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EFFECT OF INTERIOR SURFACE FINISH ON THE BREAK-UP OF COPPER SHAPED CHARGE LINERS

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A series of experiments aimed at understanding the influence of the liner interior surface finish on the break-up of shaped charge jets has been completed. The experiments used a standard 81-mm shaped charge design, loaded with LX-14 high explosive; incorporating high-precision copper shaped charged liners. The results indicate that a significant reduction of jet break-up time occurs between a surface finish of 99.30 microinches and 375.65 microinches. Surface finishes of 4.78, 44.54 and 99.30 microinches produced significantly better ductility and associated break-up times than the 375.65-microinch finish. The baseline production process high-precision liners were measured to have an average surface finish of 44.54 microinches. The results show that for the shaped charge warhead geometry and explosive combination investigated, some care must be taken in respect to surface finish, but that very fine surface finishes do not significantly improve the jet ductility and associated break-up times.

INTRODUCTION

Previous studies have investigated the role of purity of liner materials [1-3], grain size [4,5], and other liner material effects [6-8] on shaped charge jet break-up behavior. The results of these liner material investigations revealed strong correlations between microstructure and ductility, but relied on the assumption that geometrical factors were held to within some reasonable tolerance in order to separately distinguish the liner microstructural effects. Liner fabrication is known to exert a strong influence on jet straightness, but there have been no conclusive investigations focussed on determining the influence of surface finish. For this reason, it was decided to investigate the role of liner finish on jet ductility. To assure consistency in the microstructure from one liner to the next, liner blanks were back extruded and rough machined from the same starting bar. An identical heat treatment was applied to all liners to assure a consistent microstructure. A series of experiments aimed at understanding the influence of the liner interior surface finish on the break-up of shaped charge jets has been completed.

LINER SURFACE FINISH

A series of experiments aimed at understanding the influence of the liner interior surface finish on the break-up of shaped charge jets was conducted using four different liner finishes using standard 81-mm 42 degree copper shaped charge liners [9]. Figure 1a presents a photograph of the standard 81-mm shaped charge liner. The purpose of these experiments was to quantify the potential positive or negative influences on the resulting jet break-up caused by finer or coarser surface finishes beyond standard machining. Three non-standard surface finishes, referred to as fine, medium and coarse, were characterized as shown in Table I in addition to the standard production machining. The non-standard liners were machined from conventional high-precision liners at the LLNL precision machine shop. A very small amount of material was removed from the standard liners on the order of 5/10000 inches. Significant attention was paid to assuring that the liners had a constant mass, 225±1.0g, as well as constant high explosive-side surface finish at 22.6 microinches. The resulting surfaces were subsequently measured using a precision surface finish analyzer. Figures 2-4 present the results of the surface finish measurement for the three non-production finish liners.

Figure 1. Standard 81mm shaped charge liner.

TABLE I. SURFACE FINISH IN MICROINCHES

Part Number	Pole	Middle	Waist	Average	Mass (g)
Liner # 453 - Fine	4.28	4.54	5.53	4.78	225.579
Liner # 450 - Production	35.96	24.42	73.25	44.54	225.284
Liner # 461 - Medium	98.92	99.93	99.05	99.30	225.018
Liner # 473 - Coarse	361.03	373.13	392.78	375.65	225.274

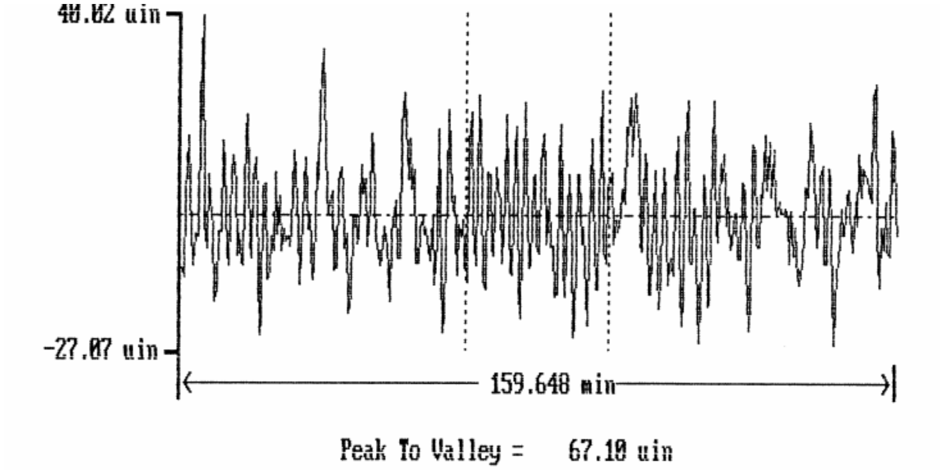


Figure 2. Surface finish trace of the pole region of fine-finish liner. This liner exhibited an average surface finish of 4.78 microinches.

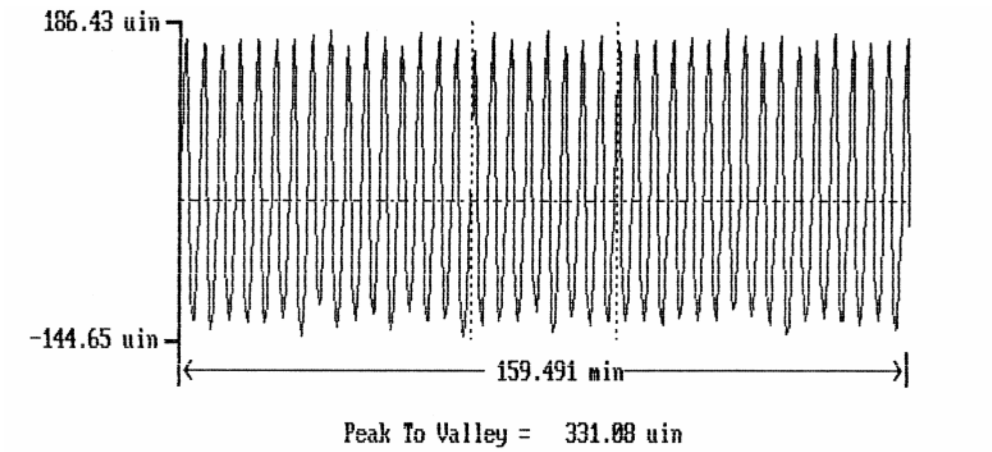


Figure 3. Surface finish trace of the waist region of medium-finish liner. This liner had an average surface finish of 99.30 microinches.

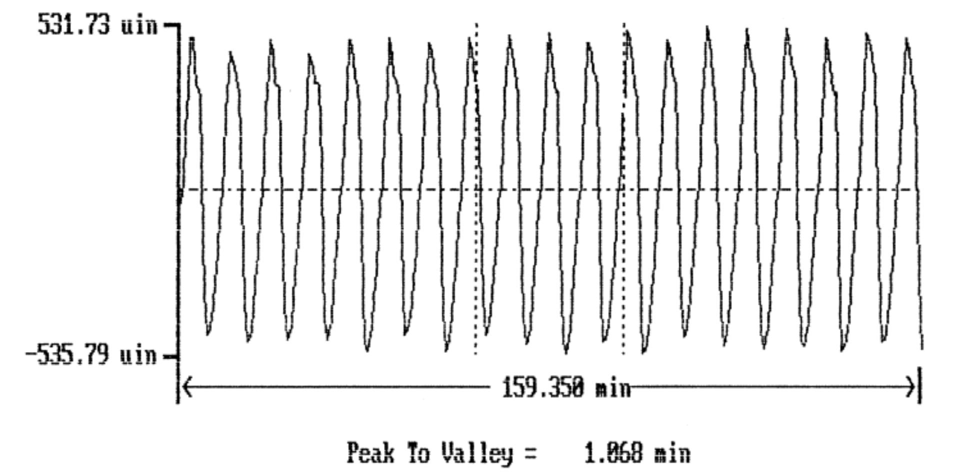
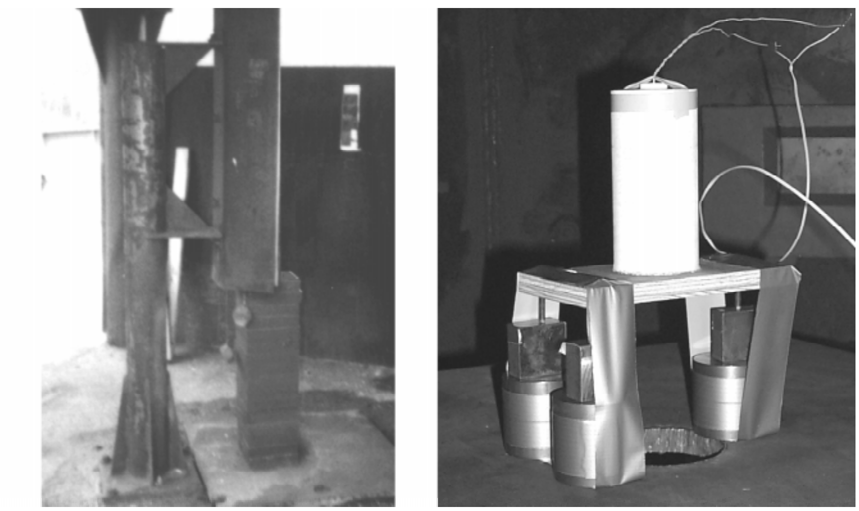


Figure 4. Surface finish trace of the waist region of coarse-finish liner. This liner had an average surface finish of 375.65 microinches.

EXPERIMENTAL SETUP

The experiments used a standard 81-mm shaped charge design, loaded with LX-14 high explosive. The liners were loaded by forming a preform cavity in a slightly oversize billet and then pressing the liners into the preform cavity under full pressure. The liners were prepared with a fine coat of estane on the explosive contact surface of the liner in order to assure liner to billet cohesion. The resulting shaped charge billets were precision machined to final dimensions and subsequently tested in a bare billet configuration to avoid potential body/billet effects. Photographs of the test stand and explosive billet configuration are shown in Figure 5 (a and b). Liners of each of the surface finishes were tested and recorded using flash x-ray radiographs at relatively long standoff (20 charge diameters) in order to observe jet break-up and post break-up jet characteristics. Reduction of the jet x-rays was accomplished using a high-precision digitizing light table and specialized software developed specifically for shaped charge jet x-ray data reduction.



(a) (b)

Figure 5. (a) Bottom of the test stand, and (b) top of the test stand revealing the explosive billet test configuration.

EXPERIMENTAL RESULTS

Figure 6 presents jet length versus jet velocity for the four different surface finishes. Figure 7 presents jet break-up time versus jet velocity for the four different surface finishes. The average break-up time of the 4.78-microinch surface finish shaped charge was 177.9μs. The average break-up time of the 44.54-microinch surface finish shaped charge was 169.2μs. The average break-up time of the 99.30-microinch surface finish shaped charge was 183.3μs. The average break-up time of the 375.65-microinch surface finish shaped charge was 138.1μs.

Long standoff triple flash radiography was used to obtain three images at different times. These radiographs are shown in Figure 8 from fine to coarse, top to bottom.

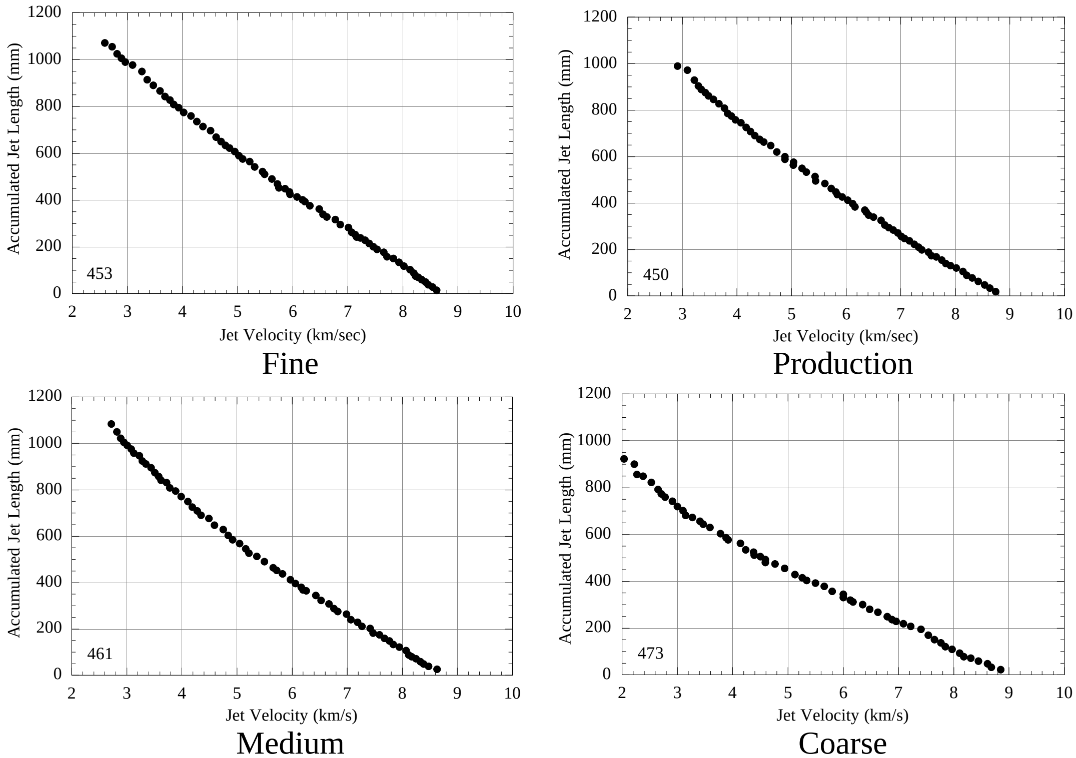


Figure 6. Jet length versus jet velocity for different surface finish shaped charges.

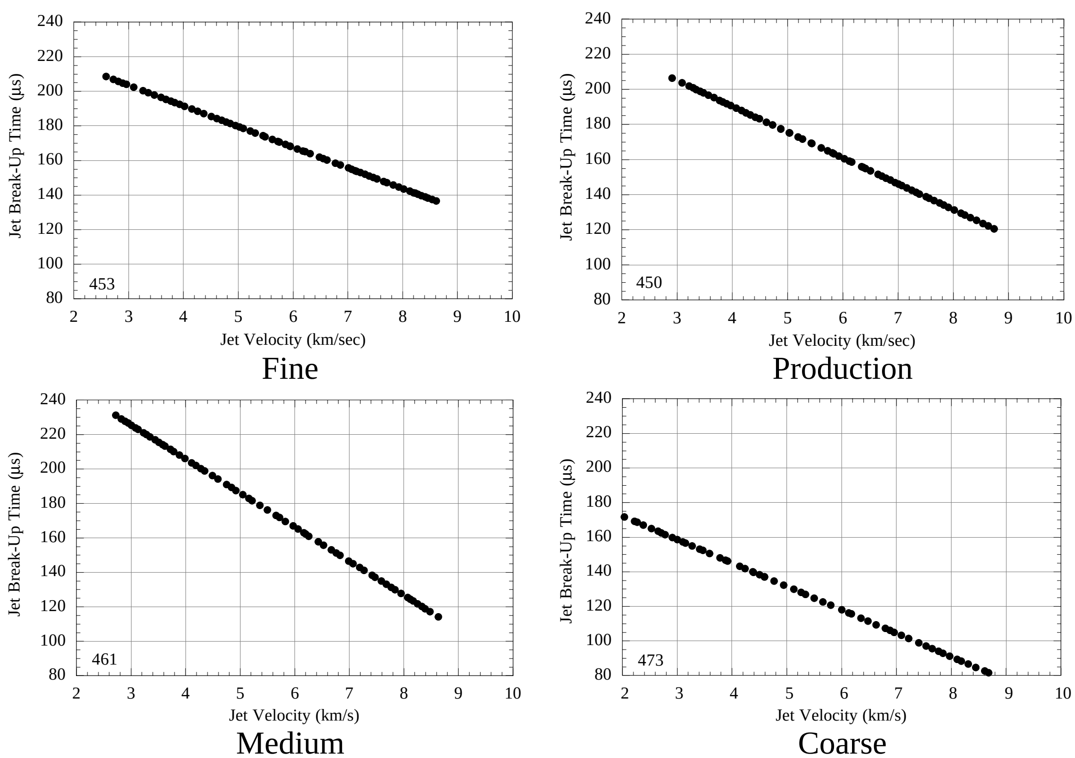


Figure 7. Jet break-up time versus jet velocity for the different surface finish shaped charges.

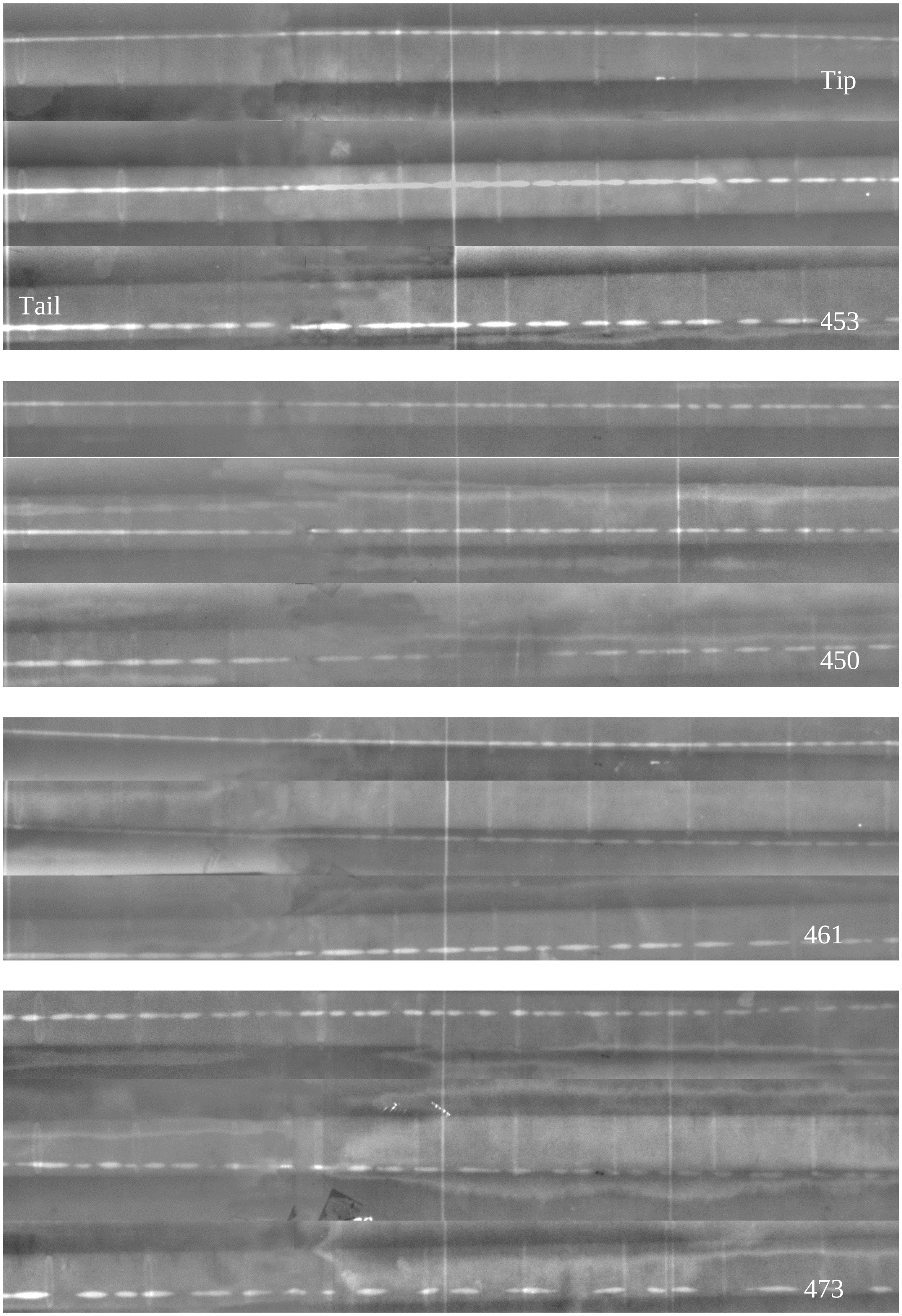


Figure 8. Triple flash radiographs of the four liners, fine to coarse, top to bottom.

DISCUSSION

Analysis of accumulated jet length as a function of jet velocity in Figure 5 indicates that the fine (#453), production (#450), and medium (#461) surface finishes all had an accumulated jet length of approximately 1000 mm at a cut-off velocity of 3 km/sec. However, the accumulated jet length of the coarse finish liner (#473) reached a maximum of approximately 920 mm at 2 km/sec, and only 720 mm at 3 km/sec. This indicates a dramatic decrease in performance with coarser surface finishes. The results in Figure 6 also indicate that a significant reduction of jet break-up time occurs between a surface finish of 99.30 microinches and 375.65 microinches. Surface finishes of 4.78 (fine), 44.54 (production) and 99.30 (medium) microinches produced significantly better ductility and associated break-up times than the 375.65-microinch finish (coarse). The average break-up times of the fine, production, and medium liners do not show a linear relationship with surface finish, however, the break-up times at the front of the jet do increase with decreasing roughness. The significance of this is not fully understood, although a correlation of the tip break-up time and the average break-up time was observed in the data in [2].

Although jet straightness was not ideal, the fine, production, and medium surface finishes all revealed ductile behavior with high aspect ratio particles as shown in Figure 8. The coarse surface finish liner exhibited quite brittle behavior. Jet particles were shorter and wider, and were observed to tumble in late times. The resolution of the radiographs was not sufficient to extract a precise particle size distribution for comparison of the effects of surface finish with computational models.

CONCLUSIONS

The results show that for the shaped charge warhead geometry and explosive combination investigated, some care must be taken in respect to surface finish, but that very fine surface finishes do not provide significant improvement of jet ductility and associated break-up times. To further validate this conclusion, another series of surface finish liner experiments are being conducted. Finally, the results of this study indicate that the previous liner material studies are independent of liner surface finish effects.

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