REPLY FORM (C485)

OPTICAL METHODS AND DATA PROCESSING IN HEAT AND FLUID FLOW, CITY UNIVERSITY, 14-15 APRIL 1994

Please complete this form and return it to:

Amanda Richards/Corinne Paine
Conference Services Department C485
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Please tick and complete where appropriate:

{ } I wish to submit a paper to the seminar

TITLE.....

.....

Synopsis is attached/follows (please delete as appropriate)

{ } Please send me information on attending the seminar (registration details available January 1994)

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International Seminar

I MECH E

First Announcement and Call for Papers

OPTICAL METHODS AND DATA PROCESSING IN HEAT AND FLUID FLOW

14-15 April 1994, City University, London, UK

Organised by the Energy and Thermofluid Mechanics Group of the Institution of Mechanical Engineers

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OPTICAL METHODS AND DATA PROCESSING IN HEAT AND FLUID FLOW

Following the success of the first international seminar on *Optical Methods and Data Processing in Heat and Fluid Flow* in 1992, IMechE is running a second event on the same topic in 1994. The venue is again London's City University.

The first seminar attracted an international array of speakers from Europe, Japan, Russia and the USA with presentations on particle image velocimetry, holography, liquid crystal and fluorescence techniques. Keynote addresses included such prominent international figures as Professor Ron Adrian from the University of Illinois and Dr Michel Riethmuller from the Von Karman Institute in Belgium.

Many recent advances have taken place in optical techniques for heat and fluid flow measurement. The 1994 seminar will be an international forum for reviewing the latest developments and innovative new approaches and will be a meeting point for industrialists and academics interested in this field. As before, emphasis will be on developments which have application in industrial environments.

Papers are invited in the following areas:-

- holographic interferometry
- particle image velocimetry
- holographic velocimetry
- laser speckle
- doppler global velocimetry
- liquid crystals
- shadowgraph
- fluorescence techniques
- real time optical techniques
- image and data processing
- new developments in laser anemometry
- computer aided flow visualisation methods
- comparison of experiment with computer models
- image anaylsis for determination of flow structures
- thermal imaging
- industrial application

Offers of papers

Synopses of papers comprising up to 200 words should be returned with the form overleaf by Friday 28 May 1993. Selected authors will be invited to submit draft papers of up to 2,000 words and up to 6 illustrations by October 1993.

The seminar will be presented in English. All offers of papers will be considered, but final acceptance will depend on the Organising Committee's decision based on the contents of the final manuscript, and subject to its receipt by January 1994.

Papers accepted for presentation will be published by IMechE in a bound volume. This will be issued to delegates at the seminar and will be available for general sale after the event. Selected papers will be considered for publication in the Proceedings of the Institution of Mechanical Engineers and those considered by the Organising Committee to be of special merit may be nominated for appropriate awards.

The presenting author of each accepted paper will be entitled to a substantial reduction in the delegate fee.

Delegates

To receive further details of this seminar please complete the reply form.

Exhibition

A supporting exhibition will be organised. Please tick the box on the reply form if you are interested in receiving further details.

ORGANISING COMMITTEE

Dr Clive Greated (Chairman), Edinburgh University
Prof Michael Collins, City University
Dr Eric Fisher, Newcastle University
Dr Geoff McGrath, British Hydromechanics Research Group
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Dr David Pinchbeck, British Gas
Prof Jan Stasiek, City University
Dr Steve Wiseall, Rolls Royce

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REFERENCE C01194/L13/Aut

29th July 1994

Professor I S Antonov
Reader
Technical University of Sofia
Dept of Mechanical Engineering
Hydroaerodynamics Dept
Sofia 1756
Bulgaria

Dear Professor Antonov

SUBMISSION TO PROCEEDINGS

Field analysis of a swirling dispersed jet

Your paper has been carefully considered by the Editorial Panel, but I regret to inform you that they have not found it possible to recommend it for publication. I enclose the referees' comments for your interest and information.

I am therefore now returning your manuscript and would like to thank you for submitting your paper to the Institution.

Yours sincerely

P.P. Sheryl McDermott (Miss)
Papers Controller, Proceedings

Encs

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FIELD ANALYSIS OF A SWIRLING DISPERSED JET

SYNOPSIS: In the present work, stream formed in spraying device of centrifugal-jet type is discussed. The numerical stream model has been worked out on the basis of two-fluid stream. A comparison between the diffusion boundary layer, dynamic boundary layer and the results of photo visual study shows that there is a good conformity of numerical results and the photo visual study.

NOTATION

S_o - order of swirling
Q_t - capacity of tangential flow
Q_o - capacity of axis flow
u_p - velocity of admixture
u_g - velocity of gas phase
ρ_g - density of gas phase
ρ_p - density of admixture
χ - concentration of admixture
w_g - tangential velocity of gas phase
w_p - tangential velocity of admixture

1 INTRODUCTION

When spraying liquids in free air, because of carrying away some particles in the motion, a two phase jet stream is formed [1]. This two phase stream has high initial concentration and comparatively large unevenness as regards the diameter of formed drops [2]. Because of these conditions, it's necessary to use photo visual methods of study in order to determine the diffusion jet border and approximate average massiveness of particles. On the other side, to realize a numerical model of the stream according to the mentioned above conditions, it's difficult to use methods of direct numerical
solution of equation of motion and apply some of usual models of turbulence about two phase jets [3,4,5]. Some models developed on the basis of
integral method [4], give steady solution of these problems. Using this method, one needs less information about the stream and no limits regarding the values of initial concentration and massiveness of particles.

2 BASIS OF THE NUMERICAL MODEL

In the present work, a stream formed in spraying device of centrifugal-jet type, is discussed [6]. As a result of interactions in device camera of axis and tangential streams, at the exit a swirling jet is formed. By regulating the relation of tangential and axis given fluid, it's possible to realize a stream with different initial order of swirling. The last is determined [7] by the following connection between the order of swirling S_0 and the initial relation of capacities $G_0 = Q_t/Q_o$.

$$S_0 = \frac{G_0/2}{1 - \left(G_0/2\right)^2} \tag{1}$$

The numerical stream model has been worked out on the basis of so called two fluid stream [8], exist two different velocity fields of phase's i. e. $\vec{V}_p \neq \vec{V}_g$. This imposes equivalent writing of the corresponding equations. The system of integral conditions, which describes a two phase swirling jet, is of the kind:

$$\frac{\partial}{\partial x}\int_0^\infty \rho_g \chi u_p r dr = 0 \tag{2}$$

$$\frac{\partial}{\partial x}\int_0^\infty \left[\rho_g u_g^2 + p\right] r dr + \frac{\partial}{\partial x}\int_0^\infty \rho_p u_p^2 r dr = 0 \tag{3}$$

$$\frac{\partial}{\partial x}\int_0^\infty \rho_g u_g w_g r^2 dr + \frac{\partial}{\partial x}\int_0^\infty \rho_p u_p w_p r^2 dr = 0 \tag{4}$$

$$\frac{\partial}{\partial x}\int_0^\infty r_g u_g^3 r dr + 2\int_0^\infty u_g \frac{\partial (pr)}{\partial x} dr = -2\int_0^\infty r_g n_{tg}\left(\frac{\partial u_g}{\partial r}\right)^2 r dr - 2\int_0^\infty u_g F_x r dr \quad (5)$$

$$\frac{\partial}{\partial x}\int_0^\infty \rho_p u_p^3 r dr = -2\int_0^\infty \rho_p \nu_{tp}\left(\frac{\partial u_p}{\partial r}\right)^2 r dr + 2\int_0^\infty u_p F_x r dr \quad (6)$$

$$\frac{\partial}{\partial x}\int_0^\infty u_p \chi^2 r dr = -2\int_0^\infty \rho_g r \frac{\nu_{tp}}{Sc_t}\left(\frac{\partial \chi}{\partial r}\right)^2 dr \quad (7)$$

$$\frac{\partial p}{\partial r} = \rho_g \frac{w_g^2}{r} \quad (8)$$

$$l_u = Sc_t l_p \quad ; R_u = Sc_t R_p \quad (9)$$

Equation (2) gives keeping the admixture contains. Equations (3) and (4) describe the total quantity and moment of quantity of motion. They are discussed as common to the two fluid stream because it's formed under the action of dispersed fluid jet. This means that its quantity of motion and initial moment redistribute between the two phases along the length of stream. Equations (5 ÷ 6) are about the kinetic energy of phases, and equation (7) is an integral condition of higher order. Differential equation (8) gives the connection between the pressure and tangential velocity. With the help of Sihmidt's turbulent number Sc_t one view the relation between dynamic and diffusion boundary layers. By analogy with [7], about the dimensionless cross distribution of velocity and pressure we accept:

$$\frac{u}{u_m} = exp\left(-K_u \eta^2\right); \qquad \frac{\chi}{\chi_m} = exp\left(-K_\chi \eta^2\right);$$

$$\frac{w}{w_m} = C\eta + D\eta^2 + E\eta^3 \; ; \frac{p_\infty - p}{p_\infty - p_{at}} = exp\left(-K_p \eta^2\right);$$

for $\eta = \frac{r}{x}, \quad k_\chi = Sc_t k_u$

The resistant force F_a and the force of own weight F_g are accepted as basic for he in-phase interaction. Turbulent viscosity is modeled by a modification of Schetz's model reading the influence of concentration and diameters of particles. The following system of equations is a result of solution, revision and doing dimensionlessness about the initial parameters:

$$A_5 \chi_m \bar{u}_{pm} \bar{x}^2 = G_1$$

$$A_1 \bar{u}_{gm}^2 \bar{x}^2 - B_1 \bar{p}_m x^2 + A_3 \bar{u}_{pm}^2 \chi_m \bar{x}^2 = I_1$$

$$\bar{p}_m = A_{66} \bar{w}_{gm}^2 + B_{66} \chi_m \bar{w}_{pm}^2$$

$$A_2 \bar{u}_{gm} \bar{w}_{gm} \bar{x}^3 + A_4 \chi_m \bar{u}_{pm} \bar{w}_{pm} \bar{x}^3 = M_1$$

$$\frac{\partial}{\partial x}\left[A_6 \chi_m^2 \bar{u}_{pm} \bar{x}^2\right] = -B_7 \chi_m^2 \bar{u}_{pm} \bar{R}_u \quad (10)$$

$$\frac{\partial}{\partial x}\left[A_8 \bar{u}_{gm}^3 \bar{x}^2\right] - B_8 \bar{u}_{gm} \frac{\partial}{\partial x}\left(\bar{p}_m \bar{x}^2\right) = -C_8 \bar{u}_{gm}^3 \bar{R}_u - D_8 \chi_m \bar{u}_{gm}\left(\bar{u}_{gm} - \bar{u}_{pm}\right)^2 \bar{x}^2$$

$$\frac{\partial}{\partial x}\left[A_9 \bar{u}_{pm}^3 \chi_m \bar{x}^2\right] = -C_9 \bar{u}_{pm}^3 \chi_m \bar{R}_u + D_8 \chi_m \bar{u}_{pm}\left(\bar{u}_{gm} - \bar{u}_{pm}\right)^2 \bar{x}^2$$

$$\bar{R}_p = \bar{R}_u / Sc_t$$

$$\bar{u}_{gm} = \bar{R}_u \bar{w}_{gm}$$

The last equation gives additional connection between components u and w of the gas phase. In system (10), A_{ij} means the values of integrals, obtained by the mentioned resemblance. Index m marks the maximum value of a section.

3 RESULTS

System (10) is numerically solved when given the following initial conditions: admixture concentration, average diameter of particles, order of swirling, initial velocities. As a result of solution one obtains the fading of maximum values of velocity components about the corresponding section of the two phases u_m and w_m, pressure p_m, concentration χ and borders of diffusion R_p and dynamic boundary layers R_u. Velocity components fading of two phases is shown in Fig. 1a, b according to the initial order of swirling when concentration is $\chi = 800$.

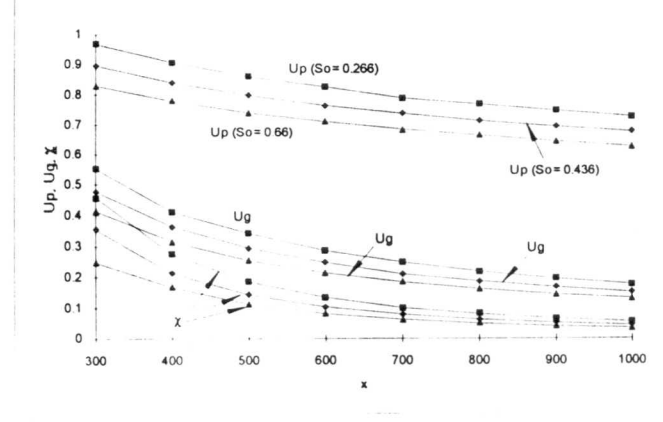

Fig.1. Variation of velocities due to swirling

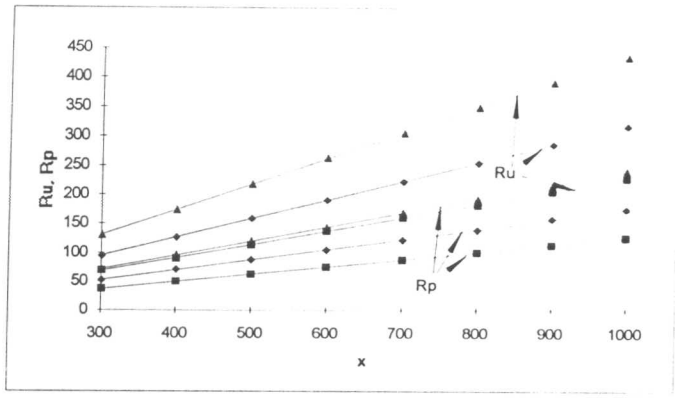

Fig. 1 Variation of boundary layer due to swirling

The results of photo visual study about three orders of swirling is shown on Fig. 2, 3 and 4. From this photos we can make a comparison between the diffusion boundary layer R_p, dynamic boundary layers R_u and the results from the numerical solution.

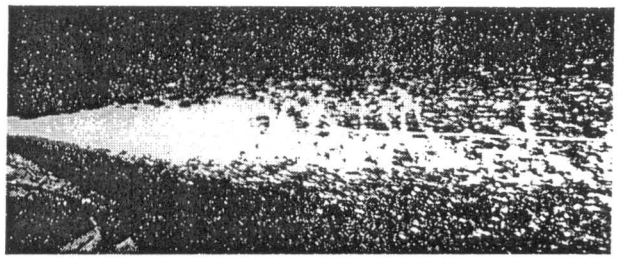

Fig. 2. D_p=150 μm, χ= 800, S_0=0.266

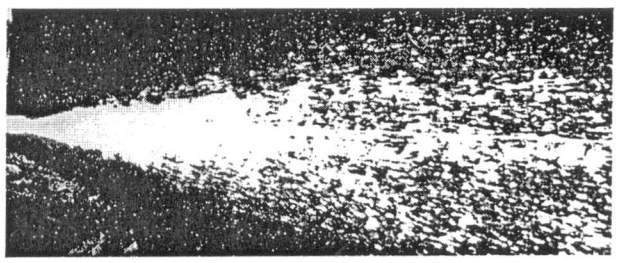

Fig. 3. D_p=150 μm, χ= 800, S_0=0.436

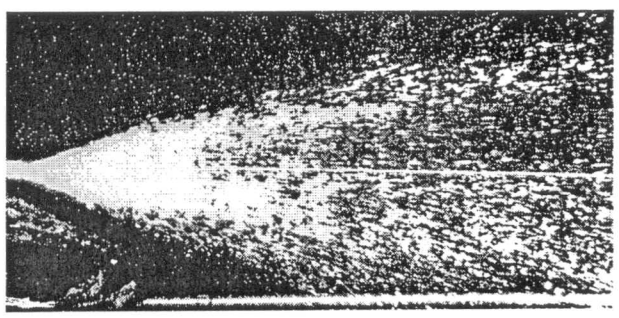

Fig. 4. D_p=150 μm, χ= 800, S_0=0.66

As the diffusion boundary layer is the only quantity that can be determined almost precisely by photographing with fast-speed camera on dark background, then according to the conformity with the results of numerical experiment one can judge about preciseness of the model.

Determine the velocity distribution with present technique is quite difficult because of high concentration of admixture and their changing massiveness when spraying out. The comparison helps to accept that when there is a good conformity of numerical result about R_p and the one photo visual study, the preciseness of numerical model is satisfying and it helps to make a quick and acceptable analysis of complex jet streams.

The work is financed by fund "Science Study" of Ministry of Education of Bulgaria - No TH - 182.

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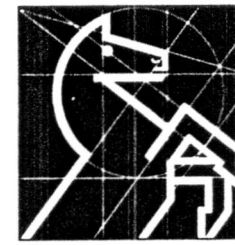

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26 March 1993

Dear Mr Antonov,

Second international seminar on *Optical Methods and Data Processing in Heat and Fluid Flow*, City University, London, UK, 14-15 April 1994

I enclose a copy of the 'First Announcement and Call for Papers' for the above seminar which is being organised by the Institution of Mechanical Engineers. I believe you will find this event of interest as many advances have taken place in optical techniques for heat and fluid flow measurement since IMechE's first seminar on the topic in 1992. *Optical Methods and Data Processing in Heat and Fluid Flow* will be an international forum for reviewing the latest developments and innovative new approaches and will be a meeting point for both industrialists and academics. As before the emphasis will be on developments which have application in industrial environments.

I hope you will decide to contribute to *Optical Methods and Data Processing in Heat and Fluid Flow* by submitting a paper. You will see that a 200 word synopsis should be returned to IMechE with the reply form by Friday 28 May 1993. Selected papers will be considered for publication in the Proceedings of the Institution of Mechanical Engineers.

If you would be interested in attending the event as a delegate or taking table-top exhibition space please also complete and return the reply form. For further copies of the 'First Announcement and Call for Papers' please contact either myself or Corinne Paine on the direct dial number of 071 973 1281 or by fax on 071 222 9881.

I look forward to hearing from you shortly.

Yours sincerely

A J Richards

Amanda Richards (Miss)
CONFERENCE EXECUTIVE

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Assoc. Prof. I S Antonov
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Technical University of Sofia
1756 Sofia
Bulgaria

11 October 1993

Dear Professor Antonov

Optical Methods and Data Processing in Heat and Fluid Flow
City University, 14 - 15 April 1994

Thank you for submitting the synopses:

Field Analysis of a Swirling Dispersed Jet

Numerical and Experimental modeling of Interaction between a Turbulent jet Flow and an Inlet

Firstly, please accept my apologies for the delay in contacting you.

The Organising Committee read your synopses with great interest and feel that they would make a very valuable contribution to this event. However, they would like you, if possible to combine elements from both synopses into one paper. Could you discuss this with your colleagues and let me know the outcome of your discussions.

In the meantime, I enclose leaflets explaining our requirements for the layout of your paper, which should reach me, together with two A4 photocopies, by **22 November 1993**. (The original deadline was Friday, 15th October. Obviously due to the delay in contacting you, it has been necessary for me to extend this until just before the next Organising Committee meeting).

The text should be approximately 2000 words, with up to 6 illustrations. Could you please complete the enclosed "Manuscript Submission Form" and return it to me immediately. All papers will be reviewed by the Organising Committee and final acceptance will be based upon this review.

If accepted, authors will be expected to attend the Conference to present their papers. Unfortunately, the Institution is unable to undertake to defray author's expenses, except to grant complimentary registration for the day of presentation to one author per paper.

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1st December 1993

Professor I S Antonov
Reader
Technical University of Sofia
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SOFIA
1756 Bulgaria

Dear Professor Antonov

Optical Methods and Data Processing in Heat and Fluid Flow
14 - 15 April 1994
City University, London

Title: Field analysis of a swirling dispersed jet

Aksed to combine with 24 but author did not think possible

Thank you for submitting your paper for this event.

The Organising Committee will now review your work and meet to discuss the papers received. I will contact you when the programme has been drafted and final decisions made on the papers submitted.

At this point, I will also send you any comments or points which have been raised when the paper was reviewed. As mentioned in the 'Call for Papers', I will need to receive the final manuscript in Januaary.

If you have any queries, or I can be of any assistance please do not hesitate to contact me.

Yours sincerely

Babs Howd
Conference Papers Executive

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6th January 1994

Professor I S Antonov
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1756 Bulgaria

Dear Professor Antonov

Optical Methods and Data Processing in Heat and Fluid Flow
14 - 15 April 1994
City University, London

Title: Field analysis of a swirling dispersed jet

I am pleased to be able to inform you that your paper has been accepted unconditionally for presentation at the above Seminar.

If you have not already submitted a final manuscript please ensure that it is either be printed on A4 paper using a laser printer, OR on the special CRC paper mentioned in the 'Instructions to Authors for Preparing CRC' leaflet. If you would like me to send you CRC paper, please let me know. Could you ensure that I receive your complete text and illustrations, together with two photocopies, no later than Monday, 24th January 1994.

Subject to you meeting the above requirements, we hereby confirm inclusion of your paper in the Seminar Programme. We will be contacting you closer to the Seminar with details of registration, scheduling of presentation, etc.

Yours sincerely

Babs Howd
Conference Papers Executive

I look forward to hearing from you in the near future. If you have any queries, or I can be of any further assistance, please do not hesitate to contact me on the telephone number quoted below.

Yours sincerely

Babs Howd
Conference Papers Executive

Direct Dial 071 973 1263