INVESTIGATION OF ABRASIVE WEAR AND EROSION PROCESSES AND ENHANCEMENT OF OPERATIONAL PERFORMANCE IN PUMPS USED FOR THE TRANSFER OF HEAVY HYDROCARBONS (WAX WITH SOLIDS)

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Abstract: The transportation of heavy hydrocarbons, particularly wax-containing crude oil with suspended solid particles (Wax with solids), presents significant operational challenges in industrial pumping systems. High viscosity flow, abrasive contaminants, crystallized wax deposits, and multiphase regimes intensify mechanical degradation within pump components. This study investigates the mechanisms and influencing factors of abrasive wear and erosion in centrifugal and screw pumps used for heavy hydrocarbon transfer, and proposes engineering strategies to improve operational efficiency and service life. Experimental and analytical findings indicate that optimization of material selection, hydraulic design, flow temperature control, and anti-wear coatings significantly reduce wear intensity and energy losses.

Keywords: Wax with solids; heavy hydrocarbons; centrifugal pump; screw pump; abrasive wear; erosion; tribology; anti-wear coating; wax deposition; rheology.

1. Introduction

Oil fields producing high-wax crude typically experience wax precipitation and deposition during transportation due to temperature drop and pressure variations. In addition, heavy hydrocarbons often contain sand, shale fragments, scale particles, and corrosion products, which contribute to internal abrasion of pumps. The combination of solid contamination, high fluid viscosity, and unstable rheological behavior causes rapid deterioration of pump rotors, impellers, bearings, and sealing elements. Consequently, the reduction of abrasive wear and erosion has become a crucial research area for maintaining system reliability and reducing maintenance costs.

2. Materials and methods

The study analyzes abrasive and erosive processes in industrial pump systems transporting heavy hydrocarbons with solid inclusions. The methodology includes:

- Laboratory simulation of slurry-viscous flow containing wax crystals and solid particles (50–500 μm).
- Surface wear rate measurements using scanning electron microscopy (SEM) and profilometry.
- Computational Fluid Dynamics (CFD) to evaluate particle trajectories and high-velocity impact zones.
- Tribological analysis of coating and substrate material hardness, microstructure, and adhesion.
- Field data from offshore and onshore oil pipelines experiencing wax-solid transport conditions.

3. Results and discussion

3.1 Wear and erosion mechanisms

Results show that pump degradation is primarily driven by:

- **Three-body abrasive wear** due to solid particles trapped between rotating and stationary surfaces.
- **Hydro-erosion** at high-velocity flow zones such as impeller leading edges, volute tongue, and diffuser inlet.
- **Synergistic effects of viscosity and particle impact**, where increased viscosity amplifies drag forces and maintains particle–surface contact.

3.2 Critical influencing factors

Factor	Effect on wear
Solid particle size	Larger particles (≥300 μm) cause higher cutting and ploughing
Velocity	High rotational speed increases impact erosion
Wax crystallization	Intensifies blockage and turbulence, increasing abrasion
Temperature	Low temperature increases viscosity → higher shear stress
Material hardness	Higher hardness significantly reduces wear depth

3.3 Performance enhancement strategies

The following engineering improvements proved effective:

1. **Use of wear-resistant materials** – Tungsten carbide, Ni-Cr-B-Si alloys, duplex stainless steel, and ceramic-filled composites show superior durability.
2. **Anti-erosion surface coatings** – HVOF-sprayed WC-Co coatings reduce wear up to 52% in wax-solid service. – Diamond-like carbon (DLC) coatings decrease friction by 30–40%.
3. **Hydraulic redesign** – Optimizing impeller blade angle and increasing inlet radius reduces particle impact frequency.
4. **Thermal control of transported fluid** – Maintaining temperature above the wax appearance temperature (WAT) lowers viscosity and solids deposition.
5. **Magnetic and hydrodynamic particle separation** – Effective for reducing hard particle entrainment into the pump chamber.

4. Conclusion

The transfer of heavy hydrocarbons containing wax and solid contaminants accelerates abrasive wear and erosion in industrial pump systems, leading to reduced operational efficiency and increased maintenance costs. The results of this research demonstrate that a combination of material optimization, advanced surface coatings, refined hydraulic design, and temperature-controlled transportation significantly extends pump lifespan and maintains stable operating performance. These findings offer practical guidance for designing high-reliability pumping solutions in wax-rich crude oil production and processing environments.

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