J-ENSISTEC (Journal of Engineering and Sustainable Technology)
Computer Science | Industrial Engineering | Mechanic Engineering | Civil Engineering
Vol. 12|No. 02 June 2026
ISSN : 2477-359X (Online)
ISSN: 2407-6007 (Print)
pp. 10528-10535

Failure Analysis of Centrifugal Pump Impeller in Textile Wastewater Using a Visual and Erosion-Corrosion Approach

Jejen Jaelani Frihatna[*1], *Wisnu Wijaya*[2], *Cecep Deni Mulyadi*[3], *Mohamad Agus Fhaizal*[4], *Winardi Sani*[5], *Hanny Rahayu*[6]

[1,2,3,4,5,6]*Department of Mechanical Engineering, Universitas Sangga Buana YPKP, Bandung, Indonesia*

Email:[1]*jejen.jaelani@usbypkp.ac.id, wisnu.wijaya@usbypkp.ac.id, denicecep30@gmail.com, mohamad.agus@usbypkp.ac.id, winardi.sani@usbypkp.ac.id, hanny.rahayu@usbypkp.ac.id*

ARTICLE INFO

Article history:
Received 10 May 2026
Revised 12 May 2026
Accepted 14 May 2026
Available online 25 June 2026

Keywords:
Centrifugal pump;
Erosion–corrosion;
Impeller failure;
Textile wastewater,
Slurry flow

IEEE style in citing this article:
J. J. Frihatna, W. Wijaya, C. D. Mulyadi, M. A. Fhaizal, W. Sani, and H. Rahayu, "Failure Analysis of Centrifugal Pump Impeller in Textile Wastewater Using a Visual and Erosion-Corrosion Approach," J-ENSITEC: Journal of Engineering and Sustainable Technology, vol. 12, no. 2, pp. 10528-10535, 2026.

Doi :
https://doi.org/10.31949/j-ensitec.v12i02.18060

ABSTRACT

Premature impeller failure is a major operational problem in textile wastewater treatment systems due to abrasive slurry flow and chemically aggressive environments. This study investigates the failure mechanism of a centrifugal pump impeller used in a textile wastewater treatment plant after approximately 1.5 years of operation. The impeller material was identified as gray cast iron operating under slurry wastewater conditions containing suspended abrasive particles and chemical contaminants. The failure analysis was conducted through visual inspection, morphology evaluation, and literature-based erosion–corrosion interpretation. Severe degradation was observed in the outer diameter region, including pitting, edge thinning, perforation, and material loss. The damage was associated with abrasive particle impact, high turbulence intensity, slurry flow, and corrosive wastewater exposure. The results indicate that synergistic erosion–corrosion was the dominant degradation mechanism. Erosion continuously removed the protective oxide layer, while corrosion accelerated material weakening and surface deterioration. Recent erosion studies on centrifugal pumps also reported severe degradation near blade tips and outer diameter regions due to high particle impact energy and turbulence effects. Compared with previous studies that separately discuss erosion or corrosion mechanisms, this study emphasizes the interaction of both mechanisms under textile wastewater operating conditions. The findings provide practical implications for improving pump reliability through better material selection, slurry filtration systems, and preventive maintenance strategies in wastewater treatment applications.

1. INTRODUCTION

Centrifugal pumps are widely used in textile wastewater treatment systems to transfer fluids containing suspended solids, sludge particles, and chemical contaminants. The impeller is one of the most critical components because it directly interacts with the working fluid during operation. Continuous exposure to abrasive slurry particles and corrosive wastewater may significantly reduce impeller service life, pumping efficiency, and operational reliability [1].

Impeller degradation generally occurs due to erosion, corrosion, cavitation, or synergistic interaction between these mechanisms [5], [6]. Erosion is caused by repeated particle impact on the material

*) Corresponding Author: jejen.jaelani@usbypkp.ac.id

surface, while corrosion occurs due to electrochemical reactions between the metal surface and surrounding fluid environment [11]. Under slurry flow conditions, erosion–corrosion interaction may accelerate material degradation significantly [17], [18].

Previous studies investigated slurry erosion and centrifugal pump degradation using experimental methods and numerical simulations [20]–[25]. Khan et al. [29] reported severe wall thinning and material loss near blade tips and outer diameter regions caused by turbulence intensity and repeated abrasive particle impingement. Their study combined SEM, EDS, laser profilometry, and CFD-DPM simulation to correlate particle-laden flow behavior with localized erosion zones in centrifugal pump blades. Similar degradation mechanisms were also observed in slurry transport systems and wastewater applications [17], [18].

Recent review studies emphasized that wear in centrifugal pumps is strongly influenced by turbulence intensity, slurry concentration, particle impact velocity, cavitation effects, and material properties [30]. Cavitation-assisted erosion may further accelerate degradation through repeated bubble collapse and localized micro-jet formation near the impeller surface.

Despite extensive studies on slurry erosion, research specifically discussing erosion–corrosion failure in textile wastewater systems remains limited. Textile wastewater contains abrasive particles, dye residues, detergents, salts, and fluctuating pH conditions that promote simultaneous mechanical and electrochemical degradation. Several recent studies published in J-ENSITEC and related engineering journals have discussed industrial equipment degradation, preventive maintenance, corrosion analysis, and material reliability under severe operating conditions [26]–[28]. However, studies specifically focusing on synergistic erosion–corrosion failure of centrifugal pump impellers in textile wastewater systems remain limited.

The novelty of this study lies in the investigation of synergistic erosion–corrosion failure in a centrifugal pump impeller operating under textile wastewater conditions. Unlike previous studies focusing separately on erosion or corrosion mechanisms, this study emphasizes the interaction between abrasive slurry flow and corrosive wastewater environments under actual industrial operating conditions. Therefore, this study provides a practical industrial case study that bridges the gap between theoretical erosion–corrosion mechanisms and actual impeller degradation in textile wastewater treatment systems.

The objective of this study is to analyze the failure mechanism of a centrifugal pump impeller used in textile wastewater service and propose engineering recommendations to improve pump reliability and operating life.

2. RESEARCH METHOD

2.1. Research Object

The object of this study was a failed centrifugal pump impeller used as a Return Activated Sludge (RAS) pump in a textile wastewater treatment plant located in Cimahi, Indonesia. The impeller operated for approximately 1.5 years before replacement due to significant performance reduction and severe material degradation.

Pump specifications are summarized as follows:

- Pump type : Centrifugal pump
- Impeller type : Closed impeller
- Material : Gray cast iron
- Capacity : 80–100 m^3/h
- Rotational speed : 1450 rpm
- Operating temperature : 30–40°C
- Wastewater pH : 6–9
- Working fluid: Textile wastewater sludge

DOI: https://doi.org/10.31949/j-ensitec.v12i02.18060

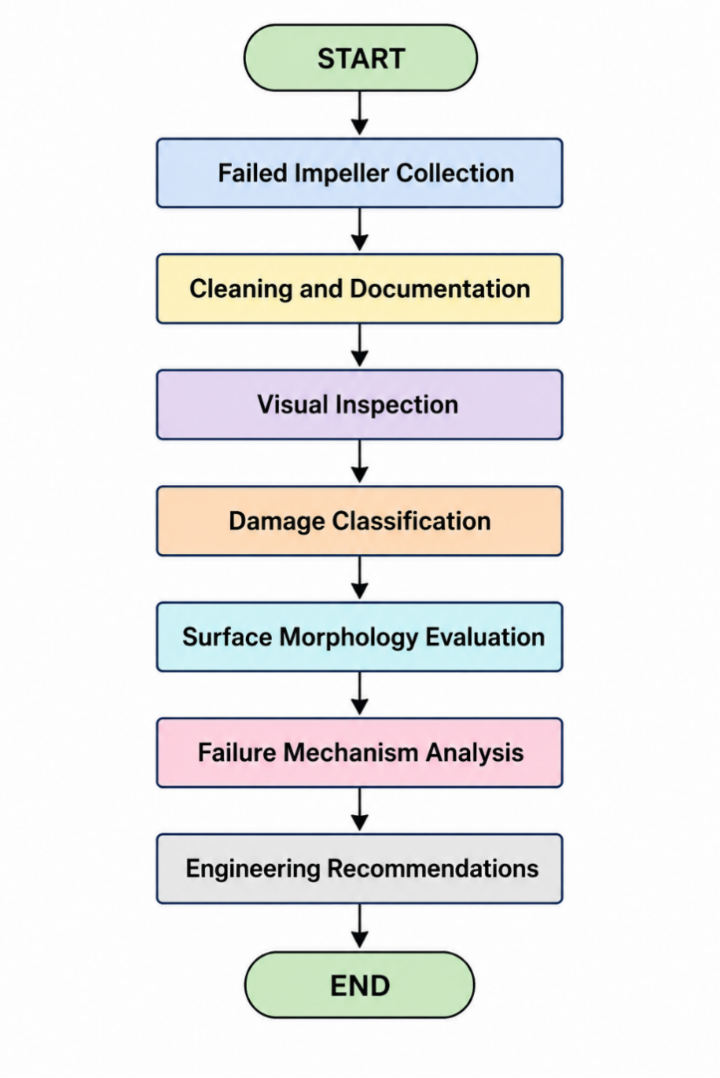
The wastewater contained suspended abrasive particles originating from textile sludge, sediment particles, and inorganic contaminants that potentially contributed to abrasive wear during pump operation.

2.2. Research Procedure

The research procedure consisted of:

1. Failed impeller collection
2. Cleaning and documentation
3. Visual inspection
4. Surface morphology evaluation
5. Damage classification
6. Failure mechanism interpretation
7. Engineering recommendation development

Figure 1. Research Methodology Flowchart



2.3 Failure Analysis Method

The analysis was conducted using macroscopic visual inspection and literature-based erosion–corrosion interpretation. Observed damage characteristics were compared with erosion and slurry degradation theories reported in previous studies [5], [17], [20]–[25].

The analysis focused on correlating degradation morphology with slurry flow behavior, turbulence intensity, particle impact, wall thinning, and corrosion mechanisms occurring in centrifugal pump systems.

SEM/EDS analysis, hardness testing, and metallographic examination were not conducted due to specimen limitations and facility constraints; however, these methods are recommended for future investigations to obtain more comprehensive microstructural characterization.

3. RESULTS AND DISCUSSION

3.1. Visual Observation

Visual inspection revealed non-uniform damage across the impeller surface. The most severe degradation occurred at the outer diameter region.

Table 1. Damage severity across impeller zones

Zone	Severity	Observed Characteristics
Hub region	Minimal	Slight discoloration without significant material loss
Blade region	Moderate	Rough surface texture and early-stage pitting
Outer diameter	Severe	Massive material loss, edge thinning, and perforation

Figure 2. Overall failed impeller condition (front side)

The impeller showed severe material loss at blade edges and tips, indicating prolonged exposure to abrasive particles and corrosive fluid.

Figure 2 shows the overall condition of the failed impeller after approximately 1.5 years of operation in textile wastewater service. Severe degradation was concentrated at blade tips and outer diameter regions. Surface roughening, edge thinning, pitting, and material perforation were clearly observed.

The outer diameter region experienced the highest circumferential velocity during operation, resulting in higher particle impact energy and accelerated material removal. Similar degradation behavior was reported by Khan et al. [29], where severe wall thinning and erosion damage occurred near blade outer edges and vane tips under slurry flow conditions.

Repeated particle impingement continuously removed material from the impeller surface and increased surface roughness. Turbulence intensity and slurry flow also accelerated erosion progression. Previous CFD-DPM investigations demonstrated that particle-laden flow significantly increases turbulence intensity and particle-wall collisions, thereby accelerating erosive wear in centrifugal pump blades [29].

Figure 3. Failed impeller showing severe perforation (red circle), edge thinning (arrow A), and material loss at the outer diameter region.

Figure 3 shows localized degradation zones observed on the impeller surface. Severe perforation and edge thinning indicate advanced erosion–corrosion interaction caused by abrasive particle impact and electrochemical degradation.

The observed damage morphology is consistent with slurry erosion mechanisms reported in previous studies [20]–[25], where localized turbulence and high particle concentration accelerated material loss. Similar degradation mechanisms were also reported by Neville and Wang [5], who explained that erosion continuously removes protective oxide films, thereby exposing fresh metal surfaces to further corrosion attack

Figure 4. Outer diameter degradation region showing severe erosion–corrosion damage and surface thinning.

Figure 4 shows severe wall thinning in the outer diameter region where slurry velocity and turbulence intensity were highest. The combination of erosion and corrosion gradually weakened the material until perforation occurred.

The degradation severity observed in the outer diameter region is associated with increased circumferential velocity and turbulence intensity. Higher flow velocity increases particle kinetic energy and impact frequency, thereby accelerating material removal and wall thinning. This mechanism is consistent with erosion models reported in slurry pump literature [20]–[25], [29].

The observed degradation mechanism is consistent with erosion–corrosion interaction reported in slurry systems [17], [18]. Material thinning became more severe in regions experiencing repeated abrasive particle collisions and unstable flow behavior.

Recent studies reported that centrifugal pump wear is strongly influenced by particle concentration, turbulence intensity, cavitation effects, and slurry velocity [30].

3.2. Failure Mechanism

The dominant failure mechanism was identified as synergistic erosion–corrosion. Erosion continuously removed protective oxide films from the material surface, while corrosion weakened the material and accelerated material loss.

Possible cavitation effects also contributed to localized degradation. Cavitation bubble collapse may produce micro-jets and shock waves that intensify surface damage and erosion progression. The combined interaction between erosion, corrosion, and cavitation significantly accelerated degradation in the outer diameter region.

Khan et al. [29] reported that high turbulence regions in centrifugal pump impellers experienced erosion rates nearly twice as severe as low-impact regions due to repeated abrasive particle collisions. Similar findings were also reported in slurry erosion studies involving centrifugal pumps and multiphase flow systems [20]–[25].

The synergistic interaction between erosion and corrosion accelerated degradation significantly beyond individual mechanisms. Repeated particle impact removed protective oxide layers from the impeller surface, while corrosive wastewater promoted electrochemical attack on exposed metal surfaces. This interaction gradually caused surface roughening, pitting, wall thinning, and eventually perforation.

3.3. Material Evaluation

The impeller material was identified as gray cast iron, which has relatively low erosion and corrosion resistance under abrasive slurry conditions.

Table 2. Comparison of Impeller Materials for Slurry and Corrosive Applications

Material	Hardness (HB)	Erosion Resistance	Corrosion Resistance
Gray cast iron	180–220	Low	Low
Ductile iron	200–300	Moderate	Moderate
Bronze alloy	80–200	Moderate	High
High-chromium white iron	500–600	Very High	High

Source: Adapted from ASM material standards and erosion–corrosion literature [13], [15].

High-chromium white iron is recommended for slurry applications because its carbide-rich microstructure provides superior abrasion resistance. Material selection plays an important role in extending pump service life because wear resistance depends on hardness, corrosion resistance, and the ability to withstand abrasive particle impact under slurry conditions [30].

Previous studies also reported that cast iron and carbon steel impellers operating under sand-laden flow conditions exhibit accelerated degradation due to repeated abrasive particle impacts and localized turbulence effects [29].

3.4. Engineering Recommendations

Several engineering recommendations are proposed:

1. Install slurry filtration or strainer systems to reduce abrasive particle entry into the pump system.
2. Replace gray cast iron with high-chromium alloy materials or bronze alloys for improved wear resistance.
3. Conduct periodic inspection and preventive maintenance to identify early-stage degradation.
4. Reduce abrasive particle concentration in the wastewater transport system.
5. Consider hydrocyclone systems for continuous slurry particle separation.

These approaches may improve pump reliability and extend impeller service life in textile wastewater applications.

4. CONCLUSION

The centrifugal pump impeller failed primarily due to synergistic erosion–corrosion under abrasive slurry flow and corrosive textile wastewater conditions. Severe degradation occurred at blade tips and outer diameter regions due to high turbulence intensity and abrasive particle impact.

The interaction between erosion and corrosion accelerated material loss and caused edge thinning, pitting, wall thinning, and perforation. Possible cavitation effects also contributed to localized surface deterioration.

The findings are consistent with recent experimental and CFD-based studies showing that high turbulence intensity, slurry concentration, and particle impact velocity strongly influence localized impeller degradation and erosion severity in centrifugal pump systems [29], [30].

This study contributes to understanding impeller degradation mechanisms in textile wastewater systems and provides practical recommendations regarding material selection, slurry filtration, and preventive maintenance strategies. The findings also provide industrial implications for improving pump reliability, reducing maintenance downtime, and extending equipment service life in wastewater treatment applications.

Future studies are recommended to include SEM/EDS analysis, hardness testing, metallographic examination, and CFD simulation to provide more comprehensive characterization of erosion–corrosion behavior in centrifugal pump systems.

This study contributes to practical failure analysis knowledge for centrifugal pumps operating under abrasive textile wastewater conditions and supports the development of more reliable slurry handling systems in industrial wastewater treatment facilities.

ACKNOWLEDGEMENTS

The authors thank PT. Jerdytex for permission to conduct this study and the Department of Mechanical Engineering, Universitas Sangga Buana YPKP and Universitas Pasundan for their support.

REFERENCES

[1] I. J. Karassik, J. P. Messina, P. Cooper, & C. C. Heald. (2008). *Pump Handbook* (4th ed.). New York, NY: McGraw-Hill.

[2] R. K. Budynas, & J. K. Nisbett. (2015). *Shigley's Mechanical Engineering Design* (10th ed.). New York, NY: McGraw-Hill.

[3] G. L. Sheldon, & I. Finnie. (1966). On the ductile behavior of nominally brittle materials during erosive cutting. *Journal of Engineering for Industry*, 88(4), 393–400.

[4] M. G. Fontana. (1986). *Corrosion Engineering* (3rd ed.). New York, NY: McGraw-Hill.

[5] A. Neville, & S. Wang. (2009). Erosion–corrosion of engineering steels—Can it be managed? *Wear*, 267(1–4), 469–478. https://doi.org/10.1016/j.wear.2008.12.051

[6] M. M. Stack, & G. H. Abdulrahman. (2010). Mapping erosion–corrosion of carbon steel in oil–water solutions: Effects of hydrodynamic and electrochemical parameters. *Tribology International*, 43(1–2), 456–468. https://doi.org/10.1016/j.triboint.2009.07.009

[7] J. A. Wharton, & R. J. K. Wood. (2005). An investigation of erosion–corrosion processes in aqueous environments. *Wear*, 259(1–6), 536–546. https://doi.org/10.1016/j.wear.2005.02.040

[8] A. W. Momber. (2004). *Wear of Materials in Slurry Systems*. Berlin, Germany: Springer.

[9] I. Finnie. (1960). Erosion of surfaces by solid particles. *Wear*, 3(2), 87–103.

[10] J. G. A. Bitter. (1963). A study of erosion phenomena. *Wear*, 6(1), 5–21.

[11] D. A. Jones. (1996). *Principles and Prevention of Corrosion* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

[12] B. Poulson. (1999). Complexities in predicting erosion corrosion. *Wear*, 233–235, 497–504.

[13] J. R. Davis. (2001). *Alloying: Understanding the Basics*. Materials Park, OH: ASM International.

[14] API Standard 610. (2021). *Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries* (12th ed.). Washington, D.C.: API Publishing Services.

[15] S. Nugroho, & S. P. Raharjo. (2009). Analisis kegagalan impeller slurry pump di sebuah industri kaolin. *ROTASI – Jurnal Teknik Mesin Universitas Diponegoro*, 11(3), 12–19..

[16] E. Febriyanti, Sutarjo, & K. Anwar. (2017). Analisis kegagalan impeller penyebab kerusakan pompa air laut. *Majalah Ilmiah Pengkajian Industri*, 11(2), 85–94.

[17] R. J. K. Wood, & S. P. Hutton. (1990). The synergistic effect of erosion and corrosion: Trends in published results. *Wear*, 140(2), 387–394.

[18] T. J. Harvey, J. A. Wharton, & R. J. K. Wood. (2007). Development of synergy model for erosion–corrosion of carbon steel in a slurry pot. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, 221(3), 257–266. https://doi.org/10.1243/13506501JET240.

[19] H. X. Guo, B. T. Lu, & J. L. Luo. (2005). Interaction of mechanical and electrochemical factors in erosion–corrosion of carbon

steel. *Electrochimica Acta*, 51(2), 315–323. https://doi.org/10.1016/j.electacta.2005.04.032.

[20] A. A. Noon, A. U. Jabbar, H. Koten, M.-H. Kim, H. W. Ahmed, U. Mueed, A. A. Shoukat, & B. Anwar. (2021). Strive to reduce slurry. erosion and cavitation in pumps through flow modifications, design optimization and some other techniques: Long term impact on process industry. *Materials*, 14(3), 521. https://doi.org/10.3390/ma14030521.

[21] J. Banka, & A. K. Rai. (2024). Erosion and flow visualization in centrifugal slurry pumps: A comprehensive review of recent. developments and future outlook. *Particulate Science and Technology*, 42(3), 427–459. https://doi.org/10.1080/02726351.2023.2259336

[22] W. Zhao, Y. Fan, & H. Fan. (2026). Sediment erosion of a centrifugal pump during startup and shutdown processes considering. transient flow in pump station. *Fluids*, 11(3), 77. https://doi.org/10.3390/fluids11030077

[23] X. Li, H. Zhang, & Y. Wang. (2024). A review on the hydraulic performance and erosion wear characteristic of the centrifugal slurry pump. *Particuology*, 95, 370–392. https://doi.org/10.1016/j.partic.2024.10.006

[24] J. Chen, M. Liu, & T. Zhao. (2026). Erosive wear characteristics and hydraulic performance of centrifugal slurry pumps under fluid–particle dynamics: A CFD–DEM approach. *Chemical Engineering Science*, 321, 122780.

[25] W. Zhang, S. Yang, D. Wu, & J. Mou. (2021). Effect of particle mass concentration on erosion characteristics of self-priming pump. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 235(23), 6445–6458. https://doi.org/10.1177/09544062211000771

[26] Ulikaryani, U. S. Jati, R. Ariawan, D. Prabowo, S. I. Khasanah, & H. Abdillah. (2025). Analisa pengukuran ketebalan steel block, aluminium block dan steel plate menggunakan ultrasonic thickness gauge. *Infotekmesin*, 16(1). https://doi.org/10.35970/infotekmesin.v16i1.2583