STUDY OF PARTICLE DYNAMICS AND EROSION IN
A CENTRIFUGAL FAN

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ABSTRACT
Fans in industrial plants are exposed to erosion due to air flows loaded by solid particles. Impellers with cambered plates lead to highly three dimensional flows with separated regions, rendering particle dynamics even more complex. This paper studies particle trajectories and erosion through a centrifugal fan based on a Lagrangian tracking approach and a semi empirical correlation of erosion rate. The obtained results show that the flow conditions, particle size and concentration strongly affect the particle dynamics, impact locations and erosion rates. Results show large non-uniformities in erosion distribution mainly over the hub and blade pressure side added to spiral casing. Erosion patterns are analyzed to reveal the effects of flow conditions, particle size and concentration. The obtained results may assist the fan producers in identifying the critical regions of erosion wear and to provide the basis for modifying the impeller design and propose adequate coating.

KEYWORDS
Centrifugal fan; Particulate flow; Particle trajectory; Erosion

NOMENCLATURE

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INTRODUCTION
The ingestion of solid particles by air compression and ventilation systems is frequent in industrial plants, and may cause related problems of fouling and/or erosion. Quartz is the most abundant erosive constituent and its abrasive impacts cause considerable erosion for the impeller blades and volute, which over time changes the geometry and degrade the performance. Experimental assessment of erosion and related phenomena of turbomachinery equipments is both
difficult and expensive; however the in-service blades inspection may provide information on the extent and severity of erosion. In the last decades the computing power has increased significantly rendering simulations reliable in predicting erosion and better understanding the phenomenon itself and finding solutions to extend the operating life. Hussein and Tabakoff (1973) provided the first 2-D computation of particle trajectory and erosion through axial blade cascade. Later, Elfeki and Tabakoff (1987) established the first computation of particle trajectory and erosion through an impeller and provided a description of the inertial forces. Since, several researchers have developed improved algorithms to simulate 3-D particle trajectories and erosion correlations. A complete survey of leading researches in axial/radial turbines and compressors is provided by Hamed et al. (2006). Early calculations of particle trajectories and erosion through centrifugal fans for power plant were obtained by Mengiiturk and Sverdrup (1985). They have shown that the centrifugal fans’ airfoils have the highest fly-ash erosion tolerance and the use of oversize, slower-rotation would reduce erosion. Ghenaiet et al. (2004, 2005) presented a complete study of the erosive process in a high speed draft axial fan stage where the particle trajectory and erosion were simulated using an in-house code adopting the Lagrangian approach and the turbulent dispersion of particles. Also, they have related the performance degradation and operation time to the geometry deterioration. Cardillo et al. (2014) studied the blade erosion of a centrifugal fan developed for industry applications using an open source code to predict the flow-field and an in house code for particle tracking and erosion prediction. As results, the zones more exposed to erosion are at the leading and trailing edges and suction side. Fritsche et al. (2017) by means of commercial code ANSYS-CFX and the standard erosion model analyzed the erosion behaviour of large radial fans with the aim to reduce erosion while keeping the required performance characteristics. More recently, Aldi et al. (2019) studied the erosion behaviour of a large-sized centrifugal fan installed in a cement plant. The particle trajectories were computed with a Lagrangian approach under the code Fluent. Also, Lai et al. (2019) studied the solid particle erosion of a centrifugal pump for liquid-solid flow adopting the two-way coupled Eulerian-Lagrangian approach under the code Fluent. The results show that the impeller is the most eroded component, and the highest average and maximum erosion rates occur at the hub of impeller and the severe erosion is at the leading edge. The review of recent numerical studies confirms that the focus is still on the modelling for various aspects associated with particle trajectories and erosion. This paper is a continuation of previous works established for different types of turbomachinery components amid configurations of axial fans (Ghenaiet et al., 2005, Ghenaiet (2008, 2010)). The present study concerns the computations of particles trajectory and erosion through a centrifugal fan using an improved version of an in-house code which has been validated experimentally (Ghenaiet et al., 2004) and demonstrated its capabilities in other relevant studies.

**CFD MODEL**

This centrifugal fan has and impeller with forward 4 full blades and 16 splitter (short) blades (Fig. 1). It has an impeller of an external diameter of 249 mm and an admission duct of 89 mm. It operates at a nominal speed of 2820 rpm and delivers a maximum flow rate of 560 m³/hr.

**Figure 1: CAD view of impeller**

Because of interactions between the impeller and the volute and its asymmetric configuration, the flow in the centrifugal fan is very complicated and asymmetric. In such a case it is necessary to
simulate the flow in the total fan geometry. The flow field is solved separately from the solid phase along the different components constituting the computational domain shown in Fig. 2. The values of total pressure and temperature imposed at inlet correspond to the standard atmospheric conditions and the free stream turbulence intensity $Tu = (2k/3)^{1/2}/V$ set at 5% while a mass flow rate is imposed at the outlet from the volute.

H-grid is used to mesh the admission duct and the impeller (Fig. 3(a-b)), but the volute used tetrahedral mesh elements (Fig. 3(c)) since the geometry is complex. For the refinement near blades, hub and shroud, the distance of the first node $\Delta y$ required that the dimensionless parameter $y^+ = \frac{\Delta y U_1}{\nu}$ be 2. The friction law gives $U_1 = V_\infty \sqrt{C_f/2}$, $C_f = 0.037Re_c^{-0.2}$, where the Reynolds number $Re_c$ is based on blade chord and averaged flow properties through the impeller. The $k\omega$ based SST turbulence model with an automatic near wall treatment permits switching between the low-Reynolds model for the finer mesh and the wall-function. The grid dependence (Table 1) showed slight variations in performance above overall grid size of 3281648 and this was considered regarding the available computing resources. Figure 4 presents the range of $y^+$ having low values (0.1-12.8) around blades and in most critical regions of blades tips, but on the hub $y^+$ values vary in between 12.8 – 44.5. As consequence, this grid size seems acceptable to carry out the flow computations.

![Figure 3: Meshing: a) Impeller hub; b) Impeller shroud; b) Volute at tongue](image)

**Table. 1 Grid dependency study**

<table>
<thead>
<tr>
<th>Grid size (nodes)</th>
<th>2726308</th>
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<th>3103948</th>
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<td>Head (mm H-20)</td>
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<td>118.705</td>
<td>118.398</td>
<td>118.194</td>
<td>117.785</td>
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<td>Isentropic efficiency (%)</td>
<td>51.432</td>
<td>51.393</td>
<td>51.380</td>
<td>51.370</td>
<td>51.320</td>
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![Figure 4: $y^+$ distribution in the rotor](image)

**FLOW FIELD RESULTS**

To correctly track particles for erosion inside the impeller it is important to reproduce the 3-D flow field and capture the peculiar flow phenomena in this asymmetrical and complex configuration of blade-to-blade passages and volute. To solve the flow field and reveal the flow details the frozen rotor model was considered, where the coupling between the cells zones is done by keeping the absolute velocity in the global coordinate, i.e., the velocities are just switched between relative and absolute frames, and the wakes between different cells zones are considered in some degree. On the
other hand, for the performance determination the stage interface was used. As a result, Fig. 5 illustrates the predicted aerodynamic performance of centrifugal fan, in terms of pressure head in water column and total-to-total isentropic efficiency. The pressure head depicts a first steep trend from the maximum flow rate downward to flow rate of 182 m$^3$/hr and below the curve changes its slope near unstable operating branch. The efficiency curve depicts an almost parabola trend with a peak value. The nominal point is pointed at the total-to-total isentropic efficiency of 21.41 % for the flow rate of 303.8 m$^3$/hr and rotational speed of 2820 rpm. This forward curved blades of the impeller generates higher flow rate and is useful to run at higher pressure as compared to backward curved for a given impeller diameter and speed. Indeed the exit whirl component is large and leading to a higher stage pressure rise, and such blades have a larger hub to tip ratio which allows large area for the flow entering the fan.

The pressure field when operating at the nominal condition to deliver $Q_N =303.8 m^3$/hr is illustrated by Fig. 6 at mid-span. As shown, a low static pressure observed around the impeller, which increases as the fluid particles approaches from the impeller tip towards the volute casing. The static pressure contours on the suction and discharge side of blade surfaces indicate existence of a wide pressure difference. Static pressure is very much reduced on interior surface near hub region due to turning of flow from axial to radial direction and lack of flow guidance available in the region of short blades. Moving toward the volute, after initial steep gradient, the static pressure increment seems to be driven by 2-d changes and losses phenomena during diffusion process appearing mostly around the critical region of tongue. The blades passages, in-between 30 - 90 deg from the tongue, experience the lowest static pressure and highest dynamic pressure. Indeed, the asymmetric distribution which locally influences the relative flow angle entering the blade causes localized separations. Conformed to the static pressure analysis, the distortion of flow influences remarkably 3-d patterns moving radially outward and justifies the presence of separated flow regions within impeller. The quite complex 3-d pattern is recognizable near the volute tongue, as seen from Fig. 8. The flow velocity reaches its maximum at trailing edges of blades then the flow enters into the volute, where the velocity decays gradually as the kinetic energy is converted into static pressure. Finally the information about the turbulent
kinetic energy dissipation (plotted in Fig. 9) within blades passages and volute is of significance to the tracking of small particles. The evolution of turbulent quantities underline the evolution of boundary layers and the presence of separated flows and flow circulations, as well as regions affected by turbulent kinetic energy over-production due to high rate of strain.

**Figure 6: Static pressure at mid-span**

**Figure 7: Flow velocity at mid-span**

**Figure 8: Flow velocity vectors**

**Figure 9: Turbulence kinetic energy**

**COMPUTATION OF PARTICLE TRAJECTORY**

In the simulation of particle-laden flows which the volume fraction is lower than $10^{-6}$ the Lagrangian approach is used to solve the particle trajectory and track the large number of particles individually and their impact conditions at the walls are easily determined. The trajectory of a particle in a moving fluid is governed by the vector balance of its rate of change of momentum and the superposition of external forces.

$$m_p \frac{dV_p}{dt} = F_R + F_D + F_B + F_P + F_{VM} + F_L$$

(1)

Where $F_R$ forces are both centripetal and Coriolis forces, $F_D$ drag force, $F_B$ buoyancy force, $F_P$ due to pressure gradient surrounding the particle which may be neglected since the density ratio is very small (Sommerfeld, 2000), $F_{VM}$ is added mass force to accelerate the virtual mass of fluid which is neglected herein. For particle sufficiently large the velocity gradient produces a lift force called Saffman force which depends on Reynolds number ($Re_p$) and shear flow Reynolds number $Re_s = \frac{\rho f}{\mu f} d^2 \|\overrightarrow{\omega_f}\|$ and $\overrightarrow{\omega_f} = \nabla \times \overrightarrow{v_f}$ (Sommerfeld, 2000), given by:

$$F_{LS} = 1.615 d_p \sqrt{\rho_f \mu_f} \frac{1}{|\omega_f|^{1/2}} (\overrightarrow{v_f} - \overrightarrow{v_p}) \times \overrightarrow{\omega_f} \cdot f(Re_p, Re_s)$$

(2)

Where $f(Re_p, Re_s)$ represents the correction function.

In most particulate flows the dominant force is the drag. The general expression for drag coefficient is due to Haider and Levenspiel (1989), where the constants $A$, $B$, $C$ and $D$ depend on the particle shape factor.
the concentration (10 - 50 mg/m^3) and sand particle size distribution (5 - 200 micron). The adopted number of seeded particles and initial positions upstream are determined by iterations by knowing

The equations of motion are derived in the rotating frame, hence resulting in the centrifugal and Coriolis forces and the drag and Saffman forces.

Other at high impact angles as follows:

abrasive particles and implemented two mechanisms one predominant at low impact angles and the

Their successful erosion model was based on 2024 aluminium alloy as a target and sand (quartz) as

The computation of particle trajectory corresponds to ideal and over-load operating points. The number of seeded particles and initial positions upstream are determined by iterations by knowing the concentration (10 - 50 mg/m^3) and sand particle size distribution (5 - 200 micron). The adopted concentration range corresponds to mid and high concentrations of sand and dust particle suspended in the polluted atmosphere of the Saharan regions. It should be noted that this range does not exceed the upper limit of volume fraction of 10^{-6}. The particle tracking is based on the finite element method which requires transforming the particle position into the local co-ordinates and updating the cell number. Owing to different vane and blade counts and due to large variation of blade staggering, domains were rotated up and down to keep tracking the particles through the next domain. The integration time step used in Runge-Kutta-Fehlberg method depends on cell size, flow velocities and truncation error. If a particle interacts with an eddy the turbulence effect is assumed to prevail as long as the particle-eddy interaction time is less than the eddy lifetime, and its displacement relative to an eddy is less than eddy length (Gosman and Ioannides, 1981). Each impact should be within a half diameter distance, and thus a more accurate time step is revaluated.

EROSION ASSESSMENTS

Erosion phenomenon depends on the physical properties of erodent, size and concentration, velocity and angle of impact as well as the physical properties of the target surface. Erosion rate is expressed as material removed (milligram) per mass of impacting particles (gram). Finnie (1960) attempted to develop the basic theoretical analysis on sand erosion, but the developments for erosion models used in turbomachinery began with the experiments of Grant and Tabakoff (1975). Their successful erosion model was based on 2024 aluminium alloy as a target and sand (quartz) as abrasive particles and implemented two mechanisms one predominant at low impact angles and the other at high impact angles as follows:

\[
\varepsilon = k_1 f(\beta_1) V_{p}^{2} \cos^2 \beta_1 (1 - R_t^2) + k_3 (V_{p} \sin \beta_1)^4
\]  

(6)

\[
f(\beta_1) = 1 + k_0 \left( k_2 \sin \left( \frac{\theta_0}{\beta_0} \beta_1 \right) \right), \quad k_0 = \begin{cases} 1 & \beta_1 \leq \beta_0 \\ 0 & \beta_1 > \beta_0 \end{cases}
\]

\(R_t\) is the tangential restitution factor. As the impeller is made from an aluminium based alloy, the angle of maximum erosion \(\beta_0 = 20\) deg and the material constants are: \(k_1 = 3.67 \times 10^{-6}, k_2 = 0.585, k_3 = 6 \times 10^{-12}\). Erosion rate (Eqt 6) depends on wall material, size and number of particles striking a
surface as well as velocity and direction of impact. As the local mass erosion values are calculated, they are cumulated on mesh faces and used to compute the equivalent erosion levels which define the erosion density.

**RESULTS AND DISCUSSION**

First, to illustrate the particle dynamics through the components of centrifugal fan, sand particles of small size (10 \(\mu\)m) and large size (100 \(\mu\)m) are tracked along their paths when operating at nominal point \(Q_N=303.8\) m\(^3\)/hr. For clarity only samples of 300 particles are presented and discussed. The eminent remark is that the small particles (Fig. 10) tend to follow closely the flow paths and are more affected by the drag force. On the other hand, the large ones (Fig. 11) deviate noticeably due to high inertia. Small particles are more sensitive to drag force and are strongly influenced by turbulence and secondary flows. The particles are driven by the large flow turning from the inlet plenum to the impeller where in first stage cause impacts from leading edge to mid of pressure side of the four full blades and thereafter keep colliding repeatedly over the pressure side until the trailing edge at velocities 20 – 35 m/s (Fig. 10). As revealed, the splitters are impacted from leading edge at high impact angle and similarly particles keep sliding over pressure side. Indeed, the blade geometry is responsible of the deflection of particle trajectories at higher curvature and particles are impacting and sliding over blade pressure side. Besides, impacts are unevenly distributed over the sixteen splitter blades, and many of small particles after crossing over the tip of full blades reach the splitter blades at mid section whereas others reach the trailing edge to induce many impacts. It should be noted that splitter blades are less impacted by small particles compared to full blades. At exit of impeller, small particles reach high velocities (Fig. 10) and by crossing the impeller/volute interface the flow in volute influences their paths as they travel close to the outer surface of volute. They travel at high velocities, about 50 m/s, from the tongue to the first half of volute whereas in the second half they reach 30 m/s and even less than 20 m/s at exit due to loss in momentum after several impacts. Particles colliding over the trailing edge of blade from pressure side exit at high velocities reaching 56.8 m/s. Large sand particles such as 100 micron, after being driven by the large flow turning in inlet plenum to the impeller and due to high inertia and centrifugation compared to drag force, deviate considerably from flow streamlines (Fig. 11) and follow ballistic trajectories. These particles after impacting full blades and some splitter blades bounce off in parabola trajectories and continue colliding several times over pressure side until trailing edge. Many particles after bouncing off pressure side cross over the tip and impact several time the shroud, while others after hitting the leading edge bounce off to impact the aft of pressure side. Other particles are seen to hit along the leading edge from pressure side and continue in ballistic trajectories to reach trailing edge. Figure 11 shows particle velocity through this centrifugal fan, which increases rapidly after flowing into the impeller and rises to maximum at impeller/volute interface, and then reduces significantly due to impacts with volute. Large particles are shown to impact the pressure side at velocities 15 - 30 m/s and the highest velocities are seen at trailing edge. Some of particles after hitting the pressure side bounce and reach and impact the suction side of opposite blade. Particles colliding over pressure side coalesce at trailing edge and enter the volute in sort of dense flux of particles of high velocities up to 70.2 m/s hitting straight the volute inducing extreme erosion. Impact velocities are extremely higher in volute compared to impeller and this why higher erosion rates are expected. On the other hand, small particles impact the first half of volute at high impact angles whereas in the second half particles collide and slide at near low angle of impact and subsequently the erosion rates are lesser. The second half of volute is impacted by large particles at high angles of impact, and also by numbers of particles impacting near optimum erosion angle and thus the erosion rates are expected to be high.

Trajectories of sand particles of different sizes (5 - 200 micron) and impacts are analyzed to investigate the subsequent erosion patterns at nominal point \(Q_N=303.8\) m\(^3\)/hr. Figure 12 shows samples of trajectories for different particle sizes, seeded randomly, which number and positions are conformed to the given concentration profile. For the clarity only samples of 300 particles are
presented and discussed. As particles are released at intake and before entering the impeller they have both axial and angular velocities components as with the fluid they rotate. Indeed, the impeller pressure surfaces do not interact with particles directly, because the density is extremely large compared to the fluid, so there is a phase difference between particle trajectories and fluid streamlines. As noticed large size particles (Fig. 12(a)) travel in ballistic trajectories, impact and bounce in a parabola shape over the pressure sides of blades, and thereafter coalesce at trailing edge to form a dense flux of particles which enter the volute at high velocities up to 70.8 m/s (Fig. 12(b)) and hit straight the volute to incur extreme erosion. In the other side, small size particles stick to the flow path after hitting the leading edge of blades. Many of these particles are seen to flow through the tip gap with leakage flow and induce erosion by colliding with the shroud back plate. The particle trajectories in the volute and discharge duct are quite different, particles concentrate on volute wall and impact several times, resulting in more spread of severe erosion. Through outlet duct, particles flow out and concentrate along the outer wall tangentially (Fig. 12(a)), and that means that the particles through volute discharge seldom impact the tongue. Particle velocity increases rapidly after flowing into the impeller and reach the maximum (Fig. 12(b)) and deviate at the entrance of volute, thereafter this velocity reduces sharply due to repeated impacts with volute wall. As noticed, the impact velocities and number of impacts are extremely high in the volute compared to the impeller and this why higher erosion rates are expected in the volute.

Figure 10: Sample of 300 particles trajectories of 10 μm coloured by velocity

Figure 11: Sample of 300 particles trajectories of 100 μm coloured by velocity

Figure 12: Sample of 300 particles trajectories: a) diameter size; b) velocities
The local erosion rates are evaluated considering the local impingement velocities and angles, for sand concentrations 10 and 50 mg/m³ when the fan operates at nominal point $Q_N = 303.8$ m³/hr and at maximum flow rate point $Q_M = 303.8$ m³/hr. Since there are high frequencies of impacts on the same mesh element face, erosion levels are better plotted in term of the equivalent erosion rates (kg/s/m²). The peculiar impact areas and large concentration of impacts occur more frequently on the paraxial area of the bend hub at entrance added to leading edge of full blades and along the junction with hub and cause large erosion regions as depicted in Fig. 13(a). Large particles induce high frequency of impacts over pressure surfaces from leading edge since they are prone to inertia forces. The lower part of blade is more impacted by mall size particles and sensitive to secondary flows. The leading edge is impacted near the normal but beyond at oblique directions whereas the aft region is impacted near the optimum erosion angle and subsequently erosion rates are extreme, as seen from Fig. 13(a). The local erosion rates also exhibit visible scatter of erosion rates along the hub of certain blades mainly by small size particles. The upper sections of blades are extremely eroded owing to centrifugation. Along the blade tip particles infiltrate through the gap and incur extreme erosion alongside blade tip, as seen from Fig. 13(a). The marked regions of extreme wear are clearer over the second half of pressure side mainly towards trailing edge. However, more erosion wear is visible over the four full blades and the tip, and these critical regions are anticipated to have high material removal. Other regions of high and moderate rates are seen over the shroud back plate (Fig. 13(b)) attributed to ballistic particles and due to small particles impinging at low angle of impact while keeping colliding therein several times. The main erosion patterns of shroud plate are visible along the leading edge from pressure side and spreading in large areas over the full blades, as seen from Fig. 13(b). Despite some impacts seen over the suction side of blades, erosion rates are insignificant. Operating conditions seem affecting erosion rates when comparing between Fig. 13 and Fig. 14. Indeed, the operation at maximum flow rate $Q_M$ results in higher flow velocities and subsequently higher particle velocities and impact velocities and subsequently high rates of erosion. As consequence the spread of erosion is more in regions such as the hub, aft of pressure side and blade tip, along hub junction and obviously over the shroud where intense erosion rates are visible and spreading more. The particle concentrations also worsen erosion developments, since more particles are involved which induce higher frequency of impacts and higher rates of erosion. This is clearly depicted by comparing Fig. 13 and Fig. 14 with Fig. 15 and Fig. 16.

**Figure 13**: Erosion rates (kg/s/m²), operating at nominal point $Q_N$ and sand concentration 10 mg/m³: a) impeller; b) shroud

![Erosion Rates](image13.png)
Particles travelling along the flow direction in volute reveal impacts with the volute wall directly after leaving the impeller, which is mainly revealed for the four full blades. This is precisely the cause of the wedge spotted distributions of erosion on the volute and the high erosion rates as depicted in Fig. 17. Besides, the particles concentrate on the volute wall and induce for more times...
and continue flowing along the discharge duct at low velocity. These are the reasons for the large range of high erosion rates spreading over the totality of volute wall. Furthermore, the junction of volute and the front are also impacted several times and exhibit erosion, but the region of the tongue is less eroded owing to reduced velocity and as it is not impacted frequently compared to outer volute wall. According to Fig. 17 and Fig. 18 the erosion patterns in the volute are more sensitive to operating condition since the flow velocities and their direction are extremely affected, and similarly the number of impacts increases at high concentration.

![Figure 17: Erosion rates (kg/s/m²) in volute, at nominal point Q_N and C=50 mg/m³](image1)

![Figure 18: Erosion rates (kg/s/m²) in volute, at maximum flow rate Q_M and C=50 mg/m³](image2)

It could be concluded that impact frequencies and high impact velocities are the main cause of severe erosion in this centrifugal fan. The regions with large impact frequencies and high impact velocities, namely the volute wall, aft of blade pressure side, blade tip and facing regions of shroud plate, have severe erosion wear. In addition, the hub at entrance bend is directly impacted by large number of particles but with low velocities. The outer wall of volute exhibits larger spread of erosion owing to high numbers of impact times. The spotted regions of extreme erosion are caused by the dense flux of particles of high velocity exiting the four full blades. Table 2 compares between maximum erosion rates at two operating conditions and particle concentrations. As revealed erosion rates of blades and volute increase sharply with particle concentration from 10 to 50 mg/m³ and subsequently the material removal results in a decline of the working lifetime.

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<th></th>
<th>C = 10 mg/m³</th>
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<th>C = 50 mg/m³</th>
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<tr>
<td></td>
<td>Q_N</td>
<td>Q_M</td>
<td>Q_N</td>
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<tr>
<td>Maximum erosion rate of blade and hub (kg/s/m²)</td>
<td>2.659x10⁻⁸</td>
<td>3.871x10⁻⁸</td>
<td>7.818x10⁻⁸</td>
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<tr>
<td>Maximum erosion rate of shroud plate (kg/s/m²)</td>
<td>4.462x10⁻⁸</td>
<td>8.818x10⁻⁸</td>
<td>8.546x10⁻⁸</td>
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<tr>
<td>Maximum erosion rate of volute (kg/s/m²)</td>
<td>5.469x10⁻⁸</td>
<td>1.356x10⁻⁷</td>
<td>2.288 x10⁻⁷</td>
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CONCLUSION

This Lagrangian tracking approach allowed predicting particle trajectories and erosion patterns through this centrifugal fan. The high impact frequencies and velocities are the main cause of serious erosion. Extreme erosion wear are visible at axial radial bend of the hub and blade junction and over the blade pressure side and tip of full blades, but lesser erosion occurs for the splitter blades. The suction side reveal insignificant erosion. Shroud erosion is extreme and concentrated alongside the blades. The volute depicts higher rates of erosion over the totality of outer wall. The wedge areas of erosion of higher rates are mainly attributed to dense flux of particles exiting full blades at high velocities. The underlined non-uniformities of erosion patterns could be associated with the inherent distortion of impeller flow and interaction with volute. Erosion behaviour is very sensitive to operating conditions and increases extremely at high flow rate and concentration and the critical regions would be severely eroded resulting in a rapid decline in working life. The present results present the necessary information to reshape the geometry of impeller and propose adequate coating to reduce the susceptibility to erosion.

REFERENCES


