A Novel Fireball Analysis for an Explosive Aerosolization Study

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The final consequent risk following an explosion of radiological dispersal device (RDD) is highly depends on final radioactive particles' size distribution creates by detonation shock wave. Respirable, aerosols contribute to risk in a different way when compare it to non respirable aerosols or to ballistic, inertial, particles or even larger fragments. While aerosols (both, respirable and non respirable) are moving downwind with the cloud, heavier, inertial particles escape the initial fireball and deposited on the ground at a short distances from the ground zero (GZ) point. Respirable aerosols are risky when inhaled into the body (internal radiation) while non respirable have risk as an external exposure on the skin and from a distance. Hence, knowing the size distribution of the radioactive particles will, thus, enable more realistic risk assessment predictions.
We show here that detonation fireball fast multispectral radiometrycan be a novel tool that can be indicative to the final particles size distribution.

During Green Field[1] experimental project, ColoRad C7, fast multispectral radiometer (FMR) of IARD-Israel[2]was used. This unique tool was aimed to detect the fast temporal evolution of the fireball in time scales of micro seconds (sampling frequency of 250 kHz).
Fireball average radiant intensity was measured each four microseconds in four different spectral bands. The aim of using it is to be able to quantify the contribution of the different particles and detonation products to the total energy released following high explosive detonation. The measurement of the radiant intensity of the aerosols and other particles involved (detonation products, soot, carbon monoxide, carbon dioxide and dirt entrained into the fireball) and a comparison between clean and dirty shots enable to study the effect of agglomeration processes occur when dirt entrained into the fireball due to the vortices created following the detonation. Further analysis can yield the temporal variation of the radiant temperature and the effective radiant area.
Since most high explosives are under balanced to Oxygen we expect two radiate peaks following detonation: **the first one** is due to oxidation of explosive atoms and molecules (mainly H_2, C, CO and other metals, if exit (Al, Mg, etc.)) and **the second** is the late oxidation of detonation products with ambient Oxygen.
The conditions for the existence of the late energy pulse (called afterburn) are: free available ambient oxygen, material to be oxidized ("fuel") and "high enough" temperatures.
During the afterburn process, the C atoms of the explosive oxidize and become CO molecules and then CO_2 molecules if there is still available oxygen and high temperatures of more than 1750^oK degrees. At this stage entrained ambient dirt can agglomerate with the radioactive particles and thus to change the initial size of the particles and the all distribution.
Enhanced amount of dirt entrained into the fireball reduce its temperature and suppress the afterburn process. In such a case the 2^{nd} peak will be lower than the in case of a clean detonation where no dirt entrained. TNT is an example of explosive which isextremelyunder balanced to Oxygen (-74%). This means that in the case of clean detonation the first energy peak (detonation energy[3])yields only about one third of the total available energy (combustion energy).The rest two third might release during the afterburn stage (if exist!).
We have used the ColoRad C7 of IARD during different explosive atmospheric dispersion tests of RA material[1].
The spectral bands (all in the SWIR and MWIR range) were chosen in order to collect the molecular emission of the detonation products and the CO_2which we use as an afterburn indicator.

Figure 1: The ColoRad C7 (left) and high speed fireball snapshot 10 ms following TNT detonation (right).

2. Experimental results: radiant intensity and temperatures

A comparison between two shots of the same explosive charge (25 kg of TNT), one is at 0.55 m height above clean steel surface (on the left) and the other is on packed soil, dirt surface, is presented on figure 2.
The fireball radiant intensity of each of the four spectral bands is presented for each of the two shots.
One can easily recognize the two peaks of the energy pulses: the first one (around 1 ms) is related to the detonation energy and the second (around 30-50 ms) is the after burn contribution of later oxidation, mainly due to the emission of the CO_2.

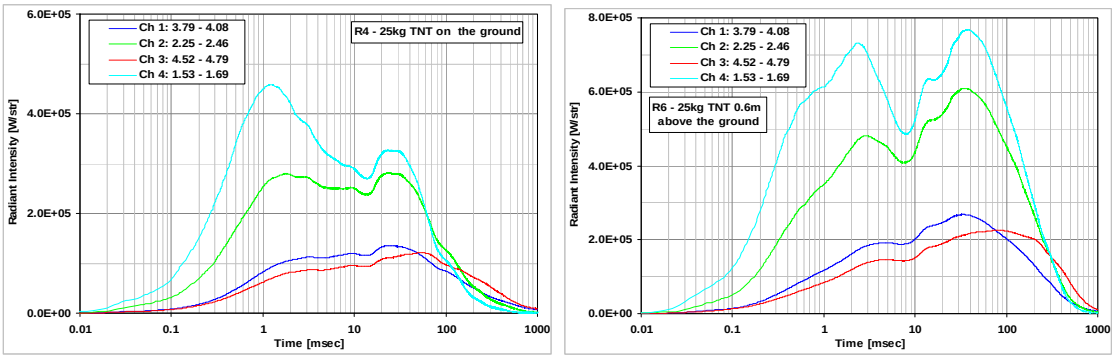

Figure 2: Fireball radiant intensity of clean (right) and dirt (left) of 25 kg of TNT charges.

The 1st and the 2ndpeaksratiofor each fireball is different when comparing the clean and the dirt shots. In the case of the clean shot, much lower amount of ambient dirt was entrained into the fireball and thus high temperatures were exist to support higher afterburn process. On the other hand, the dirt shot involves higher amount of soil that entrained by the fireball strong vortices, reduce the temperature and suppress the oxidation of the C atoms into CO_2, thus resulting in a lower after burn peak.
RA particle size distribution will be different for the two shots, even though the charges were similar! We can, thus, use the CO_2 radiant intensity (or power) as indicator for the fireball cleanness for certain explosive type. In the next stage it will be related to the reduction of the fraction of fine aerosols due to agglomeration with ambient dirt.

3. Summary

Fast multispectral radiometry of detonation fire balls is using for the study of the dynamic physical and chemical processes in the fireball. The after burn intensity, mainly due to

CO_2emission can used as an indicator for the fireball cleanness which effect the final size distribution of RA particles disperse by high explosive charges.

References

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