Fracture in the high explosive RDX/TNT

The safety and performance of many high explosives are influenced by their physical state. In particular, explosive fillings of ammunition designed for gun launching must be able to withstand the high setback forces imposed, retaining their structural integrity so that they can satisfactorily perform their explosive function at the target. In recent years, there has been considerable effort expended in describing the physical properties of cast explosives and their influence on explosive initiation and the growth to detonation. Cracks and other faults in high explosive fillings have been shown to affect both their safety and performance, although the reasons for this are not yet understood.

One of the most common of military high explosives is Composition B, a formulation containing two explosive ingredients: RDX (cyclotrimethylenetrinitramine) and TNT (trinitrotoluene). It is cast as a slurry of molten TNT containing 55 to 60% of solid RDX. Like other TNT based explosives, Composition B is a weak, brittle material, easily cracked by mechanical or thermal stress. The microstructure of the matrix of TNT [1] is normally one of highly oriented columnar grains. On solidification near the melting point, TNT undergoes a volume shrinkage of slightly over 10%, which can result in considerable intergranular voidage unless casting conditions allow a continuous path between the solidifying front and a liquid head. Shrinkage in the solid on cooling from the solidification temperature causes a significant amount of cracking in TNT-based compositions. Unless the stresses arising from the contraction of the anisotropic TNT are relieved by mass transport or intergranular sliding, cracking on a macro scale will occur. TNT is weak in shear across the grain, so that cracks can easily propagate in steps, along the weak intergranular boundary and across the grains. Although the addition of RDX to TNT produces a material of higher mechanical strength, the composite is still weak and brittle. For example [2], pure TNT has an ultimate compressive strength of about 2.3×10^6 N m^{-2} (330 lbf in^{-2}) at a strain-rate of 1/16 min^{-1}, while RDX/TNT (55:45) gave values around 1.6×10^7 N m^2 (2300 lbf in^{-2}) at the same strain-rate.

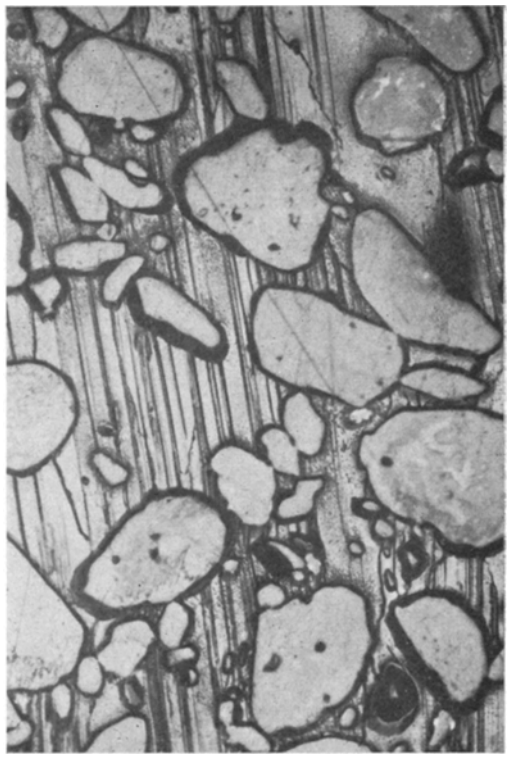


Figure 1 Polished Composition B. Bromoform etch (× 200).

Composition B can be examined in an incident light microscope, providing that a sufficiently good surface polish is achieved. Mechanical polishing with a magnesium oxide/water slurry [3] is satisfactory. Fig. 1 shows a polished RDX/TNT sample etched with bromoform, and illustrates the high degree of orientation of the

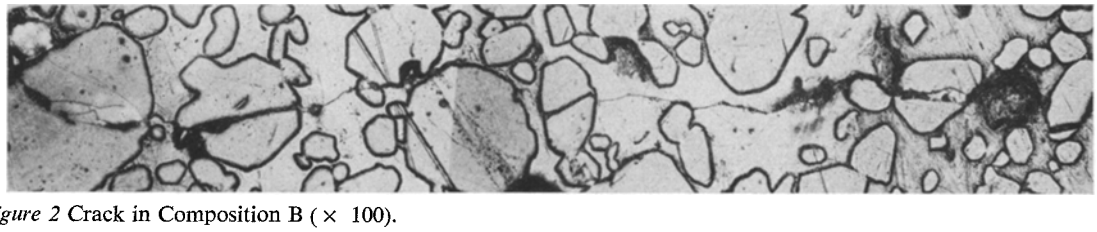


Figure 2 Crack in Composition B (× 100).

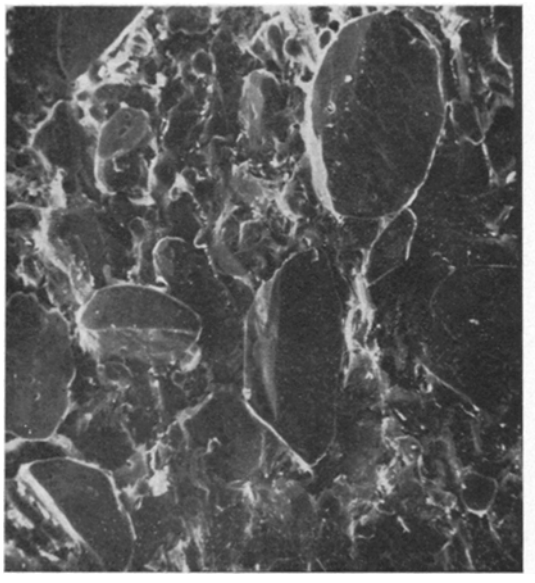


Figure 3.

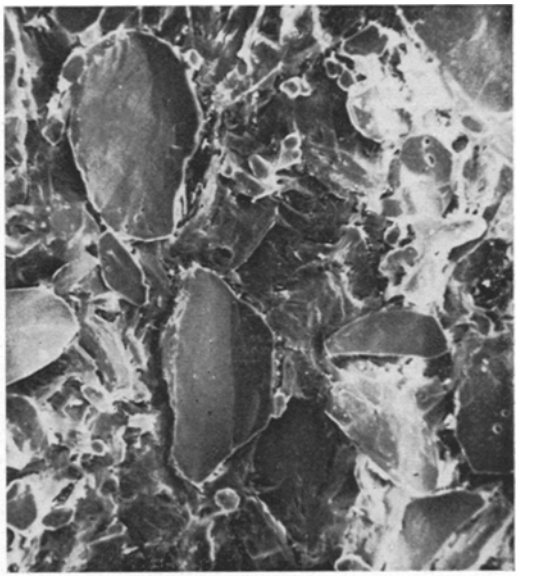


Figure 4.

Figures 3, 4 and 5 Composition B fracture pair with tracing (× 200).

TNT matrix. Although direct examination of fracture surfaces is difficult in an optical microscope, some information on the fracture may be gained by examining fine cracks in section. Fig. 2 shows a composite micrograph of a crack formed by the setback of a shell-filling during gun-firing. The crack has travelled both through and around RDX particles in its path. The dark areas in the figure are cavities where dislodged RDX particles have fallen out of the TNT matrix. This highlights one of the difficulties in microscopic examination of shell fillings; secondary damage from frictional contact between two fracture surfaces, combined with damage incurred by handling and sectioning, can obscure the original surface detail. For this reason laboratory-fractured specimens are preferred for fractographic examination, although these cannot reproduce the conditions suffered by the explosive in a shell.

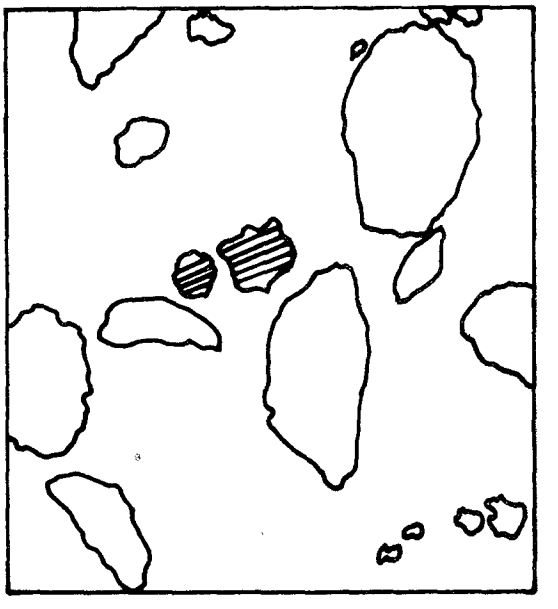
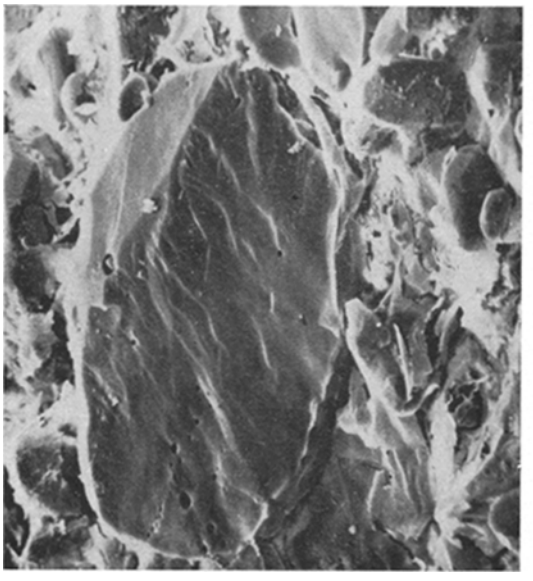
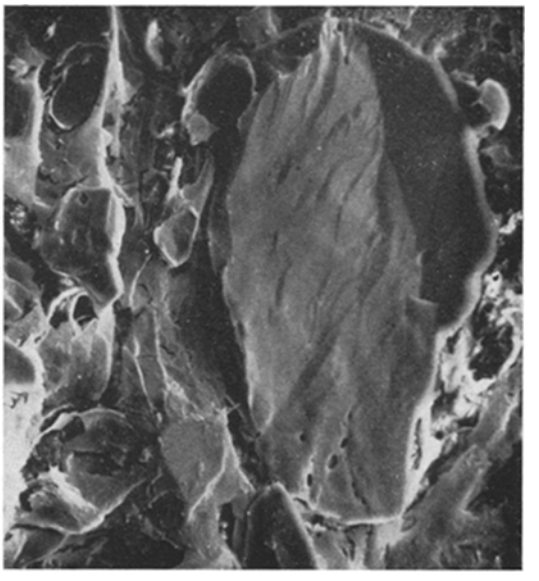


Figure 5.

In order to study the surface markings, examinations of RDX/TNT fracture have been made in the scanning electron microscope (SEM). Dumbell pieces of 6 mm circular cross-section were machined from pressure-cast RDX/TNT (55/45) and fractured in a Hounsfield tensometer at a strain-rate of 1/4 min^{-1}. Pairs of matching fracture surfaces were then mounted on specimen stubs and vapour coated with gold under vacuum to provide the conducting layer necessary for examination in the SEM. Unfortunately, this method of specimen preparation causes a small amount of sublimation in TNT which causes surface pitting. Attempts to reduce sublimation by the use of a cold stage have not so far been successful.

Fig. 3 is a scanning electron micrograph of an area whose fracture mate is seen in Fig. 4.





Figures 6 and 7 Fracture pair showing main RDX subject (× 500).

Seventeen fractured RDX particles can be identified as having a surface in each print, as indicated in the line drawing (Fig. 5). The two cross-hatched areas in the line drawing represent RDX particles which have pulled out of the TNT matrix, leaving matching cavities in the opposite surface (Fig. 4).

Fractured RDX (Figs. 6 and 7) shows the characteristics of brittle cleavage. This fracture pair is taken from the area shown in Figs. 3 and 4. The large RDX particle in Fig. 6 is cleaved in two planes. The larger fracture plane contains distinct river markings of the type normally found in cleavage and it can be seen that the crack has travelled from the top left-hand corner to the bottom right-hand corner in the figure. The smaller fracture plane on the top left of the particle was presumably cut off by initiation of the new front, which was travelling closer to the overall direction of fracture.

A large proportion of RDX particles are cleaved in Composition B fracture. This has been shown both with fillings from fired and recovered shells, and with laboratory specimens broken at low strain-rates. All broken RDX particles observed have shown evidence of brittle fracture.

Despite the unsuccessful attempts to view the fine surface detail on TNT, the scanning electron microscope has proved to be a useful tool in the investigation of fracture in RDX/TNT, permitting detailed examination of RDX fracture surfaces.

References

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