Marko Ristic
Research assistant
Institute Gosa

Radica Prokic-Cvetkovic
Full Professor
University of Belgrade
Faculty of Mechanical Engineering

Mirko Kozic
Senior Research Associate
University of Belgrade
Military Technical Institute

Slavica Ristic
Principal Research Fellow
Institute Gosa

Mirko Pavisic
Associate Professor
University of Belgrade
Faculty of Mechanical Engineering

Numerical Simulation of Multiphase Flow Around Suction Plates of Ventilation Mill in the Function of Extending its Remaning Working Life

This paper presents results of the analyses obtained by numerical simulation for the possibilities of increasing the wear resistance of the ventilation mill working parts for coal grinding in the Kostolac B power plant. The possibilities for modification are based on 3D numerical simulation of multiphase flow of ventilation mill. Mineral materials during the process of milling in the ventilation mill cause strong wear of the suction plates. The multiphase flow simulations are performed in order to obtain the mineral materials paths and velocity vectors. The mixture model of the Euler–Euler approach is used. The results obtained in the numerical simulation serve for the selection of an optimal redesign of the suction plates. The application of this approach can reduce the number of possible repairs and extends the period between them, resulting in significant economic effects.

Keywords: *ventilation mill, wear, suction plate, CFD, working life*

1. INTRODUCTION

Wear is one of main failure mechanism materials and equipment and exists in many industrial fields, such as metallurgy, mining industries, energy sources and construction industry. Hardfacing coatings have been used widely in these industries because of the coatings' excellence on abrasive wear resistance [1-3]. Wear rate for the hard coatings is controlled by several factors such as the size and distribution of the carbide particles, hardness of the carbide particles relative to the abrasive, properties of the matrix and its volume fraction and the coating process, which determines the coating characteristics such as the phases, density and micro–hardness [2-4].

The main aim of this paper is to increase the wear resistance of the suction plates of ventilation mill for coal grinding in power plants in order to define optimal technology of revitalization by hardfacing. Working parts of the device during exploitation are dominantly exposed to wear, whose consequences are the reduction in mill production capacity and its ventilatory effects compared to the projected value, as well as frequent delays due to parts replacements, which significantly affects the productivity, economy and energy-efficiency of the system. [2-4].

Multidisciplinary research of ventilation mills of thermal power plants includes a variety of theoretical, numerical, empirical and experimental methods of flow research. [6-10]

The literature shows the worldwide usage of numerical methods for different applications, simulation of the flow in complex industrial devices, plants, mixture channels, burners and combustion, as presented in papers [1, 2, 4-11]. Many numerical studies have been conducted for simple models or parts in thermal power plants, but authors didn't find the numerical simulation of the multiphase flow in the whole, real ventilation mill.

In this paper, a numerical simulation method is used to investigate the complex, multiphase flow in the ventilation mills in thermo power plant Kostolac B in Serbia, by CFD software package ANSYS FLUENT. Previous research in this ventilation mill for mill impact plates redesigning, confirmed numerical simulation as a good tool for reducing the number of experiments and for a more precise analysis of conditions for implementing appropriate hardfacing technology. The experiment has been continued in order to examine other parts of the mill exposed to the greatest wear. Due to the high velocity of mineral particles, pronounced wear of the grinding wheel elements and mill walls, there occurs decreasing of the time period between two repairs and their lifespan. The particle interaction with the surface of suction plates in a two-phase gas–solid particle flow is analyzed in this paper. Critical locations, exposed to the most intense wear were taken into consideration for revitalization, and were determined based on the results of the flow nume–rical simulation; vectors of the velocity and distribution of particles in the ventilation mill [1-3, 6–12].

Revitalization represents a unique process, and that is the reason why in practice there are no standard procedures for defining and applying the most optimal technology of reparation by hardfacing, or the assessment of remaining life of repaired components. Numerical simulation is used to achieve better uderstanding of the behaviour of the mixture (coil and other mineral particles); their attack angle on the working part, can be used for determination of a dominant wear mechanism.

Received: September 2014, Accepted: June 2015
Correspondence to: Marko Ristic,
Research assisstant, Institute Gosa,
Milana Rakica 35, Belgrade, Serbia
E-mail: marko.ristic@institutgosa.rs
doi:10.5937/fmet1602154R

2. VENTILATION MILL AND NUMERICAL SIMULATION

Ventilation mill is a very important system and its operation has a significant influence on the level of power plant efficiency. In ventilation mill there is predominantly abrasive wear and erosion at elevated temperatures. In the Kostolac B power plant, coal is ground in the ventilation mills. The system includes eight ventilation mills of EVT N 270.45 type, with a nominal capacity of 76 t/h of coal. Mill–duct system in the Kostolac B power plant is shown in the Fig. 1. The technical characteristics of the ventilation mill are as described in [1, 2, 11].

Figure 1. Ventilation mill

Some reconstructions of the system were performed in order to increase the ventilation effect, mill capacity and optimize the distribution of coal powder and combustion process. Tests performed after the reconstructions have shown that the distribution 70:30 of coal powder is not optimal for combustion process. The possibility of additional reconstruction is considered, in this case the problem of wear reducing of the suction plates. [11-13] which are shown on Fig. 2.

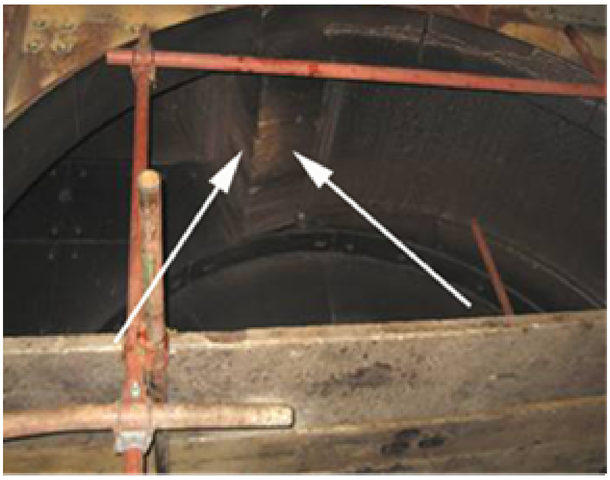

Figure 2. Position of suction plates in the working well of ventilation mill

The numerical simulation of the multiphase flow presents the first step in identifying ways for revitalization of the mill parts exposed to wear. By analyzing the velocity vector, distribution of flow mixtures, pressure on working parts, it is possible to locate the critical locations in the construction of the ventilation mill. The character of multiphase flow in the ventilation mill TE-Kostolac B is mixed by components of the air, coal dust, sand and other minerals particles, which is directly related to the ventilation efficiency of the mill, as well as to the wear process of vital parts. The changes in quality and flow of the mixture parameters directly affect changes in the combustion chamber and boiler plant. In addition to the efficiency of these changes, they are directly reflected in the emission of the combustion products.

The ANSYS FLUENT software package based on the finite volume method is used for numerical flow simulations. The Reynolds averaged Navier–Stokes partial differential equations of the turbulent multiphase flow in the mill are solved. A solution of the dispersed gas–solid flow is obtained, where granular phases are pulverized lignite, sand and other mineral particles. The coal moisture is introduced as the gas phase [1-6]. Because of the memory limitations and convergence behavior, on one side and geometry and flow complexity, on the other side, the mixture model of the Euler–Euler approach is chosen. The mixture model is a simplified multiphase model that can be used in modeling flows, where the phases move at different velocities using the concept of slip velocities. It is applicable to very low loading and intermediate one for the Stokes number less than 1. The continuity, momentum and energy equations for the mixture, the volume fraction equations for each secondary phase, and algebraic expressions for the relative velocities are solved in this model. In the considered multiphase flow the loading is very low, meaning that the gas phase influences the solid particles by turbulence and drag, but the particles have no influence on the gas carrier. The mixture model is as good as full Eulerian models in the cases where coupling between the phases is strong, or when the interphase laws are unknown. Also, computational expenses are very high for the Eulerian model due to a large number of nonlinear highly coupled transport equations.

The first step in preparation for numerical simulation is geometrical modeling of the mill obtained from the several part drawings. The numerical modeling procedure of the multiphase flow in the ventilation mill is made up of two steps. The first step is geometry preparing and mesh generating. An unstructured tetrahedral grid is generated by consisting of 2,996,772 volume and 706,444 surface elements. Geometric model of the ventilation mill with air mixture channel is shown in Fig. 3 and in Fig. 4 (arrows indicate the location of suction plates).

The mixture of the hot recirculation gases, pulverized coal and sand particles enters the mill inlet. Necessary data for numerical simulation were measured on ventilation mill and collected from data of maintenance. The volume flow rate of the gases is about 298,000 m3/h, whereas the mass flow rate of the solid phases is in the order of 60 t/h, i.e. 16.7 kg/s. Volume fractions of coal and sand are 5.91 • 10− 5 and 1.93 • 10− 5, respectively. If the influence of turbulence is obtained through the mixture k–ε turbulence model that is the first extension of the single-phase k–ε model, and can be applied in the cases when phases separate. The lignite powder is modelled as a mono dispersed granular secondary phase, with a particle diameter equalling 150 µm. The particle diameter of sand is taken to be 300, 800, 1500 µm. This paper considers the results with sands particles 1500µm. The sizes of erodent particles in this case have increased effect on the erosion rate. The particle weight and drag are accounted. The standard no-slip boundary condition is applied at all walls, including the mill impeller that rotates within 495 rpm. The adiabatic thermal boundary condition is applied, too. At all exits, the value of the static pressure is defined. The velocity at the mill entry is defined in such a way that the volume flow rate of the recirculation gases is satisfied.

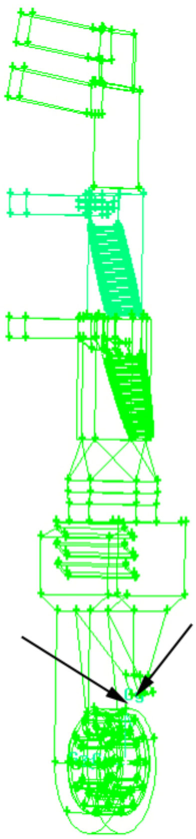

Figure 3. The geometric model of the ventilation mill with duct and channels to the entrance at the burner

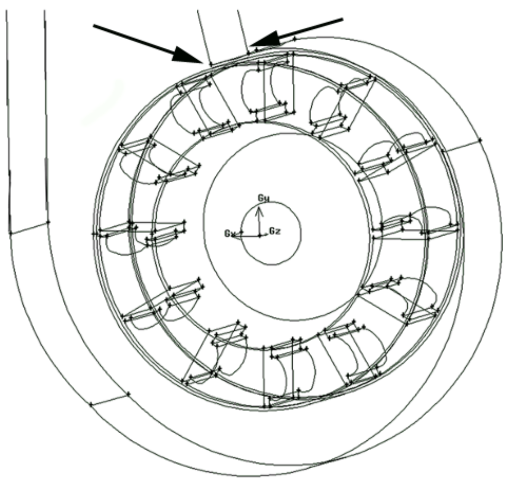

Figure 4. Detail of the geometric model the ventilation mill (arrows indicated positions of suction plates)

In numerical simulation the solution is obtained if the mixture of the recirculation gases, pulverized coal and sand entered the ventilation mill. Second type of restriction is a very complex geometry which includes the impeller mill, mill housing, and a large number of close-packed blinds. The results show the distribution of velocity vectors; volume fraction of the granular phases, turbulences and particle paths of the granular phases in the mill; attention is focused on results related to the gas mixture and sand. The numerical simulation of the flow shows that the highest turbulence occurs in the transition region, from the exit of the mill and duct, in the areas of suction plates (location is shown by arrows Fig. 3 and Fig 4.).

Due to the process of grinding wheel rotation, the velocity and direction of the mineral and sand particles, acting on the suction plates, especially on their front surfaces, are of great importance because of the pronounced wear at these places. Absolute velocity vectors of the mixture on the exit of the ventilation mill at the beginning of the duct, near suction plates, are detaly shown in detail in Fig 5. (area of suction plates is indicated by arrows). It is shown that due to the ventilation effect of the mill, part of the mixtures from the channels is drawn back into the mill, which causes strong turbulence. The highest velocity is about 140 m/s in the area where mixture goes out from the mill into the area of the suction plates.

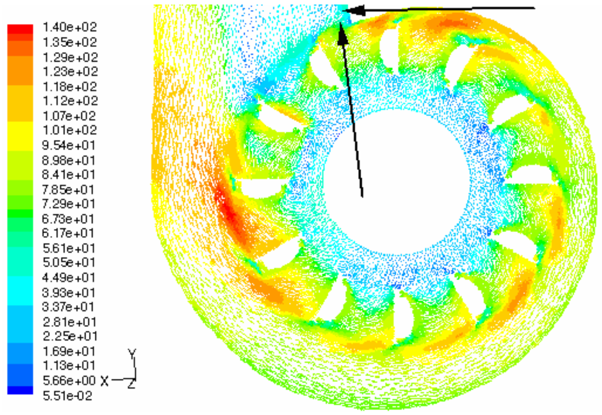

Fig. 5. Velocity vectors of the mixture on the exit from the ventilation mill, in place near suction plates and on the start of duct

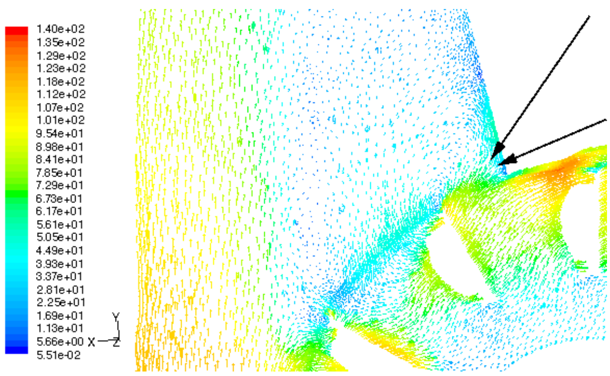

Fig. 6. Detail velocity vectors of the mixture on the exit from the ventilation mill, in place near suction plates and on the start of duct (area of suction plates is shown by arrows)

Sand particles are most abrasive, and therefore, velocity of sand particles are especially investigated. Figure 7. shows absolute velocity vectors of sand particles along the walls of the mill, and in the area of suction plates. Based on the scale on the left side, it can be seen that the intensity of the velocity is in the range of about 77 m/s up to 127 m/s. The multiphase flow of hot recirculation gases, pulverized coal and sand particles, on the exit of the ventilation mill, in the area of suction plates, have a very small angle to the surface of suction plates. The maximum velocity magnitude of sand particles is about 127 m/s, which causes damages dominantly on the suction plate's front surfaces. Analysis of the velocity vectors, flow angles of the mixture, sand and mineral materials indicates dominant erosive wear of suction plate. The process of erosion refers to a series of particles of mineral and sands striking and rebounding from the surface of the suction plates. Ductile materials have a maximum erosion rate [20], at low angles of incidence (typically 15° to 30°), which is dominant in this case.

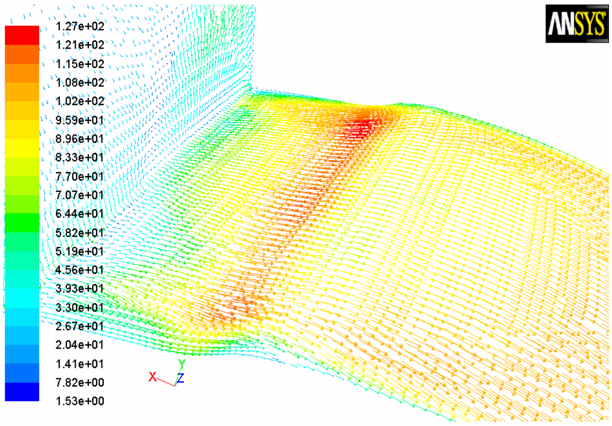

Fig. 7. Absolute velocity vectors of the particles of sands near the walls and area of suction plates of mill

Sand particles are most abrasive, and therefore the velocity of sand particles is especially investigated. Figure 7. shows absolute velocity vectors of sand particles along the walls of the mill, and in the area of the suction plates. Based on the scale on the left side, it can be seen that the intensity of the velocity is in the range of about 77 m/s up to 127 m/s. The multiphase flow of hot recirculation gases, pulverized coal and sand particles, on the exit of ventilation mill, in the area of suction plates, have a very small angle to the surface of the suction plates. The maximum velocity magnitude of the sand particles that is about 127 m/s, which causes damages of the dominantly on suction plate's front surfaces. The analysis of the velocity vectors, flow angles of the mixture, sand and mineral materials indicates dominant erosive wear of the suction plate. The process of erosion refers to a series of particles of mineral and sands striking and rebounding from the surface of suction plates. Ductile materials have a maximum erosion rate [20], at low angles of incidence (typically 15° to 30°), which is dominant in this case.

3. CONCLUSION

The numerical simulations of the multiphase flow are presented for a ventilation mill in the Kostolac B power plant. The results obtained by the numerical simulation clearly show that the CFD methods done in ANSYSS FLUENT provide detailed analyses of flow in ventilation mill.

The results obtained in the simulations are using in determination of locations, which is most exposed to wear, due to sand, coal and other mineral particles movement. The paper presents the results concerning the velocity vectors of the gas mixture and the sand particles in the mill. The maximum velocity magnitude of sand particles is 77 m/s up to 127 m/s. One of the most exposed parts to wear is the suction plates. The numerical results of the velocity vector magnitude of the sand, coal and other particles distributions in the ventilation mill walls correspond to damages due to wear on side walls and the suction plate's surface. The distribution of the gas mixture and the gas mixture average velocity, in the area of suction plates, obtained by numerical simulation are well matching with the results obtained by measurement.

Based on the numerical simulation results and experimental tests of the modal testing, the selection of critical area, optimal hardfacing technologies and filler materials for suction plate's revitalization were carried out.

The application of this approach can reduce the number of possible repairs and extends the period between them and give significant economic effects. The experimental tests of mill wearing parts in real exploitation conditions show that this approach can give good results. Research results are applied in the thermal power plant of Kostolac B and can be used for other parts in facilities and in similar facilities.

ACKNOWLEDGMENT

This paper is the result of research within the project TR 34028, which is financially supported by Ministry of Education, Science and Technological Development of Serbia, Messer Tehnogas and PD TE – KO Kostolac.

REFERENCES

[1] Kozić M, Ristić S, Puharić M, Katavić B, Prvulović M, *Comparison of Numerical and Experimental Results for Multiphase Flow in Duct System of Thermal Power Plant*, Scientific Technical Review, Vol. 60, pp. 39-47, 2010.

[2] Mirko Kozic, Slavica Ristic, Boris Katavic, Mirjana Puharic, *Redesign of impact plates of ventilation mill based on 3D numerical simulation of multiphase flow around a grinding wheel*, Fuel Processing Technology, FUPROC-03583,No of Pages 14, 2012.

[3] B. Perković, A. Mazurkijevič, V. Tarasek, Lj. Stević, Reconstruction, and realization of the projected modernization of power block B2 in the TE Kostolac, Termotehnika 1, pp.57–81, 2004.

[4] M. Kozić, S. Ristić, M. Puharić, B. Katavić, M. Prvulović, *Comparison of numerical and experimental results for multiphase flow in duct system of thermal power plan*t, Scientific Technical Review, Vol. 60, pp.39–47, 2010.

[5] K.V. Shah, R. Vuthaluru, H.B. Vuthaluru, *CFD based investigations into optimization of coal pulverize performance: effect of classifier vane settings*, Fuel Processing TechnologyVol.90, pp. 1135–1141, 2009.

[6] Kamalesh S. Bhambare, Zhanhua Ma, Lu. *Pisi, CFD modeling of MPS coal mill with moisture evaporation*, Fuel Processing Technology Vol. 91, pp 566–571, 2010.

[7] H. Ashrafizadeh, F. Ashrafizadeh, *A numerical 3D simulation for prediction of wear caused by solid particle impact*, Available online 22 December 2011, Wear, http:// dx.doi.org/10.1016/j.wear. 2011.12.003 Wear 2011.

[8] M Kozić, S Ristić, M Puharić, B Katavić, M. Kutin, *Numerical Visualization of Multiphase Flow in Ventilation Mill and Mixing Duct,* PSFVIP-8: The 8th Pacific Symposium on Flow Visualization and Image Processing, Moscow, Russia, August 21st-25th, Vol. 60, No 3-4, 2010, pp. 39-47,2011.

[9] Chao Liu, Dongxiang Jiang , Fulei Chu, Jingming Chen, *Crack cause analysis of pulverizing wheel in fan mill of 600 MW steam turbine unit*, Engineering Failure Analysis, vol. 42, No. 2, , pp. 60-73, 2014.

[10] A. Alil, B. Katavić, M. Ristić, D. Jovanović, M. Prokolab, S. Budimir, M. Kočić, *Structural and mechanical properties of different hard welded coatings for impact plate for ventilation mill*, Welding and Material Testing 3, pp.7–11 (ISSN 1453-0392), 2011.

[11] Šolar M., Bregant M., *Filler materials and application for repair welding*, Welding and Welded Structures, vol. 51, No 2, pp. 71-77, 2006.

[12] Seong-Hun C., Chang K.K., Kvangjun E., Sunghak L., Jae-Young J. and Sangho A., *Correlation of Microstructure with the Wear Resistance and Fracture Toughness of Hardfacing Alloys Reinforced with Complex Carbides,* Metallurgical and Materials Transactions, vol. 31 A, No 12, pp. 3041-3052, 2000.

[13] B. He, L. Zhu, J. Wang, S. Liu, B. Liu, Y. Cui, L. Wang, G. Wei, *Computational fluid dynamics based retrofits to reheater panel overheating of no. 3 boiler of Dagang power plant*, Computers & Fluids vol. 36, pp. 435–444, 2007.

[14] Thermo investigation and analysis of boiler plant blocks B1 and B2 in Kostolac TE, PD Ltd. Production–technical sector, (internal study), 2014.

НУМЕРИЧКА СИМУЛАЦИЈА МУЛТИ–ФАЗНОГ СТРУЈАЊА ОКО УСИСНИХ ПЛОЧА ВЕНТИЛАЦИОНОГ МЛИНА У ФУНКЦИЈИ ПРОДУЖЕТКА ПРЕОСТАЛОГ РАДНОГ ВЕКА

Марко Ристић, Радица Прокић-Цветковић, Мирко Козић, Славица Ристић, Мирко Павишић

Овај рад преставља могућност коришћења резлтата нумеричких симулација, за смањење хабања радних делова вентилационог млина за млевење угља у термоелектрани Костолац Б. Могућност ревитали–зације усисних плоча вентилационог млина је заснован на 3D нумеричкој симулацији мултифазног струјања у вентилационом млину. Чврсте честице смеше угаљ, минералне материје, песак током процеса млевења изазивају велико хабање усисних плоча. Применом софтверског пакета ANSYS FLUENT 12, добиће се детаљнији приказ мулти–фазног струјања и брзине мешавине која омогућује да се на основу интензитета и смера брзине, прециз–није одреде критичне зоне у којима ће се појавити оштећења код усисних плоча вентилационог млина. Коришћен је Euler–Euler модел мешавине. Резултати добијени помоћу нумеричке симулације користиће се за избор оптималне технологије ревитализације усисних плоча вентилационог млина. Применом овог приступа решавања проблема смањио би се број могућих интервентних поправки и продужио би се период између неопходних комплетних ремонта постројења, чиме би се остварили значајни економски ефекти и уједно повећала енергетска ефикасност термоенергетских агрегата.