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GENERATION OF PARTICULATE AERODISPERSIONS BY MEANS OF A FUNCTIONAL GRENADE SAMPLE

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A b s t r a c t :

It followed from the results of firing tests conducted with particulate grenade models under variable weather conditions in the field that the models generated a particulate aerodispersion in a cloud effective for a short time. The tested kinds of particles produced clouds of aerodispersions of similar sizes; the cloud diameters were increasing upwardly up to the 20th second after the explosive action of spreading the charge up to the value of diameter l = ~13 m in the case of Chezarb, l = ~20 m in the case of the S244 carbon fibres, l = ~22 m in the case of brass particles, and l = ~28 m in the case of aluminium particles. Particulate systems in the cloud showed good attenuating capabilities for a short time in the whole IR range of spectrum. The tests proved that their application in the multispectral protection of military objects is desirable.

1. Introduction

The protection of military objects (e.g. armoured vehicles) against reconnaissance means and sensor-guided weapons working in microwave band can be provided by some aerodispersions attenuating radiation also in the microwave region of the electromagnetic spectrum. We proved during the laboratory measurements [1-2] that the S 244 carbon fibres, conductive black Chezacarb and the CR 2995 ground natural graphite as the kinds of carbon particulate material were effective in attenuating the microwaves of frequency range $f \approx$ (8-12) GHz, $f \approx$ (2-18) GHz, respectivelly. The measurements conducted with particulate brass and aluminium were not reproducible; we stated [1] that the aforementioned materials required a more detailed research work because they also were noted [3-4] to be effective from the respect of attenuation of microwave radiation.

The means producing aerodispersions for the protection of military objects effective in the microwave region have not been readily available. A NICO-Pyrotechnic grenade is mentioned [5] which attenuates in the microwave region (35-140) GHz in the values of attenuation $L_\lambda > 15$ dB; however, a more detailed specification of this grenade payload and its composition was not described.

The Armed Forces of the Czech Republic have not yet available such a grenade. Therefore, it was desirable [6] to use, on the basis of the previous laboratory measurements [1], the selected multispectrally effective compounds in the functional samples of grenades and to test them in order to measure their power characteristics under variable meteorological conditions in the field. The found results could be used in the development of a particulate grenade for the protection of military objects.

2. Application of a Particulate Aerodispersion

The research of the use of mutispectrally effective materials in the form of a particulate aerodispersion [7] indicated that one of possible means for its generation is a particulate grenade. The explosive action of spreading the particulate materials used in this grenade proved to be a suitable technique of the particulate aerodispersion generation [8-9] applicable for the rapid protection.

The explosive method of spreading the particulate materials on the basis of carbon Chezacarb, Multiprach, graphite and limestone dust proved to be suitable for the particulate payloads of grenades with axially placed burst spreading charge [10]. Spreading characteristics of the particulate payloads were observed from the time attenuations of infrared (IR) radiation by means of the aerodispersions measured in the course of the tests. After spreading of the particulate payload, the time interval during which IR radiation was attenuated was limited by the time τ_a = (8-12) s. It was observed from the laboratory measurements of the attenuation of IR radiation by aerodispersions of conductive black Chezacarb B, ground charcoal and wood charcoal and urea-formaldehyde polycondensate Chemaform [11] that there was no significant difference between the explosive and pressure methods of spreading the used particulate materials.

The particulate materials aluminium and brass in aerodispersion showed good attenuating capabilities against IR radiation [12] under static laboratory conditions. We found out [12] that the particles of the both materials sedimented quickly due to their considerably specific weight; particles of aluminium partially burnt out during the explosive method of spreading.

We found safe spreading of aluminium in an explosive grenade model in which the particulate payload of aluminium was separated from the burst spreading charge with the fuse by means of the buffer load (by conductive black Chezacarb) [13]. The particulate payload of brass could be spread without the buffer particulate payload. We measured that the generated aerodispersions in a cloud attenuated IR radiation for a limited time under variable weather conditions of the atmosphere; time intervals τ_a of the radiation attenuation by the aluminium aerodispersion made on an average τ_a = 9 s, and on an average τ_a = 6 s in the case of the brass aerodispersion.

The works done proved that the explosive method of spreading the aforementioned particulate materials is promising for a particulate grenade. The content of this report are some results obtained from the verification of the executed samples of particulate grenades by means of firing tests under variable conditions of the field.

3. Experimental Part

3.1. The used Compounds and Materials

1. *ALBO 915 aluminium* (ALBO), manufacturer Zeveta Bojkovice, Bojkovice 1994.
2. *3P1Bright brass* (MS), manufacturer Pramet, a.s., Potštejn 1998.
3. *Chezacarb A*, conductive black (CHZC), former manufacturer Chemopetrol Group a.s., Litvínov 1996, mean diameter of particles d_{mean} = 3,9 μm.
4. *DONACARBO S244* (UV), g*round carbon fibre,* diameter d = 13 μm, length l = 0.7 mm, bulk density ρ = 190 kg.m^{-3}, manufactured by DONAC Co., Ltd., Osaka 2004, supplied by Václav Zedník – MINKO, Kutná Hora 2005.

3.2. The Used Instrumentation

1. *Digital videocamera PANASONIC NV-DX 110*, Panasonic, Japan.
2. *Diod transmitometer with detector*, the source is located in front of the object of observation. Wave length λ(1) = 0.82 μm. VOP-026 Šternberk, s.p., VTÚO Brno division.
3. *Transmitometer*. Wave length λ(2) = (3-5) μm. VOP-026 Šternberk, s.p., VTÚO Brno division.
4. *Laser CO_2 transmitometer with detector* and IR transmitter located in one site. Corner reflectors were placed in front of the object of observation. Wave length λ(3) = 10.6 μm. VOP-026 Šternberk, s.p., VTÚO Brno division.

5. *Portable smoke grenade launcher* of own design with 6 adjustable ejectors, connection cable and control box [14].

3.3. Execution of the Grenade Models for Verification by Field Tests

Grenade models were developed for the field tests that utilized the same casing and calibre [15] of the already fielded [16] DGO-1 smoke grenade. Models of particulate grenades were made [17], the schemes of which were described earlier [18], in four variants of particulate payloads in the canisters. A single-chamber canister was used for the payload of particles. The bottom part was equipped with a deceleator with primer (detonator with a detonating cord embedded along the whole axises of the particulate payload). A two-chamber canister was used for the payload of aluminium particles ALBO. Inert Chezarb was dosed to its inner chamber with a decelerator and primer. The following table 1 gives the overview of the characteristics of the prepared grenades.

Table 1

Grenade variants, payload kinds and mean weights of typical parts of the particulate grenade models

Grenade variant and payload kind	Particulate palyoad weight q_1 (g)	Weight of an inert q_2 (g)	Weight of detonating cord (g)	Canister model	Grenade total weight q (g)
A (CHZC)	264	-	18	Single-chamber	1081
B (UV)	357	-	19	Single-chamber	1272
C (MS)	1761	-	19	Single-chamber	2672
D (ALBO)	511	42	19	Double-chamber	1460

3.4. Firing Tests

The firing tests were conducted with salvoes of three grenades of the same variant. During the firing tests, the time courses of attenuation of IR radiation by the generated aerodisperions were measured at wave lengths $\lambda(1) = 0.82$ µm, $\lambda(2) = (3\text{-}5)$ µm and $\lambda(3) = 10.6$ µm according to the standard methodology of field measurement. At the same time, the courses of the generated screens were recorded by videocamera. Particulate grenades were stored in boxes at an outside-air temperature of about 6 °C during the firing. Spreading of canisters at an average time delay of 1.5 s was selected from the preliminary trials [19] for the grenade variants to be tested; elevation angle of ejectors made 11 ° and the firing angle of ejectors was 15 °.

4. Field Tests of Grenades; Results and Discussion

To achieve successful performance of the field test with the particulate grenade models, some development work was executed prior to testing. It was technically and econominacally reasonable to design the particulate grenade for the same smoke-generating device with the same dimension parameters as it was in the case of the already fielded DGO-1 smoke grenade. Designs of the particulate grenades canisters and decelerators with a primer were optimised [19] to obtain perfect fragmentation of the canister casings, ballistic properties of the models were studied as well as the arrangement of the canisters in the casing with regard to its ballistic trajectory. Weights of the particulate grenade variants differed (see Table 1): from the mean weight of the grenande in the case of Chezacarb (A variant) the paylod of which was q = 1081 g up to q = 2672 g in the case of brass payload (C variant). Number of the trials fired at the set values of firing angle and elevation angle was relatively low for the individual variants of the particulate grenade, therefore the measured attenuations of radiation with respect to the atmosphere variability (especially the changing direction of the wind blow) significantly affecting the coverage of the measured area by the aerodispersion were conclusive only with approximately a half of the firing tests.

4.1. Attenuating Capabilities of the Particulate Aerodispersions

Attenuations of IR radiation at the wavelengths comprising the whole IR range were measred during the firing tests. Attenuation values L(dB) of the individual firing tests (always determined from the measured time courses of the whole trial) are listed in Table 2. Only such tests of all the firing tests which provide trustworthy information are included in the Table.

The attenuation values listed in Table 2 confirm good attenuating capabilities of the measured particulate systems in the whole IR radiation range. Table 2 shows that the highest consealment capabilities with the values L(0.82) = 29.0 dB, $L(($3-5) = 18.8 dB and L(10.6) = 15.0 dB were achieved in the tests 63.03 and 63.22 with carbon Chezacarb. The same situation was in the tests 63.14 and 63.23 with aluminium ALBO with the values L(0.82) = 28.0 dB, L(3-5) = 19.4 dB and L(10.6) = 15.0 dB. Concealment capabilities with the values L(0.82) = 17.9 dB, L(3-5) = 9.9 dB and L(10.6) = 15.0 dB were achieved in the test 63.09 with brass. In the case of carbon fibre S244, high attenuations were observed in the far IR range of the value

L(10,6) = 13.9 dB which also applies to the other measured particulate systems with attenuations of wavelength radiation λ = 10.6 μm.

Table 2

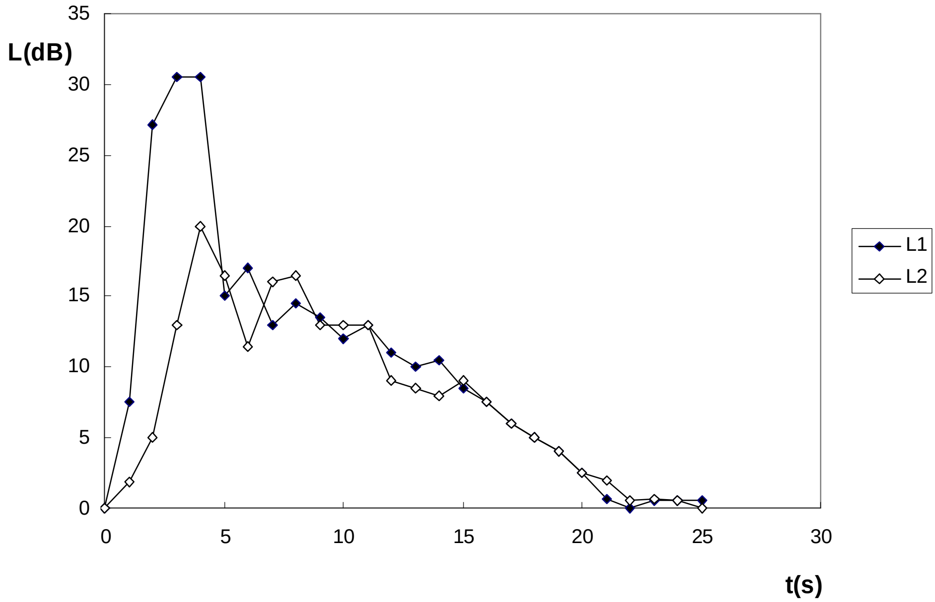
Mean attenuation values *L*(λ) in the tests with the particulate grenade models

Maximum setting of sensitivity limits: the limit is 30 dB for λ(0.82), the limit is 20 dB for λ(3-5), the limit is 15 dB for λ(10.6)

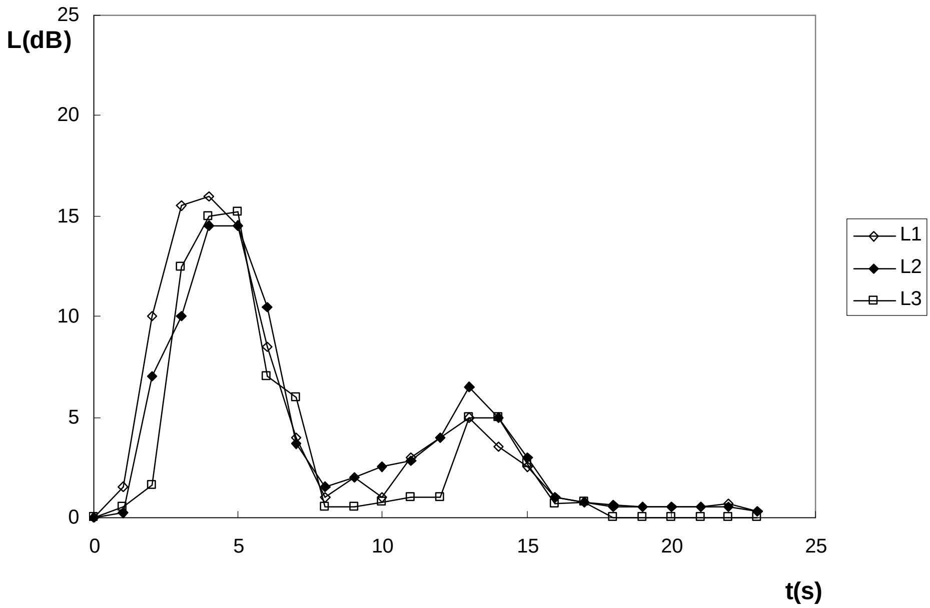
Test number	Canister payload	*L*(0.82) (dB)	*L*(3-5) (dB)	*L*(10.6) (dB)
63.03	A (CHZC)	29.0	17.4	-
63.22	A	18.4	18.8	15.0
63.18	B (UV)	6.6	7.2	4.2
63.19	B	10.8	7.6	12.2
63.20	B	10.1	9.6	13.9
63.21	B	6.2	6.7	6.3
63.05	C (MS)	8.4	9.2	-
63.09	C	17.9	9.9	15.0
63.10	C	11.7	7.2	7.1
63.14	D (ALBO)	28.0	19.4	15.0
63.23	D	19.9	12.3	15.0

The hitherto preliminary field measurements of attenuation in the microwave range by means of particles [20] were not sufficiently conclusive. However, it can be expected that the attenuation capabilities of the aforementioned particulate systems in the microwave range will be similar to the values of high attenuations in IR range (especially in far IR range) as was the case in the laboratory measurements [2]. However, it is necessary to say that similar information is still not available in technical literature to compare the measured values.

Sufficient air-borne capability of the particles in atmosphere "persistency" of the particles in the air shows the time course of attenuation in Graph 1 in the case of aerodispersion of carbon Chezacarb. In this test, radiation λ(1) = 0.82 μm was attenuated within approximately ten seconds under common weather conditions. Space shift of the cloud of aerodispersion aluminium from the grenade salvo at cross wind is illustrated by the time course in Graph 2 during which the aerodispersion from the middle grenade (the first peak) attenuated the radiation between the first and the seventh second and the aerodisperwion with a lower concentration of particles (as a result of diffusion and expansion) from the left grenade (the second peak) attenuated the radiation between the tenth and the fifteenth second.



Graph 1: Time dependance of attenuation $L(\lambda)$ on time t – test 63.03, Chezacarb (A payload)
L1 ≡ λ(1) = 0.82 µm; L2 ≡ λ(3) = 10.6 µm



Graph 2: Time dependence of attenuation $L(\lambda)$ on time t – test 63.16, aluminium ALBO (D payload)
L1 ≡ λ(1) = 0.82 μm; L2 ≡ λ(2) = (3-5) μm; L3 ≡ λ(3) = 10.6 μm

Air-borne capability of aerodispersions with the salvo of particulate grenades under variable field conditions was documented by the videorecorder time intervals of the cloud movements in the atmosphere on the picture sequences from the spreading after shot (in time t = 2 s) approximately till the maximum expansion in the area of spreading (in time t = (15-20) s).

4.2. Sizes of the Particulate Aerodispersions from the Grenades

The sizes (diameters) of the individual generated aerodispersion clouds (spherical shape to make it simplier) were estimated from the videorecords of firing tests during the salvo-shooting of the grenades. Growth of the cloud sizes was monitored in the time interval, usually from 2nd to 20th second from the moment of spreading of the canister by explosion.

Table 3:

Values of diameters *l* of coverage areas *S* of particulate clouds from individual grenades in salvo under variable wind blowing

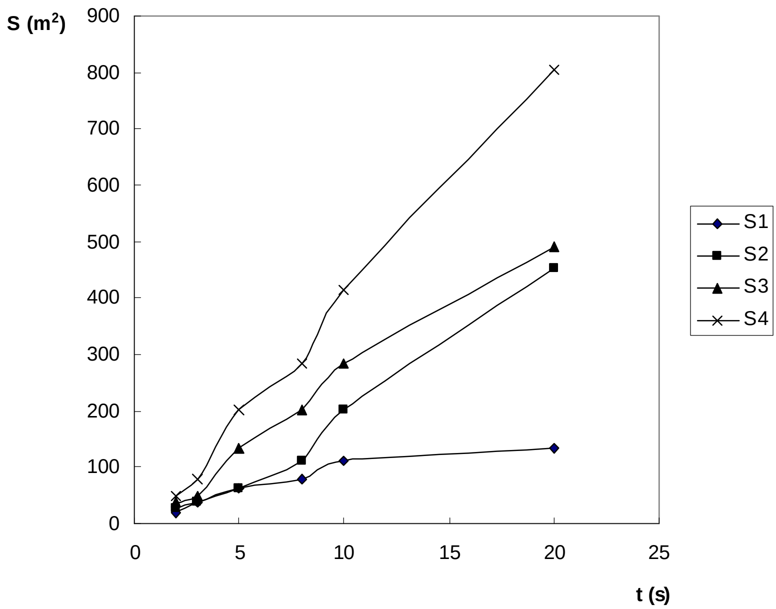
Test	*l* (m) in time from the explosion					
	2 s	3 s	5 s	8 s	10 s	~20 s
63.03	5	7	8	8	9	13
63.22	5	7	10	12	15	-
Average of CHZC	5	7	9	10	12	13
63.18	6	7	9	10	12	16
63.19	6	7	9	16	18	20
63.20	6	7	9	11	20	30
63.21	6	7	9	11	12	30
Average of UV	6	7	9	12	16	24
63.05	7	9	11	11	14	19
63.07	7	7	16	21	24	26
63.09	6	7	10	11	15	23
63.10	8	10	16	19	21	30
Average of MS	7	8	13	16	19	25
63.14	9	11	12	14	19	26
63.16	7	8	11	12	15	32
63.23	8	10	24	30	34	38
Average of ALBO	8	10	16	19	23	32

As it is illustrated by Table 3, the generation of the initial cloud of aerodispersion was finished in 2^{nd} to 3^{rd} s after the explosion and reached a diameter of cc 8 m in the case of brass and aluminium ALBO and a little smaller diameter in the case of carbon Chezacarb and carbon fibres S244. Within 5^{th} to 8^{th} s, the arerodispersion clouds reached, as a result of diffusion and expansion, an effective area (volume) of the object concealment (10-20) m from the observation direction depending on the variant of the tested grenades. As a rule, the clouds generated by individual grenade salvos began to merge after 8 s.

It could be observed during the tests that the used firing angles of 15 ° between the ejectors for the particulate grenade launching lead to considerable distances between the individual clouds of aerodispersion at the beginning of their generation which were not covered by particles. Obscuration of the object and, thus its camouflage since the finished generation of the initial cloud can be expected only with such a setting of ejectors and the used number of grenades that secure the only homogenous cloud of particles during spreading of all the shot grenades.

It can be presumed from the performed firing tests that all the tested kinds of the particles generated clouds of aerodispersions of similar sizes, especially at the beginning of dispersion. The tests showed that it is possible to generate an efficient particulate aerodispersion in a cloud from the tested grenade models on a short term basis (in a period of time of cc 20 s) under variable field conditions.

The tests showed that the coverage area of the particulate clouds *S* increased significantly with time. It can be deduced from the course of the curves of Graph 3. The lowest value of an area *S* was reached with the particles of carbon Chezacarb (in 20th s area S_{CHZB} = ~130 m^2, curve S_1), while the largets value of area *S* was observed with the particles of aluminium (in 20th s area S_{ALBO} = ~800 m^2, curve S_4).



Graph 3: Time increase of the coverage area *S* (m^2) of the particulate clouds from individual grenades under a variable wind blowing

S1 = S_{CHZB}; S2 = S_{UV}; S3 = S_{MS}; S4 = S_{ALBO}

It follows from the time dependences in Graph 3 that although a further increase of coverage area of the particulate cloud can be expected after 20 s, but also a significant drop of concentration of particles in the cloud leading to a low attenuation. Further shift of the cloud was in the wind direction so the obscuration effect of the aerodispersion was low.

5. Conclusions

The following conclusions arise from the results of fire tests conducted with particulate grenades under variable weather conditions in the field utilising the explosive method of spreading an aerodispersion of selected particulate materials:

a) The developed models of particulate grenades of a single-chamber and double-chamber canister design with an explosive method of spreading the payloads of particles secured the generation of particulate aerodispersions in a cloud. Generation of the clouds of aerodispersion was completed within 2^{nd} to 3^{rd} second after the explosion of the canister. The particles were sufficiently airborne and, as a result of diffussion and expansion, the clouds of aerodispersion reached a useful coverage of the object within 8^{th} to 20^{th} s. Thus generated clouds of aerodispersion can be characterised as effective for a short period of time.

b) It followed from the firing tests that all the tested kinds of particles generated the clouds of aerodispersions of similar sizes. In 10^{th} to 20^{th} s from the moment of the explosive method of spreading, the values of diameters of the clouds generated from the particulate grenade grew upwardly in the case of Chezacarb l = ~13 m, carbon fibres S244 l = ~20 m, brass l = ~22 m and aluminium l = ~28 m.

c) It emerged from the measurement results of the IR radiation attenuation that the particulate systems showed good attenuating properties on a short time basis in the whole region of IR radiation. It can be expected that the used particulate materials attenuate also the microwaves with regard to the previously measured attenuation capabilities of the particulate systems in the laboratory conditions [2]. The application of the tested particulate systems in multispectral protection of military objects is promising.

The findings from the functional tests [21] are the basis for the development of the particulate grenade providing the rapid multispectral protection of military objects. However, its application in the protection of concrete objects by means of an optimum method of dispersion will require further development work supported by a higher number of the shots during the shooting tests.

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Introduction of Author:

KLUSÁČEK Ladislav, M.Sc., PhD. He graduated from the Military Technical Academy Brno in 1958, he has been engaged in military science since 1960. He was a scientific worker in the field of screening smokes constituted at the VTÚO Brno in 1991. He was appointed a leader of scientific task KLABAVA. Later he was appointed a specialist of the VOP-026 Šternberk, s.p., VTÚO Brno Division with long-term investigation experience and development of screening means; today he is an external collaborator. He defended doctoral thesis in 1975 at the MA Brno. He is an author or co-author of 62 defended investigation reports and 52 scientific papers or performances in the field of screening, he is also a co-author of 21 patents or utility designs.