Downhole High-Power Acoustic & Alloy Catalytic Composite Anti-Scale Technology Technical White Paper

1. Executive Summary

In oil and gas field development, well scaling and wax deposition are core pain points leading to frequent pump inspections, production declines, and soaring operating costs. Traditional chemical dosing methods suffer from environmental pollution, high costs, and diminishing returns.

Jingtao Energy's "**Downhole High-Power Acoustic & Alloy Catalytic Composite Anti-Scale Technology**" is a revolutionary, purely mechanical physical oil recovery solution. Through a unique triple-synergy mechanism of "**Vortex Acceleration + Multi-Stage High-Intensity Acoustic Vibration + Alloy Catalytic Electrochemistry**," this technology effectively inhibits the crystallization and precipitation of inorganic scales (such as calcium carbonate) and paraffin wax without electricity or chemicals. It alters crystal morphology, significantly extending pump inspection cycles (by 1–3 times or more), reducing sucker rod pump loads, and increasing single-well daily liquid production by 1–10%. Field application data demonstrates exceptional stability and economic viability in high-salinity, deep wells, and complex operating conditions.

2. Industry Background & Challenges

Current oilfield exploitation, particularly in high-salinity blocks, faces the following severe challenges:

- Severe Scaling & Frequent Failures: Formation water salinity

ranges from 50,000 to over 200,000+ mg/L, causing rapid scaling on pump assemblies and tubing, leading to pump sticking and shutdowns.

- High Cost of Traditional Remediation: Reliance on chemical scale inhibitors incurs high chemical costs and requires frequent dosing operations, increasing labor and maintenance expenses.
- Environmental Pressure: Chemical agents pose potential pollution risks to reservoirs and formation environments, conflicting with green extraction trends.
- Low Efficiency: Scaling narrows flow channels, reduces crude oil mobility, lowers pump efficiency, increases sucker rod pump load, and raises energy consumption.
- Complex Descaling Operations: Mechanical or chemical descaling not only interrupts production but also involves high labor intensity and safety risks.

3. Technical Principles

The Jingtao Energy anti-scale device is installed below the subsurface pump. It comprises three core modules: a **Vortex Acceleration Unit**, a **Multi-Stage High-Intensity Acoustic Generator**, and an **Alloy Catalytic Anti-Scale Unit**. These work synergistically via physical mechanisms to achieve efficient anti-scaling and anti-waxing.

3.1 Vortex Acceleration Mechanism

As crude oil enters the device, it passes through cyclones and vortex generators to create high-speed rotational motion:

- Flow Regime Transition: The liquid transitions from laminar/parallel flow to a turbulent/vortex state.
- Dispersion & Melting: High shear forces cut, disperse, and melt scale ions, crystal nuclei, and wax molecules into the production fluid, inhibiting initial crystallization.
- Oil-Water Mixing: Promotes thorough emulsification and mixing of oil and water, creating optimal medium conditions for subsequent acoustic treatment.

3.2 Multi-Stage High-Intensity Acoustic Vibration Mechanism

Utilizing the pressure differential generated when fluid flows through specialized converging nozzles, the system excites a mechanical vibration system to produce high-frequency, high-energy acoustic waves (0–20 kHz):
Vibrational Lift Effect: Acoustic waves propagate in the same direction as oil flow, imparting acceleration to crude oil molecules in the lifting direction. This significantly improves mobility, preventing scale crystals from depositing during vibration.
Acoustic Streaming: Intense vibration generates radiation pressure differentials, disrupting the adsorption layer at the solid-liquid interface, weakening surface tension and friction, keeping scale particles suspended and softening them.
Shear Depolymerization: High-intensity acoustic waves force relative motion among long-chain paraffin hydrocarbons and asphaltene macromolecules. The resulting frictional forces can break C-C bonds (theoretical friction force reaches 67.8×10^{-9}N , far exceeding the fracture threshold of 4.5×10-9N), achieving viscosity reduction and wax prevention.

3.3 Alloy Catalytic Electrochemical Mechanism

- The device contains special alloy catalysts composed of copper, zinc, tin, nickel, etc., forming countless micro-batteries within the fluid:
- Micro-Battery Reaction: Anodes (Zinc, Tin, Nickel) dissolve divalent metal cations (e.g., Zn^{2+}), while reduction reactions near the cathode (Copper) generate OH^-.
- Lattice Distortion: The ionic radius of Zn^{2+} is similar to Ca^{2+} , allowing it to enter the calcium carbonate lattice to form solid solutions ($Ca-ZnCO_3$) or coordination compounds, hindering calcite crystal growth.
- Crystal Transformation: Induces the transformation of calcium carbonate into metastable aragonite or vaterite forms. These crystal structures are loose, do not adhere to pipe walls, and are

discharged with the oil flow.

- Acoustic Synergy: The stirring action of acoustic waves overcomes the barrier of crude oil on the alloy surface, unidirectionally promoting electrochemical reaction efficiency.

4. System Architecture & Functional Modules

Module Name	Core Components	Primary Function
Vortex Acceleration Unit	Cyclone, Vortex Generator	Increases flow velocity, disperses scale nuclei, achieves oil-water emulsification.
Acoustic Generation Unit	Converging Nozzle, Mechanical Vibration System	Generates 0–20 kHz high-frequency vibration, breaks paraffin chains, disrupts scale adhesion.
Alloy Catalytic Unit	Multi-Metal Composite Alloy Rod/Ring	Releases trace metal ions, alters crystal structure, inhibits calcite growth.
Main Housing	High-Strength Alloy Steel	Resists high pressure, high temperature, and corrosion; ensures long-term downhole stability.

Installation Position: Between the bottom of the subsurface pump and the screen pipe (connect one joint of tubing below the pump, then connect this device).
Flow Direction: The housing is marked with an arrow; **do not install upside down.**

5. Key Advantages

- Purely Mechanical, Zero Energy Consumption: No electrical drive

or external power source required; operates using the fluid's own energy.

- Green & Pollution-Free: No chemical agents added; causes no harm to the reservoir, formation, or produced fluids, complying with HSE standards.
- Long-Lasting & Maintenance-Free: Designed service life ≥ 3 years; tensile strength ≥ 600 KN; adapts to harsh downhole environments.
- Multi-Functional & Comprehensive Production Increase:

✓ Anti-Scale & Anti-Wax: Extends pump inspection cycles by 1–3 times or more.

✓ Viscosity Reduction & Injection Enhancement: Improves crude oil mobility and pump efficiency.

✓ Stable & Increased Production: Typically increases single-well daily liquid production by 1–10%.

✓ Energy Saving: Reduces sucker rod pump load and electricity costs.

- Easy Installation & High Compatibility: Standard pipe thread connection (2-7/8" TBG); suitable for various conventional and deep well operations.

6. Typical Technical Specifications

Parameter	Specification	Remarks
Model	JT-Sonic-Alloy Pro	Jingtao Energy Custom Model
Outer Diameter	Φ42 mm	Compatible with standard tubing
Connection Thread	2-7/8″ TBG	Standard tubing thread
Weight	56 - 58 kg	/
Vibration Frequency	0 - 20 kHz	Mechanical self-excited vibration

Parameter	Specification	Remarks
Temperature Resistance	⩽ 350 ℃	Suitable for deep high-temp wells
Pressure Resistance	⩽ 50 MPa	Suitable for high-pressure conditions
Tensile Strength	⩾ 600 KN	High-strength alloy steel
Design Life	⩾ 3 Years	Under normal operating conditions
Applicable Viscosity	⩽ 100,000 mPa·s (at 50℃)	/
Applicable Water Cut	⩾ 10%	Requires certain water phase to activate alloy

Well Selection Criteria Recommendations:

- Well Depth: ≤ 6,000 meters
- Daily Liquid Production: ≥ 2 tons/day
- Crude Oil Pour Point: ≤ 50℃
- Operating Temperature: ≤ 300℃

7. Applications & Case Studies

7.1 Applicable Scenarios

High-salinity scaling wells (Salinity > 50,000 mg/L)
Heavy oil and high-wax content wells
"Problem wells" with frequent pump sticking and short inspection cycles
Environmentally sensitive areas where chemical agents are prohibited

7.2 Case Study: Application Statistics at Shikai Center

With technical support from Jingtao Energy, the Shikai Center (Shengkai and Shengfa Management Areas) introduced this technology for high-salinity blocks. As of May 31, 2023, applications across over a dozen wells showed significant results:
Typical Well Data (Partial)

Well ID	Commission Date	Previous Pump Cycle	Extended Production Time	Current Status	Washing Status
Li 886-x15	Jan 14, 2022	105 days	395 days	Normal	None
Li 93-x23	Jun 14, 2022	90 days	275 days	Normal	None
Li 93-x31	Jun 16, 2022	108 days	257 days	Normal	None
Yigu 72-x8	Sep 23, 2022	150 days	120+ days	Normal	None

Summary of Results:

- Significantly Extended Pump Cycles: Average extension factor exceeds 2x, with some wells approaching 4x.
- Operation Without Well Washing: All test wells operated without any well washing during the extended period.
- Significant Economic Benefits: Drastically reduced the frequency of workover operations, chemical costs, and production loss due to shutdowns.

8. Installation & Maintenance Guidelines

1. Pre-Treatment: Before running in hole, thoroughly wash tubing, sucker rods, and pumps with hot water (>80℃) to ensure no residual wax or scale.
2. Tightness Check: When connecting the device sub, tighten again with pipe tongs to prevent loosening.
3. Direction Confirmation: Strictly verify the arrow indication on the device housing. Ensure flow direction matches the arrow; never install upside down.
4. Running/Pulling Operations: The device must be pulled out during pump inspection or workovers. Clean inner and outer walls.
- *Cleaning Sequence: Forward Flow → Reverse Flow → Forward Flow ("Forward" means along the oil flow direction; "Reverse" means against it).*
5. Troubleshooting: If device damage is detected, immediately contact the Jingtao Energy technical support team. The device must be repaired and tested before being run in hole again.

9. Contact Us

Jingtao Energy is dedicated to providing efficient, green, and economical extraction solutions for global oil and gas fields through innovative physical technologies. For technical consulting, solution design, or on-site services, please contact us anytime.

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