Generation and Combustion of Aerosol Clouds:
Former and current activities at Fraunhofer-ICT

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Abstract

A short review of Fraunhofer-ICT's contributions to conventional Fuel-Air-Explosives research is given. Then the idea of the use of gas generators as a means for a controlled dispersal process of energetic particles is introduced. The results of preliminary experimental tests, done with a pressurized gas system and the interpretation of the data by means of a simple model are reported elsewhere /1/. For achieving a better understanding of the physics and also as an additional input for the future design of the test set-up numerical modeling has been started. First tests with gas generators for the dispersal were performed.

1. Introduction

Fraunhofer- ICT started in the early 80's with the experimental investigation of aerosol clouds. The reason for these activities was the development of Fuel-Air-Explosives (FAE) for military applications. These conventional FAE-systems worked in such a way that a liquid fuel was dispersed from a container by means of a high explosives charge and after some time delay the liquid fuel/ air- cloud was ignited with a secondary high explosives charge to initiate a detonation propagating through the cloud /2/. In the 90's there was a new interest in those types of weapons, when the military was looking for an effective means for destroying electronic equipment in control rooms contained within strongly armed shelters or underneath the ground. The problem of penetrating the shelter walls by means of special projectiles containing the fuel material before the subsequent dispersal and ignition of the cloud called for new concepts with respect to fuel sensitivity, dispersal and ignition process /3,4/.

Apart from the special problems connected with FAE weapon systems, the knowledge on how to release and disperse energetic material – either as a liquid fuel or as small energetic particles - on a short time scale is generally important for several applications, which are dealt with at ICT: eventually as a defence system against B- and C- weapons /5/, non-lethal weapons systems, and in the field of safety technology the investigation of dust explosions and the development of fire extinguishing systems. The objective is the generation of a fuel/air- or particle cloud within some milliseconds to about 100 ms with special geometry and fuel- or particle concentration within the cloud. This can probably be best achieved by use of gas generators. These can be „tailored“

for the special application with respect to for example burning velocity, -temperature and gas output; together with an appropriate design of the mechanical construction the generation of a well-defined cloud seems to be possible.

2. Conventional FAE-systems

In the tests done under the management of the late Dr. Pförtner /2 /, a mass of 7.5 kg of ethyleneoxide - contained within a cylindrical shaped container - has been dispersed by means of a high explosive charge located in the axis of the container 1 m above the ground. After a delay of about 80 ms the fuel/air cloud has been ignited by means of a secondary high explosives charge of about 100 g. The test series was performed with single containers and with up to 3 adjacent containers for checking the overlap of different clouds which is necessary for detonation propagation if only one secondary HE is used. The main results and some video clips of high speed films taken during the tests will be shown.

3. New FAE-systems

To fit the stronger requirements on the weapon system with respect to higher performance and more reliable and easier ignition, new concepts were initiated. There were essentially two aspects: 1. studies on the possibilities to get rid of the 2^{nd} HE charge ignition concept. This should be replaced by an appropriate choice of chemical agents and constructive measures so as to be able to control the reaction kinetics and flow conditions during the dispersal process in such a way that DDT will occur (SWACER effect) /6/ and 2. the investigation of the use of solid fuel particles or HE- particles or a mixture thereof instead of liquid fuels to achieve a higher performance. For the dispersal of those sensitive particles the use of gas generators is recommended instead of HE charges, because these can be "tailored" according to the special requirements (see **1**.)

4. Experimental

The final objective of our investigations is to achieve a controlled release and dispersal of µm-sized particles into the surrounding atmosphere and the generation of a well-defined particle cloud with respect to geometry, particle density within the cloud and dispersal time by use of gas generators. First of all the gas generators were simulated by means of a pressurized gas tube system, to analyse the basic correlations of the different test parameters involved /1/. The starting pressures of 5 MPa and 10 MPa were released via a bursting disc and acted on a container filled with the particles to be dispersed. The container was a section of a cylinder with a height of 0.2 m and with an opening of 45°. The pressure release time was between 100 and 200 ms. The particles were 120 µm KCl and 6 µm Aluminum with masses up to 2.5 kg.

Tests with the use of gas generators and different particle mixtures are in progress.

5. Modeling

The propagation of the particle cloud was analysed with respect to the distance of the front of the cloud as a function of time /1/. The cloud behaves like a solid body being decelerated in a flow. The fit procedure gives the starting velocity and the drag coefficient for each test. The volume of the cloud was estimated at different times of the propagation process and the data fitted with a relation describing the volume of a rotational symmetric body with (half) opening angle α and hemispherical "cap" with radius R in front of it. The fit procedure resulted in values of α, which were close to 12.5° for each test; this is the theoretical value in the "main region" of a stationary jet of an incompressible fluid /7/. So if it is assumed that the particles are homogeneously distributed within the cloud the mean particle concentration within the cloud can be calculated by means of this simple model.

For a more detailed description of the tests numerical modelling was started. 3D numercial modeling is desirable in principle. Since such an approach is very computertime-consuming, we decided to start with the development of a 2D-model, describing a somewhat different experiment: This is the development and progress of a cloud of polydispersed solid particles generated under high pressure resulting either from the burning of a gas-generator charge or from a source of pressurized cold air. The high pressure source and the particles were contained within a cylinder with impermeable walls at its ends and 1m above the ground. The gas-generator or the source of pressurized, cold air was located in the cylinder axis and the solid particles were placed around as a shell. The mass of gas generator or pressurized air and the mass of particles were 1.6 kg and 20 kg, respectively. These data are related to the ICT-experiments in so far as 1.6 kg correspond to the amount of pressurized gas-mass and 20 kg are roughly 8 times 2.5 kg - corresponding to 8 times 45° = 360° in the case of the cylinder. The geometrical dimensions of the cylinder are also related to the dust container of ICT-tests.

General asumptions of the model are: the carrier gas is a non-reacting axisymmetric turbulent flow taking into account the presence of particles (fully coupled model); the polydisperse particles have a spherical shape; collision processes between particles are neglected. The governing equations are Faver-averaged Navier Stokes equations for the carrier gas and a Lagrangian model as a statistical approach for the particles to take into account the influence of turbulent pulsation of carrier gas on their movement. Relations for impulse- and heat- transfer along the trajectory of i- th particle are the basis for the calculations.

Averaged parameters of particles into each cell of the numerical mesh were calculated after calculations of some thousend trajectories of particles (we used about 10000). The numerical methods used are a second-order upwind difference LU scheme with TVD properties for the carrier gas and a fourth-order Runge Kutta scheme for the particles. Burning rate of the solid fuel in the gas generator was $r_b = 5(p/p_0)^{0.6}[mm/s]$ and heat of explosion $Q_b = 1.78 \cdot 10^3 [KJ/kg]$.

The propagation of the particle cloud is calculated for different situations: cold air and hot air with and without the influence of the ground. It can be seen that the particles are far from being homogeneously distributed within the cloud. Moreover, there are obviously massive differences in the cloud shape between the two situations: with and without influence of the ground. Instabilities of the emerging carrier gas flow and the interaction of the flow and the particles with the surrounding atmosphere are responsible for the production of vortices. Data of ICT- experiments, the results of the simple model and of the numerical model are compared and discussed.

6. Literature

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