

# Design and Research on the Automatic Pipe Laying Device of Workover Rigs

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**Abstract:** Well workover is an essential operation process in oilfield, and tubulars, overhauling the transportation of between pipe racks and wellhead platforms forhas long been a big problemoil rods and other tubing. Due to the inadequacy of devicesthe related tubulars transportation, there are problems such as low efficiency and insufficient safety in operationsheavy workload, tubulars lifting and lowering. Some domestic oilfields still use manual operation or semi-automated mode, which is easy to cause wear and tear of tubing, low efficiency and safety hazards. In order to solve these problems, this paper develops a set of intelligent pipelining system to improve the safety and process efficiency. First of all, we review the literature of related devices, summarize the development status of devices, domestic and foreign pipe transport design the overall scheme of , including the overall layout of the device and the detailed design of the main mechanism and force calculation, and by using automatic operationspipe removal for well workover model and assemble the device three-dimensional modeling software. utilized SolidWorks ANSYS Workbench software is to carry out static strength calibration of the main components to verify whether the structure meets the strength requirements under the maximum stress situation. Mathematical equations of kinematics and dynamics are established for the to provide theoretical basis for the motion simulation, and by using important mechanisms motion simulation of the main mechanisms and components is carried out software to verify their stability, safety and whether they can arrive at the expected motion attitude during the motion process.ADAMS.

**Keywords:** Well workover operations; tubular transportation; safety.

## 1. Introduction

With the rapid development of industry, China's demand for oil is growing, the development of the petroleum industry is also paying more and more attention to the development of the oil industry, there are a variety of processes in the oil field operations across the country, including well repair operations is an important part of the collection of oil and natural gas.

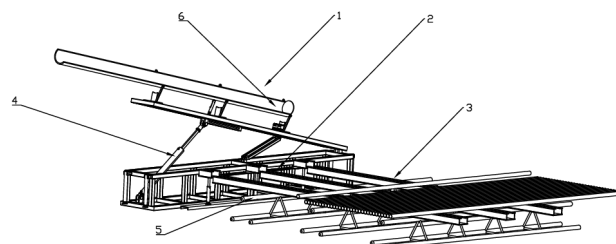
The automatic device can facilitate workover operationthe automatic arrangement of, avoiding the workers to manipulate the heavy tubulars by manpower, which greatly improves the safety of the work, saves the manpower cost and improves the working efficiency. In addition, the space on the workover platform is narrow, and the cost of storing tubulars in the limited space is very high, so it is more important to design a device to automatically access the tubulars and conveniently move them, and at the same time, in order to reduce the dangers of the platform operation and improve the economic benefits, a variety of tubulars in the platform tubulars automatic discharge system is introduced to realize the the tubularsprecise positioning of, and it can greatly increase the efficiency of the workover, and reduce the labor intensity of the workers.

### 1.1. Structural components

The automatic tubing discharge device of the well dressing machine is mainly composed of : tubing conveyor, automatic tubing discharge rack and moving device three parts<sup>[2]</sup>, and the overall model of the automatic tubing discharge device of the well dressing machine is Figure shown in .1

First of all, the tubing conveyor device, the device consists of base, lifting mechanism, extending mechanism, feeding mechanism and turning mechanism and other structural components, tubing conveyor is responsible for receiving the

tubing from the wellhead, the automatic tubing rack is responsible for receiving the tubing transported to the tubing rack and neatly arranged, the tubing conveyor includes the base, lifting frame, lifting mechanism, driving device. Automatic tubing conveyor includes base, elevator frame, lifting mechanism and driving device. Automatic tubing conveyor includes tubing trolley, tubing rack and trolley track, which is equipped with lifting device to lift tubing, and the tubing trolley in the tubing track relies on sensors to recognize and accurately locate tubing above the tubing <sup>[33)(3)(3)(3)(3)(3)</sup>. Research on the quality requirements of well completion technology for oil extraction engineering development well [J]. Petrochemical Technology Technology, 2017, 24(06): 247. which greatly improves the efficiency of oil well repair and drilling operations, and is fully in line with the requirements of the petroleum equipment industry in the direction of the development of automation, intelligence, and high efficiency <sup>[4]</sup>.



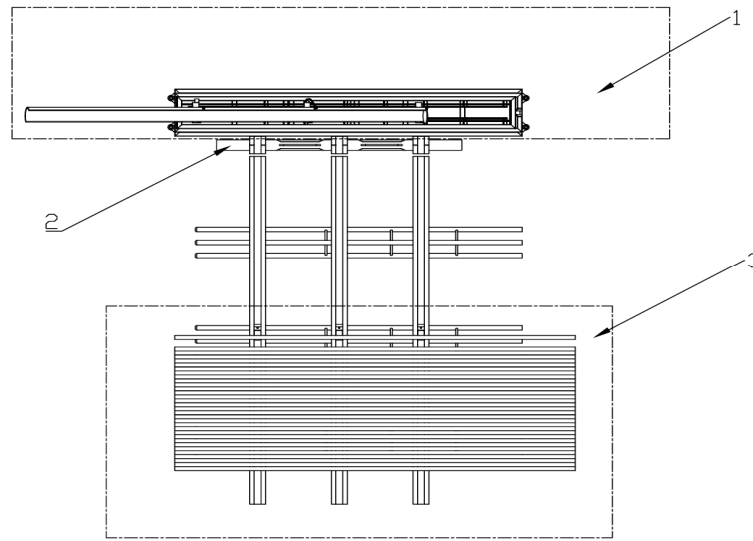
1-U-type receiver tank 2-lifting mechanism 3-moving trolley 4-hydraulic cylinder body 5-automatic pipe rack 6-lifting frame

**Figure 1.** Overall structure of the automatic tubing discharge device of the well dressing machine

## 1.2. Functional modules of the automatic piping system

In order to ensure the smooth working of the ground

automatic piping system, the following three functional modules should be taken into consideration when designing the technical solution, as shown in Fig. 2:



1. Tubing receiving module 2 - Tubing lifting module 3 - Tubing transportation module

**Figure 2.** Functional division of the drain device

(1) Tubing receiving module: Its main function is to transport the tubing or other placed on the tubing support workover tubing to the workover platform the top of<sup>[5]</sup>. Under the premise of ensuring the realization of the main function, it is also necessary to ensure that the transportation of the tubing process is as smooth as possible, and that the oil rods, tubing and other tubing are transported to reduce the bumping and avoid large deformation of the drill pipe and cracks and other phenomena, and to ensure that the performance of the pipeline in the transportation process.

(2) Lifting module: The function of this module is to be arranged lift the pipe tools or lower to to the as same the pipe racklevel . Horizontal way is not widely used, and there are limitations in the field, feeding efficiency and safety is not high enough, so in the pipe arrangement, the realization of lifting or lowering the pipe fittings can improve its reliability.

(3) Conveyor module: The function of this module is to transport the pipe tools, which can be moved back and forth, both to and from the pipe racks of the power catwalk<sup>[6]</sup>.

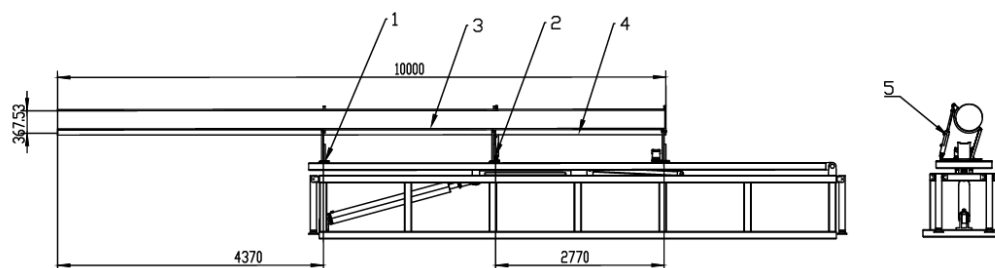
## 2. Automatic Pipe Discharge Device Structure Design

This chapter provides a comprehensive analysis of the structural design of the automatic tubing discharge device of

the well dressing machine, including tubing conveyorthedeign of the and the baseincline-making mechanism of the , the slide and its overturning mechanism, the incline-making mechanism , and elaborates in detail on the working principle of each part, structural composition, key dimensional parameters and the selection of materials.

### 2.1. Chute mechanism design

The chute includes the main chute, auxiliary chute, fixed seat, etc. The main chute as a whole presents a U-shape, this unique design helps to better support and guide the oil pipe to ensure that it remains stable during transportation, the mechanism is mounted on a two-section telescopic frame, through the expansion and contraction of the overturning cylinder to realize the U-shaped groove of the U-channel overturning and swinging, the length of 10,000mm shown in Figure 3. Inside the high-strength anti-friction plate, easy to use and can well protect the oil pipe wire buckle. The slide is equipped with a flip function to realize the oil pipe in the loading and unloading of materials into, out of the slide<sup>[7]</sup>. The middle of the chute adopts the motor driven rack to push the power to extend the arm, the inner diameter of the chute is  $\Phi 440$  outer diameter  $\Phi 500$  to extend the stroke up to 1.65 meters.



1. Two end hinge seat, 2- middle hinge seat, 3- U-channel, 4- telescopic beam, 5- overturning hydraulic cylinder,

**Figure 3.** Ramp Structure

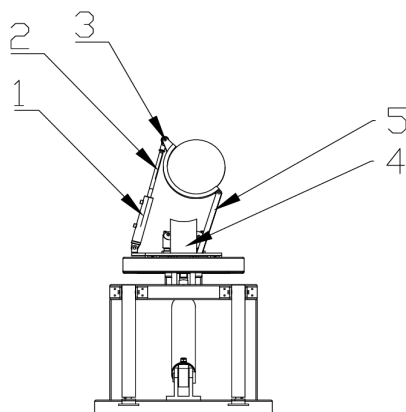
In order to connect with other mechanical structures, the top of the ramp is designed with a lug plate to connect with the edge of the drilling platform, and the bottom is designed with a lug plate to connect with the base of the , so that the angle between the ramp and the horizontal plane is land-based pipe conveyor30°.

**Table 1.** Technical parameters of the slide mechanism

sports event	Dimensions (mm)
Length of chute	10000
Width of the chute	500
Inner groove width of the chute	440
Height of chute (extended state)	7112

## 2.2. Design of tipping mechanism

It through the realizes the efficient and safe transportation and dispatching of the oil pipe components such and so on as shown inpower arm, slide rail, overturning hydraulic cylinder, joint bearing, U-groove support plate, auxiliary support Figure 4. In this system, the tipping mechanism is a crucial part, the main function is that after the receiver unit receives the oil pipe, it needs to make the oil pipe flip sideways and roll down smoothly to the oil pipe lifting mechanism next to it through the tipping mechanism [8].



1-Tilting hydraulic cylinder body 2-tilting hydraulic piston rod 3-joint bearing 4-U-channel support plate 5. auxiliary support

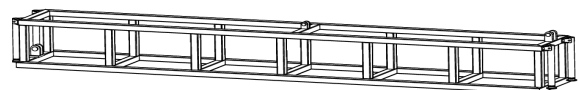
**Figure 4.** Sketch of flip mechanism

The overturning mechanism is mounted on the telescopic frame, and the overturning and is realized through the expansion and contraction of the overturning hydraulic cylinderswinging of the U-shaped groove , and the constituent parts of the overturning mechanism need to withstand the weight of the oil pipe, so there is a support plate underneath, and it should be sufficiently sufficient strength and durability, and the drive mode of the adopts the hydraulic control, which has overturning mechanism designed herein the advantage of occupying small space [9], having a simple structure, and being able to provide even power output, the tipping hydraulic cylinder is connected to the ear seat of the lift frame through a pin, the other end of the tipping hydraulic rod to the through a joint bearingis connected side of the U-shaped groove ., and the auxiliary support mechanism of the other section to the

other side of the lift frame's ear seat and through a pin to respectivelyis connected the U-shaped groove form a rotating vice , and the maximal stroke of the tipping hydraulic cylinder is 300mm, and the maximal tipping angle is 55°, with an inner diameter of 36mm .

## 2.3. Design of the base

The base is mainly subjected to the pressure from the lifting mechanism in the vertical direction and the interaction force between other mechanisms and the base, and it is also power subjected to shock loads during . The material of the base is with "the start of the catwalkwelded " steelH, which makes the overall structure of the base relatively light [10], the base is also welded with the main beam hinge seat and lifting hinge seat, respectively, with the intermediate main beam and lifting hydraulic cylinder hinged as shown in Figure 5 and easy to dismantle, and the size of its size is determined according to the height of the bottom pipe rack and the length of the oil pipe, and the total length of the oil pipe is determined by the height of the pipe rack. The dimensions are determined by the height of the bottom pipe rack and the length of the oil pipe, with a total length of 9060mm, a width of 1226mm and a height of 565mm.

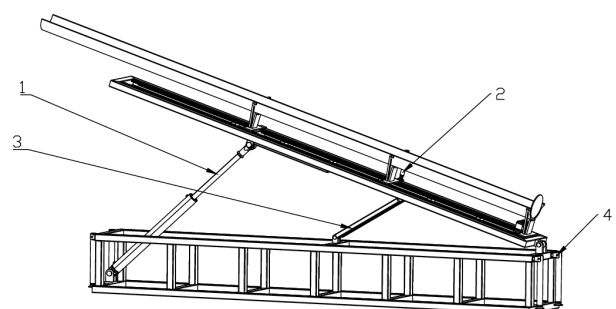


**Figure 5.** Model drawing of the base

The stabilizing mechanism is mainly linked together with the base through the support shaft, and there are four stabilizing mechanisms symmetrically distributed on both sides of the base. Ensure that the device can work smoothly, in the process of transfer device, the stabilizing mechanism is in the open state, at this time to increase the contact area between the base and the groundoil pipeline, when the transfer device does not work, the stabilizing mechanism is recycled to the base side, so that the overall structure covers an area of small, and easy to transport.

## 2.4. Skewing mechanism design

The hydraulic cylinder and piston rod for inclined lifting is the inclined supporting most important part of the mechanism, which bears the whole lifting the driving work of and lowering operation, and is subject to large force, and the hydraulic cylinder and piston rod can be safely operated during the whole lifting process [11].



1-Lifting hydraulic cylinder 2 - Tipping hydraulic cylinder 3 - Auxiliary support 4 - Pins

**Figure 6.** Sketch of tilting mechanism

### 3. Stability Finite Element Analysis of Key Components

The mechanical system of the device is relatively complex automatic tubing the well dressing machine, in order to improve the stability and reliability of the device at work, it is necessary to analyze the strength of the main load-bearing parts to ensure that there will be no instability in the work, and to reduce the potential safety hazards.

#### 3.1. Strength analysis of auxiliary support devices

Auxiliary support as auxiliary lifting hydraulic cylinder

lifting mechanical device, its work in the project can bear the weight of lifting appears to be critical [the results of the static analysis of the static .12,] need to ensure that it will not be destabilized in the work process, so this paper needs to be auxiliary support for the static analysis of the auxiliary support, auxiliary support materials selected for the mechanical analysis Q235. auxiliary support of the loads borne by the auxiliary support mainly occurs in the auxiliary support and the lifting of the loads slip connection, the results of its static analysis simulation as shown in Figure 7, Figure 8, Figure 9. The loads on the auxiliary support mainly occur in the auxiliary support and the lifting weight sliding connection, the results of the static analysis of the simulation as shown in Figure 7, Figure 8, Figure 9.

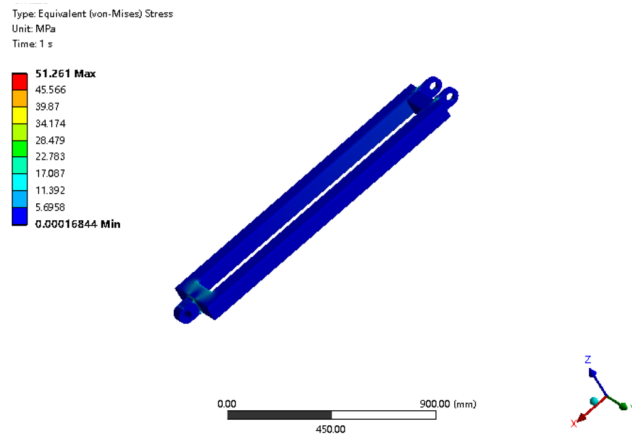


Figure 7. Displacement cloud for static analysis of auxiliary support

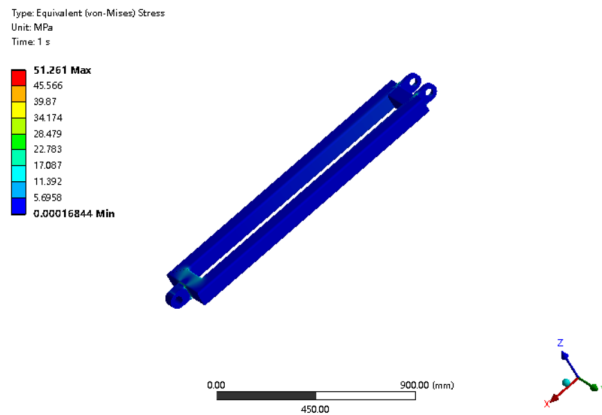


Figure 8. Stress cloud for static analysis of auxiliary support

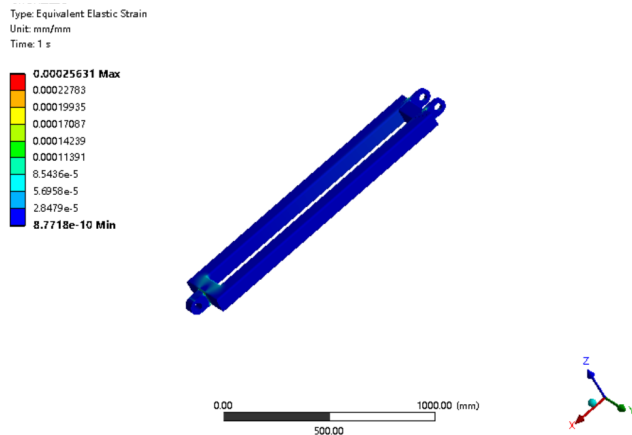


Figure 9. Strain cloud for static analysis of auxiliary support

From the simulation analysis results, it can be seen that: the maximum equivalent force of the auxiliary support occurs in the auxiliary support the middle of member, the maximum equivalent force is 51.261MPa, the maximum displacement is 0.044798mm, and the maximum strain is 0.002563mm, the permissible stress of the material is known to be 117.5MPa, which is much larger than the maximum equivalent force in the analysis results, so the design of the auxiliary support meets the strength requirements.

### 3.2. Base Strength Analysis

The base is mainly subject to the pressure from the lifting mechanism in the vertical direction and the interaction force between other mechanisms and the base, and in the the power will be subject to the impact load process of the action of . starting catwalkThe stabilizing mechanism of the base mainly includes the support pile leg, support arm, support shaft, etc. The material used is Q235.The static analysis of the base is shown in Fig.

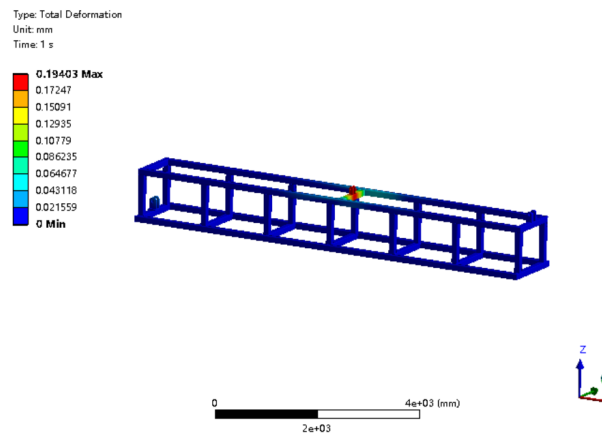


Figure 10. Cloud view of base displacement

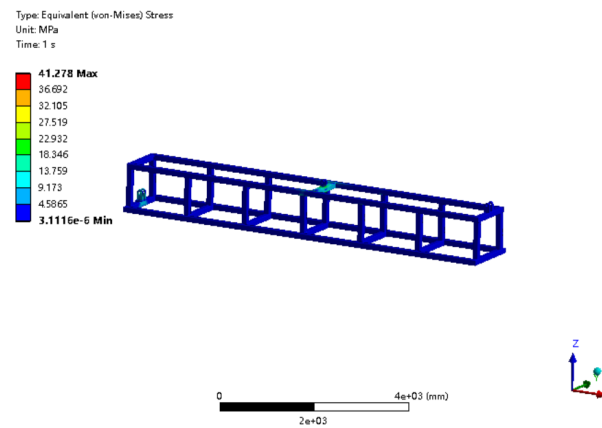


Figure 11. Stress cloud of the base

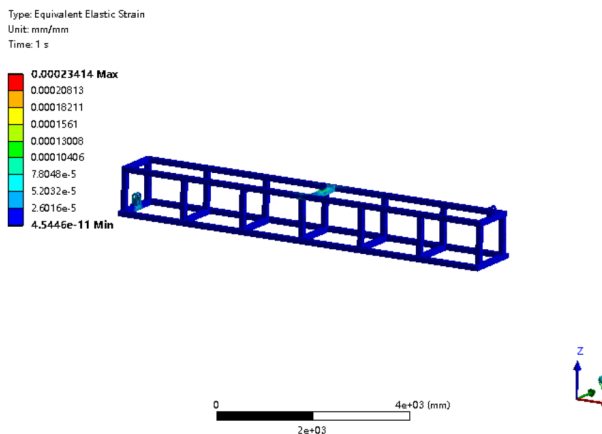


Figure 12. Strain cloud of the base

From the cloud diagram analysis, it can be seen that the maximum deformation is 0.00023mm, the maximum displacement of the base is 0.194mm, are in with the safety

range. The maximum stress occurs in the auxiliary support lugs and base articulation, the maximum equivalent force is 41.278MPa. the known material The permissible stress of is

Q235 117.5Mpa, which is much larger than the maximum equivalent force of the base, so the designed base can ensure the strength requirements of the device, and can ensure the smooth and safe operation of the device in the process of operation.

### 3.3. Lifting mechanism constraints

There are five parts in this assembly: the base, the cross link, the hydraulic cylinder, the two guides and the pin.

Constraints are then added to add a fixed vice between the base and the earth so that the base and earth form a single unit. As shown. Add the moving vice between the hydraulic cylinder and the piston rod to ensure that the piston rod can move in a straight line relative to the hydraulic cylinder, so that the cross-link can be freely extended and retracted, and add the fixed vice between the hydraulic cylinder and the base, so that the hydraulic cylinder and the base become a whole.

**Table 2.** Lifting mechanism constraints

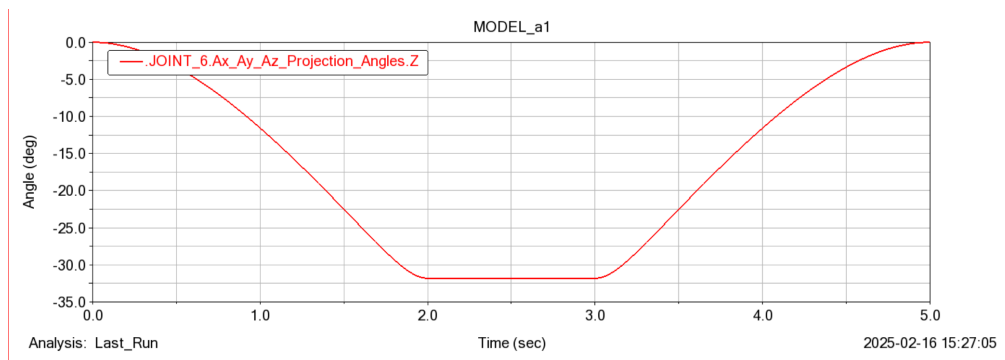
serial number	Component 1	Component 2	restraint
1	foundation	geodetic	stationary sub
2	Crossbar 1	Crossbar 3	rotating disk
3	Crossbar 2	Crossbar 4	rotating disk
4	Upper Lug 1	Crossbar 1	rotating disk
5	Upper Lug 1	Guideway 1	mobile subs
6	Upper Ear Holder 2	Crossbar 2	rotating disk
7	Upper Ear Holder 2	Guideway 2	mobile subs
8	Lower Lug 1	Crossbar 1	rotating disk
9	Lower Lug 1	Guide 3	mobile subs
10	Lower Lug 2	Crossbar 2	rotating disk
11	Lower Lug 2	Guide 4	mobile subs
12	push rod or tappet	crossbar	stationary sub

The model is validated after the constraints and drivers have been applied to check whether the constraints applied are reasonable. The model is validated correctly.

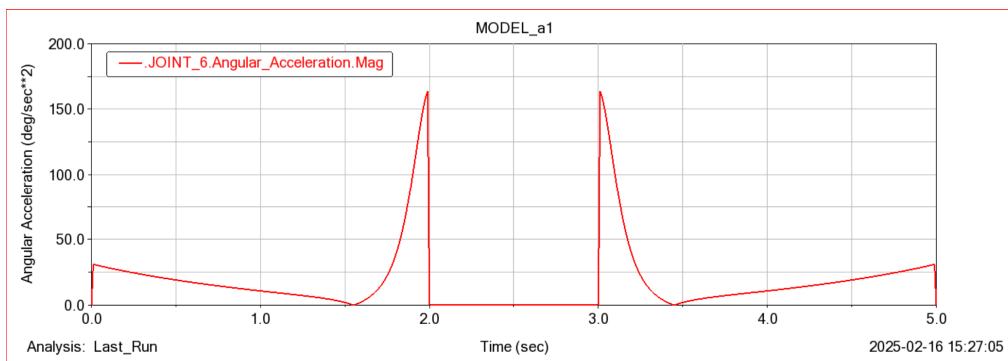
### 3.4. Simulation result analysis of lifting mechanism

As shown in Figure 13 and Figure 14 at about the time points of seconds, there are two distinct peaks in angular acceleration exceeding  $2$  and  $3 \times 150 \text{ }^\circ/\text{s}^2$  degrees per second squared and  $100 \text{ }^\circ/\text{s}^2$  degrees per

second squared. This indicates that the corresponding joints in the model experienced rapid acceleration or deceleration processes at these time points. The rest of the time period is relatively low and the change in angular acceleration is gentle. If the angular acceleration changes too drastically, it indicates that in the operation of the device there is a large shock or instability, which may cause unwanted impacts on the other connecting components or systems, leading to mechanical damage, fatigue, or degradation of performance.



**Figure 13.** Crossbar Angular Velocity



**Figure 14.** Crossbar Angular Acceleration

In summary, the simulation diagrams of angular velocity and angular acceleration not only provide an important basis for the design optimization of the device, but also ensure that

the device can operate smoothly and reliably in practical applications.

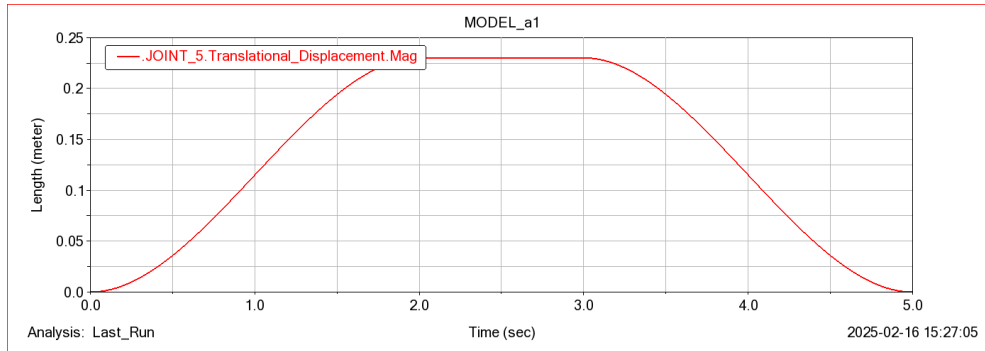


Figure 15. Hydraulic Cylinder Expansion Displacement

As shown in shows lifting mechanism in the Figure 15 the displacement change curve of the direction. The horizontal axis represents time (seconds) and the vertical axis represents displacement (meters). From the figure, it can be seen that the beginning of the simulation the hydraulic actuator rapidly from the initial position (extends 0 m) to about a position of 0.2 m. Subsequently, there is a gradual slowdown from 0.2 to 0.5 seconds, and the displacement continues to rise, reaching a maximum point of approximately 0.25 m, indicating that the hydraulic rod elongation has peaked. After 0.5 seconds, the displacement begins to recover and returns to a position close to the initial position (at 5.0 seconds), and the displacement changes show a process of "first acceleration, then retention, then deceleration" which is in line with a lifting and unloading motion cycle.

#### 4. Summary

Research on the research status of tubing conveyor device, analyze the demand of tubing conveyor device in major oilfields, combine with the existing tubing conveyor device, and determine automatic automated well dressing machine the overall design scheme of transfer device for. Complete the lifting mechanism, of the automated well dressing machine automatic pipelaying device tubing structural design of the sliding way, turning mechanism and base and theoretical calculations and finite element analysis of the main load-bearing parts, and finally complete the construction of the three-dimensional model, and use the ADAMS simulation software to establish the simulation model of the lifting mechanism, and carry out the dynamics of simulation analysis of its simulation results show that: the lifting mechanism thrust and the speed of the piston rod movement is very different from the previous theoretical calculation results. The simulation results show that the thrust force of the lifting mechanism and the movement speed of the piston rod error with the previous theoretical calculation results have very little, which can effectively reduce the damage of the oil pipe and the pumping rod in the conveying process, and verifies the reasonableness of the design of the automatic pipe removal mechanism.

#### References

- [1] Gao Hanchen. Development of oil pipe righting device for mechanized well repair operation[J]. Chemical Management, 2018, (07):136.
- [2] Zhang Lei. Optimized design of spatial motion trajectory of oil pipe conveying device[J]. Drilling and mining process, 2017, 40(02): 71-73+10.
- [3] PANG Yuhan. Research on the quality requirements of well completion technology for oil extraction engineering development well[J]. Petrochemical technology, 2017, 24(06): 247.
- [4] Zhang Baoping. Optimization of jack-up platform seating design during oilfield development[J]. Marine Engineering, 2024, 53(05): 120-125.
- [5] YANG Zhen, HAN Kui Liang, WU Song Ping, et al. Research on lifting technology of well dressing machine[J]. Petroleum and Chemical Equipment, 2024, 27(07):80-84.
- [6] YANG Xijun, LIU Yao, ZHAO Dong, et al. Design and analysis of pickup and delivery device for automatic automated rod and pipe well dressing machine[J]. Petroleum Mining Machinery, 2023, 52(06):39-46.
- [7] MU Xiaoping. Design of hydraulic control system for vehicle-mounted integrated well dressing machine with pressure operation[J]. Hydraulic Pneumatic and Sealing, 2023, 43(05): 37-42.
- [8] Mao Jianhua. Management and maintenance of mechanical equipment for oil well repair[J]. Chemical Design Newsletter, 2022, 48(05):26-28.
- [9] Huang Jingling. Design and analysis of blowout preventer spreader for offshore platform workover[J]. Equipment Manufacturing Technology, 2022, (02):225-228.
- [10] YAO Jun-Cai, YIN Ze-Gang. Application of hydraulic lifting workover technology in Bohai oilfield [J]. Technical Supervision of Petroleum Industry, 2022, 38(01):51-54.
- [11] QI Jie, LIU Xuejia, LIU Shifeng. Research on blowout preventer control system for pressurized workover operation problems based on solving well control safety [J]. China Equipment Engineering, 2021, (15):26-27.
- [12] Wang LX. Analysis of applicability of different well workover modes in offshore oilfields[J]. Guangdong Chemical Industry, 2021, 48(09):156-157.