THESCIENCE POST

The Science Post| www.thesciencepostjournal.com

Development and Optimization of an Automated Guided Vehicle (AGV) Forklift System

Iftekhar Ahamed Rafee[1*]

[1]Department of Mechanical Engineering, Beibu Gulf University, China
Email: ahmedrafeeiftekhar@gmail.com

Abstract

The fork type AGV is a new type of unmanned forklift. Its safety and efficiency are higher than that of the ordinary forklift. At present, the AGV forklift is in the semi-mature stage. In order to cope with various working conditions, the various technologies of AGV need to be improved. Disadvantages of AGVs include Potentially High Initial Investment, Maintenance Costs, Not Suitable for Non-Repetitive Tasks, Decreased Flexibility of Operations. Most disadvantages of adopting an AGV solution are short-term, such as the initial cost of investment and ensuring your facility can be adapted to leverage AGV's. The lifetime of AGV solution is typically 15-20 years, yet, it can be extended through moderation packages and regular maintenance. This paper discusses the design of AGV ontology.

Keywords

AGV, Working Device, Balanced Weight.

1. Introduction

With rapid technological advancements and the rise of e-commerce, efficient cargo handling has become essential, leading to the evolution of forklifts. Traditional manual forklifts can no longer meet increasing logistics demands, making Automated Guided Vehicle (AGV) forklifts the future of industrial transportation. AGV forklifts integrate automation, wireless communication, and PLC control systems to ensure seamless warehouse operations. They communicate with a central system in real time, receiving commands and reporting operational status, enabling precise tracking, positioning, and scheduling.

To meet industry needs, AGV forklift manufacturers focus on intelligence, flexibility, and standardization. Future designs will incorporate modularization and automation to enhance efficiency, improve adaptability, and ensure user-friendly operation [3]. These forklifts must balance affordability with functionality, making them practical for widespread industrial use. Additionally, AGV forklifts are expected to increase operational speed, boost accuracy, and adopt artificial intelligence to learn, simulate human behavior, and recognize objects [5].

As AGV forklifts continue advancing, they will expand their market presence, revolutionizing logistics and warehouse management. Their automation capabilities will drive efficiency, reduce labor costs, and improve safety. With a strong market foundation, AGV forklifts will play a crucial role in the future of intelligent, automated material handling, creating significant value across industries [7].

2. Methods & Forklift Body Design Plan

The frame is the main component of the mechanical body of the AGV forklift. The mechanism design and reasonable process of the frame are directly related to the quality of the AGV forklift and the feasibility of operation. The frame is composed of: lifting device, control box, balance rudder and so on.

As long as this design is the external design of the AGV forklift, the outside of the control box is a hollow frame. In the AGV forklift, it mainly serves to cover up and protect the internal control system (PLC system, drive system, etc.), and the shape and material strength. There is no requirement for rigidity. This design does not include the design of the control box, but mainly the design of the lifting system and the balance rudder. Improving existing Automated Guided Vehicle (AGV) forklift trucks can involve various aspects, ranging from optimizing performance and efficiency to enhancing safety and functionality [1]. Suggestions for improving AGV forklift trucks include upgrading the navigation system, implementing advanced obstacle detection and avoidance, optimizing path planning algorithms, increasing load capacity and versatility, and integrating IoT capabilities. These improvements can help improve accuracy, reduce the risk of collisions, increase efficiency, and provide safer and more versatile vehicles. AGV forklift trucks can be improved to provide insights into operational performance, maintenance needs, and optimization opportunities. Energy-saving measures such as regenerative braking systems, power management algorithms, or the use of more efficient motors can extend the AGV's operating time between charges and reduce overall energy consumption. Safety features such as proximity sensors, emergency stop buttons, or audible and visual warning systems should be integrated. Remote monitoring and control capabilities should be enabled through a centralized control system or mobile applications. Predictive maintenance should be utilized to prevent unexpected downtime and allow for proactive maintenance scheduling. Continuous employee training is essential to maximize the AGV's performance and address any issues promptly.

Table 1.1 The design technical parameters of the AGV forklift body

Rated lifting capacity Q (kg)	2000
Load center distance C (mm)	500
Lifting height H (mm)	2000
Model structure	front leg balance
way of promotion	Electric (hydraulic and chain)
way of working	fully automatic

2.1. Introduction to Working Device

The working device of the forklift is also called the lifting device (see Figure 1). Its main function is to complete the transportation of goods, directly carry the full weight of the goods, and complete the procedures of picking up, lifting, and stacking. The working device of the forklift is composed of forks, fork frames, slide frames, inner and outer masts, lifting cylinders, chain pulleys and other parts [15].

The forks are installed on the fork frame, and the fork frame is directly connected with the slide frame and installed on the mast together. There are two pairs of pulleys in front of the frame and the mast to reduce friction and guide. The lifting of the goods is mainly carried out by the belt of the fork. The weight of the cargo, the entire weight of the forks, forks and carriages are supported by the lifting chains. One section of the chain is fixed directly on the mast, and the other end is linked to the carriage. The lifting cylinder is vertically installed at the bottom of the mast, and a set of chain wheels is connected with the chain at the upper end of the cylinder push rod. When the forklift is working to lift heavy objects, under the hydraulic pressure of the hydraulic cylinder, the cylinder push rod goes up, the chain and the chain rotate together, the chain at one end of the carriage rises, and the carriage is pulled up to realize the lifting of the goods.

2.2. Lifting Mechanism

The fork is the attachment of the forklift, and the fork is equivalent to the manipulator. For general forklifts, forks are the most basic and commonly used pick-up parts. General forklifts are equipped with two identical forks, which function to balance and lift heavy objects to ensure smooth and safe work. There are many types of forks, such as ordinary forks, cover-type forks, square forks, etc. According to different occasions, different forks are used, and the L- shaped fork of ordinary cargo forks is the most common. The L-shaped fork is divided into two parts, the horizontal section and the vertical section. The two sections of many forklifts are connected together to form a whole [20].
When the forklift picks up the goods, the front end of the horizontal section of the fork is first inserted into the bottom of the goods or the under-frame of the goods. The fork is lifted, the horizontal section is used to carry the goods, and the vertical section is connected to the fork frame to hold the goods. In terms of design, the horizontal section must be horizontal. The front end of the horizontal section has

a slope. Generally, the bottom gradually narrows toward the thickness of the fork tip. It is convenient to enter and exit the bottom of the cargo or the bottom of the cargo chassis. The back of the vertical section has a hook at the top and bottom, which is used to hang on the fork and fix it. The existence of the hook separates the fork frame from the fork, which is convenient for disassembly and replacement, and the distance between the two forks can be adjusted according to different occasions.

The fork is an essential and important load-bearing component of the fork. Therefore, the fork bears a large force, requires a small cross-section and volume, and is light in weight. The material used for the fork is generally made of steel, copper-containing carbon steel, high-silicon copper-containing steel and other materials, and it must also undergo appropriate heat treatment and forging to increase the material toughness and wear resistance of the fork.

2.3. Carriage

The sliding frame is an attachment used to install a fork or other fetching parts. The carriage is actually a vertically moving load-bearing trolley, which is mainly composed of two parts. The front part is a frame welded by an upper beam, a lower beam and two vertical plates, and the latter part is a row of rollers on the left and right sides. The forks or other pick-up accessories are installed on the front frame, the rear part is installed on the door frame, and the two rows of rollers are inserted into the guide rails of the door frame. The slide frame is also linked with the lifting chain, and the weight of the goods passes through the fork, which is passed to the fork frame to the slide frame, and finally to the chain. The torque of the total weight of cargo, pallet fork, fork frame, etc. is also transferred to the mast with the slide frame. There are two types of carriages : plate type and slider type. Different fork hooks require different sliders, and plate-type sliders should be used for hanging forks. The torque generated by the gravity of the cargo is transmitted to the mast in the form of a force couple through the two rows of guide rollers on the left and right. The guide rollers roll along the inner wall of the mast column to play a guiding role, ensuring that the carriage can only move up and down smoothly along the guide rail.

2.4. Hydraulic Cylinder

The hydraulic cylinder is an actuator, the material used is hydraulic oil, and the hydraulic pump pressure oil generates oil pressure. It converts hydraulic energy into mechanical energy, and makes linear back-and-forth circular motion, or swing motion. According to the structure, there are three types of hydraulic cylinders: piston type, plunger type, and swing type. The hydraulic cylinders used in forklift working devices are generally piston type. The mechanism of the hydraulic cylinder is simple, the operation is very stable, there is no transmission gap during the movement, the work is reliable, and it can be used as a deceleration device in reciprocating machinery, and it has been widely used in various industries [18].

The working device of a general forklift consists of two hydraulic cylinders, one lifting cylinder and one tilting cylinder. The cylinder barrel of the tilting cylinder is hinged to the fork frame, and the push rod is hinged to the mast, forming a certain angle with the horizontal plane. The reciprocating motion of the tilting hydraulic cylinder and the angle of the control mast are beneficial to the fork to pick up the goods and the center of gravity of the goods. The adjustment makes the forklift work more stable and safe. The power of lifting the goods mainly comes from the lifting cylinder, which gets the top of the push rod and links the chain pulley. When lifting the goods, the push rod pushes up, and the chain pulley turns to move up the leg chain, and the chain pulls and slides. The frame rises to realize cargo lifting [21].

2.5. Work Device Design

In this design working device, the fork adopts the hook type, and the fork frame and the slide frame are directly welded as a whole. The maximum lifting height is only two meters, so the mast is designed as a single mast. The lifting power adopts single hydraulic cylinder, double chain and double chain pulley type, located in the middle of the mast. The working device cannot adjust the angle, so there is no tilt cylinder. In the design, the strength and rigidity of representative parts (fork, fork frame, mast, lifting cylinder) are calculated.

2.5.1. Design and calculation of working device

- Technical parameters of forks

Various parameters of the fork:

The meaning of L represents the length of the horizontal segment;

The meaning of H represents the height of the vertical section;

Axb represents the meaning of the section size (a is the thickness of the fork; b is the width of the fork) [3].

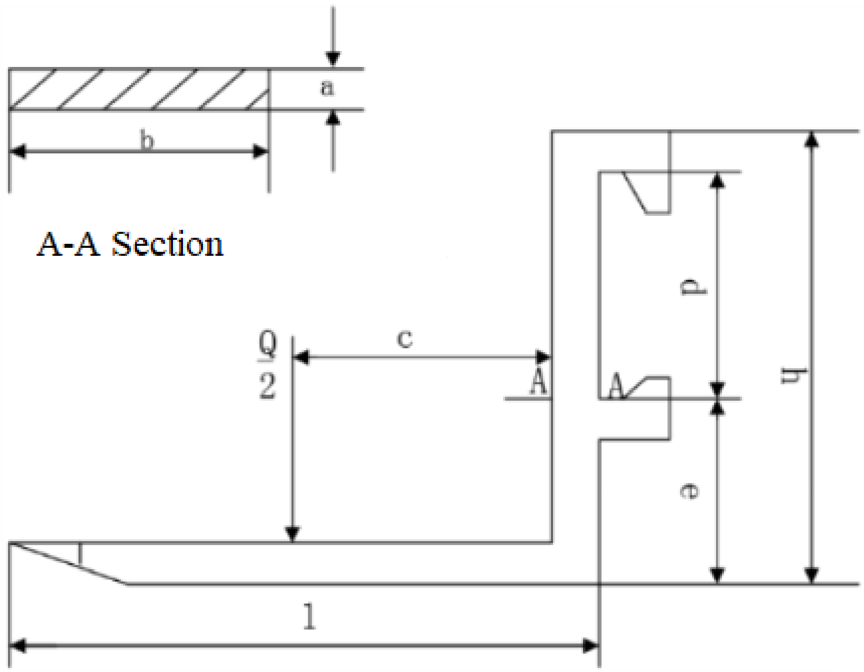

Fig.1. Structure and size of the fork.

The size selection of the forklift fork is mainly affected by two factors: the lifting weight Q; the load center distance c; the selected parameters of this design are: lifting weight Q = 2000kg, according to the national standard (ISO/DIS 1214- 79) regulations. Therefore, the load center distance C selected for 2000 kg should be 500 mm. Then follow the two national standards of ISO/DIS 2326-81 and 1S02382-77. Therefore, the parameters of this design are as follows [13].

for the fork: 40Cr steel;

Yield strength port: δs ≥539MPa ;

Treatment process: heat treatment method, quenched and tempered 40Cr steel;

section length of the fork: L= 1000mm;

Fork vertical section height: H=525mm;

horizontal section of the fork: axb =4 0 x100mm 2;

two hinge points of the fork: a =408mm;

2.6. Calculation of Various Parameters of the Fork

There are two types of links between the fork and the fork frame. The forms of their links are different, so the types of supported loads are also different. National standard 1S02328 — 77 regulations. For a 2-ton AGV forklift, the connection between the fork and the fork frame can be regarded as a fixed support. And simplified to active link support. The fork can also be seen as a statically indeterminate frame (see Fig.2). Because when the hooked fork is connected with the fork frame, there is a gap between the upper and lower parts, and it is not necessarily completely combined and cannot be rotated. Therefore, the fork can also be regarded as a static steel frame (see Fig.3).

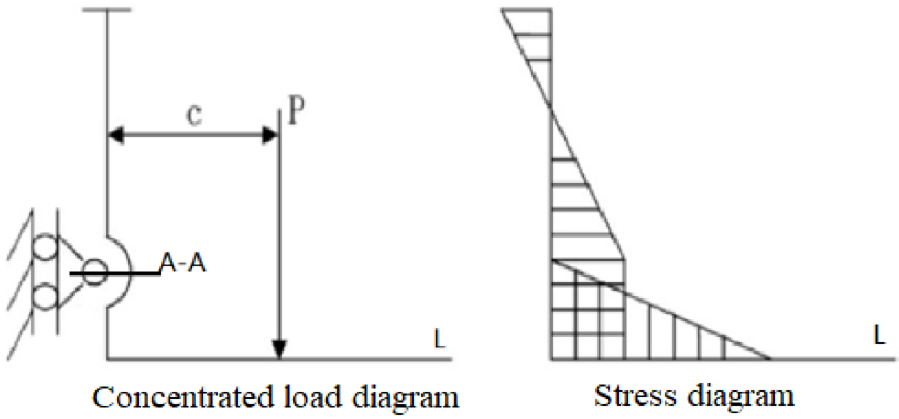

Fig.2. Calculation diagram of statically indeterminate steel frame

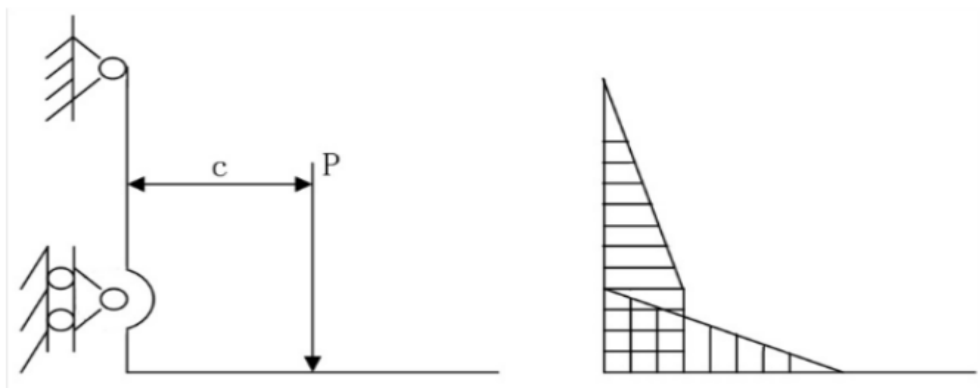

Fig.3. Calculation diagram of statically determinate steel frame

The above two figures are the calculation of the concentrated load P force. It can be seen that in the statically determinate steel frame calculation diagram, the A - A section and the lower part are the most dangerous places for the fork, and the stress state and strength are the same, mainly because of the deformation. The horizontal section of the shelf is relatively large. Because there are gaps in the upper and lower parts of the hook-type fork, it can be rotated freely due to inadvertent absolute meshing when linking. Therefore, the strength and stiffness of the fork are checked according to the calculation method of the statically determinate steel frame.

2.6.1. Strength Check of Fork

To calculate the shear stress on the level of the fork, it can be obtained by the force of the concentrated load P that the fork is subjected to. Because the section below the A - A section of the fork lower fork is a dangerous section, therefore, the maximum normal stress on this section is [19]:

$$\sigma_{max} = \sigma_a + \sigma_b = \frac{M_{max}}{W} + \frac{P}{F} = \frac{P \times D_H}{W} + \frac{P}{F} \leq [\sigma] \qquad \text{eq. 1}$$

In the above formula:

P stands for the calculated load of the fork;

D H represents the load center distance;

W stands for the flexural section modulus, W=W= d2b /6;

F represents the cross-sectional area of the vertical section of the fork, F =dx b;

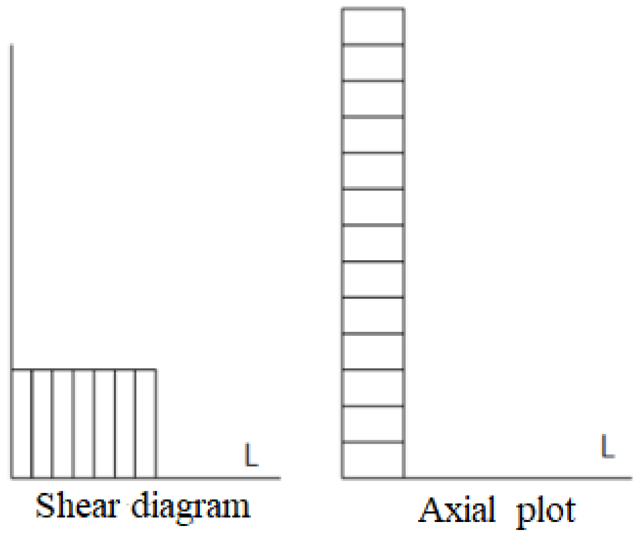

Fig.4. Simplified diagram of fork subjected to concentrated load

$$P = K_1 K_2 \frac{Q}{2} \qquad \text{eq.2}$$

In the formula:

represented by Q is the lifting weight force ;

(K stands for dynamic load coefficient)

the dynamic load coefficient represented by K1 is K,=1,2 ;

the partial load coefficient represented by K2 is K,=1.3 ;

$P = \frac{1.2X1.3X20000}{2} = 15600N$

From the above calculation, the average load of the fork is P =15600N;

2.6.2. Determination of safety factor n of fork

The fork of the forklift is the mechanism for the forklift to pick up the goods, and bears the full weight of the goods on the front. Therefore, the selection of the safety factor n of the forklift is particularly important, and it has a close relationship with the following items: 1 dynamic load coefficient K 1, 2 partial load coefficient K 2, 3 The calculated load size of the fork . According to the clarity of the calculated load, the size n of the safety factor can also be selected. If the calculated load has known its size or approximate value, the selected safety factor will always take a smaller value. If the calculated load is completely uncertain in size, select the safety factor The coefficient takes the larger value. The safety factor usually selected is : $n \geq 1.5$.

for forklift strength calculation should meet the following conditions:

$$n = \frac{\sigma_s}{\sigma} \geq 1.5 \qquad \text{eq. 3}$$

In the formula:

n represents the meaning strength safety factor:

This time the design factor is set at n=1.8.

The allowable stress of the fork [σ] is calculated as follows:

$$[\sigma] = \frac{\sigma_s}{n} = \frac{539}{1.8} = 299.44\text{MPa} \qquad \text{eq. 4}$$

Substituting the above data into the strength checking formula above, we get :

$$\sigma_{MAX} = \frac{15600 \times 500}{\frac{40^2 \times 100}{6} + \frac{15600}{40 \times 100}} = 292.46 < [\sigma]$$

Therefore, the strength of the fork meets the requirements

Fork stiffness check Whether the stiffness of the fork meets the requirements is reflected according to the static deflection at the fork tip of the fork.

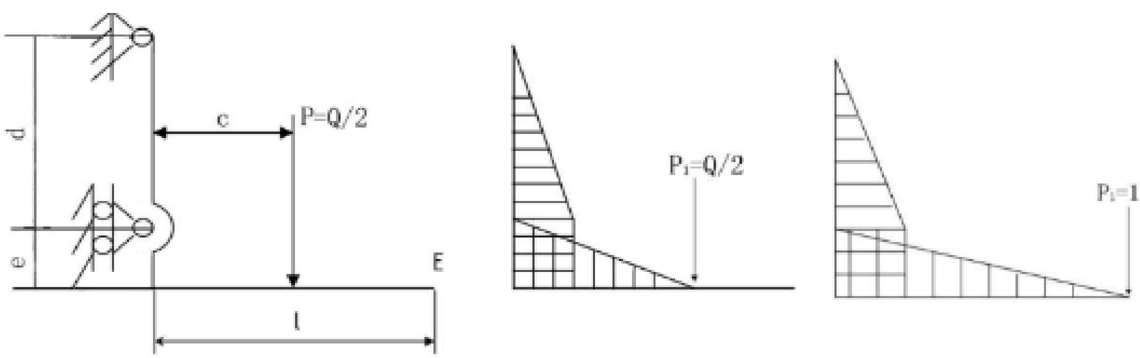

Fig.5. (a) Calculation diagram (b) Mp bending moment diagram (c) M’ bending moment diagram

2.6.3. Calculation diagram of fork tip deflection

Calculation formula for deflection at fork tip

$$F_E = \frac{P_1 D_H L}{6EI} \times \left[\frac{D_H}{L} \times (3L - D_H) + 6e + 2h\right] \leq [F_E] \qquad \text{eq. 5}$$

In the above formula

E-40cr steel modulus of elasticity $E = 205.8 \times 10^9 \frac{N}{m^2}$

I The moment of inertia of the fork section of the forklift

It is calculated according to the equal section , so the calculation of I is as follows

$$I = \frac{d^3 b}{12} \qquad \text{eq. 6}$$

P1 represents the rated tangential load force of the forklift fork, which is calculated as follows:

$$P_1 = \frac{Q}{2} = 10000\text{N}$$

$$F_E = \frac{10000 \times 50 \times 100}{6 \times 205.8 \times 10^5 \frac{4^3 \times 10}{10}} \times \left[\frac{50}{100} \times (3 \times 100 - 50) + 6 \times 7.3 + 2 \times 41.1\right] \quad = 15.9\text{mm}$$

The allowable deflection of a general forklift is$[F_E] = \frac{L}{50} = 20\text{mm}$

Because F E =17.3mm < [F E], the design of the fork can meet the requirements.

2.7. Design and checking calculation of fork frame

2.7.1. Calculation and stiffness verification of various parameters of the fork

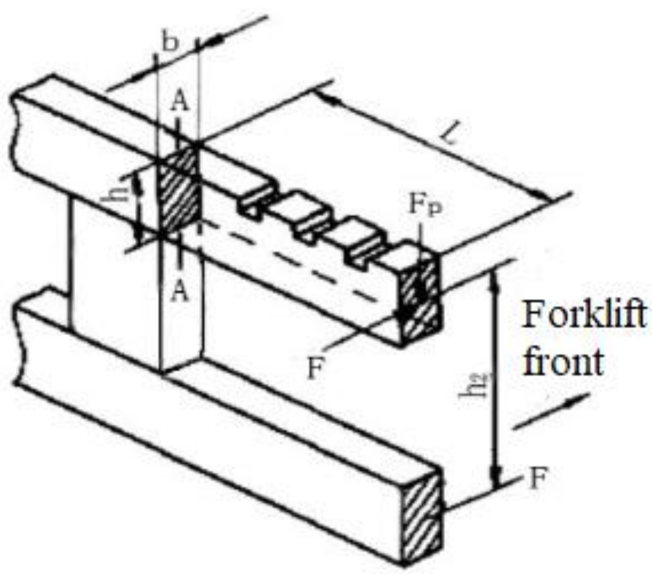

Fig.6. Simplified diagram of fork force

Fig.7, the dangerous section is at the A - A section, which is the maximum stress of the entire forklift fork frame, and the formula for calculating (MP a) is:

$$\sigma = \frac{M_X}{W_X} + \frac{M_Y}{W_Y} = \left[\frac{F_P L}{bh^2/6}\right] + \left[\frac{FL}{hb^2/6}\right] = \frac{6L\left(\frac{F_P}{h} + \frac{F}{b}\right)}{bh} \qquad \text{eq. 7}$$

In the formula:

b represents the net width of the cross-section of the suspension wall of the beam on the fork frame, mm, b = M = 31mm;

c represents the fork load center distance, c=500mm.

F stands for horizontal load, N. F= FPm /h2, h2, the thickness of the fork is a;

h stands for the net height of the cantilever wall section of the beam on the fork frame, mm ;

Fp stands for the vertical load, N. Fp =9800Q/2, which is half of the rated lifting capacity of the forklift ;

L represents the distance between the root of the crossbeam arm on the fork frame and the outermost suspension point of the fork, mm;

Table.2 Dimensions of installed forks

Lifting capacity/t	0.5~0.75	1~2,5	2.75~4.75	5~6
h2/mm	307	383	478	599

Take hz = 383mm, h = 120mm, L = 200mm, know a = 40mm, b = 31mm, c = 500mm into the formula , get

$$F_P = \frac{9800 \times 2.0}{2} = 9800N$$

$$m = 500 + 45 + 0.5 \times 31 = 560.5mm$$

$$F = \frac{9800 \times 560.5}{383} = 14341.78N$$

$$\sigma = \frac{6 \times 200 \times [\frac{9800}{120} + \frac{14341.78}{31}]}{31 \times 120} \approx 175.58MPa$$

$$[\sigma] = 317.06]$$

because,

$$\sigma = 175.5837MPa < [\sigma] = 317.06MPa$$

Therefore, the AGV forklift fork frame design meets the requirements.

The rest of the fork frame has basically no gaps between the links and can be ignored, so it can be regarded as a statically indeterminate frame structure with high strength and rigidity , which has met the requirements and does not need to be calculated and checked , so the safety meet the requirements.

2.8. Mast design and verification

2.8.1. Design and calculation of various parameters of the mast

Of the portal frame in this design is 16 Mn, and its shear elastic modulus is: yield point [σ]=2400 kg/cm 2 , G =8.4 x 106kg/cm 2 , yield point [σs] =3500 kg /cm 2 , shear resistance [τ]=1450 kg/cm 2 . Each part of the forklift, such as the weight of the cargo, as well as the weight of the fork and the fork frame, the slide frame, etc., are all based on several rolling rollers on the slide frame and the door frame, and act on them with several combined forces. door frame. Therefore, the sliding frame can be taken as a free body, and the pressure P 1 and P 2 of the rollers on the door frame can be calculated.

$$P_1 = \frac{k}{2h_2} \left(Qa_0\cos a + Qb_0\sin a + G_1a_1\cos a + G_1b_1\sin a - sa_2\right) \qquad \text{eq. 8}$$

$$P_2 = P_1 - \frac{1}{2}(Q + G_1)\sin a \qquad \text{eq.9}$$

$$S = (Q + G_1) \times k \qquad \text{eq. 10}$$

In the formula

K stands for dynamic load coefficient, K=K 1 (dynamic coefficient) XK 2 (cargo eccentric load coefficient)

G1 means the sum of the total weight of the fork and the fork frame, kg;

a represents the maximum forward inclination angle of the mast, in degrees, a =00;

Q stands for the rated lifting capacity of the forklift, kg;

S represents the total tension of the chain, kg;

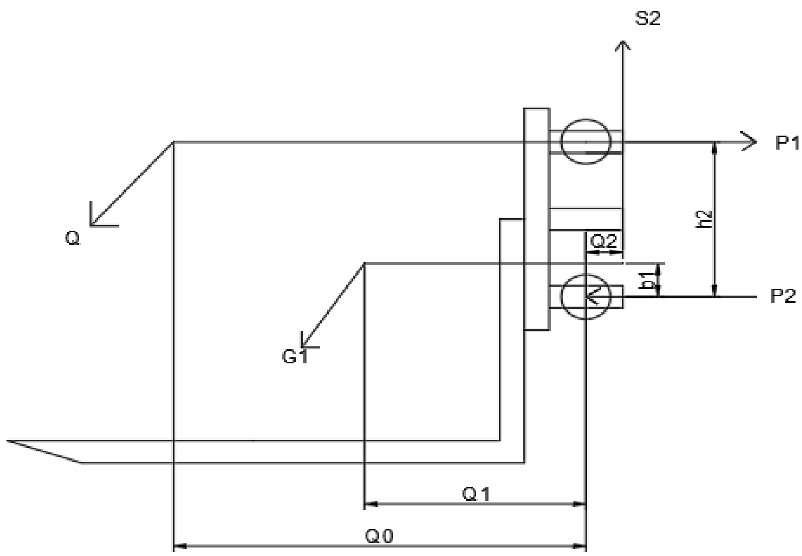

Fig.7. AGV forklift mast load diagram.

Among them, Q= 2000kg, a 0 =666mm, a 1 = 262mm, G 1 = 250kg, h 2 = 370mm, b 0 = 380mm, b 1 = 300mm, a 2 = 40mm, K =1.2.

mast of the lifting device of the forklift is designed as a single mast with an inclined oil cylinder, so the inclination a of the mast is 0.

Therefore,

$$S = (2000 + 250)X1.2 = 2700\text{kg}$$

$$P_1 = \frac{1.2}{2 \times 370} \times 2000 \times 666 \times \cos 0^o + 2000 \times 380 \times \sin 0^o + 1000 \times 262 \times \cos 0^o$$
$$+ 1000 \times 300 \times \sin 0^0 - 3900 \times 40 = 3627.48\text{kg}$$

$$P_2 = 3627.84 \times \frac{1}{2}(2000 + 250) = 3457.98\text{kg}$$

It can be seen from the above calculation that the center of the roller is subjected to the torque of the chain to generate a moment, which reduces the pressure of the roller and the load of the mast. Under normal circumstances, the standing distance generated by the chain is numerically close to the moment of lifting the weight of the cargo by 9 % to 10%. During loading and unloading, the tension of the chain and the pressure of the mast on the rollers are almost equal, so to simplify the calculation, it can be omitted and calculated according to the upright state of the mast.

Bending moment check of mast

The door frame is regarded as a cantilever beam, which can be calculated as a single thin-walled rod with a hinge at one end and a free end at the other end. In the plane perpendicular to the mast, due to the concentrated force of several rollers, there is a bending moment in the mast column, which has the maximum value. The most dangerous section is at point B.

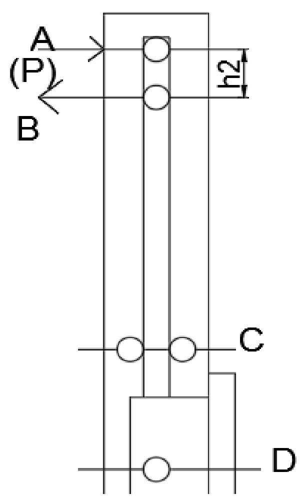

Fig.8. Mast Column.

The maximum bending moment at point B of the section is:

$$\mathrm{M_{bmax}} = \mathrm{P_1} h_2 = 330.54 \times 37 = 123565.98\mathrm{kg.cm} \qquad \mathrm{eq.}\,11$$

The bending normal stress of the integral gantry column is:

$$\sigma_\mathrm{w} = \frac{\mathrm{KM_{bmax}}}{\mathrm{W_x}} = \frac{1.2 \times 123566.98}{225.41} = 658.01\mathrm{kg/cm^2} \qquad \mathrm{eq.}\,12$$

In the above formula:

Sectional flexural modulus: W x =22541mm 2;

The bending safety factor K is taken as 1.2;

Bending stress is (take N =4)

$$[\sigma] = \frac{[\sigma_\mathrm{s}]}{\mathrm{N}} = \frac{3500}{4} = 875\mathrm{kg/cm}^{\ 2} \qquad \mathrm{eq.}\,13$$

From the above formula: σw<[σ], so the overall bending resistance of the mast is safe.

2.8.2. Calibration of the thickness of mast column

In this design, the base surface of the mast column of the forklift is the same, and the lifting weight is 2 t. According to " Mechanical Course Design “, the type of channel steel is selected as 16 a, and the cross-sectional dimensions corresponding to the size of the mast column of the forklift are: t 1 = 14mm, b = 52mm, t 2 = 18mm, h=152mm.

The section flange thickness δ of the gantry column of the lifting device, according to the calculation formula of local bending stress;

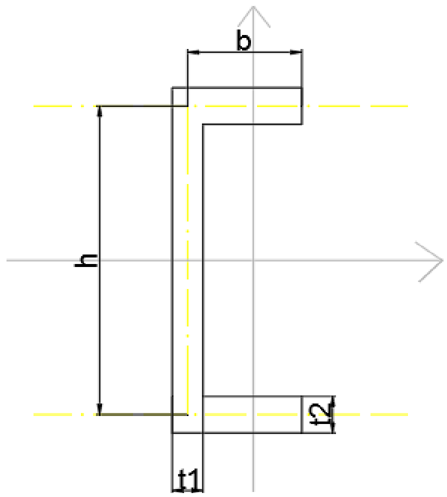

Fig.9. Fracture section thickness of gantry

$$\sigma_{partial} = \frac{3.06P}{\delta^2} \leq [\sigma_s] \qquad eq. 14$$

$$therefore: \ \delta \geq \sqrt{\frac{3.06P}{[\sigma_s]}}$$

In the above formula

Material yield limit, 16M n steel = 3500kg/cm 2;

Roller pressure is P, P =P 2 =3331.54kg.

$$\text{so get}\delta \geq \sqrt{\frac{3.06\times3340.5}{3500}} = 1.71mm$$

Because 1.71mm <1.8mm, the design thickness is reasonable.

Design Calculation of Lifting Cylinder

Cylinder thrust

$$F_R = \frac{2(Q + G_h + W_1)}{\eta_2} + G_s + W_2 \qquad eq. 15$$

In the formula:

The efficiency of the meaning pulley represented by η 2;

Q stands for the weight of the cargo;

Gh represents the total gravity of the carriage and the fork;

The efficiency of the meaning pulley represented by η 2;

G1 represents the total gravity of the plunger pulley and the mast that rises together;

W1 represents the resistance of the carriage extending the mast movement;

W represents the resistance of the movement of the inner mast to the outer mast;

When roughly calculated, the jacking thrust of the plunger lift is;

$$F_R = \frac{2\ (Q + G_h)}{\eta_q} \quad \text{eq. 16}$$

In the formula:

η q is the efficiency of the total lifting mechanism, η q=0.8-0.9.

$$F_R = (Q + G_h)\frac{1}{\eta_q} = 2(2000 + 175)\frac{1}{0.8} = 5437.5N \quad \text{eq. 17}$$

2.8.3. Determination of Basic Parameters of Lifting Cylinder

The working pressure of the oil cylinder

The working pressure of the oil cylinder selected this time is p =130kg/cm 2

the inner diameter D of the cylinder, for the plunger:

$$D = \sqrt{\frac{4F_R}{\pi P \eta_M}} = \sqrt{\frac{4 \times 5437.5}{3.14 \times 130 \times 0.95}} = 7.49cm = 74.9mm \quad \text{eq. 18}$$

In the formula

F R represents the jacking force of the oil cylinder;

P represents the working pressure of the oil cylinder;

D represents the inner diameter of the cylinder;

η m represents the mechanical efficiency of the hydraulic cylinder, generally η m=0.95

(2) The working speed of the oil cylinder

According to the given technical parameters and the working principle of fork lifting

$$V_h = 2V_s \quad \text{eq. 19}$$

$$V_s \frac{V_h}{2} = 6cm/s$$

In the formula:

Vs represents the cylinder piston lifting speed;

V h represents the average speed of cargo lifting;

guide length H of the lifting cylinder

Ordinary hydraulic cylinders, the minimum guide length H should meet the requirements

$$H \geq \frac{L}{20} + \frac{D}{2} = 1025\text{mm} \qquad \text{eq. } 20$$

In the formula

D represents the inner diameter of the cylinder;

L represents the maximum stroke of the hydraulic cylinder;

2.8.3. Stability Calculation of Oil Cylinder

When the length-to-length ratio of the plunger-cylinder is greater than 10, a stability check is required. its stability

$$F = \frac{F_k}{\eta_k} \qquad \text{eq. } 21$$

In the formula

F k represents the stable critical force of the hydraulic cylinder;

F stands for the maximum thrust of the plunger rod;

η k represents is stable safety factor, η k=2～4;

Among them: F k =9252.1kg F=2957.5kg

$$\eta_\kappa = \frac{F_\kappa}{F} = \frac{166693.12}{5437.5} = 3.07 \qquad \text{eq. } 22$$

The safety factor is within the range of η k, so the stability of the hydraulic cylinder meets the requirements.

3. Results Balance Analysis of AGV Forklift

3.1. Forklift Balance Weight

For a balanced forklift, the balance of the forklift is a very important technical indicator, and the balance has a huge impact on the normal operation of the forklift. When the balance forklift is forking and lifting the goods, the lifting end of the forklift is subject to the weight of the goods, and the front wheel of the forklift is used as the fulcrum to form a lever, and the pick-up end becomes heavier, causing the forklift to appear unbalanced. For the balance of a forklift, it is necessary to counterweight the forklift to prevent the rear wheels from leaving the ground or tipping forward and overturning. The selection of the weight of the balance weight has a significant impact on the stability, traction and other performance of the forklift.

3.1.1. Calculation of balance weights

The AGV forklift are: hard road surface and ground undulation less than 5 degrees. The AGV forklift runs stably at low speed. Forklift fully loaded counterweight:

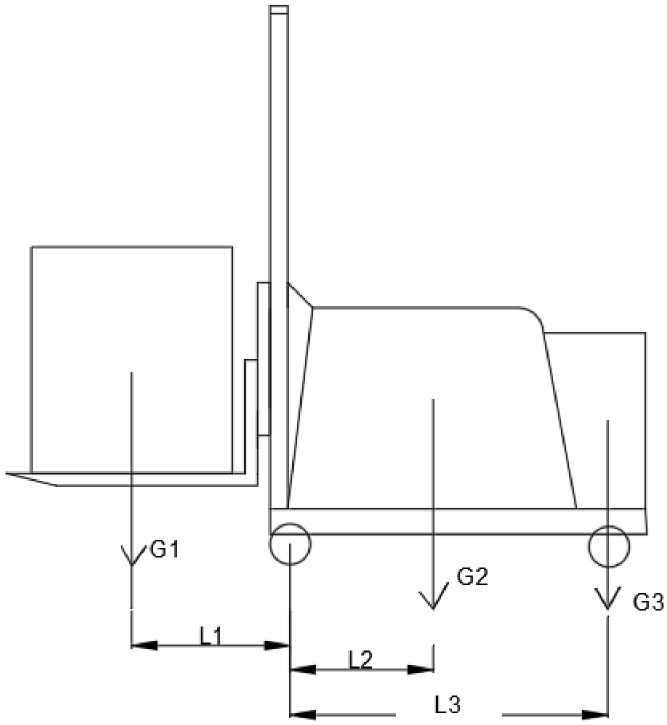

Fig.10. Forklift mass distribution.

$$G3 = \frac{G1L1 - G2L2}{L1} \qquad eq.23$$

In the formula:

G1 represents the total weight of goods, forks, carriages, etc.;

G2 represents the weight of the body (weight of the control box, chassis, etc.);

G3 means balance weight;

L1 represents the distance from the front wheel to the load center of the fork;

L2 represents the distance from the front wheel to the center of gravity of the body;

L3 represents the distance from the front wheel to the counterweight;

$$\mathrm{G3} = \frac{(2000 + 170) \times 625 - (525 \times 400)}{900} = 1273.6\mathrm{Kg}$$

The AGV forklift are: hard road surface and ground undulation less than 5 degrees. The AGV forklift runs stably at low speed. The ground conditions are good, the speed is stable, and the slope balance, turning balance and static balance are basically the same. Empty forklift does not affect the balance of the forklift itself, so it will not be counted. (The balance calculation method is only suitable for this design)

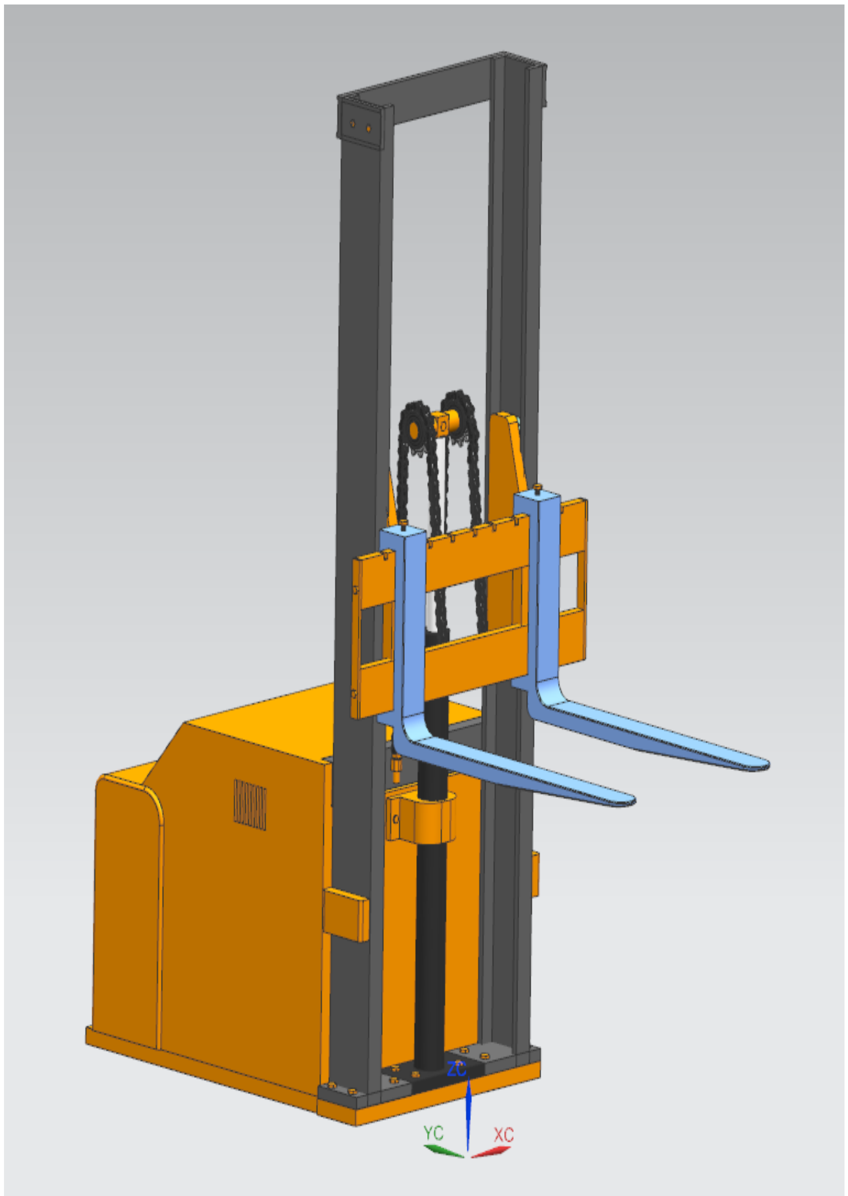

Fig.11. UG General Assembly Drawing

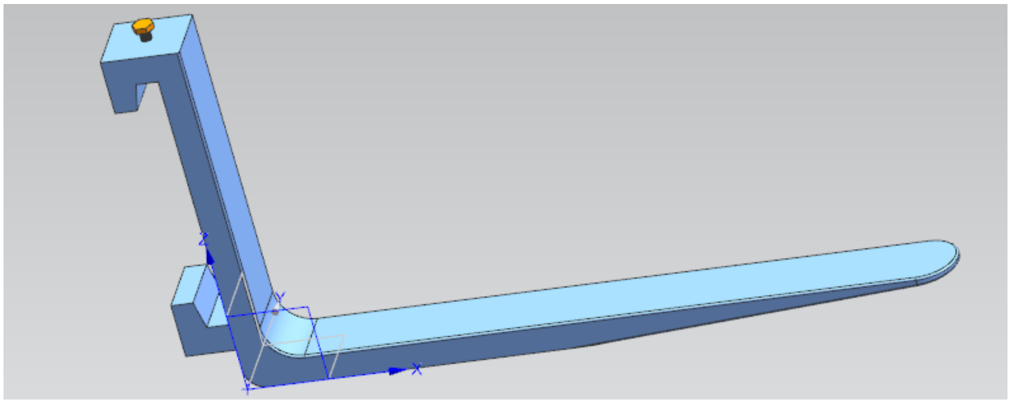

Fig.12. 3D drawing of fork UG

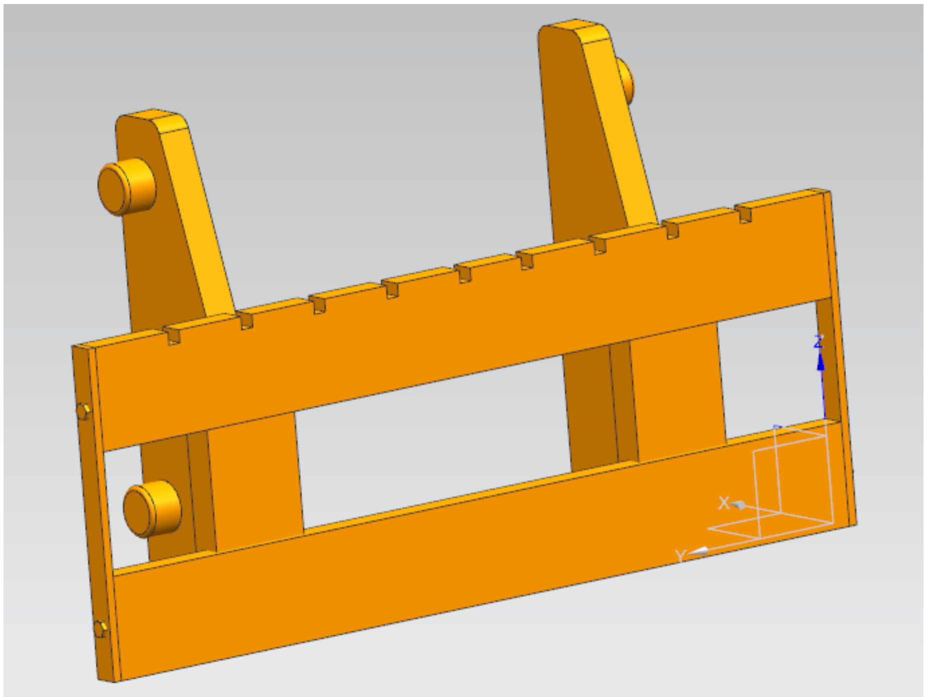

Fig.13. UG 3D drawing of fork and slide frame combination

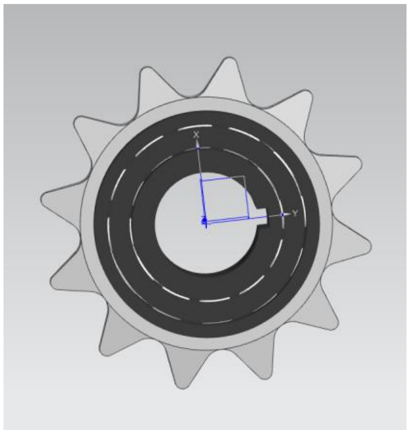

Fig. 14. UG 3D drawing of sprocket wheel

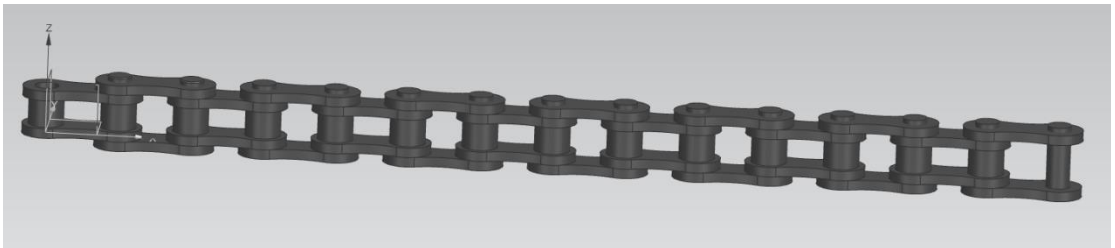

Fig.15. UG 3D diagram of chain

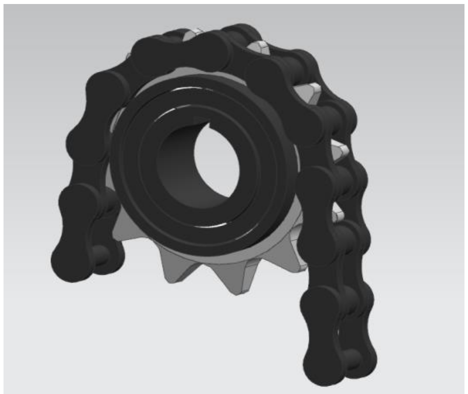

Fig.16. UG three-dimensional diagram of chain and sprocket wheel

4. Conclusion

This design belongs to the mechanical design. At the same time, this time, it is the graduation design for the mechanical engineering major of Beau Gulf University. The overall mechanical design of the AGV forklift body is carried out. During the design process, UG and CAD are used for drawing. My topic is: fork-type AGV mechanical body design. When I first came into contact with this topic, I felt very confused because I didn't know much about AGV forklifts at that time. Later, I found out on the Internet that the AGV forklift is a kind of unmanned moving vehicle. The difference from the general forklift is whether it is operated by personnel, but there are many similarities in the mechanism. I have had the experience of working in a factory several times, and I have been in contact with ordinary forklifts, so I have a little understanding of forklifts. After receiving the design topic, I checked some AGV forklift- related materials and pictures on the Internet so I comprehensively learned about AGV forklifts.

The completion of the design is mainly divided into the following three stages:

The first is to understand and analyze the topic. Just received the design topic, the instructor held a meeting to discuss the content of the topic with me, and analyzed the mechanism composition of the AGV forklift mechanical body, its design requirements, etc. Afterwards, in order to have a deeper understanding, I checked the relevant information on the Internet. data to prepare for the design of the subject.

Then for the overall design and analysis of the topic content, I asked the teacher about the main content of the design of this topic, discussed and analyzed it with the teacher many times, consulted the information, completed the research content required by the topic, and divided it into blocks.

For the last project, I actively searched for a large amount of information about AGV forklifts on the Internet, and went to the library to consult a number of books about forklifts. I recorded important materials, then sorted and analyzed them, and finally combined the research content and design points to complete the design.

References

[1] Editor-in-Chief Liu Changqi . Selection and Design of Storage System Facilities and Equipment [M] . Machinery Industry Press, 2011

[2] Editor-in-chief Zhou Weixing. Loading and unloading vehicles [M]. Beijing: People's Communications Press, 2001

[3] Chen Tieming. New Design Atlas of Mechanical Design Course [M]. Beijing: Higher Education Press, 2003

[4] Editor-in-Chief Liu Weixin. Structural Analysis and Design Calculation of Automobile Braking System [M]. Tsinghua University Press, 2004

[5] Edited by Hofsky. Translated by Li Qiang and others. Mechanical Principles [M]. Volume II. Third Edition. Beijing: Higher Education Press, 2006.29

[6] Qin Tongshun . Selection of Forklifts [J]. Port Handling, 2001, 02: 13-30

[7] Tao Yuanfang, Wei Liangbao . "Forklift Structure and Design" [M]. Mechanical Industry Press. 2010-2-1 , 16 -98

[8] Zhang Liping. "Hydraulic Pneumatic Technology Quick Reference Manual" [M]. Chemical Industry Press, 08:69-71

[9] Chen Muchen, editor-in-chief. Loading and unloading vehicles [M]. Beijing: People's Communications Publishing House, 1986, 3:22-29

[10] Xu Fuling, Chen Yaoming, editor-in-chief. Hydraulic and pneumatic transmission [M]. Beijing: Mechanical Industry Press, 2006, 07:59-69

[11] Editor-in-Chief Liu Hongwen. Mechanics of Materials Fourth Edition [M]. Beijing: Higher Education Press, 2004.1, 07:69-77

[12] Wu Kejian, Yu Xiaohong, Qian Ruiming, chief editors. Mechanical Design [M]. Beijing: Higher Education Press, 2003, 04:35

[13] Editor-in-Chief Luo Shengguo . Mechanical Design Course Design Manual [M]. Beijing: Higher Education Press, 2004, 06:65-79

[14] Guo Yan , Yan Bin , editor-in-chief . Port cranes [M] . Wuhan. Wuhan University of Technology Press, 2013

[15] Li Lan, Chen Manlong editor-in-chief . Hydraulic and pneumatic transmission [M] . Wuhan ; Huazhong University of Science and Technology Press, 2012

[16] Zhang Changjian. Reliability Analysis and Calculation of 2 Ton Forklift Mast [J]. Hoisting and Transportation Machinery, 1998, 02:42-43

[17] Jiang Xudong, Hu Xiaochun. Design of four-section mast for forklift [J]. Hoisting and Transportation Machinery, 2005, 11: 12-14

[18] Chen Juan. Heli G Series Counterbalanced Forklifts [J]. Construction Machinery and Maintenance, 2008, 07: 130

[19] Ling Ming. CPCD-5 Forklift Mast Structure and Process Improvement [J]. Hoisting and Transporting Machinery, 2006, 04: 28 47

[20] MR Smith. Mechanisms And Machine Theory [M]. Higher Education Press, 2001, 05: 49-64

[21] Rakesh V. Vohra. Mechanism Design: A Linear Programming Approach[M]. Cambridge