam. This can also be used for the column calculations to find what point load will cause the columns to buckle. Shigley's Mechanical Engineering Design book shows how to calculate the loads on the beam supports and gussets along with the Mohr's circle to find the max shear and normal stresses. This will help find the Factor of Safety for the frame of this design.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Figure 6: Jet 3.2-ton hoist (CPO Jet Tools 2013)

PROCEDURES AND METHODS

Design

The design was based off of previously built gantry carne. The aluminum gantry crane was used as a design to avoid especially the "A" frame section used for the supports. The material used was based on what was available and what would be a strong but not overkill to avoid adding too much weight on the casters. The upright supports were made to be cut at 45 degrees to make it easy to cut. The pipe gussets were made at a sharper angle because that allowed the trolley to have a wider distance to move back and forth. The specifications for the members can be found in Appendix A. The material that was available was the S10X25.4, which had already been cut at 8ft, the 4X4X2 the W6X12, miscellaneous plate, and 3in pipe.

Fabrication

A basic design was made first to get an idea of how much metal was needed and what materials were available to be used to build the aluminum gantry crane. A few rough dimensions were estimated such as the caster height, which varies based on wheel material, and overall height of the hoist. The width however, was set by the availability of the beam which was already at 08ft. Once a basic design was drawn up and the available material was evaluated, the design was drawn in CREO parametric 2.0 and assembled. From the CREO parametric 2.0 models of each part the dimensions were drawn out and each part drawing was used for a cut list. Parts drawings can be found in Appendix A for later reference. All the material was loaded up and taken to one of the shops at Paramount Citrus to cut the majority of the material to length using a band saw as shown in the figures below.

Fig7: Trailer loaded with material.

Fig8: Material cut in band saw.

Fig9: Material cut to length.

Fig10: Bottom plate cut to match caster mount piece.

The only material that had to be cut afterwards with a cutoff wheel were the bottom flanges on the uprights and the 3" pipe that had to be marked with an angle finder and custom cut with a cutoff wheel. The pipe gusset was cut to have a steeper angle to allow the trolley to move farther across the beam. It was harder to make the cut with a cutoff wheel instead of being able to use the band saw so the cut may have been less accurate but welding would fill in any gaps.

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Fig11: Pipe gusset cut.

Fig12:.Drilling holes.

Drilling the holes for the mounting plates on the beam was done with a magnetic base portable drill press borrowed from Paramount Citrus. The mounting plates were clamped to the beam and 5/8" holes were drilled through both the plate and beam at the same time. The magnetic drill made drilling the holes much easier than it would have been with a normal hand held drill. The magnet base was very smooth to operate and was much faster than a hand drill avoiding worrying about catching the bit and twisting everything up. Once the holes were drilled the plates were bolted down to the beam and the uprights and pipe gussets were tack welded in place. They were taken off after for finish welding to avoid getting weld on the bolts, washers, and nuts.

Fig13: Final product, aluminum gantry carne with hoist.

RESULTS AND DISCUSSION
Theoretical Calculations
Based On Strength of Materials
We know that maximum deflection formula for simply supported beam, when it is subjected to point load or concentrated load at middle of the beam

Formulae:

Maximum deflection can be expressed as

$$\delta = w L3 / (E I 48) \qquad (1)$$

Where

δ = maximum deflection (m, mm, in)

E = modulus of elasticity (Pa (N/m2), N/mm2, psi)

We know

W=5000N

L=1828.8mm

E=70GPa

I=moment of inertia of the rectangular cross section of the beam

=bd3/12

b=50.8mm; d=101.6mm

I= (50.8*(101.6)3)/12

=4,439,801.89mm4

Substitute the values in below formula, we get

$$\delta = w L3 / (E I 48)$$

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

= (5000*(1828.8)3)/ (48*(4,439,801.89)*(70000);

δ =2.05mm

This is the maximum deflection which occurred at middle of the beam

We know that

The maximum stress in a (6ft*4in*2in) aluminum Wide Flange beam, moment of inertia 4,439,801 mm4, Modulus of elasticity 70GPa, with a centre load of 5000N can be calculated like

$$\sigma_{max} = y_{max} W L / (4 I) \quad (2)$$

=26156302Pa (N/m2)

According To Thumb Rule

Some Typical Vertical Deflection Limits

Total deflection: span/250
Live load deflection: span/360
Cantilevers: span/180
Domestic timber floor joists: span/330 (max 14 mm)
Brittle elements: span/500
Crane girders: span/600

Real time calculation using engineering tool box

Maximum static deflection is: span/250

δ =7.32mm (engineeringtoolbox.com)

Maximum dynamic deflection is: span/360

δ =5.08mm;

Engineering Tool Box

Single Centre Load Beam Calculator - Metric Units
F - Load (N)
L - Length of Beam (mm)
I - Moment of Inertia (mm4)
E - Modulus of Elasticity (N/mm2)
y - Distance of extreme point off neutral axis (mm)
Total Load: 5000N
Length of Beam - L: 1829 (mm)
Moment of Inertia - I: 4439802 (mm4)
Modulus of Elasticity - E: 70000 (N/mm2)
Distance of extreme point off neutral axis - y: 50.8 (mm)
Support Force - R1: 2500 (N)
Support Force - R2: 2500 (N)
Maximum Stress - : 26156303 (Pa (N/m2))
Maximum Deflection - : 2.05 (mm)

Fig14: aluminum gantry crane with loads

RESEARCHERID
THOMSON REUTERS

[Umesh* *et al.*, 6(9): September, 2017]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Static analysis results

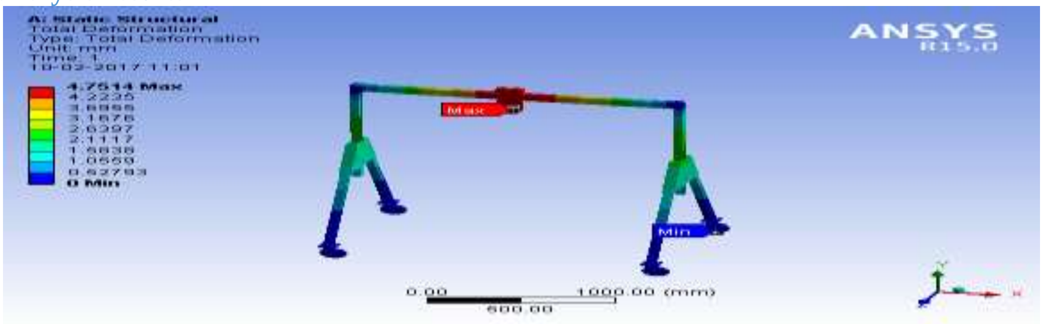


Fig15: total deformation

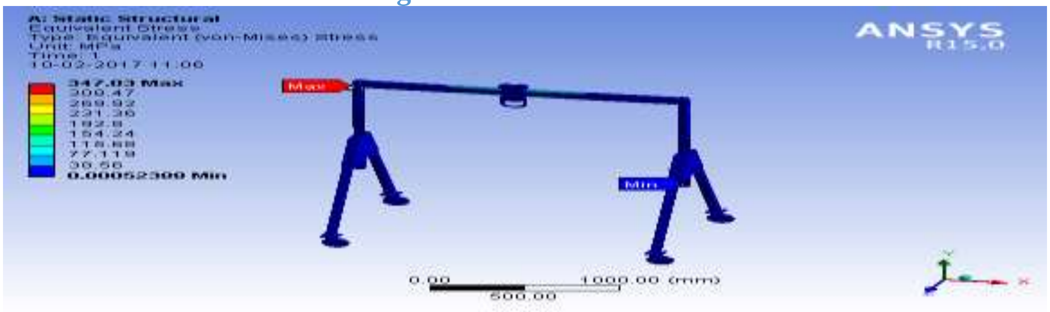


Fig16: Equivalent stress

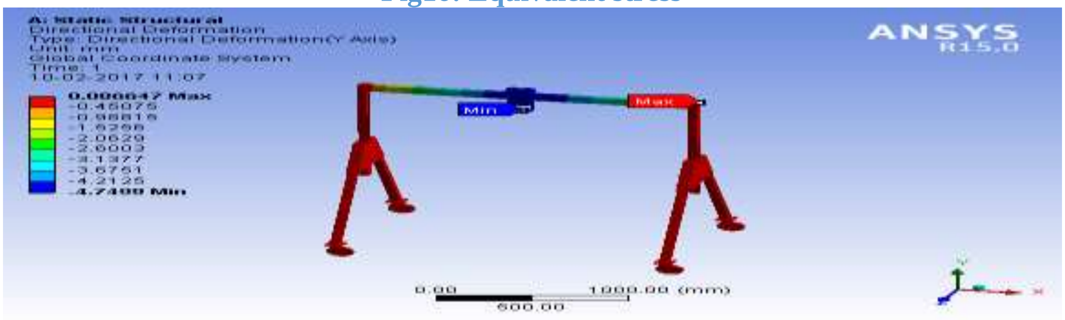


Fig17: Deformation (Y - axis)

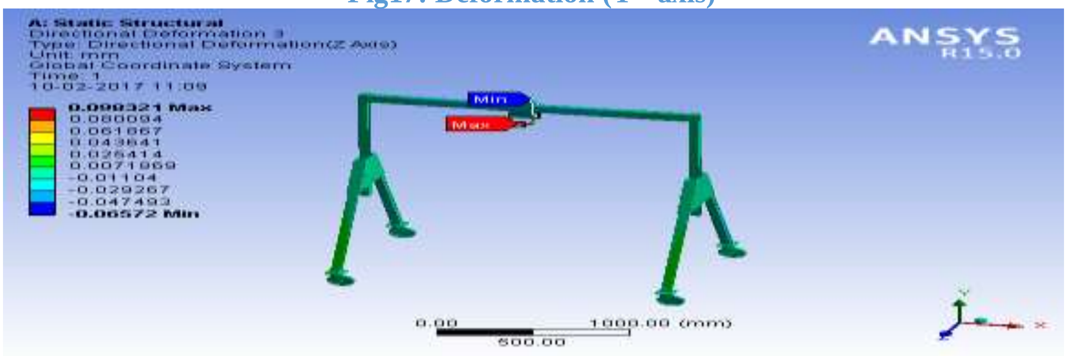
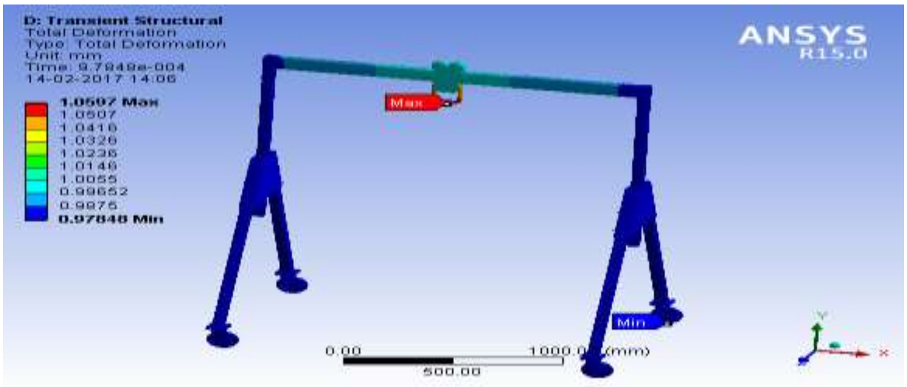


Fig18: Deformation (Z - axis)

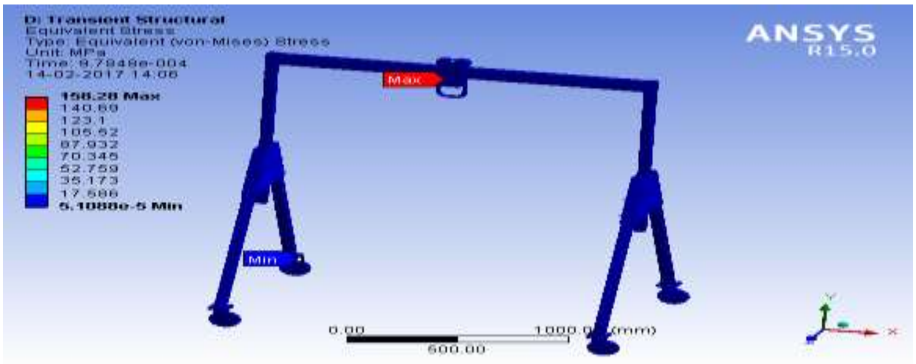
ISSN: 2277-9655
Impact Factor: 4.116
CODEN: IJESS7

Dynamic Load Analysis

Total deformation



Equivalent stress



CONCLUSION

The design and analysis of gantry crane main beam is presented. Analytical stress calculations and stress analysis with different load combination cases are studied. The Light Weight Aluminum Gantry crane was tested by lifting a 5000N. The comparison between the theoretical calculation results and analyses results of gantry crane. Generally it is expected that the difference between the theoretical calculation results and analysis results may be maximum 20 %. So, the results obtained in the study are acceptable. However, it can be easily seen that the difference between the results of static and dynamic loads cases are bigger than the other differences. This is so because the gantry crane has two legs which carry the main beam and one of them is (left side leg) rigidly supported to the main beam and the other one is (right side leg) jointed supported to the main beam. Rigid leg must carry more load than the jointed leg, so the left side of the main beam has a stronger inside structure. Hence the difference between the results of static and dynamic is high. This weight is enough to satisfy the ANSI B30.2 standardized 125% of the rated capacity that a hoist must be able to lift for its load rating so the design is adequate.

REFERENCES

[1] Total Asset Visibility. Lynn Torres. The Military Engineer, No 565. pp 35-37 v 86. August-September 1994.
[2] Tracking all trucks. (Mobile communication systems for vehicle fleets), Nation's Business, Dec 1994 v82 n12 p60 (3).
[3] Tips on truckload shipping. (Includes related article on satellite tracking), Traffic Management, May 1993 v32 n5 p63 (4).
[4] Tracking numbers and taking phone calls. Baltimore Business Journal, Nov 18, 1994 v12 n26 p11 (1).
[5] Skyway adopts satellite tracking system for transcontinental truck fleet. Business Wire, Jan 19, 1995 p. 01190003.
[6] M.S. Carriers looks into satellite-tracking system), Memphis Business Journal, Nov 18, 1991 v13 n27 p8 (1).

[7] UPS' nationwide data via cellular network comes on-line. Mobile Phone News, Feb 15, 1993 v11 n6 p2 (2).
[8] Alcatel Qualcomm's Euteltracs satellite tracking system. (Operating in Germany and Denmark) (Satellite and International), Communications Daily March 25, 1991 v11 n57 p7(1).
[9] Geo technology Development (GD), Herndon, Va., and broom signed product development agreement to pursue opportunities in container and vehicle tracking monitoring markets. (Satellite and International), Communications Daily, July 15, 1993 v13 n135 p12(1).
[10] Tracking for dollars. (Satellite positioning and communication technology usage by the trucking industry) (Richards) (Column), Automotive Industries, Dec 1991 v171 n12 pT4 (1). 133.
[11] Australians dismiss electronic container tagging standard. Zucker, Paul. Newsbytes, Feb 22, 1990 pNEW02220022. Standards Australia (the national standards authority) has taken a strong stand against the International Standards Organization's (ISO) adoption of Amtech technology for the electronic tagging of shipping containers worldwide. Australia has voted against adopting Am tech's transponder tagging system, over serious concerns the technology emits unacceptable levels of radiation.
[12] One mystery, no panic. Railway Age, August 1992 v193, n8, p91 (3).
[13] Mandatory AEI? Private car owners and smaller roads like the concept, not the cost. Railway Age, April 1991 vol 192, n 4, p 14(2).
[14] Microcircuit Technology Improves Readiness, Saves Resources. M. Lawler. SIGNAL Magazine, August 1993.
[15] Bar code label standards, Modern Materials Handling, Nov 1990 v45 n13 p62 (4).
[16] Haul monitor: a new scan able bar code promises to revolutionize the tracking of shipping containers., Supermarket News, Oct 25, 1993 v43 n43 p19(3).
[17] Two dimensions, many facets. (2D symbologies in bar codes), Transportation & Distribution, May 1995 v36 n5 p89 (4).
[18] Marine Terminal Control System (TCS), Progress Report, MARAD Contract No. 3-36255, Computer Identics Corporation, March 1973.
[19] PRS Inc, "Sealift technology development program. Assessment of cargo handling technology," DoT/Marad Tech. Rep. MA-RD-840-93003, August 1993.
[20] M.A. Jordan, "Dockside container cranes," Proc. of PORTS '95, March 1995.
[21] M.A. Jordan and C.D. Rudolf III, "New container crane concepts," Facilities Engineering Seminar, Savannah, Georgia, 993. 134
[22] A Bhimani, C. Morris, and S. Karasuda, "Dockside container crane design for the 21st century," Container Efficiency Conference, Singapore, March 1996.
[23] URL: http://www.wagner.com
[24] URL: http://www.august-design.com
[25] Bostelman et al. "Applications of the NIST rob crane," Proc. 5th Inter. Symp. Robotics and Manufacturing, Maui, HI, Aug. 1994.
[26] "TETRA Project," NIST-Intelligent Systems Division proposal submitted to Office of Naval Research,
[27] Peters B. A., Smith J.S., Venkatesh S., "A Control classification of Automated Guided Vehicle Systems," International Journal of Industrial engineering, Vol.3, No. 1, 1996, PP 29-39.
[28] Co C.G., Tanchoco J.M.A., "A Review of Research on the AGVS Vehicle Management", Engineering Costs and Production & Economics, Vol.21, 1991, PP 3542.
[29] Egbelu P.J., Tanchoco J.M.A., "Characterization of automatic guided vehicle dispatching rules," International Journal of reduction Research, Vol. 22, No. 3, 1984, PP.359-374.
[30] URL: http://ahs.volpe.dot.gov/avcsdoc
[31] URL: http://www.agve.se/
[32] URL: http://www.noell.de/
[33] G. Corrigan, A. Giua, and G. Usai, "An implicit gain-scheduling controller for cranes," IEEE Tr. Control Systems Technology, vol. 6, pp. 15-20, 1998.
[34] URL: http://www.deltaport.com/
[35] URL: http://www.bromma.com/
[36] P. Ionone and J. Sun, Robust Adaptive Control, Prentice Hall, 1996.
[37] URL: http://www.dir.37/135
[38] T. Kailath, Linear Systems, Prentice Hall, 1980.
[39] Now Computainer, Port Development Int'l, March 1991.
[40] URL: http://www.tts-hs.no/