

Study of Grooved Warhead Structure on Performance of Warhead Fragment Distribution Pattern

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ABSTRACT

Fragment distribution pattern is a major factor for fragmentation warhead of medium diameter gun weapon, two different grooved warhead structures on the outer surface of warhead are proposed in this paper to improve warhead fragment distribution pattern. Experiments are performed to validate effectiveness of said efforts, and results show diamond-grooved warhead structure produces more fragment distribution density around warhead axis than parallel-grooved warhead structure, while keeping identical fragment projecting angle and dispersion angle. Finally, optimum depth on the surface of diamond-groove warhead structure is also obtained through experiments, showing impressive capability to withstand barrel gunpowder pressure more than 300 hundred million pascal per square meter.

1. INTRODUCTION

Medium diameter gun receives widespread attentions for advantages of fast deployment speed, launching interval, and efficient cost, providing terminal defense for the high-valued weapon platforms, e.g. 76mm diameter gun of Oto Melara Company in Italy was extensively equipped in the Western navies such as the United States, Britain, and France etc. Unfortunately fragments generated on the detonation of medium diameter warhead have undesirable uneven shrapnel size, shape, mass, and distribution pattern, leading to undesirable destruction toward intended target. For this reason, defense contractors across the world increasingly design preformed warhead structure to improve fragment size, shape, mass, and distribution pattern, enhancing lethality of medium diameter warhead. Oto Melara in Italy, for instance, adopts a preformed warhead with hundreds of tungsten alloy spheres around outer surface of warhead explosive charge, evidently increase lethality of 76mm diameter warhead.

2. GROOVE STRUCTURE DESIGN

Amongst various preformed methods, full preformed fragmentation and partial preformed fragmentation are extensively used in the warhead design to enhance destruction capacity. Full preformed fragmentation mainly applied in such mild launching environment as general launchers for the reason of lower launching overload, in such circumstance warhead should have a thinner wall thickness to save space to arrange hundreds or thousands of full

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preformed metal fragments around explosive charge, then even fragment size, even fragment shape, even fragment mass, and more fragment distribution density are obtained, while relatively lower fragment projecting velocity is also obtained.

Partial preformed fragmentation, for the reason of thick warhead structure wall, could withstand such typical harsh launching environment as gun barrel, and relatively even fragment size, fragment shape, fragment mass, and fragment distribution density are also obtained.

Grooved warhead structure, a typical partial preformed fragmentation, has a series of deep grooves on the surface of warhead, which could generate a series of stress concentration points, these concentration points break up upon detonation of warhead explosive charge, then numerous even-sized fragments are obtained, and projecting toward target at supersonic velocity, penetrating intended target[1].

2.1 Experiment Sample

Two different kind of experiment samples were machined on outer surface of warhead structure, sample #1 is grooved in parallel arrangement with 90 degrees on the outer surface, sample #2 is grooved in diamond arrangement with 45 degrees, in this case, equivalent thickness of grooved warhead structures of sample #1 and sample #2 is thinner than ungrooved section of warhead structure, leading to reduction of tensile stress and compressive stress in the grooved section, which produces stress concentration points in the grooved section of warhead structure. Once upon detonation of warhead explosive charge, detonation shock wave quickly sweeps across inner surface of warhead structure, bring about a series of breakup lines along stress concentration points, then warhead structure simultaneously fractures along the breakup lines, generating hundreds or thousands of metal fragments, which show a desirable performance of even shape, even size, and even mass, punching numerous even-sized circular holes on the intended target.

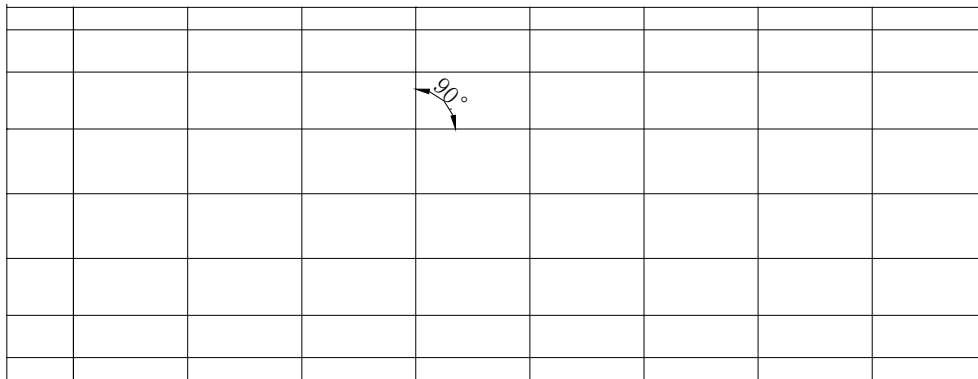


Figure 1: Parallel-grooved Warhead Structure

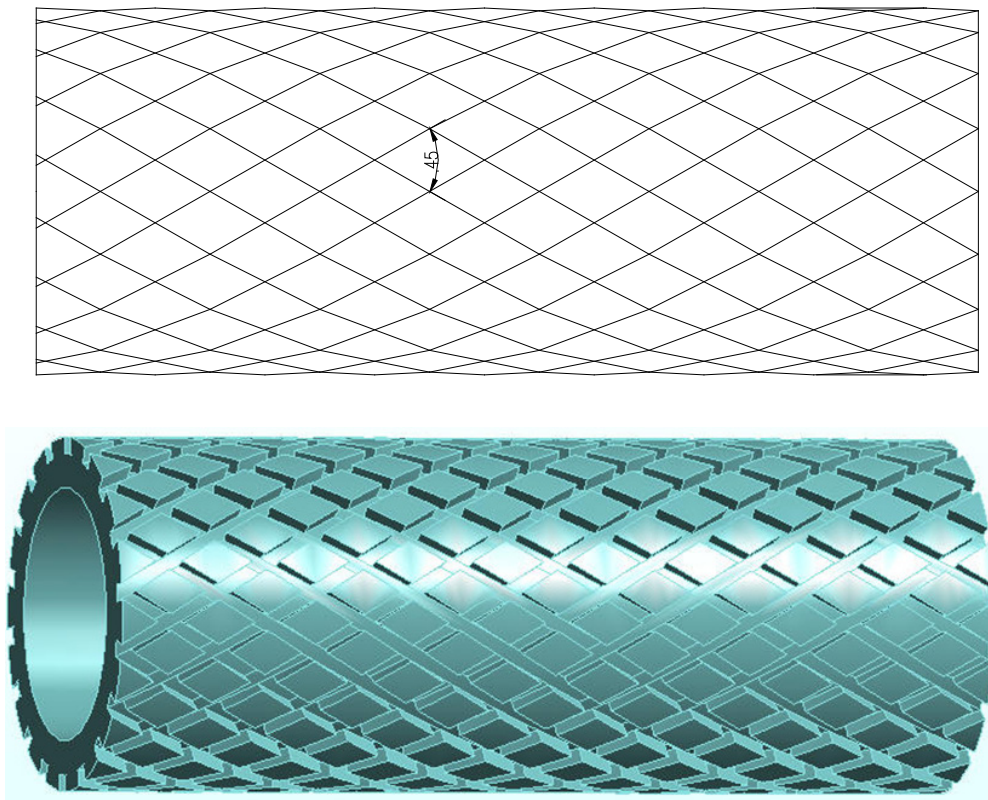


Figure 2: Diamond-grooved Warhead Structure

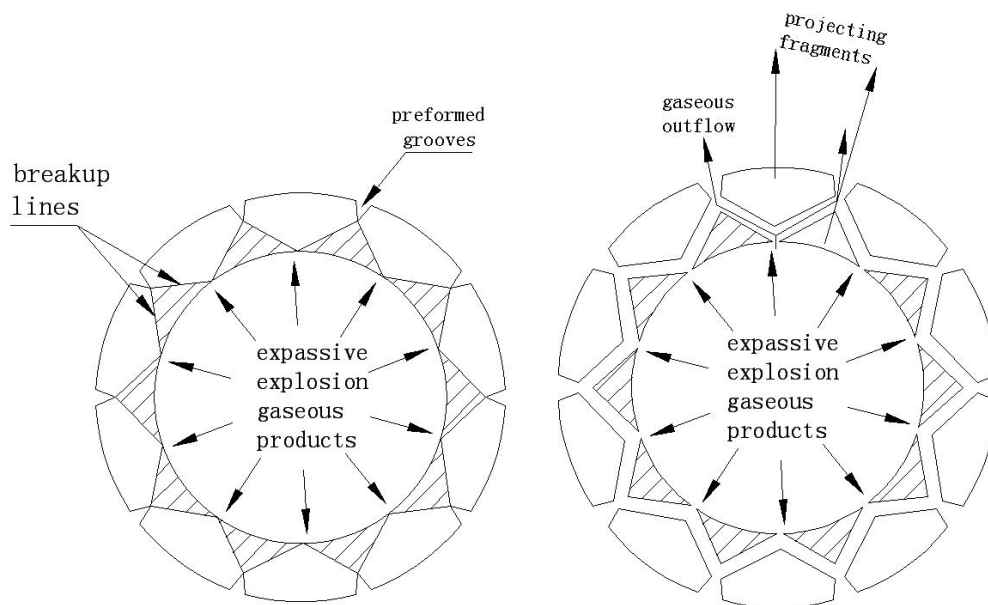


Figure 3: Cross-sectional View of Breakup Lines and Projecting Fragments

2.2 Experimental results and analysis

The specifications of experimental samples are

- (1) Single point center detonation in on end of warhead,
- (1) HMX-based explosive charge,
- (2) Warhead structure of low carbon steel,
- (3) Warhead structure diameter of 76mm,
- (4) Intended target of type Q235A steel.

The lethality of above experimental samples are verified in the static ground explosion experiments, results are listed in Table 1. Sample #1 of parallel-grooved warhead structure produces a combination of bar-shaped fragments pattern and square-shaped fragments, with fragment distribution density of 11.9 fragments per square meter. While sample #2 of diamond-grooved structure produces almost identical square-shaped fragments, with a distribution density of 38 fragments per square meter toward intended target of type Q235A steel, obviously sample #2 of diamond-grooved warhead structure show more uniform fragment distribution pattern than sample #1 of parallel-grooved warhead structure, meantime, sample #2 of diamond-grooved warhead structure exhibit more fragment distribution density.

Table 1: Experimental Results of Grooved Structure Warhead

sample	Warhead structure	Fragment shape	Distribution density
#1	Parallel grooved structure	Bar-shaped square-shaped	11.9
#2	Diamond grooved structure	square-shaped	38.0

3. GROOVE DEPTH OPTIMIZATION

For grooved warhead structure with different groove depth, shallow groove depth could relatively lessen warhead structure stress, providing more robust constraints confining explosive gaseous products before warhead structure fracturing, then a relatively longer loaded time of high pressure expansion gaseous products inside warhead structure results in higher projecting velocity of fragments. Deeper groove depth could relatively weaken warhead structure, providing lesser constraints to the explosive gaseous products, then a relatively shorter loaded time of explosive pressure on grooved structure results in relatively lower projecting velocity, meantime an acceptable even fragment size, mass, and distribution pattern are also obtained.

3.1 Optimal groove depth

In this paper, sample #3 and sample #4 are prepared on the basis of sample #2 with different diamond-grooved depth of 1/2 and 2/3 of warhead wall thickness respectively, static ground explosion experiment is performed to validate lethality performance, experimental results are listed in table 2. Experimental results show that groove depth in the surface of warhead structure significantly influence fragment projecting velocity and distribution density while keeping an identical fragment projecting angle of 4 degrees and dispersion angle of 8 degrees. Sample #4 could produce 5.7% more fragments than sample #3 for the reason of excellent fragment-generating capacity due to deeper groove depth, whereas achieving 5.6% relatively lower than sample #3 in fragment projecting velocity for the reason of soft constraint due to thicker warhead structure of sample #4.

Table 2: Influence of grooved depth on fragment projecting velocity and distribution properties

Sample number	Grooved depth	Fragment projecting velocity (m/s)	Fragment distribution density (per square meter)	Fragment dispersion angle (degree)	Fragment projecting angle (degree)
#3	1/2 of warhead wall thickness	1665	47.7	8	4
#4	2/3 of warhead wall thickness	1577	50.4	8	4

3.2 Stress assessment of warhead structure

Besides general launching overload, warhead used in the medium-sized gun must resist gun barrel gunpowder pressure of hundreds of million pascal per square meter, then stress of warhead structure should be considered and assessed in the course of grooved depth optimization. So sample #5 is prepared and subject to stress assessment in artificial gun barrel simulator.



Figure 4: Gun Barrel Simulator

In the stress assessment, grooved warhead structure was compressed by fast burning of standard gunpowder, which is equivalent to gun barrel launching overload. Stress assessment result shows that a diamond-grooved 1/2 depth of warhead structure wall thickness could resist simulated barrel gunpowder pressure of 350 million pascal per square meter, while keeping explosive charge intact, meeting requirements of harsh launching overpressure in gun barrel.

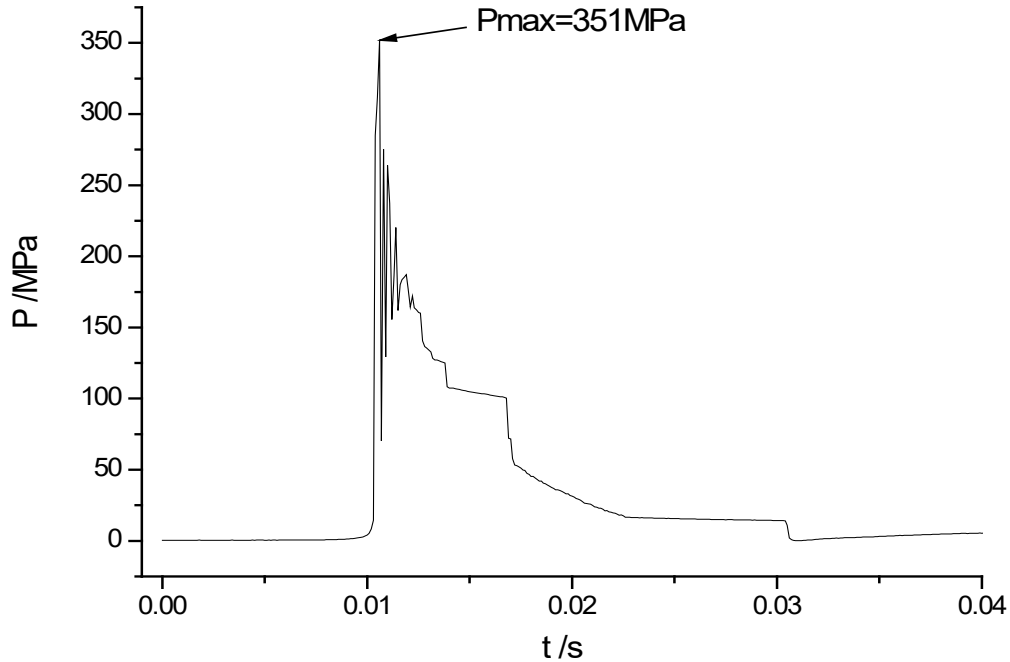


Figure 5: Pressure Curve of Artificial Gun Barrel Simulator during Launching Stage

4. CONCLUSIONS

- (1) Machining a series of grooved depth on the surface of medium diameter gun could produce a series of stress concentration points, providing desirable breakup lines to form fragments upon detonation of explosive charge;
- (2) Comparing to parallel grooves on the surface of warhead of medium diameter gun, diamond grooves could evidently produce fragments characterized of evenly size and shape, enhance lethality of warhead.
- (3) Diamond grooved depth of more than 1/2 warhead structure wall thickness could produce more fragments around warhead axis toward intended target.
- (4) Considering fragment distribution density, projecting velocity, and launching overpressure in the gun barrel, machining a series of 1/2 grooved depth of warhead structure could enhance lethality of medium diameter warhead, which is desirable in the engineering development of medium diameter gun warhead.

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