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Paint Removal of Airplane & Water Jet Application

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Abstract

The paint removal and recoating are the very important process in airplane maintenance. The traditional technology is to use the chemical way corroding the paint with paint remover. For changing the defects, corrosion & pollution & manual working, of the traditional technology, the physical process which removes the paint of airplane with 250MPa/ 250kW ultra-high pressure rotary water jetting though the surface cleaner installed on the six axes robot is studied. The paint layer of airplane is very thin and close. The contradiction of water jetting paint removal is to remove the paint layer wholly and not damage the surface of airplane. In order to solve the contradiction, the best working condition must be reached through tests. The paint removal efficiency with ultra-high pressure and move speed of not damaged to the surface. The move speed of this test is about 2m/min, and the paint removal efficiency is about 30~40m^2/h, and the paint removal active area is 85-90%. No-repeat and no-omit are the base requests of the robot program. The physical paint removal technology will be applied in airplane maintenance, and will face the safety detection of application permission.

Keywords: Airplane surface; Paint removal; Ultra-high pressure; Water jetting technology; Six axes robot; Test research

1. Current status of airplane paint removal

Paint removal for airplane is an important process for airplane maintenance. The reasons for paint removal of airplane are as follows: 1) No matter the military aircraft or common airplane, the oxidize bottom paint/polyurethane surface paint will be cracked and dropped by all kinds of corrosion, radiation and complicated environment, so the average life of these paint is four to five years [1] and they must be removed partly or wholly. 2) When the airplane need be returned to factory to repair, old airplane removal and new paint spraying is a necessary process. But the popular paint removal method is chemical process using chemical paint remover.

Chemical method of airplane paint removal is achieved through smear, dissolution, permeability, swelling, peeling, and the reaction etc. [2-3] series physical and chemical processes with solvent-based paint remover, which mainly contains chlorinated hydrocarbon solvent. The principle is that the main solvent molecules could permeate to the gap between the macromolecular chains of the polymer. It could swell and stretch the chains, and thereby to produce stress to release the adhesion of the film to the substrate. The efficiency is high but it need 2.4 ton paint remover for removal of a medium-sized transport aircraft. The toxic solvent will pollute the air, environment and human health. For solving these problems, people tried many other technologies such as paint remover without chlorinated solvent, shot blasting with plastic pellet, and laser light. But these methods could not be used for many reasons.

Due to serious harm with chemical paint removal process, the author used ultra-high pressure and big flow rotary water jetting technology to remove paint of airplane which has big size and curve surface. This process is cooperated by six axes robot and vacuum suction system. This paper introduced the threshold pressure test and water jetting test, with surface cleaner device and vacuum suction system. Furthermore, teach and program robot to move the surface cleaner device toward airplane and change two rotary water jetting type, we got expected result of paint removal quality and efficiency from old airplane. It is absolutely no polluted for atmosphere, environment and human health, and it is a physical process paint removal with water.

2. Similarities and differences for paint removal and rust removal

The research for airplane paint removal using ultra-high pressure rotary water jetting technology is mainly based on ship rust removal application, which is researched by author for long time. What are the similarities and differences for paint removal and rust removal? The common points of paint and rust are as follows: they are the subsidiary matter of metal surface and they can be removed by force; they are adhered to the big size and curve surface, the robot is the perfect operating device; after removal they need be collected and the vacuum suction system is the effective method; the most important is, the water jetting parameters of paint removal and rust removal are basically same. The differences of paint and rust are that they have different material and

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structure. The rust is oxidized layer and the paint is chemical layer, rust layer is looser and thicker than paint layer, rust layer can be 10mm or thicker but the attach force of rust is less than paint. As the rust layer will oxidize the original paint, the rust layer is almost mix matter with paint depending the oxidize degree, the rust removal quantity is more lager than paint. Furthermore, the base material layers are different. The former is steel material, easily produce rust and strong enough to rust removal. The latter is aluminum alloy or compound material, uneasily produce rust but easily broken by water jetting force, because the paint layer is very thin which is less than 1mm and it will be dealt carefully and scientifically. However, the airplane surface is quite complicated. There is no simple and big flat, so it cannot use device like crawler of ship rust removal. Obviously, it is quite difficult to remove airplane paint with water jetting.

It is no doubt that no matter ship rust removal or airplane paint removal, the principle of ultra-high pressure rotary water jetting are the same. The layer under microscope is uneven and roughness, the rotary water jetting is like one sword to spade the paint coat (see Figure 1). The rotary water jetting makes the radial jetting have the feature of tangential jetting. It has the capacity of vertical force and horizontal removal. Therefore, 30°~60°angle of water jetting are to get combination of direct, bending and shearing force(see Figure 2)[4-5]. The paint layer will become the powder under the rotary water jetting, and they will be drawn with water by vacuum suction system. It is an absolute physical process. Because of feature of airplane paint removal, the diameter of water jetting and moving speed is small, and the removal efficiency is less than ship rust removal.

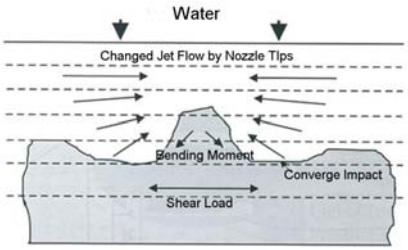


Fig. 1 Principal of water jetting layer removal

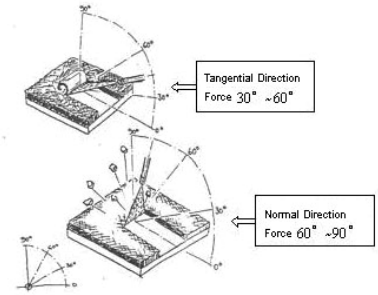


Fig. 2 Radial and tangential direction force mechanism

3. Threshold pressure test

It is known that the water jetting power is related to pressure and flow, increasing the pressure or flow will also increase the power of pump unit. The pressure is an ability parameter, the different water jetting application like cleaning, blasting, rust removal, cutting and so on need different pressure, the different flow will cause different working efficiency as well. As for one special application, these two parameters will be optimized by test and can be neither balanced nor extreme [6-7]. It is sure that the high difficult application need big power pump unit.

The author takes the ship rust removal parameter to airplane paint removal, which is 220MPa, 50L/min, 250kW. The paint layer was removed, but the base aluminum alloy was broken, because the aluminum alloy is thinner than steel material. If the working pressure is reduced to 180MPa and the water jetting is no-stop and no-repeat, the perfect paint removal effect will be achieved. Pressure is reduced 20% and the flow is increased 20% which is 60L/min, but the removal efficiency is improved quietly. Because the identical paint thickness and attach force, the parameter of airplane paint removal must be stable. Figure 3 shows the effect of plane aluminum alloy paint removal under different pressure.

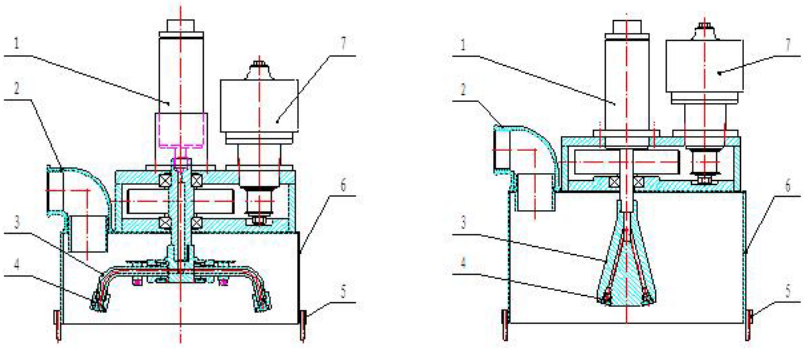
a)220MPa

b)180MPa

Fig. 3 Paint removal effect under different pressure

In order to not break the airplane surface, the best and stable jetting target distance must be assured. The surface cleaner device, which has 30mm stable jetting target distance and 300mm jetting diameter, move toward surface not less than 300mm/min, and the contradiction between the paint removal quality, efficiency and surface damage is perfectly solved. The surface cleaner device will be loaded and moved by mechanical arm, the nozzle head in this device will be pneumatically driven to optimized rotary speed about 300~400rpm, the ultra-high pressure water will go through swivel seal, jetting shaft and nozzle tips to become the ultra-high pressure rotary water jetting. In the vacuum chamber, most of water can be sucked during operation; meanwhile, the temperature field of vacuum chamber is up to 85℃-90℃. Therefore, the surface could be dried immediately and there is no fog in work place. Figure 4 shows the surface cleaner device.

Certainly, in order to deal with big size and curve airplane surface paint removal, 300mm working diameter surface cleaner and 150mm nozzle head must be installed on six axes robot located 90°. They are separately used to big size flat surface and small crossed curve surface.



a) Large diameter surface cleaner

1.Ultra-high pressure swivel seal 2.Vacuum suction inlet
3.Jetting shaft 4.Nozzle 5.Vacuum seal 6.Vacuum chambe
7.Pnumatic motor

b) Small diameter nozzle head

1.Ultra-high pressure swivel seal 2.Vacuum suction inlet
3.Nozzle head 4.Nozzle 5.Vacuum seal 6.Vacuum chamber
7.Pnumatic motor

Fig. 4 Surface cleaner device

4. Ultra-high pressure water jetting airplane paint removal application

4.1 Ultra-high pressure water jetting paint removal equipment for airplane

Figure 5 shows the equipment for airplane paint removal with ultra-high pressure water jetting technology. According to operating efficiency, two systems can be assembled around the airplane, including ultra-high pressure pump unit, vacuum suction system, six axes robot, surface cleaner device and teaching electronic control system.

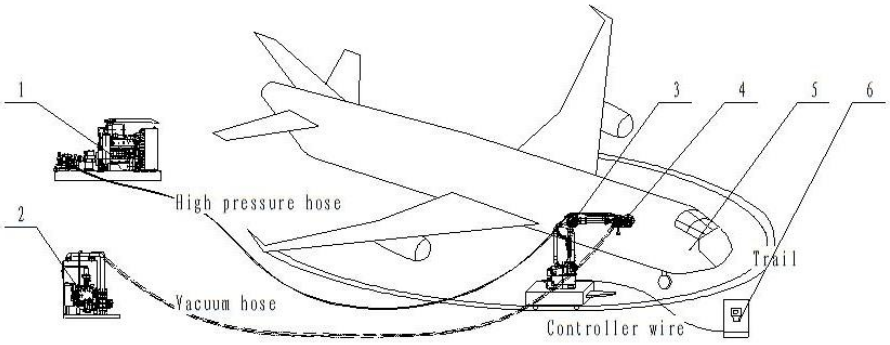


Fig. 5 Ultra-high pressure water jetting paint removal equipment for airplane

1. Ultra-high pressure pump unit 2. Vacuum suction system 3. Six axes robot 4. Surface cleaner device 5.Plane 6. Teaching electronic control

Figure 6 shows the schematic diagram of whole equipment. The physical process is as follow: normal water was boosted from water tank by booster pump and gone through the filter, and then ultra-high pressure pump brings the water jetting. If the working pressure exceeds, the safety valve will dump. The pneumatic pressure valve regulates the water pressure and high pressure hose delivers the water to large diameter surface cleaner or small diameter nozzle head which are located in robot arm and directionally controlled by valve. Finally ultra-high pressure rotary water jetting spray to airplane, meanwhile vacuum suction system sucks the sewage into tank by vacuum hose.

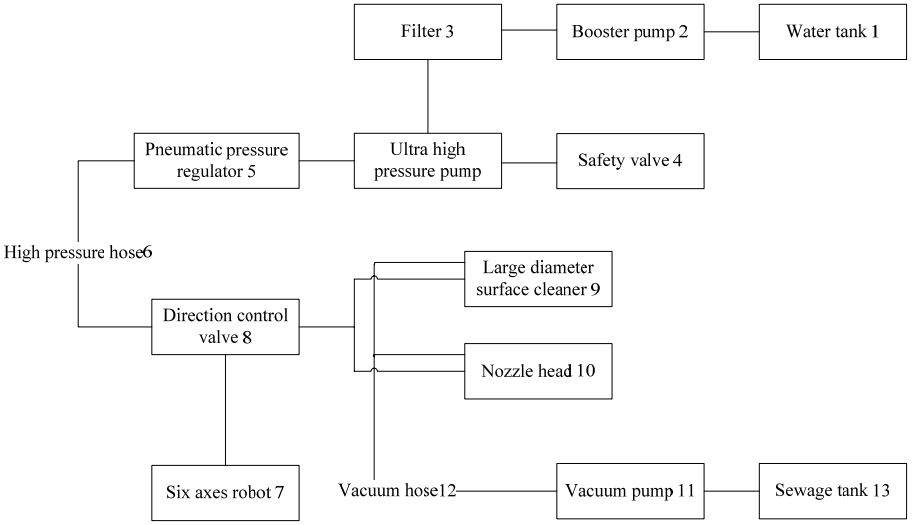


Fig. 6 Schematic diagram of whole equipment

Six axes robot makes a stage of water jetting work. When it enters a new stage, the robot will teach program and remember step by step. After the jetting pressure is regulated by valve, the robot will load and move the surface cleaner in the arm according to before-mentioned expected path, attach the cleaner toward the airplane surface in a certain range. All the equipments are operated by one person in one controller system.

4.2 Technology parameters

The key technology parameters of ultra-high pressure airplane paint removal equipment are as follows:

1) Ultra-high pressure pump unit: pressure is 250MPa, flow is 30~60L/min, medium is water, power is 150~250kW, the water jetting diameter is Φ300mm and Φ150mm.

2) Six axes robot: Max load is 130kg, cover range is 2.65m, moving rate with cleaner is 0~6m/min.

3) Vacuum suction system: Max vacuum degree is -0.04MPa, power is 37 kW.

4.3 Ultra-high pressure water jetting test for airplane paint removal

Figure 7 shows the robot operating in airplane paint removal site. Φ300mm large diameter rotary surface cleaner (see Fig. 4a) and Φ150mm small diameter rotary nozzle head (see Fig. 4b) were using in the robot arm, the paint removal effects are shown in table 1.

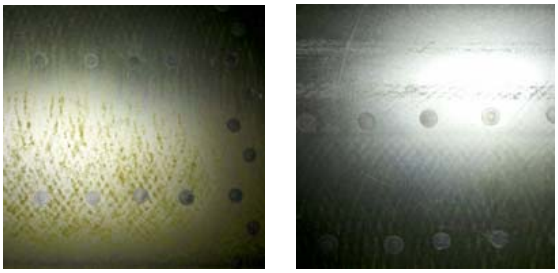
Fig. 7 Six axes robot operating in airplane paint removal site

Table 1 Paint removal test (Robot with Φ300mm Ultra-high pressure rotary water jetting surface cleaner)

Item	Pressure	Moving speed	Removal efficiency	Result	Stabilization of robot
1	160MPa	2.4m/min	43.2m^2/h	Have some base paint	Stable
2	180MPa	2.4m/min	43.2m^2/h	Removed	Stable
3	200MPa	2.4m/min	43.2m^2/h	Wholly removed	Stable
4	180MPa	1.5m/min	32.4m^2/h	Removed	Stable
5	200MPa	1.5m/min	32.4m^2/h	Wholly removed	Stable

Corresponding paint removal effect is as follows:

a) Paint removal effect under 2.4m/min and different pressure



b) Paint removal effect under 1.5m/min and different pressure

Fig. 8 Paint removal effect

4.4 Auxiliary cleaner

Most surface of airplane can be seen as flat surface of 300mm breadth. Two types of cleaner assembled in robot arm can achieve expected result, but the auxiliary cleaners should be used when the robot arm could not reach the range of airplane.

These two auxiliary cleaners are based on cleaners shown in Figure 4. They are moved by manual, they both have manual and pneumatic valve to shut the pressure on or off. In the same way, they have the vacuum chamber and will not produce fogy. We also got 85-90% paint removal effect, but it is still important to make stable, no-stop and no-repeat working to avoid surface damage.

5. Problems and Solutions

5.1 Guide the market to accept new technology

Paint removal of airplane with water jet is a new and incredible proposition. First, paint strongly adhered on aluminum and the paint is at least two layers. Ultra-high pressure and large flow rotary water jetting must be used to remove the paint layer. Second, advanced technology is needed to resolve the damage of the airplane surface. Third, airplane surface is very complicated and multi intelligent tools are needed. Paint removal of the real airplane could answer these three questions and it also can guide the market. Obviously, no corrosion and pollution is the power of this task.

5.2 No-repeat could avoid damage the surface

Except stable working conditions and dexterous robot, no-repeat of water jetting is especially important to avoid damage the surface. No-repeat of water jet path is easy. But no-repeat water jetting border is also very important. Great amount tests prove that no-repeat could avoid damaging the surface.

5.3 Work with teach program

Except stable working conditions and dexterous robot, no-repeat of water jetting is especially important to avoid damage the surface. No-repeat of water jet path is easy. But no-repeat water jetting border is also very important. Great amount tests prove that no-repeat could avoid damaging the surface.

5.4 Stable working conditions and strict control of working pressure

Based on the stable working conditions, program gives the gradient of the pressure on the beginning and end. The changes of the pressure avoid damage of surface at the path ends. This is the summery of program test.

5.5 Forecast of composites paint removal for airplane

This issue researched the removal of aluminum which is the main material of the airplane surface currently. However, composites are widely used for airplane surface especially military aircraft. Tests showed that the paint removal of aluminum could not be used to removal paint on the surface of composite because the base would be damaged. And the paint could not be removal with lower pressure. So we need to try other jetting methods, for example, mid-pressure abrasive rotary water jetting. We can see that paint removal of airplane is superb art and its wide research field needs more focus and tests.

6. Conclusion

1) Ultra-high pressure rotary water jetting for airplane paint removal is a physical process; it uses water and sucks the sewage by vacuum suction system. The water jetting for airplane paint removal is a no pollution and environmental process.

2) Ultra-high pressure water jetting paint removal equipment for airplane make the ultra-pressure pump unit and vacuum suction system as master engine. They are cooperated by six axes robot, which assembles large diameter surface cleaner and small diameter nozzle head, respectively use for large flat surface and curve surface. The robot moved the cleaner toward the airplane surface, as constant target distance and vacuum seal, remembers to teach and program step by step, make no-repeat and no-omission paint removal.

3) The water jetting test shown that the parameters of pump unit (250MPa, 60L/min, 250kW) is suitable to airplane paint removal, the working pressure is 180~200MPa, moving speed of cleaner is about 2m/min, and the paint removal area is 85~90%.

References

[1] Li Bin, Sun Xiujuan, 2010, “Brief survey of paint remover and paint removal techniques for aircraft,” Cleaning world, Vol. 26, No. 1, pp. 30-34.

[2] He Nai, Lei Junzhi, 2000, Aircraft Coatings and Coating Technology: Chemical industry press, Beijing.

[3] Li Weiyi, 2004, “Progress of study on paint strippers,” Electroplating & finishing, Vol. 23, No. 3, pp. 37-40.

[4] Xue Shengxiong, Wang Leqing, and Peng Haojun, 2004, “Experimental research on mechanism of ultrahigh pressure waterjet de-rusting,” China Mechanical Engineering, Vol. 15, No. 20, pp. 1790-1793.

[5] Xue Shengxiong, 2003, PRC Standard No. GJB5251-2003.

[6] XUE Shengxiong, 2006, High pressure waterjet technology & engineering: Hefei University of Technology Press, Hefei.

[7] Xue Shengxiong, Ren Qile, and Chen Zhengwen, 2011, “Design on Magnetic Gap Adhesion Typed Crawler,” Journal of mechanical engineering, Vol. 47, No. 21, pp. 37-40.