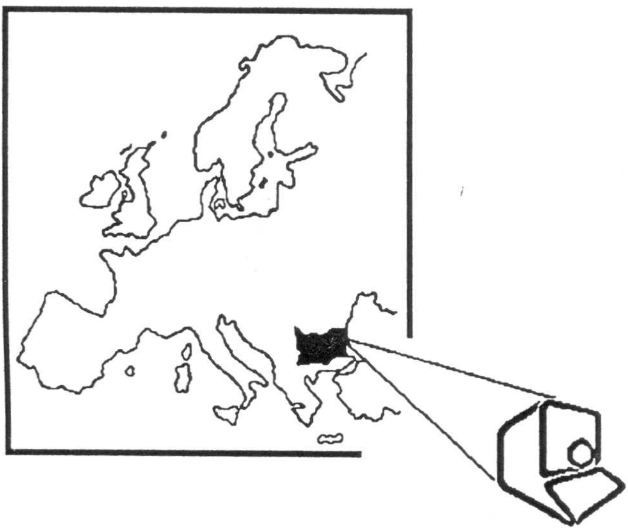
COMPUTER SYSTEMS AND COMPUTER - AIDED APPLICATIONS



PROCEEDINGS

of the 10th International Conference
"Systems for Automation of Engineering and Research"
and DECUS NUG Seminar

September 27-29, 1996

COMPUTER SYSTEMS AND COMPUTER - AIDED APPLICATIONS

Proceedings
of the 10th International Conference "SAER '96
and DECUS NUG Seminar'96

September 27-29, 1996, St. Konstantin resort, Varna, BULGARIA

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Radi ROMANSKY, Ph.D. (Associated Professor)

ISBN 954-8329-12-3

Published by: SAER Forum Group and DECUS NUG, Bulgaria
P.O. Box 90, 1756 Sofia, BULGARIA

Printed by: Printing House of USB, Sofia, BULGARIA

The book is printed in 150 copies

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AND

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Under the patronage of the
Ministry of Education, Science
and Technologies; Bulgaria

Proceedings
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and DECUS National Users Group Seminar '96

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Sofia, 1996

Organizers and Publishers:

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Phone: (+359 2) 705-257; Fax: (+359 2) 703-556

ISBN 954-8329-12-3

The Proceedings of SAER '96 & DECUS NUG Seminar '96 are printed by Printing House of Union of Scientists in Bulgaria.

Phone (+359 2) 722-381 (157), manager Mr. R. Dimitrov

SAER '96 and DECUS NUG Seminar '96
are organized under the auspices and financial support of:

CAD Research and Development Centre
Bulgaria

Technical University - Sofia
Bulgaria

FESTO-Bulgaria EOOD

National Science Fund
Ministry of Education, Science
and Technologies; Bulgaria

Union of Scientists in Bulgaria

11th International Conference
"SYSTEMS FOR AUTOMATION OF ENGINEERING AND RESEARCH" (SAER '97)
and DECUS NUG Seminar '97

October 7 - 9, 1997, St. Konstantin resort
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To take part in SAER '97 & Seminar '97 You should send to the address of the Program Committee **before March 1st, 1997** the following:

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The papers will be reviewed for their scientific contents and authors will be notified of acceptance or rejection by **May 1st, 1997**. The revised and final versions of accepted papers must arrive in **camera-ready form** before **June 1st, 1997**. The accepted papers will be published in PROCEEDINGS (with ISBN) which will be deposited in over 15 libraries in the World (see p.9).

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About 10-th Anniversary of the SAER Conference

I am pleased warmly to welcome all participants of the International Conference 'Systems for Automation of Engineering and Research'. This 10-th anniversary issue is held under the patronage of the Ministry of Education, Science and Technologies.

Created in 1987 as National Youth School with International Participation this annual event grew up and since 1991 it has transferred into International Conference on Systems for Automation of Engineering and Research, which technical content covers a wide range of interests in Automation, Electronics, and Communication. Despite evident economic problems the Conference continued to enhance and extend its activities. Moreover, in last two years, one third of the published papers have been submitted by foreign authors. As an example, in 1995 there were participants from Poland, Belgium, Belarus, Russia, Portugal, Ukraine, The Netherlands, Macedonia. Over the last three years, according to the international requirements for such events, the official language for papers presentation as well as in the Conference Proceedings is English.

Thanks to the endorsement of the National Center for Information and Documentation (NACID) - Sofia, the Conference Proceedings is deposited in about 20 world famous libraries. Since 1991 a satellite second stream of the Conference is DECUS National User Group seminar aiming effective utilization of up-to-date computer systems, manufactured by Digital Equipment Corporation. Our thanks to Mr. Pl. Mateev - Chairman of DECUS NUG Bulgaria and CAD R&D Center "Progress" for the participation and valuable support.

I wish to acknowledge many peoples for their contribution to the Conference. Some special thanks to the first Chairman D. Batanov and to my colleagues R. Romansky and I. Tashev. Finally, I take the opportunity to extend our gratitude to the sponsorship organizations - Ministry of Education, Science and Technologies of Bulgaria and National Science Fund, Union of Scientists in Bulgaria, Technical University of Sofia, FESTO Bulgaria and to all which helped us in making this Conference success.

On behalf of the International Program Committee of SAER'96, we wish you a pleasant stay in St. Constantin resort and hope that all of you will enjoy both the scientific activities of the Conference and the cultural and tourist attractions of the Varna region. We are looking forward to meeting you at the next Conference editions.

Yours Sincerely,

Popov

A. Popov,
Chairman of SAER'96

INTEGRAL METHODS FOR INVESTIGATION OF TWO DIMENSIONAL TWO-PHASE TURBULENT JETS

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ABSTRACT

The integral methods for investigation of jet stream find a wide application in the contemporary theory of the turbulent jets. This can be explained with their possibilities for obtaining comparatively exact solutions using a simpler mathematical apparatus. The main moment in these methods is the replacement of the private differential equations for the jet boundary layer with integral relations, which are most often simple differential equations.

The integral methods are considerably easier for application in comparison with the numerical methods for a direct integration of equations for motion; they require not so much powerful computer facilities and less machine time. They are very well physically substantiated, because the integral conditions used in their greater part are based on such proved conceptions like quantity of motion, momentum of the quantity of motion, turbulent energy, preservation of mixtures contents, etc.. A definite positive quality of the integral methods is their visualaids, while for their application in solving concrete problems it is necessary to have a deep and profound knowledge of the object under investigation. A basic necessity in applying the integral methods is the issuing of normalized cross speed and of the other parameters distribution. It should be issued according to known experimental data related to analogical or close to the reviewing stream. The distribution of two dimensional two-phase turbulent jets in a companion medium of the carrier (gas) phase has been discussed in this article, using the integral methods. The good coincidence dives advantage for using the method described for investigation of two-phase turbulent jets.

INTRODUCTION

The integral methods belong to the class of the boundary layer methods in solving turbulent jets. As in each method used as far as they're concerned, the problem about the accuracy of the decisions made is of importance. It should be said that the deviation of the numerical results of the experiment does not surpass the errors imposed by the used semi-empirical dependencies of parameters distribution of the stream, the used models of turbulence, etc. It should be underlined that in no case the numerical solutions of given problems are not the ground for neglecting the investigation integral methods. The completeness of a scientific investigation requires the simultaneous simulation of a given stream by means of integral and numerical methods [4]. This leads to a greater completeness of the solution because both methods mutually complement and enrich each other. We should not miss one more important advantage of the integral methods - the necessity from a considerably smaller in volume and quality information described to be input into the machine as well as the possibility to use integral parameters for analysis of the results obtained [1,2,3].

METHOD

The equations in an integral type which describe the distribution of two-phase two dimensional turbulent jets in a companion medium from the carrier phase, have the following aspect:

1. $$\frac{\partial}{\partial x}\int_0^\infty \rho_g u_p \chi y^j dy = 0$$

2. $$\frac{\partial}{\partial x}\int_0^\infty \rho_g u_g\left(u_g - u_2\right) y^j dy + \frac{\partial}{\partial x}\int_0^\infty \rho_p u_p^2 y^j dy = 0$$

3. $$\frac{\partial}{\partial x}\int_0^\infty \rho_g u_g\left(u_g - u_2\right)^2 y^j dy = -2\int_0^\infty \rho_g \nu_{tg}\left(\frac{\partial u_g}{\partial y}\right)^2 y^j dy - 2\int_0^\infty \left(u_g - u_2\right) F_x y^j dy$$

4. $$\frac{\partial}{\partial x}\int_0^\infty \rho_p u_p^3 y^j dy = -2\int_0^\infty \rho_p \nu_{tp}\left(\frac{\partial u_p}{\partial y}\right)^2 y^j dy + 2\int_0^\infty u_p F_x y^j dy$$

5. $$\frac{\partial}{\partial x}\int_0^\infty u_p \chi^2 y^j dy = -2\int_0^\infty \rho_g y \frac{\nu_{tp}}{Sc_t}\left(\frac{\partial \chi}{\partial y}\right) y^j dy,$$

where j=0 for plane, and j=1 for axially symmetrical jets.

The equation 1 represents in itself the condition for keeping the content of mixtures in the stream. The quantity of motion can be described from the equation 2. In this case the equations for quantity and motion of the carrier (gas) phase and of the mixtures are united. This is done with the purpose to universalize the equation in order to be applied also in these case when the two-phase jet is formed after it has been flowed out in the environment, for example in dispersing liquids, pulverization, etc.. By means of this equation record the possibility for inner redistribution of quality of motion between the phases can be illustrated.

The equations 3, 4 describe the turbulent energy of the gas medium and of the mixtures. On their right side figure the turbulent tangential voltages, respectively turbulent viscosity and integral of the inter-phase interaction forces.

The equation 5 is in itself an integral condition of a higher order as regards the mixtures parameters. As it is underlined in [5]. as well, such conditions do not have a definite physical interpretation but their usage for closing up the system of equations of motion is embossed. Because from a mathematical point of view they are perfectly well explained, their application do not decrease the accuracy of investigation.

To the system of equations 1 - 5 a closing condition is added which gives the connection between the dynamic and diffuse boundary layer.

6. $$Ru = Sc_t Rp$$

The system of equations put down above by means of the input exponent j describes the distribution of flat (at j = 0) and of axially symmetric (j = 1) jets. The processing of the equations will be done in the most general aspect related to the motion of two-dimensional jets in a companion medium.

When solving equations 1÷6 the same similarity for normalized cross distribution of the jet [5] parameters is accepted.

7. $$\frac{u_g - u_2}{u_{g\,max} - u_2} = \frac{u_p}{u_{p\,max}} = \exp\left(-K_u \eta^2\right);\ \frac{\chi}{\chi_m} = \exp\left(-K_\chi \eta^2\right)$$

where, $k_\chi = Sc_t k_u$ and the constant k_u can be determined at a rotation degree S = 0.

The selection of expressions describing the normalized cross distribution of parameters can be done at the discretion of the author in solving a concrete problem and should not obligatorily be proposed here.

The turbulent viscosity ν_{tg} and ν_{tp} can be determined after a modification of the model of Shetz [4,6]. The following expression is proposed for the turbulent viscosity.

$$\nu_{tg} = B\left[f(Re_d).f(\chi_0)\right]\delta_i \Delta u_{i\,max}$$

where: B = 0,01÷0,03 proportionality constant d - thickness of the boundary jet layer, respectively of the gas phase and for the mixtures $\Delta u_{i\,max}$ - maximum velocities difference.

As regards the function $f(Re_d)$ an analogical dependence to that for determining the resistance coefficient is proposed to be used.

For example in this study it is accepted that,

$$f(Re_d) = 1 + b_1 Re_d^{0.5} + b_2 Re_d, \quad f(\chi_0) = (1+\chi_0)^{-3/2}$$

where [9] is taken $b_1 = 0.179, b_2 = 0.013, Re_d = \frac{u_p d_p}{\nu_g}$

The input designations in the equations worked out are given in [4].

On the basis of the review done and normalization, we obtain the following system of equations

8. $$A_{11}\chi_{max}\bar{u}_{pm}\bar{x}^2 = G_1$$

9. $$A_{21}\bar{u}_{gm}^{\bullet 2}\bar{x}^{j+1} + A_{22}m\bar{u}_{gm}^{\bullet}\bar{x}^{j+1} + A_{24}\chi_m\bar{u}_{pm}^2\bar{x}^{j+1} = I_1$$

10. $$\frac{\partial}{\partial x}\left[A_{41}\bar{u}_{gm}^{\bullet 3}\bar{x}^{j+1} + A_{42}m\bar{u}_{gm}^{\bullet 2}\bar{x}^{j+1}\right] = A_{44}\bar{u}_{gm}^{\bullet 3}Ru - A_{45}\bar{u}_{gn}^{\bullet}\left(\bar{u}_{gm}^{\bullet} - \bar{u}_{pm} + m\right)^2\bar{x}^{j+1}$$

11. $$\frac{\partial}{\partial x}\left[A_{51}\chi_m\bar{u}_{pm}^3\bar{x}^{j+1}\right] = -A_{52}\chi_m\bar{u}_{pm}^3 Ru + A_{53}\chi_m\bar{u}_{pm}\left(\bar{u}_{gm}^{\bullet} - \bar{u}_{pm} + m\right)^2\bar{x}^{j-1}$$

12. $$\frac{\partial}{\partial x}\left[A_{71}\chi_m^2\bar{u}_{pm}\bar{x}^{j+1}\right] = -A_{72}\chi_m^2\bar{u}_{pm}\overline{Ru}$$

13. $$\overline{Ru} = Sc_t\overline{Rp}$$

where the values of A_{ij} are given in [4].

On the basis of the system of equations (8÷13) is built up on the algorithm for calculating the stream.

Equation (8) is differentiated along $\bar{x}$ and we obtain

14. $$\frac{1}{\chi_m}\frac{\partial\chi_m}{\partial\bar{x}} = -\frac{1}{\bar{u}_{pm}}\frac{\partial\bar{u}_{pm}}{\partial\bar{x}} - (j+1)\frac{1}{\bar{x}}$$

From equation 9 after differentiation along $\bar{x}$ and the respective processing it follows

15. $$\frac{1}{\chi_m}\frac{\partial\chi_m}{\partial\bar{x}} = -\frac{A_{72}}{A_{71}}\frac{Ru}{\bar{x}^{j+1}}$$

In order to determine the term figuring on the right side of equation 11 which contains the difference between the maximum velocities of the carrier-medium and of the mixtures, we shall solve the equation of quantity of mixtures motion, which has the appearance:

$$\frac{\partial}{\partial x}\int_0^{y_*}\rho_p u_p^2 y^j dy = \int_0^{y_*}F_x y^j dy$$

The integrals in this equation should be solved as follows

$$\frac{\partial}{\partial x}\left[\rho_g \chi_m u_{pm}^2 x^{j+1}\int_o^\infty \frac{\chi}{\chi_m}\left(\frac{u_p}{u_{pm}}\right)^2 \eta^{j+1} = \rho_g \chi_m \left(u_g - u_{pm}\right)^2 x^{j+1}\int_o^\infty K_x \frac{\chi}{\chi_m}\left(\frac{u_p}{u_{pm}}\right)^2 \eta^j d\eta\right]$$

of which after the normalization of the variables and input of the respective designations for the integrals, the following expression is obtained

16. $$\frac{\partial}{\partial x}\left[\chi_m \bar{u}_{pm}^2 \bar{x}^{j+1} A_{24}\right] = \chi_m \left(\bar{u}_{gm} - \bar{u}_{pm}\right)^2 \bar{x}^{j+1} A_{45}$$

by the right side of which the term contain the velocities difference square is replaced in equation 16.

Equations 14 and 15 are equalized from where the relation is determined

17. $$\frac{Ru}{\bar{x}^{j+1}} = -\frac{A_{71}}{A_{72}}\left[\frac{1}{\bar{u}_{pm}}\frac{\partial \bar{u}_{pm}}{\partial \bar{x}} + \frac{j+1}{\bar{x}}\right]$$

After 16 and 17 have been replaced in the equation for the turbulent energy for the mixtures, we obtain

18. $$\frac{d\bar{u}_{pm}}{u_{pm}} = -(j+1)N_1 \frac{d\bar{x}}{\bar{x}}$$

where: $N_1 = \dfrac{A_{52}A_{71}}{A_{72}A_{51-}A_{53}A_{24}A_{72} - A_{71}A_{53}}$

We impose (j + 1)N1 = N of which it follows that

19. $$\frac{d\bar{u}_{pm}}{u_{pm}} = -N\frac{d\bar{x}}{\bar{x}}$$

The solution of 14 has the appearance

20. $\bar{u}_{pm} = Mu\bar{x}^{-N}$,where the integration constant Mu is determined by means of the transient cross-section co-ordinate x_p: $Mu = x_p^N$ at x_p and Mr are respectively equal to

$$X_p = \frac{1}{Mr}\frac{1.73(1+\chi_o)\sqrt{1+\chi_o}}{(1+0.5\chi_o)(0.584+0.691\chi_o)} \text{ along [1] } \quad Mr = \frac{A_{71}}{A_{72}}\left[(j+1)-N\right]\frac{1-m}{1+\chi_m m}$$

After processing, from equation 17 we obtain

21. $Ru = Mr\bar{x}$

With the definite dependence for $\bar{u}_{pm}$ according to 20, we replace in equation 8 where from there follows an expression for calculating of χ_m:

22. $\chi_m = M_\chi \bar{x}^{-(2-N)}$, where $M_\chi = \dfrac{G_1}{A_{11}Mu}$

The equation for quantity of motion 9 is processed according to the following way

$A_{21}\bar{x}^2 u_{gm}^{\bullet 2} + A_{22}m\bar{x}^2 u_{gm}^{\bullet} - \left(I_1 - A_{24}\chi_m u_{pm}^2 x^2\right)$, that can be written also in the type

23. $A_{25}\bar{u}_{gm}^{\bullet 2} + A_{26}\bar{u}_{gm}^{\bullet} - I_{12} = 0$

in which the designations have been introduced

$A_{25} = A_{21}\bar{x}^2$; $A_{26} = A_{22}m\bar{x}^2$; $I_{12} = I_1 - A_{24}\chi_m \bar{x}^2 \bar{u}_{pm}^2$

The determinant of 23 has the appearance

24. $DE = A_{26}^2 + 4A_{25}I_{12}$

The solution of 23 gives the following dependence for determining of the velocity difference for the carrier (gas) phase.

25. $\bar{u}^{\bullet}_{gm} = \dfrac{-A_{26} + \sqrt{DE}}{2A_{25}}$

From the connection 8 the widening of the diffuse boundary layer can be calculated.

26. $Rp = \dfrac{Ru}{Sc_t}$

At the equation diagram used in such a way, equation 10 can be used for control of the results obtained. Of course, the calculation cannot be organized in such a way that the additional integral condition 12 cannot be used for the solution but in that way the possibility for an additional check is lost by one physically explained integral condition of the results from the numerical solution.

RESULTS

The test results are shown on fig.1. for the case when the particle size is minimum and concentration is disappeared. Comparison is done with the results from [1,3]. A comparison between the numerical results and experimental ones from [3] are given on fig.2.The good coincidence dives advantage for using the method described for investigation of two-phase turbulent jets.

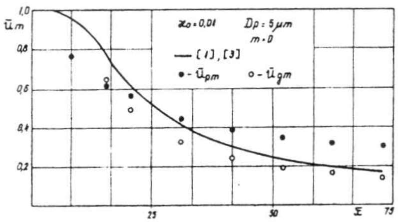

Fig. 1. Test case - experimental results from [1.3]

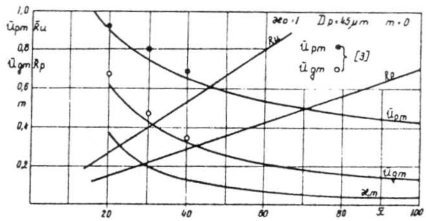

Fig.2. Comparison between the numerical results and experimental from[3]

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