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Centrifugal Slurry Pumps Design & Selection for Sustainable Mining Industry – A Review

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***Abstract*— Centrifugal Slurry Pumps are the heart of wet process operations in mineral processing plants and for hydro-transport duties. Sustainable mining industry is driven by technological innovation to minimize environmental impact and slurry pumps are strategic and critical assets in this process. Designing efficient and durable slurry pumps will not only reduce operations costs but will have significant environment impact by reducing energy consumption during pumps operation and its manufacturing process. Durable, long-lasting pumps significantly contribute to resource conservation by reducing need for frequent manufacturing, lowering energy consumption, minimizing industrial waste, and preserving raw materials.**

Unlike hydraulic turbines, which are custom designed for specific site conditions allowing specific optimization of their geometry and blade angles to operate under steady and controlled conditions, centrifugal pumps use standard designs to handle different operating conditions which limits their efficiency. Slurry pumps are required to operate under severe conditions involving solid particles, high densities and viscosities. These factors increase internal hydraulic losses and accelerate slurry pumps wear, creating major constraints and significant challenges for achieving cost-effective optimizations.

This work is aimed to categorise slurry pumps design and optimisation considering applications and material selection. Review of numerical and experimental studies undertaken in this field have been summarised to develop a simplified flowchart as guide for centrifugal slurry pumps selection, while future improvements depend on continued CFD researches and composite material innovations.

***Keywords*— Slurry, Centrifugal Pumps, Wet end, Impeller, Volute, Wear Rate, Erosion, Abrasion, Flow, Head, Efficiency, BEP, CFD.**

I. INTRODUCTION

Centrifugal slurry pumps are the most common type of slurry pumps in mining industry thanks to their flexible performance, suitability for wide range of applications and their ability to perform reliably across varied process conditions. For centrifugal pumps design while Navier–Stokes equations are applied in CFD modelling (Computational Fluid Dynamics) for detailed flow simulations, Euler's equations provide simplified approach for calculating pump performance during design by linking specific work delivered to the fluid with impeller's geometry and velocity distribution.

Hydraulic Institute [1] defines slurry as mixture of solids with specific gravity typically greater than 1 in a liquid carrier, usually water and the pumps suitable for pumping this mixture are slurry pumps.

Many researches has been conducted to improve performances of centrifugal pumps using numerical and experimental methods, advanced data acquisition, machine learning, and artificial intelligence techniques. Different results confirmed that design improvements, material upgrades and optimised operation can significantly enhance efficiency, reduce running cost and extend service life [2]–[10].

II. WEAR MECHANISM & MODES IN CENTRIFUGAL SLURRY PUMPS

Wear is defined as damage to a solid surface, generally involving progressive loss of material caused by relative motion between that surface and an interacting substance. Wear mechanisms are generally categorized into mechanical, chemical and thermal, while wear modes are abrasive, adhesive, flow, fatigue, corrosive, melt and diffusive wear to describe and illustrate material degradation processes [11].

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In centrifugal slurry pumps dominant wear modes are Erosion and Abrasion with possibility of combination with Cavitation and Corrosion. During slurry pumps operation one or more of wear modes can occur and affect pumps components.

III. Construction Material of Internal Hydraulic of Slurry Pumps

A. Metallic

Metal alloys in slurry pumps are selected for abrasion and corrosion resistance. High-Chrome White Iron suitable for dominant abrasion and Duplex Stainless Steel for abrasion-corrosion combined resistance. Xie et al. [12] highlighted material selection should match wear mode and operating conditions. Robert and Dan [13] confirmed large particle impact wear greatly shortens pump life, especially at impeller edges and volute cutwater

B. Elastomer

Metal alloys resist wear through hardness and microstructure, while elastomers rely on resilience to absorb particle impacts. Craig [14] noted rubber suits fine particles, whereas high-chrome is better for coarse particles and that wear depends on impeller geometry and particles size. Xie & Co [15] found elastomers excel against small, rounded particles, and that both elastomers and plastics outperform steels in erosion resistance for fine, rounded particles [16].”

C. Ceramic

Ceramics have high hardness and high wear resistance but their brittleness makes them unsuitable for most slurry pumps applications where impact resistance is critical.

D. Composite

Composites offer enhanced performance by integrating the beneficial properties of distinct base materials and are strongly recommended to achieve even wear and durability.

Wang et al. [17] demonstrated the importance of developing composite materials with enhanced wear resistance as they offer superior strength, toughness, and higher resistance to wear. However, their fabrication is challenging.

IV. Hydraulic Design of Slurry Pumps

Beyond selecting wear-resistant materials, hydraulic design requires special attention in slurry pumps development due to solid-liquid mixtures pumping complexities, excessive wear and clogging associated to internal velocities and turbulent flows.

Critical components for optimal hydraulic design are impeller and volute. Peng et al. used CFD and experimental validation [18] to demonstrate that improving impeller design increased head and efficiency and reduced localised wear in critical areas.

Wang et al. [2] provided a CFD-DEM framework for predicting and mitigating wear in slurry pumps as it enhances pump’s durability and performance. Cellek & Co found that the number and geometry of impeller blades significantly influence pump’s head and efficiency [19]. Tse & Co. [20] designed a prognostic method to assess impeller degradation and estimate its Remaining Useful Life based on statistical data extracted from vibration signals collected during pumps operation.

Pagalthivarthi et al. [21] confirmed volute cutwater geometry and curvature influences on pumps performance and wear pattern.

Alawadhi et al. [22] demonstrated that using Response Surface Methodology improved efficiency and reduce erosion rate. Roudnev et al. [23] demonstrated the importance of using CFD simulations during the early design phases to predict wear location.

V. Main Design Parameters for Slurry Pumps :

Key parameters for designing and selecting centrifugal slurry pumps are summarized below :

A. Applications and Handled Product Specifications

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Slurry pumps design and selection are based on applications as they involve different carrier fluids having distinct properties such as Chemical composition, PH level and Temperature.

B. Particle size distribution, solids size, shape and abrasiveness

Hao et al. [24] showed that larger particles cause severe wear due to higher inertia and slip velocity, with uneven distribution across wet-end components. Tarodiya & Co [25] confirmed erosion varies along pump casing due to particles velocity, solids concentration, and impact angles. Deng et al. [26] linked particle motion to drag and collision forces, while Pokharel et al. [27] noted high relative velocity gradients increase erosion. Kumar et al. [28] observed head and efficiency depend on solid concentration and slurry properties and that adding fly ash to bottom ash improves both. Wang et al. [29] found coarse particles increase turbulence and that optimal particle size reduces wear and enhances performance.

C. Solids concentration

Kumar et al. [30] confirmed that higher silica sand concentration increases wear across pump components. Peng et al. [31] used CFD and experiments to show that high solids concentration and large particle size degrade hydraulic performance and accelerate wear. Macia et al. [32] found that reducing solids concentration and D50 significantly lowers energy use. Makwana & Co [33] and Patel et al. [3] reported that increasing slurry concentration and particle size reduces head and efficiency

D. Specific gravity of the slurry

Pagalthivarthi et al. [34] have used CFD modelling to simulate dense slurry flow within pump casing, aiming to optimize design for reduced wear and enhanced performance. Tarodiya & Co [35] demonstrated that handling slurry by centrifugal pumps reduces pump head, efficiency and increases linearly power consumption slurry specific gravity.

E. Flow Rate and Head

Head and Volume Flow Rate of slurry will determine required pump size. Higher heads require larger impeller diameters or even few pumps in series might be needed especially for hydraulic transport and tailing.

VI. Centrifugal Slurry Pumps Selection Flowchart

Based on insights from various research studies and practical application reviews, the below flowchart has been developed as a reference tool and guideline for selecting centrifugal slurry pumps. Selection criteria include impeller tip speed, particle size and shape, fluid temperature, PH level, presence of oils, solvent or strong acids.

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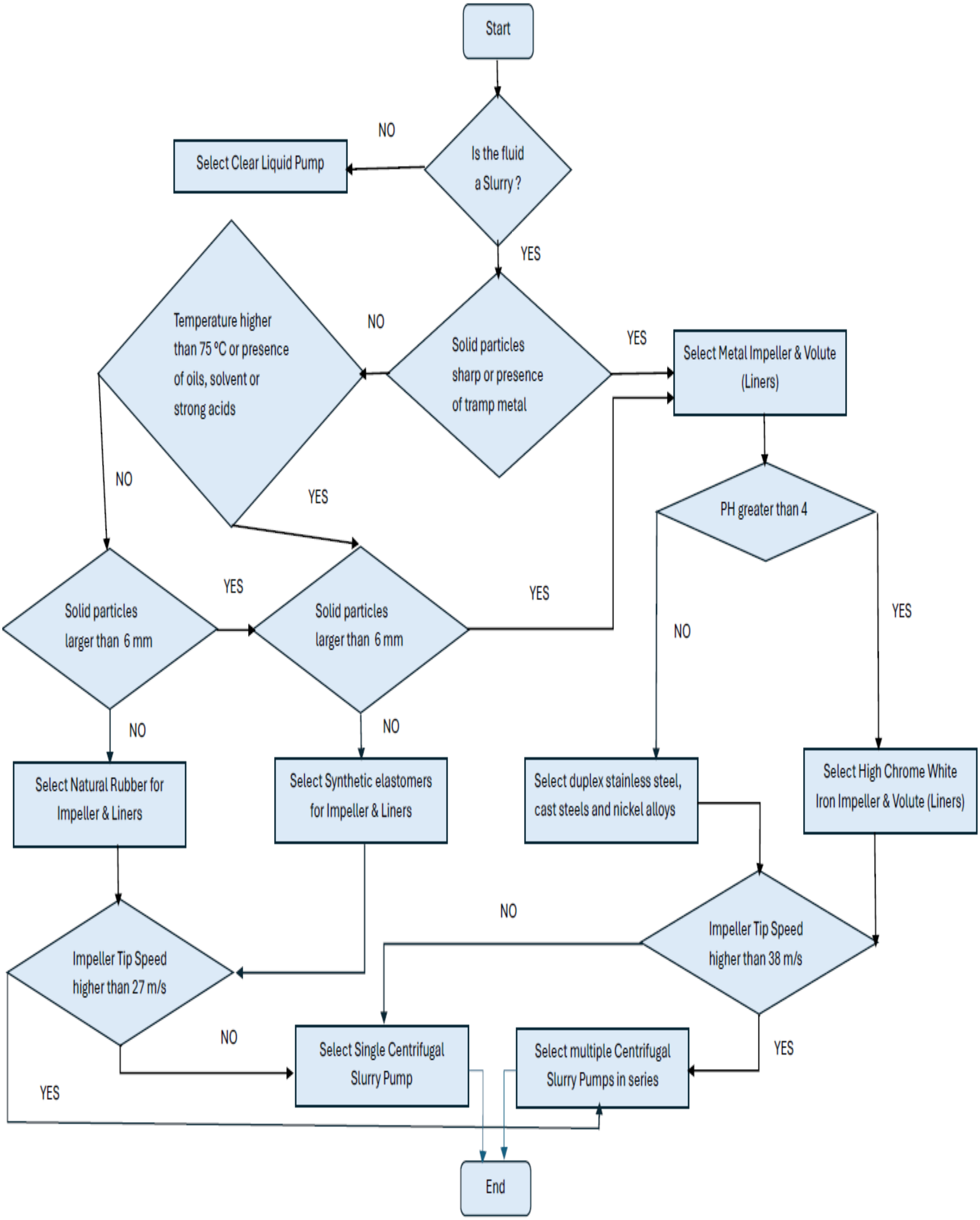

Fig. 1 Centrifugal slurry pumps selection flowchart

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VII. CONCLUSIONS

In mining and mineral processing, handled products are process-driven, with the primary objectives being efficient liberation of valuable minerals from waste and maximizing recovery while minimizing energy consumption. As a result, slurry pumps are required to handle a wide range of slurry compositions across varying process conditions to comply with operational demands.

Wear in centrifugal slurry pumps is correlated with fluid dynamics, abrasive particles interactions, material properties, and operating conditions, reflecting its complexity.

Researches and field experience in mining show that no single material nor hydraulic design can adequately address all challenges related to centrifugal slurry pumps. Therefore, addressing diverse applications and operational conditions requires a range of solutions, integrating customized hydraulic designs and combination of material selections.

Although the developed flowchart is recommended for centrifugal slurry pumps selection, future researches should focus on CFD simulations and advanced composite material technologies to improve predictive accuracy and optimize design for a sustainable mining industry.

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