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CAVITATION INDUCED ACCELERATED EROSION IN LARGE SLURRY PUMPS

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ABSTRACT

Abstract: Centrifugal slurry plumps experience accelerated erosion. Research to understand and to control has been inconclusive. This investigation is being conducted to qualitatively examine the patterns of accelerated erosion in the samples photographed or collected from slurry pumps in the field, and to compare with the patterns on an aluminium specimen eroded by a submerged fast moving cavitating water jet in abrasives.

The selected field samples are a front liner, and the front shroud of an impeller.

The examination has resulted in

- Identification of three areas in slurry pumps which experience accelerated erosion the front liner, the front shroud and the impeller's vanes.
- Identification of the three common features both in the samples and in the aluminium specimen; namely: directional groves along the direction of the main slurry-flow, cavities and pitting, and the embedding of abrasive in the surfaces.

The paper concludes the common features of localised cavitation and corresponding accelerated erosion in slurry pumps which are observed in the lowest local pressure areas. The current definition of cavitation is based on the lowest mean-pressure in the cross section area is replaced with a lowest-local-pressure based definition which is followed with redefinition of the Cavitation Number based on local parameters, the flow mapping of vortexes, vortices, flow separation behind obstacles, and tensile forces within a velocity boundary layer, and prediction of localised cavitation at the design stage, and adopting cavitation erosion preventative measures such as air entrainment in erosion areas.

KEYWORDS:

Slurry Pump Erosion, Cavitation Erosion; Submerged high speed water jet;

INTRODUCTION

Centrifugal pumps convey slurries in mining and chemical industries, and experience accelerated wear, shortened life, and poor performance. Over the last decades, research and development effort to understand the mechanics has been inconclusive, mainly due to the complexity and commercial confidentiality of the topic [1].

Slurry pumps conventionally wear due to the relative motion of the slurry. The conventional wear may be addressed in the design stage by using rubber and wear resistant materials in liners and impellers, rubber coating, and a selection of thicker and fewer vanes.

Centrifugal slurry pumps also suffer accelerated erosion due to the off-design operations. For example, centrifugal pumps designed for clear fluids, perform differently with slurries. Some recent investigations with Particle Image Velocimetry (PIV) have identified the flow separation, vortices, and the highest velocity on the suction side, in a slurry pump, when operated with clear water [2,3,4]. Pumps are assumed to operate cavitation free with keeping the mean inlet pressure to the pump above the vapour pressure. However, It locally cavitates wherever the local pressure in the fluid is reduced below the vapour pressure. The localised cavitation and its accelerated erosion effects in slurry handling devices have been investigated in vortex-amplifiers [5], conical diffusers [6], valves [7], and low speed water-jet-nozzles [8] with material removal rates to be many times more than expected from summing the effects of the individual mechanisms of cavitation and abrasive erosions. Material removal rate by a fast moving abrasive suspension (pre-mixed) water jet (ASJ) has showed up to fivefold improvement over an injected abrasive water jet (AWJ) which operated in the same conditions but cavitation free. [9].

Further reviews of the flow pattern and surface morphology have indicated that the random bombardment, and surface pitting which characterize cavitation have caused accelerated erosion in slurry environment [10,11,12,13]

A study on a high pressure, and high velocity cavitating water jet submerged in a slurry has shown localised accelerated erosion on a target [14].

The accelerated erosion in a pump liner and in an impeller near the front shroud [11,15,16] was reported to be due to vortex flows. However, both surfaces in the pump are cavitation locations where the generated bubbles in the vortex eye have collapsed on the surfaces and caused accelerated erosion. There have been similar speculations to the cause of the slurry pump erosion in other locations [17,18,19]. However, characterisation of the accelerated erosion in slurry pumps has been inconclusive partly due to ignoring the cavitation effects. This work has focussed on the accelerated erosion patterns from the field and laboratory to further improve our understand of cavitation induced accelerated erosion in slurry pumps.

EXPERIMENTAL METHODS AND PROCEDURES: A FIELD STUDY

A field study on the accelerated erosion was carried out in the operating plants, maintenance plants, and the disposal sites of slurry pumps in North of Chile. Three areas for the accelerated erosion areas were identified and photographed and specimens were collected for further analysis in Sydney. The first area is on the impeller vane, near the front shroud. The severity of erosion was more visible in the pumps with lower inlet pressure. The first author noticed this in the first pump in a copper concentrate plant. The plant was equipped with four identical centrifugal pumps operating in a serial arrangement. The first pump was located upstream of other pumps and downstream of an elevated slurry feeding tank. A similar erosion area was also reported in the literature and speculated to be due to a vortex [1]. However, milder erosion patterns were observed in the three downstream pumps. This may suggest that the lower inlet pressure and cavitation need to be also considered in the accelerated erosion. The tank swirls the slurry flows at its discharge and may superimpose a vortex flow at inlet to the pumps. The low pressure region at the eye of the vortex induces cavitation which accelerates impeller erosion near the front shroud, where cavitation bubbles collapse.

The second and the third severely eroded areas were in the front liners, and in the impeller’s front shroud respectively. Specimens from liners and impellers, in both metallic and rubber, and smaller size and large size were photographed, or collected for analyses.

The top photo in figure 1 shows accelerated erosion pattern in a metallic liner of a large centrifugal pump. The bottom photo shows similar patterns in a metallic liner of a smaller centrifugal pump. Both photos in the figure 1 show the accelerated erosion patterns are confined to locations in the proximity of the pump inlet, with groves suggesting a combination of spiral and vortex slurry flows. A rotating boundary layer is developed in the slurry flow between the rotating shroud, and the stationary liner. The superposition of a radial flow in the boundary layer, either outward due to the pumping action of expellers, or inward due to the recirculation, will result in a spiral boundary layer. The spiral slurry flows normally cavitate and cause accelerated erosion as seen in Vortex-Amplifiers [5].

The microscopic photos from similar locations in both liners follow. Figure 2 Shows the original surface of the metallic liner with only slight wear. It is enlarged x300 and taken as the basis for comparison in the study.

Figure 3 shows the accelerated erosion surface on the small liner, with a number of isolated dark spots which may represent surface pitting by micro jets from cavitation. It is reported that cavitation is characterised with formation of localized bubbles and their subsequent collapse when bubbles move into a region of higher pressure. It is proven that when a bubble collapses, a liquid micro-jet is formed and threads through the bubble [20]. A slurry micro-jet may cause pitting and accelerated erosion when impinges on a solid boundary. The picture also show one of the deep groves where the surface is directionally cut by the spiral motion of the slurry flow. This may suggest that cavitating slurry causes sever erosion as it moves over the liner.

Figure 4 shows x1000 the surface area between two groves which is embedded with micro-abrasives. The embedding or plantation of abrasives may be due to water hammer and micro jet impacts during the collapse of cavitation bubbles as proven with experimental and numerical studies. A numerical model showed that a micro-jet with an average velocity of 130m/s, and a "water-hammer" in order of 2000 atmospheres may be generated during a cavitation bubble collapse[21]. The micro jet will enhance wear when impact on a solid boundary. The validity of the numerical model was also confirmed experimentally [22]. The magnitude and direction of the momentum carried by the jet is dependent on the dynamic properties of the bubble and its surrounding slurry and location relative to the surface, the degree of flexibility and the shape of the surface [23]

Figure 5 Shows the abrasives embeddings in the deepest part of the holes generated by cavitating swirling slurries. The metallic surface is completely covered by a blanket of abrasives which prevent further material removal from the surface.

Figure 6 shows the accelerated erosion patterns in the third identified area, on a front shroud of a rubber impeller. Due to the narrow gap between a liner and a shroud, similar erosion patterns are seen to be generated on liners and shrouds. In the rubber shroud, the eroded areas are in the wake of obstacles including in the inner side of the Suction Ring, and in the wake of the Expellers. These may not be eroded due to a direct contact with slurries. The are eroded by the secondary motions initiated by cavitation.

Finally A fast moving cavitating water jet was developed experimentally in a slurry flow and erosion patterns on a submerged aluminium specimen was studied. The experimental setup for this experiment is explained elsewhere [14] (x100)

Figure 7 shows the surface morphology of a submerged aluminium specimen in abrasives and eroded by a nearly parallel fast moving cavitating water jet. Figure 8 shows abrasive embedding on the surface. Directional groves cut by abrasives in the flow direction, cavities and pitting, and abrasive embeddings are all in common with those on the liners and the shrouds. It seems that the surface bombardment by the slurry micro jets cut groves at lower contact angles, while may cause embedment of abrasives and fatigue on the surface at larger angles. on the surface. It was noticed that the embedment of slurry on the liner and the shroud have blanketed the surfaces and consequently alleviated material removal from the robber shroud, and the metallic liner and preventing to create a hole on the surfaces. While in the larger liners, where embedment was absent, the accelerated erosion has led to creation of holes in the surface.

CONCLUSION

Examination of the patterns of accelerated erosion location in the slurry pumps have identified

[1] three low pressure locations in the proximity to the pumps' inlet, namely; a) impeller's vanes, b) impeller's front shroud, and c) the front liners.

[2] Directional groves, pitting and abrasive embeddings in liners and the shrouds in common with the surface eroded by a fast moving cavitating water jet.

[3] Feasibility of localised cavitation and its accelerated erosion effects in slurry pumps.

[4] Local pressure and local velocity as parameters in defining standards for the prediction of cavitation. Cavitation may be triggered by the localised flow separation behind obstacles, vortex, swirling, rapid acceleration, or high tensile force in the flow should be considered in the design stage of any slurry handling device. It also possible to employ air entrainment methods to keep local pressures and local tensile forces under control. Finally, it is also possible to direct collapse of cavitating bubbles to the bulk of the fluid away from solid boundaries to ease erosion by cavitation.

[5] A fluid mapping across the fluid domain for the potential locations for vortices, boundary layer flow separations behind obstacles, the eye of a vortex, and tensile force within velocity boundary layer developed over a fast moving water jet. The critical locations to induce cavitations need to be identified from the mapping considered in the design to alleviate or control the accelerated erosion. In additions, air entrainment, and cavitation in the bulk of the slurry need to be considered too. suggested to alleviate the accelerated erosion. Cavitation may be generated in the

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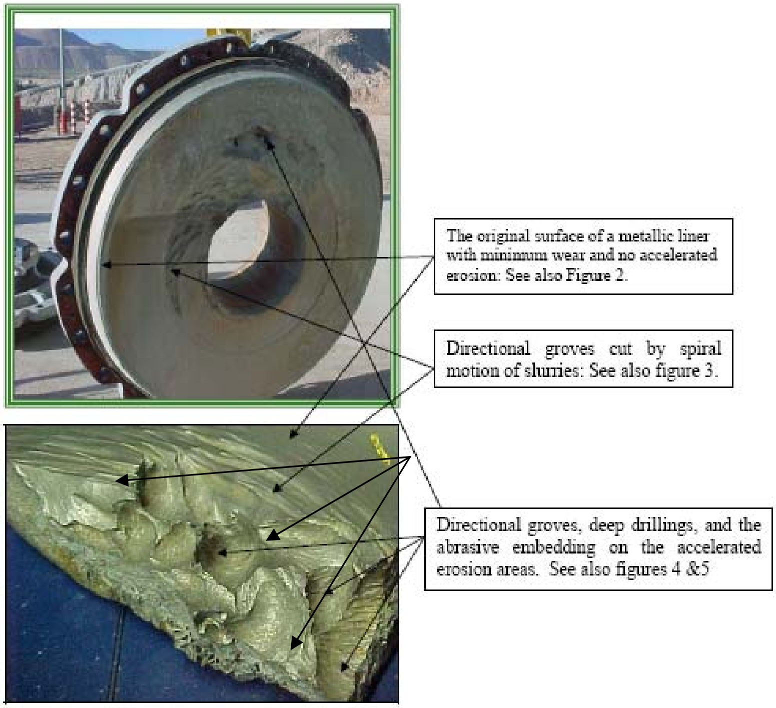

The original surface of a metallic liner with minimum wear and no accelerated erosion: See also Figure 2.

Directional groves cut by spiral motion of slurries: See also figure 3.

Directional groves, deep drillings, and the abrasive embedding on the accelerated erosion areas. See also figures 4 &5

FIGURE 1: Two metallic front liners from a large centrifugal slurry pump (the top picture), and a smaller centrifugal slurry pump with common erosion patterns of a) directional groves, b) pitting, and c) the abrasive embedding.

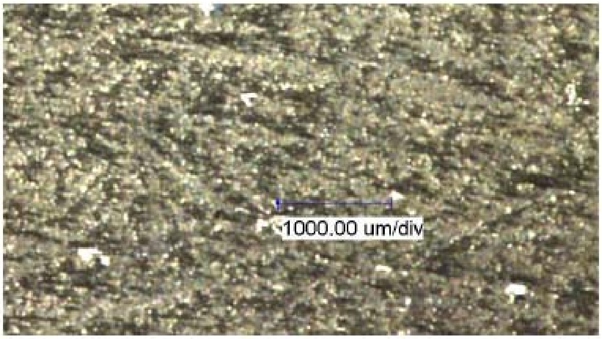

Figure 2: The original surface of a metallic liner with minimum wear. No accelerated erosion in a slurry pump (x350)

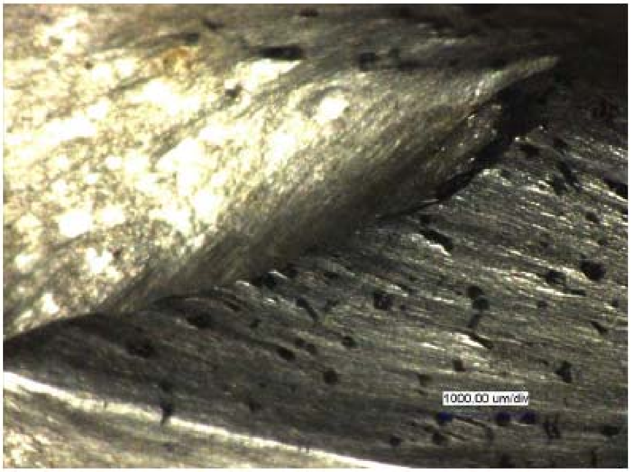

Figure 3: A directional grove and dark spots on the liner of a slurry pump (x200).

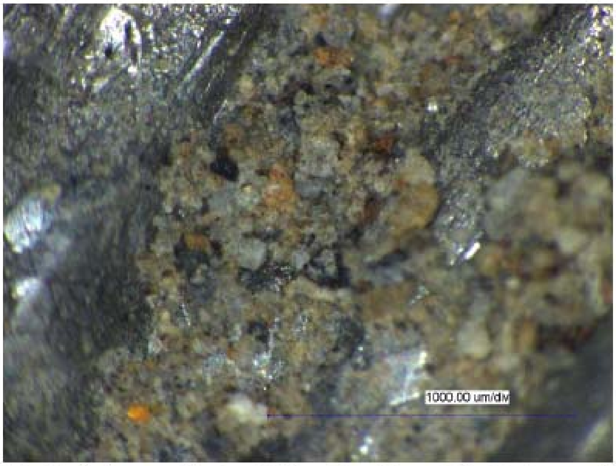

FIGURE 4: Two directional groves and abrasive-embedding on the eroded areas of a liner in a slurry pump (x800).

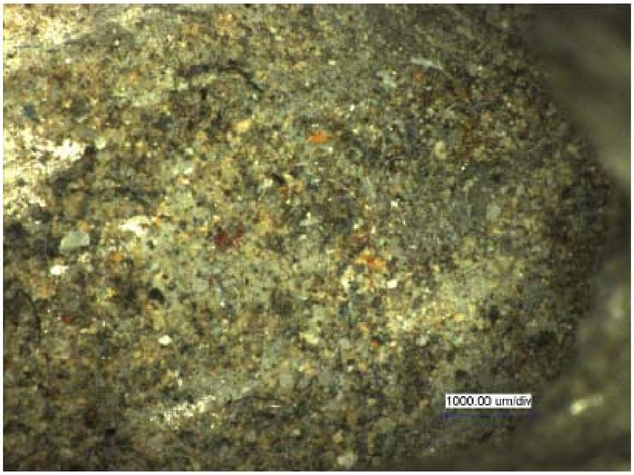

FIGURE 5: The abrasive-embeddings in the a metallic front liner of a slurry pump (x200).

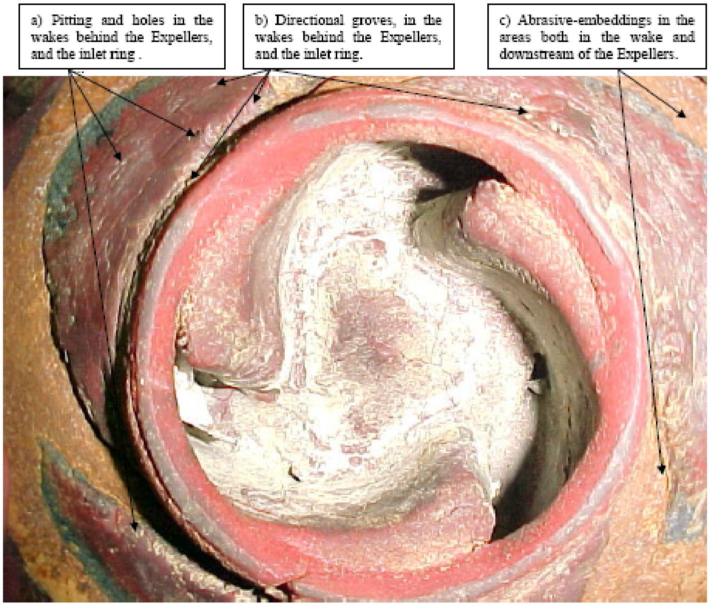

FIGURE 6: The front shroud of a rubber impeller in a small centrifugal slurry pump with common erosion patterns of directional groves, pitting, and the abrasive embedding.

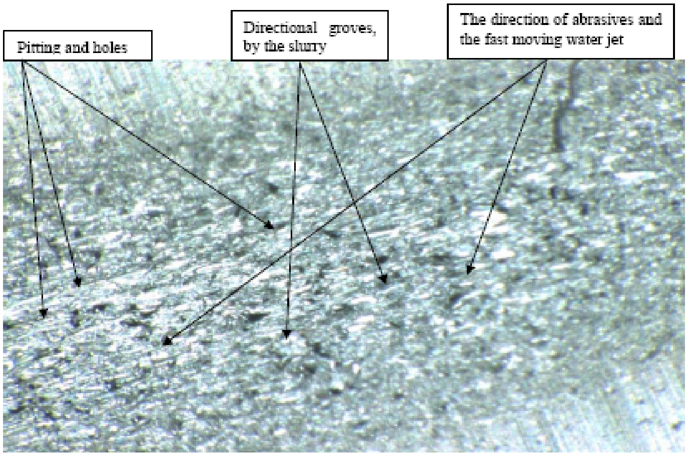

FIGURE 7 The patterns on an aluminium specimen eroded by a fast moving cavitating water jet submerged, with common features of the directional groves, and the pitting [x100].

FIGURE 8: The patterns on an aluminium specimen eroded by a fast moving cavitating water jet submerged, with the common features of the directional groves, and the abrasive embedding [x245].

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INTRODUCTION TO PROCEEDINGS

The purpose of most conferences in this field, including this one, is to provide a forum for specialists in heat transfer, fluid mechanics and thermodynamics from all corners of the globe to present the latest progress and developments in the field. This will not only allow the dissemination of the state of the art, but it will serve as a catalyst for discussions on future directions and priorities in the areas of heat transfer, fluid mechanics and thermodynamics. The additional purposes of this conference are to introduce Africa to the rest of the world and to initiate collaboration in research.

In 2002, the 1st International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT2002) was hosted in the Kruger National Park, South Africa. In 2003, the 2nd International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT2003) was hosted at the Victoria Falls, Zambia. The 2004 conference (HEFAT2004) was in Cape Town and the 4th conference (HEFAT2005) took place in Cairo, while the 5th conference (HEFAT2007) was in Sun City. The 6th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT2008), was held in Pretoria, South Africa as part of the University of Pretoria’s 100-year celebrations “A century in the service of knowledge”.

This year’s conference, the 7th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics (HEFAT2010), is held in Antalya, Turkey.

For this conference and proceedings, all papers were peer-reviewed by and approximately 360 papers were accepted. The review policy was that only original research papers that were recommended unconditionally by an independent reviewer who is a distinguished subject specialist in the field of the relevant paper were accepted.

A large number of papers were submitted, and I wish to express my sincere thanks to the reviewers whose generous efforts made it possible to select only papers of a high standard for publication in the proceedings.

The papers in these proceedings will be read in 64 parallel lecture sessions over a period of three days from 19 to 21 July 2010 during which ten keynote papers will be presented. The large number of scheduled presentations will no doubt contribute towards creating a meaningful forum for discussing the latest developments as well as for keeping abreast with the state of the art in heat transfer, fluid mechanics and thermodynamics.

Allow me to extend my sincere gratitude to the keynote speakers as well as participants for their invaluable written and oral contributions to HEFAT2010. Thanks are also due to every reviewer, member of the International Advisory Committee, and member of the Organising Committee, named and unnamed, who have contributed to the success of this conference and the quality of these proceedings.

It is my pleasure to welcome you now at HEFAT2010 on behalf of the Organising Committee. I trust that this conference will reach the common objective of bringing together scientists and engineers, and for inspiring us to uncover, share and glean more knowledge in order to tackle humankind’s future problems.

JP Meyer
Editor

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