Design and Application of New Support and Power System of Residential Building Machine

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Abstract. In recent years, with the transformation and upgrading of national development and the acceleration of urbanization, the construction mode of high energy consumption, high pollution and high labor intensity in the construction industry can no longer meet the development needs. The State Council and the Ministry of Housing and Urban-Rural Development have successfully issued policies and initiatives to improve industrialization and intelligent construction. In 2021, the Ministry of Housing and Urban-Rural Development issued a building height limit order, and it has become a trend that aerial building machines have begun to diversify into ordinary high-rise residences. The "14th Five-Year Plan" construction industry development plan issued by the Ministry of Housing and Urban-Rural Development proposed accelerating the coordinated development of intelligent construction and new building industrialization and promoting digital design, intelligent production and intelligent construction. In response to the national policy guidance and leading the development of the industry, solve the inherent problems in the construction industry, learn from the application concept of super high-rise heavy-duty construction equipment integration, create a "factory-like" construction environment for ordinary high-rise through lightweight, standardization and intelligent and other innovative technologies, and explore a construction integration platform suitable for high-rise residences, called "high-rise building industrialization construction lightweight construction operation integration platform" (referred to as "building machine"). Based on the first generation of building construction machines, continuous improvement and replacement, the supporting power system has dramatically improved in support capacity and lightweight. The effective combination of a support column, hydraulic cylinder, and pump station has been realized, which is more convenient and faster, and the construction is more efficient.

Keywords: Intelligent Construction; Residential Building Machine; Bearings and Power Systems.

1. Introduction

"Building machine" is the full name of "high-rise building construction lightweight construction operation integration platform," which is mainly composed of a support and jacking system, steel platform system, hanger system, formwork system, auxiliary facility system, integrated operation machinery and material storage yard integrated multi-layer operation platform.

The functional partition of the "building machine" facade is successively divided into a subsequent operation layer, fulcrum climbing layer, concrete curing layer, template operation layer, steel bar operation layer, steel platform layer and top pile layer from the bottom to the top, thus forming a three-layer three-dimensional cross operation, which reduces the safety risk compared with the traditional construction mold frame, improves the working environment, realizes all-weather construction operation scenario, and dramatically improves the construction efficiency.

Compared with the previous "top die system," the main components are standardized and prefabricated steel parts. The turnover rate of various components can reach more than 90%, which significantly improves the turnover rate, reduces the cost and improves the applicability.

Fig 1. Engineering effect.

2. Support system design

In the continuous improvement of the building machine, the support and lifting system is also constantly improving, to the support capacity is more substantial, lighter weight trend development has formed a new generation of support and lifting system, the central support system is mainly composed of the support column, lifting cylinder, support hanging jaw, wall support (three supports, from top to bottom, support one, support two, support three). Therefore, the details of each step are as follows: In the construction state, each group of supporting columns is supported and fixed by three supports. In the jacking state, only the upper support and the middle support bear the force, the middle support bears the main load, and the upper support only bears the horizontal force. When jacking up, the column is placed on the upper support and the middle support hook claws and the force is exerted. First, action a locks the lifting pull rod at the middle support, and then the oil cylinder of action b pushes the bottom beam of the lifting pull rod downward to drive the column up. The hook claws at the column and the support are detached [1]. Action c unlocks the lifting rod at the middle support. The cylinder is withdrawn, driving the rod to rise. After recovering a stroke, lock the middle support rod again, and then repeat actions A, b, c to repeat the cycle until the top rises to the predetermined height.

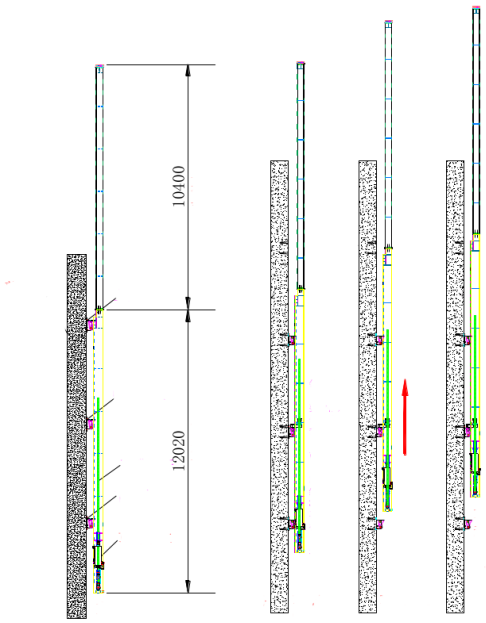

Fig 2. Hoisting principle diagram of the support system.

2.1. Design of connection between bearing support and structure

An embedded rotating screw connects the fulcrum and the structure. The embedded screw is buried in the vertical steel bar by locating the steel plate. After the concrete is poured, the locking bolt is removed, the positioning template is removed, and the wall support is installed [2]. Single wall support is fixed by six bolts (4 in the upper row and 2 in the lower row). When linear bolts cannot be installed in the rigid structure of the wall, horn bolts with the same bearing capacity level can be used instead. Details are shown in Figure 3.

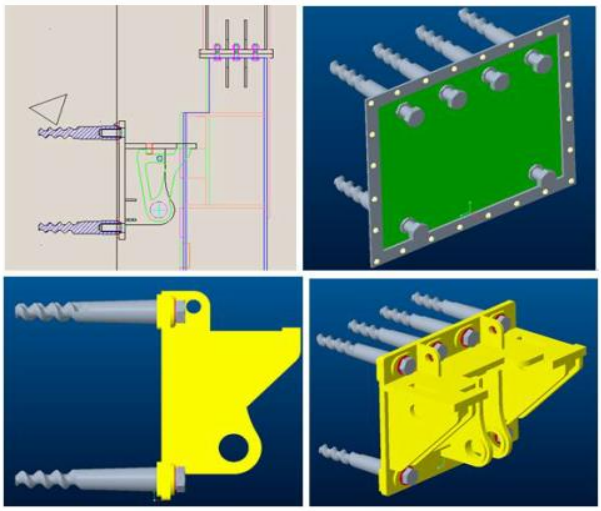

Fig 3. Schematic diagram of support system fulcrum assembly.

2.2. Anti-fall and anti-overturning function design of the supporting system

The anti-overturning function is realized through the meshing matching design of the opening profile of the attached wall support's end face and the supporting column's cross-section profile. The hanging PAWS of the support stand against the ladder of the supporting column and limit the fall of the guide rail to achieve the anti-fall function, as shown in FIG. 4 for details:

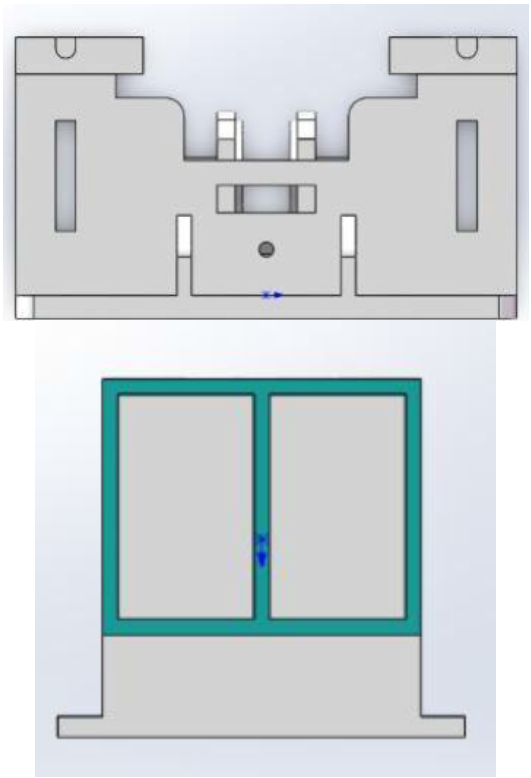

Fig 4. Schematic diagram of the anti-overturning structure.

3. Power and control system design

3.1. Basic Functions

The power system of the intelligent jacking frame adopts an electro-hydraulic direct drive hydraulic system. The basic principle is that the speed-regulating motor drives the bidirectional hydraulic pump, and the hydraulic cylinder is directly driven by the bidirectional hydraulic pump [3]. The system comprises an electro-hydraulic direct drive oil cylinder, electrical control cabinet, connecting cable, etc. Multiple electro-hydraulic direct drive oil cylinders are dynamically adjusted and monitored synchronously through oil pressure and real-time displacement to realize synchronous lifting of multiple oil cylinders. At the same time, each electro-hydraulic direct drive cylinder has a manual emergency operation in the fault state, and a single cylinder can be put back to the lowest position. The electro-hydraulic direct drive hydraulic system can be used generally under humid air, vibration and shock caused by regular platform operation.

3.2. Main Components Description

The components of the electro-hydraulic direct drive hydraulic system are shown in Table 1 below.

Table 1. Components of electro-hydraulic direct drive hydraulic system of intelligent jacking die frame.

serial number	Feature	Detailed
1	Electrohydraulic direct drive cylinder	The power system of intelligent jacking frame lifting, including the oil cylinder, motor pump group
2	Electrical control cabinet	Accept the command from the control room of the intelligent jacking mold frame, and control the synchronous lifting of multiple electro-hydraulic direct-drive cylinders, including control software and HMI (touch) of the operating end. Screen).
3	Connecting power cable	Electric control cabinet to electro-hydraulic direct drive cylinder transfer motor power signal, including Special plug.
4	Connect the signal shielding cable	Electrical control cabinet to electro-hydraulic direct drive cylinder transfer sensor signal, including special Use the plug.

3.3. Main equipment technical solutions

3.3.1. Electro-hydraulic direct drive cylinder

According to the working conditions and technical requirements of the intelligent jacking system, the overall structure of the designed electro-hydraulic direct drive cylinder is shown in Figure 5 below.

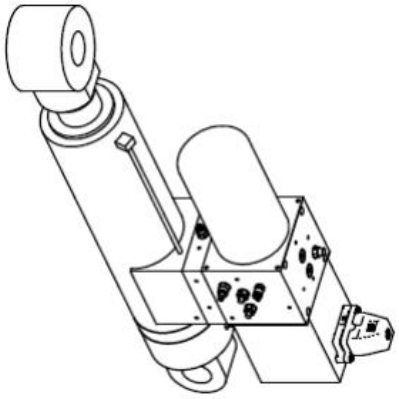

Fig 5. Electrohydraulic direct drive cylinder.

3.3.2. Electrical Control Cabinet

The electronic control system has manual, automatic and mode.

Manual mode is usually used for maintenance conditions: Each electro-hydraulic direct drive actuator's rise, fall and stop can be adjusted separately.

Automatic mode is usually used for local operation synchronous lifting conditions: In automatic mode, the multi-cylinder synchronization function is automatically invested, which can realize the synchronous rise, fall and stop of local operation instructions.

The operation panel of the electrical control cabinet is provided with the manual operation button of the lifting system and the running status indicator. The layout is shown in Figure 6 below:

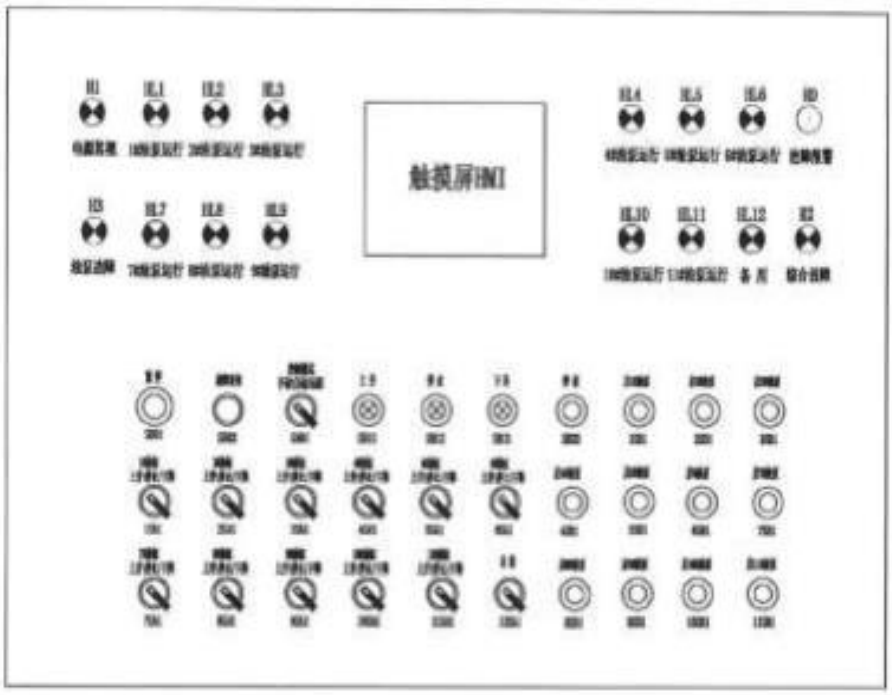

Fig 6. Operation panel of electrical control cabinet.

Cylinder parameters are designed as follows. Known: cylinder diameter D=226mm, rod diameter d=160mm, speed V=3mm/s, hydraulic cylinder thrust F=100T. Then:

Rodless cavity area S1=0.25*pi*D*D=0.04 m^2.

Rod cavity area S2=0.25*pi*D*D-0.25*pi* D*D =0.02m^2

Hydraulic cylinder flow Q=S1*V=7.22L/min.

The maximum working pressure of the hydraulic cylinder P=F/S1=25MPa.

Motor power W=P*Q=3.27kW, choose 4kW motor.

4. Support system check

According to the Midas checking model and material weight statistics, the maximum vertical force of a single fulcrum is not more than 1000kN (100t). 1000kN vertical force is the standard checking calculation

4.1. Checking the calculation of the attached wall supports

The support material of the attached wall is Q355, and the hook and pin materials are 40Cr. considering the force of only one support in the most unfavorable state, the vertical force of 1000kN is applied to the hook and pin of the attached wall support. The concentration is not apparent, and the maximum stress is less than 345MPa. The maximum stress of the hook is less than 785MPa, which meets the requirements of the mechanical properties of materials. This is shown in Figures 7 through 9.

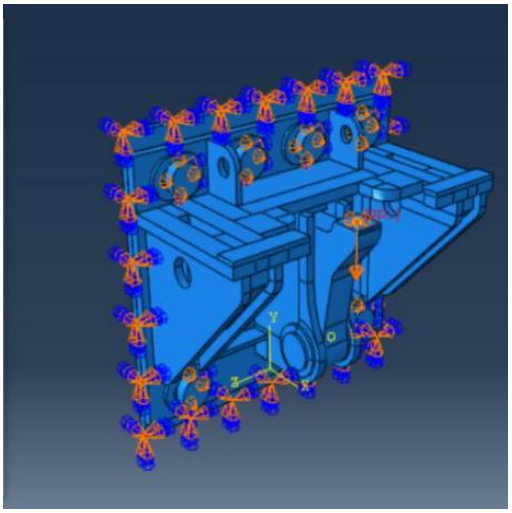

Fig 7. Loading of attached wall supports.

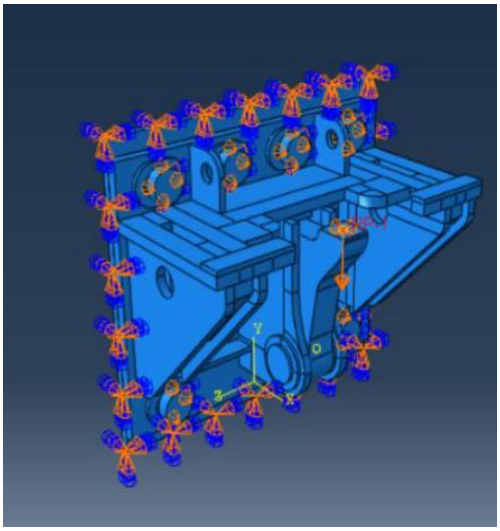

Fig 8. Overall checking results of wall support.

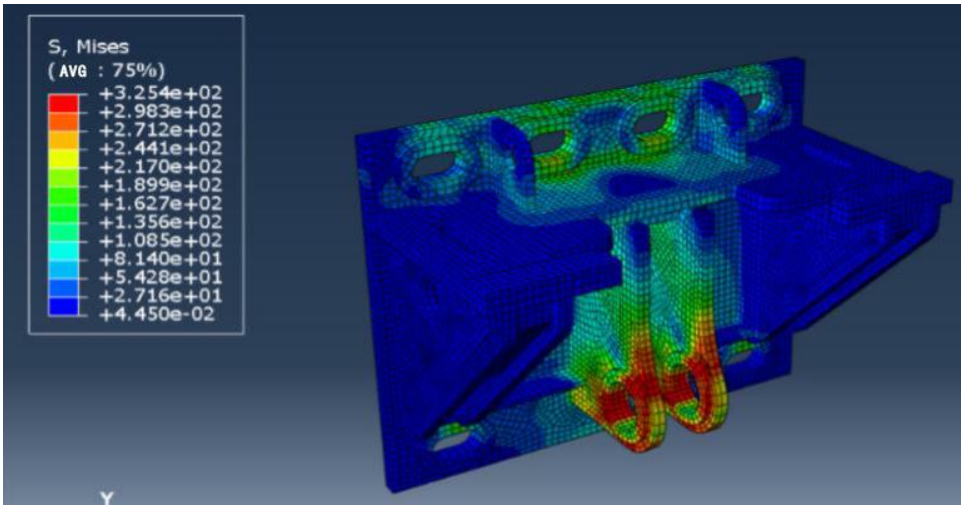

Fig 9. Verification results of the bottom plate of the attached wall support.

4.2. Check the height column

The material of the tall column is Q355, and the vertical force of 1000kN is applied to the top of the tall column for simulation. Results the maximum stress was 318MPa, and the strength met the requirements of material properties. The results are shown in Figures 10 and 11.

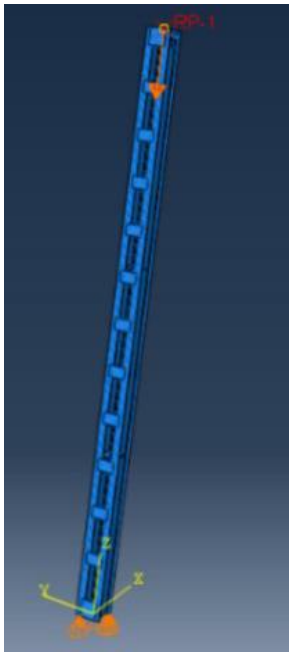

Fig 10. Loading with high column.

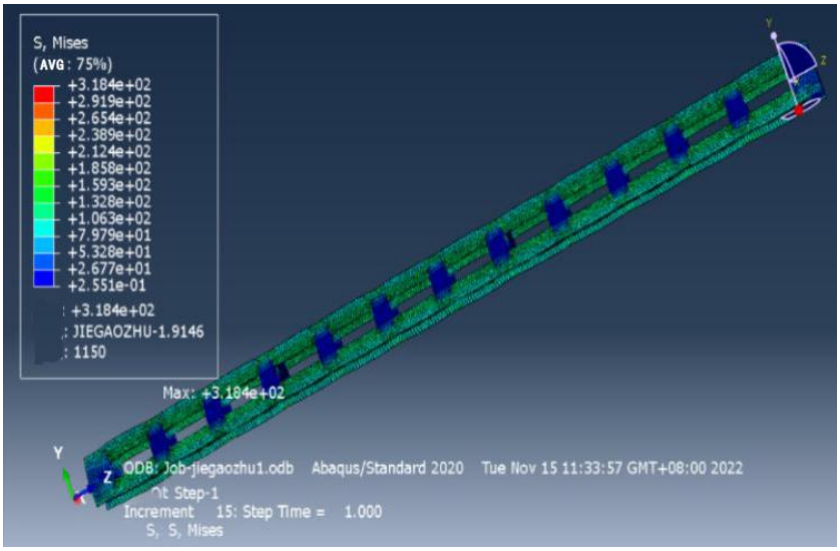

Fig 11. Results of checking the high column.

4.3. Verification of support columns

The material of the supporting column is Q355, and the material of the bearing part of the hook is 40Cr. The vertical force of 1000kN is applied to the top of the column, the horizontal tension of the two supports is provided to prevent overturning, and the vertical upward boundary condition is provided to simulate the hanging claw in the middle. Results the maximum stress of 559MPa is less than the allowable stress of 40Cr material 785MPa, which conforms to the mechanical properties, and the bearing capacity of the column meets the requirements (FIG. 12-13).

Fig 12. Loading of a support column.

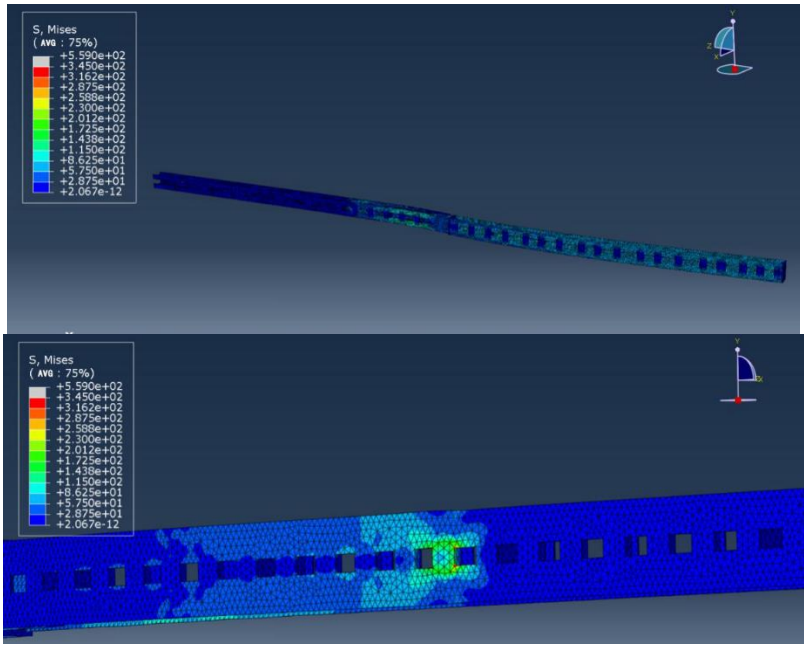

Fig 13. The most unfavorable part of the support column.

5. Acceptance requirements and safety assurance measures

5.1. Acceptance Requirements

According to the relevant requirements, it is necessary to accept the intelligent lift-up support system and hydraulic system during the approach, and installation stage, before the first lift, before each lift, and after each lift.

5.2. Security Measures

The tower and formwork must be securely connected to the platform; Check the connection node bolts regularly and keep them tight; Check welds regularly, and repair in time if cracks appear; Check uprightness regularly.

6. Concluding Remarks

Through the continuous improvement of technology based on the first generation of residential building machines, through the application of lightweight and standardized technological innovation, the effective combination of the support column, the hydraulic cylinder, and the pumping station is realized. All of them are installed on the support column, reducing the redundant process and realizing the weight reduction of the frame, which can be applied in similar high-rise residential projects.

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