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Paper

Engineering Application of Ultra High Pressure Water Jet Rust Removal

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ABSTRACT

The water can be rusty, can also remove rust. The 300~500mm diameter rotary nozzles, driven by 250MPa and 50L/min flow water jet, can achieve Sa2.0 Level rust removal quality to the railway lories with 4m/min sway speed. The 3D robot as the water jet actuators can satisfy the work request of the railway lories complex surface. Twelve units equipments (300kW power) assemble two railway lories rust removal lines (six units in one line), four work stations operate at the same time —— it is the newest technology achievement of the writer —— Ultra high pressure water jet rust removal Engineering application. This text will introduce the achievement in detail, and show the measures for the problem during the engineering application. The appearance of water jet rust removal manufacture line resolves the pollution problem of traditional blasting technology, and is an example for clean manufacture.

Key word: Ultra High Pressure Water Jet Rust (Paint) Removal Manufacture Line

INTRODUCTION

Rust removal, named surface preparation too, will not be dispensable as in the cleaning field of industry when it serves as the necessary manufacturing technique. Continuous and automatic operation, dealing with complex surface, increasing efficiency, not re-rusting and etc., requests of these items are pressing and specific when water jet technique becomes one link in the manufacture. Realization of ultra-high pressure water jet rust removal application can advance the development of water jet technique.

MAIN BODY SECTION

1. Design of Rust Removal Line

Rust removal is the first step of rail cars (mostly open cars) maintenance, including exposed surface and bottom. Its traditional technique is steel ball blast, just as that a set of centrifugal impellers blast the steel balls to shot the rail cars for rust removal. Rust removal result of ball blast technique is that the surface can not be “white gold”, especially inside wall. Although traditional ball blast technique is confirmed in the enclosed workshop, the swashing steel balls will cause the serious pollution yet and post treatment of steel balls will cost large land.
The proofs and tests of that, using ultra-high pressure water jet rust removal technique to replace the traditional technique, are the complex and long process. Because the target distance of water jet is limited and the surface of rail cars is complex, the design of rust removal line has a lot of variables.
Based on the target distance can be guaranteed, water jet rust removal can achieve the uniform of quality, efficiency and pro-environment. The design of rust removal line is shown as Figure 1. The goals of the design are, to de-rust one car with 360m2 area in 45 minutes, to achieve Sa 2.0 surface quality.
In the design, there are 4 work stations just as five pump units and 3-D robots.
1st work station uses two pump units to de-rust outside surface. Because the maximum surface-distance is about 140 mm and minimum is about 70mm, the target distance is set as 150 mm during horizontal move and 80mm during vertical move. Apparently, rust removal quality of vertical move is better than horizontal, but horizontal move has easier operation than vertical because of fewer turning.
2nd work station uses one pump unit to de-rust inside wall. Because the inside wall is neat, the nozzles can move fast with short target distance. Although there are large area, 500mm diameters nozzles can de-rust very fast with good quality and efficiency, and it is equipped with vacuum suction system to keep the cleaned surface dry. Inside wall de-rust work can be finished with the rail cars is turned 90 degree by direction change frame.
3rd work station de-rust the bottom after overturn. Although there are few areas to de-rust, the surface is very complex and there are some steel hang parts, it is the difficult point in whole design. 2 units of 3-D robots work together, and each has Φ300mm andΦ100mm rotary nozzles, one is for large area de-rusting and the other is for complete. The machinery arm can exactly transport the nozzles to the complex surface, especially to the channel steel.
4th work station sprays the rust preventive to the cleaned rail cars, so that the rail cars will not re-rust before painting.
This kind of rust removal line design can keep the work efficiency with same operational time. The writer design two lines with 10 pump units to guarantee the surface preparation of 12000 rail cars per year.

2. Operation Condition

In the design, the work parameters of each pump are the study key. The following function equation restricts the study and test.

T=f(p, q, s, Nm, Na, Nd, V, n, Sa, t)

In the equation — T: Target, just as /car /40min, Sa 2.0;
p: pump work pressure, MPa;
q: pump actual flow, L/min;
s: nozzle target distance, mm;
Nm: nozzle tips quantity and diameter;
Na: nozzle tips installation degree;
Nd: Nozzle diameter, mm
V: nozzle move speed, m/min;
n: nozzle rotary speed, rpml
Sa: rust removal quality;
t: nozzle turn number.

Obviously, when ultra-high pressure water jet can achieve the rust removal Sa 2.0~2.5 quality for the rail cars, numerous study work is to decide the parameters of above equation. Here is the conclusion of the writer:

Technique parameters of the pump unit: 250MPa, 250kW, 50L/min. Actual work pressure is 220~230MPa, and pressure is controlled by the transducer. Pressure is the function parameter and Flow is the efficiency parameter. When both of them are increased, the unit power will increase the energy consumption and cost. Decision of the pump unit parameter is the base of whole rust removal line.

Nozzle target distance is 80~150mm, it effects the de-rust quality directly. For inside wall, the target distance can be within 20mm, so the Φ500mm nozzle can achieve good quality and fast speed. When lateral wall has some rib plates, Φ300mm nozzle with 80mm target distance can achieve Sa 2.5 surface quality during vertical move. During horizontal move, Φ300mm nozzle with 150mm target distance can achieve Sa 2.0 surface quality. All of the parameters can increase the efficiency.

Nozzle tips quantity, installation degree and diameters are the objects of study. For different surfaces, the writher designs Φ500mm, Φ300mm, Φ200mm and Φ100mm rotary nozzles. Nozzle tips quantity is 4~8, and installation degree is toward to Normal to keep the jet shoot force.

3-D robots, shown as figure 2, bring the nozzles to work with 4~5m/min speed for outside wall and 5~7m/min for inside wall. The speed adjust is related to the diameters and target distance of the nozzles, and also match nozzle move speed.

Nozzle rotary speed is about 500rpm. Because it is the forced rotary, this parameter can keep the jet from pulverization.

It can be satisfied mostly that de-rust removal quality require Sa 2.0, but too long target distance and fast move speed will get Sa 1.5 only. Because the result is determined by sight mostly, it is very important to achieve the proprietor’s agreement. It is certain that the surface quality of water jet rust removal is much better than ball blast, and it is the key to replace the ball blast technique.

Nozzle turn numbers mean change the horizontal move of nozzles to new line. Based on the rust removal quality, large target distance nozzle can turn with the least number, and horizontally move with the longest distance.

3. Rust Removal Quality & Speed

Based on the Sa 2.0 surface quality, the speed would be the sooner and the better, but it is related to factors such as S, n, Nd and so on. Because Sa is from the sight, the writer offers the rubber removal test list Table 1 to expound it.
Figure 3~6 shows rust removal quality in test. Based on surface quality, the rust removal speed is 4~6m/min that is 1.2~1.8m2/min. certainly, such speed is only single directional test data. Actually, it is related to some factors such as nozzle contraposition, change new line, control, water jet parameters, surface condition and so on.

4. Complex Surface Rust Removal

The shortcoming of water jet rust removal is the limited target distance, and it means that large target distance need large flow parameter. This problem can not be resolved in complex surface mostly, so the writer tried it from the special nozzles and robots。
Cone form of the nozzle body can guarantee the large covering surface of rotary jet, and expend the work surface with same Normal shoot force. It can suit the plane surface work not only, but also the right angle surface and flute profile surface. It can mostly resolve the rust removal work of complex surface with high efficiency.
Φ100mm rotary nozzle is very propitious to complete missing surface. It can put in the cavity and de-rust the right-angle welding line and steel hang part.
Test proved above two kinds of nozzles can fulfill the work of complex bottom.
3-D robot is very important, and it guarantees the nozzles exact operation. 3-D robot valid motion is shown as Figure 2. Hydraulic control system is located in the console cabinet and it guarantees the safety and flexibility of ultra-high pressure water jet work.

5. Operation of the Rust Removal Manufacture Line

The rust removal manufacture line which the writer desings has worked well for half year, and the operation situation is summarized as the following:

5.1 Outside Wall Rust /Paint Removal

In the test, it is difficult to adapt the water jet target distance to suit the complex surface. In practice, it is appeared more difficult. The writer uses 150mm target distance for all complex surface of outside wall, and less than 100mm target distance for both end wall. The working pressure is 230~240MPa. Figure 7 shows the contrast between before rust removal and after. Because the target distance is too larger than the best distance, the writer has to pay attention to every details of the pressure loss, for example, the jet lances are holistic bend model, not assembled with two lances connected squarely; the designs of the connections' seal and the variation of pipe diameter are optimized.
The operation condisions show: paint removal is harder than rust removal, especially with the large water jet target distance. The nozzles move speed for paint removal is 3~4m/min, less than the test result obviously.

5.2 Inner Wall Rust Removal

Actual working conditions of inner wall is a simple rust removal project.
Figure 8 shows that the locomotive is overturn 90° by the overturn mechanism, and the arm

of 3-D robot works in the inner wall. The rotary nozzles can get the best target distance and, the vacuum system can collect the dirty water and rust into the dirty water tank. The actual operation speed for inner wall is 5~6m/min, the operation pressure is 220~230MPa.

5.3 Underframe Rust Removal

Because the underframe is very complex, using same method can not satisfy the rust removal speed request, and it ask more sensitivity for 3-D robot, it has to be changed to the abrasive jet and manual hand-gun operation. This method is more simple and flexible, and cheaper. See figure 9.

5.4 Re-rust Problem

For avoiding that the surfaces re-rust befor next paint process, the rust protection fluid is sprayed to the surface after rust removal. This process can protect the surface from rust for three days.

6. Problems

There is not the precedent that applying ten units of high pressure large power pumps into the rust removal manufacture line for railway locomotives, so some problemes apear, and are resolved step by step.

6.1 Noise

Noise is the avoidless problems of high pressure water jet, and only can be resolved through the shield. Peoples can not accept the over 100dB(A) noise, and the shield must reduce the noise less than 85dB(A). It is not achieved now and just be relieved.

6.2 Water Fog

Water fog is another avolidless problems of high pressure water jet, especially in the out-side wall rust removal with 150mm large target distance. Water fog will effect the normal operation, and make the electrical device damp.

6.3 Reliability

The rust removal manufacture line works for 16 hours continuosly on two shifts. Any small problems in any places will stop the whole manufacture line. The maintenance and inspection for every components are very important, especially the pipe line and connections of high pressure pumps. In the past half year, the manufacture has passed through the reliability test.

7. Conclusion

7.1 it is feasible that ultra-high pressure water jet is applied in rust/ paint removal. The parameters of single unit are: 250MPa pressure, 50L/min flow, 250kW power.

7.2 actual operation efficiency is lower than the test, because the operation of actual paint locomotives are harder than the rust locomotives in test.

7.3 large target distance operation resolves the problem of complex surface rust/ paint removal, but cause more noise and water fog problems.

7.4 the rust reomval quality of ultra-high pressure water jet can meet the customers' paint request, generally achieve Sa 2.0 surface level. Because of the complex surface, some miss parts may be finished through manual hand-gun works.

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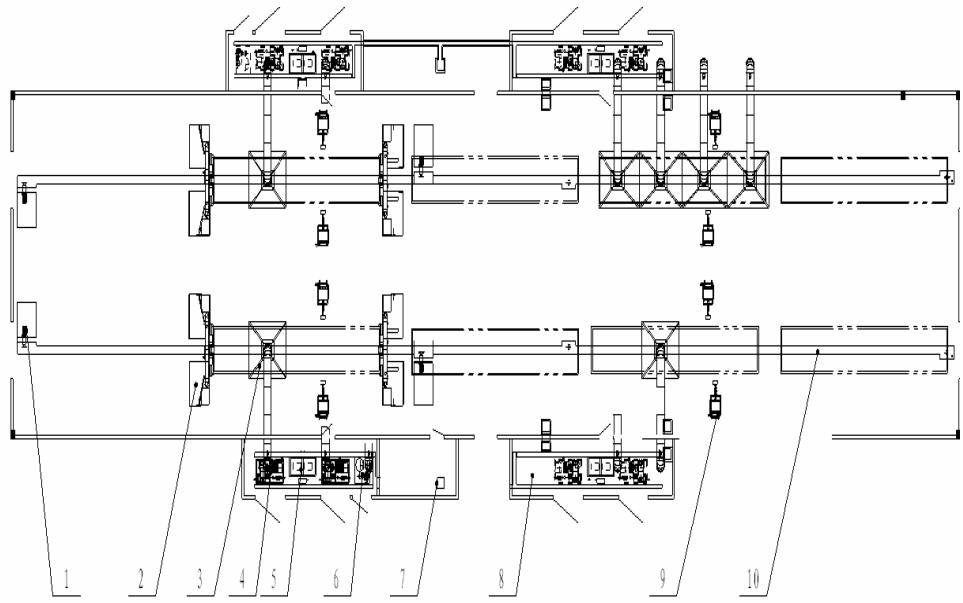

1. Draughting Mechanism 2. Overturn Mechanism 3. Vacuum Suction System
4. High Pressure Pump Unit 5. Transducer 6. Vacuum Pump Unit
7. Surveillance Room 8. Pumps Room 9. 3-D Robot 10. Rail

Figure 1. Design of Rust Removal Line

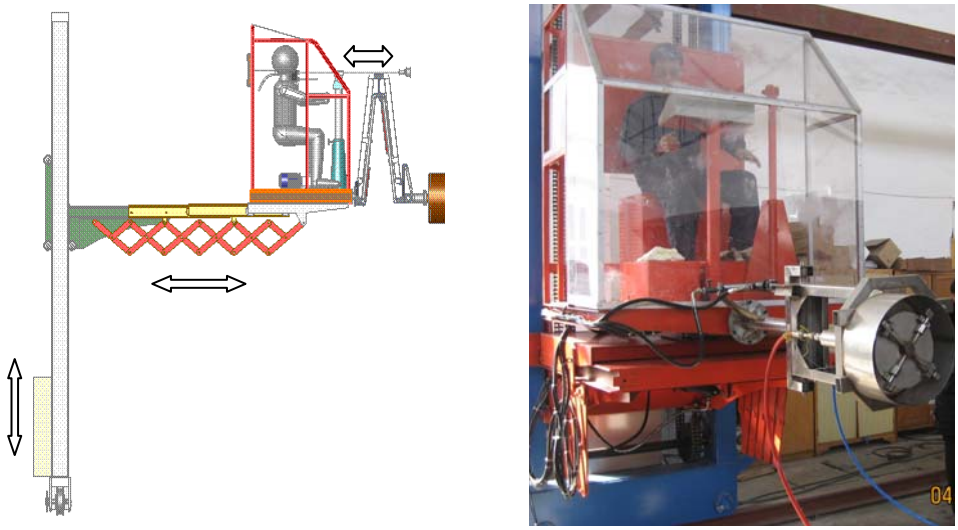

Figure 2. 3-D Robot Valid Motion

Figure 3. Test 1 Result

Figure 4. Test 2 Result

Figure 5. Test 3 Result

Figure 6. Test 4 Result

Table 1. Rust Removal Test List

Item	Pressure /MPa	Nozzle Rotating /RPM	Removal Speed m/min	Target Distance /mm
1	225	450	8	150
2	225	450	6.3	150
3	220	450	4	50 & 100
4	220	450	4	Slope cleaner
Test Description				
Item 1	Side plate rust removal, plane cleaner move 5 meters horizontally (Figure 3)			
Item 2	Side plate rust removal, plane cleaner move 5 meters horizontally (Figure 4)			
Item 3	Header rust removal, plane cleaner move 1.2 meters forward (Figure 5) 50mm target distance for raised part; 100mm target distance for normal part;			
Item 4	Header rust removal, plane cleaner move 1.2 meters forward (Figure 6)			

Figure 7. Outside wall rust removal

Figure 8. Inner wall rust removal

Figure 9. Underframe Rust Removal