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Overall Scheme Design and Related Verification Calculation of Column Lift

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Abstract

The column lifting mechanism is a device that lifts and lowers a car by supporting a certain part of the car chassis or body. Car lifts play a crucial role in maintenance and upkeep,whether it's major or minor repairs, they are indispensable. Mechanical car lifts, as a member of the entire car lift system, have advantages that other lifts do not have, such as a wide working range, the ability to repair high ceiling vehicles, and a small working space. This article provides a comprehensive introduction to the types of lifts, and after determining the design plan, designs and explains the structure and characteristics requirements of the lifts. Specifically, it involves the analysis and selection of the prime mover, the analysis and design of the belt drive, the analysis and design of the screw drive, the analysis and selection of the guide rail, the stress verification of the support cantilever, and the selection of the locking mechanism.

Keywords: Car; Post lift; Screw transmission; Mechanical drive

Introduction and Development Overview of Automotive Elevators

Car lifts play an important role in the automotive maintenance and repair industry. The car lift is a device that reliably and safely lifts a car from the ground to a suitable height according to maintenance and repair conditions, facilitating workers' tasks. Traditional maintenance methods, involving technicians working underneath cars, suffered from limited space, poor lighting, and resultant inefficiencies. Early car lifts, powered by electricity, offered limited lifting heights. For instance, in the 1920s, Weaver and Manley produced lifts with a maximum height of 4 feet, adjustable at the peak according to work requirements. These lifts supported the axle, allowing wheels to rotate freely once lifted [1].

However, early designs had their limitations. The electric lifts were not as versatile or height-adjustable as modern versions, and the space beneath lifted cars remained restricted, impacting the ease and comprehensiveness of repairs. Despite improvements, such as Lunati's hydraulic lift inspired by barber seats, which enhanced repair efficiency, subsequent single-column frame contact lifts sacrificed vehicle bottom space, impeding access to certain components. The advent of two-column lifts addressed these issues but required ongoing technological refinements.

Finite Element Analysis (FEA) simulations were instrumental in validating stress distributions and optimizing lift designs. These simulations helped engineers understand and mitigate stress concentrations, ensuring the structural integrity and safety of the lifts under various loading conditions.

China's car lift industry, emerging in the early 1980s based on foreign technology, gradually replaced the traditional trench mode due to its advantages. With the burgeoning automobile industry, the market for car lifts expanded rapidly, evolving into diverse forms and types by 2000, becoming essential for Level 2 maintenance qualifications. As private car ownership soared, car lifts became indispensable maintenance equipment.

China's accession to the WTO significantly impacted the automotive repair industry, prompting foreign automakers to enter the Chinese market. This influx introduced advanced technology, presenting an opportunity for domestic upgrades and transformations. Modern maintenance integrates car sales, parts sales, information, and after-sales service, replacing traditional models focused solely on repairs.

Despite advancements, ongoing research is crucial. Future directions include AI-based predictive maintenance, which leverages data analytics to forecast and preemptively address potential issues, enhancing efficiency and reducing downtime. FEA simulations will continue to play a pivotal role in refining lift designs, ensuring safety and performance. As the automotive industry evolves, promoting high-quality, branded, and digitized services in maintenance will be imperative, positioning China's automotive repair industry competitively in the global market [2-10].

Overall Scheme Design

After reviewing relevant materials and conducting research on automotive maintenance companies, the overall transmission plan includes the following aspects, which are listed as alternative solutions.

Based on the actual dimensions and quality of the sedan, as well as on-site inspections by maintenance shops, the parameters required for designing the column lift of the car are: rated lifting mass, maximum lifting height, lowest height of the cantilever tray from the ground, full rise/fall time, and lift dimensions.

Due to the lack of unified national regulations on the parameters of different types of cars on the market, the various parameters of each car are not exactly the same, and corresponding adjustments need to be made when facing different types of cars.

Table 1: Alternative functional solutions for each category

Categories	Possible solutions
Motorconfiguration scheme	1.Single motor scheme
	2. Dual motor scheme

Transmission mode	1. Gear transmission.
	2. Ball screw transmission.
	3. Sliding spiral drive.
	4. hydraulic transmission.
synchronizatio n mechanism	1. Spiral pair - bevel gear - long shaft - bevel gear - mechanical transmission structure of spiral pair.
	2. Select two motors with similar external rotation and two screw pairs with similar machining accuracy for adjustment and selection during assembly.
	3. Chain drive structure.
	4. synchronous belt transmission.
Locking safety device	1. Self locking safety device including electromagnet, spring or brake plate.
	2. Set up several stop plates to achieve necking effect.
	3. Adopting rail clamps suitable for use on fixed Z-axis (vertical axis).

Based on the above information, two options can be determined. Option 1: The prime mover adopts a motor, which transmits motion and torque to the right screw through a common V-belt transmission. The spiral transmission converts the rotational motion of the right screw into linear motion of the nut, and the rotation of the left screw is transmitted to the right screw through a chain transmission with a transmission ratio of 1, achieving synchronous motion of the left and right screws, that is, the rotation of the right screw is converted into linear motion of the nut. Option 2: The prime mover is two motors installed on the left and right columns respectively. The synchronous motion of the left and right screws is achieved through the power on/off of the two motors. The screw converts its rotation into linear motion, which in turn causes the nut to move up and down synchronously. The car lifting prime mover is two motors installed on the left and right columns respectively. The synchronous motion of the left and right screws is achieved through the power on/off of the two motors. The screw converts its rotation into linear motion, which in turn causes the nut to move up and down synchronously, realizing the car lifting.

Analysis and Selection of Nuts

The basic principle of spiral transmission is to transmit motion and power through the rotation of screws and nuts. Spiral transmission mainly converts rotational motion into linear motion, which can obtain large thrust with small torque or be used to adjust the mutual position of parts. When the spiral drive is not self-locking, linear motion can also be converted into rotational motion. According to the different friction properties of threaded pairs, they can be divided into sliding spiral transmission, rolling spiral transmission, and static pressure spiral transmission. Different types of spiral drives have different applicable scenarios and need to be adjusted according to the actual situation. If used in the wrong situation, it may cause problems such as inability to achieve the expected effect.The characteristics and application examples of each type of spiral transmission are as follows:

Table 2: Characteristics and Applications of Various Spiral Transmission Systems

Categories	**characteristic**
Sliding spiral drive	1. High frictional resistance and low transmission efficiency
	2. Simple structure and easy processing
	3. Easy to self lock.
	4. Smooth operation, but crawling may occur at lowspeeds or during fine-tuning

	5. The thread has lateral clearance, and there is clearance inthe reverse direction
	6.Quick wear and tear
Rolling spiral transmission	1. Low frictional resistance and high transmission efficiency
	2. Complex structure and difficult manufacturing.
	3. It has reversible transmission capability.
	4. Smooth operation, no vibration during start-up, and nocrawling at low speeds
	5. Poor impact resistance
	6.Long working life and less prone to malfunctions
Static pressure spiral transmission	1. Extremely low frictional resistance and high transmissionefficiency
	2. The nut structure is complex.
	3. It has reversible transmission capability
	4. Work smoothly without crawling phenomenon.
	5. No empty travel in reverse
	6. Low wear and long service life.

Table 3: Characteristics of three types of nut structures

Categories	**Explanations for each category**
Integral nut	The structure is simple, but the axial clearance caused by wear cannot be compensated for, and is only suitable for low precision spiral transmissions
Combination nut	The structure is complex, but it can be adjusted regularly to eliminate axial clearance and avoid backlash caused by reverse rotation.
Split nut	The structure is complex, but it can compensate for the wear of the mating thread

Although combination nuts and split nuts have the advantages of compensating for clearance, avoiding reverse travel, or compensating for wear, their structures are too complex, and split nuts are mainly used in conductive screws. Therefore, in most cases, column lifts choose integral nuts.

Applicable Spiral Pair Calculation Methods

The failure of sliding screw pairs is mainly due to thread wear, so the diameter of the screw and the height of the nut are usually determined based on wear resistance calculations.

$$d_z = \xi \sqrt{\frac{F}{\varphi[p]}} \qquad (1)$$

Rectangular thread ξ=0.8;F represents single column axial load, with a safety factor of 1.5.[p] represents the allowable pressure, with different values depending on different usage situations.The value of π is selected according to the form of the nut, and the overall value is taken as 2.5~3.5.

Due to the need to meet the design requirements of wear resistance, self-locking, screw strength, thread strength, screw stability, and lateral vibration of the screw, the selected value of the screw diameter should be greater than the actual calculated value, and rounding should be carried out according to the national standard value.

The nut height H, the number of turns Z, the working height h, and the working pressure P can be calculated from the following formulas to determine the relevant parameters.

$$H = \varphi \times d_2 \tag{2}$$

$$Z = \frac{H}{P} \leq 10 \sim 12 \tag{3}$$

$$p = \frac{F}{\pi d_2 h_Z} \leq [p] \tag{4}$$

For column lifts, the verification of self-locking performance is an essential step, and the self-locking screw should be checked for its self-locking performance.

$$\rho' = \arctan \frac{\mu_s}{\cos \frac{\alpha}{2}} \tag{5}$$

$$\psi = \arctan \frac{L}{\pi d_2} \tag{6}$$

The value calculated by formula (5) is the equivalent friction angle. If the value calculated by formula (6) is less than formula (5), it meets the self-locking requirement.

In structural mechanics, a dangerous section refers to a section where the internal forces (such as bending moment, shear force, and axial force) reach their maximum value under the action of internal forces. These sections are usually located at critical parts of the structure, such as support points, connection points, or changing sections of beams. Due to the concentration of internal forces in these locations, they are more prone to damage or deformation, hence they are referred to as dangerous sections.We can verify the dangerous section according to formula (7).

$$\sigma = \sqrt{\left(\frac{4F}{\pi d_1^2}\right)^2 + 3\left(\frac{T}{0.2 d_1^3}\right)^2} \tag{7}$$

4304715-397703In terms of material selection, screw and nut materials should not only have sufficient strength and good processing performance, but also have intersecting friction coefficients and high wear resistance when screwed together. Therefore, the screw of this car lift should undergo heat treatment to ensure its wear resistance.

For medium precision general transmission, 45 steel is selected as the screw material, and the heat treatment process is as follows: preliminary heat treatment: normalizing (170~200HBS); Final heat treatment: quenching and tempering (220~250HBS).

The traditional nut material is ZCuAl10Fe3Mn2, which is used in conjunction with steel screws to achieve low friction coefficient and high strength, making it suitable for heavy-duty and low-speed transmission.

Supporting Structure Analysis

The cantilever part of the lifting platform belongs to the support mechanism of this car lift. When the target car enters the range of the car lift, the entire support mechanism changes the width of the entire working range of the cantilever by changing the angle and length of the cantilever. The support mechanism designed for this car lift is a symmetrical cantilever, which is beneficial for maintaining the stability of the car during maintenance, making the force distribution of each mechanism in the column more uniform, and also meeting the distance requirements of various types of cars.

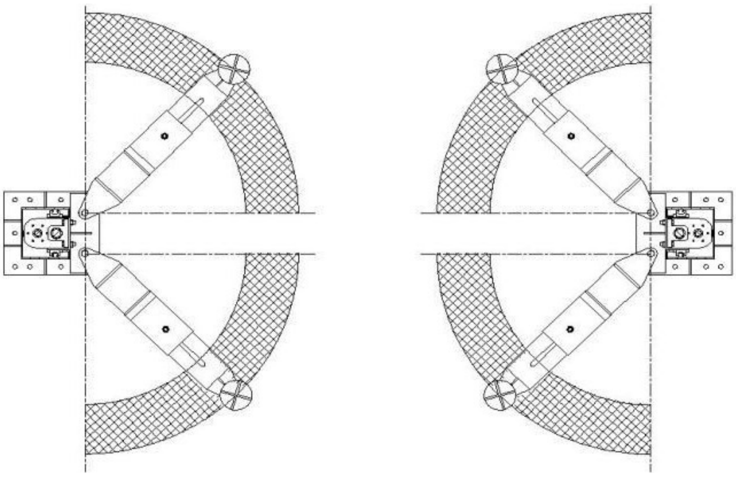

Figure 1: Schematic diagram of symmetrical cantilever

Stress Verification Method for Supporting Mechanism

This section will verify the supporting structure by simplifying the model. The entire cantilever can be simplified as a cantilever beam, with a load applied at the end of the cantilever beam. The cross-section of the cantilever beam is a hollow rectangle. Below, we will verify the bending normal stress and bending shear stress of the cantilever separately.

The verification formulas for bending normal stress and bending shear stress are as follows:

$$\tau = \frac{F_s S^*}{I_z b} \tag{8}$$

$$\sigma_{\max} = \frac{M_{\max}}{W} \tag{9}$$

$$W = \frac{I_z}{y_{\max}} \tag{10}$$

Meaning of each data item in the formula:

Fs - Shear force on the cross-section. b - Section width.

Iz - the moment of inertia of the entire cross-section about the neutral axis.

S^*z - The static distance of the area outside the horizontal line y from the neutral axis on the cross-section to the neutral axis.

Mmax - maximum bending moment of cantilever.

W - Bending section coefficient, related to the geometric shape of the section. ymax - The horizontal line on the cross--section that is y away from the neutral axis.

Fs and other data should be adjusted based on the actual weight of the lifted vehicle.

Stress Verification Method for Supporting Mechanism

Select the rolling linear guide according to the working conditions of the car lift. Rolling linear guides have four directions of equal load type, light load type, separation type, radial type, and cross roller V-shaped linear guide pairs.If a four-way equal load rolling linear guide pair is used, it has the following advantages.

1.The rolling element is in contact with the circular groove, which has a higher load-bearing capacity and better rigidity compared to point contact.

2.The friction coefficient is small, generally less than 0.005, only 1/20~1/50 of the sliding rail pair, saving power and able to withstand loads in four directions: up, down, left, and right.

3.Longer lifespan, easy installation, maintenance, and lubrication. Flexible and impact free movement, it can effectively control the position and size during low-speed micro feed.

Conclusions and Recommendations

By analyzing and calculating the transmission mode and internal structure of the car lift, a relatively simple and reliable transmission mode was selected based on the existing transmission mode and structure of the lift. At the same time, the strength and stiffness verification of the main load-bearing components were introduced; Introduced the selection and verification calculation of the spiral transmission device and belt transmission device, and introduced the selection and verification calculation of important threaded connections to ensure the safety and practicality of the designed machinery [11].

However, there are still many shortcomings and limitations of column lifts, and there is still research significance. For example, the double column car lift is suitable for light and medium vehicles and cannot be used for the maintenance of heavy vehicles. The double column car lift needs to be fixedly installed on other structures on the ground and cannot be moved or transported, which limits its flexibility and versatility. The operation of a double column car lift requires high skills and experience, otherwise safety accidents may occur, requiring regular maintenance and inspection, replacement of oil seals and hydraulic pipe components, resulting in high operational requirements and maintenance costs. Future research directions can focus on optimizing these defects.

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