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COMPARING TURBULENCE MODELS FOR GAS-PARTICLE MIXTURE PNEUMATIC CONVEYING

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Abstract: *The system of transport tertiary air in cement kiln installation is one of the elements, which has the very large influence on production processing. This paper analyses numerical calculation in the installation for tertiary air in a cement plant. The operation condition of the installation is to ensure transport of gas with the smallest number of particles. By comparing several turbulence models used for calculation gas phase motion and Lagrangian model for discrete phase one can find an optimal solution. The particle trajectories depend on velocity field in researched models. For analyzed examples, the same pressure drop between inlet and outlet to the tertiary air duct were set.*

Keywords: Pneumatic conveying, Turbulence models, Two-phase flow, CFD.

1. Introduction

The purpose of the tertiary air duct of kiln installation is to supply stream of hot gas with a minimum number of particles carried away from the kiln head (Lain et al., 2011). For optimization of the kiln, it is necessary to understand the detailed processes occurring in the installation. The specific requirements of process on design stage the burner system is to provide a burner design that will deliver efficient and reliable combustion (Lederer, 1996). Yet, extensive use of this form of transportation may bring about some problems that need to be eliminated. During pneumatic conveying we can observe uncontrolled particles segregation (Akili et al., 2001). These phenomenon influenced at flow direction changed by gravity and centrifugal force. As an effect, it forms, so called, the ‘rope’ of particles inside the gas stream, which distorts the conveying process and conducts to the premature erosion of the system elements (Wydrych, 2010). There are many references, on both theoretical and experimental research on homogeneous fluid flow through a single bend, especially focusing on energy losses (Grabavic et al., 1995, Hu et al., 2006).

2. Methods

In this work, the object of analysis is to study involving optimization of the design of the installation for supply hot gasses from the clinker cooler section to decarbonizator, where low-calorific fuel is burned (Saidura et al., 2011). The system of tertiary air pipe is designed as an element of the cement kiln installation (Fidaros et al., 2007). The problem to solve is separation particles from a gas, to reduce the deposition of particles in a horizontal channel (Levy et al., 1998).

In work (Borsuk et al., 2016) one alternative design was presented. Fig. 1 presents a general view of the rotary kiln. An integral part of this installation is a connection between kiln head and precalciner. The inlet to this installation is located at the outflow from clinker cooler. This work presents calculations results applied to the determination of construction of pneumatic installations for tertiary air. Researches were made for several turbulence models.

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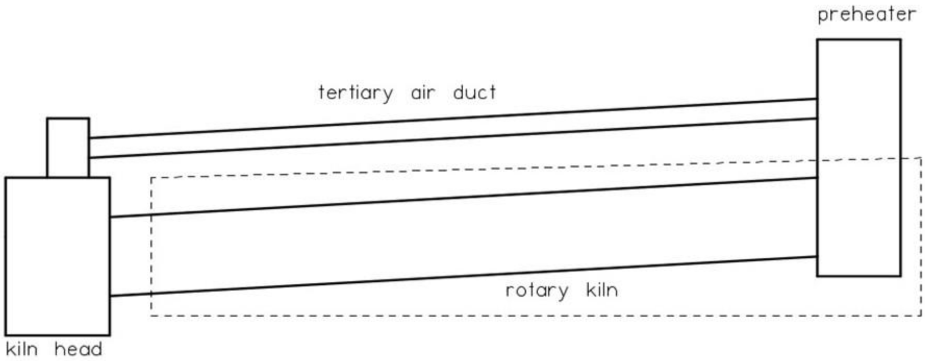

Fig. 1: Rotary kiln with the tertiary air installation.

2.1. Boundary conditions

The purpose of calculation domain development was describing the complex process of cement production Due to this, only flow distribution through the kiln head was included for subsequent analysis. Consequently, authors decided to consider a design of the cement kiln installation using only those elements which are necessary to bring correct results of pneumatic transport in the tertiary air duct. For the calculations, there were set the same boundary conditions for each turbulence model. From the cement plant, there was an information about the flow rate of incoming air to the head of rotary kiln. Boundary conditions in the exits it was set -12 Pa for the kiln and -900 Pa for the tertiary air pipe for each example.

For the particle calculation, Rosin-Rammler-Sperling distribution was used and 10 fractions of particles with the range from 15 to 600 µm were determined. Table 1 presents the distribution of particles in each fraction determined as a part of the total mass flow rate. The same number of intake points for all particle fractions was assumed in the calculations. The adopted boundary conditions gave the expected calculations of the pressure drop values. Calculations were performed using ANSYS Package (Ansys Inc. 2015).

The first result of the calculation it was the velocity profile. In next stage, the same number of particles were injected to the domain and calculation included interaction between gas and particles. Simultaneously quantity of particles transported in the tertiary air installation was counted.

Tab. 2 presents results of velocity calculation at the outlet to the cement kiln and tertiary air pipe for analyzed turbulence models.

Tab. 1: Particle ratios.

d [µm]	percentage
15	7.51
35	9.39
55	10.32
75	14.12
110	17.16
150	18.66
220	16.67
350	5.15
450	0.95
600	0.07

Tab. 2: Turbulence model.

Model	**type**	velocity [m/s]		v/v_{av} [%]	
		kiln	pipe	kiln	pipe
Standard k - ω Model	T01	3.37	29.60	-3.9	5.3
Transition k - ω Model	T02	5.42	16.42	54.7	-41.6
Shear-Stress Transport (SST) k – ω model	T03	3.31	29.57	-5.5	5.2
Linear Pressure-Strain Model	T04	3.13	30.72	-10.8	9.2
Stress-Omega Model	T05	3.07	31.13	-12.4	10.7
Spalart-Allmaras Model	T06	3.46	28.11	-1.1	0.0
Strandard k - ε Model	T07	3.31	29.28	-5.4	4.1
RNG k - ε Model	T08	3.20	29.31	-8.8	4.3
Realizable k - ε Model	T09	3.26	28.93	-6.8	2.9
	av	3.50	28.12		

Comparing the results of average velocity in the exit of kiln and pipe in the installation with vertical pipe there is a significant difference for model T02 (k - ω Transition model). The velocity is lower more by 40 % in the pipe than average value. It has an influence on the number of particles transported in tertiary air pipe. Fig. 2 presents particle trajectories for all alternative models for particles with a diameter in range 110 ÷ 450 μm. For turbulence model T02 small number of particles is transported to the tertiary air pipe as a result of the small gas velocity.

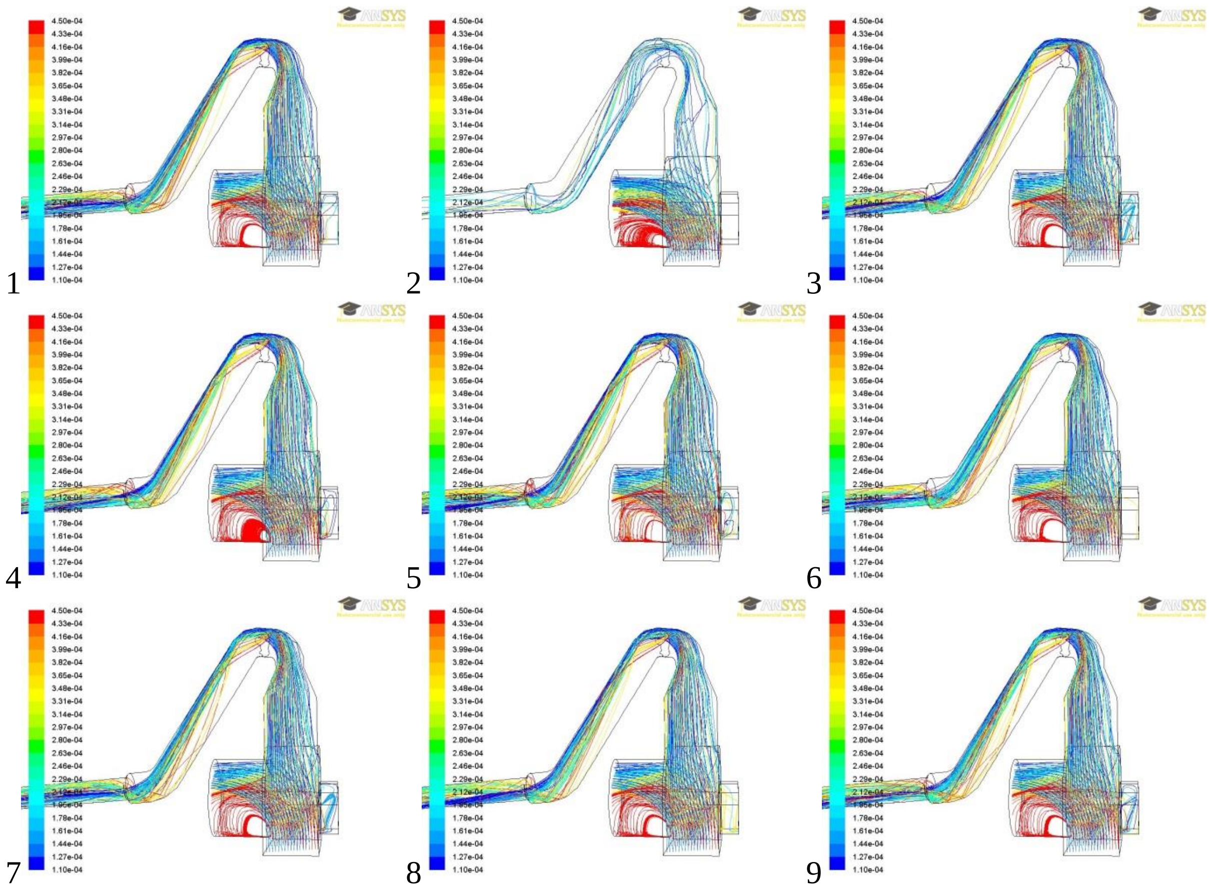

Fig. 2: Particle trajectories for different alternative turbulent model (d110 - d450 μm).

Figs. 3 and 4 show the percentage of particles transported to the tertiary air duct. There is some difference between the number of particles for all diameters. In those pictures, eight alternative models are presented, without model T02.

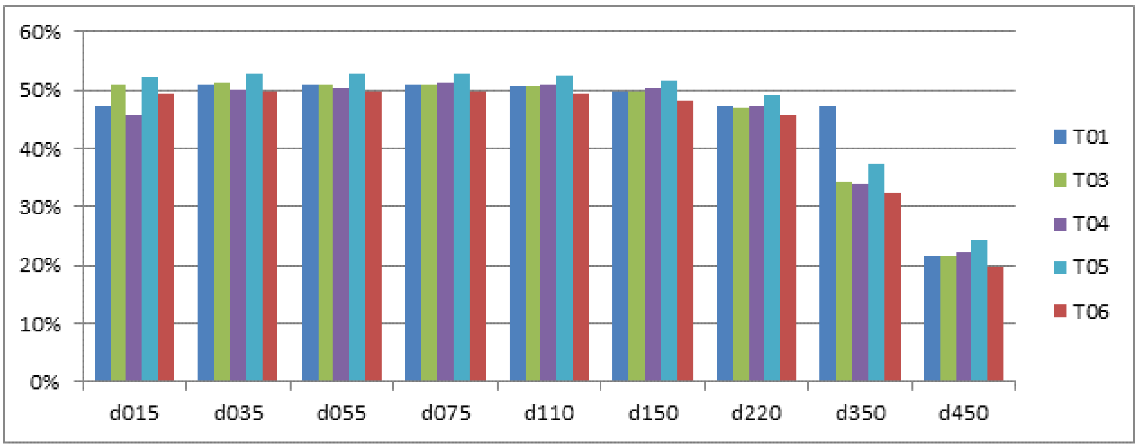

Fig. 3: The percentage of particles transported to the tertiary air pipe for selected models.

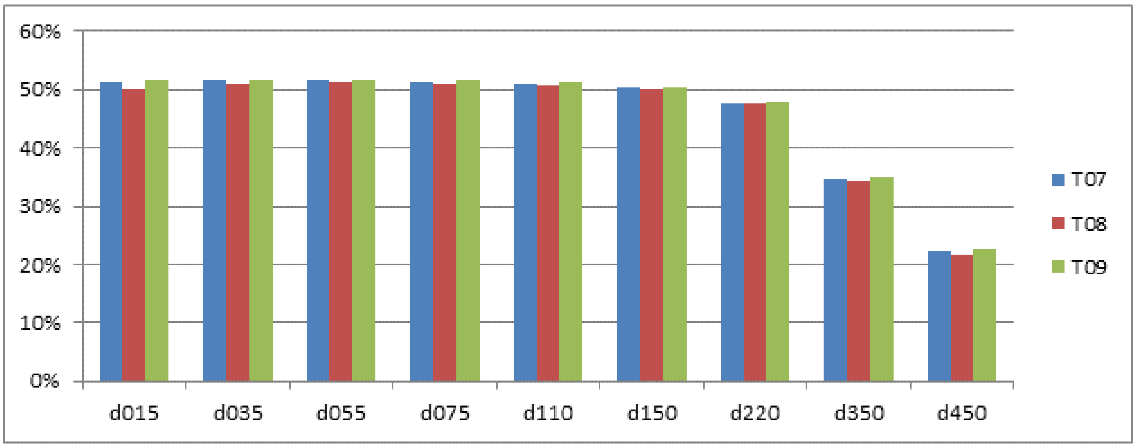

Fig. 4: The percentage of particles transported to the tertiary air pipe for models T07 ÷ T09.

3. Conclusions

In this work, different turbulence models were tested in order to find the most suitable solution to use as a part of the numerical model for particle conveying. Installation with a vertical pipe from the kiln head was researched for each turbulence model. Pressure values at the inlet and two outlets were always the same and treated as the boundary conditions for all sets.

Initially, velocity vectors for each alternative domain were calculated. In next stage particle tracks for each turbulence model was calculated. From that part of the calculations, there are some conclusions.

In an installation with a vertical pipe, almost all turbulence model bring similar velocity at the exit of the pipe. From that, the same numbers of particles are going to the pipe and kiln. Only for the model type T02, there is a very small number of particles transported through the tertiary air pipe. The best particle reduction in the tertiary air is for alternative model type T06, it is for all diameters. Model type T04 is better than others only for small particles. In model type T05 the reduction of particles in tertiary air duct was less effectively.

The comparison of the results proves that the choice of the proper turbulence model is very important. The final results of modeling should be compared with experimental data.

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