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Paper

ULTRA HIGH PRESSURE WATERJET

RUST REMOVAL LINE DESIGN AND TEST

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ABSTRACT

The water can be rusty, can also remove rust. Traditional rust removal technique uses sand blasting and pill throwing with bad work environment and severe pollution. Large-scale rust removal line has been looking for a new technique to change this kind of condition thoroughly.

Aiming for the large-scale rust removal engineering in manufacture and maintenance of locomotives, the writer applies the ultra high pressure waterjet to the rust removal line.

Assemble some pump units with 250MPa pressure and 250kW into the four different rust removal lines: for Plates, for Sheet Metals (0.8mm), for Shape and for Whole trucks.

Their features are the following:

- Plates rust removal: double faced work synchronously.
- Shape rust removal: apply the arms with one or more sets of rotary nozzles to clean for different form and dimensions.
- Whole Locomotive rust removal: apply the arm to achieve some kinds of motions of the rotary nozzles, Up and Down/ Forward and Back, so as to realize large-scale cleaning.

All above technique have been verified by tests and in implementation phase now.

1. INTRODUCTION

Five locomotive factories of China South Locomotive and Rolling Stock Industry Corporation (CSR) constitute one locomotives production base what named WuHan ChangJiang Locomotive Company applying newest technique and equipments. For resolving the long-term serious pollution problem of steel surface preparation, my institute HeFei General Machinery Research Institute (GMRI) proofs "ultra high pressure waterjet rust removal Line" with CSR. It is the rust removal technique revolution in Chinese Locomotive Manufacture Area.

Following are the items what CSR requires:

- Whole Locomotive – Dimensions: 14×2.8×3m; Surface Area: 300m2; Removal Speed: 40min/unit; Rust Removing Quality: Sa 2.0.
- Sheet Metal – Double faced rust removal synchronously; Dry after rust removal; Rust removal without deformation.

2. TRADITIONAL TECHNOLOGY

The traditional technology in Chinese Locomotive rust removal area is SHOT BLASTING, just as, the centrifugal wheel blasts the steel balls to steel surface for rust removal in one closed room. This technology is valid for plates and shapes, but according to the large dimensions of whole locomotives it shall not be valid any more. Because whole locomotives need one too large closed room, the SHOT BLASTING will cause serious pollution and lose normal rust removal quality for too long jet distance.

Changing Dry Rust Removal to West Rust Removal is the hope of professional technical personnel. In ages of low working pressure, the abrasive waterjet makes some valid attempt, but it can not meet the demand of industrialize because of its harsh working condition just as – dry, uniform, continuous transport – and low job effectiveness. In ninety century the writer ever applied this technology for ship rust removal, but could not spread it.

3. PURE WATERJET RUST REMOVAL

What is WATERJET – One small jetting bunch of fluid can turn the pressure energy into kinetic energy and it works on the target material with kinetic energy turned into mechanical energy.

The energy of waterjet can be shown as $P_e = p \times q_v / 60$. P_e means effective power, p means PRESSURE, q_v means FLOW. According to this, the energy will be up with the pressure and flow. Pressure up can keep the waterjet working ability and Flow up can keep

the waterjet working effectiveness, but two parameters up will cost more and increase instability. When cleaning target is decided, suitable pressure have been selected too, so larger flow can offer larger effectiveness.

When people realize waterjet power, people will not suspect that waterjet can remove rust any more. Now how to choose the parameters of waterjet so that waterjet can have enough power to remove rust is the problem.

(See figure 1. and figure 2.)

4. ESTABLISH PARAMETERS WITH TEST

Ultra high pressure and power pump unit costs expensively, and it is one important element of Rust Removal Line Design, so must establish the suitable parameters through test first. In early days the test parameters are 200MPa and 20LPM and 160kW.

In Europe and America, there are some applications of waterjet rust removal in ship. The same point between locomotive rust removal and ship rust removal is large area and the different point is just as – Robot work easily in ship because ship's surface is similar to one plane & locomotive's surface is very complex and the altitude disparity is about 140mm.

In test, using 300mm plane cleaner to large face & 40mm rotary nozzles to complex back plane. Set plane cleaner as the following:

- Rotary speed: regulated form 325rpm to 479rpm;
- Target distance: 90mm (horizontal motion) & 150mm (vertical motion)
- Rust removal speed: 2m/min & 3m/min

Test results of two rust removal speeds have a little of difference and both of them achieve normal rust removing quality – there are only some inherent patches and attain the request.

For satisfy the request of rust removal line, the horizontal moving speed shall be updated to 6m/min or higher, so the design parameters have been established based on the test parameters: 250MPa Pressure (work pressure 220-230MPa); 50LPM Flow; 250kW Power.

5. RUST REMOVAL LINE PROJECT

After establishing the parameters, the project design rules are just as the following:

- Ensure to harmonize all parts of this manufacture line;
- Transport waterjet to every point which need remove rust;
- Produce, Regulation, control and operation of waterjet.

For 1000 units of locomotives rust removal in one year, there are two coordinate rust removal lines what includes nine pump units in the project. One line has two work tables for rust removal, one work table has two pumps, so the rest one pump unit is spare and used by both lines together if it is necessary. First work table operates for outside surface and second work table operates for inside and back plane.

For transporting waterjet to all rust removing points, there are eight units of 3D Robots. 3D Robots are quipped with plane cleaners used for large area and Gun-Rotary-Nozzles used for complex surface. 3D Robots can move with the locomotives and achieve three motions – 1.5m Up and Down for outside side-plane operation; 1.5m Forward and Back for end face operation; Control plane cleaners to turn 0-90° for right angle area operation.

Waterjet equipments are the key technique of this project. The selection rules are practicability, safety, economy and advance. This rust removal line consists of Ultra High Pressure Waterjet System, 3D Robots (**see figure 3.**), Control System, Antirust Agent Spray System, Water Recover and Treatment System.

Ultra high pressure waterjet system consists of high pressure pump, kinds of valves, plane cleaners, spray guns, rotary nozzles, high pressure hoses, booster pump and filters. Its work process: normal water, pressurized to 0.3MPa through the booster pump, goes through filters into the suction valve of high pressure pump and then transported to plane cleaners or spray guns or rotary nozzles after pressurized to work pressure by high pressure pump.

5.1 Ultra high pressure pump

For achieving the ultra high pressure work situation, inlet and outlet valve insert can down lord the pressure through spring mode, suction and discharge valve use one valve seat, the packing of plunger reciprocating seal can be installed by spring mode, the design of can guarantee the pump continuous 500h work without changing spare parts. All of above are the design features of triple plunger horizontal high pressure pump.

5.2 Plane cleaner and rotary nozzle

It is very important to guarantee the rust removal effectiveness that suitable nozzles can be chosen.

- Normal plane cleaner with 350mm diameter is used to clean the side plate of locomotives and rotary nozzles with small diameters are used to clean the corner what plane cleaner can not work well (**see figure 4.**);
- Large plane cleaner with 400 – 500mm diameter is used to clean inside surface of locomotives and water recover treatment system cycles the waste water;
- Small plane cleaner with 200 – 250mm diameter is used to clean the back plane of locomotives and 8 jets rotary nozzles are used to clean hollow trough.

8 jets rotary nozzles (**see figure 5.**) can produce axial and radial jet, so that we can clean polyhedron inside cavity. Rotary coupling is the key part of above tools and the service life of high pressure rotary seal is more than 200h.

5.3 Ultra high pressure valve and spray gun

Ultra high pressure valves are the control tools of the system, consists of the following kinds:

- Safety Valve: overlord 1.0 – 1.15 pressure, safety valve will down lord pressure to protect the pump unit.
- Pneumatic Over Flow Valve: working pressure≤250MPa; Flow 45lpm.
- Pneumatic Shutoff Valve: working pressure≤250MPa; Flow 50lpm.

Spray gun consists of the nozzle and valve and the valve is overflow mode.

Because water recover and treatment system can not work except inside surface, so the antirust agent spray system is used to guarantee the rust removal quality for some days.

6. TEST OPERATION

6.1 Whole Locomotives Rust removal

Whole locomotives rust removal equipments (**see figure 6.**) has two modes for complete rust locomotives and complete paint locomotives. Rust removal cleaner consists of 4 Jets (two 0.6mm diameter tips; two 0.7 mm diameter tips), and its diameter is 300mm. Test result data **seeing Table 1.**

6.2 Whole Locomotive Paint Removal

Test situation and nozzle tips are same as the above. Test result data **seeing Table 2.**

6.3 Rust-resistant

Spray antirust agent to the surface after rust removal, and the surface keeps the quality after for two days. For inside surface of locomotives, the vacuum system work well as the antirust agent spray system and avoid water smoke.
(**See figure 15.**)

6.4 Sheet Metals Rust Removal

Sheet metals rust removal equipment consists of one high pressure pump and two 500mm diameter plane cleaners and there are 4 nozzle tips in every cleaner. Sheet metals go through

two plane cleaners so that both sides of surfaces will be cleaned at the same time. Rust removal speed is about 3m/min (both sides).

7. CONCLUSION

- It is feasible to use ultra-high pressure waterjet to remove the rust of locomotives what have complex surface, whatever operating with the short target distance (50mm) for the inside surface, or long target distance (150mm) for the outside plane, adaptive operating parameters can meet all the working request.
- 220-230Mpa pressure and 50L/min flow are the suitable parameters of rotary waterjet for rust and paint removal, and the removal speed can be 6.3m/min ($2m^2$/min). For both side of sheet metal, the removal speed can be 3m/min. all of the rust removed metal can meet the painting request.
- Decrease the target distance to 50mm, the rust removal speed will be increased into 8-10m/min. working efficiency has a great increase.
- For removing the plane's rust, vacuum pump can meet the request of rust removal without re-rust. For the complex surface rust removal, spray the antirust agent to guarantee the surface quality more than two days without re-rust, which meets the time's request of the painting.
- 4 units pump work simultaneity and it can meet the 40min time request for every locomotive rust removal.
- Ultra-high pressure waterjet rust removal technology resolves the pollution problems and replaces the backward technology "Shot Blasting". It will be applied widely in Chinese Locomotives manufacture and maintenance.

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Table 1. Whole Locomotives Rust removal Test Data

Item	Pressure	RPM of Rotary Nozzle	Rust Removal Speed	Target Distance	Test Description
1	225 MPa	450 RPM	8m/min	150 mm	Side plate rust removal, plane cleaner move 5 meters horizontally (Figure 7)
2	225 MPa	450 RPM	6.3m/min	150 mm	Side plate rust removal, plane cleaner move 5 meters horizontally (Figure 8)
3	220 MPa	450 RPM	4 m/min	50 & 100 mm	Header rust removal, plane cleaner move 1.2 meters forward (Figure 9) 50mm target distance for raised part; 100mm target distance for normal part;
4	220 MPa	450 RPM	4 m/min	Slope cleaner	Header rust removal, plane cleaner move 1.2 meters forward (Figure 10)

Table 2. Whole Locomotives Paint removal Test Data

Item	Pressure	RPM of Rotary Nozzle	Paint Removal Speed	Target Distance	Test Description
1	225 MPa	450 RPM	8m/min	150 mm	Side plate paint removal, plane cleaner move 2.5 meters horizontally (Figure. 11)
2	225 MPa	450 RPM	8m/min	90 mm	Side plate paint removal, plane cleaner move 2.5 meters horizontally (Figure. 12))
3	225 MPa	450 RPM	6.3m/min	90 mm	Side plate paint removal, plane cleaner move 2.5 meters horizontally (Figure. 13)
4	225 MPa	450 RPM	6.3m/min	150mm	Side plate paint removal, plane cleaner move 2.5 meters horizontally (Figure. 14)

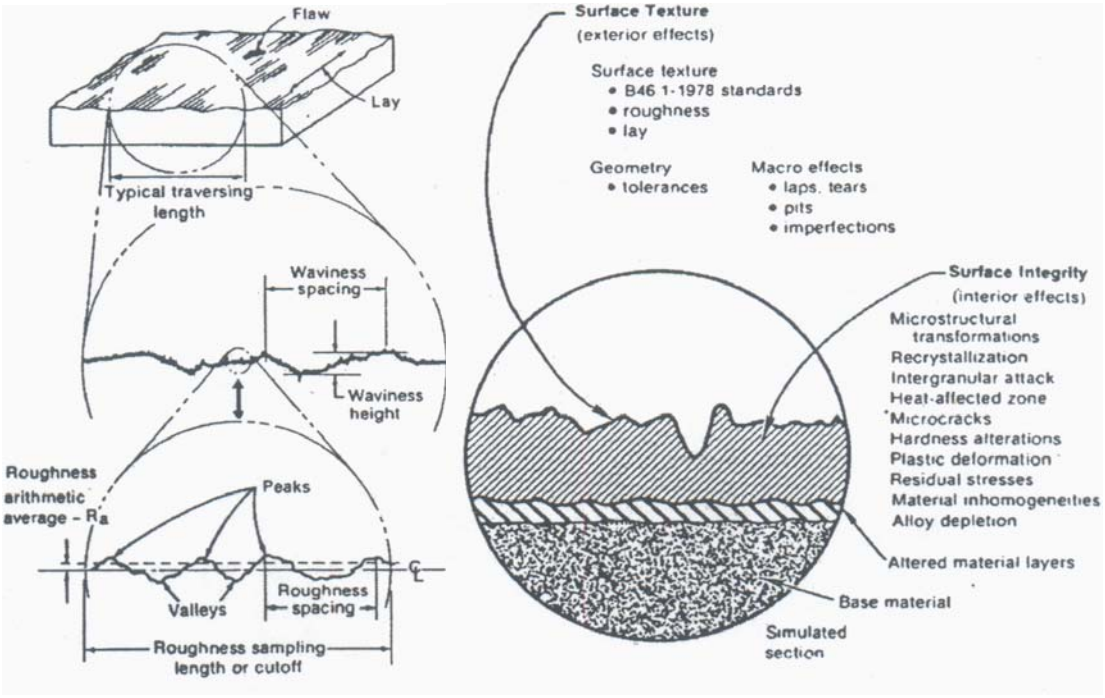

Figure 1. Appearance and Effect of Steel Surface

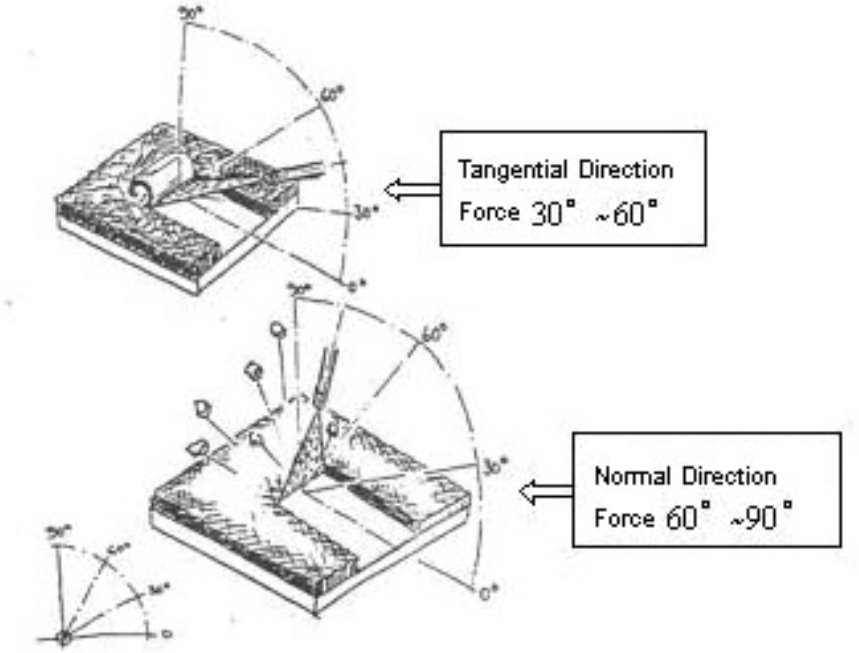

Figure 2. Normal and Tangential Direction Force Mechanism

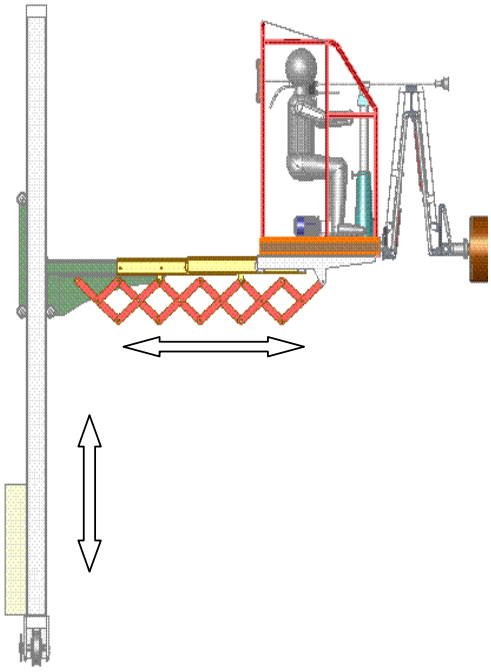

Figure 3. 3D Robot

Figure 4. Plane Cleaner

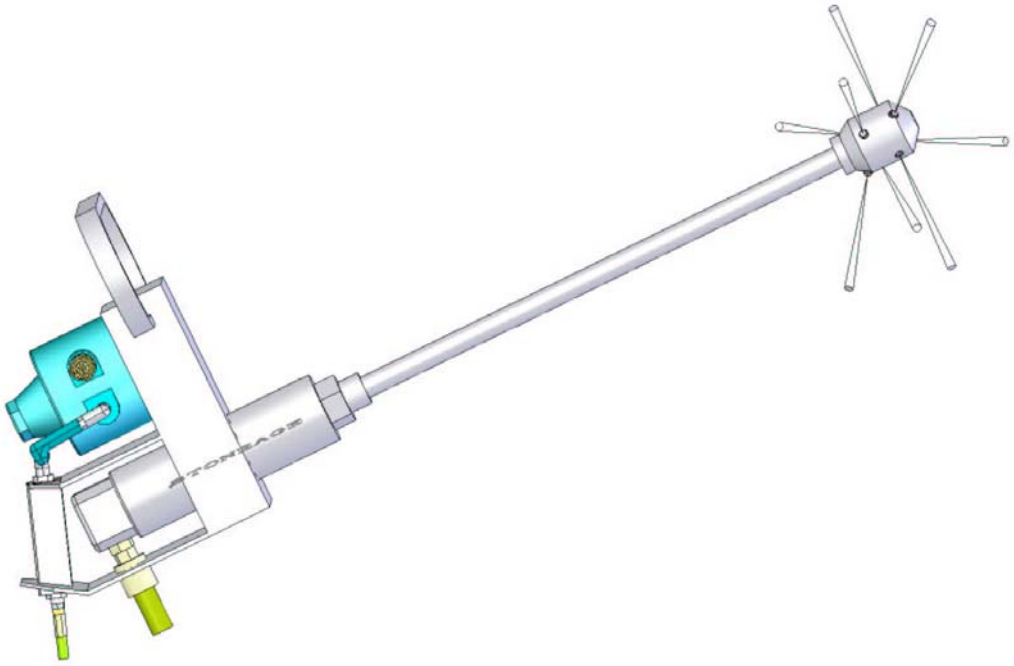

Figure 5. 8 Jets Rotary Nozzles for Complex Surface

Figure 6. Locomotives Rust Removal Equipment

Figure 7.

Figure 8.

Figure 9.

Figure 10.

Figure 11.

Figure 12.

Figure 13.

Figure 14.

Figure 15.