Design and development of lift for an automatic car parking system

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Abstract -Metropolitan cities strongly need advanced parking systems, providing drivers with parking information. Existing parking systems usually ignore the parking price factor and do not automatically provide optimal car parks matching drivers' demand. Currently, the parking price has no negotiable space; consumers lose their bargaining position to obtain better and cheaper parking. This dissertation study gives an automatic car parking system, and considering negotiable parking prices, selects the optimal car park for the driver. The autonomous coordination activities challenge traditional approaches and call for new paradigms and supporting middleware. The coordination network is proposed to bring true benefit to drivers and car park operators. This automatic car parking system has capabilities including planning, mobility, execution monitoring and coordination.

INTRODUCTION

As the city modernization progresses, the number of vehicles increases accordingly, Instead of taking public transportation, people travel in personal vehicles to different locations in the cities for convenience and comfort. Due to the lack of a well-planned policy for parking facilities, the demand of parking spaces is generally much greater than the supply. Additionally, downtown areas are gradually saturated with commercial office buildings but not as many parking spaces. Drivers generally need to spend a significant amount of time circling the blocks around their destination searching and waiting for available parking spaces. To overcome above problem there is need of an advanced car parking system. There are following types of automatic (advanced) car parking systems;

1. Stacker type car parking system
2. Puzzle type car parking system
3. Level type car parking system
4. Chess type car parking system
5. Rotary type car parking system
6. Tower type car parking system

But lift is used only in tower type car parking system.

Objectives:-

- To survey existing parking system
- To survey of existing lifts
- To select suitable lift mechanism
- To identify critical components of lift
- To design components of lift
- To analyze lift components by FEA.
- To test designed lift performance

Inputs from customer and problem definition:-

The inputs from customer are given in following figure.

Maximum car size			
SEDAN		SUV	
Length	5300 mm	Length	5300 mm
Width	2100 mm (With mirror)	Width	2100 mm (With mirror)
Height	1500 mm	Height	1500 mm
Weight	2000 kg	Weight	2500 kg

Specifications	
Total car parking	33
Quantity of SUV	13
Quantity of Sedan cars	20
Entrance condition	Ground level entrance

Table:1- Inputs from customer

Total space available for parking:-

Length = 14210 mm

Width = 7450 mm

Height = 20612 mm

According to area available for parking only five cars can be parked on each floor. Therefore there is necessity of four numbers of floors to fulfill the requirement of customer.

Selection of suitable parking system and proposed parking layout:-

According to space available and requirements from customer there are three options of parking system which are as follows;

1. Puzzle parking system
2. Level parking system
3. Tower parking system

There is no space for reverse of vehicle. Hence Puzzle and Level parking system are not suitable for this requirement. Tower parking is suitable for this requirement because turn table can be mounted for this system and requirement will be fulfilled. Tower parking system requires lift for vertical transportation of vehicles.

There are two options for lift one is hydraulic lift and another is traction lift. The hydraulic lift is suitable up to moderate height when height of increases hydraulic lift becomes very costly. At this situation traction lift is better option than hydraulic lift.

The traction lift consists of following components which are either designed or selected from standard one.

1. Pallet
2. Push-pull mechanism
3. Turn table mechanism
4. Lift cart
5. Elevator rails
6. Geared machine
7. Traveling cable
8. Control system
9. Sheaves and Wire ropes
10. Motor
11. Counter weight
12. Car buffer and Counter weight buffer.

By considering requirement of customer and space available following parking layout is made.

Design of lift components:-

Design of pallet:-

The first component of lift is the pallet on which vehicle is placed. The design of pallet is done by referring following procedure.

Maximum weight of vehicle (Hummer – H2) = 3000 kg, mass of pallet = 880 kg

Reaction at front Wheel is given by;

$$(W) = \frac{2 \times \text{Weight of vehicle}}{3} + \frac{\text{Mass of pallet}}{2}$$

$$= 2440 \text{ kg} = 23936.4 \text{ N}$$

Wheel base = 3300 mm, Wheel track = 1100 mm

Distance between two rollers of pellet (Along length) =5300 mm

Distance from wheel of pallet wheel to nearest wheel of car (a) = 1000 mm.

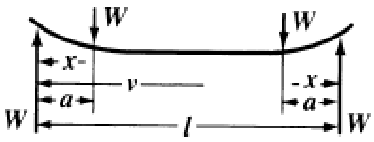

Fig.:1- Loading condition for pallet

Maximum Stress in pallet = Wa÷Z = 23936.4 ×1000÷510387.21 = 46.90 N/ mm²

$$\text{Deflection at Center (Max)} = \frac{W \times a}{24EI} \times (3l^2 - 4a^2)$$

$$= 11.17 \text{ mm}$$

$$\text{Deflection at CAR Wheels} = \frac{W \times a^2}{6EI} \times (3l - 4a)$$

$$= 6.92 \text{ mm}$$

FEA analysis of pallet by ANSYS workbench:-

The three dimensional model of pallet prepared in solid edge modeling software is imported in ANSYS workbench and load is applied at the wheel resting portion and results are obtained.

Stresses developed in pallet:- Maximum stress = 102.85 MPa

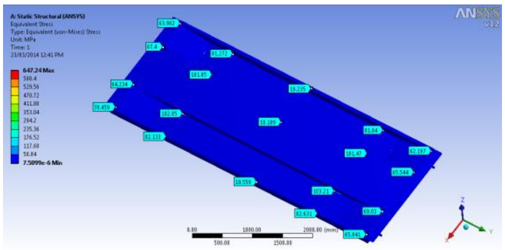

Fig.:2- Stresses in pallet

Deformation in pallet: - Maximum Deformation = 3.27 mm

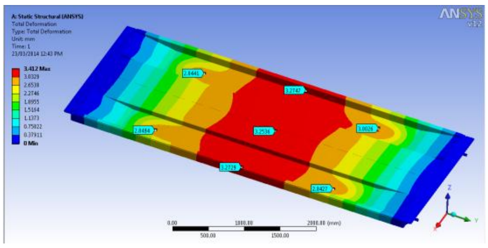

Fig.:3- Deformations in pallet

Design of push-pull mechanism:-

This mechanism is used to push the pallet from lift cart away from cart as well as to pull the pallet towards the lift cart.

Chain layout:-

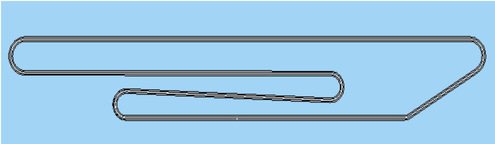

Fig.:4- Chain layout of push-pull mechanism

Selection of chain:-

Total pulling force required Ft = 9879.4 N

For this application suitable chain is Chain No.Q16003 of 1" pitch having breaking strength = 22500 N.

Factor of safety for chain = $\frac{\text{Breaking strength of chain}}{\text{Pulling force acting on chain}}$

$= \frac{22500}{2496.85} = 9.12$

Selection of gear box and selection of motor:-

Motor for this required application = 5.5 kw

Factor of safety = $\frac{\text{Selected motor power}}{\text{requred power}} = \frac{5.5}{4.52} = 1.22$

From gear box and motor catalogue following gearbox and motor is selected.

Gear box:

F RO 53 B3 H1 27.68 132 B5 AC 50 BTV LH

Motor: - BA 132 S B4 B5 MGM VARVEL

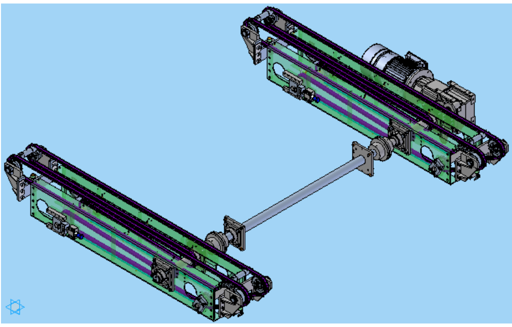

Fig:6- Push pull mechanism

Design turn table mechanism:-

This mechanism is used to rotate the pallet along with vehicle for easy removing of vehicle from out of parking system.

Design the frame of turntable:-

The following figure shows the cross-section of turn table at which chain is passing through frame;

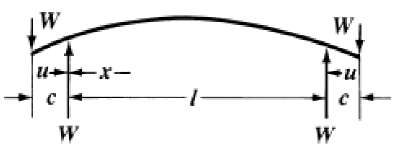

Fig.:7- Loading condition for turn table frame 'C' channel along length.

Load (W) is given by

$W = \frac{\text{Car weight}}{3} + \frac{\text{Pallet weight}}{4} + \frac{\text{push-pull mechanism weight}}{2} + \text{Ramp weight} + \frac{\text{Self wight of C channels}}{2}$

= 18078.85 N

Stress at critical point (at supports) is given by;

$\sigma = \frac{W \times c}{Z} = 52.38 \text{ N/mm}^2.$

Deflection at loads = $\frac{Wc^2(2c+3l)}{6EI} = 8.59$ mm

Deflection at center = $\frac{Wc\,l^2}{8EI} = 1.93$ mm

Selection of gear box and motor for turn table rotation:-

Required power of motor is given by;

$Kw = \frac{\text{Motor speed} \times Tm}{9550} = \frac{1440 \times 4.87}{9550} = 0.73$ kw

Motor is selected of power (kw) = 1.1 kw

Factor of safety for motor power = $\frac{1.1}{0.73} = 1.5$

Gear box: RO 43 B3 V1 115.73 AC 50, Motor: BM SA4.

Design of lift cart frame:-

It is a part of lift on which turn table mechanism and push pull mechanism are mounted. On turntable frame pallet along with car is placed.

The load (W) acting on cantilever portion of cart on which on turntable will be mounted on it is given by;

$W = \frac{\text{Car Wt}}{3} + \frac{\text{Wt of (Pallet + Push pull + tunrtable mechanism)}}{4} +$ Self weight of cantilever portion = 18638 N

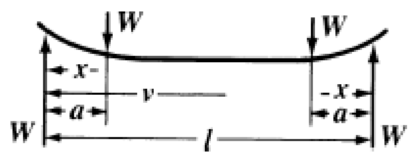

Fig.:8- Loading condition for lift cart frame.

Now, bending stress at load is given by;

$\sigma = \frac{W \times a}{Z} = 40.8 \text{ N/ mm}^2$

Deflection at center is given by;

$(\partial 2) = \frac{W \times a}{24 \times E \times I} \times (3l^2 - 4a^2) = 2.1\text{mm}$

Deflection at loads is given by;

$(\partial 1) = \frac{W \times a^2}{6 \times E \times I} \times (3l - 4a) = 1.9$ mm

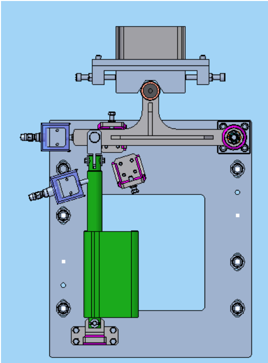

Fig.:9- Turn table locking mechanism

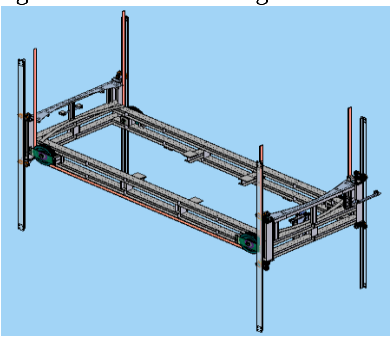

Fig.:10- Lift cart frame

Design of driving system:

Selection of gear box and selection of motor:-

Motor for this required application = 45 kw

Factor of safety = $\frac{\text{Selected motor power}}{\text{requred power}} = \frac{45}{37} = 1.22$

From gear box and motor catalogue following gearbox and motor is selected.

Geared motor designation: GFL14-2M HAR 180C32

Design of counter weight:

Mass of counter weight (Mcwt) = $P + \frac{Q}{2}$ = 6900 kg

Where P = Masses of the empty car and components supported by the car

Q = rated load

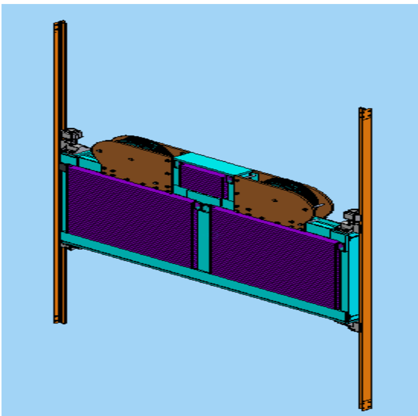

Fig.:11- Counter weight

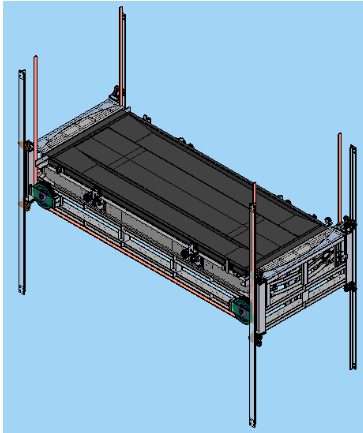

Fig: 12- Lift cart assembly

Testing report:

Sr. No.	**Points to be Checked**	**Target**	**Remarks**
Functional Testing for Parking Bay			
1	Turn table rotates smoothly with proper stopping accuracy with Car & Without Car		ok
2	Pallet transfer with/without Car from Parking slot to Lift	Smooth transfer, vibrations, noise	ok
3	Pallet transfer with/without from Lift to Parking slot		ok
4	Car Transfer from Ground to Parking		ok
5	Car Transfer from Parking to ground		ok
Technical Testing			
1	Lift Max Speed	1000 mm/sec	ok
2	Lift Acceleration	0.3 m/s^2	ok
3	Motor Current drawn in percentage of Full Load current (rated current 67.4 A)	75%	Close loop 86 amp/open loop 48 amp
4	Pallet deflection at load	7 mm	ok
5	Pallet deflection at center	9 mm	ok
Stopping Accuracy Test			
1	Lift at max Speed, with Full Load	+/- 2 mm	-2 mm
2	Lift at max speed,	+/- 2 mm	

	with no load		
3	Lift at 40% Speed, with Full Load	+/- 2 mm	
4	Lift at 40% speed, with no load	+/- 2 mm	
Noise level Test			
1	At full speed, with load / without load	< 40 db	Too optimistic
Application Test for Lift			
1	Car parking Testing	To check in actual trial	
2	Check car parking and retrieval with simulated site conditions.		
VFD Parameters			
1	VFD to reach?? In current trial setup max speed will not be achieved.	To check in actual trial	
2	VFD rated current to be?? In current trial setup max speed will not be achieved.		
3	Zero Speed current 2 to 3 A (Break current) to handle car weight		
4	Auto correction when car approaches		
5	VFD in flux-control mode		

CONCLUSION

As per the requirement, the lift has been designed. The critical components are analyzed by FEA and tested experimentally and it is found that they are safe for given load**.** As well as push pull mechanism is able to push and pull the desired weight, turntable mechanism is able to rotate the desired weight and drive unit are able to lift the desired weight with required velocity and acceleration.

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