The analysis of experiments and calculations for determination of turbulent mixing intensity on the basis of turbulent mixing model of diffusion type

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The paper presents the analysis and comparison of known experimental and calculation (direct numerical simulation) results of investigation of gravitational turbulent mixing from the common positions on the basis of semi-empirical turbulent mixing model of diffusive type. In the process of analysis the value of mixing constant α_1 was determined, which describes intensity of light substance penetration into heavy. Unfortunately, a scatter in determination of α_1 remains significant. Uncertainty in value α_1 by most of experimental and calculation results is $\alpha_1 = 0.02 \div 0.08$.

Introduction

The first theoretical consideration of turbulent mixing (TM) at the interface of substances within the gravity field [1] lead to the following analytical dependence

$$L = \tilde{\alpha} g t^2 \ln n, \tag{1}$$

which is applicable at $1 \le n = \rho_1/\rho_2 \le 4$, where g - constant acceleration, ρ_1/ρ_2 - ratio of densities of heavy substance (ρ_1) to light one (ρ_2), t - time, $\tilde{\alpha}$ - empirical constant, L – full width of turbulent mixing area.

Formula (1) was specified in paper [2]:

$$L = a\,Agt^2, \tag{2}$$

where $A=(\rho_1-\rho_2)/(\rho_1+\rho_2)$ is Atwood number.

Further Youngs [3] noted that mixing develops asymmetrically and the following formula was used when processing experiments:

$$L_1 = a_1 Agt^2, \tag{3}$$

where L_1 - width towards heavy substance, which is determined by emerging bubbles of light substance.

In spite of multiple experimental papers [4-25], no full agreement was obtained on determination of turbulent mixing constant. Spread in values remains rather considerable. At that comparison of results is complicated by the fact that experimenters process experiments in different manners: in most cases they measure depth of light substance penetration into heavy one [7-15, 20-24] (a_1 is determined correspondingly) or full width of TM area [4-6,16-19,25] (a is determined).

Thus, from one hand, in most experiments [3, 8, 14, 15, 20-23] for incompressible fluids they got $\alpha_1 = 0.05 \div 0.08$. From the other hand, in [16-19] for gases interface mixed under action of decelerating shock wave the value $a = 0.32 \pm 0.04$ is provided.

3D numerical simulation did not provide final clarity: in a number of cases the experimental and calculation values of mixing intensity differ rather considerably, and spread of the calculation values obtained by different techniques remains considerable as well. Thus, Youngs [26] determined $\alpha_1 = 0.03 \div 0.04$ by computational calculations, that lies beyond the above indicated interval of values determined in experiments [20, 21]. The calculations conducted in VNIITF [27] provide value $a_1 = 0.07$. The calculations performed in VNIIEF [28, 29] determine $\alpha_1 = 0.03 \div 0.055$.

Every time at international workshops on turbulent mixing problems the discussion arises about the value of turbulent mixing constant. And one should note that no single opining has obtained yet.

The aim of the given investigation is to analyze and compare in a common manner the published results of the latest papers in the belief to reduce spread in determination of this constant. At that, for the sake of uniformity we will consider value a_1. Together with simple test problems the paper uses experimental material of the experiments, in which complex non-self-similar conditions were implemented. Due to availability of exact solution these complex flows could be processed and constant a_1 could be determined from them.

At first the experimental results are analyzed for incompressible fluids. The three cases are considered: 1) self-similar problem with mixing of two adjacent fluids with densities ρ_1 and ρ_2, being in gravitational field g, 2) the same problem, but the fluids are intersoluble, therefore the interface at the initial moment is fuzzy, 3) mixing of a layer of finite size placed into continuous medium of different density. For these three problems the experimental results are available, and within the frameworks of lv-model the exact analytical solutions are constructed that allows to determine the value of constant a_1.

And a number of experiments with compressible gases were processed as well. The results of 3D numerical simulation of turbulent mixing were analyzed.

Unfortunately, we did not manage to completely reduce spread in determination of a_1. The main difference remains between the results of A.M.Vasilenko, obtained for gases, and the results of other investigators who studied mixing of fluids.

§1. Determination of turbulent mixing constant α_1

Specification of formula (3), which demonstrates nonlinear dependence on Atwood number, was given in paper [35]:

$$L_1 = a_1\left(1 + 0.25A^2\right)Agt^2 . \qquad (4)$$

To compare the results of various investigators one should take into account asymmetrical character of turbulent mixing at the interface. We assume that a measure of asymmetry is determined by formula [35]:

$$\frac{L_2}{L_1} = \left(1 + A\right)^{0.45} = \sqrt{\beta_2} , \qquad (5)$$

where L_2 - turbulent mixing width towards light substance.

To determine the relation between α and α_1 we use formulas (4) and (5), at that we are to pass from L_1 to full width L

$$L = L_1 + L_2 = \left(1 + (1+A)^{0.45}\right) L_1 = \alpha_1 \left(1 + (1+A)^{0.45}\right)\left(1 + 0.25A^2\right) Agt^2 \qquad (6)$$

In case when working acceleration *g(t)* is not constant, in [3] formula (3) takes the form

$$L_1 = 2a_1 AS\,, \qquad (7)$$

where $S = \frac{1}{2}\left(\int \sqrt{g}\,dt\right)^2$ (in case of constant acceleration $S = \frac{gt^2}{2}$).

It is known [34] that in case of considerable influence of initial data one should perform processing in variables $\sqrt{L}$ and $\sqrt{S}$:

$$\sqrt{L} = \sqrt{L_0} + \sqrt{2\alpha AS}\,, \qquad (8)$$

where L_0 - initial roughness.

Therefore everywhere, where possible, we will process the results of the experiments, where light substance penetration is determined, with use of formula

$$\sqrt{L_1} = \sqrt{L_{01}} + \sqrt{2\alpha_1 A(1 + 0.25A^2)S}\,. \qquad (9)$$

For the experiments, where the full width of mixing area is determined

$$\sqrt{L} = \sqrt{L_0} + \sqrt{2\alpha_1 (1 + (1+A)^{0.45})(1 + 0.25A^2)S}\,. \qquad (10)$$

§2. Turbulent mixing of incompressible fluids in case of constant acceleration

The first determination of mixing constant was provided by Belenkiy and Fradkin [1] by recalculation of the constant determined in the experiments on shear mixing (in formula (1) $\tilde{\alpha} \approx \left[0.06 \div 0.15\right]$), at that a considerable spread was revealed in determination of constant α among the experiments.

By virtue of specific character of turbulent mixing taking place under action of constant acceleration, the special experiments were conducted in order to determine constant α (or α_1).

The first experiments on measurement of α in Earth gravity field were conducted by a group of Alekseev Yu.F. [4,5] in 1956. The facility consisted on a container, in which water and copper vitriol solution was placed separated with a partition, at that a heavier fluid was above. Then the partition was pulled out. The authors of these experiments noted significant influence of viscosity.

In those years the experiments were conducted under leadership of Kikoin I.K. [6]. The authors tried to avoid influence of viscosity, therefore a container with different fluids was exposed to acceleration, which was (2-3)g_0 in the units of the Earth gravity field. They got rid of the partition by accelerating down the container with the interface initially stable in the Earth gravity field, in the result the system of fluids became unstable, and turbulent mixing was developed. However the absence of initial perturbations lead to delay in turbulent mixing development, and to get rid of this delay, one was to create the initial perturbations specially.

In the experiments conducted by Kucherenko Yu.A. et al. [7,8] the closed container containing light fluid poured over a heavy one was speed up down with compressible gas, in the result of which mixing was developed. As compared with experiments [6], considerable great accelerations are obtained here - $(10^2\text{-}10^4)g_0$. Random perturbation was specified at the interface by adding solid particles. Both full width of mixing area and the width by dimensionless density of light substance $\delta = \frac{\rho - \rho_2}{\rho_1 - \rho_2}$ within the limits from 0.01 to 0.98 were determined.

In the experiments described by Reed and Youngs [3,20,21], the initially container at rest with stable system of fluids was accelerated down with the help of rocket. In the experiments of Dimonti and Schneider [14,15] the container was accelerated in electromagnetic field.

In the experiments conducted by Meshkov E.E. et al. [22-24] the layer of fluid [22,24] retained in the channel by a plate, or gel [23], was accelerated by compressible gas [22] or by the explosion products of gas mixture [23]. In [24] acceleration was performed by gas compressed with a hard pistol driven by products of gas mixture detonation. Perturbations at the fluid surface were specified by adding solid particles. In the given experiments under great difference of densities the accelerations $10^2\text{-}10^5 g_0$ are obtained.

Here it would be interesting to note the results [24] – with growth g from $10^2 g_0$ to $10^3 g_0$ value α_1 grows from 0.015 to 0.14, further with growth of g up to $10^5 g_0$ values α_1 decrease down to 0.03. It is explained by the mixing character: under great accelerations the role of surface tension and viscosity decreases in TM development, that leads to formation of small bubbles. Under low accelerations surface tension and viscosity suppress development of small-scale structure of TM area, mainly big bubbles are developed, which grow faster than smaller ones, therefore velocity of gas penetration into fluid increases.

The results of the indicated experiments and their processing are presented in Table 1. One can note that for incompressible fluids the results are fit mainly within the range $\alpha_1 = 0.02 \div 0.07$. The results beyond this range can be most likely explained by the role of surface tension and viscosity and by the fact that the flow did not yet emerge to self-similar regime of mixing.

Table 1. Determination of value α_1 in experiments with fluids

Source	Density ratio $n = \rho_1/\rho_2$	Acceleration (here g_0=9.8m/s^2)	Obtained in experiments value α or α_1	Improved value α_1
Alekseev Yu.F. et al. [5]	1.19 ÷ 1.83	g_0	$\alpha = 0.24 \pm 0.08$ ($\alpha = 0.13 \pm 0.04$*)	$\alpha_1 = 0.04 \div 0.076$
Kikoin I.K.et al. [6]	1.44 ÷ 1.98	(2-3)g_0	$\alpha = 0.34 \pm 0.12$	$\alpha_1 = 0.1 \div 0.21$
Kucherenko Yu.A. et al. [8]	3; 20	$10^2 \div 10^4 g_0$	$\alpha_1 = 0.07 \pm 0.0025$ $\alpha_1 = 0.055 \pm 0.005$ (from 0.01 to 0.98)	$\alpha_1 = 0.056 \div 0.068$ $\alpha_1 = 0.047 \div 0.057$
Reed [20], Youngs [3]	1.6	(15-70)g_0	$\alpha_1 = 0.06 \div 0.07$	$\alpha_1 = 0.059 \div 0.069$
Youngs [21]	8.5-29.1		$\alpha_1 = 0.05 \div 0.077$	$\alpha_1 = 0.045 \div 0.065$
Dimonti, Schneider [14,15]	$1.37 \div 50$	(30-80)g_0	$\alpha_1 = 0.051 \pm 0.005$	$\alpha_1 = 0.037 \div 0.055$
Meshkov et al. [22,23]	50-60	$10^2 \div 10^4 g_0$	$\alpha_1 = 0.053 \div 0.126$ (increases as gas pressure increases)	$\alpha_1 = 0.043 \div 0.102$
Nevmerzhitsky et al.[24]	60	$10^2 \div 10^5 g_0$	- as g increase from $10^2 g_0$ to $10^3 g_0$ α_1 increases from 0.015 to 0.14 - then as g increases to $10^5 g_0$ α_1 decreases down to 0.03	- with increase of g from $10^2 g_0$ to $10^3 g_0$ α_1 increases from 0.012 to 0.11 - then as g increases to $10^5 g_0$ α_1 decreases down to 0.024

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* Processing of results of experiments in roots is made by Yakovlev V.G.

§3. Mixing of thin layer

Problem on mixing of fluid thin layer with another fluid surrounding it is interesting by the fact that at great times, when $\frac{L}{L_0} >> 1$ (where L_0 - initial width of thin layer), the linear law of development of mixing area width in time is established. In the experiments the coefficient of this dependence is determined, and in theory the dependence of this coefficient on model constants is established. The detailed statement of this problem can be found in [36]. Here we will limit ourselves with presenting the formula for asymptotic stage

$$\frac{L}{\sqrt{2sL_0}} = b\sqrt{\frac{\left|\rho^0 - \rho\right|}{\rho}}, \tag{11}$$

where ρ^0, L_0 - density and initial width of the layer placed into medium with density ρ. In the experiments of different authors [6,36,37] $b = 0.35 \div 0.63$ was obtained. Such dispersion is obviously connected with great uncertainty in determination of mixing front at great times. This problem was discussed in [36], where the experiments were processed [37], in which density distribution was measured in the mixing area.

For the other hand, within the frameworks of diffusion lv-model in approximation of piecewise-constant coefficient of diffusion [38] it is possible to obtains

$$\frac{dL}{d\sqrt{2sL_0}} = 2^{3/2}\alpha_m^2\pi\sqrt{\frac{1-e^{-\pi}}{\nu+\alpha_m^2\,\pi}}\sqrt{\frac{|\,\rho^0-\rho\,|}{\rho}} \quad , \tag{12}$$

where α_m, ν are the constants. Constant ν is determined from the condition of decelerating of turbulence at inoperative sources, which generate it [38].

$$\nu = 16\eta_1^2\alpha_m^2 \,, \quad где \quad \eta_1 = \frac{2}{\sqrt{\pi}} .$$

Comparison of (11) and (12) provides possibility to determine constant α_m, if we know *b*. At $b = 0.35 \div 0.63$ we obtain $\alpha_m = 0.195 \div 0.351$.

Value α_m in formula (11) can be connected with standard value α from (2) with relation [38]:

$$\alpha = 1.511\alpha_m^2 \ . \tag{13}$$

Thus, the experiments with the thin layer lead to the value

$$\alpha = 0.0574 \div 0.186 .$$

Accounting formulas (2) and (6), for density ratio from [6,36,37] we obtain

$$\alpha_1 = 0.025 \div 0.08 .$$

Unfortunately, such great dissipation in determination of α_1 does not provide any new, except that all the previous experiments are within the frameworks of the resulted uncertainty.

§4. Mixing of two intersoluble fluids

Experiments on studying of mixing of intersoluble fluids were conducted by Kucherenko Yu.A. [39,9], and by Kikoin I.K.[6]. The peculiarity of these experiments is the delay in development of turbulent mixing, which arises from continuous density profile established at the interface by reason of fluids solubility. In the experiments of Kucherenko Yu.A. the dependence of the delay on the scale of initial perturbations is established. This phenomenon was studied theoretically [40]. On should say that the phenomenon under discussion was also simulated by direct numerical calculations in 2D implementation [41] and the results concordant with the experiment and the theory were obtained.

The main result of theoretical consideration [40] consists in of the formula:

$$\sqrt{\frac{L_c}{L_0}} = \exp\left(2\eta_1\alpha_m\sqrt{\frac{\Phi(\eta_1)gA}{(1+2k)L_c}}\;t_c\right) = \exp\left(\frac{4\alpha_m}{\sqrt{\pi}}\sqrt{\frac{0.254gA}{L_c}}\;t_c\right), \tag{14}$$

providing dependence of delay time t_c of mixing on the problem initial parameters. L_0 - initial roughness, L_c - width of initial fuzziness of the interface (density profile), α_m - model constant.

To determine value α_m we process the latest experimental results [9] according to formula (14) (see Fig. 1). The experiments were conducted for two pairs of fluids with different ration of densities: n=2 and n=4. If we introduce new variables $x = \ln(L_c / L_0)$, $y = \sqrt{As^* / L_c}$, where $s^* = gt_c^2 / 2$, then the experimental data are described by the relation $y = 0.933x + 1.4024$.

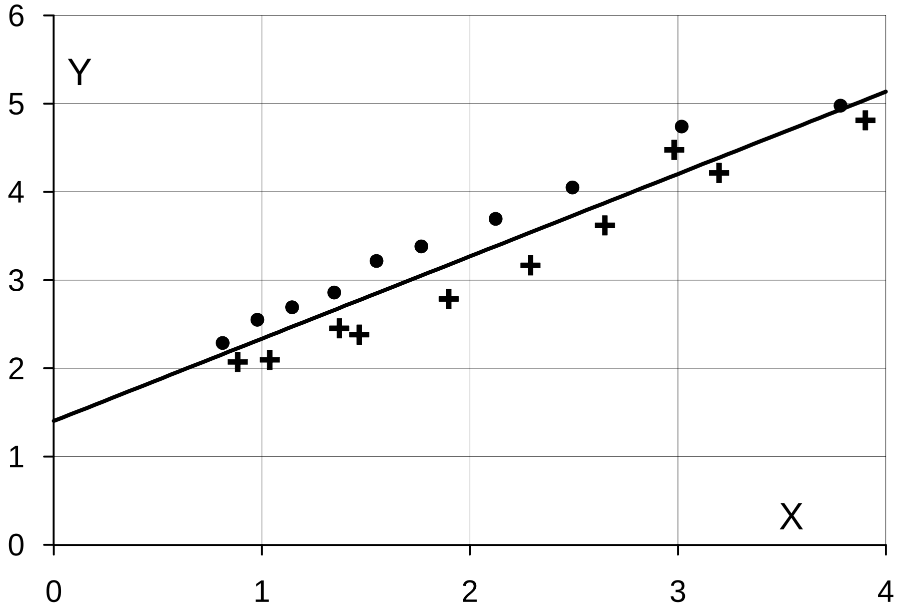

Fig. 1. Experimental dependence of delay in mixing development for n=2 and n=4. The data are from Kucherenko Yu.A. et al. [9]. Notation: $x = \ln(L_c / L_o)$, $y = \sqrt{Agt_c^2 /(2L_c)}$, ● - n=4, + - n=2.

Comparing the obtained result with theoretical dependence (14), we determine $\alpha_m = 0.333$. Using (13), we obtain value $\alpha = 1.511\alpha_m^2$=0.167, and accounting relations α and α_1 (see (2) and (6)), for ratios of densities 2 and 4 we obtain $\alpha_1 = 0.076$ and 0.071 correspondingly. Thus the value of constant α_1 is within the limits determined at mixing of thin layer.

§5. Determination of α_1 in experiments with gases

5.1. Experiments of Kucherenko Yu.A. et al for gases

Experiments at multifunction shock tube [10,11] were conducted with gases, where the so-called phantom-diaphragm is used as a dividing partition (fluid film is applied onto thin wires, which then is destructed with the help of electric current). It is assumed that such initial division of gases reduces the influence of boundary effects to minimum. The study was conducted for the two situations: when the interface is accelerated with the help of compression wave [11] (constant of gravitational turbulent mixing $\alpha_1 = 0.04$ was found), and then the interface is destructed in the Earth gravity field [10] ($\alpha_1 = 0.078$). The obtained values of turbulent mixing intensity differ nearly in two times that requires explanation.

5.1.1. Mixing under action of compression wave [11]

In the facility the compression wave was formed, which was spread along shock tube. The gases interface was accelerated ($g \approx 4000 g_0$) and the turbulent mixing area occurred at it, conditioned by Raleigh-Taylor instability. In [11] for cases A=0.35 (Ar-Kr) and A=0.82 (Ar-He) the dependence of width of turbulent mixing area on the interface shift was constructed and the constant of gravitational turbulent mixing was found $\alpha_1 = 0.04$.

It is known [34] that if initial perturbations contribute considerably into the process of mixing development, then the preference is to be for processing in “roots” (that is in variables $\sqrt{L}$ and $\sqrt{S}$). In our case use of traditional (7) linear dependence L on S leads to values $\alpha_1 = 0.035 \quad (A = 0.35)$ and $\alpha_1 = 0.036 \quad (A = 0.82)$. Processing on roots accounting nonlinear dependence on Atwood number (9) leads to the same value $\alpha_1 = 0.02$ for both cases.

Thus, initial perturbations in the conducted experiments have considerable influence. In the result we obtain turbulent mixing intensity $\alpha_1 = 0.020$, that is considerably smaller than the value, which is determined by experiments of Kucherenko Yu.A. [8] with incompressible fluids (see Table 1).

5.1.2. Mixing in Earth gravity field [10]

Gases divided by phantom-diaphragm was in stationary container, heavy gas – in the top part, light one – in the bottom part. Since destruction of the membrane under the action of acceleration of gravity $g_0 = 9.81\,\mathrm{m/s^2}$ the turbulent mixing area occurred. Value of constant $\alpha_1 = 0.078$ obtained in [10] exceeded the values determined earlier by Kucherenko et al from the experiments of other types [7,8,11].

Accounting that the phantom-diaphragm provides considerable initial perturbations, we perform processing in “roots”. Under processing the initial points are also discarded additionally, when it is assumed that there is no full turbulization of flow yet, and while determining α_1 we take (9) into account. For pairs of gases Ar-Kr (A=0.35), Ar-SF$_6$ (A=0.57) and He-SF$_6$ (A=0.95) the experimental data and the processing results are presented in Table 2.

Table 2. Determination of value α_1 (mixing in Earth gravity field).

Atwood number A	Values α_1 (processing L on S)	Values α_1 (processing $\sqrt{L}$ *om* $\sqrt{S}$)
0.35	0.09	0.075
0.57	0.075	0.045
0.95	0.078	0.027

In [42] the explanation of divergence between experimental data [11] and [10] is proposed. It is supposed that self-similar speed of growth of TM area $\alpha_1 = \frac{1}{2A}\frac{\partial L_1}{\partial S}$ depends on turbulent number of Reynolds. It is shown that as Reynolds number grows the dependence of width of turbulent mixing area passes to standard one $L_1 = \alpha_1 A g t^2$, at that $\alpha_1 \to 0.04$. For medium Reynolds numbers the processes of viscosity and diffusion are of great influence that breaks dynamics and mechanism of destruction of great vortexes, that is speed of growth of turbulent mixing becomes dependent on kinetic characteristics of mixed gases, value α_1 increases, and dependence of width of turbulent mixing area on $S = \frac{gt^2}{2}$ becomes nonlinear and self-similar law of growth of area of gravitation turbulent mixing is not performed. In the experiments in the gravity field value *S*, and correspondingly, Reynolds number, is considerably lower than in the experiments with compression wave, therefore one can consider that here there is no self-similar mixing yet.

5.2. Experiments of Zaitsev S.G. and Vasilenko A.M.

In the experiments of Zaitsev S.G. et al. [25] the channel was divided with a plate into two parts, which were filled correspondingly with inert gas and oxygen-hydrogen mixture. At the moment of full removal of the plate from the channel the ignition was performed. Flame front was moving along the channel and drove the compression wave in front of itself, which involves into accelerated movement the area formed in the result of the plate removal. For $0.33 < A < 0.8$ in [25] value $\alpha = 0.175 \pm 0.05$ was obtained.

Having conducted the above described processing of the obtained result accounting mixing asymmetry and nonlinear dependence on Atwood number, we obtain

$\alpha_1 = 0.05 \div 0.09$. In spite of the fact that in these experiments compressibility of gases and influence of initial width of mixing area is considerable, the obtained result is generally nearly concordant with the case of incompressible fluids.

In the experiments of Vasilenko A.M. [16-18] development of instability and mixing at the gases interface after passing of strong decelerating shock wave generated in electromagnetic tube was investigated. In this situation shock acceleration (caused by action of shock wave) and quasiconstant one (connected with unloading wave) act sequentially on the interface. Turbulent mixing for late times, mainly, is determined by action of quasistationary acceleration. The analysis conducted by Vasilenko A.M. [19] shows that in the experiments the film, which initially divided gases, under the action of radiation coming from shock wave, is destructed before coming of the shock wave, and thereby the ideal conditions are created for successive mixing. Full width of turbulent mixing area was measured.

In [16,17] for case $A = 0.86$ for sinusoidal initial perturbation of the interface the value $\alpha = 0.32 \pm 0.01$ was obtained. In experiments with flat interface [18] at $0.17 < A < 0.9$ the mixing intensity was $\alpha = 0.29 \div 0.35$.

Accounting of (10) the processing of experimental results of Vasilenko A.M. provides value $\alpha_1 = 0.105 \div 0.135$, that considerably differs from the results of most experiments.

In paper [30] on the basis of calculations of development of regular and random interface perturbations the with the help of 2D techniques it is supposed that in the experiments of Vasilenko A.M. at the finite time moments the transition to self-similar stage of turbulence has not occurred yet. Overestimation of the value of mixing constant can be caused by involvement of nonlinear stage into processing of the results, availability of initial kinetic energy of the layer (this energy is caused by passing of shock wave through the interface). For the experiments with initially flat interface the overestimation can be caused by availability of additional long-wave component in the initial perturbation spectrum.

The results of experiments of Vasilenko A.M. are discussed in the papers of American authors [32,33,43], where it is supposed that in the experiments the transition to the stage of self-similar mixing did not yet occurred, and therefore the influence of initial conditions is considerable.

§6. Determination of turbulent mixing intensity by direct numerical simulation

Direct numerical simulation (that is simulation by direct calculations by codes of numerical solution of equations of Euler or Navier-Stocks, without use of any special turbulence models) has considerable role in investigations of turbulent mixing. For gravitational (Raleigh-Taylor) instability the development of perturbations of the interface of two substances of different densities being in stationary gravity field is considered.

The first determinations of mixing constant with the help of 2D numerical calculations were presented in papers [3,7,21]. Subsequent computational determination of mixing intensity was performed already with attracting of 3D techniques [13,26-29,44-50]. Brief review of the results of numerical simulation of Raleigh-Taylor instability and determination of α_1 value, performed by American authors, can be found in [15,47,48], at that one can note that the results of 2D calculations approximately in 15% exceed the 3D ones. Particularly, in

[47-48] the following results are presented: not numerous theoretical papers for A=1 provide $\alpha_1 = 0.01 \div 0.06$, direct 3D numerical simulation provides $\alpha_1 = 0.03 \div 0.07$.

Table 3 presents some calculation results obtained by 3D techniques.

Table 3. Calculation values α_1.

Source	Mesh	Atwood number A	Calculated value α_1
Youngs [26]	$160\times160\times160$ $240\times160\times160$	0.2 0.5	0.04 0.035
Youngs [44]	$270\times160\times160$ $270\times160\times160$ $270\times160\times160$	0.2 0.5 0.9	0.027 0.025-0.028 0.029
Anuchina N.N. et al. [27]	$60\times60\times60$ $120\times120\times120$	0.49	0.064 0.074
Yanilkin Yu.A. et al. [28,29]	$200\times200\times400$	0.5 – 0.95	0.025 – 0.055
Linden et al. [13]	$168\times168\times230$	0.2	0.033
Li [45]	$40\times40\times120$	0.33	0.07
Cheng et al. [46]	$100\times100\times200$	0.33	0.08
Dutta et al. [49]	$128\times128\times512$	0.5	0.08
Dimits [43]	$256\times256\times256$	0.33	0.011-0.013
Weber et al. [50]	$256\times256\times512$	0.5	Monotonously decreases in time from 0.055 down to 0.03

Because of great volume of calculations in 3D calculations one cannot manage to check convergence at mesh refinement. Though in a number of foreign techniques it is shown that at increase of a number of counting cells the obtaining value of turbulent constant α_1 decreases [26,43,13].

For completeness of the review we note some more papers, the results of which differ from most of the ones presented in this paper. In [43] the equations of Navier-Stocks are solved and it is shown that the obtaining value α_1 increases as physical viscosity grows (in Table 3 presents the result without viscosity accounting). In [32] in calculations at rather detailed meshes (to $512\times512\times2040$) it is shown that the resulting value α_1 depends on initial conditions and is not a monotonous.

Thus, direct 3D simulation does not enter finite clarity into the problem on determination of value of turbulent mixing constant. Spread of the values obtained by different techniques α_1 remains considerable.

Recalculation of values of mixing intensity accounting nonlinear dependence on Atwood number (3) provides for all the presented calculations the range of change $\alpha_1 = 0.01 \div 0.077$, that in general corresponds to the results obtained by the experiments with incompressible fluids (see §2).

Conclusion

The conducted studying and comparison of experimental and calculation results on determination of turbulent mixing intensity shows great spread in its determination. This refers not only to gravitational mixing, but to transition to turbulence in general. Most likely, the reason for that is slow coming to developed self-similar turbulence, that leads to the initial data to be stored for long.

In [42] the fact of dependence of self-similar speed of growth on Reynolds number was established, that can allow explaining numerous convergences between experimental data of various authors, which take place currently. So it would be interesting to conduct analysis of all the conducted measurements just from those points. But it is a subject of another investigation.

And yet, evidently, one should consider that mixing constant has the following uncertainty: $\alpha_1 = 0.02 \div 0.08$.

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