Saimaa University of Applied Sciences
Lappeenranta
Mechanical Engineering and Production Technology

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Parking Shaft

Thesis 2011

Abstract

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Parking Shaft, 42 pages

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The purpose of the project was to design a shaft that can park two cars in the garage for the families.

The information was gathered from the Internet, lecture materials, and measuring the family garage in China. It was difficult to design the structure of the shaft, actually we design three different structures for the shaft were designed, and was chosen the one that can let the door of the garage open or close as normally.

The final result of this thesis was to help the families to park two cars in the old garage, which could only park one car before. The families can get more space to use for other things.

Keywords

Mechanical parking system, Parking, Hydraulic, Garage, 2-floors shaft

Contents

1 Introduction

1.1 Background

With the booming of the Chinese economy, the living standard has remarkable improvement. The explosion in the number of cars is a phenomenon. As of late 2003, the number of vehicles in China is 12 427 672. The number of private cars is 4 890 387, the rise is 1 462 441 from 2003 to 2003, the rate is 42.7%.

Parking spaces cannot synchronize the growth of the number of vehicles at the same time. As in many new households, the district and the parking ratio is 1:1. Vehicles parked nowhere is the problem of the urban social, economic and transport development to a certain extent.

Mechanical parking equipment is also called stereo garage. Compared with traditional garage, the most obvious advantage is that the space can be maximum utilization; it is safer and more convenient. This kind of equipment is useful solve no parking space in the limit space of city.

Chinese government has made policies clear to support stereo garage like an important technical. (Promulgated by Decree No. 6 of the People's Republic of China on Jan 1, 1998). Overall, we can see the stereo garage is wide market and vast economic and social efficiency.

1.2 Purpose

From a research for private cars we can see that the number of private cars is increasing every year. For example, the number of cars in Chengdu was 1

600 000 in 2005, and it is increased by the rate of 80 000 per year. Data shows that currently in Chengdu, 2 / 3 of the vehicles have no parking place. The purpose is to design parking equipment for a private garage.

Nowadays, the private garage normally can park only one car, but most of the families have more than one car. So the task was to design mechanical equipment that can store 2 cars in one normal garage. It is called a parking shaft.

The idea is that the cars can go out or get in at any time without any problems. When we want to move any one of the cars, we do not need to move the other one.

Figure 1

This picture shows the different structure of the garage in China.

2 The overview of mechanical parking garage

Garage equipment develops especially in Japan has been going on nearly 30-40 years, whether technically or in terms of experience it has been a success. In the beginning of the 1990s also China developed mechanical parking equipment.

2.1 Classifying the MPS

Chinese JB/T 8713 - 1998 [1] (Mechanical parking systems :classification, models and basic parameters), classifies the mechanical parking systems.

- Lifting and transferring
  The code is SX
  It means using the parking board up-down or (and) lateral translation to parking cars.

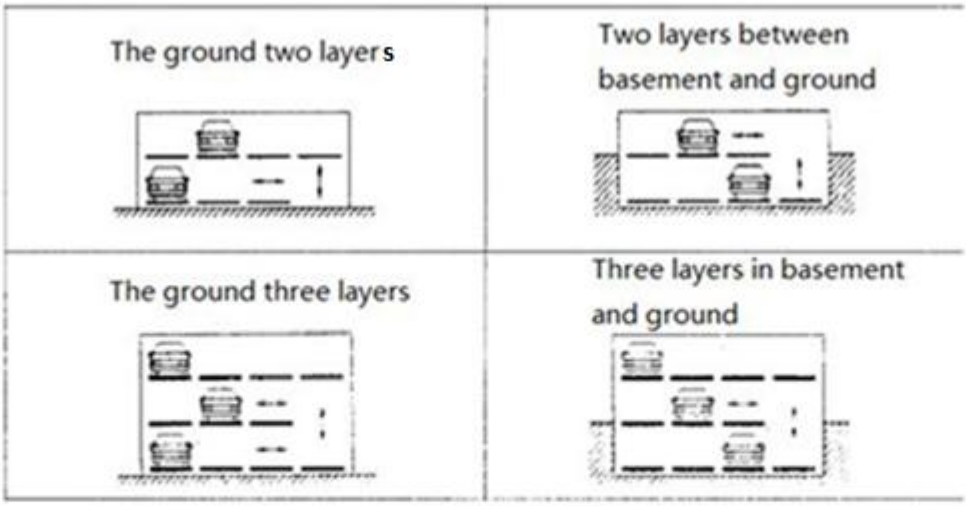

Figure 2

[1] <Mechanical parking systems : classification, models and basic parameters>http://www.docin.com/p-23343789.html

- Vertical continuous

  The code is CX

  It means the transport apparatus moves vertically to park cars.

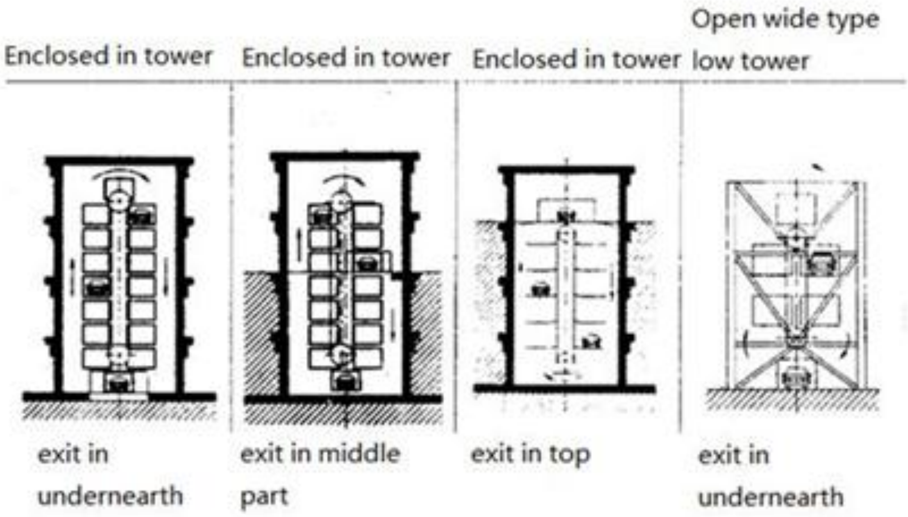

Figure 3

- Horizontal continuous

  The code is SX

  It means the transport apparatus moves horizontally to park cars.

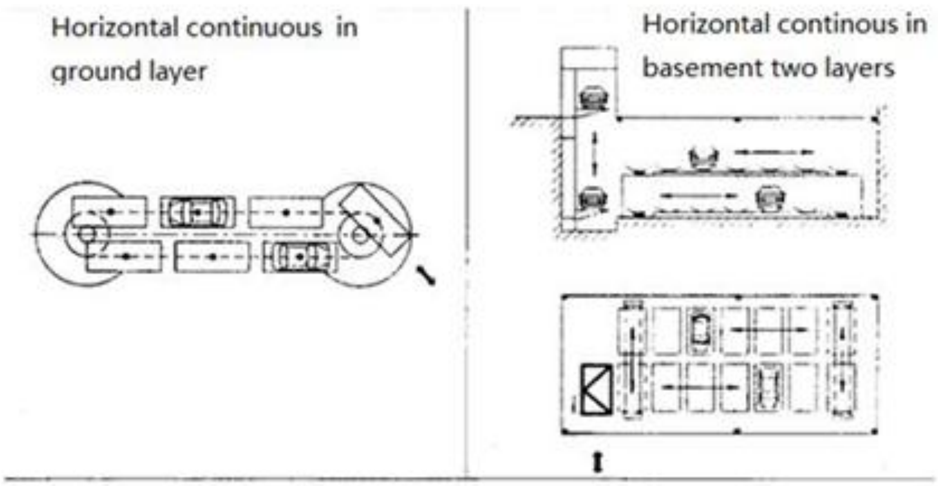

Figure 4

- Multi-storey cycle

  The code is DX

  The transport apparatus makes the parking units to do circulation movement.

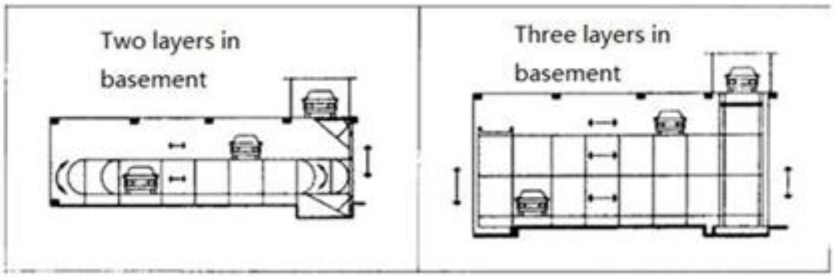

Figure 5

- Horizontal movement

  The code is PY

  Parking boards in the same floor do the horizontal movement.

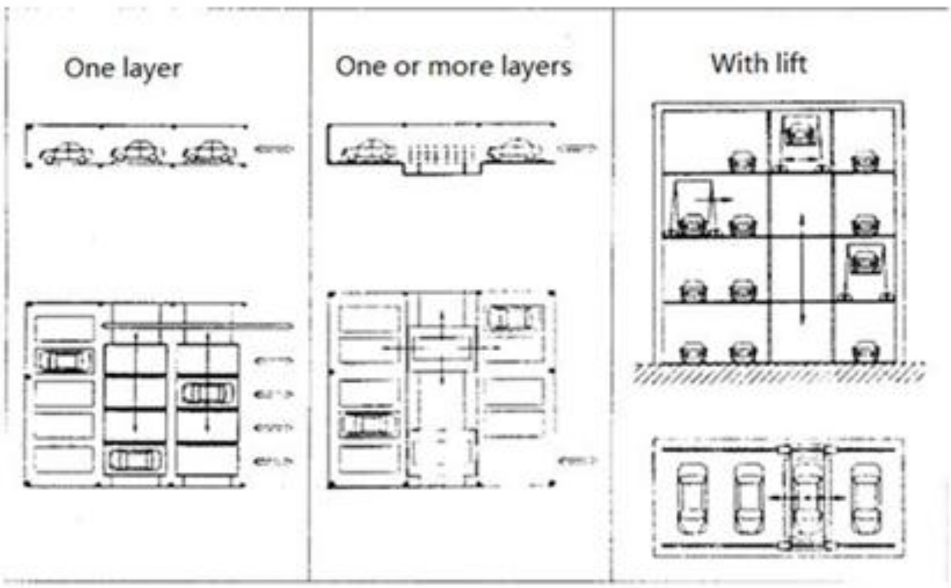

Figure 6

- Roadway Stacker

  The code is XD

  Aisle stacking crane moves the car which is in the transport apparatus to the parking unit.

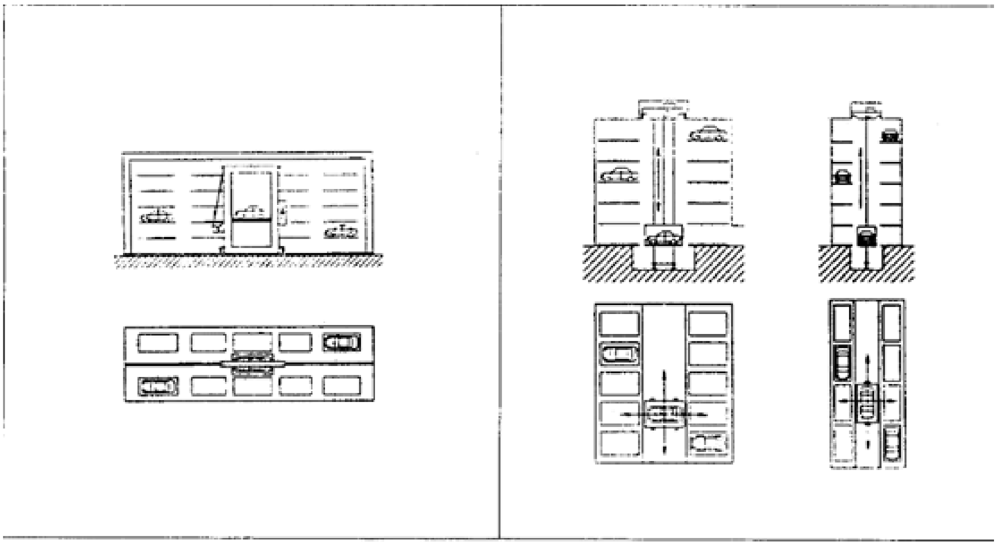

Figure 7

- Vertical up-down

  The code is CS

  Use lifter to the floor, then use storage/retrieve machine.

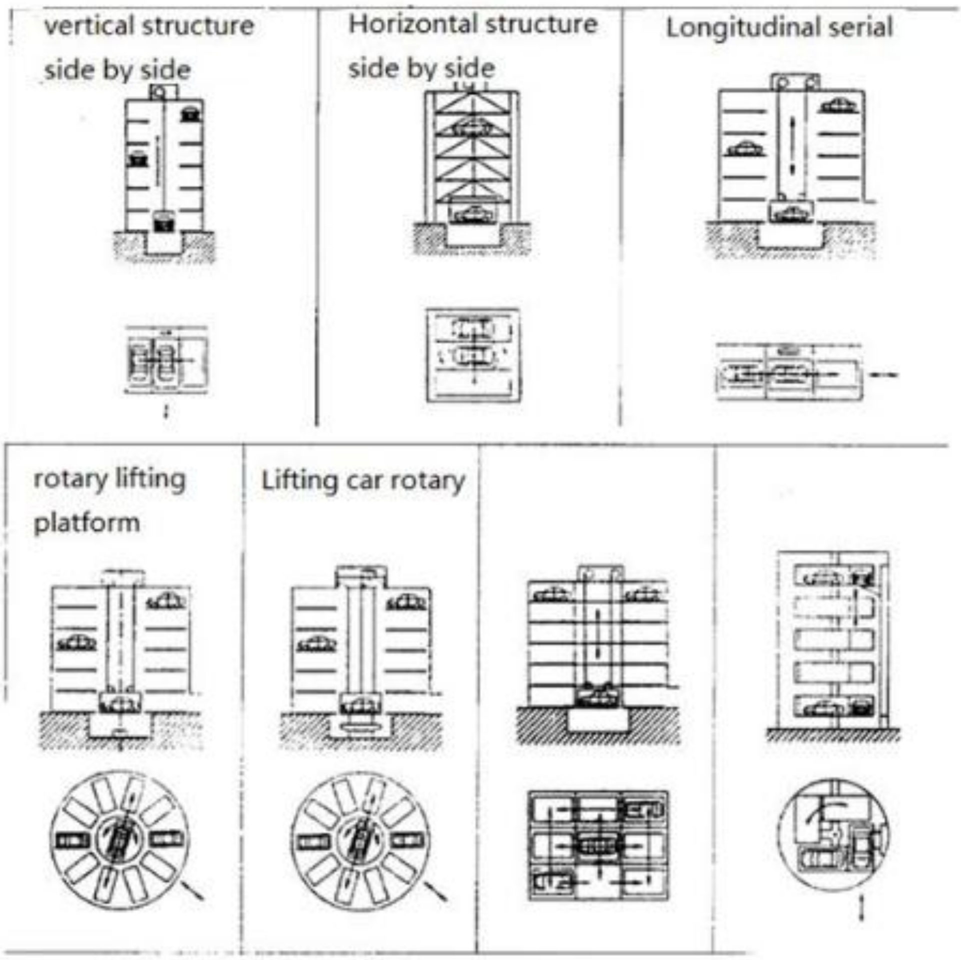

Figure 8

- Simplicity up-down

  The code is JS

  Use lift and tilt mechanisms to park cars.

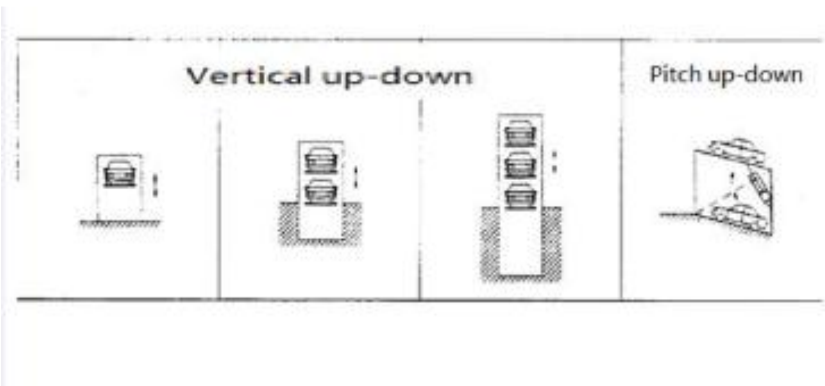

Figure 9

3 Choosing the mode by comparing the MPS

From the introduction of mechanical parking systems, we can see the advantages of each MPS.

3.1 Lifting and transferring

Figure 10(1)

Figure 10(2)

http://imgchina.tradeprince.com/723/20100312/92ad98e2-bebe-455a-be3f-507502d287d7.jpg

In lifting and transferring garage modular design, each module can be designed into two, three, four levels, the five-story, semi-submerged in various forms, such as the number of parking spaces from a few to hundreds. This applies three-dimensional garage on the ground and underground car parks, configuration flexibility and low cost.

- Features of product
  a) Saves space, the configuration flexibility, shorter construction period.
  b) Low prices, firefighting and exterior decoration with a total investment on small foundations.
  c) Uses automatic control, simple structure, safe and reliable.

d) Access to quick, short waiting times.

e) Running a smooth, low noise.

f) Applies to commercial, offices, and residential quarters supporting the use of car parks.

- Cost about 400 000€ (4 floors like figure 10)[2]

3.2 Roadway Stacker

Figure 11

http://cn.sm160.com/Img/Product/00/00/32/70/327014.jpg

[2]http://www.projectbidding.cn/zaobiao/gonggao/20091010/2002540883.html

Aisle stacking garage is used as a stacking machine tool to access vehicles, so the stacker requirements high technology, single stacker need higher costs, so aisle stacking applied to the parking garage needs more customers.

This garage has very high degree of automation, totally enclosed construction, and it is very safe.

- Cost about 700,000-1,000,000€[3]

3.3 Vertical up-down

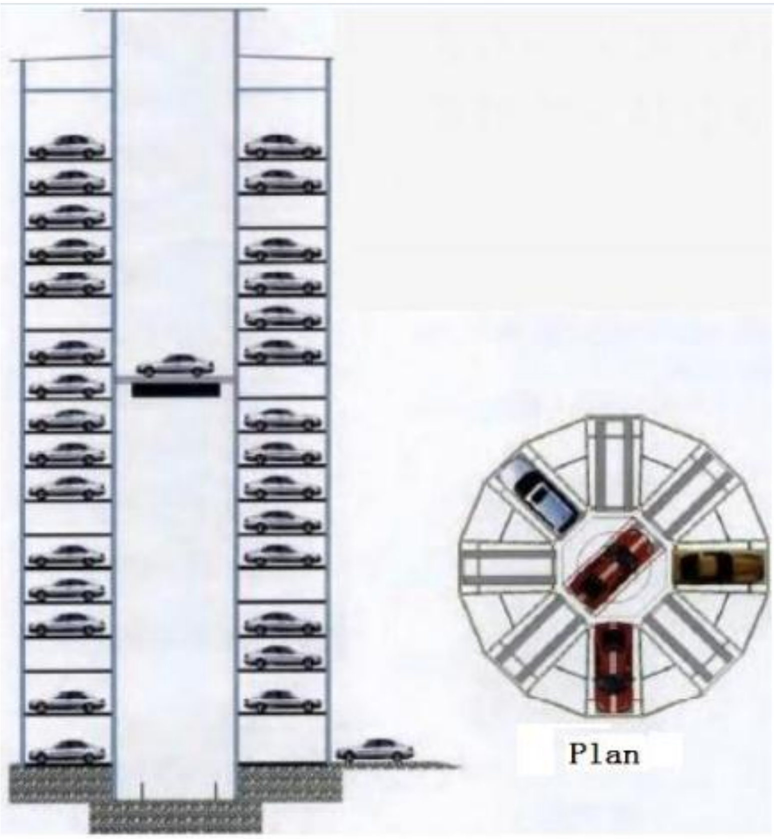

Figure 12

http://www.szsdxf.com/upload/08_01.jpg

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[3]http://www.sm160.com/Buyer/OfferDetail/000-0730-424.html

Vertical up-down garage is similar to the elevator. Both sides of the elevator have parking units. The ground normally needs a vehicle rotary table, so the car does not need to be turned round by the driver. This kind of garage always needs very high height (dozens of meters), high requirement of equipment, so the cost is very high, but it takes the smallest area.

- Cost: more than 1,000,000€[4]

[4]http://www.daynews.com.cn/sxjjrb/151543.html

3.4 Vertical Continue

Figure 13

http://www.user0.jqw.com/2010/11/10/311422/product/b20101111707514942.jpg

- Features of product:
  a) Small area, 6-10 vehicles can park in 2 parking units.
  b) Low cost.
  c) Short period to build.

d) Uses automatic control, safe and reliable operation.

- Cost about 500,000€ [5]

3.5 Simplicity up-down

Figure 14

http://hi.tz1288.com/infopic/20100715/87591x101830.jpg

This is the simplest garage, very easy to build, and the cost of it is the cheapest. In this case, a parking unit always can park 1 or 3 cars. It is suitable for a private garage.

- Cost about 5 000€

[5]http://detail.cn.china.cn/provide/detail,1309082710.html

From this contradistinction, the simplicity up-down garage is chosen for the project. A parking shaft move is designed by storage/retrieve machine.

4 Structure design for parking shaft

4.1 Basic dimensions

Garage

Width (side-to-side dimension)	3.5 m
Length	6 m
Height	4 m

Vehicle

STRUCTURE / SIZE / KINDS	Size (m)		
	Length	Width	Height
Minivan	3.50	1.60	1.80
Passenger car	4.80	1.80	2.00
Light bus	7.00	2.10	2.60
Medium bus	9.00	2.50	3.20(4.00)
Large bus	12.00	2.50	3.20
Articulated bus	18.00	2.50	3.20
Heavy truck	10.00	2.50	4.00
Articulated truck	16.50	2.50	4.00

Figure 15

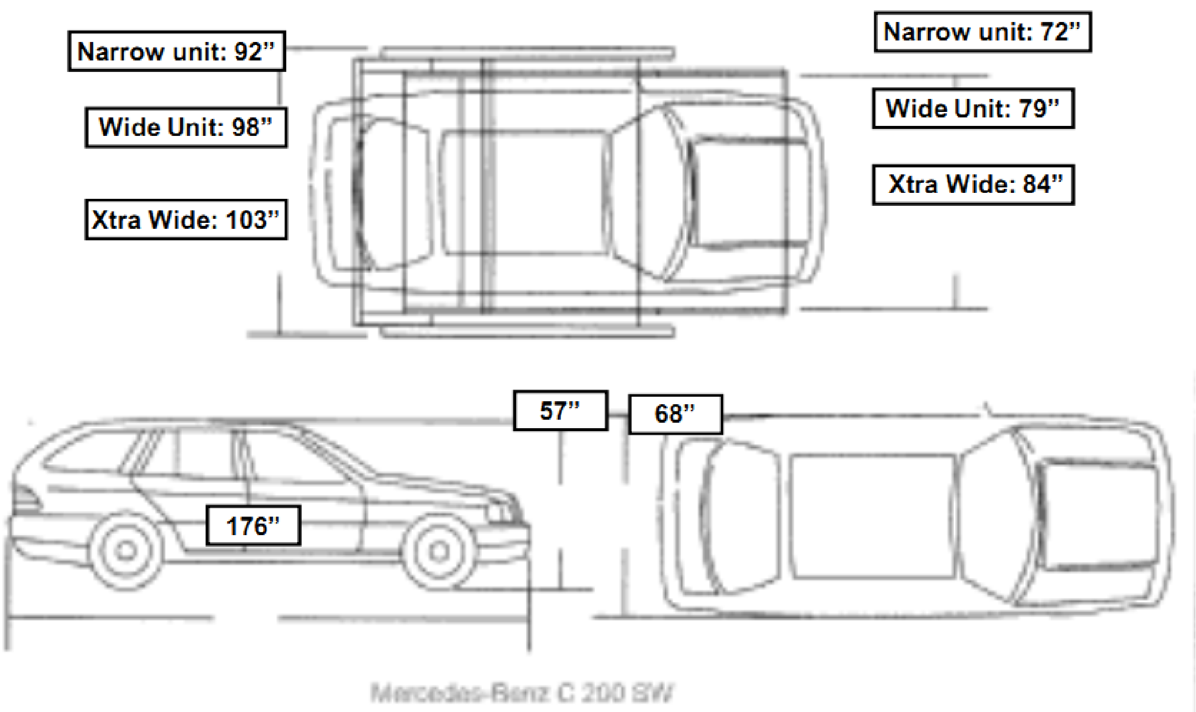


Figure 16

Benz C 200 SW

http://www.hardingsteel.com/downloads.shtml

[Parking Lifts by Harding steel]

92" = 3.1 m

98" = 3.3 m

103" = 3.4 m

176" = 5.9 m

57" = 1.9 m

68" = 2.3 m

4.2 Choosing the type of the structure

At first, 3 different structures for the parking shaft are made.

Case1:

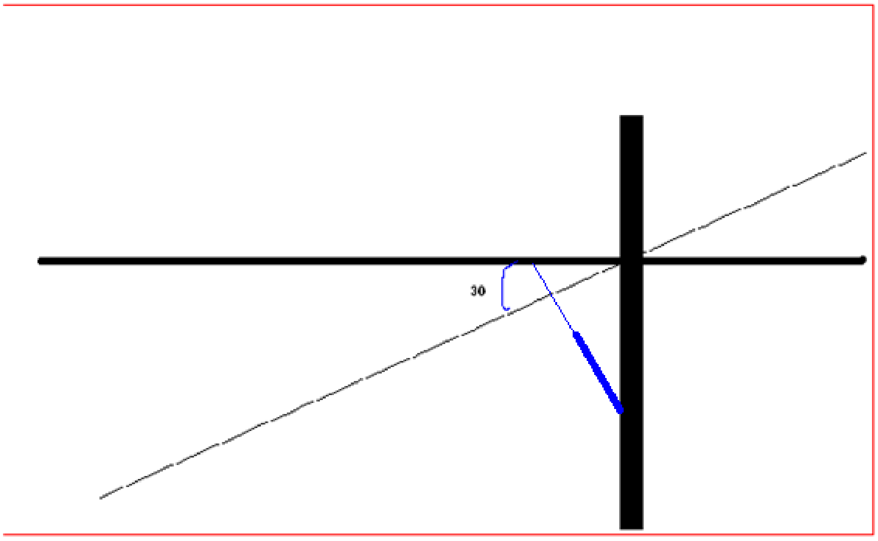


Figure 17

In this structure, the whole steel board will move by 30°, it will make some danger for the car which is parked on the first floor.

Case 2:

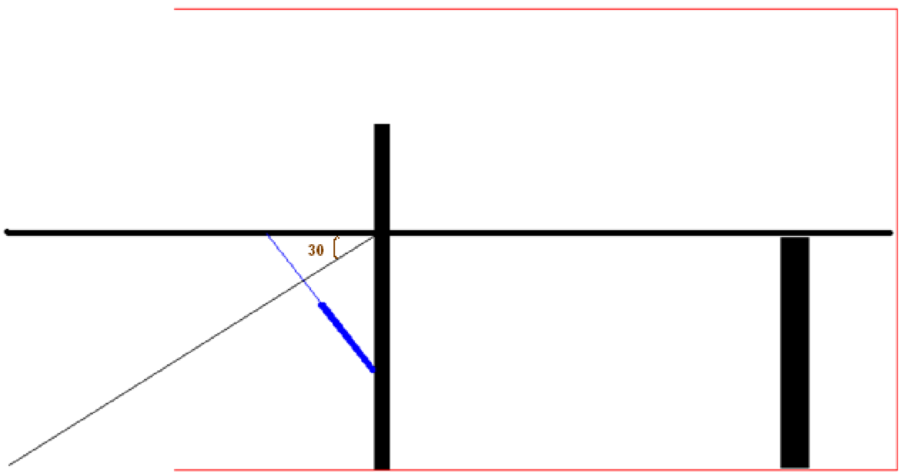


Figure 18

In this structure the length of the moving steel board will be too long, it will make danger for the people and cars which are outside the garage and the door cannot close.

Case 3:

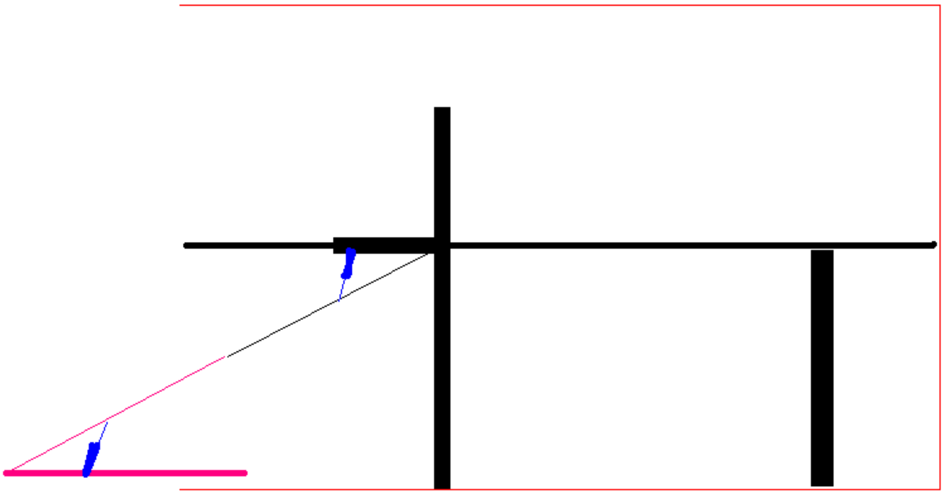


Figure 19

In this structure the move steel board is divided into 2 parts. So we can make sure the shaft will not make any danger for the cars and people inside or outside the garage.

4.3 Composes

Based on the structure of the garage, the shaft is designed like this.

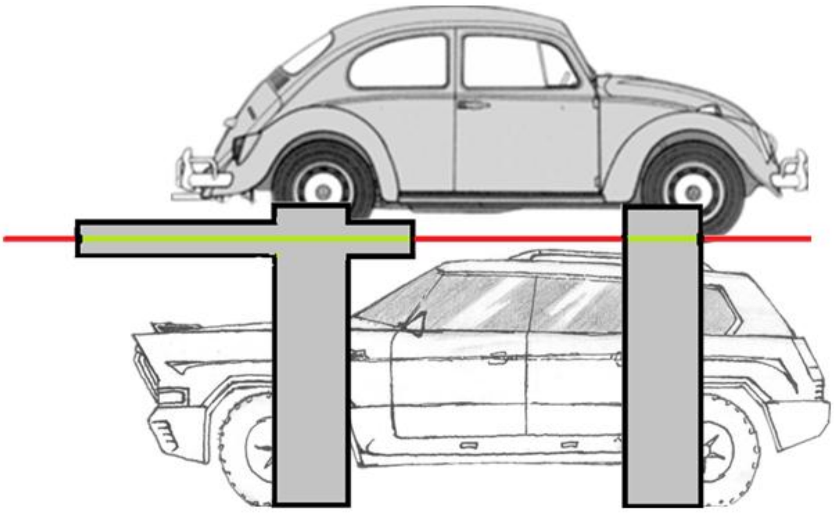


Figure 20

Accommodates the most popular SUVs and minivans.

The parking shaft consists of four upright posts, one platform and hydraulic lifting cylinders.

Four upright posts give four supporting points to the platform and makes the platform safer.

The platform is divided into 2 parts. Four hydraulic lifting cylinders are used to rise and drop the steel platform, 2 for the upper one and 2 for the lower one. It has a self-standing, self-supporting unit. The cylinders have a common hydraulic power pack.

Vehicle

STRUCTURE / SIZE / KINDS	Size (m)		
	Length	Width	Height
Minivan	3.50	1.60	1.80
Passenger car	4.80	1.80	2.00

Figure 21

From the vehicle table, the first data for minivans is chosen.

Length = 3.5 m

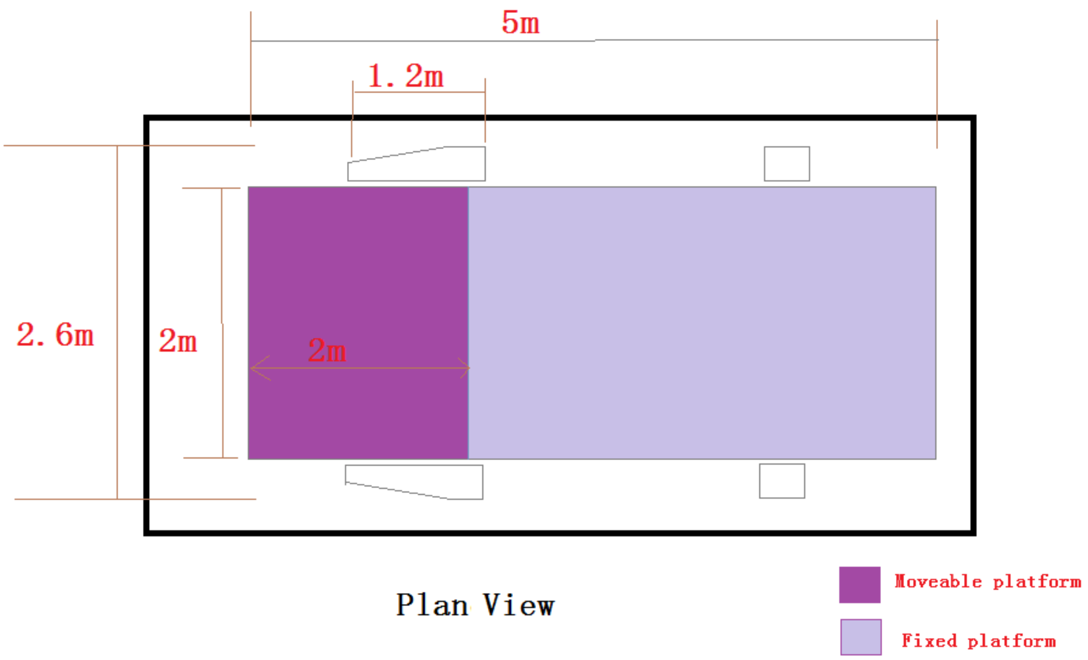
Wide = 1.6 m

Height = 1.8 m

To prevent the vehicle touching the upright posts, the distance between the vehicle and the upright post should be 8 cm, 10 cm is chosen.

For the platform

Length = 5 m (movable = 2 m, fixed part = 3 m)



Plan View

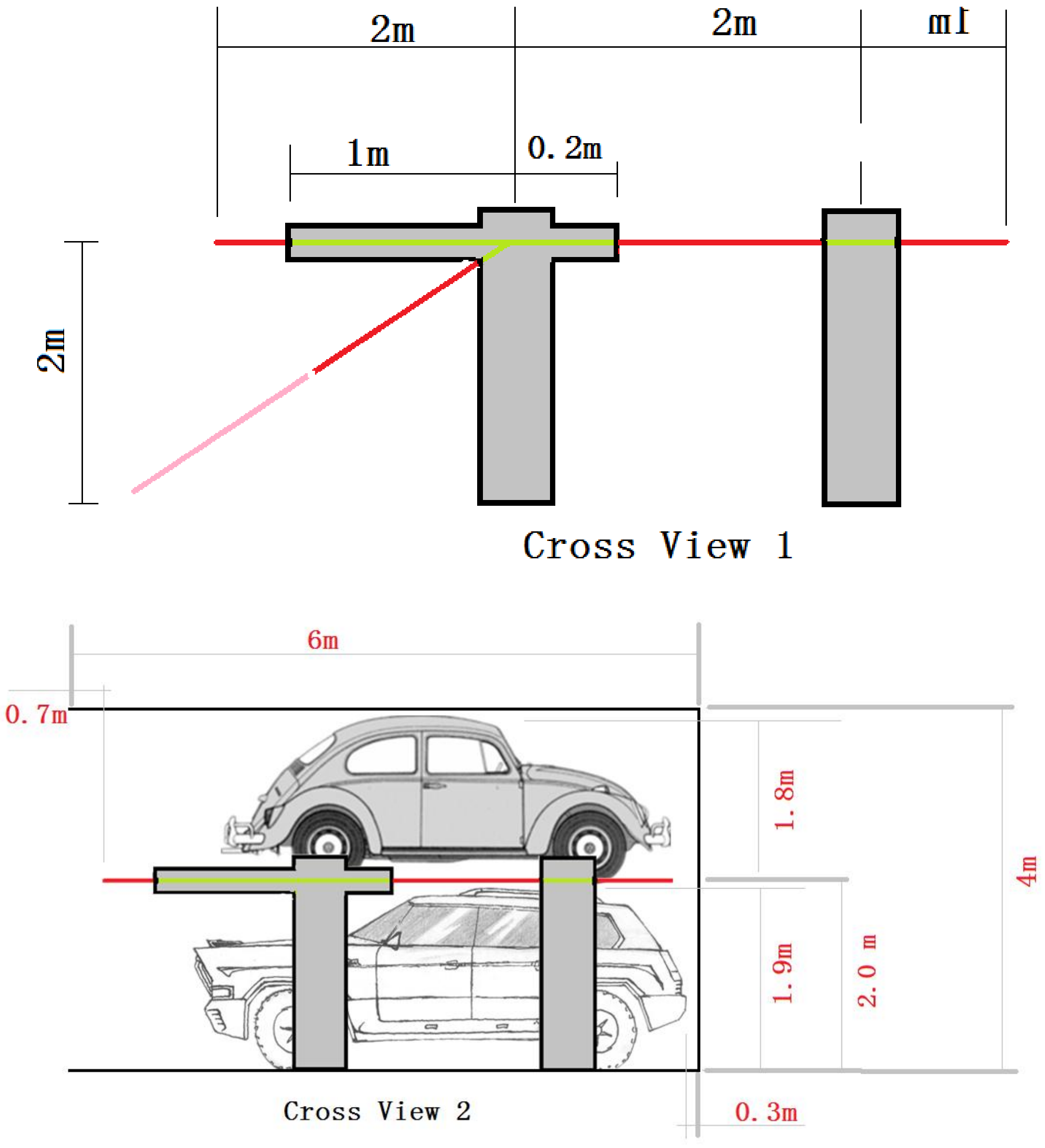


Figure 22

4.4 Working process

This parking shaft can store two cars. The platform is for minivans.

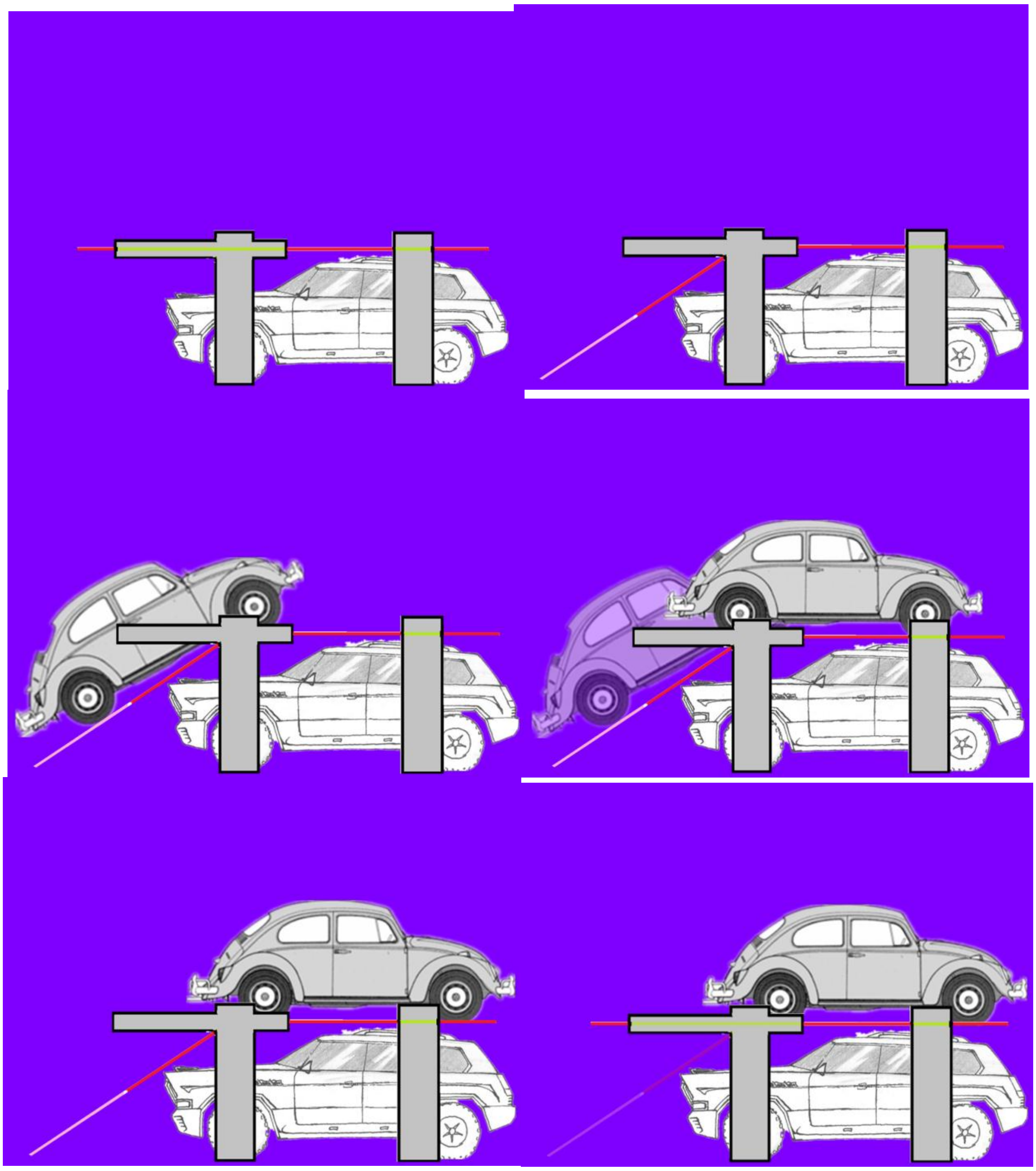


Figure 23 (1)

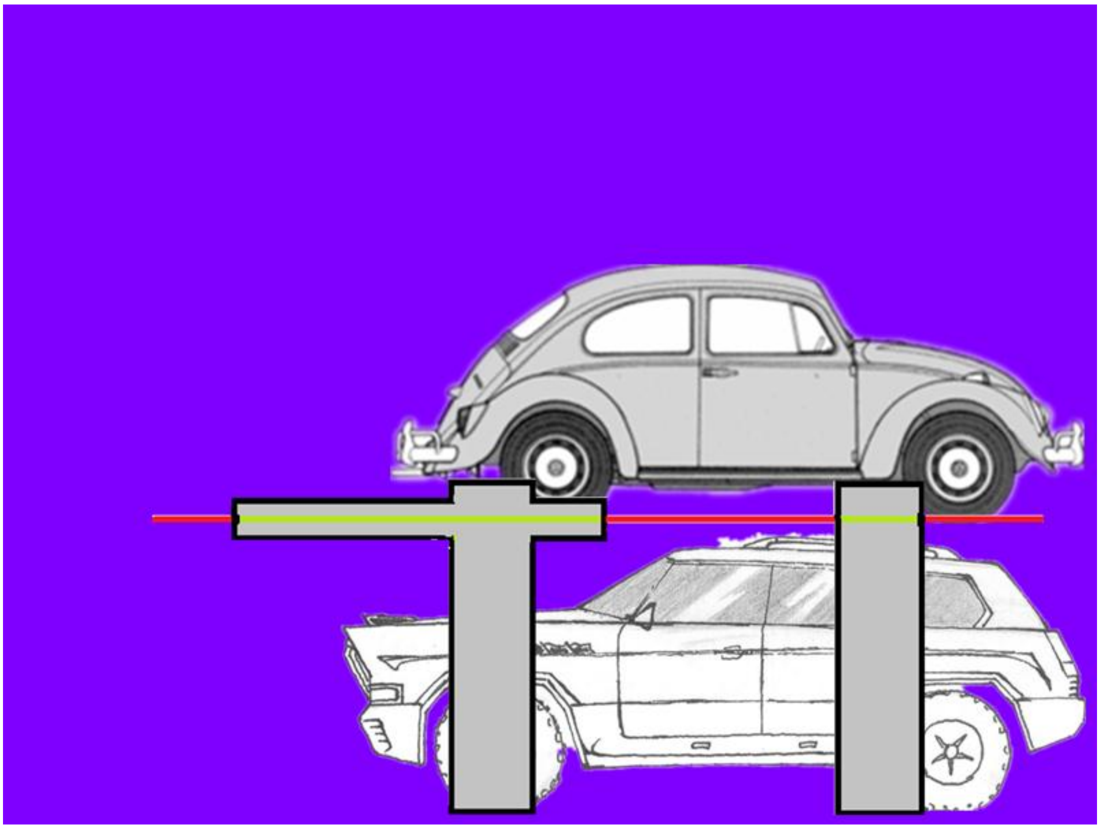


Figure 23(2)

Whatever which car move in or out at first, there is no problem in the program. And there is also no problem to open or close the door of the garage.

The car parked in the first floor can go in or out without any problem, when the 2 movable platforms close, both are kept on a horizontal line.

When the car, which will park in the second floor, wants to move in or out, the whole movable platform will be raised up by the cylinders. They make 30 degrees with the ground as a slope at first, after the car moves in or out in the second floor, the movable platform will get back to the normal place.

When the cars have parked in the right place, the door can be closed normally.

5 Hydraulic work part design

5.1 Basic parameters

Hydraulic type (Boom Type)

The values for the design work

Name	**Work**	**Type of lift**	**External load**	**Lifting time**	**Min. height**	**Max. Height**
He Linyuan, Chen Han	**No.**	Boom Type	**[kg]**	**[s]**	**[m]**	**[m]**
	4		1 700	30		1

Figure 24

This picture shows the information of shaft in hydraulic files.

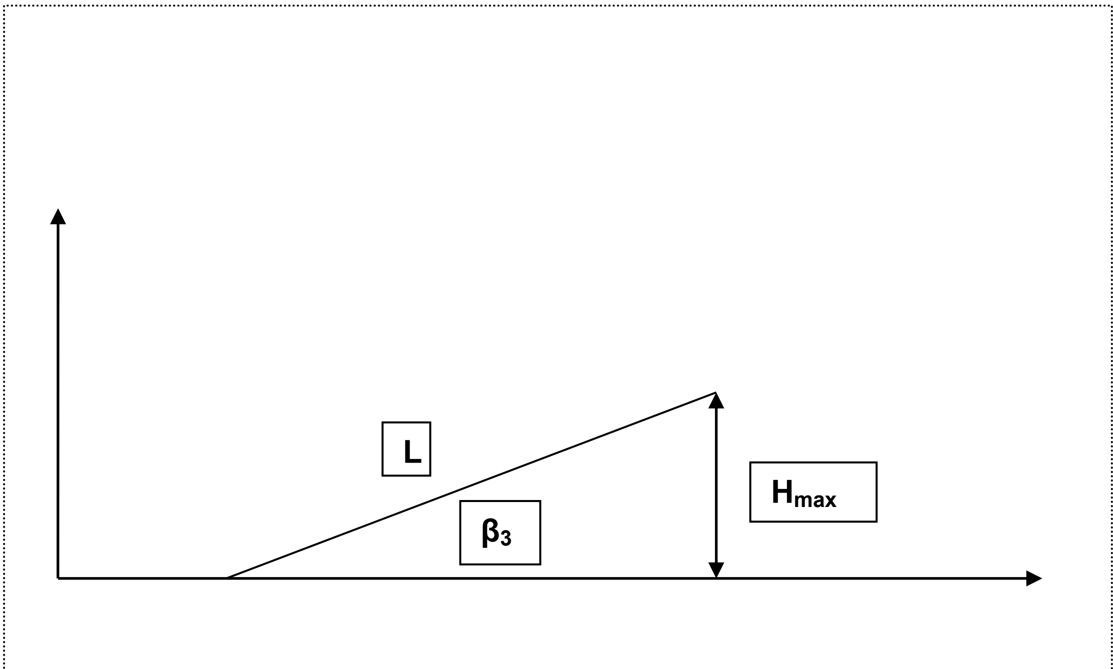


Figure 25(1)

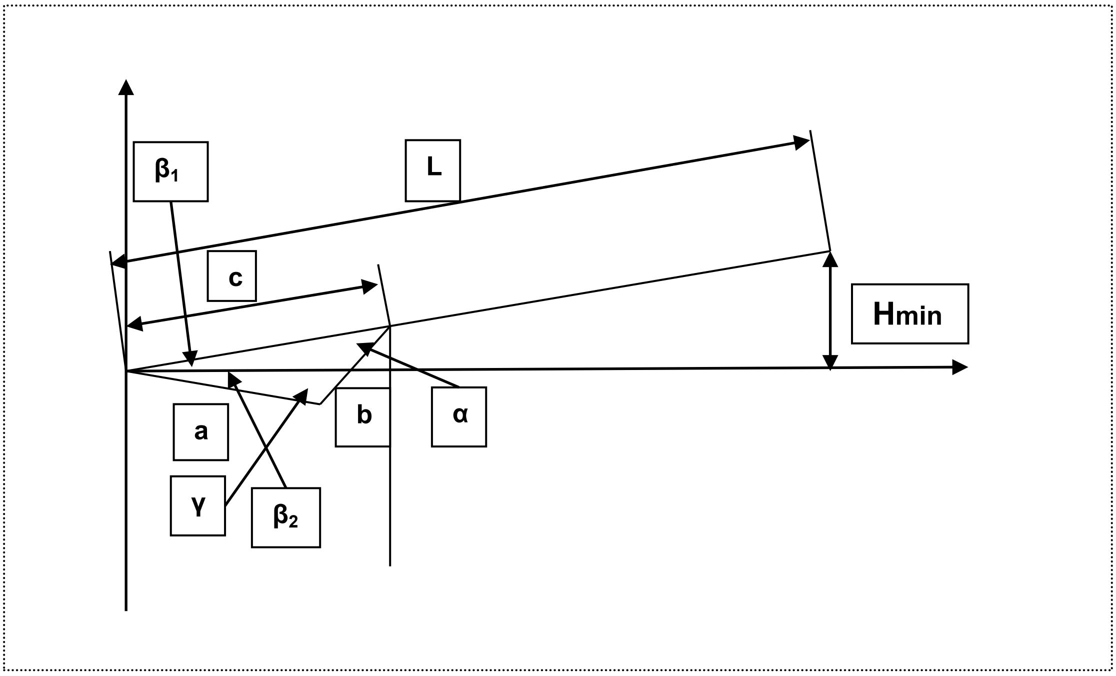
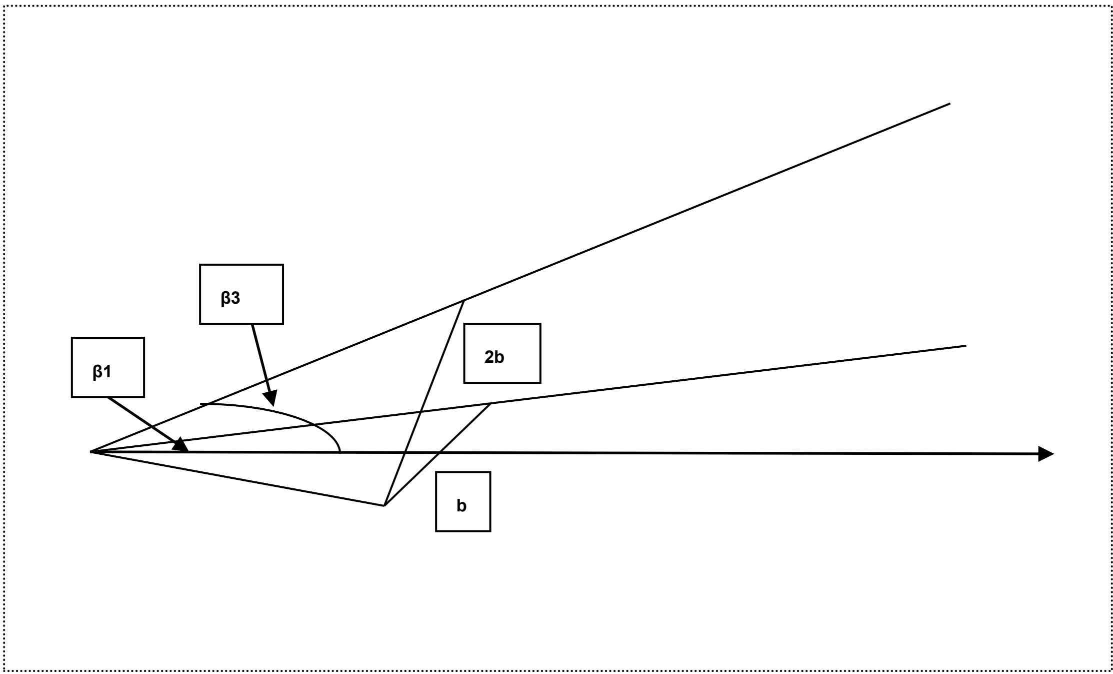


Figure 25(2)

The measurements of the lift elements

- Length of the cylinder [b] =150mm
- Maximum lifting angle =30^{o}
- Maximum lifting height [$H_{max.}$] = 1 000 mm
- Length of the beam [L] =2 000mm
- Minimum lifting height [$H_{min.}$]≤

5.2 Finding the situation for cylinder



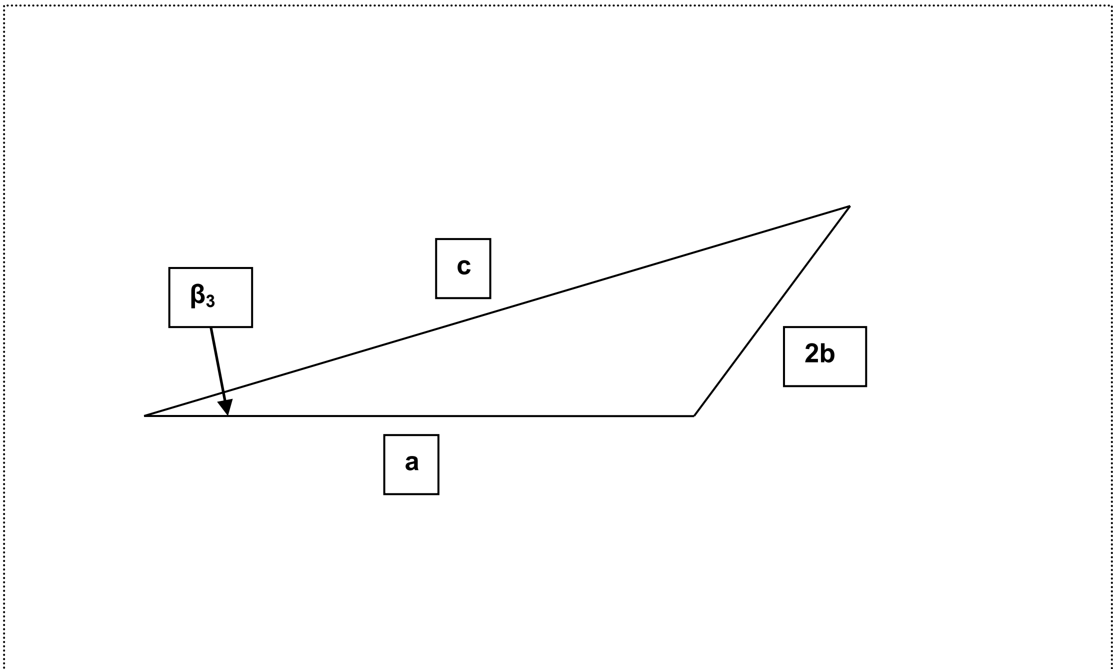


Figure 26

$\beta_3 = 30^o$

a = 450 mm

b=150 mm; 2b =300 mm

LAW OF COSINES

$c^2 = a^2 + b^2 – 2abCos\ \gamma$ (1)

From this formula, we can get:

$Cos\ \gamma = (a^2 + b^2 – c^2)/ (2ab)$

$Cos\ 30^o = (c^2 + 450^2 – 300^2) / (2 \times 450 \times c)$

$\rightarrow c = 588.143$ mm

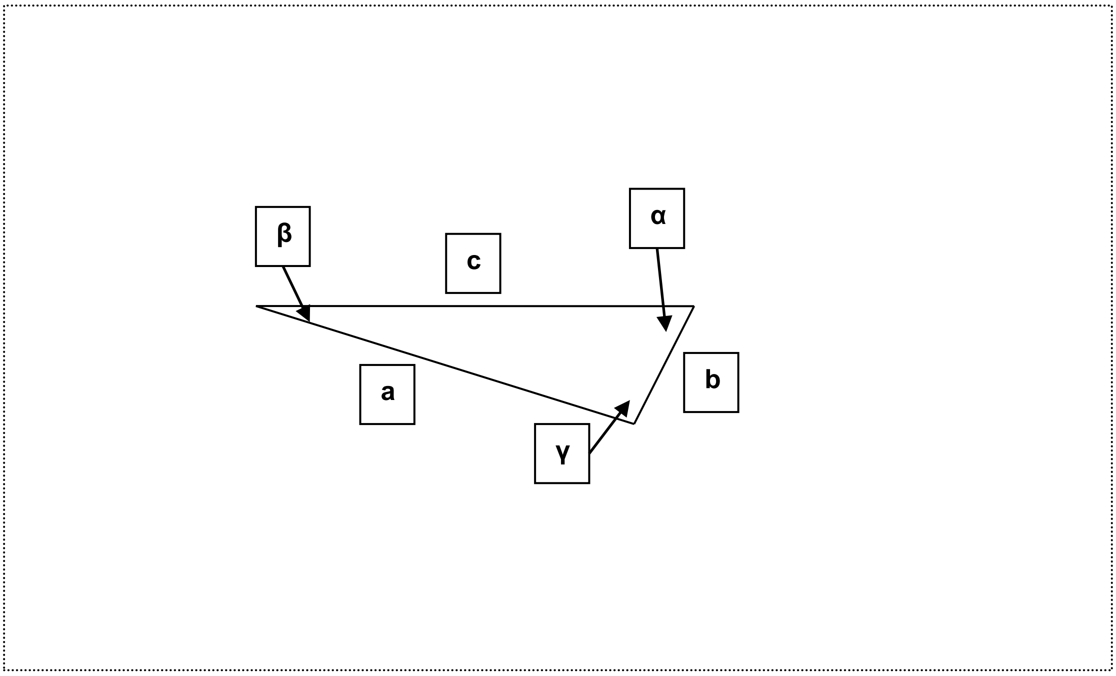


Figure 27

LAW OF COSINES

$c^2 = a^2 + b^2 – 2abCos\ \gamma$ (2)

From this formula, we can get:

$Cos\ \gamma = (a^2 + b^2 – c^2)/ (2ab)$

$Cos\ \beta = (588.143^2 + 450^2 -150^2) / (2 \times 588.143 \times 450)$

$\rightarrow \beta = 6.51^o$

$\beta = \beta_1 + \beta_2$

Assuming angle $\beta_2 = 3^o$

$\rightarrow \beta_1 = 3.51^o$

FORMULARS FOR RIGHT TRIANGLES

$Sin\ A = a / c$ = (opposite / hypotenuse) (3)

From this formula, we can get:

a = c x Sin A

H_{min} = 2 000 x Sin 3.51 = 122.445mm

The cars normally can go through with this height.

LAW OF COSINES

$c^2 = a^2 + b^2 - 2abCos\ \gamma$ (4)

From this formula, we can get:

$Cos\ \gamma = (a^2 + b^2 - c^2) / (2ab)$

$Cos\ \alpha = (588.143^2 + 150^2 - 450^2) / (2 \times 588.143 \times 150)$

$\rightarrow \alpha = 19.90^o$

5.3 Resolving cylinder force

The formula for the weight of the steel board:

http://zhidao.baidu.com/question/213729422.html

W = 7.85 x T x A

*W = Weight [kg]

*T=Thickness [mm]

*A=Area [m^2]

$\rightarrow W_{max.}$ = 7.85 x 10 x 6 = 471 kg

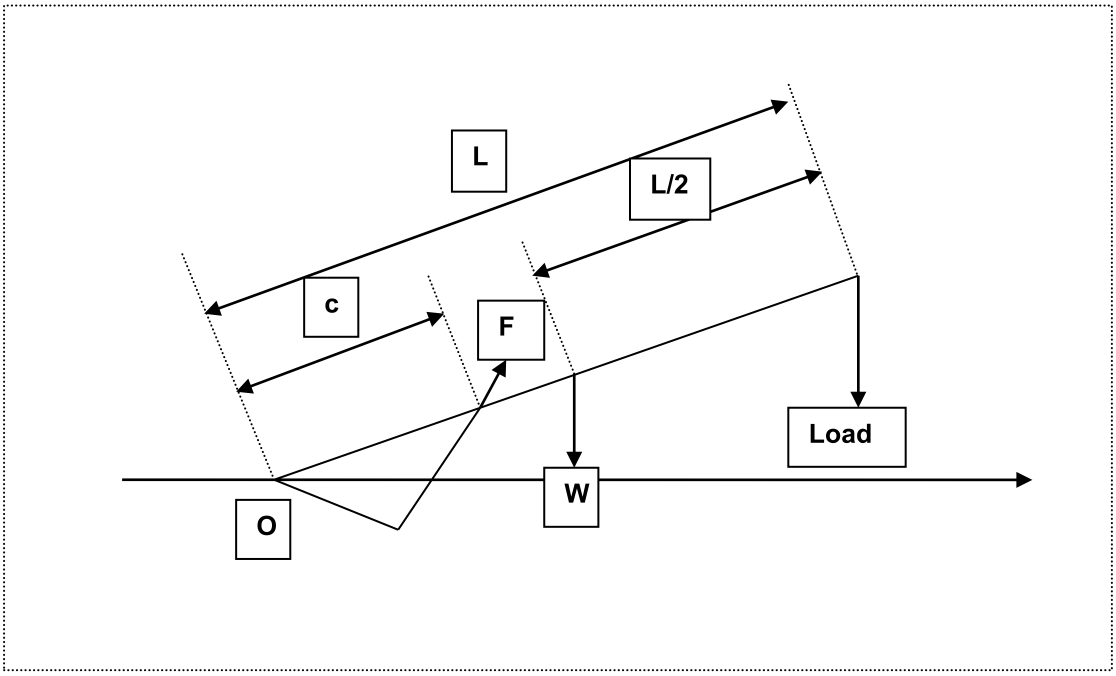


Figure 28

M = F x d （5）

FORMULARS FOR RIGHT TRIANGLES

Sin A = a / c = (opposite / hypotenuse) (6)

From this formula, we can get:

a = c x Sin A

Cos A = b / c = (adjacent/ hypotenuse) (7)

From this formula, we can get:

b = c x Cos A

ΣO = 0

→ 2 x F_c x Sin 19.90 x 588.143 – 471 x 9.81 x Cos 3.51 x 1 000 – 1 700 x 9.81 x Cos 3.51 x 2 000 = 0

→ F_c =94.67 KN = 9 467 daN

5.4 Diameter of the piston and the rod of the cylinder

Pressure (P) used is 250 bar

The force produced by a double acting hydraulic piston on the rod side can be expressed as

$F_1 = \pi / 4 (d_2^2 - d_1^2) P_1$ (8)

where

F_1 = *rod pull force (lb)*

d_1 = *rod diameter (inches)*

d_2 = *piston diameter (inches)*

P_1 = *pressure in the cylinder (rod side)* (lf_f/in^2)

The force produced opposite the rod can be expressed as

$F_2 = \pi / 4\ d_2^2\ P_2$ (9)

where

F_2 = *rod push force (lb)*

P_2 = *pressure in the cylinder (opposite rod)* (lf_f/in^2)

$d_{piston} = \sqrt{(4x F / (P x \pi))} = \sqrt{(4 x 94.67 x 1\,000/(250 x 10^5 x \pi))}$

$= 0.0694$ m = 69.4 mm

$d_{rod} = 69.4/\sqrt{2} = 49.1$ mm

5.5 Buckling Calculation

Factor of safety (V)=3

Table 4: Euler's loading cases

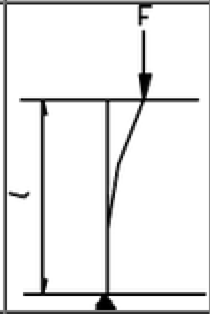
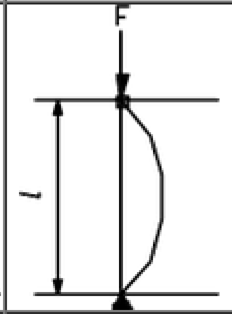
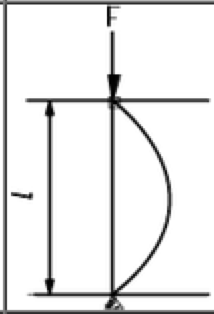
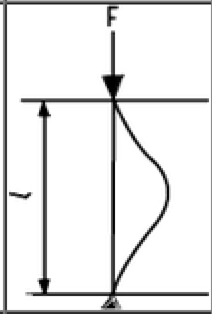
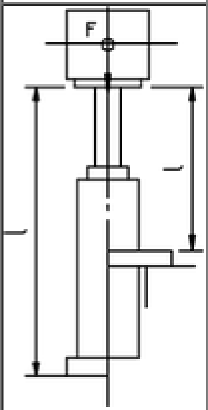
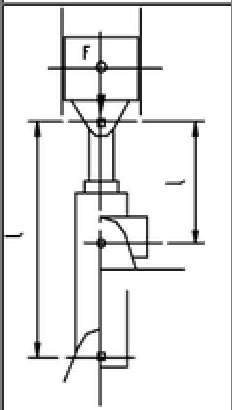
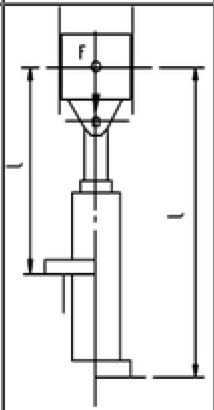
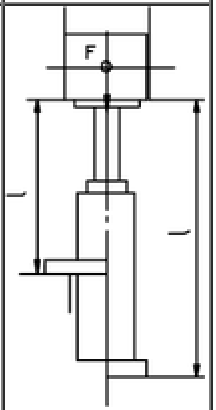
Euler's loading case	Case 1 One end free, one end rigidly connected.	Case 2 (Basis case) Two ends pivoted.	Case 3 One end pivoted, one end rigidly connected.	Case 4 Two ends rigidly connected.
Illustration				
Free buckling length	$S_k = 2 \cdot l$	$S_k = l$	$S_k = l \cdot \sqrt{1/2}$	$S_k = l/2$
Installation position for cylinder				
Note	Mounting type FA,FB,LA,LB, MF3, ME7,MF4,MB8,MS2	Mounting type TA,TC,CA,CB,MP3,MP1, MT4	Mounting type FA,FB,LA,LB,MF3,ME7, MF4,MB8,MS2 Load must be carefully guided, or else possible bracing.	Mounting type FA,FB,LA,LB,MF3,ME7, MF4,MB8,MS2 Not suitable, as bracing is to be expected.

Figure 29

http://www.actuatec.com/htm/technology05.htm

We choose the case 2 : $S_k = l$

This is the length of the cylinder used = 150 mm = 15 cm

$d_{rod} = \sqrt[4]{(F_c \times S_k \times V / (\pi^2 \times E \times 0.0491))} = \sqrt[4]{(9\,467 daN \times 15^2 \times 3/(\pi^2 \times 2.1 \cdot 10^6 \times 0.0491))} = 1.58$ cm = 15.8 mm

*S_k = free buckling length in mm

*E = modulus of elasticity (2.1 x 10 * for steel) in N/mm ㎟

Reading from the buckling table, the diameter chosen for the rod is 20 mm

For the piston is (√2)x 20= 28.3 mm

Reading from the buckling table, the diameter chosen for the piston is 28 mm

YHG 型液压缸

油口系列　　表 2　mm

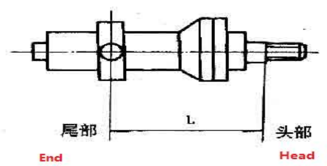
Diameter of cyclinder	40	50	63	80	90	100	110	125	
Diameter of piston rod	10	10	15	15	15	20	20	20	
Thread	M18 × 1.5	M18 × 1.5	M27 × 2	M27 × 2	M27 × 2	M33 × 2	M33 × 2	M33 × 2	
Diameter of cyclinder	140	150	160	180	200	220	250	280	320
Diameter of piston rod 径	25	25	25	32	32	32	40	40	40
Thread	M42 × 2	M42 × 2	M42 × 2	M48 × 2	M48 × 2	M48 × 2			

最大行程　Stroke　　表 3　mm

Diameter of cyclinder	D	40		50		63		80		90		100		110		125	
Diameter of piston rod	d	22	28	28	36	36	45	45	56	50	63	56	70	63	80	70	90
最大行程 Max. Stroke	s_1	540	960	730	1360	990	1640	1240	1990	1370	2080	1550	2320	1700	2660	1850	2980
	s_2	115	260	180	390	260	490	330	600	370	620	420	700	470	800	520	920
	s_3	190	420	300	620	430	750	550	920	600	960	680	1070	760	1240	830	1390
	s_4	90	170	130	240	180	300	230	360	250	380	280	420	310	480	340	540
	s_5	140	290	210	430	290	520	370	640	450	660	470	740	520	860	570	970
	s_6	350	650	480	920	560	1120	830	1360	910	1420	1040	1580	1140	1830	1250	2050

140		150		160		180		200		220		250		280		320	
80	100	85	105	90	110	100	125	110	140	125	160	140	180	160	200	280	220
2150	3130	2280	3160	2330	3210	2560	3610	2780	4120	3240	4660	3590	4860	3810	5210	4600	5800
620	970	660	990	670	1000	740	1110	800	1270	940	1440	1040	1490	1100	1590	1350	1780
970	1460	1030	1500	1050	1510	1160	1680	1250	1920	1470	2180	1630	2270	1720	2420	2100	2700
390	560	410	580	420	590	470	650	510	740	590	840	650	880	690	940	840	1050
670	1020	720	1040	730	1050	800	1170	870	1340	1020	1520	1130	1580	1190	1690	1460	1880
1460	2150	1550	2200	1580	2220	1740	2480	1880	2830	2210	3210	2440	3340	2580	3570	3130	3980

(注)1. 此油口尺寸根据活塞油口最高流速 V 取 5m/sec 而定。
2. 缸径 D≧250 油口采用对开式法兰结构。



行程系列　　表 4　mm

行　程　S Stroke	25	50	80	100	125	160	200	250	320	400	500
	630	800	1000	1250	1600	2000	2500	3150	4000	5000	

注：表中数字是按稳定性计算的最大行程，超出此表范围均为非标准需用户自行保证稳定性。

MHMPG010/98　　3

Figure 30

http://wenku.baidu.com/view/b89d4171f242336c1eb95eb2.html

This figure shows the hydraulics data of the tank.

5.6 Hydraulic motor

Axial motor

The specification of motor: PM-O power motor

Figure 31

Hydraulic motor + Speed reducer

- Space is saved due to compact design.
- Cost is reduced due to integrated design.
- The output torque is quadrupled due to a built-in speed reducer (1/4).

Features

- Low-speed
- High-torque
- High-performance
- Power-saving power motor

Applications

Winch and hoist for vehicles, fishing machinery, construction machinery and various industrial machines

Specifications

- Release pressure 1.0MPa
- Max. flow rate 70 L/min

- Permissible back pressure 7.0 MPa
- Speed reduction ratio 1/4
- Load in radial direction 9 800 N
- Load in thrust direction 8 670 N

http://www.nopgroup.com/english/products/yua/c.html

Model	PM-070	PM-100	PM-120	PM-160	PM-170	PM-190	PM-240	PM-280	PM-310	PM-380	PM-410
Theoretical displacement (cm^3/rev)	206.0	285.6	394.0	473.6	653.6	754.0	942.0	113.0	1227.6	1505.6	1639.6
Max. revolution (min^{-1})	245	230	180	145	110	95	75	60	55	50	45
Rated torque (N・m)	440	620	840	1000	1000	1000	1000	1000	1000	1000	1000
Max. torque (N・m)	536	732	1024	1200	1300	1300	1300	1300	1300	1300	1300
Rated Pressure (MPa)	15.5	15.5	15.5	15.5	10.5	7.5	7.5	6.7	6.6	5.4	5.0
Max. pressure (MPa)	19.0	19.0	19.0	18.5	17.0	12.0	12.0	8.7	8.6	7.0	6.5

Note: When a rectangular flange for installation is selected, 3 kg must be added to the above weight.

Figure 32

Mechanical and Volumetric efficiency calculations

-Mechanical efficiency (η_m) = Torque/ (D*∘P) % = 1 024*100/ (394*15.5) % = 16.77%

-volumetric efficiency calculation (η_v)

η_v = D*∘P*η_m/ (20*π) % = 394*15.5*0.1677*100/ (20*π) = 1 629.98%

5.7 Flow rate calculation

Q = Flow rate

N = Speed (revolution/min.)

η_v= Volumetric efficiency

D = Displacement

$Q = D*n/ (1\,000*\eta_v)$ litres/min

Q = 394*180/ (1 000*16.2998) = 4.35 litres/min.

Tank size:

The accepted rule for a tank = (3to5)*Q

Therefore the size of the tank = 5*4.35 = 21.75 litres

Hydraulic fluid temperature (Temperatures/Housing cooling)

Excessive system temperature reduces the life of the shaft seal and can lower the oil viscosity below the recommended level. A system temperature of 60 ºC and a drain flow temperature of 90 ºC must not be exceeded. Cooling/flushing of the motor housing can be needed to keep the drain flow temperature at an acceptable level. **The range of fluid temperature is between -20 ºC and 80 ºC**

6 Cost estimation

Number	Description	Amount in Euros (€)
1	Electrical connection 0V	50€
1	Electrical connection 24V	50€
1	Pump unit	500€
4	2-way flow control valve	160€*4 = 640€
4	4/n way valve	300€*4 = 1 200€
4	Check valve	60€*4 = 240€
4	Filter	350€*4 = 1 400€
2	Flow divider valve	150€*2 = 300€
4	Double acting cylinder	450€*4 = 1 800€

	with shock adsorber at stroke end	
4	Pushbutton (make)	60€*4 = 240€
4	Valve solenoid	120€*4 = 480€
4	Check valve with pilot control	350€*4 = 1 400€
8	Hose with quick-action coupling	150€*8 = 1 200€
4	Member of bars , pins , bolts and nuts	450€*4 = 1 800€
	Miscellaneous expenses	2 000€
Total		**13 300€**

6.1 References

1. http://www.ecalc.com/math-help/worksheet/trigonometry-identities/
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7 Conclusions

The above discussion has evaluated the parking shaft could save the space successfully and cost lower than other equipment. Nowadays in China, save space is more and more important. The idea of the design is suitable for the Chinese socials situation. The shaft is suitable for most families and it can be concluded that the new product developed has a big opportunity to conquer the marketplace.

At this half year for the thesis, we get more experience for the how to use the mechanical technology in real life, especially in hydraulic design.