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Miniature Detonating Cord (MDC) for Breaking Organic Glass Plates

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Abstract: In order to develop a method to break the aircrafts canopy, a miniature detonating cords (MDC) of 1 mm in diameter were manufactured and its detonation properties were studied. MDC in a heavy lead confinement were also manufactured and were examined for breaking of organic glass plates. Results show that MDC in lead confinement with 1 g plastic explosive per metre, cuts organic glass plate 10 mm thick.

Key words: detonating cord, small critical diameter, PMMA plate cutting

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1 Introduction

Detonating cords are widely used in explosion technology, particularly in rock blasting industry and for military applications. A typical mining or military detonating cord of about 7 mm in diameter has about 10 g of loose sensitive explosive (PETN, RDX) per metre, which invented by Bickford in mid-19th century. The core consisting of loose explosive is braided over with layers of cotton and coated with PVC to make the detonating cord waterproof and increase its mechanical strength.

Decreasing the explosive to far below 10 grams per metre of MDC increases the risk of the detonation. To produce a new generation of detonating cords with ten times less explosive per metre requires a different approach. A relevant proposal was submitted by Du Pont[1] in which a sensitive, fine-crystalline explosive with a density above 1.5 g · cm^{-3} was used with some plasticizer added. The critical diameter of the explosive was less than 1 mm. Hawker Siddeley Aviation Ltd [2-3] offered an innovative design of miniature detonating cord (MDC) for the explosive breaking of aircrafts canopy. This paper presents the manufacture of MDC[4] used for breaking organic glass plates to develop a method for breaking aircrafts canopy.

2 Explosive properties of MDC

In order to obtain an explosive with a small critical diameter, the fine-crystalline PETN (grain size below 0.01 mm) was used as the main ingredient. A solution of poorly volatile organic solvent and nitrocellulose was used as a plasticizer. Lead tetraoxide was used as a thickener for the composition. The latter additive also reduces moderately the explosive properties but enhances its effectiveness.

The explosive ingredients were mixed at an elevated temperature in a Werner-Pfeiderer type machine. The obtained material had a density above 1.5 g · cm^{-3}. Miniature detonating cords with different diameters were obtained by extrusion through calibrated dies at elevated temperatures of up to 75 ℃. The MDC so produced are marked by good plasticity at a normal temperature and a mechanical strength sufficient to enable handling sections several metres long. Table 1 presents explosion characteristics of MDC with different chemical compositions. The velocity of detonation (VoD) was measured for MDC of 3.0 mm diameter. The weights of one meter long cord sections are provided for the critical diameter value. Fig. 1 shows a manufactured section of MDC with a diameter of 1 mm, a length of 20 m and the chemical composition provided in Table 1 at No. 2.

Also developed was a technology of an MDC in a lead confinement. The total weight of one metre amounted to between 50 and 150 grams. The quantity of explosive per metre was from 1 to 2 grams. The shape of the MDC cross-section in a lead confinement was circular or semi-circular. The cross-sections of semi-circular MDC are shown in Fig. 2.

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Table 1　Explosive characteristics of MDC

No.	content/%			density /g·cm^{-3}	D[1) /m·s^{-1}	critical diameter /mm	weight[2) of 1 m /g
	PETN	plasticizer	Pb_3O_4				
1	84	16	–	1.58	7650	<0.6	<0.45
2	80	20	–	1.56	7450	0.7	0.60
3	75	25	–	1.55	7240	1.0	1.25
4	70	20	10	1.65	7080	1.0	1.34
5	63	17	20	1.83	6600	1.2	2.15
6	60	15	25	1.90	6450	2.0	5.7

Note: 1) measured for 3 mm diameter; 2) measured for critical diameter.

3　Crushing PMMA plates by means of MDC

The manufactured miniature detonating cords of various designs were intended to cutting (crushing) organic glass plates (PMMA) with thick of 10 mm. A miniature detonating cord weighing 1.5 g/m, positioned freely on a PMMA plate leaves a barely visible trace on the surface (see path 1 on Fig. 3). A MDC of the same weight in a lead confinement of 50 g/m, pasted to the plate, cuts it effectively (path 3) whereas in a lead confinement of 150 g/m it destroys the plate structure at the point where the MDC was laid and makes additional parallel cracks (path 2).

The effect of a MDC in a lead confinement on PMMA plate was observed by a super high speed electron-optical camera. A piece of MDC in a semi-circular lead confinement (Fig. 4) was pasted onto the upper surface of a PMMA block 50 mm thick. The camera lens was positioned at the level of the block surface, perpendicular to the MDC axis. Fig. 4 shows the moment of detonation of the MDC on the PMMA block, a shock wave (1) generated in it, the detonation products expanding in the air (2) and an area of cracks forming in the block (3).

The effect of the MDC arrangement on a PMMA block upon the final fragmentation of the block was examined in another experiment. A miniature detonating cord in a lead confinement was shaped into many sharp V-bends that are conductive to additional fragmentation of the plate (Fig. 5a). The MDC contained 1.2 g of explosive per metre and the semi-circular confinement had a weight of 50 g/m. The experiment corroborated the cooperative effect of the V-bends of the miniature detonating cord, which improved the fragmentation of the PMMA plate (Fig. 5b).

The collected experience results made it possible to prepare a test for the explosive crushing of training aircraft canopy using MDC. The length of the MDC installed on the organic glass shield was about 5 m, which means that the total weight of explosive was 6 g. The canopy was fixed to a mobile rig. At the moment of detonation, the speed of the rig amounted to 150 km per hour. The experimental progress was registered using a video camera. Fig. 6 shows the cockpit image after 10 miliseconds from the moment of MDC detonation. An estimated speed of the canopy fragments, flying outside the cabin, with respect to the frame remaining on the plane dummy was about 10 m/s.

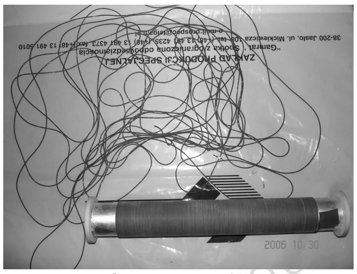


Fig. 1　The section of MDC

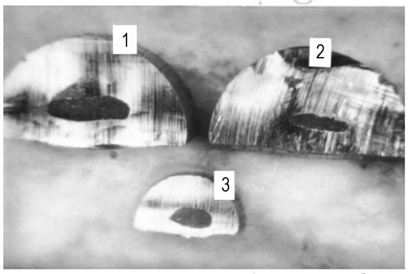


Fig. 2　Cross-sections of semi-circular MDC in a lead confinement

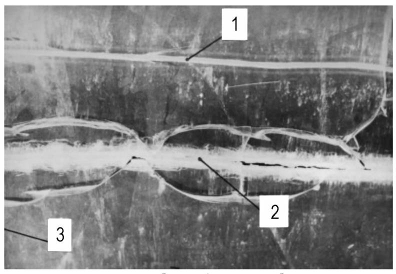


Fig. 3　Results of MDC detonation on a 10 mm PMMA plate

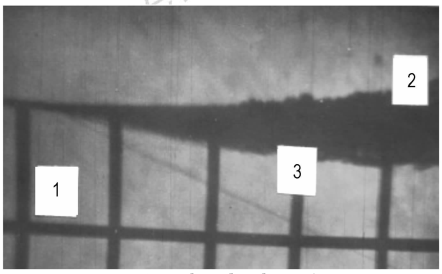
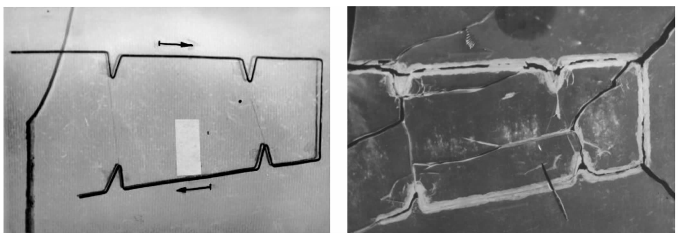


Fig. 4　MDC with a lead confinement detonated on a PMMA block



a. PMMA plate　　b. detonation results

Fig. 5　MDC in a lead confinement with V-bends installed on a PMMA plate (a) and its detonation results (b)

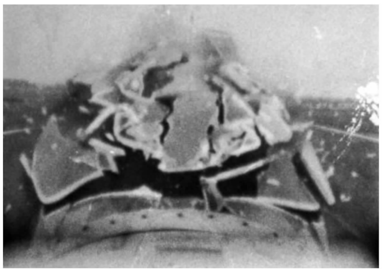


Fig. 6 Explosive crushing of cockpit shield using an MDC in a lead confinement

4 Measurements of pressure pulse in the air as generated by MDC

The high detonation speed of MDC causes powerful shock waves in the surrounding air. However, some untypical dependencies were expected due to the elongated shape of the explosive, its very small weight and the influence of the heavy lead confinement. The measurement of the pressure pulse generated by detonated MDC was made with pressure gauges manufactured by PCB Piezotronics [5]. One-metre sections of MDC were laid on PMMA plates. The pressure gauge was installed in the middle of the MDC length at a distance of 1 ft (about 30 cm), perpendicular to the MDC. The MDC detonation cap was covered by dry sand to avoid its relatively powerful pressure pulse overlapping the pulse generated by the MDC. Fig. 7(a) shows a pressure pulse generated by an MDC weighing 1.2 g/m. The pressure amounted to 0.7 bar and the pulse duration was about 0.1 millisecond. The effect of the lead confinement, weighing 150 g/m, is that the same MDC produces a pressure pulse (Fig. 7(b)) several times less, i. e. a pressure of 0.15 bar, the pulse duration of 0.05 millisecond. The disturbance visible further into the sequence is caused by the lead confinement splinters. The lead confinement clearly reduces the value of the pressure pulse generated during detonation. Nevertheless, the lead confinement produces splinters of relatively little energy.

5 Conclusions

The performed technology work led to the development of a plastic explosive based on a fine-crystalline PETN as the main ingredient. The tested explosive is marked by a small critical diameter (below 1 mm) and a high detonation velocity (above 7 km/s). The mechanical properties of the material make it suitable for the manufacture of MDC with a diameter in the neighbourhood of 1 mm and a strength sufficient to permit further processing.

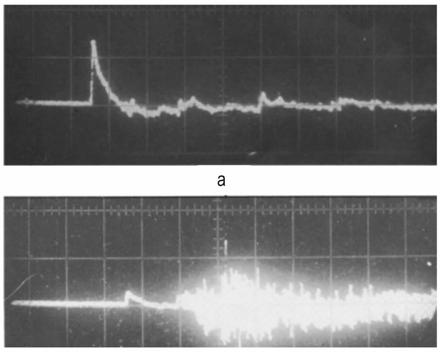


Fig. 7 The pressure pulse in the air generated by an MDC with weigh of 1.2 g/m without confinement (a), and with a lead confinement weighing 150 $g \cdot m^{-1}$ (b)

The developed plastic explosive can be used to produce MDC in lead confinement with different cross-section shapes, and within a wide range of the ratio of the explosive to the lead confinement. The MDC in lead confinement, containing 1 g of plastic explosive per metre, are capable to cut effectively organic glass plates 10 mm thick.

MDC in lead confinement is used for the explosive crushing of combat aircraft cockpit shields where the effectiveness of fragmentising the organic glass into desirable small pieces can be boosted by proper geometrical arrangement of the MDC on the cockpit shield. The maximum pressure, the duration of the blast wave generated by the MDC detonation and the energy of the lead confinement splinters will not be dangerous for a properly protected human located at one-foot distance from the detonated MDC.

References:

[1] Explosive connecting cord and cord-manufacturing method and apparatus[P]. GB Patent 1 582 903, 1981.

[2] Improvements in or relating to aircraft canopy emergency break-up system[P]. GB Patent 1 383 511, 1975.

[3] Improvements in or relating to detonating cord for aircraft canopy emergency break-up system[P]. GB Patent 1 383 512, 1975.

[4] Zygmunt B et al. Plastic miniature detonating cord (in Polish)[J]. *Biuletyn WAT*, 38, 3, 1989: 123 - 134.

[5] Zygmunt B. Explosive properties of the Mg-Al/PTFE composition[J]. *Chinese Journal of Energetic Materials (Hanneng Cailiao)*, 2007, 15 (6): 592 - 596.