Project coordinator: Fernanda A.R. Oliveira

Third Main Meeting

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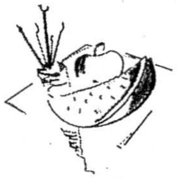

PROCESS OPTIMIZATION AND MINIMAL PROCESSING OF FOODS

Contract CIPA - CT94 - 0195
COPERNICUS PROGRAMME

ESCOLA SUPERIOR DE BIOTECNOLOGIA
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Minimal & Combined Processes

P1.9/L - Development of Perforation Mediated Modified Atmosphere Packing for Fresh Cut Vegetables - S. C. DA FONSECA and F.A.R. Oliveira, Escola Superior de Biotecnologia, Porto, Portugal

P3.2/P - Combined Treatments using Bacteriocins for Inhibition of Growth of *Listeria monocytogenes* - J. FARKAS, University of Horticulture and Food Industry, Budapest, Hungary

P6/SC - High Oxygen-Modified Atmosphere Packaging, a Novel Approach with Minimally Processed Vegetables - L.G.M. Gorris and A. AMANATIDOU, Institut voor Agrotechnologish Onderzoek, Wageningen, The Netherlands

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P11.5/P - Application of Hydrodynamic Cavitation for Purification of Water-Alcohol Solutions - M. ANGELOV, Higher Institute of Food & Flavour Industries, Plovdiv, Bulgaria

P11.6/P - Research on the Rheological Properties of the Melted Product During Wheat and Maize Semolina Extrusion Through Rectangular Dies - A. LAMBREV, Higher Institute of Food & Flavour Industries, Plovdiv, Bulgaria

P12.2/P - Optimisation of Pre-Cooking and Extension of Shelf-Life for Sous Vide Cooked Meat - M. Voldrich and T. MARTENS, Alma University Restaurants VWZ, Leuven, Belgium

P12.3/P - The use of Lactic Acid and Lactates in the Mechanically Deboned Poultry - P. Pipek, J. BRYCHTA and J. Jelenikova[1]

P12.4/P - Active Packing - Immobilisation of Preservatives on/in PPacking Materials - J. Dobias, M. VOLDRICH, M. Marek and M. Cerovsky, Institute of Chemical Technology, Praha, Czech Republic

Computational Modelling of Flow in a Cavitator

M. S. Angelov

In many processing equipment the cavitation is an injurious phenomenon, but over the last years this phenomenon was found to have an useful application. In the food industry the hydrodynamic cavitation is utilised for the purification of alcohol solutions and liquid foods, to produce suspensions and in fine grinding of bioproducts and medicines. Flow through passages with a specific shape are used to achieve the phenomenon of hydrodynamic cavitation with minimum consumption of energy. The application of computational modelling to the flow of a liquid fluid product through a cavitator with a specific geometry is the main objective of the present paper. To model the turbulent characteristies of the flow, the k-e model of turbulence (Launder - Sharma model) was applied. The calculations were performed with the non-orthogonal finite-volume procedure "STREAM". The flow around a step with a different angle of incidence of the opposite wall was analysed as a case-study. The flow in this cavitator was characterised by the existence of two circulation zones. Being the circulation zone closest to the step of great importance for the intensification of the exchange processes. The results show the general and turbulent characteristics of the flow upon change of the flow on the cavitator. The influence of the geometry of the cavitator on the flow characteristics energy and the dissipation rate, is also discussed.

P11.4/P
Minimal & Combined Processes

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COMPUTATIONAL MODELING OF FLOW IN A CAVITATOR

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ABSTRACT

In a row of technical equipment the cavitation is an injurious phenomenon. Over the last years a new application of this phenomenon has been observed as useful. In food industry the hydrodynamic cavitation is utilized as a useful phenomenon in the process of purification of alcohol solutions, liquid food staff, to produce suspensions, in fine grinding of bio-products and medicines. Passing passages with a specific form are used to achieve the phenomenon of hydrodynamic cavitation. Their form is constructed in a way that allows cavitation development and minimum consumption of energy. The possibility of computational modeling of the flow in a cavitator of a specific form is the main point of the present paper. The cavitator is used for cavitation treatment of liquid food products. To model the turbulent character of the flow, the **k-ε** model of turbulence (Launder - Sharma model) was applied. The present calculations were performed with the non-orthogonal finite-volume procedure **STREAM.** As a test case was used the flow around a step with a different angle of incidence of the opposite wall. The flow in the studied cavitator was characterized by the existence of two circulation zones. Of great importance for the intensification of the exchange processes is the circulation zone closest to the step. The results are the basic, general and turbulent characteristics of the flow upon change of the flow of the passing passage. The opportunity of optimization of the form of the cavitator was shown: through alteration of the basic turbulent characteristics - the kinetic turbulent energy and the dissipation rate. The results of the computational modeling show the possibility for model investigation of complex turbulent flows, which replaces the highly expensive experimental tests.

NOMENCLATURE

- C_1, C_2 , C_μ - empirical constant appearing in k-e turbulence model;
- k - turbulence kinetic energy
- R_T - Reynolds number of turbulence
- ε- rate of dissipation of turbulence kinetic energy;
- μ - dynamic viscosity
- ν - kinematic viscosity
- ρ- density
- x - Cartesian coordinate in the main flow direction
- y - Cartesian coordinate normal to the wall
- u - streamwise velocity
- v - cross stream velocity

1. INTRODUCTION

Passing passages with a specific form are used to achieve the phenomenon of hydrodynamic cavitation. Their form is constructed in a way that allows cavitation development and minimum consumption of energy. The possibility of computational modeling of the flow in a cavitator of a specific form is the main point of the present paper. Separation, recirculation and reattachment are features encountered in numerous practical situation such as the cavitator. Recirculation has profound consequences in relation to pressure recovery, pressure drag, wall friction and heat transfer characteristics. It is also a powerful generator of turbulence and hence mixing and losses. Separated flows have thus naturally been the subject of many studies, both experimental and computational (Eaton J.K., Johnston J. P., 1980). The general emphasis has been on understanding and capturing the separation process, on resolving the structure of the separated shear layer and the recirculated zone it envelops, on describing the location of reattachment region and predicting the process governing the flow recovery in the wake region following the reattachment.

2. MODEL OF TURBULENCE

In the last few years a number of models of turbulent momentum transport have been developed in which the effective transport coefficients are related to local values of certain turbulent correlations. These correlations are computed simultaneously with the main field variables. In order to provide prediction of the flow within the viscous layer adjacent to the wall the following set of equations was considered (Jones W.P., Launder B.E., 1972). To model the turbulent character of the flow, the energy-dissipation model - k-ε model - of turbulence (Launder B, Sharma L. 1974) was applied.

The equation for the turbulence energy:

$$\rho\frac{Dk}{\partial t}=\frac{\partial}{\partial y}\left[\left(\mu+\frac{\mu_T}{\sigma_k}\right)\frac{\partial k}{\partial y}\right]+\mu_T\left(\frac{\partial u}{\partial y}\right)^2-\rho\varepsilon-2\mu\left(\frac{\partial k^{1/2}}{\partial y}\right)^2 \tag{1}$$

The equation for the energy dissipation:

$$\rho\frac{D\varepsilon}{\partial t}=\frac{\partial}{\partial y}\left[\left(\mu+\frac{\mu_T}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial y}\right]+c_1\frac{\varepsilon}{k}\mu_T\left[\left(\frac{\partial u}{\partial y}\right)+\right]-c_2\rho\frac{\varepsilon^2}{k}+2.0\mu\mu_T\left(\frac{\partial u}{\partial y}\right) \tag{2}$$

Turbulent viscosity hypothesis

$$\mu_t=c_\mu\rho k^2/\varepsilon \tag{3}$$

and $R_t=\rho k^2/\mu\varepsilon$, the turbulent Reynolds number.

At the low Reynolds number C_{μ} and C_2 become dependent upon the value of the turbulence Reynolds number. The influence of Reynolds number is introduced by the way of the functions which are assigned the following forms:

$$c_{\mu} = 0.09 \exp\left[-3.4/(1+R_T/50)^2\right]$$

$$c_2 = 1.92\left[1 - 0.3\exp\left(-R_T^2\right)\right]$$

In the above equations the C's and σ's retain the following values:

$c = 1.44; \sigma_k = 1.0; \sigma_{\varepsilon} = 1.3.$

The present calculations were performed with the non-orthogonal finite-volume procedure STREAM developed by Lien and Leschziner (Lien F. and Leschziner M., 1994). This method adopts the high order QUICK approximation and the MUSCL/TVD scheme to approximate advective volume-face fluxes. The solution is iterated to the steady state by means of pressure-correction scheme. The numerical grid used to obtain the solution contained 61x41 grid lines. This density was selected on the bases of grid-independence tests. The grid was arranged to cover a domain from 24 steps heights and additional transverse lines were arranged so as to give preferential support to the separated flow in the two zones. The grid is shown in Fig. 1. and also identify the geometry of the flow domain.

The solution was assumed to have converged when the maximum residuals for mass and momentum normalized by the respective inlet fluxes fell below 0.1 %. To achieve this state with the grid given above required between 2500 and 3000 iteration. Execution times varied between 15 and 20 CPU minutes on a Intel Pentium processor.

As a test case was used the flow around a step with a different angle of incidence of the opposite wall.

3. RESULTS AND DISCUSIONS

The flow in the studied cavitator was characterized by the existence of two circulation zones. Of great importance for the intensification of the exchange processes is the circulation zone closest to the step. The results are the basic, general and turbulent characteristics of the flow upon change of the flow of the passing passage.

We chose different, but typical sections for analysis the characteristics of the flow. One section is close to input (x=0.020), the second is close to the step (x=0.046), where the flow is separated. The next sections characterized the two circulation zones (x=0.067, x=0.075), the section close to the reattachment (x=0.154) point and fully developed flow (x=0.209).

The velocity distribution as a vector is shown in fig.2. The profiles of the velocity down the stream is shown in fig. 3 and cross stream velocity distribution in fig. 4. The distribution of the kinetic energy is shown in fig. 5 and the distribution of the energy dissipation rate is shown in fig. 6. We can receive information concerning the circulation zone and attachment points analyzing these figures.

The opportunity of optimization of the form of the cavitator was shown: through alteration of the basic turbulent characteristics - the kinetic turbulent energy and the dissipation rate. The results of the computational modeling show the possibility for model investigation of complex turbulent flows, which replaces the highly expensive experimental tests. The future plans of investigation are to use more complicated turbulence models (non-linear) for predicting the flow in the cavitator.

ACKNOWLEGMENTS

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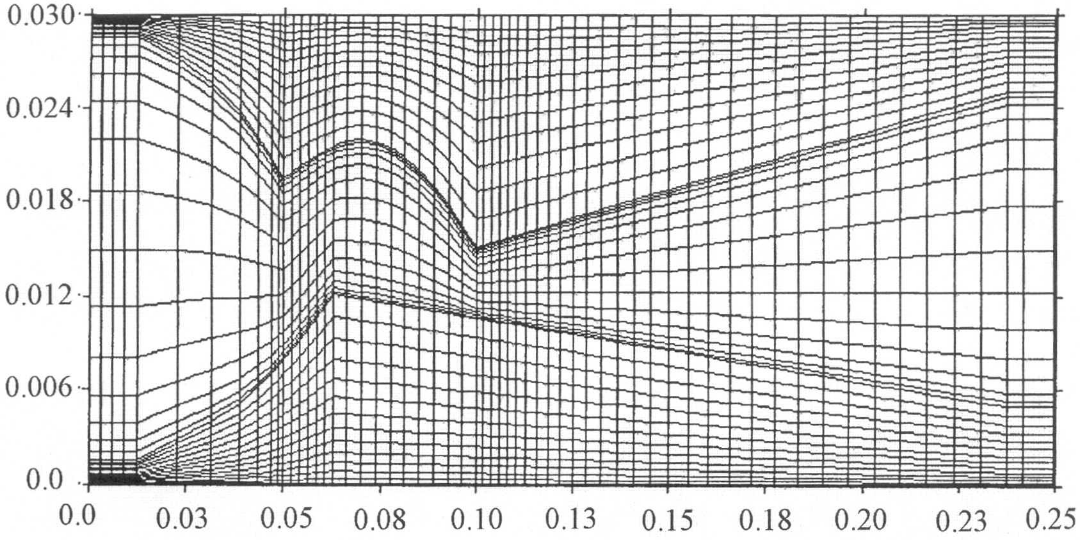

FIGURE 1. The calculation grid

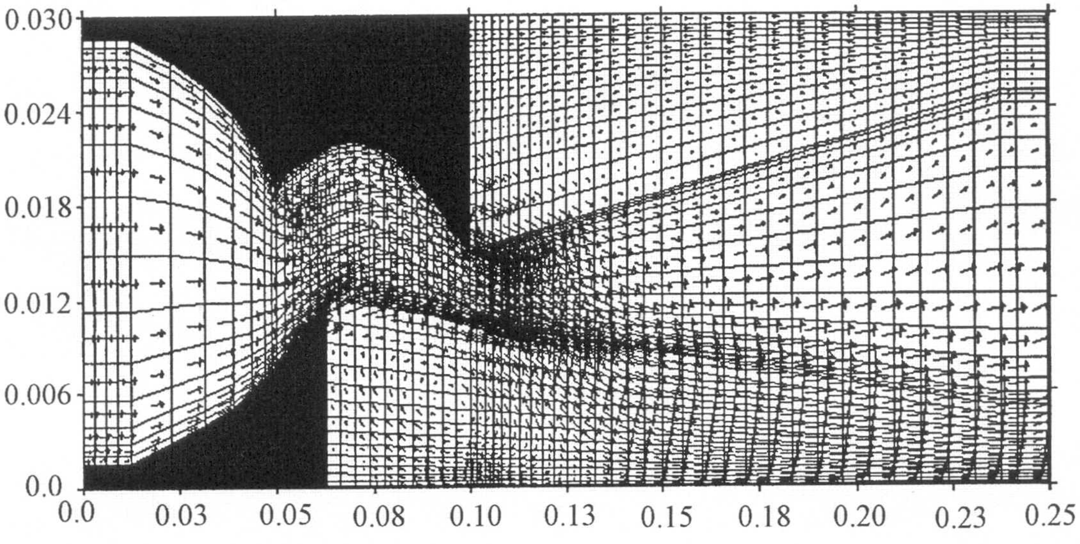

FIGURE 2. Velocity distribution as a vector

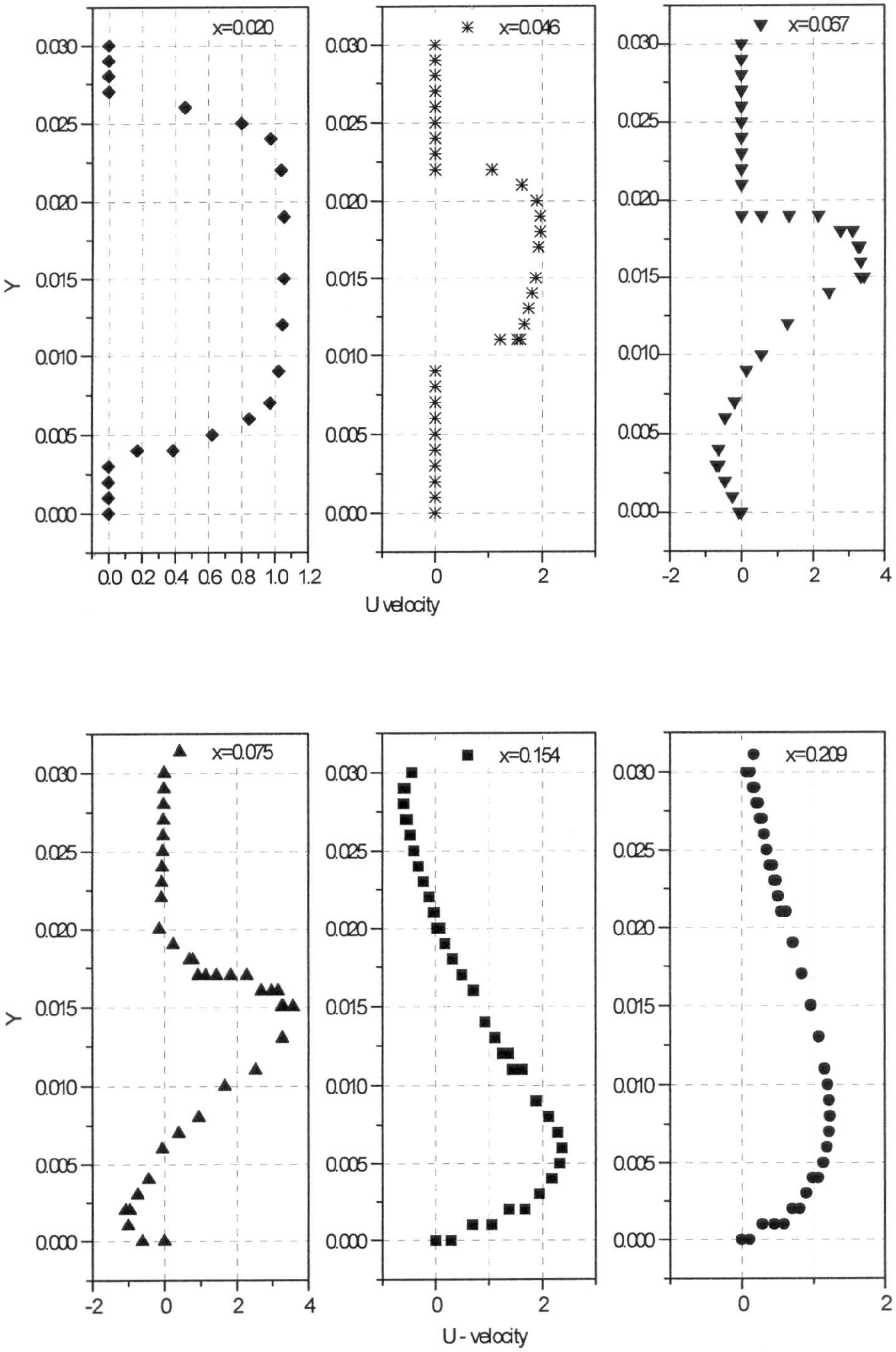

FIGURE 3. The profiles of the velocity down the stream

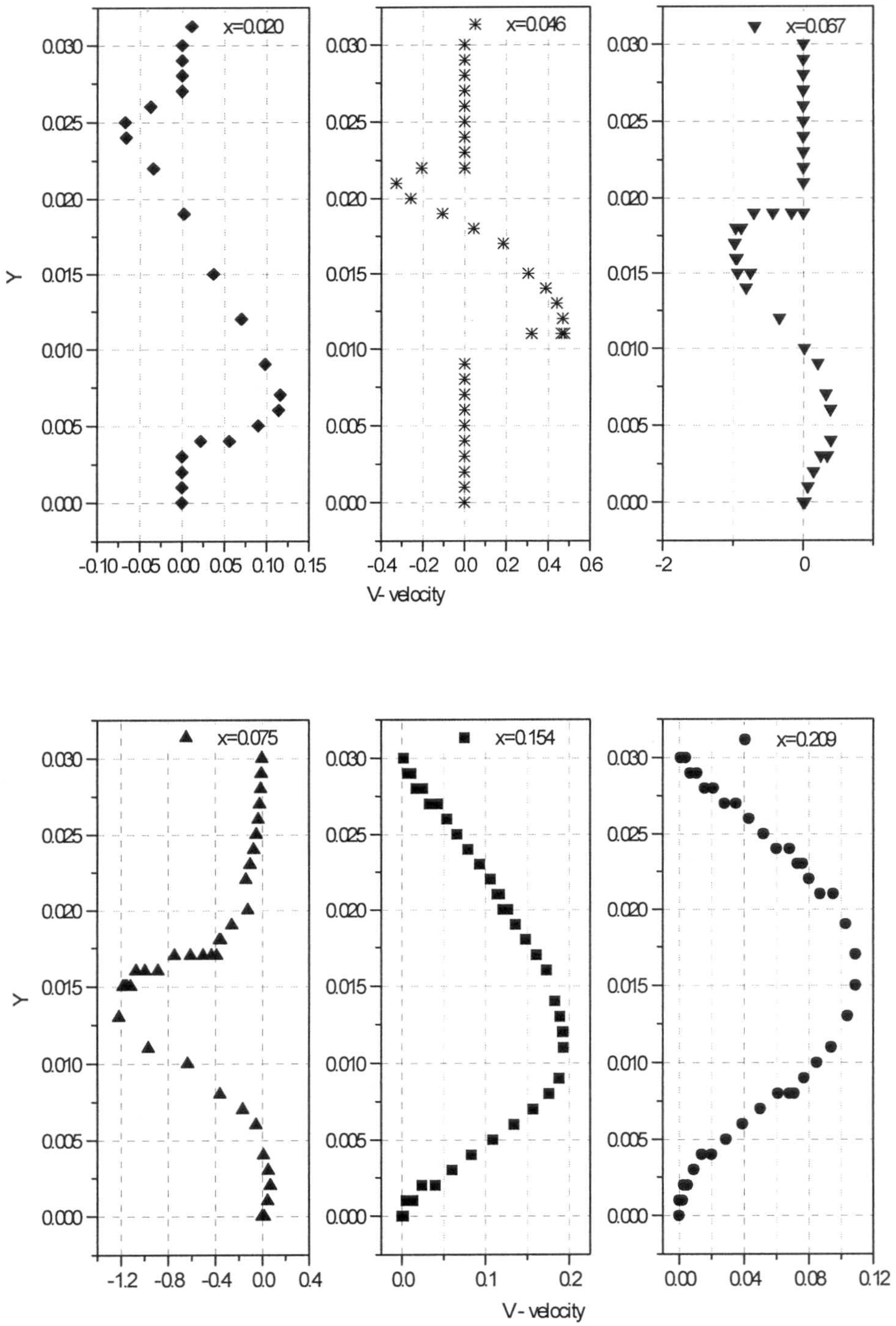

FIGURE 4. Cross stream velocity distribution

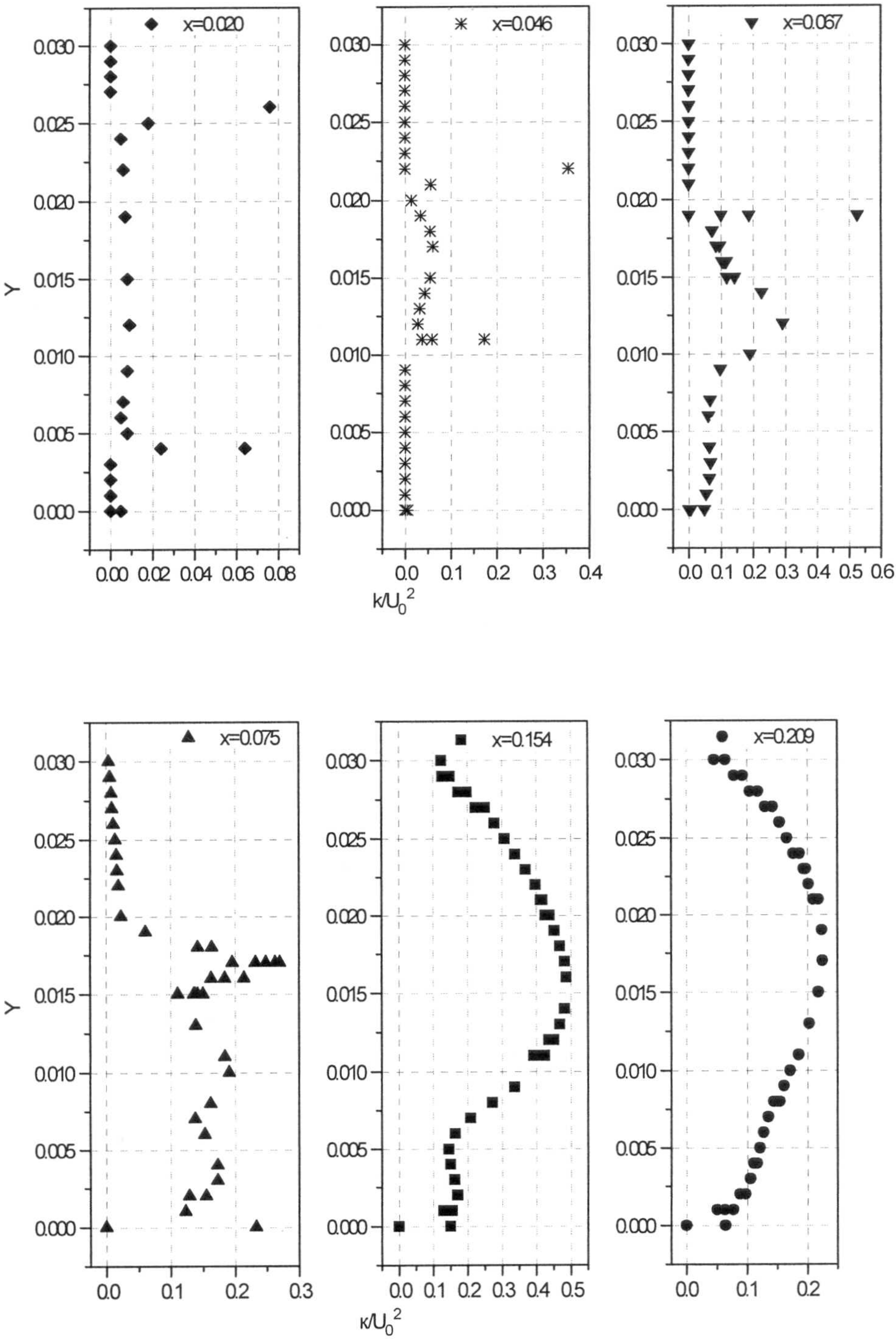

FIGURE 5. Distribution of the kinetic energy

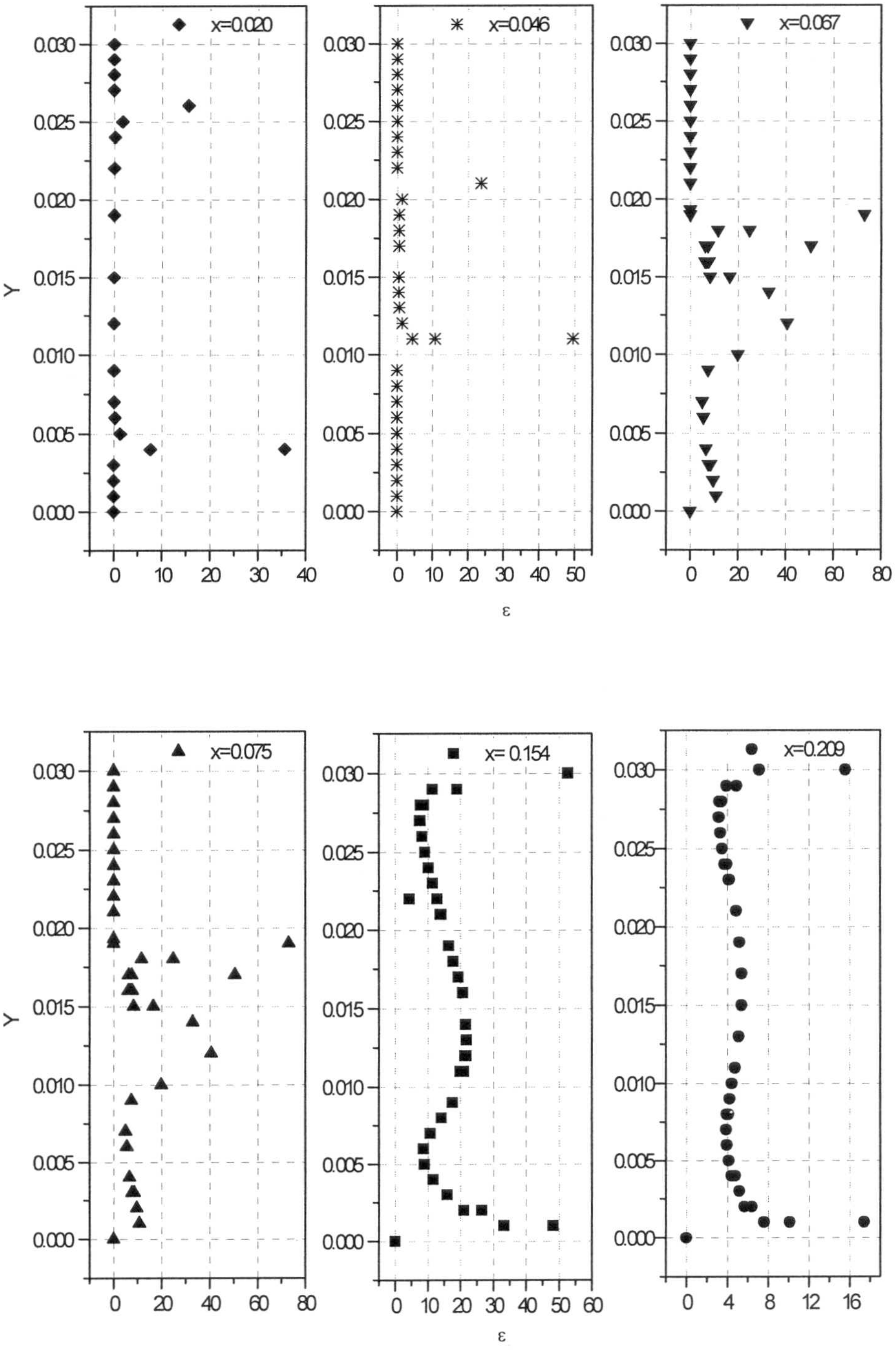

FIGURE 6. Distribution of the energy dissipation rate