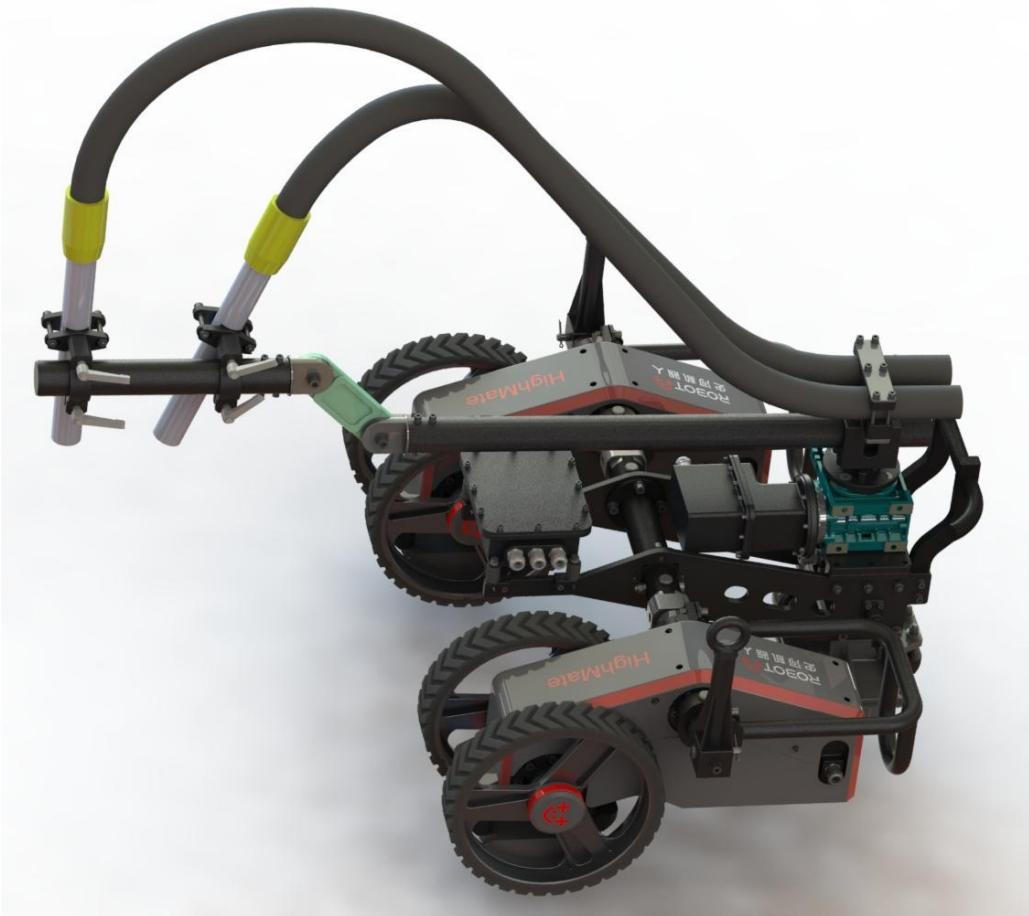


HighMate® A-Series Swing Arm Blasting Robot Operation Manual



www.robotplusplus.com

RobotPlusPlus Co., Ltd.

2024.04

Preface

No toxic or harmful materials are used in the manufacturing process of the robot products.

Environmental protection in the production process is implemented in accordance with ISO14001 standards.

This robot product complies with the following specifications and standards:

● Chinese Standards

Classification of work at heights: GB3608-2008

Electrical safety of machinery — Electrical equipment of machines — Part 1: General requirements: GB/T5226.1-2019 / IEC 60204-1:2016

Safety rules for aerial work machinery: JG/T 5199-1998

Safety specification for the use of manually operated high pressure waterjet equipment: GB 26148-2010

● International Standards

The surface after cleaning meets the standard of AMPP (NACE NO.5 / SSPC-SP12): Surface Preparation and Cleaning of Steel and Other Hard Materials by High- and Ultrahigh-Pressure Water Jetting Prior to Recoating

EU MD (Machinery Directive) 2006/42/EC

EU RED (the Radio E Directive): 2014/53/EU under CE

Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environment: EN 61000-6-2:2019

This manual is prepared and revised by RobotPlusPlus Co., Ltd., Product Development Department.

To the extent permitted by Chinese laws and regulations, RobotPlusPlus Co., Ltd. reserves the right to interpret this manual.

This manual was first published in April 2024.

Safety Guide

Typical Symbols



This is a safety warning logo. Once this logo is noticed in this manual or on the machine, please be aware of the possible risks involved. Follow the safety precautions and operate safely.



This symbol, DANGER, indicates immediate hazards which **will** result in severe personal injury or death.



This symbol, WARNING, indicates hazards or unsafe practices which **could** result in severe personal injury or death.



This symbol, CAUTION, indicates hazards or unsafe practices which **may** result in minor personal injury or product or property damage.



This symbol, NOTICE, is used to highlight suggestions which **will** result in enhanced installation, reliability or operation.

Declaration

Before using/operating our product, please read this manual carefully and make sure a comprehensive understanding is achieved in order to use the product correctly and safely, hence preventing any property loss or accidents due to human errors.

Qualified Operation and Maintenance Personnel

Only trained personnel with basic safe operation and maintenance skills are allowed to implement the robot products or systems in this manual. Its operation and maintenance shall follow the instructions in this manual, especially the safety requirements and warnings therein.

Warranty Instructions

The company provides limited warranty (under normal use and in accordance with operating instructions) for each product it manufactures. If sold to the end user, the warranty period commences from the date of delivery to the use, and the limited warranty maybe carried on to any subsequent assignee.

Our limited warranty does not apply to the following conditions:

- 1) Consumables, including but not limited to nozzles, tyres, rotator parts and seals, brushes, etc.
- 2) Failure caused by methods not recommended by the manual or human damage.
- 3) Changes or modifications without written permission of Robot++, which may adversely affect the stability, operation or reliability of the equipment.
- 4) Failure caused by misuse of parts, operation errors, accidents or improper maintenance of equipment and other similar behaviors.

Product Upgrade

The company reserves the right to update and upgrade the robot products without prior notice. Except for its own safety defects, the company does not provide free updates and upgrades services.

Copyright Declaration

All contents of this manual are copyrighted by RobotPlusPlus Co., Ltd., and shall not be reproduced, copied, translated, distributed or otherwise exploited without the permission of RobotPlusPlus Co., Ltd. This manual contains no warranties of any kind, statements of position, or other implications. The product specifications and information mentioned in this manual are for the reference of this model robot only.

FCC Certification Declaration

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Radiation Exposure Statement:

1. This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment.

This equipment should be installed and operated with minimum distance 20cm between the radiator & your body.

2. The device has been evaluated to meet general RF exposure requirement.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and

on, the user is encouraged to try to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

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1. Safety Instructions

HighMate A10/20 uses abrasives propelled by compressed air or Ultra High Pressure (UHP) water as the medium to do surface preparation and cleaning jobs at high altitudes, which has certain risks in use. Therefore, the following instructions should be read carefully to prevent accidents.

- 1) **Safety training:** relevant personnel should be trained before any set-up, operation or maintenance.
- 2) **PPE (Personal Protective Equipment):** workers must wear appropriate PPEs, including safety helmet, safety belts, safety shoes, suits, goggles, etc.
- 3) **Risks of hydroblasting:** operators of hydroblasting should realize the risks of it, since it could cause serious injuries or deaths to human.
- 4) **Requirements of surfaces:** since the robot uses strong magnets to keep adsorption, the surfaces need to be made of steel. The thickness should be more than 8 mm to prevent the robot from falling.
- 5) **Risks of strong magnets:** the robot is mounted with strong neodymium magnets, hence relevant personnel must prevent themselves from putting hands between the magnets and any steel tools or plates, or any metal that can produce attraction forces to avoid injuries.
- 6) **Electrical safety measures:** the power of control cabinet for the robot is 220V AC, and the direct supply to the robot is 48V DC. The installation and maintenance should be done by professional electricians to avoid electric shock.
- 7) **Safety accessories:** to ensure safety, accessories such as fall arrestor, fixed pulley, safety tether and safety buckles are used together with the robot.
- 8) **Cold environment:** while working at low temperatures, any stop or even a short pause of work requires the operator to drain all the water from the water jet assemblies. On the other hand, a careful check must be done every time before start working, to ensure nothing is frozen so that it can work properly.

2. Robot Introduction

2.1 Product Overview

HighMate® Swing Arm Robot is used to blast the coating or rust on the steel surfaces like ship hulls and storage tanks. It has the functions of one-key lane changing, automatic and manual control, etc. The robot has characteristics of high efficiency, wonderful surface curvature adaptability, strong obstacle crossing ability and good anti-slip performance. It mainly consists of a robot, a control cabinet and a remote control, shown by Fig 1.

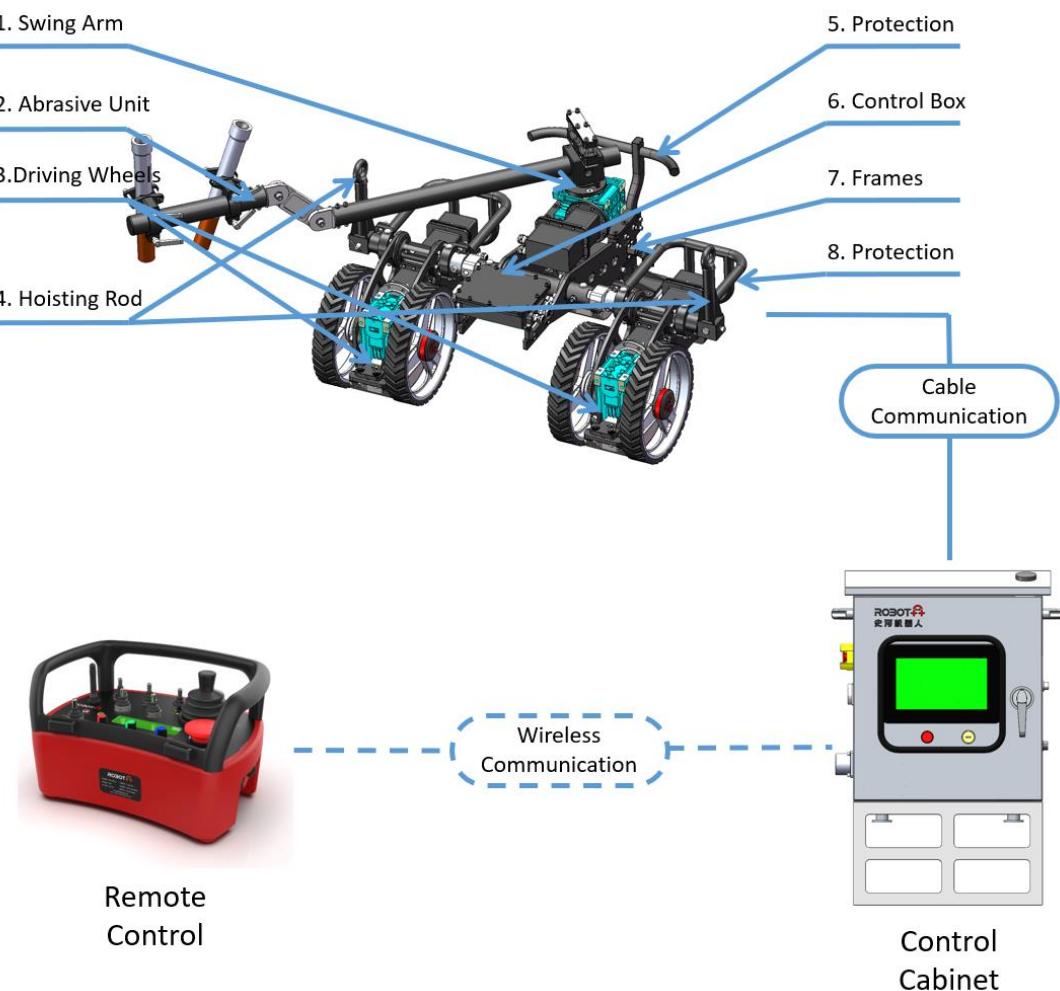


Fig 1. HighMate A-Series Robot Overview (A20 as example)

2.2 Technical Specifications of the Product

Item	Specifications
Power Supply	Electrical Control Cabinet 110 - 240V AC 47 - 63 Hz
	Robot 48V DC
	Total Power 1400 W
Driving System	Power 600 W * 2
	Speed 0 – 10 m/min
Remote Control	Frequency 915 MHz
	Distance 80 m
Platform Performance Specifications	Weight A15: 96 kg / A25: 93.5 kg
	Size A15: 1200*1045*590 mm A25: 1426*1045*610 mm
	Maximum Load 150 kg
	Minimum Curvature 3 m Radius
	Obstacle Crossing ≤18 mm
Hydroblasting Specifications	Efficiency 30 – 50 m ² /h (WJ2.0 / Wa2.5)
	Working Width 1400 mm
	Working Temperature 0 – 55 °C
	Maximum Flow Rate 30 L/min
	Maximum Pressure 2800 bar
Abrasive Blasting specifications	Efficiency (per nozzle) 30 – 40 m ² /h
	Working Width 1700 mm
	Working Temperature -10 – 55 °C
	No. of Nozzles Recommended 2
	Air Pressure 0.8 MPa
Swing Arm Specifications	Power 200 W
	Speed 0 – 4.25 rpm
	Torque 110 Nm
	Swing Angle 90° Default, Adjustable
Adhesion Method	Permanent Magnet
Protection Degree	IP 65, Key Parts IP 68
Operation Method	Autonomous / Semi-autonomous / Manual

2.3 System Instructions

2.3.1 Interfaces

HighMate® Swing Arm Robot has only one external 6P interface, as shown by Fig 2. Users can connect the corresponding aviation plug of the power supply to the 6P connector of the robot.

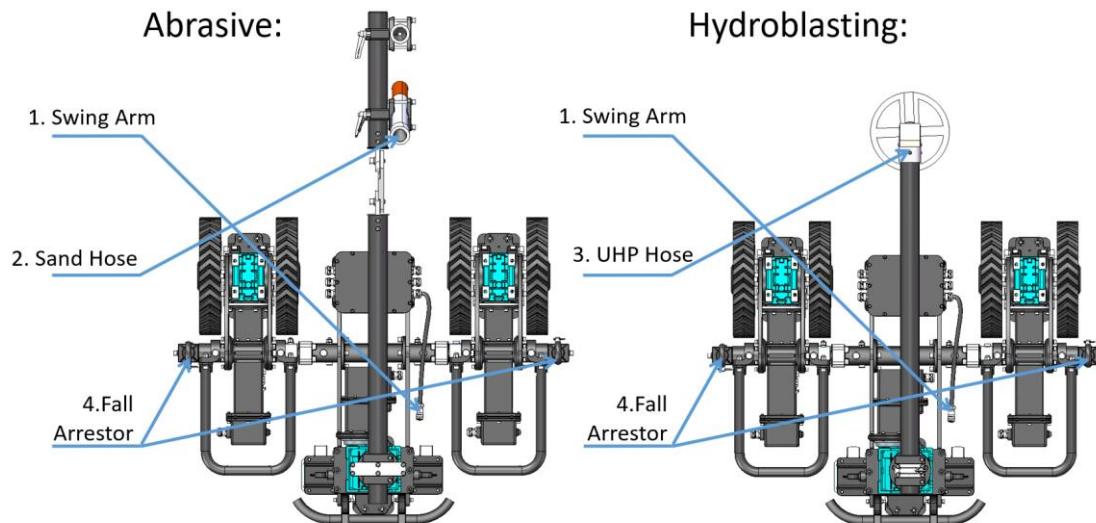


Fig 2. Robot Interfaces

Take Note:

- 1) When connecting the cable to the interface, a click sound represents that the connection is in place. Note that the aviation plug has a fool-proof design, and it needs to be ensured that the plug is inserted to the holes on the socket correctly. If an obvious resistance force is felt during inserting, do not continue and re-check, otherwise it will cause damage to the plug.
- 2) The connection point under abrasive-blasting mode is used to connect the sand pot. Clean both the inlet and outlet of the connector before connection to prevent any jammed nozzles. Use burst proof chain to fix the sand hose onto the swing arm.
- 3) The connection point under hydroblasting mode is used to connect the UHP pump. When connecting, the tube head and the inlet must be cleaned up to avoid any foreign bodies. The tube should be fixed onto the swing arm with a burst proof chain.

- 4) Every robot needs two fall arrestors while working. The arrestors need to be hung on the shackles of the lifting rod simultaneously.

2.3.2 Interface and Accessories of the Control Cabinet

Control cabinet is the ground control terminal specifically designed for the robot. By using a remote control, the robot can be operated. Take note that the remote control and control cabinets are paired up and follow a strict one-to-one requirement. When the devices are delivered, there are already obvious labels indicating the pair. Users can also add their own label or marks to prevent confusion.

1) External Components

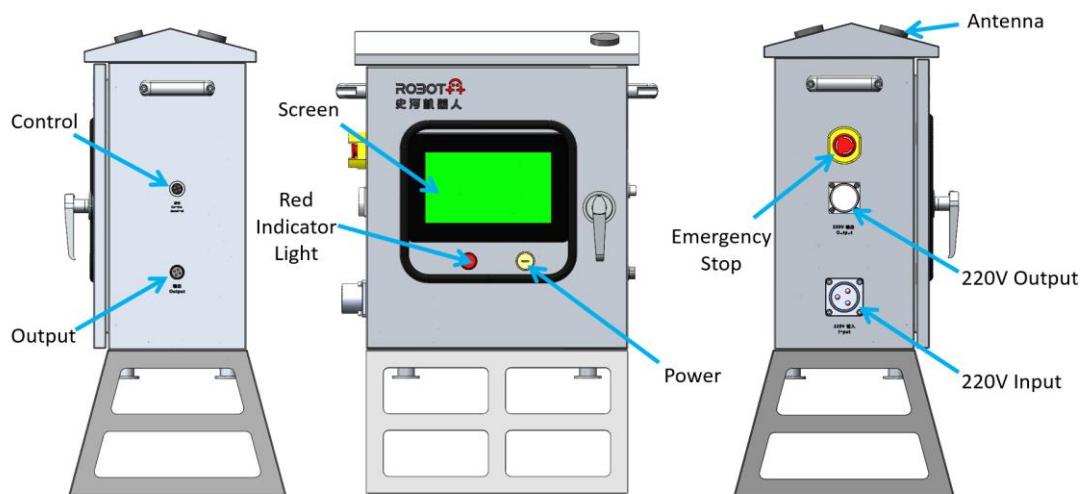


Fig 3. External Structure of the Control Cabinet

- Control interface: control the spot blasting valve and UHP pump
- Output interface: power supply between the cabinet and the robot
- 220V Input interface: power input of the 220V AC
- 220V Output interface: 220V AC socket
- Emergency stop button: used for emergency stop, cut-off the power of robot immediately
- Antenna: remote control antenna, 915 MHz frequency.
- Indicator light – red: when it is on or blinking, it means that there is an error or the emergency stop button is not released

- Switch: control the power of the cabinet
- Screen: after the power is turned on, a logo will be shown. When the robot is operating, the screen will show the specifications include total time, error code, moving speed, loading percentage, version number, track changing distance and current operation method.

2) Internal Components

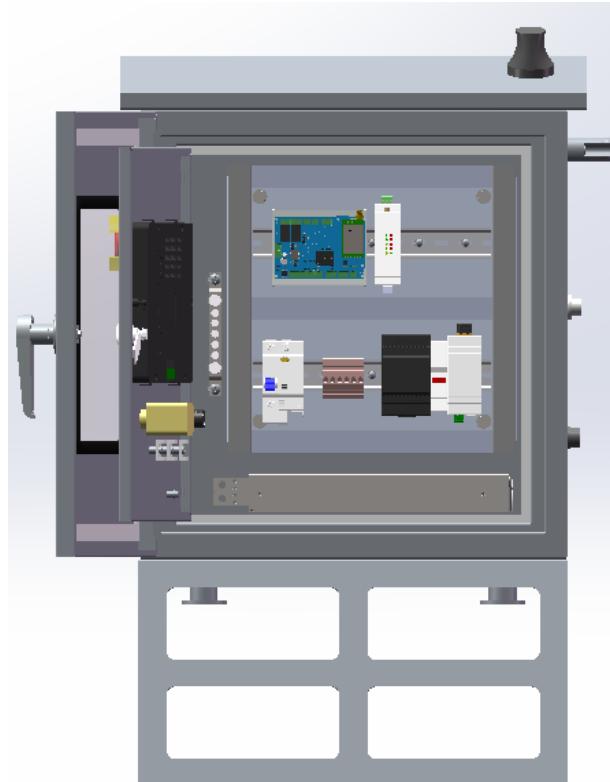


Fig 4. Internal Structure of the Control Cabinet

- Antenna 1: remote control antenna, 915 MHz.
- Mainboard: cabinet control module and communication with robot
- DTU Module: 4G module, communication with IOT
- RCD: overload and short-circuit protection module, mainly used in accidents of leakage failure and fatal danger of personal shock protection
- Switching Power Supply 1: power module transforming 220V to 24V, supplies power to the control circuit
- Switching Power Supply 2: power module transforming 220V to 48V,

supplier power to the robot

- DC Fuse: 32A DC fuse
- Ground Terminal: ground wire connection point for the shell of the cabinet.

2.3.3 Remote Control Introduction

Fig 5 shows the remote control and corresponding buttons.



Fig 5. Different Views of the Remote Control

Item	Button	Instruction
1	S1	Moving speed.
2	S3	Arm swing speed.
3	S6	On / off button for the swing arm.
4	S8	Start button of the robot, can be used to reset to solve some error.
5	S9	Switch between manual and semi-auto mode.
6	S10	Forward distance -10 mm.
7	S11	Change the arm direction at manual mode.
8	S12	Forward distance +10 mm.
9	S14	Switch of the remote. Hold the button will turn on the remote, a logo on the screen shows success.
10	S15	Emergency stop.
11	S16	Red light: shines when turning on which means certain button is not reset. Blinks when there is an error in the remote, and go out if no error.
12	S17	Green light: blinks during operation means low power.
13	X1	Screen. Shows some specifications and robot status.
14	J1	Moving direction control. Hold to control at manual mode, toggle control at semi-auto mode.
15	Others	Reserved buttons for future functions.

2.4 Safety Accessories and Instructions

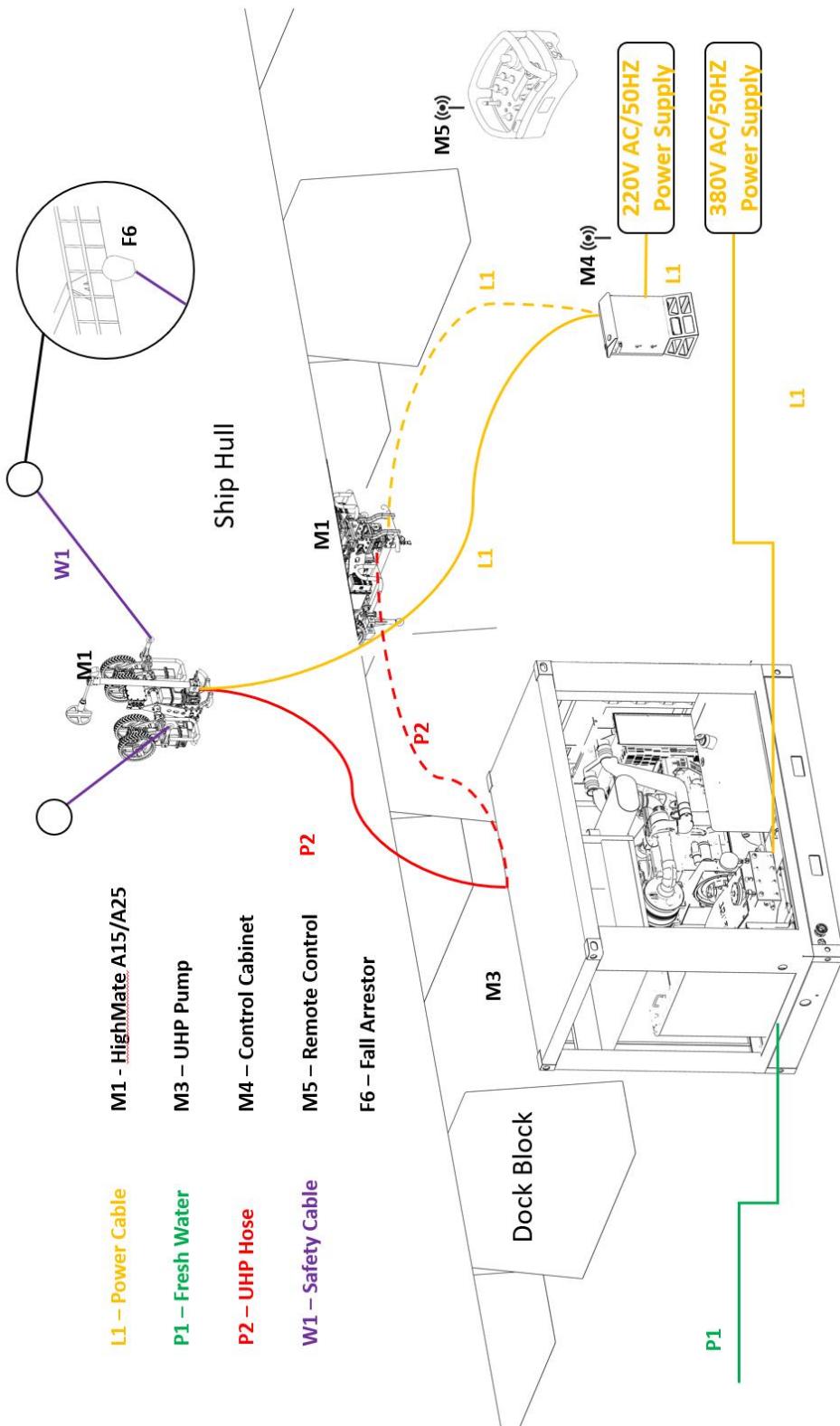


Fig 6. Robot Set-ups including the Safety Accessories

2.4.1 Fall Arrester



Fig 7. Fall Arrester

⚠️ WARNING

- a) Every robot is equipped with two fall arresters. Before operation, make sure fall arresters are properly installed. The operation area should be between the two fall arresters.
- b) The hooks and cables of the fixed end of the fall arrester must be hung on reliable positions of the hull which can withstand greater force, such as the cable pile, column, lifting lug, etc. It cannot be hung on any unstable objects like temporary scaffoldings.
- c) Keep the fall arrester vertical as far as possible (make the shell of fall arrester parallel to the vertical hull) to ensure the smooth retracting and discharging of the rope.
- d) The hook must be hung on the shackle of the hoisting rod.

2.4.2 Fixed Pulley



Fig 8. Fixed Pulley

NOTICE

- a) Every robot is equipped with a fixed pulley with corresponding lifting ropes, used for hanging UHP water hoses, recovery pipes, abrasive hoses and power cables to lower the loading carried by the robot. The hoisting point chosen should leave enough length for the water hose to allow the robot to move freely between the two fall arresters. For abrasive, the hoisting point should be within the range of 8 meters with the abrasive hoses clamped on the robot.

CAUTION

- b) The fixed pulley should be hung on reliable positions of the hull, such as the guardrail beam, upper edge of the ship plate, etc. It should not be hung on any unstable objects like temporary scaffoldings.
- c) The fixed pulley can be installed between the two fall arresters.

2.4.3 Loading and Unloading Device (Optional)

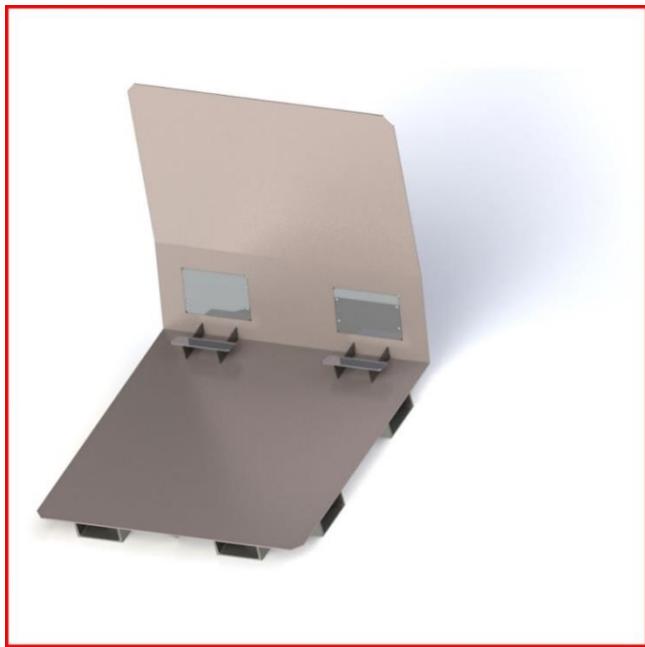


Fig 9. Loading and Unloading Device

This device needs to be used together with a forklift. Loading and unloading of the robot should be done by using this device, and avoid manual pulling in the process.

2.4.4 Anti-off Chain / Burst Proof Chain



Fig 10. Anti-off Chain Set-ups

⚠ WARNING

As shown by Fig 10, every robot requires two anti-off chains. At hydroblasting mode, insert one end of the chain into the other end around the right-angle joint, repeat the steps for the second anti-off chain, then insert the UHP tube through the 2 anti-off chains and tighten the tube. At abrasive blasting mode, similarly, insert one end of the chain into the other end around the right-angle joint, and insert the sand hose into the link, and repeat the same procedure for the second sand hose.

3. Safety Operation Procedures

3.1 Operator Responsibilities

- 1) Operators should be trained before carrying out any operation of the robot, and must follow this instruction during any operation.
- 2) Operators are responsible for the safety uses of the robot products, including the preparation, inspection and arrangements before, during and after operation.
- 3) Operators are responsible for strictly following the regulations of safety operations, which includes correctly use and install the accessories, wear and use of PPEs, etc.
- 4) Operators are responsible for the daily maintenance of the robot to ensure its safety functions are effective.
- 5) Keep records of robot operation and maintenance as required.
- 6) Report and deal with accident and emergency on site.

3.2 Before Operation

3.2.1 Safety Requirements Before Operation

NOTICE

- 1) The robot operator must be trained before operation. Interns should operator the robot under the guidance of experienced operators and avoid independent operation.
- 2) Inspect the site before operation to make sure that safety accessories such as fall arresters are firmly fixed.
- 3) Placement of auxiliary devices
 - a) For hydroblasting operation, the position and number of UHP and recovery pumps should be reasonably arranged according to the operation location and amount of work. The equipment should be placed in a safe area firmly with no obstacles in the area. The UHP pump should be placed near the water source, and the length of the hose should be less than 100 meters. The distance between the recovery pump and the robot pipeline should be less than 100 meters.
 - b) For abrasive blasting operation, the position and number of air compressors and sand pots should be reasonably arranged according to the operation location and amount of work. The equipment should be placed in a safe area firmly with no obstacles in the area. The sand pot should be placed near the air compressor, and the length of the hose between the pot and the robot should be less than 40 meters.
- 4) Check the power cables and waterproof plugs connecting the robot and the control cabinet. Make sure there is no loose, damage or leakage of electricity. Check all protection devices of the cabinet, such as overload protection, leakage protection and phase loss protection, are intact.
- 5) Before connecting the UHP tube, the tube should be flushed to avoid nozzle blockage or sudden overpressure. Only after applying anti-bite agent on the outer thread, the tube can be connected with any joint or inlet. For abrasive,

use compressed air to clear the abrasive hose before connection to avoid clogging.



Fig 11. UHP Tube Flushing

- 6) After loading the robot to its target surface, install all safety accessories in time. The position of the accessories should be kept in line with the robot's working area.

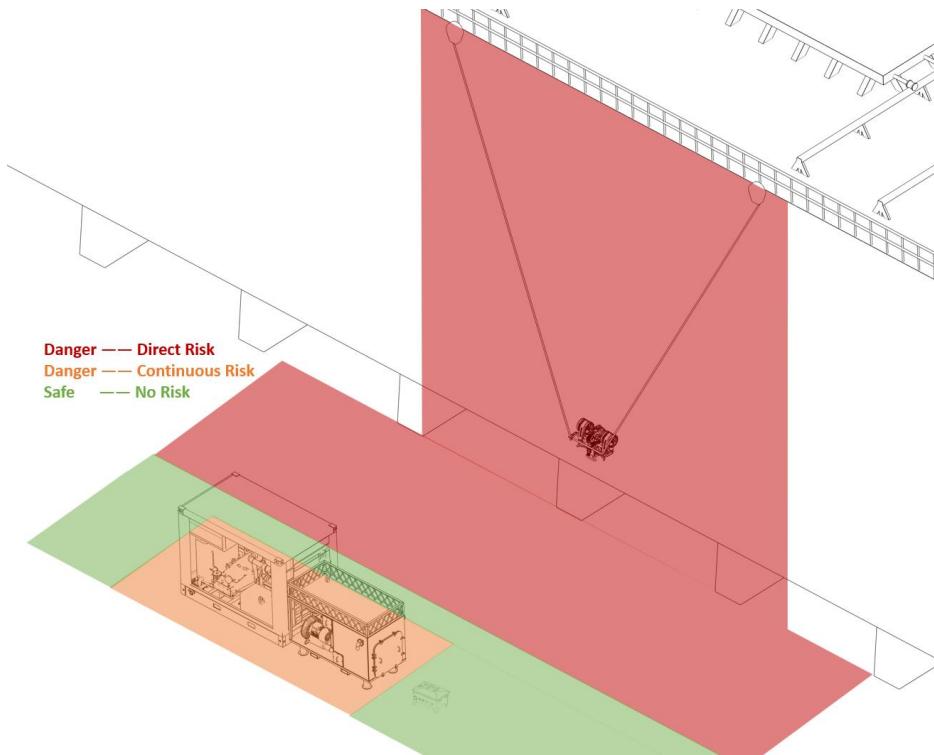


Fig 12. Safety Area of Operation (Same as Abrasive Blasting)

⚠ CAUTION

- 7) When transporting and handling the robot, extra attention should be paid to the strong magnets, so that normal steel or metal tools and materials should

be kept in distance. Any part of human body especially hands are strictly prohibited from being placed between the magnets and the metal surfaces.

- 8) When loading the robot to the ship hull, arrange the driving wheel to adsorb it first, then adsorb the driven wheel after that.

⚠ WARNING

- 9) Check if the UHP tube / abrasive blasting hose and safety knuckles are in good condition. Any damage or aging is strictly prohibited.
- 10) Before Operation, according to the site environment situation and corresponding safety requirements, protective equipment should be worn including but not limited to the following: safety helmets, safety shoes, work clothes, safety belts, safety goggles, mask and reflective vests for night operation.
- 11) The control cabinet should be kept away from low-lying area and the place right under the drainage outlet to avoid water and electric leakage.

⚠ DANGER

- 12) Before operation, two fall arresters, fixed pulley and auxiliary lifting rope must be properly installed to prevent the robot from falling and crashing.

3.2.2 Procedures and Requirements Before Operation

- 1) For hydroblasting operation
 - a) According to the actual flow of the UHP pump used and the maximum flow rate allowed of the rotary (30 L/min), use corresponding number and type of nozzles to match the specifications (see attachment for the standard flow rate and specifications table for nozzles).
 - b) According to the flatness and curvature of the actual working surfaces, the stand-off distance (the distance between nozzles and the target surface) of the spray lance should be adjusted. On the premise of ensuring safety, lowering the distance can improve the strength and efficiency. At normal condition, the recommended distance is 16 mm.

The spray lance should be kept parallel to the target surface as much as possible.

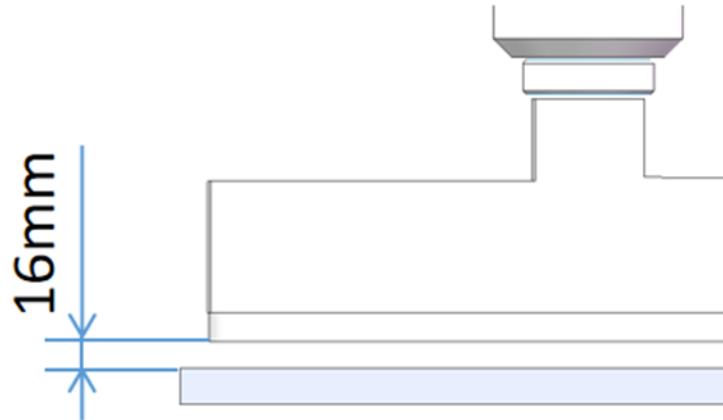


Fig 13. Stand-off Distance

- c) Power cable connection: connect the power cable of the electric control cabinet to the distribution box/cabinet, and connect the ground wire. Then connect the robot power cable to the control cabinet.
- d) UHP tube connection: connect the pre-flushed UHP tube from the UHP pump to the robot.
- e) When working in the dock or at the dock, the robot can be loaded to the hull by using a cherry picker or loading & unloading device. If the working surface is directly linked to the standing surface of the operator, the robot can be loaded to the surface with the assistance of at least two more persons manually. Note that the swing arm should be moved to one side when using the loading device to prevent collision.
- f) Before start working, test if the robot functions properly using the remote control.

2) For abrasive blasting operation

- a) According to the amount of work, use corresponding number of abrasive nozzles, maximum 2 for each robot, and the working air pressure is 0.8 MPa.

- b) According to the situation of the actual working surfaces, the stand-off distance (the distance between nozzles and the target surface) of the abrasive nozzles should be adjusted. The distance should be as far as possible, at the premises of making sure that the result reaches expected standards, so that the cleaning area is increased and hence increasing the efficiency. The nozzles can be tilted 20 degrees to increase the distance.
- c) Power cable connection: connect the power cable of the electric control cabinet to the distribution box/cabinet, and connect the ground wire. Then connect the robot power cable to the control cabinet.
- d) Abrasive hose connection: connect the pre-aired abrasive hose from the sand pot to the robot.
- e) When working in the dock or at the dock, the robot can be loaded to the hull by using a cherry picker or loading & unloading device. If the working surface is directly linked to the standing surface of the operator, the robot can be loaded to the surface with the assistance of at least two more persons manually. Note that the swing arm should be moved to one side when using the loading device to prevent collision.
- f) Before start working, test if the robot functions properly using the remote control.

3.3 During Operation

3.3.1 Safety Requirements During Operation

NOTICE

- 1) When loading the robot, choose a flat surface and avoid any welding seams and bulges, so that to prevent the contact between the magnets and seams or bulges and causes damage or demagnetization of magnets, or causing the wheels to be pressed on the seams, increasing the distance between the magnets and the surface and leading to weaker magnetic force and cause the robot to fall from the surface.
- 2) When the robot is working and moving horizontally, find a relevant reference to make sure the robot moves in a straight line to minimize missed out area and affects the efficiency.
- 3) In case of failure during operation, shut down the UHP pump, recovery pump, sand pot, compressor and power supply in time, and unload the robot with the help of cherry pickers and trained personnel.
- 4) When the height of the hydroblasting surface exceeds 15 meters or abrasive blasting surface exceeds 7 meters, it is not allowed to let the robot directly carry the UHP tube, power cable, abrasive hose and recovery pipe during operation. Auxiliary lifting ropes and fixed pulley should be used to share the weight of the pipes of the robot to avoid possible overloading, in order to prevent falling and extra mechanical parts wearing.
- 5) The robot should be operated at lower speed and with extra attention at following situations: crossing 5-15 mm obstacles; working at surfaces with low friction that may slip; surfaces with small curvatures, etc.
- 6) When installing the nozzles, the appropriate torque is 17-18 Nm. If the torque is too large, it may damage the nozzles, and if the torque is small, the sealing will not be perfect.

CAUTION

- 7) When the robot is working at flat surfaces (such as flat bottom of the ships), standing or staying under the robot is strictly prohibited. At the same time, all UHP tubes, abrasive hoses, power cables and recovery pipes should be prevented from being stuck or dragged by foreign obstacles that may cause falling and crashing.
- 8) When the robot is working at reverse surfaces (with a certain upside-down angle), standing or staying under the robot is strictly prohibited.
- 9) When the robot is working vertically (up and down), the main driving wheel must always be upward and the free wheel must downward, to avoid falling and crashing.
- 10) Whenever the robot needs to be stopped, either temporary or finished working, it should be placed at a safe position and shut down the power to prevent others from false operating.

 **WARNING**

- 11) If the operator is operating at the bottom of the dock, pay more attention to the water on the deck to avoid water entering the control cabinet. At the same time, make sure the power cable not to be passed or damaged by vehicles or soak in water which may cause electric leakage.

 **DANGER**

- 12) During floating dock operation, the operator shall be supervised when working on the ship with crane operation carrying out at the same time. The operator should not cross the dock railings, and pay attention to the door crane to prevent squeezing.

3.3.2 Procedures and Requirements During Operation

- 1) Operation steps and modes of the remote control (See Fig 5. for instructions of the switch and corresponding buttons)
 - a) Start up: reset all the switches on the panel, and long press the power button (S14). Release the button when a Robot++ logo appears on the

screen, and the remote is successfully power-on and the communication of the robot will start. Turn the switch S8 on to start the power supply and the robot can be controlled manually.

- b) Speed control: according to the actual working condition and working efficiency, adjust the speed button S1.
- c) Robot swing arm control: when button S6 is down, the swing arm function is off, turn on S6 to start the swinging, it will swing according to the speed set by button S3. When it is started, the default direction of movement is right. After the arm reaches the limit position, it will change its moving direction automatically. During the movement process, if S6 is turned down, the arm will stop moving immediately.
- d) There are two different control methods for the robot: manual mode and stepping mode.
 - i. Manual mode: keep S8 on and push the lever J1. The robot moves forward with pushing up, and moves backward with pulling down. It will spot turn left or right when pushes the lever to left or right. It will not move when there is no action. When S6 is up, the swing arm will move back and forth automatically according to the speed set by S3. When S6 is down, the swing arm function is off and the arm will not move.
 - ii. Stepping mode: keep S8 on and set S9 to cruise. At this mode, robot will be working in auto-stepping mode, that every time the arm complete one movement (from left to right or right to left), the robot will move forward/backward for a certain distance (150mm by default). Pushing J1 up once will keep the robot operating forward, while pulling J1 down once will keep the robot operating backward. The stepping distance can be adjusted by setting S10 and S12, every time will be adjusted by 10mm. The minimum stepping distance is 20mm, and the maximum is 200mm.

2) The coatings and rust condition for different surfaces are different. Therefore,

at the start of hydroblasting operation, adjust the moving speed of the robot to observe the cleaning quality at different speed. Choose the speed that can just meets the surface requirement to achieve fast cleaning and cost-saving. For abrasive blasting operation, other than adjusting robot speed, also adjust the nozzle angle and stand-off distance to achieve the best efficiency.

- 3) The robot operator should be always in contact with the person operating the UHP pump or sand pot, so that to inform each other to stop processing timely if there is error or failures in the robot or the pump/pot. If the swing arm is stopped or the robot needs to move to another spot without operation, the pump or pot operator need to be informed and stop the pump/pot.
- 4) If there is a sudden drop in the pressure during hydroblasting operation, the most possible reason may be wearing of nozzles or leakage of the UHP rotator. Change the nozzles or rotator parts in time before continuing the operation. If pressure drops happen during abrasive blasting operation, the most possible reason is the wearing of blasting nozzles or leakage in the blasting hose, replace the nozzle or fix the hose to continue the operation.

3.4 Operation Complete

3.4.1 Safety Requirements Before and After Operation Complete

NOTICE

- 1) After the movements of the robot has stopped, the UHP pump and sand pot need to be turned off in time to prevent the blasting from operating at the same spot for a long time and causes damage to the surface.
- 2) The UHP tube inlet and the joints needs to be protected. After dissembling of each operation, the UHP water inlet of the rotator should be blocked or sealed by tape or a plug to prevent any foreign body from entering.
- 3) After removing the connection cables of the robot and the control cabinet, the interface should be protected by their covers or tapes to prevent water or any other particles from entering and affect subsequent operations.

CAUTION

- 4) If the robot is unload from the hull manually, at least three persons are required to work together.
- 5) After the robot is unloaded, it should be placed on the ground in reverse, with the magnets facing up. It is even more important if the standing surface is made of steel, to avoid human injuries and mechanical damages caused by impact of the robot.

3.4.2 Procedures and Requirements Before and After Operation Complete

- 1) Move the robot to the lower end of the working surfaces to avoid unloading the robot at high altitude.
- 2) After operation complete and the robot has reached a safe position, turn off the power supply, and disconnect the UHP tube / abrasive hose after pressure relief, then disassemble the accessories including fall arresters, abrasive nozzle, auxiliary lifting ropes and fix pulleys step by step.
- 3) Clean the pollutants on the robot, especially the magnets in time, to avoid

corrosion.

- 4) The robot and its accessories should be stored at a dry condition indoor, and keep the magnets away from steel or metal objects.
- 5) Charge the remote battery in time. Take out the battery if it is not in use and for long term storage to avoid aging or damaging the battery.

3.5 Emergency Requirements

- 1) Electric shock: in case of electric shock accidents, the rescuers should cut off the power supply first, if time does not allow, use insulated objects to separate the cable from the victim. Before cutting off the power supply, rescuers should not touch the shocked person with hands, neither uses metal or wet objects to contact with the cable. Carry out on-site rescue after carry the shocked person to a safe position.
- 2) In case of falling and crashing of robot or injuries of the operator, the power supply and UHP water should be cut off at once. In addition to trying to rescue the injured person immediately, maintain the scene of the accident and report to relevant departments in time according to the local requirements.

4. Robot Maintenance

4.1 Daily Maintenance (every shift)

- 1) Check the magnet bottom to observe the accumulation of foreign bodies like rust residue, clean them in time.
- 2) Check the battery power of the remote control.
- 3) Check if the control cabinet is closed properly to avoid water entry.
- 4) Check if the recovery dome can drain smoothly.
- 5) Check if the free wheel is stuck.
- 6) Check the working pressure, if there is an obvious drop from the standard pressure, it means that some nozzles have wear and need to be replaced.
- 7) Check if the UHP tube, blasting hose and power cables are damaged or caught with any foreign bodies.
- 8) Check if other equipment runs normally, including UHP pump, recovery pump, air compressor, sand pot and other devices involved in the entire blasting system.

4.2 50 Hours Maintenance (every ship/project)

1) UHP rotary disassemble and maintenance

This part consists many consumables that require frequent check and replacement. During maintenance of rotary, avoid crashing or tapping, do not use wrench or spanner to clamp the magnet module (part no. 12).

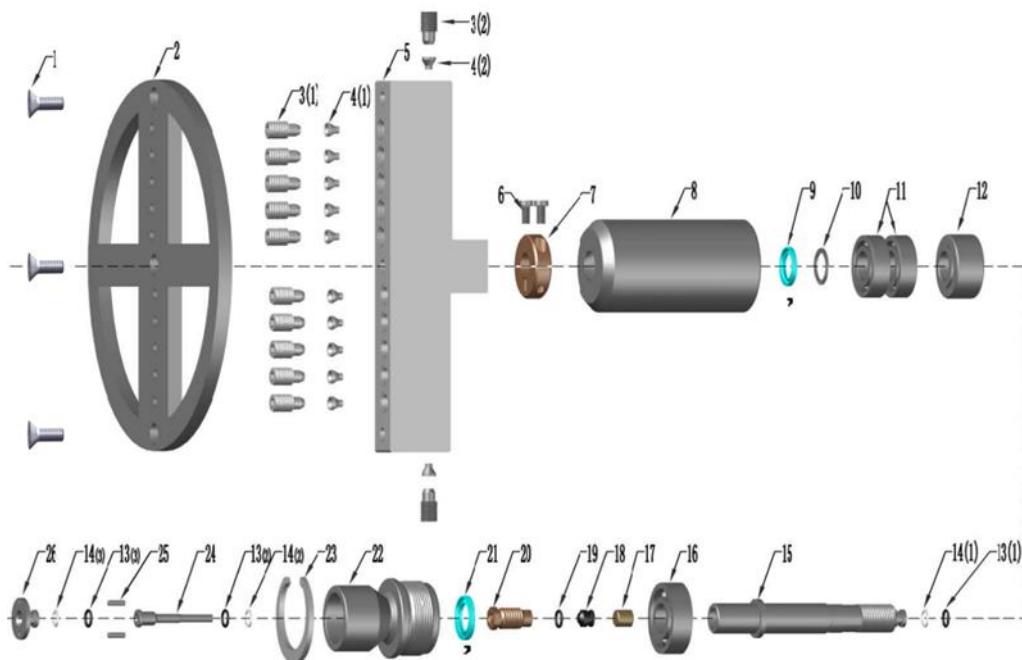


Fig 14. Exploded View of UHP Rotary

- 1.M8 countersunk screw 2.Nozzle plate cover 3(1).Nozzle 3(2).Nozzle plug 4.Nozzle sealing
- 5.Nozzle plate 6.M5 hexagonal screw 7.Shaft casing 8.Shell 9.Oil seal 10.Shaft elastic washer
- 11.Bearing I 12.Magnet module 13.O-ring 14.Plastic seal 15.Rotary shaft 16.Bearing II
- 17.Copper washer 18.HP seal 19.HP seal O-ring 20.Hollow nut 21.Oil seal 22.Inlet connector
- 23.Retaining ring 24.Sealing rod 25.φ3mm cylindrical pin 26.Sealing block

- a) Check the bearing status, with part number 11 and 16. The thread and end face of the rotating shaft should not be damaged. The inner ring and outer ring of the bearing should not appear obvious axial and radial spacing, and the rotation should be smooth without any stuck, otherwise it should be replaced in time.



Fig 15. Bearing Checks

- b) Clean and grease the rotary.



Fig 16. Greasing the Rotary

- c) Check the sealing rod, part number 24. If shallow impression appears in the transverse direction (Fig 17), it can be polished using sandpaper above 0# (320 mesh) and used. If longitudinal wear appears (Fig 18) it should be replaced immediately.



Fig 17. Sealing Rod Maintenance



Fig 18. Sealing Rods Needs to be Replaced

- d) Check the hollow nut and copper washer, part number 20 and 17, and replace if wears. The spacing should be even as shown, if any side is larger then need to be replaced.



Fig 19. Hollow Nut Maintenance

- e) Check the high-pressure seal (HP seal), part number 18, replace the worn high-pressure seal. When replacing the high-pressure seal, it is better to use the HP seal disassemble tool (shown in Fig 20), since using the tool correctly can prevent the seal from being damaged, disassembling HP seal without using the tool can cause damage to the seal. Pay attention to the direction of the HP seal while installing. When tightening the hollow nut, do not use too much force since it may hold the sealing rod too tight, resulting in accelerated wear of the sealings.



Fig 20. HP Seal Disassemble Tool

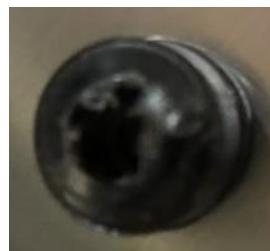


Fig 21. Rotary High-Pressure Seal

- f) Check the oil seal, part number 9 and 21, and change the worn ones.

Pay attention to the direction while installing.

- g) Check the rotary shell, part number 8. If there is any deformation or wear found in the inner surface of the shell, replace in time.



Fig 22. Worn Rotary Shell

- h) Check the sealing block, part number 26. If the cone surface shows obvious wears, replace it.

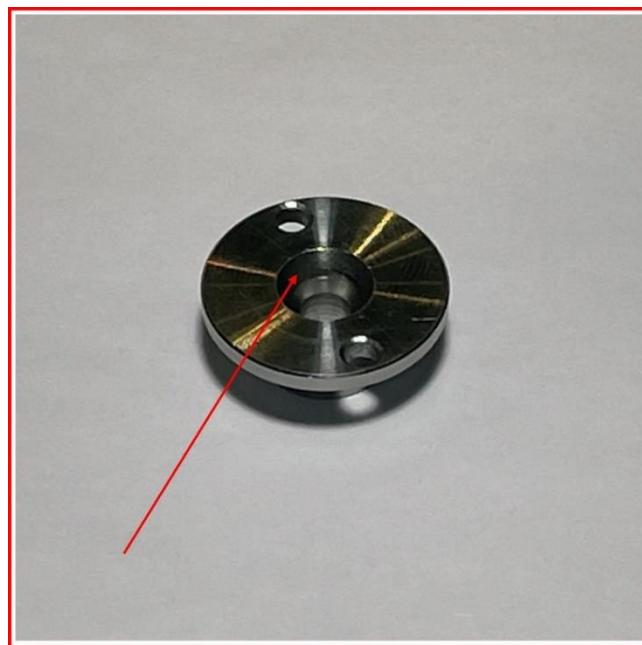


Fig 23. Sealing Block Cone Surface

- i) Check the rotary shaft, part number 15. If obvious wears appear on the contact part, replace it. The rotator sleeve, stainless-steel sealing plate and rotary shaft are all long-lasting consumables, usually the lifetime could exceed 800 hours.



Fig 24. Rotary Shaft Contact Part

- j) Check the retaining ring, part number 10. If damaged, worn or deformed, replace.
- k) Check the nozzles, part number 3(1). Replaced damaged or worn ones.
- 2) Clean the magnets thoroughly to clear all foreign bodies such as rust, check whether the magnet cover is damaged. If there is any damage, stop using the magnet and contact any after-sales to check for the treatment process.

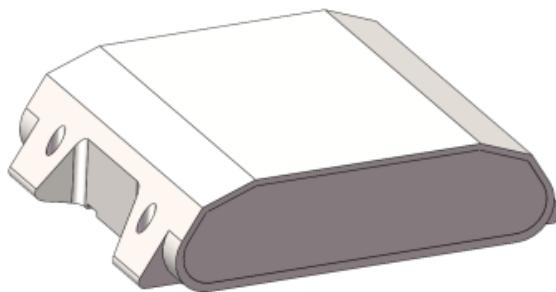


Fig 25. An Example of Magnet

- 3) Check whether there is any wear, deformation, stuck in the bearings or inflexible steering for the free wheel. Replace the damaged free wheel.
- 4) Check the safety accessories like fall arresters and fixed pulley. If the wire rope is stuck or once there is impact caused by the falling of robot in the operation process, they need to be returned to the factory for maintenance before using again. See Annex 3 for simple failure analysis and solution of

the fall arrestors

- 5) After operation, the robot needs to be cleaned to get rid of the waste residue or paint to prevent corrosion.
- 6) Check all electric components and terminals in the control cabinet, whether they are securely fixed and properly grounded. Check whether the wireless transmitter and receivers are intact.

4.3 150 Hours Maintenance (every month)

- 1) Check the main driving wheel: check if the magnet distance adjusting bolt and lock nut are loose. Raise the magnet position (shorten the clearance) correspondingly according to the wear situation of the rubber tread of the main driving wheel.

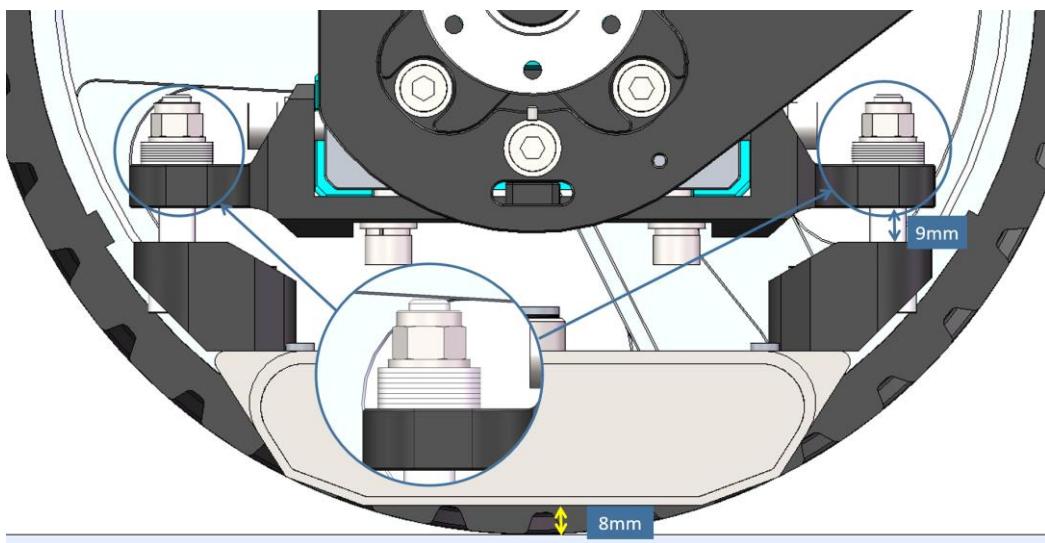


Fig 26. Standard Magnet Distance of Main Driving Wheel

- 2) Check the free wheel: check if the magnet distance adjusting bolt and lock nut are loose. Raise the magnet position (shorten the clearance) correspondingly according to the wear situation of the rubber tread of the free wheel.

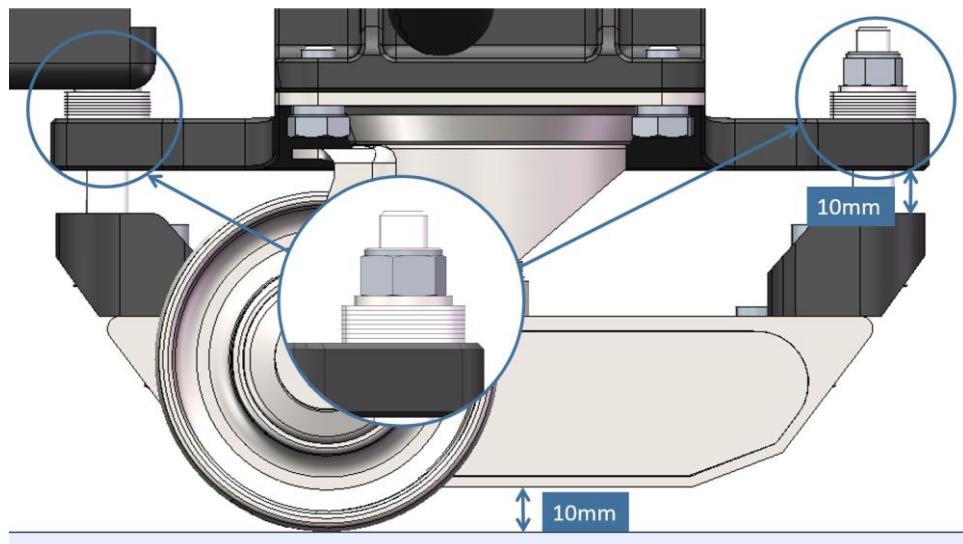


Fig 27. Standard Magnet Distance of Free Wheel

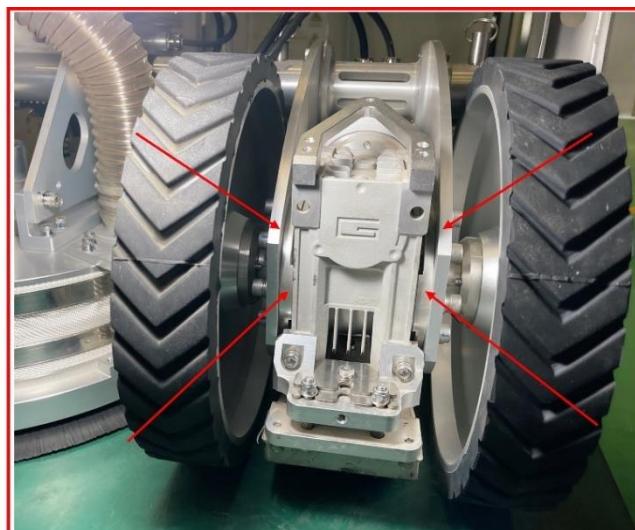
- 3) Check the wear of the solid rubber tread of the main driving wheel.

Replace the wheel if the tread is almost worn out.



Fig 28. Driving Wheel Needs to be Replaced

- 4) Check all external fixing bolts and latches, and pay extra attention to the hoisting rod and the bolts of vacuum recovery dome and abrasive module.
- 5) Check whether the side plate bracket of the driving wheel and the worm reducer are firmly fixed. Shake the motor cover with hands, if the arrowed parts are loose, check the fixing bolts on the side plate and the reducer cover plate and tighten them if needed.



Shake the motor cover with hands. If the arrowed parts are loose, check the fixing bolts on the side plate and the reducer cover plate.

Fig 29. Driving Wheel Side Plate Checks

- 6) Check the fixing bolts of the driving shaft: pull the four driving wheels by hands. If there is displacement, remove the wheel and tighten the bolts at

the shaft end.

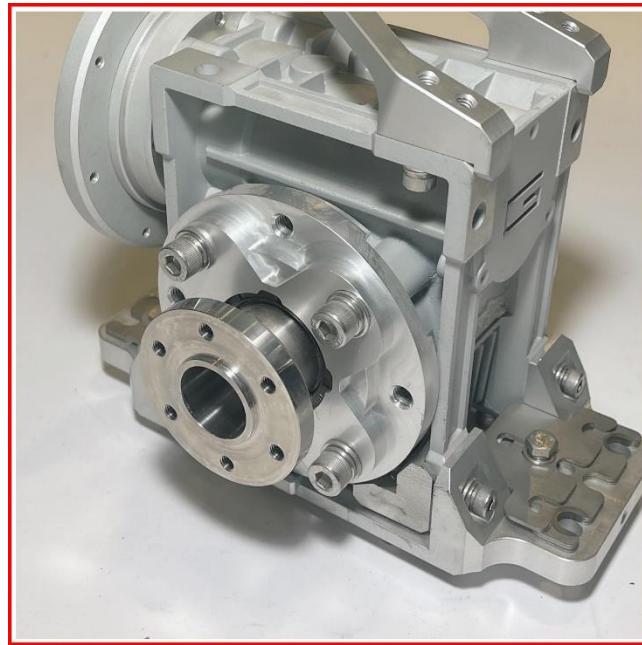


Fig 30. Driving Shaft Bolts Check

- 7) Check the cover of the driving motor. If there is any water left due to seal failure, it must be reinstalled and checked again to ensure the waterproof performance. If the gasket or sealing plug are aged, replace them in time. The swing arm motor also needs to be checked, change the sealings (O-ring, gasket, power cable sealing plugs) if aging or wears.

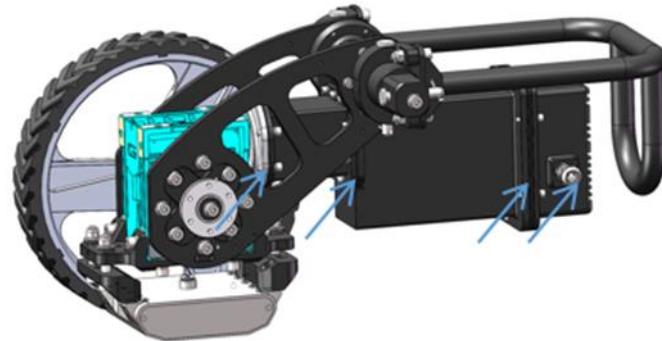


Fig 31. Driving Motor Cover Checks

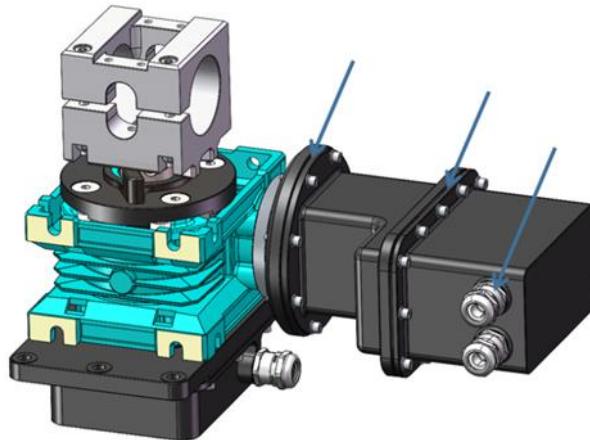


Fig 32. Swing Arm Motor Cover Checks

- 8) Check the connection between the motor and planetary reducer. Disassemble the back cover of the motor, shake the motor with hands, if the motor is loose, then it needs to be tightened.



Fig 33. Driving Motor Planetary Reducer and Motor Checks

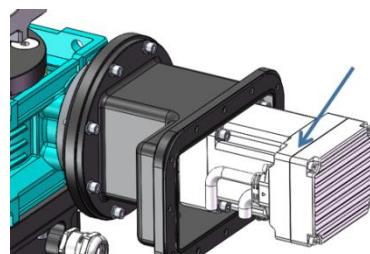


Fig 34. Arm Planetary Reducer and Motor Checks

- 9) Check the sealing inside the electric control box. If there is leakage, check if the sealing ring and cable waterproof joint are aging. If there is, it must be replaced to prevent further series of electrical component failures. When re-assemble, all screws and bolts need to be greased with thread sealant. If the driver has been disassembled, then silicone thermal grease needs to be applied on the bottom of the driver. Check and maintain the arm control box

in the same way.

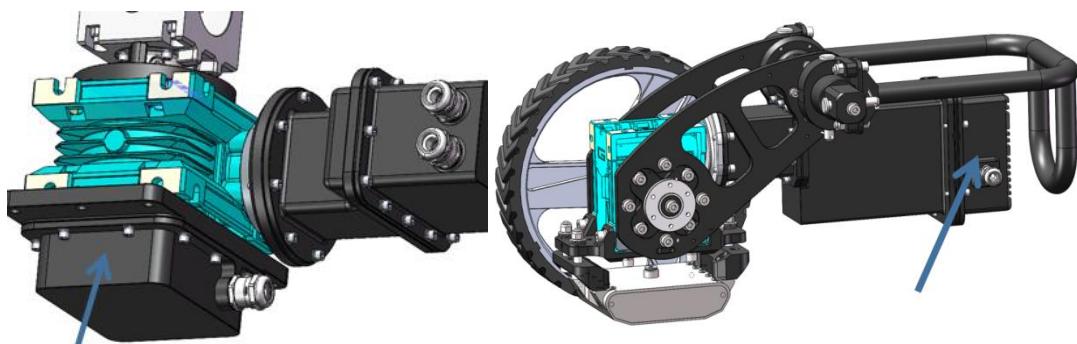


Fig 35. O-ring and Plugs of the Control Box



Fig 36. Arm Control Box

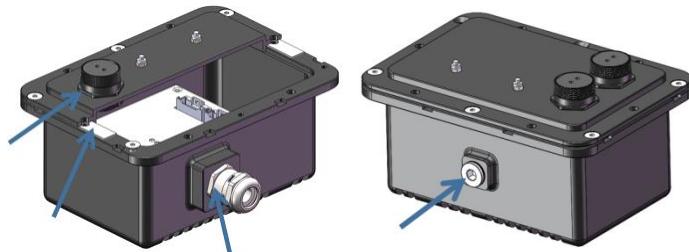


Fig 37. Sealing Ring and Plugs of the Arm Control Box

10) Check if there is any corrosion or oxidation caused by water entering of all circuit boards in the electric control box, as well as if there is any discoloration of the wiring due to heating. In the case of corrosion and oxidation, use anhydrous alcohol to wipe. After drying, put coating adhesive. Wiring should be replaced in case of heating. If the corrosion and oxidation are serious, replace with new circuit boards.

11) Check the power communication cable: whether there is local damage, whether there is any deformation, discoloration or welding joints problem of the plug and socket. Replace the damaged and aged cables, plugs and socket in time.

12) Check the aviation plugs. If there is any corrosion or rust, use spray rust remover to clean it. It can be reconnected after cleaning and drying. At the same time, the spray can be used to clean rusty bolts.

13) Check if other bolts and screws on the robot are loose and tighten if needed.

14) During normal operation period, the magnet should be checked every 30 days. Leakage detecting test should be done, and check all sealings of hexagonal plug for their aging condition, replace them if needed. After checks, clean and wipe the hexagonal plug and make sure it is leak-proof when re-assemble. (Note that if no operation has been performed since the inspection, the inspection time is then calculated 30 days from the day of the first operation)

The process of the leakage detecting test:

- Remove the magnet to be inspected from the robot. (Note that only one magnet can be removed each time, and the disassembled magnet should be kept away from other objects that can be attracted by the magnet, so as to avoid injury due to magnet attraction)
- Place the removed magnet away from any steel object, and then remove the hexagonal plug on the top of the magnet.



Fig 38. Hexagonal Plug on the Magnet

- Then install a single-sideband M12*1.5 thread gas pipe quick connector at the thread where the plug is removed.

- d) Connect one end of the gas pipe to the connector, one end to the pressure regulator, and then connect the pressure regulator to the air source through the gas pipe.
- e) Close the pressure regulator valve, and then turn on the air supply.
- f) Gradually increase the pressure from the pressure regulator, until the pressure reaches 0.1-0.2MPa.
- g) Immerse the magnet and the quick connector in water, hold the pressure for 30 minutes, and observe whether there are bubbles on the magnet plug, on sides of the magnet, and on the welding nut in the middle. If there are no bubbles, it passes the test.
- h) Remove the gas pipe, connector and other parts, re-install the hexagon plug.
- i) Re-assemble the magnet back to the robot, carry out the test for the other magnet.

4.4 400 Hours Maintenance (every season)

- 1) Check the wear of worm gear set

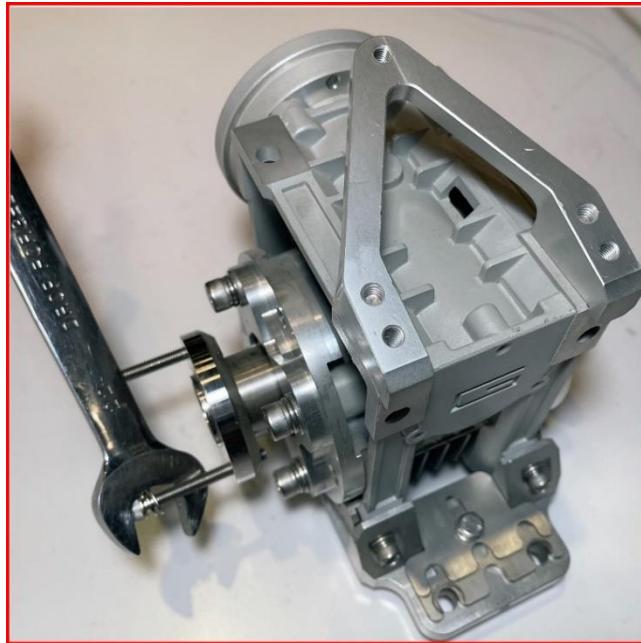


Fig 39. Worm Gear Reducer Wear Check

As shown by Fig 39, install the shaft and flange on the worm gear, with two long screws on the flange. Use a wrench to turn it as the figure shows, if it can be rotated easily then replace the worm gear set.

- 2) Check the sealings of the worm gears, including the sealing gasket, lip seal on the sealing cover, O-ring, motor sealing gasket, etc. If there are any deformation found due to collision or falling or the robot, they need to be replaced or greasing with sealant to increase the sealing performance. If there are any worn or aging parts, they need to be replaced. Sealing part and cover of the arm module also require the same check and maintenance.

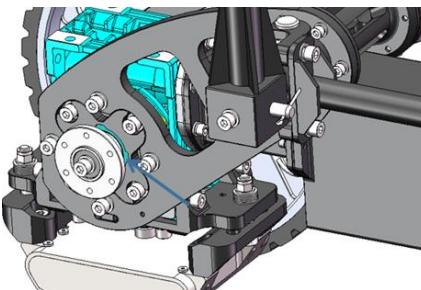


Fig 40. Worm Gear Flange Sealings

5. Error Codes, Problem Description and Troubleshooting

Take Note: Most errors mentioned need to be fixed by professional electricians, if they cannot be fixed on site, please contact our professional after-sales service.

Error Code	Description	Possible Reason	Troubleshooting
F001	CAN communication error of the driver	CAN cable incorrectly connected	Reconnect the cable correctly
		Water entering the control box	Clean and dry the damp, use anhydrous alcohol to wipe out the oxide. Check if any component is damaged due to short circuit and replace accordingly
		Main control board damaged	Test if there is 48V output from the main control board
		Driver damaged	Replace the driver
F005	Communication error between the robot and the electric control cabinet	48V power supply anomaly	Test the output voltage
		Power and communication cable damaged	Replace cables
		Power and communication cable plugs or sockets loosened	Ensure the plugs and sockets are firmly fixed and inserted
		Water entering the control box	Clean and dry the damp, use anhydrous alcohol to wipe out the oxide. Check if any component is damaged due to short circuit and replace accordingly
		485 communication cable anomalies	Make sure the cable is correctly connected
F007	Disconnection between the transmitter and receiver of the remote control	Low battery	Change battery
		Receiver antennae damaged	Replace antennae
		Receiver antennae not grounded	Make sure it is correctly connected
		Main board damaged	Replace the main board
		Remote control damaged	Replace the remote control set

F010	Emergency stop	The emergency stop button of the cabinet is not reset	Release the button
		Emergency stop button damaged	Replace the button
1001	Driver 1 error	Driver internal hardware trouble	Replace driver
1002	Driver 1 encoder signal error	Encoder disconnect or wrong connection	<ol style="list-style-type: none"> 1) Check if the cables are correctly connected 2) Check if the pin of the connector is properly connected
1004	Driver 1 encoder error	Driver internal error or damaged	<ol style="list-style-type: none"> 1) Check if the cables are correctly connected 2) Check if the pin of the connector is properly connected 3) Replace motor
1020	Shaft 1 cable overvoltage	Power source voltage is higher than the rated voltage	<ol style="list-style-type: none"> 1) Check the switching power supply voltage 2) Check if the power source voltage is stable
		Missing or damaged braking resistor	<ol style="list-style-type: none"> 1) Connect a proper braking resistor 2) Replace braking resistor
1040	Shaft 1 cable voltage low	Power source voltage is lower than the rated voltage	<ol style="list-style-type: none"> 1) Check the switching power supply voltage 2) Check the 50m cable resistance
1080	Driver 1 output short circuit	Driver UVW and PE output short circuit	<ol style="list-style-type: none"> 1) Check the motor power cable connection 2) Driver damaged, replace the driver
1800	Shaft 1 motor or driver IIT error	When motor is running, brake is not released or partly released	Check if the brake connection is correct
100A	Shaft 1 input pulse frequency high	Driver damaged	Replace driver

100B	Shaft 1 motor temperature high	Motor overload, stuck or damaged	1) Check the shaft and load 2) Replace motor
100C	Shaft 1 encoder information error	Encoder disconnect, or communication timeout	1) Check the encoder cable 2) Replace motor 3) Check the driver
100D	Shaft 1 EEPROM data error	Driver damaged	Replace driver
2001	Driver 2 error	Driver internal hardware trouble	Replace driver
2002	Driver 2 encoder signal error	Encoder disconnect or wrong connection	1) Check if the cables are correctly connected 2) Check if the pin of the connector is properly connected
2004	Driver 2 encoder error	Driver internal error or damaged	1) Check if the cables are correctly connected 2) Check if the pin of the connector is properly connected 3) Replace motor
2020	Shaft 2 cable overvoltage	Power source voltage is higher than the rated voltage	1) Check the switching power supply voltage 2) Check if the power source voltage is stable
		Missing or damaged braking resistor	1) Connect a proper braking resistor 2) Replace braking resistor
2040	Shaft 2 cable voltage low	Power source voltage is lower than the rated voltage	1) Check the switching power supply voltage 2) Check the 50m cable resistance
2080	Driver 2 output short circuit	Driver UVW and PE output short circuit	1) Check the motor power cable connection 2) Driver damaged, replace the driver

2800	Shaft 2 motor or driver IIT error	When motor is running, brake is not released or partly released	Check if the brake connection is correct
200A	Shaft 2 input pulse frequency high	Driver damaged	Replace driver
200B	Shaft 2 motor temperature high	Motor overload, stuck or damaged	<ol style="list-style-type: none"> 1) Check the shaft and load 2) Replace motor
200C	Shaft 2 encoder information error	Encoder disconnect, or communication timeout	<ol style="list-style-type: none"> 1) Check the encoder cable 2) Replace motor 3) Check the driver
200D	Shaft 2 EEPROM data error	Driver damaged	Replace driver

6. Common Mechanical Failure and Troubleshooting

No.	Failure	Possible reason	Troubleshooting
1	UHP pump pressure decreased	UHP hose damage	Replace UHP hose
		Nozzle wears	Replace nozzles
		HP sealing damaged	Replace HP Sealing
		Sealing rod or block damaged	Replace damaged sealing rod or sealing block
		O-ring or sealing ring damaged	Replace damaged sealing ring / O-ring
		UHP connector is not tightened	Tighten the connector
		UHP pump faulty, pressure cannot go up	Repair UHP pump
		Spray lance damaged, water leaked from pressure relief	Replace spray lance
2	Blasting pot pressure decrease	Nozzle aging, inner diameter of nozzle increase	Replace nozzle
		Abrasive hose, connector damaged or leakage	Find the leak point to repair or replace
		Air compressor error	Repair air compressor
3	Robot slips	Magnet distance is too big	Adjust the distance
		Too many particles attracted on the magnets	Clean the magnets
		Demagnetization of magnets	Replace magnet
		Rubber wheels damaged or worn	Replace rubber wheels
4	Free wheels rotation stuck	Free wheels worn	Replace free wheel
		Foreign bodies go into the wheels and jammed	Clean the free wheel. If still in trouble, replace the wheel
5	Free wheels turning stuck	Bearing is jammed	Clean the foreign bodies. If still in trouble, replace the free wheel frame
6	Cleaning module rotation problem	Water pressure low	Increase water pressure. If cannot increase, see failure 1.
		Nozzle jammed	Clean the foreign bodies
		HP seal, sealing rod, sealing seat and other parts damage	Replace damaged part
		Bearing direction reverse	Re-assemble the bearing
		Bearing damage	Replace bearing

7	Water leakage from the rotary	Water pressure low	Increase pressure
		Bolt not tightened	Tighten the bolts
		Sealing ring and/or U-ring damaged	Replace damaged parts
		Sealing rod or block damaged	Replace damaged parts
8	Cleaning module rotation speed abnormal	Rotary bearing, shaft or shell worn	Replace worn parts
9	Fall arrestor damaged	Fall arrestor damaged	See Annex 3
10	Robot operation no reaction or lose control	Control wire error or water enters	Check the connector. Clean or replace the short-circuit connector
		Control box error or water enters	Replace short-circuit components in the control box
		Motor sealing shell error or water enters	Clean the motor connector; Replace motor
		Remote control error or runs out of battery	Repair remote control or change battery
		Control cabinet error or water enters	Clean and dry the water inside cabinet, check and replace electric component

7. Unbox and Storage Procedure

7.1 Robot Packing Box

The dimension for the wooden packing box is: 1416*1416*865mm.

Dimension for the swing arm module packing is: 1416*710*789mm.

Quantity required: each robot requires 1 packing box.

Packing handling and storage requirements:

- Handle with care with forklift.
- Pay attention to the direction.
- Do not tilt or invert.
- The packing box is wooden, keep away from water.

Unbox notice:

- 1) During forklift transportation, keep a safe distance with the equipment to avoid being squeezed between components.
- 2) During forklift transportation, pay attention to the warning signs in the working area and follow.
- 3) During forklift transportation, wear PPEs.
- 4) During forklift transportation, keep the equipment safe from tipping over which may cause serious or fatal injuries.
- 5) During forklift transportation, to take the connection point and center of gravity into consideration, do not hang any heavy load on the top or side of the packing.
- 6) During forklift transportation, only approved lifting equipment and accessories should be used to carry the full weight of the load.
- 7) During forklift transportation, all operations should be under supervision.
- 8) The device can only be placed on a stable and uniform surface.
- 9) The wooden box is secured by butterfly latch. However, the latch may be squeezed and deformed during transportation, therefore it needs to be straightened by wire cutters and then opened.
- 10) Open the cover and take out the control cabinet, fall arrestors, remote control, power cable, safety ropes and other accessories.

- 11) Remove the box, release the strap tightening the robot.
- 12) Take down the robot from the base. The robot should be placed on uniform surface that cannot be attracted by magnets.

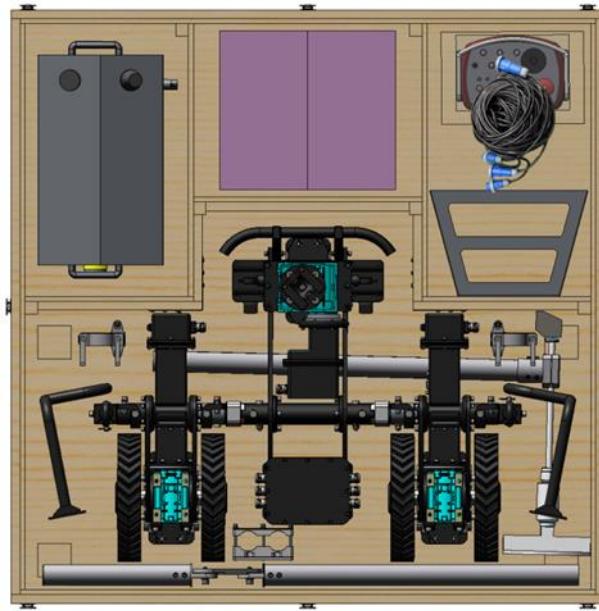


Fig 41. Complete Machine Packing

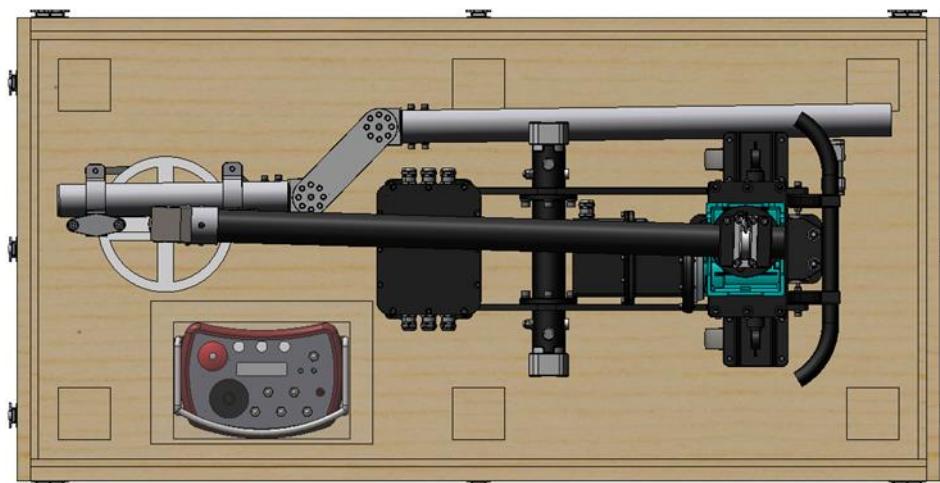


Fig 42. Swing Arm Module Packing

7.2 Product Storage Procedure

7.2.1 Robot Storage (Before Unbox)

When new robot is not unpacked, it should be placed on a flat surface.

The packing case should not be tilted or put upside down. Pay attention to the direction sign. The case is wooden and includes electronic components, therefore pay more attention to keep away from rain and other water source.

If the packing is soaked or rained, it is necessary to open the case and other device like control cabinets, thoroughly dry them before operation.

7.2.2 Robot Storage (Unbox without operation)

After unpacking, the robot should be place on a flat but not steel surface.

If the robot will not be used for a long time, place it upside down to make the magnet face upwards, and keep away from rain and other water source. Keep the aviation plugs clean, and use tape to cover the plugs if necessary to prevent dust and other foreign bodies. Rotary should be covered with dust cover. In case the cover is lost, use tape to seal the UHP water inlet to keep away other particles from entering. If the outlet is not connected to a spray lance, also seal the outlet. Place the robot in a dry space while not in operation.

The control cabinet should be put on a flat surface vertically in the right direction, and keep away from rain and water. If water enters, it is necessary to open the cabinet, thoroughly dry it before operation. When not in use, store in a dry room.

Other devices including remote control, power cable, safety ropes, toolkit, fall arrestors, and so on need to be put in to dry room for storage.

7.3 Robot Storage (After Operation)

- 1) After disconnecting the UHP hose, use compressed air to blow away the water in the rotary and spray lance, and seal the rotary water inlet (and outlet if spray lance is taken down) with cap or tape to prevent impurities from entering.
- 2) Use water to flush the debris and dirt on the robot. The iron slug attached on the magnet should be cleaned, as well as the waste in the vacuum dome and recovery pipe. Then use compressed air to dry them.
- 3) After unplugging the aviation plug, ensure no water can enter the plug. If there is, use compressed air to dry the plug until it is totally dry before operation again.
- 4) Dry the robot before put it into the warehouse. Then refer to **7.2.2 Robot Storage (Unbox without operation)** to keep the robot.
- 5) Dry the control cabinet surface, clean the stains, and then unplug the aviation plug and power cable. Refer to **7.2.2 Robot Storage (Unbox but no operation)** to keep the cabinet.
- 6) Other devices including remote control, power cable, safety ropes, toolkit, fall arrestors, and so on need to be dry and cleaned, then refer to **7.2.2 Robot Storage (Unbox without operation)** to keep the accessories.

Annex 1. Nozzle Specifications and Water Jet Reaction Force

1) Performance of Different Nozzles at Various Flow Rate

Nozzle size in U.S. Gal / min at 40 psi	Nozzles Ød mm	Pressure in bar							
		Density of water							
		200	500	750	1000	1500	2000	2500	3000
		kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³	kg/m³
0002	0.10	1010.028	1020.675	1029.36875	1037.9	1054.475	1070.4	1085.675	1100.3
0003	0.125	0.100	0.157	0.191	0.220	0.267	0.306	0.340	0.370
0004	0.15	0.143	0.226	0.275	0.316	0.385	0.441	0.489	0.532
0006	0.175	0.197	0.309	0.377	0.434	0.527	0.604	0.671	0.730
0008	0.20	0.255	0.401	0.489	0.563	0.684	0.784	0.870	0.946
0012	0.25	0.402	0.632	0.771	0.887	1.078	1.235	1.371	1.492
0018	0.30	0.574	0.903	1.101	1.266	1.538	1.763	1.957	2.130
0025	0.35	0.808	1.270	1.549	1.781	2.165	2.481	2.754	2.997
0032	0.40	1.026	1.614	1.969	2.264	2.751	3.153	3.500	3.808
0040	0.45	1.301	2.046	2.495	2.869	3.486	3.996	4.436	4.827
0050	0.50	1.638	2.577	3.143	3.614	4.391	5.032	5.587	6.079
0061	0.55	1.982	3.118	3.802	4.373	5.313	6.089	6.760	7.356
0072	0.60	2.343	3.685	4.494	5.168	6.280	7.197	7.990	8.694
0085	0.65	2.769	4.355	5.311	6.107	7.421	8.505	9.442	10.274
0098	0.70	3.200	5.034	6.139	7.060	8.578	9.831	10.914	11.876
0114	0.75	3.700	5.820	7.098	8.162	9.918	11.367	12.619	13.731
0131	0.80	4.261	6.702	8.174	9.399	11.421	13.090	14.531	15.812
0148	0.85	4.810	7.566	9.228	10.611	12.893	14.777	16.404	17.850
0166	0.90	5.401	8.495	10.360	11.913	14.475	16.590	18.417	20.040
0187	0.95	6.094	9.584	11.689	13.441	16.332	18.718	20.780	22.611
0213	1.00	6.930	10.900	13.293	15.287	18.574	21.288	23.632	25.715
0258	1.10	8.39	13.19	16.08	18.50	22.48	25.76	28.60	31.12
0307	1.20	9.99	15.72	19.17	22.04	26.78	30.70	34.08	37.08
0361	1.30	11.73	18.45	22.50	25.87	31.43	36.02	39.99	43.52
0418	1.40	13.60	21.39	26.09	30.00	36.46	41.78	46.38	50.47
0480	1.50	15.61	24.56	29.95	34.44	41.85	47.96	53.24	57.94
0546	1.60	17.76	27.94	34.08	39.19	47.61	54.57	60.58	65.92
0617	1.70	20.05	31.54	38.47	44.24	53.75	61.60	68.39	74.42
0684	1.80	22.24	34.98	42.66	49.06	59.61	68.32	75.84	82.53

2) UHP Pump Flow Rate Calculation

Designed Flow Rate = Plunger diameter × Number of plungers × Plunger Travel

× crankcase pump speed at rated speed

Rated Actual Flow Rate = Designed Flow Rate × Volumetric Efficiency (80-92%)

3) Hydroblasting Reaction Force Calculation

$$Lb(f) = 0.052 * \text{Flow Rate (gpm)} * \sqrt{\text{Pressure (psi)}}$$

$$N = 0.2357 * \text{Flow Rate (Lpm)} * \sqrt{\text{Pressure (bar)}}$$

4) Matching the Nozzle Size and Pump Flow Rate

The size of the nozzle should match the pump flow rate. Taking an example of 16 nozzles spray lance which has an effective cleaning width of 305mm, if the

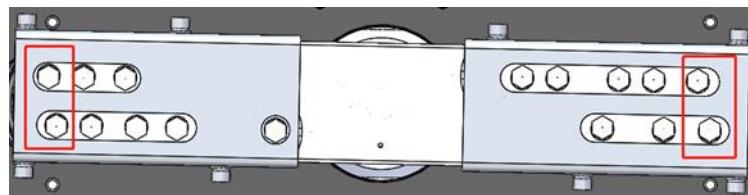
maximum pressure for a UHP pump is 2800 bar, the working pressure is 2500 bar, theoretical maximum flow rate 43 L/min, volumetric efficiency 0.8, then the actual flow rate is around 34.4 L/min. According to this data, match the nozzle type, flow rate and pressure according to the table above, 16 nozzles with 0.3mm can be used, and the flow rate in this case is calculated:

$$16 \times 1.95 = 31.2 \text{ L/min}$$

There are still 3.2 L/min flow wasted, in this case we can change the nozzles to 12*0.3mm with 4*0.35mm nozzles, and the flow rate will be

$$12 \times 1.95 + 4 \times 2.75 = 34.4 \text{ L/min}$$

It matches the flow rate of the pump. 4*0.35mm nozzles should be arranged at the outer position (larger flow rate nozzles should be installed at the outer position with symmetrical arrangements), and the arrangements of the nozzles are shown below:

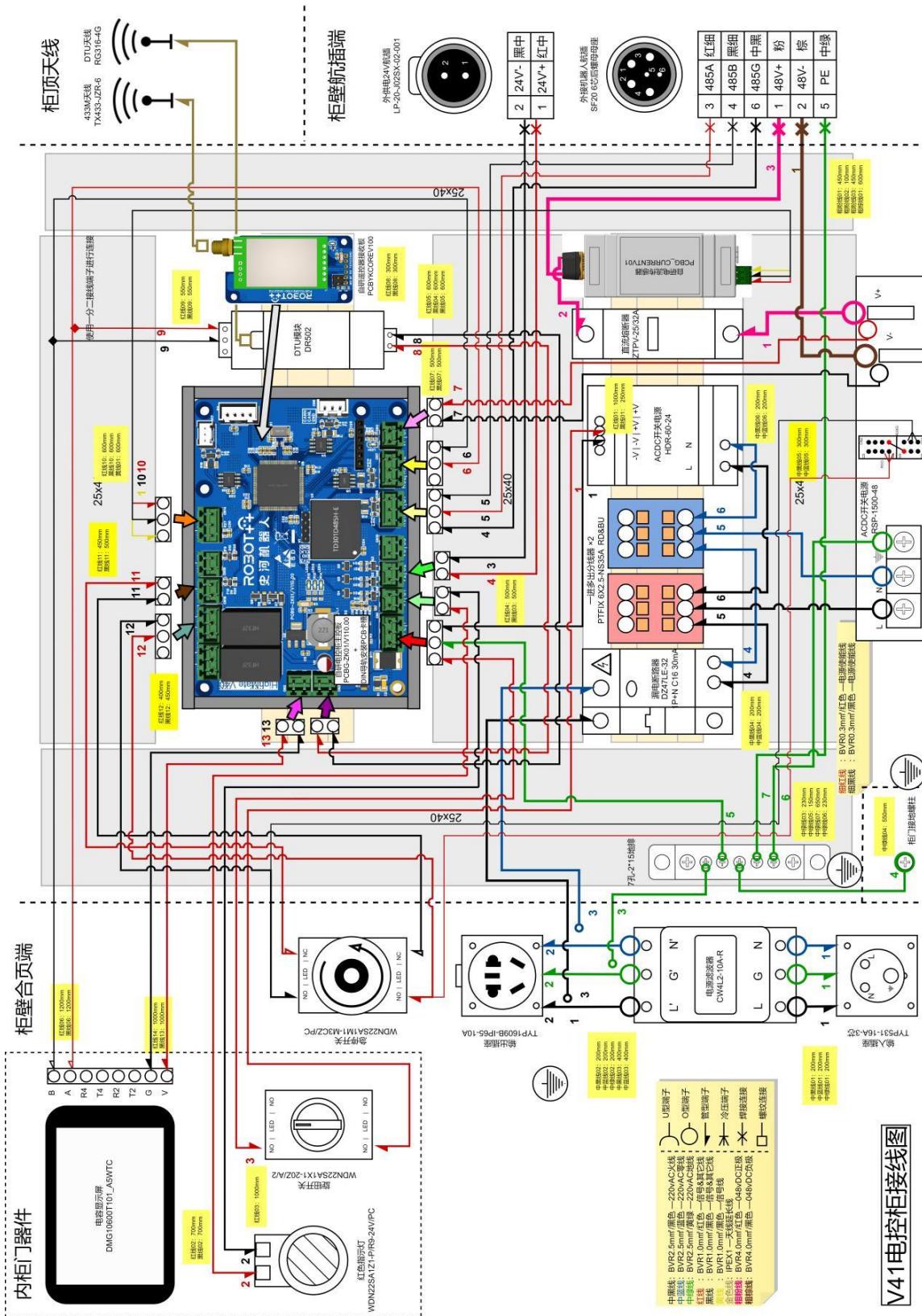


Note:

1. During assembly, the nozzles, nozzle plugs, threads, sealing cone surfaces need to be checked. If there are any machining defects like burrs, scratches and pits found, it should not be assembled and should be returned for repair.
2. When assembling nozzles or plugs, use compressed air to blow the path, nozzle, plugs, threads of the spray lance to clean them, especially the sealing cone surface, and grease with proper amount of blue lubricant.
3. When tightening the nozzles or plugs, the torque should be kept 17-18 Nm. If the torque is too large, it may damage the nozzles, and if the torque is small, the sealing will not be perfect which may lead to damaging the thread or leakage.
4. Every time before testing the nozzle, make sure the nozzles and plugs are tightened according to expected torque, and the cone surface is perfectly

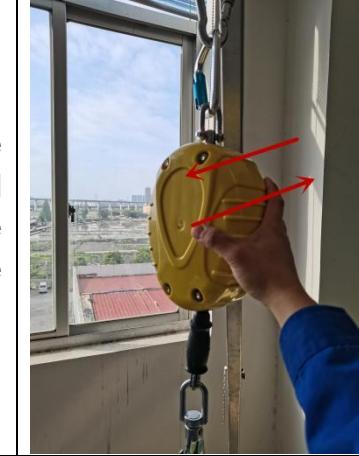
sealed without any gaps. If the surface is not in good contact, the spray lance may be damaged.

Annex 2. Schematic Diagram of Electric Control Cabinet



Annex 3. Fall Arrestor Common Fault Analysis and Solution

Item	Faulty Example	Description	Failure Cause	Troubleshooting	Finish Photo	Remarks
1		When lifeline is completely retracted, it cannot be pulled out	The brake ratchet and the brake gear are in the contact points	Hold the lifeline handle, squeeze it in the direction of retraction, separate the ratchet and the gear and the fall arrestor can work normally		
2		After a certain length of lifeline is pulled out, it cannot be pulled anymore	Lifeline in the shells twist and squeeze	<p>Method 1: Pull the lifeline slowly until cannot continue, pull it with larger force until it works normally.</p> <p>Method 2: Pull the lifeline slowly until cannot continue, pull it with large force suddenly to make it work normally.</p>		

3		<p>After a certain length of lifeline is pulled out, it cannot be pulled anymore</p>	<p>Lifeline in the shells twist and squeeze</p>	<p>Use appropriate force to shake the fall arrestor, then pull the lifeline until it can be pulled out completely</p>		
4		<p>After a certain length of lifeline is pulled out, it cannot be pulled anymore</p>	<p>Lifeline in the shells twist and squeeze</p>	<p>Use appropriate force to slap the fall arrestor, then pull out the lifeline until it can be pulled out completely</p>		

More Technical Support and Information:

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The Company reserves the right to upgrade and update the existing products. The technical data of this product is subject to change without prior notice.

The scope of the products to be delivered and the services to be performed shall be subject to the contract.

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