Researches concerning the turbulent flow and the parameters which characterize the dust particles of coal injected into furnace of 35 MW burner

Mihai D.L. Țălu and Ştefan D.L. Țălu

***Abstract*—**In the paper there are described the analysis of turbulent flow and the combustion process developed into a non-turbionar jet burner of 35MW on coal. This research is fulfilled using the FLUENT programme and the results permit to correct the functional parameters of burner from the exploitation point of view. This work demonstrates that the proposed procedure is a powerful tool in the optimum design of a burner efficiency.

***Keywords*—**Burner, coal-air mixture, computational simulation, non-turbionar jet.

I. Introduction

THE paper presents the numerical results of calculus fulfilled using the Finite Element Method concerning the distribution fields, the medium and maximum values of physical sizes involved in the burning process of dust coal into the non-turbionar jet burner of 35 MW.

In recent ten years the optimum design in order to increase the energetic efficiency of non-turbionar jet burner of 35MW on coal is becoming a main research direction [1]-[7].

The recommended constructive sizes of burner obtained through theoretical calculus and experimental correction, which in practice give the best results, were established as a consequence of collaboration between T.K.T.I. Company and the Boilers Factory from Taganorog (Russia). In Fig. 1 is shown the sketch of dust coal injector into the furnace with the constructive dimensions designed by these companies [8].

Into the furnace is injected a mixture of air and dust coal which velocity v_{AP} and a secondary air with velocity v_{AS}, which fulfilled a stable burning process with long flame, considering the exclusive case of work only coal.

Table I presents the values of velocity and temperature of secondary air mixture [9].

Table I. The values of velocity and temperature of secondary air mixture.

v_{AP} [m/s]	20 [m/s]	T_{AP} [°K]	645 [°K]
v_{AS} [m/s]	30.3 [m/s]	T_{AS} [°K]	645 [°K]

The flow regime of mixture fuel into the furnace is designed to be a turbulent regime from initial conditions [9].

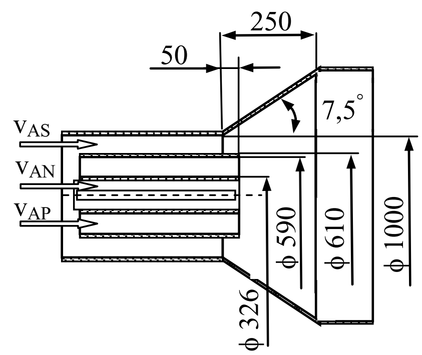

Fig. 1. The sketch of dust coal injector into the furnace with the main constructive dimensions.

The internal recirculation of mixture is strong influenced by the central pipe and the external recirculation by the interior conical shape of burner (which have an angle by $\alpha = 7.5°$, according with Fig. 1). The ignition device and the injector of black oil are placed into the central pipe of injector. In case of supplementary work with black oil in the burning process, through the central pipe is injected air with velocity v_{AN}.

II. The Analysis with the F.E.M.

Starting the examination of flow with axial symmetry for fuel mixture, the results of simulation are given on axial plane identical with the section indicated in Fig. 2.

Manuscript received May 9, 2007; Revised version received November 1, 2007. This work was supported in part by the Romanian Ministry of Education, Research and Youth, through The National University Research Council, Grant PN–II–ID–PCE–2007–1, no. 440/1.10.2007, code ID_1107, 2007 - 2010.

Mihai D.L. Țălu is with the University of Craiova, Romania. He is now with the Department of Applied Mechanics, Faculty of Mechanics, 165 Calea Bucuresti Street, Craiova, 200585 Romania (phone: +40-251-418-803; fax: +40-251-418-803; e-mail: mihai_talu@yahoo.com).

Ştefan D.L. Țălu is with the Technical University of Cluj-Napoca, Romania. He is now with the Department of Descriptive Geometry and Engineering Graphics, Faculty of Mechanics, 103-105 B-dul Muncii Street, Cluj-Napoca, 400641 Romania (e-mail: stefan_ta@yahoo.com).

The 3D model is designed with the Gambit 2.2.30 programme and the Finite Element Analysis (F.E.A.) is made with Fluent 6.2.16 programme.

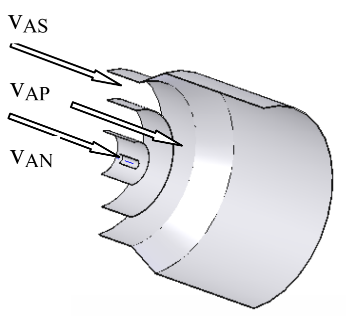

Fig. 2. The axial plane through the 3D model.

The imput sizes of simulation with the F.E.M. are:
- the injection of coal is Q_{coal} = 6.36 [kg/s];
- the fuel consists from the elements: 61 % char, 30 % volatiles and 9 % ash;
- the temperature of inner wall of burning chamber is T_p = 1100 [°K];
- the total length of furnace is L = 10.5 [m];
- the products of burning process are send directly to atmosphere.

From Fig. 3 to Fig. 9 are shown the distribution of fields for magnitude velocity (v), x velocity (v_x), y velocity (v_y), tangential velocity (v_{tan}), turbulence intensity (IT), total temperature (T_{tot}) and radiation temperature (T_{rad}) of the combustible mixture from the furnace of burning installation.

Also there are shown the study of variation for v and T_{tot} on the interior surface of the burning chamber on the symmetry axis of furnace and on the output cross section.

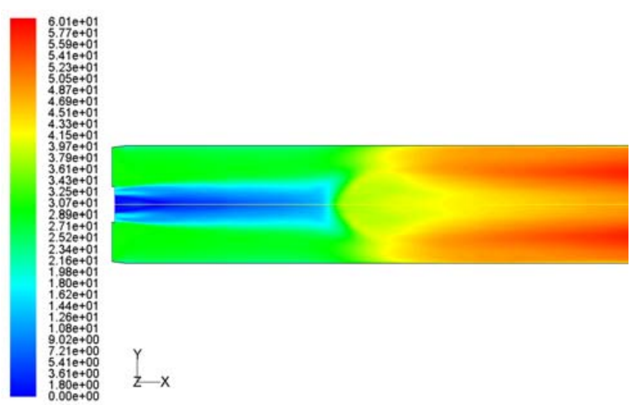

Fig. 3. The magnitude velocity.

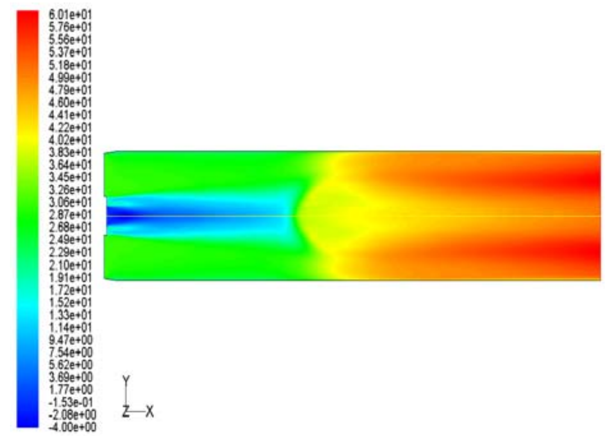

Fig. 4. The x velocity.

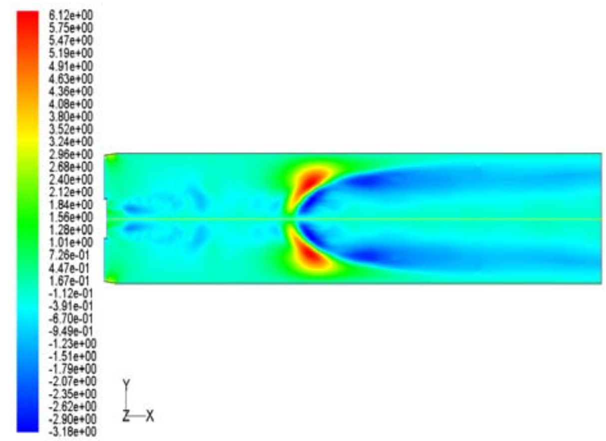

Fig. 5. The y velocity.

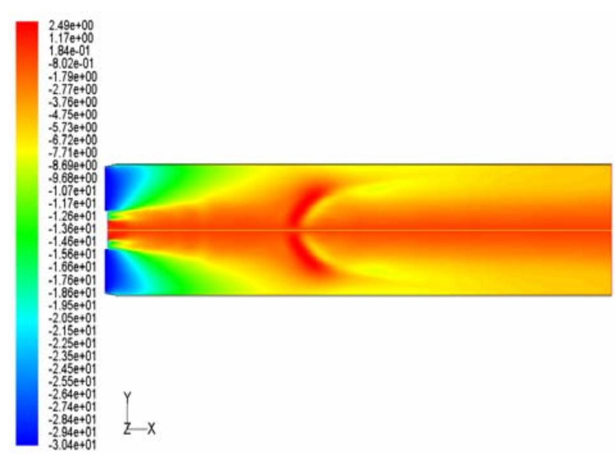

Fig. 6. The tangential velocity.

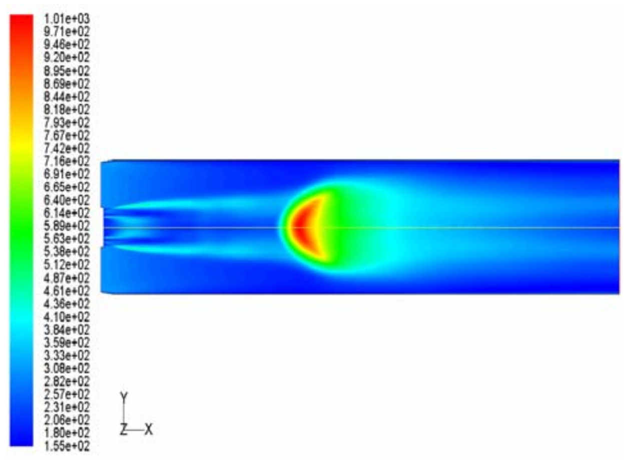

Fig. 7. The turbulence intensity.

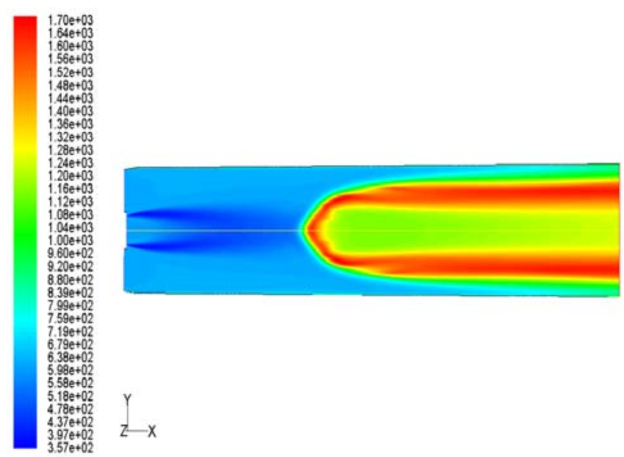

Fig. 8. The total temperature.

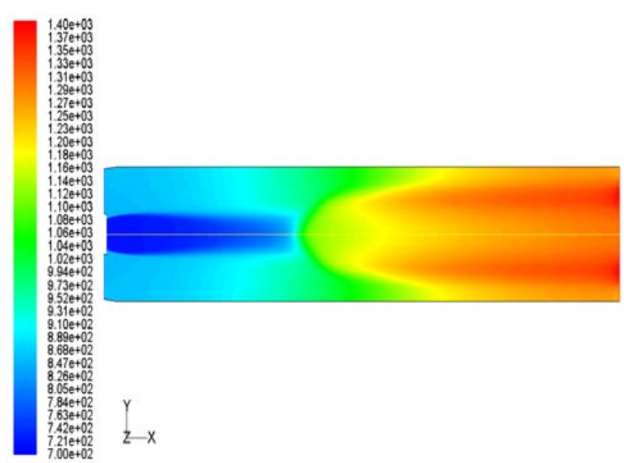

Fig. 9. The radiation temperature.

The results with F.E.M. concerning the medium and maximum values of temperature corresponding on the interior wall, output section and symmetry axis are given in Table II.

Table II. The medium and maximum values of temperature corresponding on the interior wall, output section and symmetry axis

Temperature of surface T [°K]		
Surface	Medium	Maximum
Interior wall	761.6 [°K]	901.3 [°K]
Symmetry axis	959 [°K]	1627.4 [°K]
Output section	1311.3 [°K]	1652.6 [°K]

The plots of variations for T_{tot} on the furnace symmetry axis are marked with continue line and on the interior wall of burner with discontinue line (Fig. 10); the graphics for the output section are given in Fig. 11.

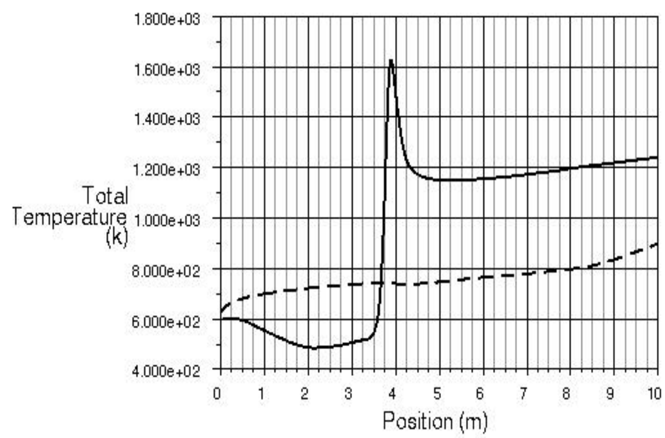

Fig. 10. The plots of variations for T_{tot} on the furnace symmetry axis and on the interior wall of burner.

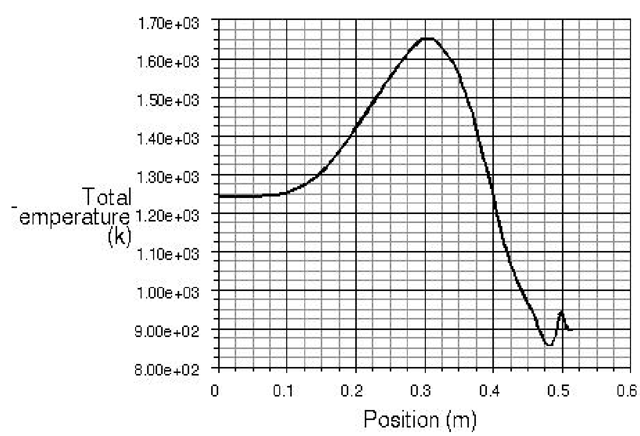

Fig.11. The plots of variations for T_{tot} in the output section.

Because the pulverized particles of dust coal traveling with aid of the gas and devolatilize in time of combustion, it is interesting to present the evolution in time of some parameters which characterize the combustible of particle.

The plots from Fig. 12 to Fig. 18 give on the 3D field trajectories of particles, the evolution of residence in time (t_r), diameter (d), density (ρ), magnitude velocity (v), turbulence intensity (IT), total temperature (T_{tot}) and radiation temperature (T_{rad}).

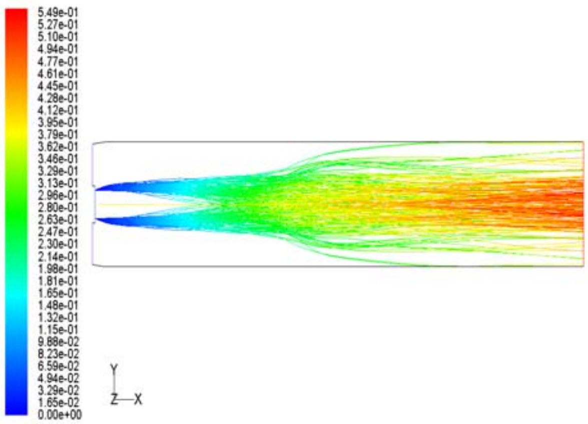

Fig. 12. The residence in time.

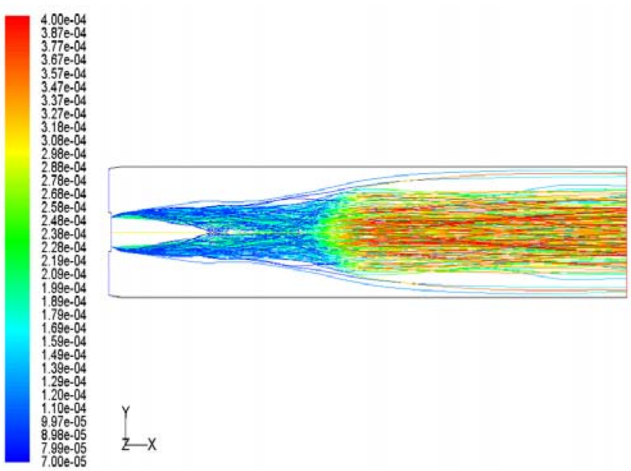

Fig. 13. The diameter.

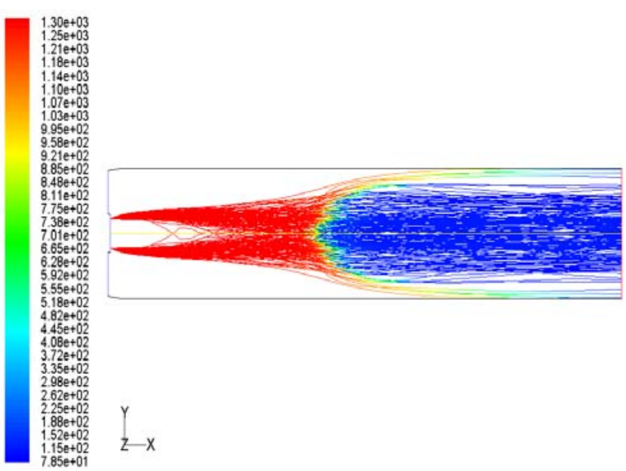

Fig. 14. The density.

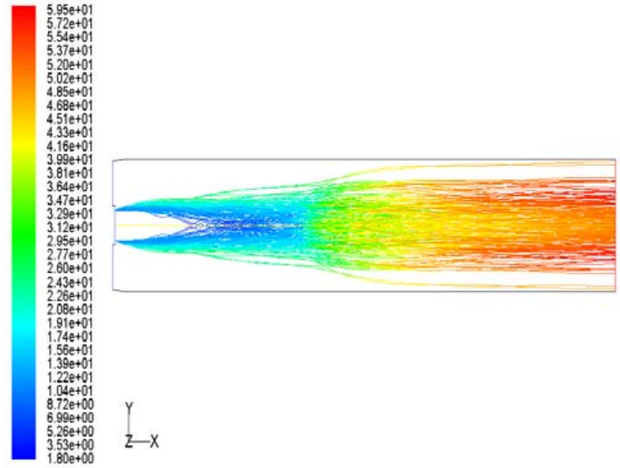

Fig. 15. The magnitude velocity.

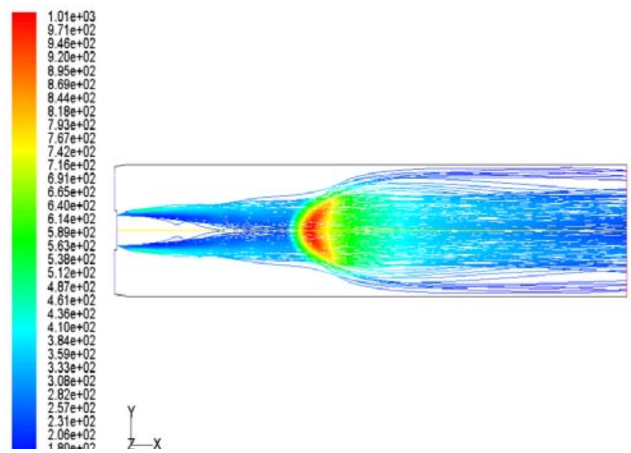

Fig. 16. The turbulence intensity.

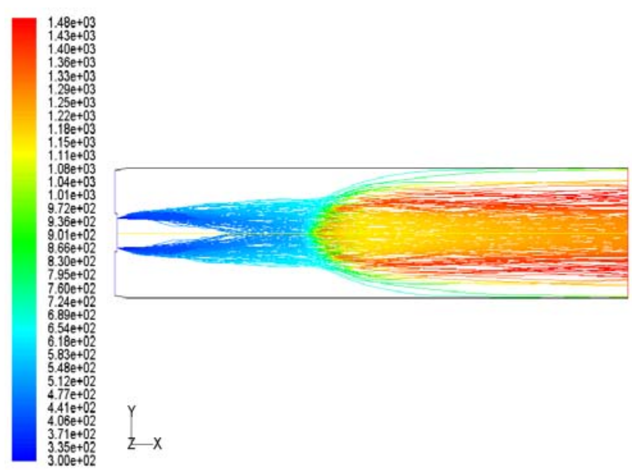

Fig. 17. The total temperature.

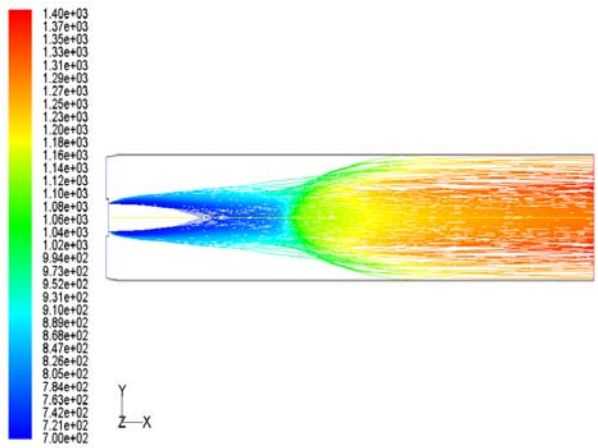

Fig. 18. The radiation temperature.

Also, the volume integral weight-average into 3D domain of flow of burner is given in Table III.

Table III. The volume integral weight-average into 3D domain of flow of burner.

Physical sizes	The volume integral weight-average
v [m/s]	37.61
v_x [m/s]	37.57
v_y [m/s]	0.22
v_{rad} [m/s]	36.20
v_{tan} [m/s]	5.79
IT [%]	303.71
T_{tot} [K]	963.12
T_{rad} [K]	1081.79

The average values and maximum values on the interior flow (3D domain) on the lateral wall and on the output section (3D surfaces) are given in Table IV and Table V.

Table IV. The average values on the interior flow on the lateral wall and on the output section.

Physical sizes	Interior flow	Lateral wall	Output section
	Average values		
v [m/s]	37.65	0	54.63
v_x [m/s]	37.61	0	54.72
v_y [m/s]	0.22	0	0.462
v_{tan} [m/s]	2.49	0	3.30
IT [%]	303.73	246.95	234
T_{tot} [K]	963.51	1099.83	1311.30
T_{rad} [K]	1081.92	1065.25	1325.41

Table V. The maximum values on the interior flow on the lateral wall and on the output section.

Physical sizes	Interior flow	Lateral wall	Output section
	Maximum values		
v [m/s]	60.12	0	60.12
v_x [m/s]	60.13	0	60.13
v_y [m/s]	6.12	0	0.0066
v_{tan} [m/s]	5.81	0	4.95
IT [%]	1005.14	305.81	303.77
T_{tot} [K]	1697.04	1100	1652.54
T_{rad} [K]	1401.02	1268.26	1401.02

The minimum and maximum values of residence time, diameter, density and mass of particles are given in Table VI.

Table VI. The minimum and maximum values of residence time, diameter, density and mass of particles.

Physical size	Minimum values	Maximum values
t_r [s]	0	0.566
d [m]	$7 \cdot 10^{-5}$	$4 \cdot 10^{-4}$
ρ [kg/m^3]	78.459	1300
m [kg]	$9.24 \cdot 10^{-11}$	$5.44 \cdot 10^{-9}$

III. CONCLUSIONS

The analysis with the Finite Element Method confirms the turbulent character of flow into the furnace of burner. The internal and the external recirculation zones are viewed in proximity of the interior shape and of the symmetry axis (Fig. 3 to Fig. 7).

The high field of temperature gives the high stability of burning process. The premixture injected burns the volatiles of coal and then the stability of process is provided by the supply of heat of burnt gas cycling into the flame (Fig. 3, Fig. 7 and Fig. 8).

The following observations of physical size of burning process made references to: velocity, v for (Fig. 3 to Fig. 6); to turbulence intensity, IT, Fig. 7; and for temperature T to (Fig. 8 and Fig. 9); Table V and Table VI.

The flame along the symmetry axis of furnace is divided in three zones:

- the input zone $L_{input} \approx 31\%$ L, with moderate gradients of increasing for T, v and IT;

- the middle zone $L_{middle} \approx 68\%$ L, with hight gradients of variation for T and v and the maximum value of sizes given in Table 2;

- the optput zone $L_{ouput} \approx 11\%$ L, where the burning process filling in totality the jet's section, with moderate decreasing gradients of T, v and IT.

Analyzing the parameters which characterize the evolution of coal particles, starting at Fig. 12 to Fig. 18, and Table VI we can conclude next:

- the 3D shape of particles trajectory are complicated as consequence of turbulent flow;
- on the input zone t_r, φ, T and v have small values, Table VI;
- on the middle zone arriving the particles with medium value of t_r and φ. The sizes T and v are in continuous increasing;
- on the output zone arriving we meet particles with large values of t_r and φ. Also in this zone the v and T have large values.

In conclusion the analysis with the F.E.M. is an efficient mode to investigate the character of flow process and the parameters attach to particle of coal to this volatilize, which give information about 3D fields and numerical values.

REFERENCES

[1] A. Bejan et al., *Advanced Engineering Thermodynamics*, Second edition, New York: John Wiley & Sons, 1997, pp. 62-110.

[2] J. L. Ferzieger and M. Peric, *Computational Methods for Fluid Dynamics*, Heidelberg: Springer-Verlag, 1996, pp. 86-123.

[3] E. M. Greitzer, C. S. Tan and M. B. Graf, *Internal Flow*, New York, Cambridge Univ. Press, 2004, pp. 23-78.

[4] F. P. Incropera et al., *Fundamentals of Heat and Mass Transfer*, Second edition, New York: John Wiley & Sons, 1985, pp. 112-156.

[5] S. E. Kim, D. Choudhury and B. Patel, “Computations of Complex Turbulent Flows Using the Commercial Code FLUENT”, presented at Symposium on Modeling Complex Turbulent Flows Hampton, Virginia, USA, 1997.

[6] A. F. Mills, *Basic Head & Mass Transfer*, New Jersey: Prentince Hall, 1999, pp. 34-82.

[7] M. Moran, H. Shapiro, *Fundamentals of engineering thermodynamics*, New York: John Wiley & Sons, 2000, pp. 105-128.

[8] I. Mihailescu I., *Arzătoare turbionare. Teorie, construcție, utilizare*, București, Ed. Tehnică, 1986, pp. 53-112.

[9] M. Țălu, Ș. Țălu, M. Negru, “*The simulation with the Finite Element Method of the velocity and temperature fields for a nonturbionar jet burner of 35MW feeding with pulverized coal*”, presented at the 11th WSEAS International Conference on COMPUTERS (part of the 11th WSEAS International Multiconference CSCC), Agios Nikolaos, Crete Island, Greece, July 26-28, 2007, pp. 263-268.

Mihai D.L. Țălu was born in Florești, county Vaslui, Romania, on November 5, 1962. He graduated as a mechanical engineer from University of Craiova, Faculty of Mechanics, Romania in 1987. He received his Ph.D. degree in technical sciences with specialty in mechanical engineering, on 2000 from the University of Craiova, Romania.

From 1990 to 2001, he was Assistant Professor in Department of Applied Mechanics, Faculty of Mechanics, University of Craiova, Romania. From 2001 at present, he is Lecturer in Department of Applied Mechanics, Faculty of Mechanics, University of Craiova, Romania. He has published 10 books and 93 scientific papers in international journals, national and international conferences. His research interests include applied mechanics, mechanics of fluids, the finite element method, multiobjective optimization, numerical calculus, applied statistics, thermotechnics and computer simulation.

Dr. Mihai has been involved in numerous research projects led at the Technical University of Craiova, Romania and some scientific grants with the Romanian Ministry of Education, Research and Youth, through The National University Research Council. Currently he is a member of the Romanian Society of Theoretical and Applied Mechanics.

Ștefan D.L. Țălu was born in Florești, county Vaslui, Romania, on July 31, 1964. He graduated as a mechanical engineer from University of Craiova, Faculty of Mechanics, Romania in 1988. He received his Ph.D. degree in technical sciences with specialty in technology of machine building, on 1998 from the Technical University of Cluj-Napoca, Romania.

From 1991 to present, he worked in Department of Descriptive Geometry and Computer Graphics, Faculty of Mechanics, Technical University of Cluj-Napoca, Romania. He is currently Associate Professor in Department of Descriptive Geometry and Computer Graphics, Faculty of Mechanics, Technical University of Cluj-Napoca, Romania. He has published 13 books and 142 scientific papers in international journals, national and international conferences. His research interests include descriptive geometry, technical drawing, mathematical algorithms for solving the optimum problems, technology of machine building and computer aided design.

Dr. Ștefan has been involved in numerous research projects led at the Technical University of Cluj-Napoca, Romania and some scientific grants with the Romanian Ministry of Education, Research and Youth, through The National University Research Council. Currently he is a member of the Romanian Association of Engineering Graphics, member of the General Association of Romanian Engineers as well as member of the Romanian Committee for the History and Philosophy of Science and Technology of Cluj territorial branch of the Romanian Academy.