



Technical White Paper: Intelligent Wall-Climbing Robots Automated Corrosion Protection Solutions for Storage Tanks, Ships, and Wind Turbine Towers

1. Introduction

Amid the global energy transition and the rise of Industry 4.0, large-scale steel infrastructure—including onshore/offshore wind turbine towers, crude oil and LNG storage tanks, ship hulls, bridges, and petrochemical reactors—faces escalating corrosion challenges. These assets typically operate over service lives of 20–30 years, and their structural integrity directly impacts operational safety, environmental compliance, and economic performance.

However, traditional manual corrosion maintenance methods are increasingly unsustainable worldwide due to systemic bottlenecks: high safety risks, low efficiency, growing environmental pressures, and acute labor shortages. In regions such as North America, Europe, the Middle East, and Southeast Asia, stringent HSE (Health, Safety, and Environment) regulations and rising labor costs have rendered conventional approaches impractical.

Dongying Jingtao Energy has developed a modular, magnetically-adhered wall-climbing robotic platform that integrates high-pressure water blasting, automated surface preparation, and intelligent coating application. This solution enables unmanned, standardized, and eco-friendly corrosion maintenance. Validated across multiple industrial sites, our system is designed for global deployment and delivers measurable improvements in safety, efficiency, and sustainability.



2. Technical Challenges and Industry Needs

2.1 Corrosion: The Global “Hidden Tax”

According to NACE International, corrosion costs the global economy approximately **\$2.5 trillion annually**—equivalent to **3.4%** of global GDP, exceeding the national budgets of most countries. Critically, 15 – 35% of these losses could be avoided through advanced protective technologies.

In the energy sector, corrosion failures carry severe consequences:

- **Wind Energy:** Coating degradation on towers can compromise structural strength, potentially leading to catastrophic collapse. A single unplanned shutdown may cost millions of dollars.
- **Petrochemicals:** Bottom corrosion in storage tanks can cause leaks, fires, or explosions—resulting in massive financial losses and major environmental incidents.
- **Maritime:** Hull corrosion jeopardizes compliance with the IMO’s Performance Standard for Protective Coatings (PSPC), risking vessel detention or failed inspections.

Thus, corrosion protection is no longer just a maintenance expense—it is a strategic investment in asset lifecycle value.

2.2 Global Limitations of Traditional Maintenance

Despite regional differences in industrial maturity, manual corrosion maintenance faces universally shared challenges:

Dimension	Global Challenges
Personnel Safety	• North America/EU: OSHA and EU-OSHA strictly limit work at height and in confined spaces under the ALARP (“As Low As Reasonably Practicable”) principle. • Middle East/SE Asia: Heat stress and fall risks intensify in hot, humid



Dimension	Global Challenges
	environments. • Global Consensus: Minimizing human presence in hazardous zones is central to modern HSE strategy.
Operational Efficiency	• Scaffolding erection/dismantling consumes 30–50% of total project time. • Manual abrasive blasting averages <15 m²/h, heavily affected by weather and fatigue. • Offshore wind farms and remote refineries face narrow operational windows—delays incur steep costs.
Environmental Compliance	• EU: Solvent Emissions Directive (1999/13/EC) tightly restricts VOC emissions. • USA: EPA enforces strict controls on heavy-metal-laden dust (e.g., lead, chromium). • Global Trend: Dry abrasive blasting is being phased out in new projects; waterjet and laser cleaning are becoming preferred green alternatives.
Quality Consistency	• Surface preparation quality (e.g., ISO 8501-1 Sa2.5) relies heavily on operator skill, leading to batch-to-batch variability. • Poor coating adhesion is a primary cause of premature failure, with rework rates exceeding 20%.
Labor Shortage	• North America/EU: Skilled corrosion technicians average over 50 years old; younger workers avoid high-risk manual labor. • Emerging Markets: Labor is available but often lacks consistent training, increasing onboarding costs. • EPC contractors globally report “projects without personnel.”

2.3 International Standards: Automation as the Inevitable Path

Regulatory frameworks worldwide are accelerating the shift toward automated, remote, and dust-free maintenance:

- **ISO 12944:** Mandates that corrosion protection systems be designed for maintainability, encouraging mechanization.
- **SSPC-SP 10 / NACE No. 2:** Requires near-white metal blast cleanliness with verifiable, controllable processes.
- **ATEX (EU) / IECEx (Global):** Equipment used in explosive



atmospheres must be certified.

- **IMO PSPC:** Demands full digital traceability of coating application in ballast tanks—difficult to achieve manually.
- **OSHA 1910.146 (USA):** Confined space entry requires extensive permitting; automation eliminates this need entirely.

Collectively, these standards drive the industry toward **automation, remote operation, and emission-free processes.**

3. Solution: Modular Intelligent Wall-Climbing Robotic Platform

Jingtao Energy's platform is built on three core technologies: **permanent magnetic adhesion, omnidirectional mobility, and quick-swap end-effectors**, enabling scalable automation across diverse corrosion maintenance workflows.

3.1 Core Technical Advantages

- **Permanent Magnetic Adhesion System:**

Requires no power to maintain strong adhesion on carbon steel surfaces. Operates reliably on vertical walls, overhead ceilings, and curved surfaces (minimum radius: 1.5 m). Superior to vacuum-based systems (which need continuous power) and friction-driven tracks (prone to slippage).

- **Omnidirectional Mobile Chassis:**

Four independently driven and steered wheels enable forward motion, lateral strafing, and in-place rotation—ideal for navigating tight manholes and complex weld geometries, minimizing manual intervention.

- **Modular End-Effector System:**

Rapid tool swapping between grinding, high-pressure water blasting,



and spray modules enables “**one robot, multiple functions,**” reducing capital expenditure and inventory complexity.

- **Safe Low-Voltage Power:**

Powered by **48V DC lithium batteries**, compliant with **IEC 60204-1** machinery safety standards. Optional **ATEX-certified** versions available for use in explosive zones.

3.2 Product Portfolio

(1) XBR-1-F – Wind Turbine Tower Maintenance Robot

- Functions: Integrated automated grinding + intelligent coating
- Applications: External surfaces of onshore/offshore wind towers (diameter: 3 – 8 m)
- Key Specs:
- Grinding speed: 20 m²/h
- Spraying speed: 100 m²/h
- Max payload: 80 kg
- Control: Wireless remote (2.4 GHz, range ≥ 100 m)
- IP Rating: IP54 (dust and splash resistant)

(2) XBR-MT – Multi-Function Storage Tank Robot

- Functions: Ultra-high-pressure water blasting (280 MPa) + integrated wastewater recovery + optional spraying
- Innovations:
 - Split-body design fits through manholes ≥ 600 mm
 - Closed-loop water recycling enables “dust-free, waste-free” operation
- Certifications: ATEX-compliant motors available for Zone 1/2 hazardous areas

(3) XB2 – Heavy-Duty Quad-Drive Platform

- Target Use: Large spherical tanks, bridges, ship hulls



- Expandability: Supports third-party tools — robotic arms, inspection sensors, laser cleaners
- Obstacle Clearance: Navigates weld seams and surface irregularities up to 15 mm

4. Performance Validation & Customer Value

Metric	Traditional Manual	Jingtao Robot	Customer Benefit
Daily Effective Area	50–80 m ²	150–300 m ²	>50% shorter downtime; reduced vessel/production line idle costs
Surface Prep Consistency	Highly variable	Stable Sa2.5 compliance	+30% coating lifespan; lower lifecycle cost
Safety Incident Risk	High	Near-zero (remote operation)	Eliminates injury claims, insurance hikes, reputational damage
VOC/Dust Emissions	High	Negligible (especially in waterjet mode)	Full compliance with EPA/EU regulations; avoids fines
3-Year TCO	Baseline	30–45% lower	ROI typically achieved in <18 months

4.1 Field Performance Comparison (Typical Conditions)

Note: Data based on field trials (2023 – 2025); results vary by site conditions.

4.2 Key Application Scenarios

- Offshore Wind Farms: Replaces suspended platforms, reduces vessel standby time and O&M costs.



- Refinery Tank Farms: Completes internal maintenance within tight shutdown windows.
- LNG Terminals: Operates reliably in cold, humid environments to protect critical infrastructure.
- Ship Repair Yards: Automates above-waterline hull blasting, ensuring IMO PSPC compliance.

5. Global Compatibility & Support

- Electrical: Compatible with 110V/220V/380V, 50/60 Hz.
- Certifications: ATEX and IECEx options available.
- Environmental Resilience: Operating temperature – 20° C to +50° C; passes 500+ hours neutral salt spray test (ASTM B117).
- User Interface: Remote control supports English, Spanish, and Arabic.
- Service Network: Global partners provide training, spare parts, and 24/7 remote technical support.

6. Future Roadmap

- **AI-Powered Intelligence** : Integrate computer vision for automatic rust detection and autonomous path planning.
- **Green Process Expansion**: Scale ultra-high-pressure (UHP) waterjet systems with on-site wastewater filtration and reuse.
- **Digital Twin Integration**: Feed real-time operational data into client CMMS/EAM platforms for predictive maintenance.
- **Extreme Environment Adaptation**: Develop variants for nuclear facilities, deep-sea platforms, and polar installations.

7. Conclusion

Corrosion protection has evolved beyond simple “paint-and-patch” repairs — it is now a strategic imperative tied to asset longevity, operational safety, and environmental stewardship. As the world advances toward net-zero emissions and industrial intelligence, maintenance must shift from **reactive correction** to **proactive defense**.



Dongying Jingtao Energy delivers **reliable, efficient, and sustainable** robotic solutions that empower global operators to automate corrosion management effectively. We invite engineering firms, asset owners, and system integrators worldwide to collaborate with us in building a safer, smarter, and more sustainable future for industrial maintenance.

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