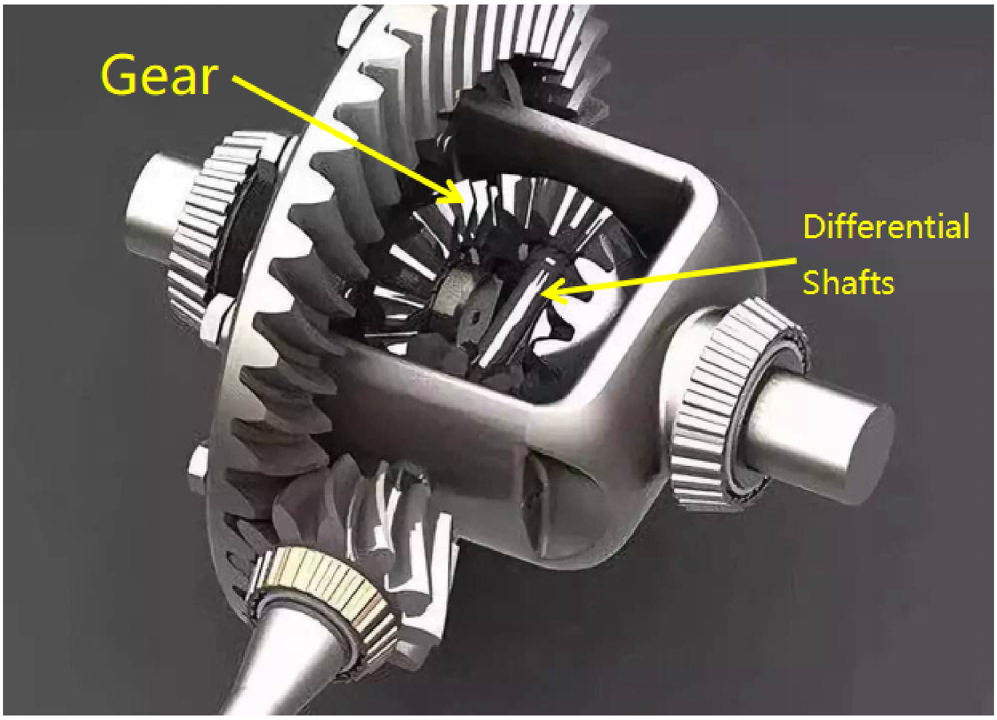
DLC Coatings Empower Differential Shafts: Solving Transmission Challenges and Leading Gear & Drive Technology Upgrades

1. Differential Shafts: The “Key Power Transmission Component” in Gear and Drive Systems

In automotive, construction machinery, and agricultural gear systems, differential shafts are core components for precise power distribution and speed adjustment. For example, in automotive drivetrains, the differential shaft connects the differential housing to planetary gears, transmitting engine or motor power to the half shafts. It directly affects vehicle cornering smoothness and power output efficiency. With the rapid growth of new energy vehicles, the precision and stability requirements of differential shafts have increased significantly, while in conventional AT and DCT transmissions, shaft performance still determines the overall reliability of the drive system.

From a market perspective, as the global gear and drive system market expands, demand for differential shafts grows simultaneously. Data shows that by 2025, the global automotive transmission market is expected to exceed CNY 800 billion, with differential-related components accounting for over 20%. As a core component, the differential shaft market alone will exceed CNY 30 billion. China, as the largest automotive producer and consumer, requires over 50 million differential shafts annually, with demand in the new energy vehicle sector growing over 40% per year, driving the transition of shafts from “basic functional components” to “high-performance precision components” with increasingly stringent surface performance requirements.



Differential Structure

2. Challenges: Four Core Issues for Differential Shafts in Use
Under the complex conditions of gear and transmission systems, differential shafts face multiple performance challenges, and traditional processes struggle to meet current requirements:

Severe wear under high load: The mating surfaces of the shaft and planetary gears endure high-frequency impact loads and sliding friction. Traditional surface treatments (e.g., quenching, nitriding) produce a hardened layer with only HV800-1200 hardness. Under high contact stress (up to 1500 MPa), surface wear and scratches occur, increasing clearance, reducing transmission accuracy, and limiting service life to 30,000–50,000 km.

Frictional loss reducing efficiency: Traditional surface-treated shafts have higher friction (dry friction coefficient ≈0.5–0.8 with steel), generating significant energy loss. In electric drivetrains, this directly increases motor consumption and reduces range by 5–8%, contrary to EV efficiency goals.

Weak corrosion resistance in harsh environments: In rain, snow, muddy conditions, or outdoor construction work, shafts are exposed to water, salts, and oils. Traditional treatments provide limited corrosion protection, with salt spray life only 200–500 hours, leading to rust, accelerated wear, and potential transmission failures.

Insufficient toughness under low temperature and impact: In cold climates or heavy-load startup, shafts must withstand low-temperature impact and instantaneous high torque. While hardening increases hardness, it reduces toughness, causing brittle fracture below -30°C, a major safety concern in construction machinery and heavy trucks.

3. Technical Adaptation: DLC Coatings as a "Performance Upgrade Tool" for Differential Shafts
The properties of DLC coatings align closely with differential shaft requirements, addressing traditional process limitations:

Workload specificity: For "high load, high friction, and corrosion-prone" shafts, DLC coatings reduce friction (dry coefficient <0.1), resist wear (hardness up to 3000HV), and chemically isolate against corrosion, providing comprehensive protection for demanding gear and transmission systems.

Process compatibility: Huasheng Nanotechnology's self-developed DLC coating equipment operates below 150°C, preserving precision tolerances (0.01–0.05 mm), with adhesion strength reaching HF1 grade, preventing delamination and cracking. Compatible with various materials including 45# steel, 20CrMnTi, and powder metallurgy alloys.

Economic practicality: DLC treatment extends shaft life 3–5 times, reduces frictional losses by over 80%, cutting maintenance costs while improving system efficiency. For EVs, annual electricity savings per vehicle reach CNY 1,000–2,000, reducing life-cycle costs by 20–30%.

4. Technical Breakthroughs: Five Key Advantages of DLC Coatings on Differential Shafts

High hardness and excellent wear resistance: By controlling sp3 bonding in the carbon layer, DLC hardness reaches ~2500HV; wear rate drops to 10^-8 mm^3/N·m, 5–10 times lower than traditional nitriding. Shaft life extends to 150,000–200,000 km.

Ultra-low friction and energy efficiency: Dry friction coefficient 0.05–0.1 (with steel or copper), lubricated coefficient <0.03. Reduces transmission friction 30–50%, increasing EV range 5–8% and reducing ICE fuel consumption 0.3–0.5 L/100 km.

Outstanding corrosion and environmental resistance: Dense structure and chemical inertness prevent rust in salt, oil, and harsh conditions.

Good toughness and low-temperature adaptability: Multi-layer design maintains hardness while improving toughness. Stable from -40°C to 150°C, suitable for polar exploration vehicles, cold-region machinery, and other extreme conditions.

Precision and customization: Coating thickness precisely controlled without affecting mating accuracy; composition and structure customizable for automotive, construction, or agricultural applications.

5. Application Deployment: DLC Coatings Across Differential Shaft Scenarios

Automotive: DCT differential shafts for Volkswagen and Toyota show 2–3dB noise reduction, life extended to 180,000 km. EVs like BYD and Tesla reduce friction by 40%, increasing range 6–7%. Huasheng provides DLC processing for many major OEMs in China.

Construction machinery: Heavy-load shafts in excavators/loaders with high-hardness, high-toughness DLC see failure rates drop 70%, maintenance cycles extend from 3 to 12 months.

Agricultural & specialty vehicles: Resistance to mud, fertilizers, and corrosion extends life to 8–10 years, 3–4 times longer than traditional processes. Low-temperature and impact-resistant DLC suitable for military and explosion-proof vehicles.

6. Authority Recognition: Global Expert Endorsement

MIT Professor Caroline Ross: DLC reduces friction >50%, triples shaft life, critical for improving transmission efficiency and EV energy savings.

Fraunhofer IWS Chief Scientist Thomas Lampke: Multi-layer DLC balances hardness and toughness, outperforming nitriding and chrome plating in heavy-load tests.

ISO Standards: Recommend DLC as the preferred surface treatment for high-end differential shafts and gears, especially in EVs and heavy machinery.

7. Future Outlook: Co-Evolution of Differential Shafts and DLC Technology

Material–coating–structure integration: Use lightweight high-strength materials (e.g., titanium alloys, CFRP), with adapted DLC coatings for high adhesion, low-temperature deposition (<120°C), and optimized layer thickness at high-stress points.

Smart coatings with condition monitoring: Embedding nano-sensors for real-time wear, stress, and temperature monitoring, enabling predictive maintenance.

Green, low-carbon coating processes: DLC deposition using hydrocarbons (methane, acetylene) avoids heavy metals and consumes only 1/3 of chrome plating energy. By 2030, DLC penetration in differential shafts expected >70%, reducing CO_2 emissions by >500,000 tons annually.

DLC-coated differential shafts are set to become the global standard, driving efficiency, durability, and sustainability in modern transmission systems.