Numerical simulation of turbulent stage of Richtmyer-Meshkov instability with multi-shock interaction.

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At present work the numerical simulation of some experimental results [1] is fulfilled. In particular, the experiment [1] was devoted to the investigation in detail the longitudinal velocity correlations in connection with mixing zone dynamics and an initial perturbation spectrum. In [1] the Richtmyer-Meshkov instability has developed for SF6/Air (adiabatic exponents are 1,094 and 1,4) situation.

We accept the following model, closed to the experimental conditions. The experimental setup, in our calculation version, is presented at Fig.1. The distances along the shock tube are indicated in *mm*. In Fig.1 the short vertical lines indicate the positions of LDA (laser Doppler anemometers), the long vertical lines indicate the initial positions of the shock wave and the contact boundary. The initial physical conditions are the following. The initial temperature before shock wave is 291 Kelvin. The pressure in low-pressure camera is 1Bar, after the shock wave in SF_6 the pressure is 2.152 Bar and density is $1.209{\cdot}10^{-2}$ g/cc. The initial densities of SF_6 and air in low-pressure camera are $6.037{\cdot}10^{-3}$ g/cc and $1.198{\cdot}10^{-3}$ g/cc correspondingly. The shock speed is 195.2 m/s, the flow speed after the shock wave is 97.76 m/s.

At these conditions, after shock pass of the contact boundary, the velocity of the first shock in air will be 428.7 m/s, velocity of the contact boundary will be 130.1 m/s. In our model the SF_6 are the perfect gases.

The initial perturbations were made by the following way. The density jump at the contact boundary was changed into linear density profile between z=0 and z=2 mm. In each calculation cell within this range value of density randomly changed more or less than this linear profile up to 20% or 10% in different simulations.

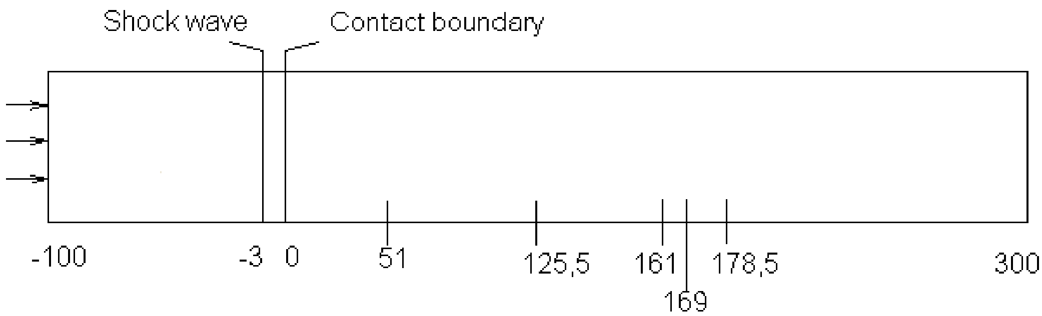

Fig.1

On the basis of the calculations executed on grids with h=1 and 0,5mm it is possible to draw the following conclusions:

For satisfactory reproduction of experimental data [1] it is enough to carry out calculations in area with the sizes $0 \le x \le 80$ мм, $0 \le y \le 80$ мм, $-100 \le z \le 300$ мм;

The sizes of cross-section section of a tube do not render appreciable influence on results of calculations.

The type of the problem and size of initial perturbations of density noticeably affect results of calculations.

For the further calculations we shall reduce a step of a grid (h=0.333 mm) and we shall keep a level of initial perturbations in a transitive layer (20 % of a variation of density with the additional requirement $0 \le C \le 1$).

These calculations can be lead for section of a tube 4x4 sm that will allow to reduce the general number of accounting cells twice.

The obtained view of a mixing zone is presented at Fig.2. There are a good agreement with experimental results, which are indicated by crosses.

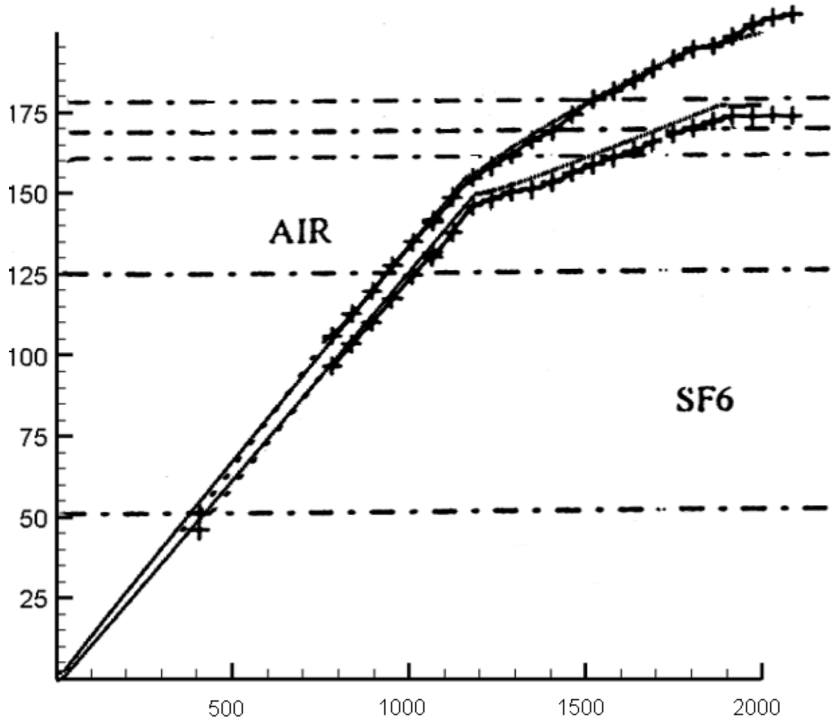

Fig.2

The longitudinal velocity pulsations are presented at Fig.3 in comparison with the experimental results. One can see, that in simulations these pulsations reduce more considerably than in the experiment.

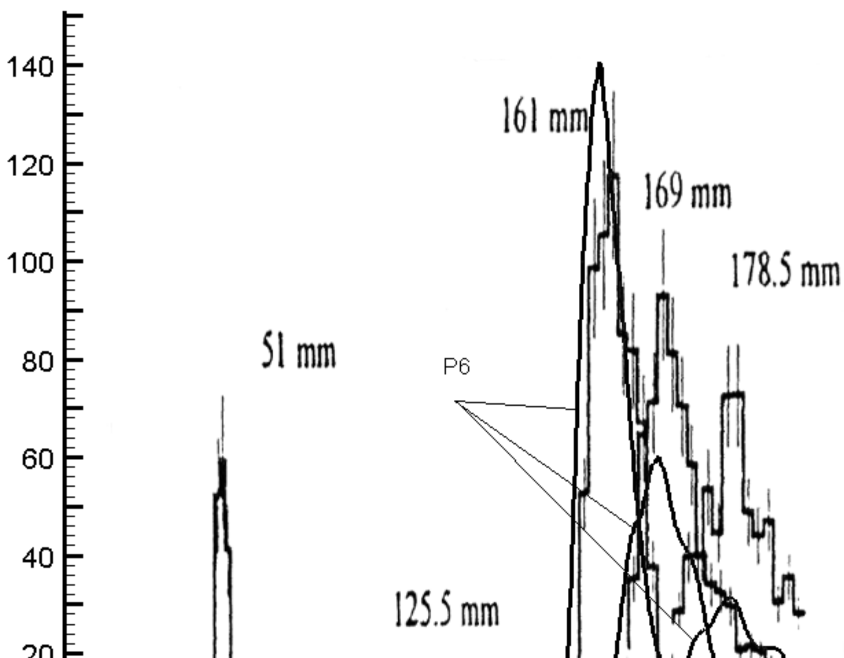

Fig.3

Pulsations in the mixing zone *Wp(t)* may be approximate by expression $W_p(t)=B(t-t^*)^{-m}$. This dependence can be connected with a low of the mixing zone growth L~ $(t-t^*)^k$. Namely, $Wp \sim (dL/dt)^2 \sim (L/t)^2 \sim (t-t^*)^{2k-2}$, $m=2-2k$.

The maximum values of pulsations at the last three LDA are presented at Fig.4 with the values of m in a low of the pulsation reduction.

At Fig.4 letters indicate the following: T2 means the simulation with space step h=1mm and 20% density perturbation, T6 means the simulation with h=0,333mm and 20% density perturbation, T7 means h=0,333mm and 10% density perturbation

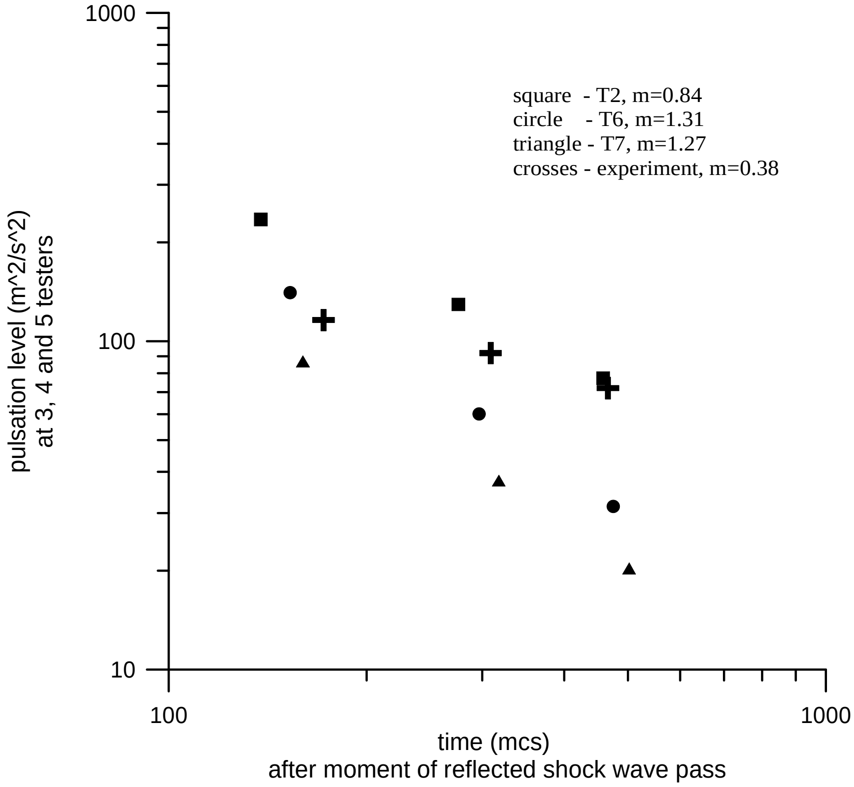

Fig.4

At Fig.5-8 the density isosurfaces are presented to illustrate the mixing zone development.

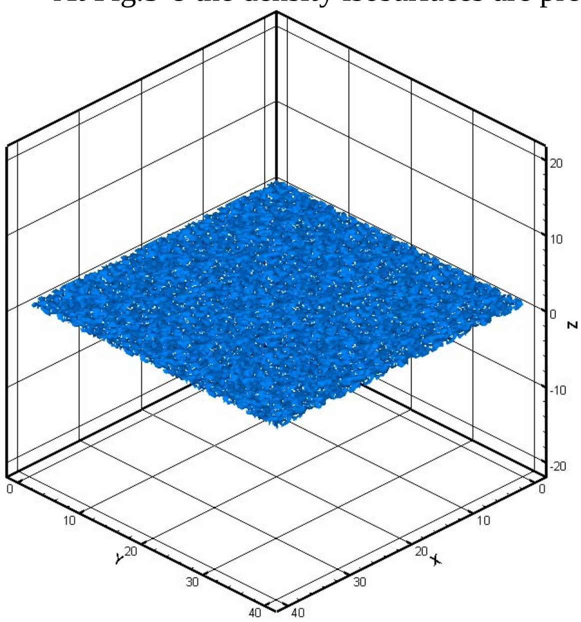

Fig.5 t=0mks

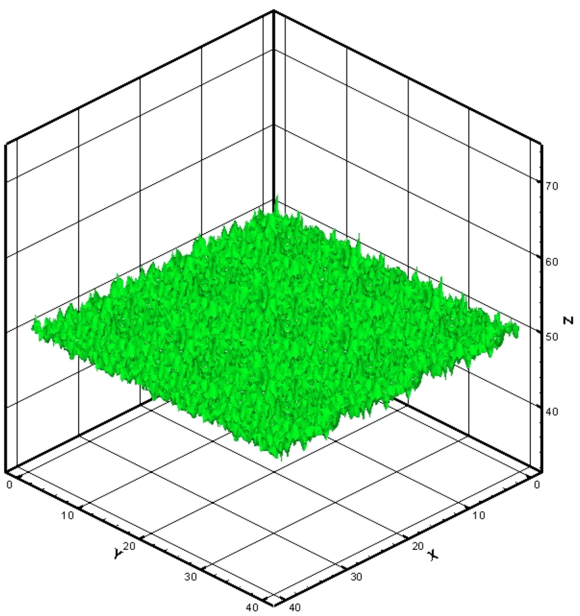

Fig.6 t=400mks

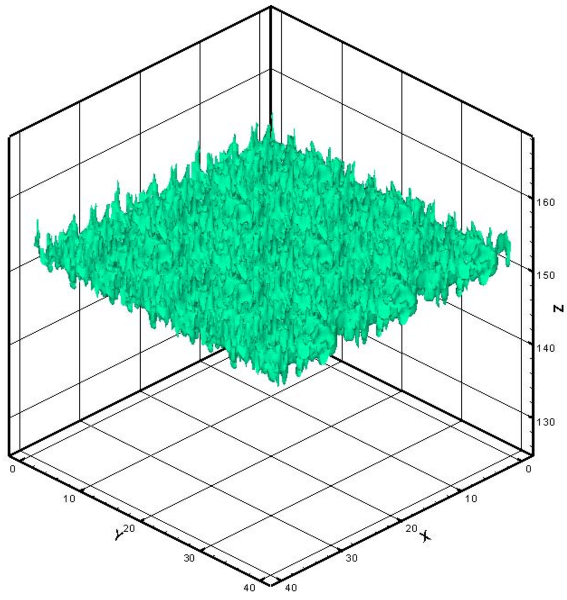

Fig.7 t=1200mks

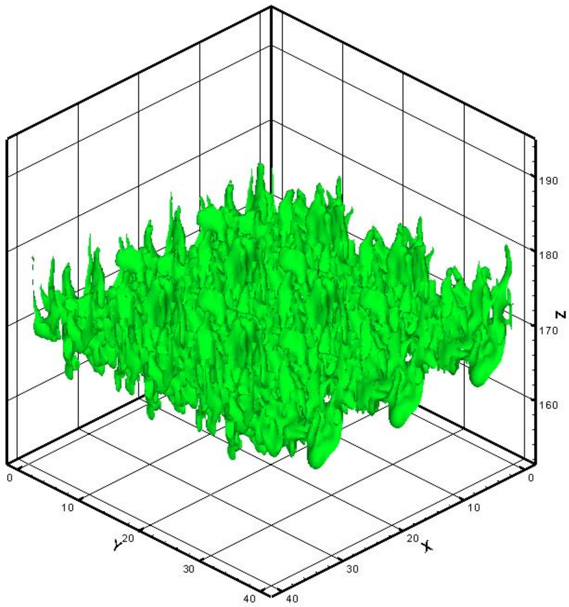

Fig.8 t=1600mks

The dependence of spectral density of kinetic energy E on the wave number value Q is presented at Fig.9, 10. The lines at the figures are inclined, corresponding to $E \sim Q^{-5/3}$ (inertial interval) and to $E \sim Q^{-11/3}$.

It is interesting, that the same intervals can be indicated and for the experimental data (see Fig. 11, 12) of many various experiments.

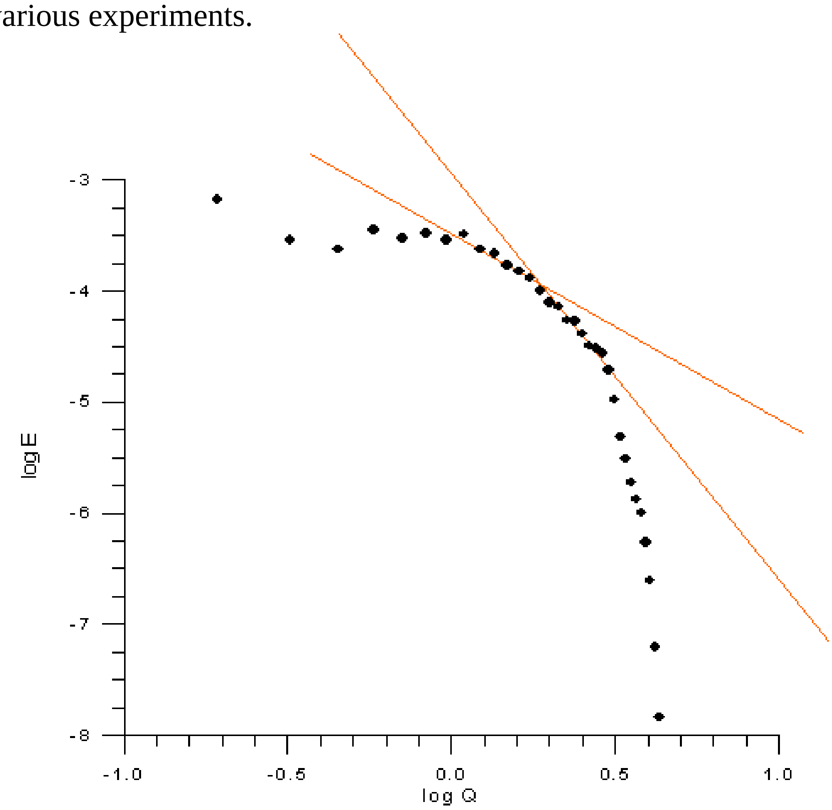

Fig.9 T6 t=1200mks

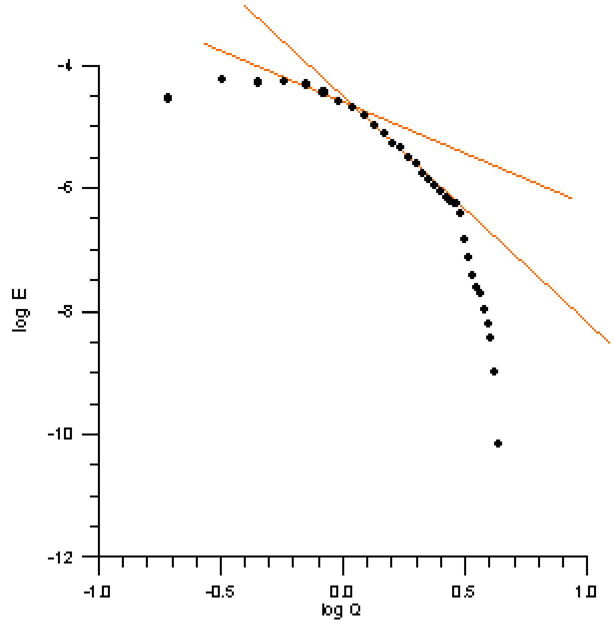

Fig.10 T6 t=1600mks

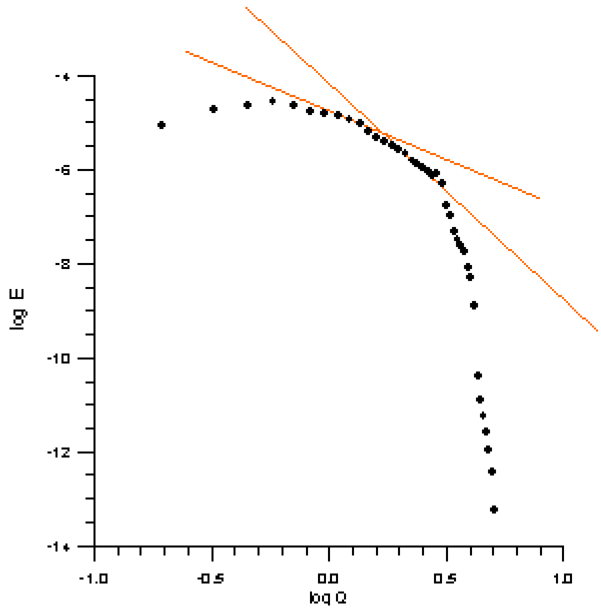

Fig.11 T7 t=1600mks

Figure from A.S.Monin and A.M.Jaglom monograph. Experimental value of spectral density. Lines have inclination –5/3 and –11/3.

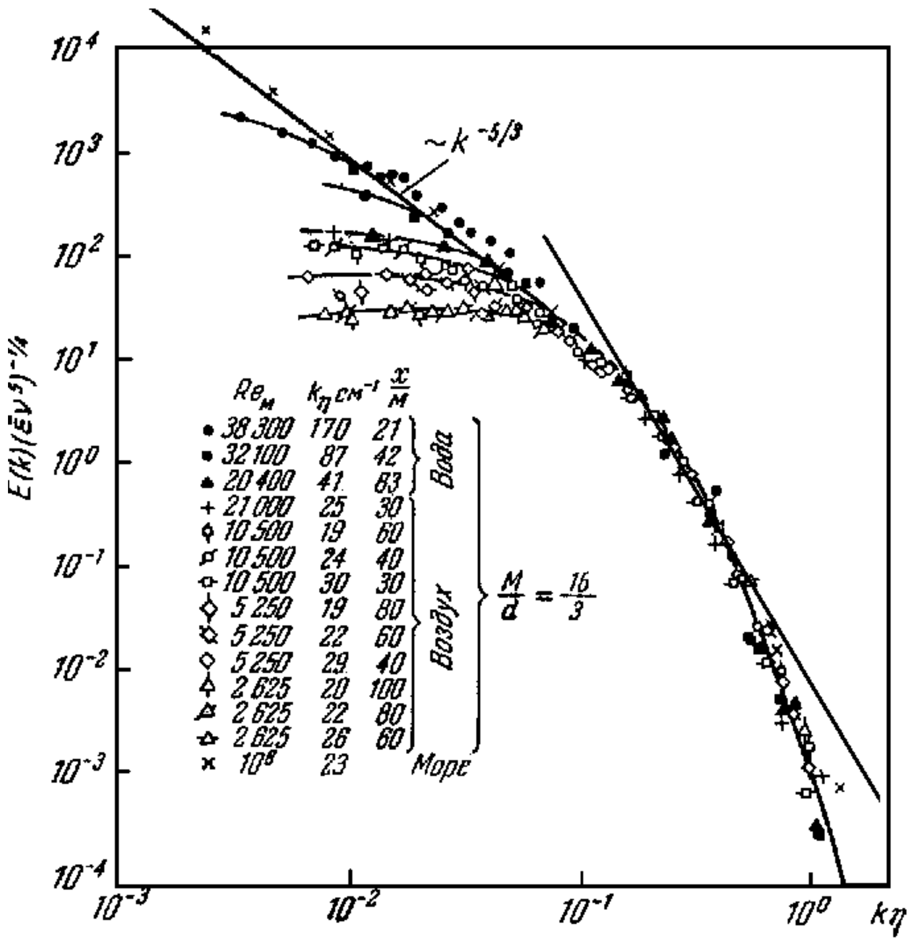

Fig.12

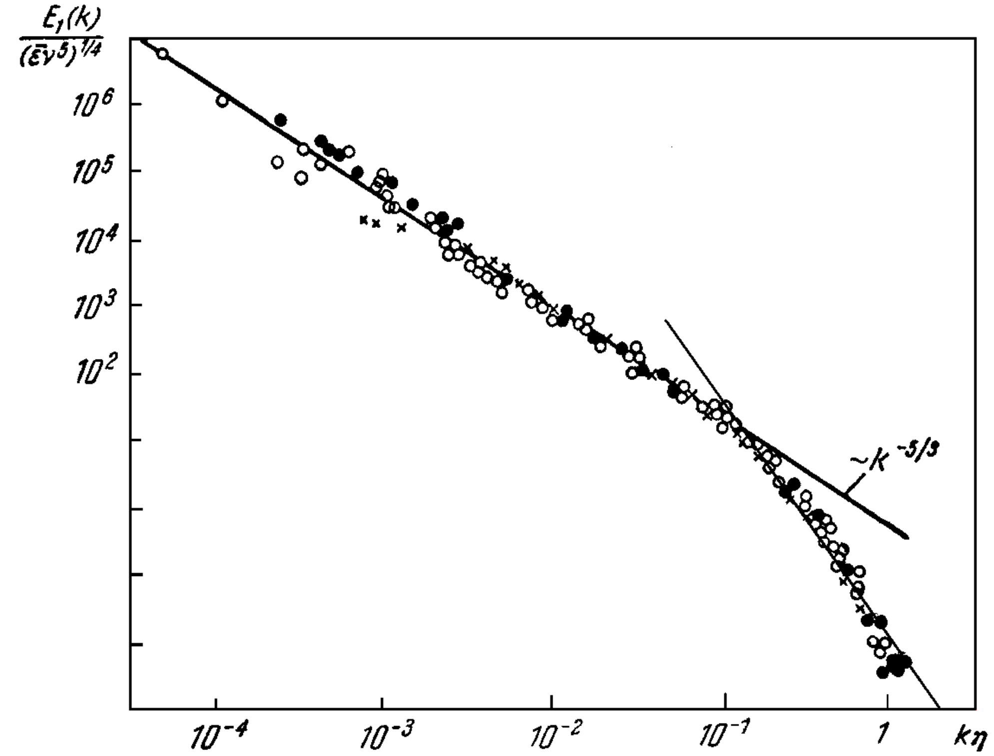

Fig.12

Conclusion

Simulations of Richtmyer-Meshkov instability were fulfilled (parallel version of the NUT code) at a set of the condensed grids. (h=1.0, 0.5 and 1/3mm).

Dependence of mixing zone and velocity pulsations are obtain.

The main characteristics of a mixing zone width growth with time and level of pulsation are established in a connection with the forms and amplitudes of the initial perturbations.

The spectral analysis of the turbulent kinetic energy shows, that we observe inertial interval ($E{\sim}q^{-5/3}$) and dissipative interval ($E{\sim}q^{-11/3}$)

References

[1] F.Poggi, M.-H.Thorembey, G.Rodriguez. Velocity measurements in turbulent gaseous mixtures induced by Richtmyer-Meshkov instability.// Physics of Fluids, 1998, Vol.10, No.11, pp.2698-2700