

# Vibration Level Improvement of Id Fan in a Cement Plant Based On CFD Study of Incoming Dust Particles Streamline

<sup>1</sup>Prihadi Setyo Darmanto, <sup>2</sup>Arief Syahlan and <sup>2</sup>Alfi Amalia

<sup>1</sup>Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Indonesia;

<sup>2</sup>Indonesia Cement and Concrete Institute;

prihadisetyo@gmail.com; arief.syahlan@gmail.com; alfiamalia@yahoo.com

## ABSTRACT

This paper presents numerical study of aerosol flow inside of the induce draft (ID) fan inlet duct of a cement plant and the field observation of the proposed guide plate implementation as vibration reducer. Since ID fan sucks the flow from the outlet of cyclone separator, that is normally swirling flow, and the geometry of the duct tends to produce unbalance fine particles distribution over the duct cross section, the vibration of ID fan increases periodically due to unbalance built-up of the fine particles over fan blades surface. Numerical result shows that, at the ID fan inlet, the distribution of fine particles is unbalance. The ratio of particles concentration in the gas entering fan side and motor side of the ID fan is 1.4 to 1 which influences on the unbalance deposition of sticky particles over related blades surface. Using proper guide plate installed in the last duct elbow before entering to the fan, the ratio of unbalance fine particles concentration reduces to 1.05 to 1 and is kept up to the fan free side and motor side inlets. The proposed guide plate has also already installed in a cement plant ID fan duct and vibration characteristic was also observed during 4 months after tie-in period. The plant vibration observation shows that its level is practically unchanged and maintained at low level (around 2 mm/s at fan side and 0.5 mm/s at motor side) which is still lower than maximum limit (11 mm/s). This condition reduces significantly vibration level and eliminates practically plant stop due to over vibration of ID fan along last 4 months operation which was normally suffered every 1.5 months before implementation of this study.

**Keywords:** Particle Concentration, unbalance, ID fan blades, built-up.

## 1 Introduction

The operation of ID (induced draft) fan of a cement plant at lower than maximum setting of vibration level is a must in order to keep smoothly kiln operation. The increase of ID fan vibration level up to the maximum limit level causes stop of the whole kiln system operation. It is obviously important to maintain vibration level of ID fan at acceptable value. However the operation of ID fan is actually influenced by some factors such as impeller speed, gas temperature and flow rate, damper position, dust resistivity, up-stream duct geometry and construction, dust content and chemical composition in the gas etc [1,3-4]. These factors could eventually change vibration level during operation, especially the change of build-up rate and weight distribution over the blades surface. If maximum setting vibration level is reached, fan should be stopped and followed by cleaning of impeller's blade coating in order to decrease vibration level back to the allowable normal level for safe operating. In addition the increase of stop frequency of

ID fan for cleaning of the blades coating imposes on the following unexpected conditions such as mechanical disturbance of kiln lining, loss of production, fuel inefficiency, loss of financial gain opportunity as well as deceleration on reaching production target. In general, fan impeller shall be statically and dynamically balanced in accordance with AMCA Standard 20496 [2]. However, especially in cement industry which normally operates with dust laden in high temperature gas, the increase of vibration level of ID fan during operation is seemly unavoidable [4,5]. Furthermore, with the increase of cement demand, the capacity of a plant increases accordingly that implies on the greater demands of ID fan. These fans should be designed with ever increasing volume and static pressure requirements as well as be operated at high dust content and temperature of gas. It means, of course, ID fan will operate at high tip speeds which increases markedly the problem of build-up on the impeller. In many plants, typically, this build-up is extremely hard, layered and brick like that imposes fan rotor unbalance and vibration. Many plants shut down frequently to remove this build-up from the fan impeller in order to reduce vibration level. This, of course, is very costly as it reduces significantly plant availability and increases maintenance cost.

Many efforts on the reducing the rate of build-up have been reported such as changing impeller geometry, reducing impact velocity of the dust as it strikes fan rotor, reducing gas temperature, using water spray directly onto fan rotor, and over sizing rotor shaft prior to reducing sensitivity of unbalance[4-6].

However, according to our understanding, fewer papers that propose solution of reducing the rate of ID fan vibration by improving stream lines of the gas flow introducing to the fan. It is the aim to the paper to propose a simple solution of reducing unbalance deposition of build-up onto the impeller blades surface of ID fan based on the result of CFD study of the gas and solid particles flow characteristic modification before entering to the ID fan.

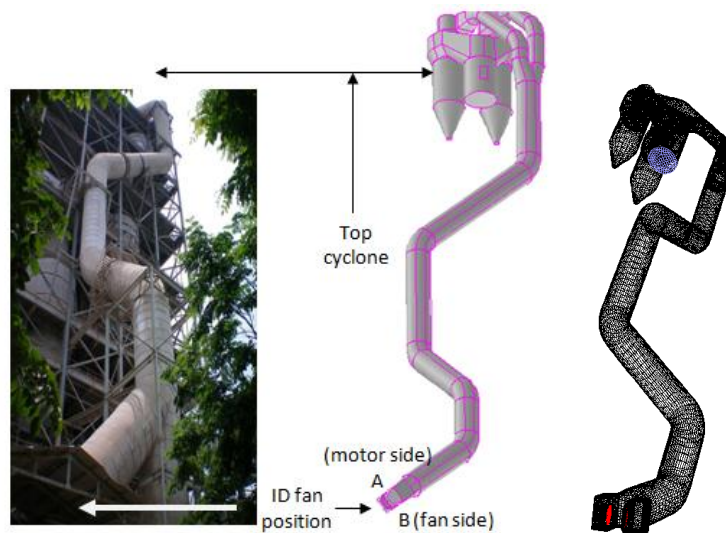
## **2 Clinker Production Process, Methodology and Case Study Data**

The production of Portland cement requires a big amount of thermal energy. The effective requirement of thermal energy is approximately 3.2-6 MJ/kg of clinker depending on the process [2]. In the dry process, cement plant requires multi-stages cyclone separators which are connected one to each other with riser duct to form pre-heater. Pre-heater is designed for pre-heating of raw materials using hot gas exhausted from kiln or calciner before entering to kiln. The gas is also used as transport media of raw materials through pre-heater. The exhaust gas and materials which form aerosol is normally drawn by induced draft fan (ID fan). The ID fan normally used in cement industries is double inlet type due to the big volume of exhaust gas to be drawn. Due to the imperfectness of top cyclone pre-heater as kiln feed materials separating device and duct that connects this top cyclones to the ID fan, the flow of hot non separated fine materials and gas (aerosol) towards ID fan distributes asymmetrically through the duct. These hot fine materials are dominated by lime stone where its property at high temperature becomes sticky. Depending on the flow characteristics of the aerosol entering ID fan, the concentration of fine materials is normally not uniform which causes asymmetry deposition on the impeller blades surface. The non-uniform deposition of fine materials on the fan blades produces slowly vibration of the whole ID fan impeller. The non-uniform deposition grows with the elapse time and finally the vibration reaches the maximum limit value and ID fan will stop automatically. Impeller unbalance that can be created during operation produces a high level of vibration which possibly damages fan bearings or the other components. Operating a fan within the range of its component natural frequencies can cause a high level

of vibration in the impellers, causing serious damage. ID fan failure can cause expensive unscheduled plant shutdowns. In a cement plant especially, ID fan trip causes stop of clinker production and blades should normally be cleaned before restarted. The frequency of ID fan stop due to over vibration limit depends on fine materials concentration, inlet duct construction, flow characteristic of aerosol leaving top cyclones and sticky fine materials deposition rate. Especially the flow characteristic of cyclone exit gas, Wang et. al.[11] shows that the flow is still swirling or circulating up to the distance of several diameters of outlet cyclone duct. This swirling flow causes particles are distributed asymmetrically through duct, higher concentration near the duct wall and lower in the center. Particles deposition mechanism from turbulent flow has already discussed widely [6]. With the variation of geometry of the duct especially the existence of some elbows since aerosol exiting cyclone separator to the suction sides of the ID fan, both the swirling flow and particles concentration distribution are changed.

The methodology applied in the present study is numerical observation of aerosol flow characteristic and particles concentration distribution through the entering duct of the ID fan in order to understand well the root cause of unbalance particles deposition on the impeller blades that cause the increase of vibration level. Implementation of proposed guide plate at the last elbow of the duct for improving uniformity of particles concentration before entering ID fan suction sides was also observed by CFD method as well as vibration level measurement before and after guide plate installation.

The construction of hot gas duct that connects top cyclones and ID fan in a cement plant being studied as the case study is presented in Figure 1as well as its isometric drawing.



**Figure 1 Case study construction of hot gas duct as well as its related isometric drawing and control volume grids of the CFD modeling.**

Based on the heat and mass balance calculation at production capacity of around 8000 ton per day (TPD) clinker, the following data is related to the operational of top cyclone and ID fan, such as:

- Kiln Capacity : 8097.9 TPD
- Gas flow rate from 2-nd stage cyclone : 88.48 kg/s
- Dust flow rate from 2-nd stage cyclone : 12.28 kg/s
- *Fresh feed* flow rate through the top cyclones : 79.1 kg/s
- Gas temperature entering to the cyclones : 550 °C

Particle size distribution of materials of the kiln feed is gathering from normal condition of dry process cement plant operation. With this operation conditions, the example of vibration level measurement of the fan's bearings is shown in Figure 2. This figure shows that the level of fan vibration is in the range of 3.4 to 8.45 mm/s and tends normally to rise with the time elapse when the unbalance build up on the impeller's surface of its two inlets (motor side (A) and fan side (B)) increases. So the increasing of vibration level periodically is due to some following reasons such as asymmetries of aerosols entering to the fan and both non uniformity of dust concentration inside of the duct as well as non-uniformity of buildup formed on the blades and impeller wearing rate.

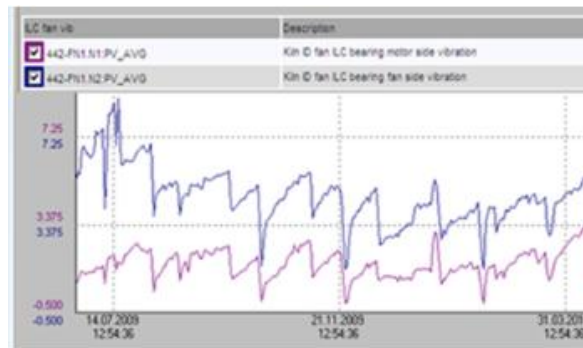


Figure 2 Vibration level measurement results on the motor and fan sides bearings in [mm/s]

### 3 CFD modeling and Simulation

CFD software solves the governing equations of continuity, momentum and energy over each of the control volume formed by the computational grid as presented in Figure 1[6-9]. After integrating these equations over the control volume, velocity and pressure coupling are resolved via the Semi-Implicit-Pressure-Linked-Equation (SIMPLE) algorithm. Turbulence closure was provided by the k- $\omega$  turbulence model with standard coefficients, although other turbulence models are also available. The turbulent boundary conditions for momentum and heat transfer in the near wall region followed the logarithmic law of the near wall. Conduction in the cyclone and duct wall was accounted for using a conjugate heat transfer model. The technical drawing of the existing duct and proposed modification by implementing guide plate in the last elbow before gas entering to the fan is presented in Figure 3.

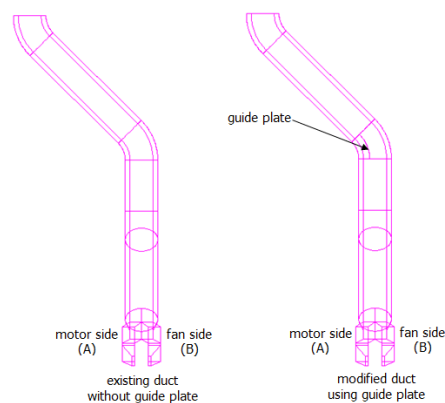
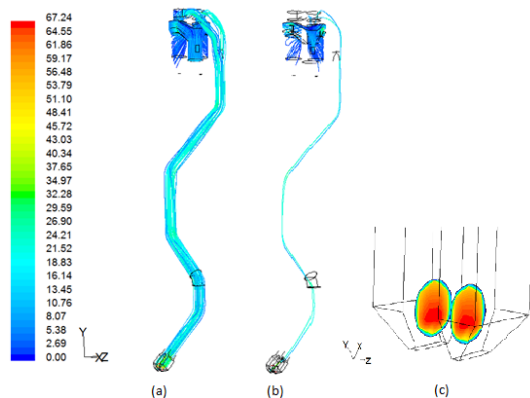


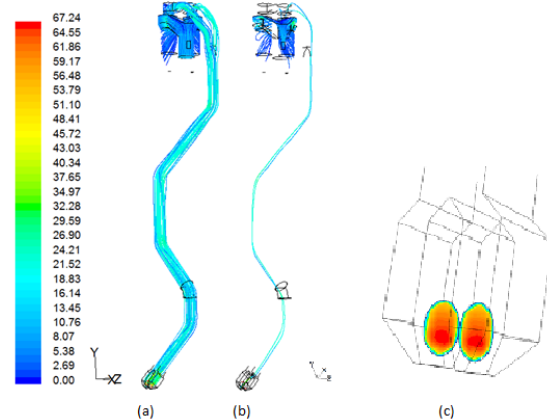
Figure 3 Existing and proposed modification of duct.

The evaluation of solid particles mass flow rate entering motor side and fan side of the impeller is based on the numerical results of the CFD mass balances as well as the evaluation of system pressure drop and main flow velocities that based on the result of pressure and velocities distributions along the control volume. The pressure drop of the system is the difference pressure between inlet and outlet gas through the control volume [10]. For the existing condition, the CFD simulation results of velocity distribution of gas flow through duct from top cyclones to the motor side and fan side cross section duct outlets, single particle tracking velocity and velocity contour of the gas at duct outlets cross-section are presenting in Figure 4. This results show unbalance flows of both gas as well as particles since exiting of the top cyclones characterized by gradation of velocity along duct cross section especially before entering and after leaving the elbows. This gas and particles velocity distribution continues up to the duct outlets mentioned by the dissimilar velocity contour through the motor side and fan side cross section duct outlets as shown in Figure 4, (c). This velocity variation and unbalance flow of particles entering to the fan's impeller which causes unbalance build-up formed on the impeller blades surface are suggested as the root cause of the periodically vibration of the impeller. The ratio of particles concentration in the gas entering fan side and motor side of the ID fan is 1.4 to 1. Based on this results, the idea on the laminarization of flow through the duct in order to balance the mass flow rate of the particles entering to motor and fan sides of the ID fan. This idea could be realized by implementing guide plate in the last elbow before the gas entering to the fan impeller as shown in Figure 3.

The position of guide plate was varied during simulation process. The optimum results based on the criteria of minimum pressure drop and minimum difference of solid mass flow rate through between motor side and fan side cross section duct outlets were obtained when the position of guide plate is one third diameter from the small radii of the elbow as mentioned in Figure 3. The results of the CFD simulation for the case using guide plate implemented in the last elbow before entering section of the fan are presented in **Error! Reference source not found..**



**Figure 4 Gas velocity distribution (a), particles velocity tracking (b) and velocity contour at motor side and fan side cross-section duct outlets (c) in [m/s].**



**Figure 5 Gas velocity distribution (a), particles velocity tracking (b) and velocity contour at motor side and fan side cross-section duct outlets (c) in [m/s].**

For the proposed modification by implementing guide plate in the last elbow before the gas entering to the fan, the CFD simulation results of velocity distribution of the gas flow through duct from top cyclones

to the motor side and fan side cross section duct outlets, particles tracking velocity and velocity contour of the gas at duct outlets cross-section are shown in Figure 5. This figure shows less variation of flow velocity of both gas as well as particles since leaving for the last second elbow before entering to the fan and more uniform flow velocity characterized by similar contour of velocity at the cross section entering the fan. The ratio of fine solid particles concentration between fan side and motor side before entering to the fan reduces to 1.05 to 1. This more uniform gas and particles velocity could be seen as the better signal on the improvement of buildup formation that expected to be more uniform. Finally this better condition could be expected on reducing significantly vibration level of the fan's impeller.

#### 4 Implementation of Proposed Guide Plate

The above mention idea on flow laminarization by implementing guide plate in the last elbow before entering to the fan was finally executed. The detail drawing of the guide plate that was installed in the plant is presented in Figure 5. With the condition of operating production data and parameters, the level of vibration of this ID fan was measured during certain period. The comparison results of the vibration level between the conditions before implementation of the guide plate (existing condition) and after guide plate installation is shown in Figure 6. It should be noted from this figure that significant reduction of vibration level was obtained. The vibration level of the ID fan bearings after implementation of guide plate is dropped to in order of less than 3.7 (mm/s) that is far from limit value (11 mm/s). For the motor side bearing, it seems that the level of vibration during 4 months of monitoring is practically zero, while the fan side is still less than 3.7 mm/s which are around of 2 mm/s in average value. It means that the implementation of guide plate can reduce significantly the level of fan vibration as well as reduces the plant stop due to this reason. In the other word, this simple effort could improve significantly production reliability, productivity as well as plant availability.

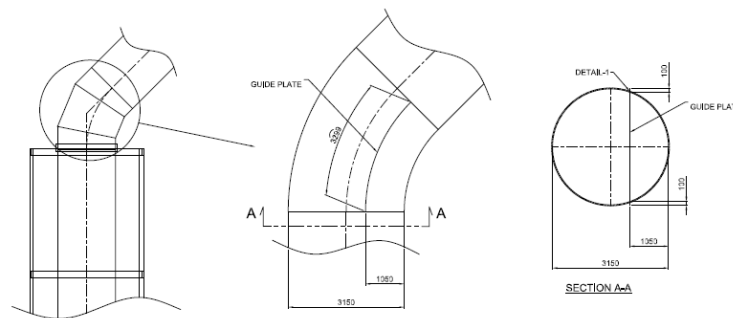


Figure 5 Detail drawing of the guide plate installed in the plant (unit in mm).



Figure 6 Vibration level measurement results on the motor and fan sides bearings before and after guide plate installation, in [mm/s]



## 5 Conclusion

This paper presents the effort on the minimizing operational disturbance of cement plant due to the high level vibration of ID fan. In this case, vibration level increases periodically due to the unbalance build up formed on the impeller's blades surface. This unbalance build up formation is suggested due to the unbalance mass flow rate of solid particles entering to the fan between motor side and fan side. This unbalance flow is the main root cause of the increasing vibration level and close related to the duct geometries at the entering fan section. Using CFD method, the existing flow characteristic was studied and analyzed. Simple propose flow laminarization to increase flow uniformity before entering to the fan was proposed by guide plate implementation. Based on the CFD simulation of the flow characteristic, optimization of guide plate position and dimension could be conducted before real installation in the plant. Installation of this idea in the real plant was already executed and 4 months vibration level monitoring was also reported. The results show that not only the vibration level on both fan and motor side bearings decreased significantly far away from the limit value, but also the reliability and productivity of the plant increased due to the reduction of plant trip disturbances caused by over limit vibration level of the ID fan.

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