Application of water borne paint on the tractor chassis

H C Kang¹,³, A K Cai¹, R Bi²; B Wang², C Q Ma¹, L F Yan¹, X Liu¹, B B Zhang¹ and X Y Shi¹

¹ Technology and Materials Research Institute, YTO Group Corporation, Luoyang 471003, China
² Harbin Institute of Technology Shenzhen Graduate School, Shenzhen 518055, China
E-mail: hchk878@163.com

Abstract. This paper introduces the test and application of cleaner water borne paint coating mode on great wheel tractor chassis.

1. Introduction
At present, accounting for the world's most polluted cities PM2.5 more than half in China, the ecological environment is grim, haze and other natural disasters frequently occur, the number of cancer patients is dramatically increasing. It is the high time for China to develop a low carbon economy to implement the cleaner production. The HJ/T293-2006 Cleaner production standard–Automobile manufacturing (Painting) was released by China in 2006. Recently, water borne paint and short process have been used in almost of Chinese new automobile coating lines, controlling the generation of pollutants from the source of production [1]. As the international agricultural enterprises and Chinese automobiles, engineering machinery industry have entered, the competition is fierce for Chinese tractor industry. It is an inevitable trend that the tractor coating technology tends to economic goals [2].

As safety accidents caused by corrosion occurred continuously, so the great tractor chassis has a direct relationship with safety of the driving and drivers. The shape structure of tractor chassis is complicated and hulking, which includes four major series of more than 1000 varieties, and its maximum is 4500 mm×2600 mm×1600 mm, and maximum weight is 3800 kg. Compared with the other parts of a car, the diversity and complexity increase significantly in many aspects including the shape structure of the chassis. As a result, copying the existing water borne paint spraying technology and robotics technology doesn’t work. Water Borne Paint has been investigated in this paper to apply
on the tractor chassis”.

2. The major contents of research

2.1. The research of main technical indicators of chassis painting with water borne paint

According to the requirements of technology advances in tractor manufacturing and the standard of advanced foreign counterparts in several aspects including environmental influence, salt spray resistance and adhesion, etc [3], it can be benchmarked to advanced counterparts. The main indications such as salt spray resistance was increased from 96 h to 240 h, paint film thickness was elevated by 15~25 um to 30~50 um.

2.2. Feasibility research of the chassis painting with water borne paint

Achieving clean paint, adopting high efficient robots, low consumption of airmix spraying and other new technology is the best choice, which whether or not be applied to the great wheel tractor chassis, it need to complete the following research:

2.2.1. Research of new airmix Spraying Application on Chassis. It is a compared experiment between the new airmix spraying and conventional air spraying mode. The laboratory test shows that utilization rate of airmix spraying way more than higher 40% than air spraying way; the axle test shows that the amount of paint of air spraying is the airmix spraying four times for unit film thickness. As shown in the table 1.

| Serial number | Spraying way | Axle | The average thickness of paint film (μm) | Paint consumption (kg) | Paint consumption of unite of film thickness (kg/μm) |
|---------------|--------------|------|----------------------------------------|------------------------|-----------------------------------------------|
| 1             | Airmix spraying | 44.4 | 0.04 | 0.0025 |
| 2             | Air spraying   | 57.8 | 0.61 | 0.0105 |

2.2.2. Research of water borne paint products meeting the chassis. For four sample water borne paints, their performances were test in laboratory. To make spraying test in production site, choosing B and C two sample from test data, as shown in the tables 2 and 3. Through the experiments of single, low-volume and batch spraying, it shows that the film properties and appearance of product B meet the requirements. The phenomenon that shrinks of paint happened in the testing ground. Combining with the airmix spraying mode, the prescriptive of water borne paint about thixtotropic was adjusted through commutating with B product technical staffs. It met the requirements of batch spray in the production site.
## Table 2. Screening experiment.

| Design indicators          | A     | B     | C     | D     |
|----------------------------|-------|-------|-------|-------|
| Solids (%) ≥48             | 49.9  | 48.7  | 48.5  | 45.5  |
| Viscosity (s) ≥60          | 154   | 106   | 62    | 134   |
| Finess ≤30 μm              | 30    | 28    | 26    | 35    |
| Hardness >0.4              | 0.61  | 0.5   | 0.69  | 0.53  |
| Gloss (%) ≥80              | 80    | 80    | 96.2  | 67.2  |
| Film color and appearance  | The shrink of the paint film on the surface | Standard template | Standard template | A little of pinhole on the surface of the paint film |
| Salt spray resistance (h)  | 240   | 240   | 240   |       |
|                           | Corrosion of paintfilm: 1.2 mm, large area of bubble and wrinkle | 240 | 240 | 240 | Mild foaming |

Research Conclusions:

Applications of epoxy acrylic water-based paint on the chassis, the appearance of the paint film in Chassis was smooth, and the environment is improved obviously. So it can replace the oil paint for mass production. The application of water borne paint in the chassis also can reduce the emissions of atmospheric pollutants VOC from the source (from 133 g/table dropped to 10 g/table) to meet clean production standards. Research and development of epoxy acrylic water borne paint which is suitable for a variety of chassis material (the casting, mechanical parts, plastic parts, rubber parts) and a variety of the coated surface (primer coat, top coat, smooth surface) bottom and low temperature (80°C), and high corrosion resistance (240 h), it improves the coating’s corrosion resistance and weather resistance. Then the coated surface adhesion of form a complete set is ensured, the spraying operation environment is improved, and the fire danger is also reduced. A lot of technical problems are resolved at the same time, which are the low resistant to high temperature of rubber-plastic part and the energy dissipation and large heat capacity of casting-forging.

2.2.3. **Research of robot automatic spray technology on the chassis.** In order to meet the requirements of the chassis in high quality and fast step coating (2 min) for different coated surfaces, variable flow technology of automatic airmix spray was developed which improves the efficiency of the coating uniformity, spraying and painting rate (from 30%-40% to 45%-60%); the coating thickness can reach to 40 μm±5 μm which can replace traditional manual air spraying, reduce equipment investment and covers of area [5]. Optimized automatic spraying area can be up to 85%-95% which achieved automatic spraying in high level, then reduced the dosage of artificial.

Conclusion of Experiment:

- For the tractors’ chassis parts with large and complex shape, preliminary program was completed
Table 3. Production test.

| Serial number | Spray form | Models | B (HD—E0704—1) | Spraying quantity | Spraying effect | C | Spraying quantity | Spraying effect |
|---------------|------------|--------|-----------------|-------------------|-----------------|   |                  |                |
|               |            |        |                 |                   |                 |   |                  |                |
| 1             | Single spraying | Above 140 horsepower | 4 batches | 6 chassis | surface of paint film is smooth, no ills; the spraying environment is good, no odor | 2 chassis | Surface of Paint film is good. Problem: The color is greyish after spraying, the viscosity of paint cannot meet the technical requirements, so the on-site spray next step was canceled |
| 2             |            | Below 140 horsepower | 12 batches | 20 chassis | surface of paint film is smooth, no ills |   |                  |                |
| 3             | Small batch spraying | Above 140 horsepower | 230 batches | 230 chassis | surface of paint film is smooth, no ills |   |                  |                |
| 4             |            | Below 140 horsepower | 113 batches | 113 chassis | surface of paint film is smooth, no ills |   |                  |                |
| 5             | batch spraying | Below 140 horsepower | 300 batches | 300 chassis | surface of paint film is smooth, no ills |   |                  |                |

by adopting robot simulation with off-line and brief 3D drawings. Robot spraying program can be optimized by adopting reverse modulus and online teaching [5, 6]. As the impact of catenary hanging workpiece, a small area of about 5 to 10 percent can not be sprayed, it needs manually fill spray in simulation process.

- Four P250iA/15 robots, two sides and bottom of the workpiece were sprayed by two robots, the surface of the workpiece was sprayed by other robots. Each robot the spraying flow is in an average of 360 cc/m, and the flow of the spray gun must be 500 cc/m from the perspective in protection of spray gun (i.e., the maximum flow of the spray gun for using is 70%). Spraying of the workpieces was completed in 2.0 min.
- In the condition of any robot unattended, the most of spraying work can be completed by...
extending the production rhythm appropriately and using a robot on each side.

- Automatic identification of different artifacts with RFID technology, selecting the spraying process can meet the needs of the many kinds of mixed production line.
- Spraying robot, conveyor system and centralized paint supply were controlled by mutual interlock, providing a reliable guarantee for the equipment at the scene of production safety.

3. Factors of chassis with water borne paint

3.1. The viscosity effect

Because the water paint is pseudoplastic non-Newtonian fluid, so its viscosity can be influenced by the shear stress and temperature. The coating viscosity curve of water paint was always plotted in the lab by coating suppliers, while the flow time was determined by -4#cup as the construction basis on site paint mix. If construction viscosity of the water paint needs to be controlled precisely, test instrument of rotational viscometer is recommended because it can determine the different viscosity numbers under different shear stress.

The viscosity with rotational viscometer was used in laboratory, and the water addition proportion should be controlled in 5%~10%. According to the original paint viscosity in construction, deionized water index was controlled to be PH=7, and conductivity to be 220 s/cm. they were mixed well by agitator, then test quickly the flow time up to 40～50 s by 4-cup in construction, resulting in better painting result.

3.2. The effect of cleanness

The requirement of cleanness level of parts’ surface for the water borne paints is higher than solvent paint, because water has higher surface tension, and faults such as attachment difficult for paint film and shrinkage cavity would be shown in the case of there was a contaminant as oil, etc.

Therefore, in water-based paint coating, two processes both are added up for the degreasing and washing. Small flow preflush was added before the first hot wash and predegreasing, and fresh water flush was added at the outlet, what is more, the degreaser must also be compatible with the water paint.

3.3. The effect of environment

The evaporation speed of the diluent of water paint evaporate is slower than solvent of solvent paint. The water paint has more stringent requirements for range of work temperature and humidity. The optimum spraying environment is listed as follows: the temperature is (23±3)℃[7], the humidity is (65±5)%, spraying booth keep slight positive pressure, spraying area settlement wind speed is 0.2~0.5 m/s.

The paint coat defects would be shown as orange peel if the surface drying is too fast, when the temperature is too high and humidity too low; the paint film is easily sagging under the action of gravity if the temperature is too low or humidity is too high; or in the water in the paint coat did not volatilize in time, which lead to defect as pinhole and heat rash after drying.

If the settlement wind speed in the spraying area is too high, it will take too much coating material, and paint film is easily sagging; if the settlement wind speed is too low, paint spray will fly in all
directions, the equipment will be contaminated.

Air distribution system of air-conditioning in the spraying booth need configure temperature control, humidity control, and filtration device. For YTO chassis coating Plant, wetting device is the only device in winter according to the location and climate.

3.4. The effect of drying

The diluent of water paint is water, which vaporization heat is higher and is difficult to control. Normally, the baked temperature of water borne paint is higher than 100°C, it cannot quick heat like the oil paint after spraying and flowing flat, it needs self-volatilizing, or 3~5min flash dry at 60~80°C (Absolute humidity is controlled at 7~10 g/kg, the wind speed of vent is controlled at 6~10 m/s), keeps the solid content of paint film in 80%~90%, then go into process the dry oven, so flash dry device should be set up.

If the time for flash dry is too short, the water in the paint coating cannot volatilize in time, lead to defect as pinhole and heat rash when high-temperature baking. If the time for flash dry is too long, the surface of paint film will be too dry, paint coat defects would be shown as orange peel. The greatest weight of chassis is 3.8 tons, choice the 80°C fast dry water paint, make water natural evaporation by prolonging the flow flat time, at the same time, chassis is heating slowly. It needs 8~10 min for the surface temperature of parts increasing to 80°C, so adding flash dry device is not needed. Water paint dry curves are shown in the figure 1.

![Figure 1. Water paint dry curves.](image)

4. Equipment of chassis with water born paint and points of fire

4.1. Points of robot application

Robot airmix spraying with water paint, based on the off-line programming of the spraying track, according to different varieties and production tact, optimizing the track and the process parameters can be ensured quality and efficiency of spray. Through adjusting track and parameters, the got process parameter about 2min [8] of production tact as follows:
Spraying speed is 600~700 mm/s: After the parameters such as thickness of paint film, overlapping rate of spray span and times of spraying was determined, the productivity is only concerned to the spraying speed and the wide of spray span. Because each of the spray gun has an optimum running speed, in this case we used gas mixing spray gun, the proposed optimum spraying speed is 600~700 mm/s, then productivity is only concerned in spray span.

The paint quantity of spray gun is 400 cc/min [9] to get the optimum spray effect, the flow of airmix spraying should not exceed 500cc/min, in this case, spraying flow is 400 cc/min, the flow controlling pressure is 0.2 MPa, the atomization controlling pressure is 0.1 MPa, the thickness of paint film is 30μm.

The wide of spray span is 250~280 mm. As the spray span of the gun related the atomization, according to the text, the spray span of the airmix gun should be controlled in 250~280 mm, and the spray spancontrolling pressure is 0.1 MPa.

Overlapping rate is 50%: Considering the paint film character of chassis parts, selecting overlapping rate of spray spanat is 50%; for automobile panel, the overlapping rate of spray span is always 2/3 or 3/4.

Purge pressure is 0.6 MPa. Spraying robot is explosion-proof robot, before the start of each service; it needs purge to get rid of the flammable and explosive toxic gas in the robot’s cavity. At this time it needs consume a large amount of compressed air 1250 L/min for each of machine: the pressure of compressed air should be keep more than 0.6 MPa, and compressed air need further treatment. The compressed air technical index as follows: the pressure is 0.6 MPa, the particle diameter: <5 um; the concentration: <5 mg/m3, the pressure dew point: -20℃; the oil content: <0.0005 mg/m3. If the above parameters cannot be kept, the work of the robot may be wrong.

4.2. Points of coatings supply system used

4.2.1. Control of temperature. Avoiding dry and crust of paint caused by water evaporation of paint bucket. Coatings supply system should have a temperature control system, to ensure the coating temperature stable at a certain range of 37±3℃ (related to the use of paint products). It can avoid great fluctuation and unreliability.

4.2.2. Low shear [10]. Water paint has poor dispersion stability against mechanical force. The solid dispersed particle in paint is compressed into solid particles when the flow rate changes dramatically in the pipeline, leading to paint film pitting. To prevent coating precipitation and leaving dead-angle, all the agitators and pumps should use low shear device, and pipelines and their joints should be smooth. The diameter of pipes should be larger than that of solvent paint to reduce the resistance. The main pipe: φ16 mm, the branch pipe: φ10 mm, the flow rate; >18 m/min.

4.2.3. Coating filtration [11]. 180~200 mesh filter bags were used in air spraying; 220 mesh filter bags were used in airmix spraying, pressure of Filtration diaphragm should be chosen 3:1.

4.2.4. Liquid level control. After water paint level drop, coating attached to the wall of the container leads to powder chipping easily because of water evaporation, and it can’t be removed when adding new coating. The powder chipping put a bad affect upon the coating quality, so the requirement
of liquid level control for water paint is higher than solvent paint. In paint and circulating buckets, the level of liquid level controller should be added.

4.2.5. **Pipeline design and maintenance.** It’s better to adopt dual line circulation or three line circulation, the main pipes and branch pipes join into the recycle, so it isn’t easily precipitate. The recycle of main pipe should be adopted, the branch pipe and spray gun every day should be to prevent clogging after spraying, main pipe should be cleaned thoroughly each six months.

4.3. **Corrosion requirements of process equipment**
As water paint has higher surface tension than oil paint and higher electrical conductivity, so it easily occurs electrolytic corrosion reaction. The phenomena will lead to oxidation and rusty of pipeline and coatings device, so the stainless steel or aluminizing plate are used in water borne paint equipment, such as coating supply system, spray room, flow flat room dry oven and coatings supply system.

4.4. **Fire requirements**
Though water paint is water-soluble, it has the same performance with solvent paint after paint film dried, so the contaminated device and grid should be clean in time to avoid the clog of ventilation system, which will influence the spray effect, or increase the difficulty of cleaning and maintenance and cause the fire risk. Recommended to setting fire extinguishing equipment in paint spraying room, leveling room and drying room. Paint mixing room and the combustible gas alarm device may not be provided.

5. **Conclusions**
Because the window of water paint construction is narrow, in circumstance of certain shear force, the viscosity with a greater influence on the environment temperature, it easily occurs problems in winter and summer. In winter and summer, so temperature and humidity should be controlled in mixing room, coatings supply system and painting room, otherwise it occurs the phenomenon of difficult transport which due to leveling and high viscosity.

The great tractor chassis adopts water born paint technology of robot airmix spraying, operating costs be equivalent to consumption of original paint, the film quality can meet or exceed the quality of the original paint, salt spray resistance also can be improved [12]. The investment on equipment increases 5%, so operation cost of equipment will be increased slightly. Application of water borne paint on the great tractor chassis is first line in Chinese agriculture industry [13], it embodies the social responsibility of YTO group that attaches great importance to environmental protection. In addition, it supplies a good demonstration effect to the domestic agricultural machinery industry for the application of water borne paint.

**References**
[1] Xing W P 2009 Application of water borne paint on automobile painting line *Shanghai Coatings* **8** 26-9
[2] Le H M 2010 Application of water borne paint on automobile painting *Shanghai Coatings* **3** 40-3
[3] Wang X C, Li W G and Gong J B 2014 Enhance the responsibility of creating green painting workshop: to improve the design level of coating process *Modern Paint and Finishing* China 11-5

[4] Aznar A C, Pardini O R and Amalvy J I 2006 Glossy topcoat exterior paint formulations using water borne polyurethane/acrylic hybrid binders *Progress in Organic Coatings* 55 43-9

[5] Chen H, Sheng W, Xi N, et al. 2002 Automated robot trajectory planning for spray painting of free-form surfaces in automotive manufacturing *Proc. ICRA’02. IEEE Int. Conf. on Robotics and Automation* vol 1 pp 450-5

[6] Vecellio A M 1985 Robot painting system for automobiles *US Patent* 4532148

[7] Liu S D, Ma C Q, Kang H C, et al. 2011 Analysis of the application of tractor chassis painting with water borne paint *Modern Paint and Finishing* 8 50-2

[8] Arıkan S and Balkan T 2000 Process modeling, simulation, and paint thickness measurement for robotic spray painting *Journal of Robotic Systems* 17 479-94

[9] Kang H C and Wang J J 2012 Large tractor chassis integrated system of automatic spray robot *Modern Painting* 7 59-62

[10] Tian Y, Wang M and Zhang D M 2009 Construction of water borne paint coating line equipment requirements *Automotive Technology and Materials* 2 27-9

[11] Yan J, Yang K F, Li G B and Pan Z L 2010 Application and development of environmental water borne paint *Painting Technology* 7 113-5

[12] Kang H C, Xie Z. 2013 Clean production of coating process and equipment on large tractor chassis *Plating and Fishing* 1 76-81

[13] Wang H, Lu H X and Xu C 2010 Application of water borne paint on automobile body painting *Painting Industry* 4 22-5