Abstract: The present invention relates to a composite perforating device with scallops on its inner wall to improve the depth of penetration in the oil reservoir during perforation of oil and gas well. In one embodiment, the scallops on the inner wall of the gun body are located at a position corresponding to the open end of a perforating charge. In one embodiment, the scallop may have a stepped-cylindrical or truncated-conical inner peripheral surface and a conical or flat bottom surface. Alternatively, the scallop may have an inner conical surface. The scallops on the inner wall of the gun body increased the burst heights of the perforating charges such that the penetration depth of the perforating device is increased.
COMPOSITE PERFORATING DEVICE WITH SCALLOPS ON THE INNER WALL

[0001] This application claims benefit of Chinese application CN 201120533902.3, filed December 15, 2011. The content of the preceding application is hereby incorporated in its entirety by reference into this application. Throughout this application, various publications are referenced. Disclosures of these publications in their entireties are hereby incorporated by reference into this application in order to more fully describe the state of the art to which this invention pertains.

FIELD OF THE INVENTION

[0002] The present invention relates to the field of oil exploration and exploitation, especially to a composite perforating device having scallops on the inner wall of the gun body.

BACKGROUND OF THE INVENTION

[0003] In the field of exploration and exploitation of oil and gas well, composite perforation technology is widely used in the well completion process as an effective method to increase productivity. On the basis of the penetration produced by the detonation of perforating charges, in combination with the energy from the high-energy gas fracturing techniques, the perforation tunnel is impacted to eliminate the influence of the compaction zone and generate a plurality of microcracks in the formation which will expand and extend the cracks. Conventional composite perforating guns possess generally scallops on the outer wall of the perforating gun so as to decrease the topical wall thickness of the perforating gun and reduce the loss of jet flow of the perforating charge. However, restricted by the outer diameter of the perforating gun, the burst height of the perforating charge within the gun body tends to be relatively low and far lower than the ideal burst height. This causes the jet flow generated by the detonation of the perforating charge to encounter obstacles prematurely, the gathering energy effect and energy of the perforating charge is not able to exert fully, and the penetration depth of the perforating gun is therefore decreased. For a perforating gun with 102mm external diameter, the burst height for the perforating charges is only around 12% of the ideal burst height, thereby greatly hinders the full stretching of the jet flow. Moreover, to increase the penetration depth, a combination of small perforating gun with large perforating charges is most often used. The actual burst height of the large perforating charge in the gun body is much far less than the ideal burst height of the charge, and the actual penetration depth is greatly reduced. The relationship between burst height and penetration depth of a perforating charge is shown in Fig. 1. When the actual burst height is less than the ideal burst height, an increase in the burst height will lead to a linear increase in the penetration depth of perforation. Therefore, although the dimension of the
perforating charge was increased in current composite perforating guns, there is no improved
effect on penetration depth of perforation as the actual burst height is limited.

**SUMMARY OF THE INVENTION**

[0004] This invention provides a composite perforating device with scallops on its inner wall
that is capable of improving the penetration depth in oil reservoir during perforation.

[0005] In a perforating gun, the burst height of a perforating charge in the gun body refers to the
distance between the plane of energy cavity on the open end of the perforating charge (i.e., the
jet emitting end) and the inner wall of the gun body along the axis of the perforating charge.

[0006] The train of thought in solving the aforesaid problem is: in accordance with the theories
in the detonation of perforating charges, when the burst height of a perforating charge is less
than the ideal burst height, an increase in burst height can significantly increase the penetration
depth of perforation. Currently, the burst heights of the perforating charges in the perforating
guns used for oil and gas wells are far less than the ideal burst height. For this reason, a scallop
may be set up at a position corresponding to the open end of a perforating charge on the inner
wall of the gun body of a composite perforating gun to increase the burst height of the
perforating charge, thereby increasing the penetration depth of the perforating gun.

[0007] The technical solution for solving aforesaid problem is: to provide a composite
perforating device comprising a gun body and perforating charges, wherein scallops are set up
on the inner wall of the gun body at a position corresponding to the open end of the perforating
charge.

[0008] The scallops on the inner wall of the gun body of the perforating gun may be in a
plurality of shapes. In one embodiment, the scallop has an inner conical surface. In another
embodiment, the inner peripheral surface of the scallop may be a stepped cylindrical surface or a
truncated-conical surface, while the bottom surface of the scallop is a conical or flat surface.

[0009] In another embodiment, the scallop is formed by first drilling the gun body of the
composite perforating device to form a stepped through hole, followed by mounting of a sealing
cap onto the stepped through hole, i.e., the scallop on the inner wall is formed from a stepped
through hole within the gun body and a sealing cap mounted onto the step of the stepped through
hole. The scallop on the inner wall formed by the stepped through hole and sealing cap is
different and distinct from the pressure releasing hole in the art. The pressure releasing hole in
the art is found at the position on the inner wall of the gun body corresponding to the trailing end
(non-jet emitting end) of the perforating charge so as to release part of the high energy gases
produced as a result of the perforation through the part of the gun body corresponding to the
trailing end of the perforating charge and control the pressure inside the gun body to ensure that the bulging of the outer diameter of the perforating device is within the range allowed in technical standards. This guarantees the safety of the perforating device and its easy removal from the well bore without being plugged in the wellbore. In this invention, the scallop on the inner wall of the gun body is at the position on the inner wall of the gun body corresponding to the open end of the perforating charge (jet emitting end) directly facing the direction of the jet flow formed after the detonation of the perforating charge.

[0010] The scallop on the inner wall of the gun body has two purposes: (1) to decrease wall thickness that would substantially reduce the barrier the wall thickness of the perforating device poses to the high speed jet flow, thereby increasing the energy utilization and the penetration depth of the perforating device; and (2) increase the burst height of the perforating charge in the gun body, thereby increasing the penetration depth of the perforating device from another aspect.

[0011] In one embodiment, said scallop is at the open end of each perforating charge. In another embodiment, the diameter of the scallop is smaller than the diameter of the open end of the perforating charge or the jet flow.

[0012] The present invention provides a simple method of increasing the penetration depth of the perforating charge after detonation by increasing the burst height of the perforating charge.

BRIEF DESCRIPTION OF THE FIGURES

[0013] Figure 1 shows the relationship between the burst height and the penetration depth of a perforating charge.

[0014] Figure 2 shows the structure of the present invention in example 1; the semi-circle in the figure is the semi-sectional view of the scallop on the inner wall of the gun body.

[0015] Figure 3 shows the structure of the present invention in example 2; the semi-circle in the figure is the semi-sectional view of the scallop on the inner wall of the gun body.

[0016] Figure 4 shows the structure of the present invention in example 3; the semi-circle in the figure is the semi-sectional view of the scallop on the inner wall of the gun body.

[0017] Figure 5 shows the structure of the present invention in example 4; the semi-circle in the figure is the semi-sectional view of the scallop on the inner wall of the gun body.

[0018] Figure 6 shows the structure of the present invention in example 5; the semi-circle in the figure is the semi-sectional view of the scallop on the inner wall of the gun body.

[0019] Figure 7 shows the structure of the present invention in example 6.

[0020] Figure 8 shows the structure of the present invention in example 7.
[0021] Figure 9 shows a schematic diagram indicating the burst height \( H_0 \) of a perforating charge in the gun body of a conventional perforating gun.

[0022] Figure 10 shows a schematic diagram indicating the burst height \( H_1 \) of a perforating charge in the gun body of the present invention in example 3.

[0023] Legend of the figures:
1 - gun body; 2 - perforating charge; 11 to 16 - scallop on inner wall; 17 - stepped through hole; 171 - sealing cap; 172 - sealant; 18 - stepped through hole; 181 - sealing cap

**DETAILED DESCRIPTION OF THE INVENTION**

[0024] As shown in Figure 1, "H" refers to burst height, and "L" refers to penetration depth. When the burst height of perforating charge 2 is less than the ideal burst height \( h \), the penetration depth will increase linearly with the burst height.

[0025] With the same burst height, the penetration depth of the perforating device will be the same even when the scallops on the inner wall of the gun body vary in their shapes. In one embodiment, when the burst height of the perforating charge increases by 2mm, the penetration depth of the perforating device increases by around 24mm.

[0026] In one embodiment, the present invention provides a composite perforating device having one or more scallops on the inner wall of the gun body of the perforator, wherein each scallop is located opposite to the open end of a perforating charge 2.

[0027] In one embodiment, the scallop is for increasing the burst height of the perforating charge.

[0028] In another embodiment, the scallop has a stepped-cylindrical inner surface, and flat or conical bottom surface.

[0029] In another embodiment, the scallop has a conical inner surface.

[0030] In yet another embodiment, the scallop has a cylindrical inner surface, and conical bottom surface.

[0031] In some embodiments, the scallop has a truncated-conical surface, and a flat bottom surface.

[0032] In another embodiment, the scallop has a truncated-conical surface, and a conical bottom surface.

[0033] In a further embodiment, the scallop comprises a stepped through hole in the gun body and a sealing cap mounted onto the step of said stepped through hole.
In one embodiment, the sealing cap has a flat bottom surface.

In another embodiment, the sealing cap has a concave spherical bottom surface.

The invention will be better understood by reference to the Experimental Details which follow, but those skilled in the art will readily appreciate that the specific examples are for illustrative purposes only and should not limit the scope of the invention which is defined by the claims which follow thereafter. It is to be noted that the transitional term "comprising", which is synonymous with "including", "containing" or "characterized by", is inclusive or open-ended and does not exclude additional, un-recited elements or method steps.

EXAMPLE 1

Figure 2 shows example 1 of the present invention, wherein on the inner wall of the gun body is a scallop 11 or 12 with inner peripheral surface being a stepped-cylindrical, and the bottom surface being flat or conical. That is, the bottom surface of scallop 11 is flat, while the bottom surface of scallop 12 is conical. The use of the stepped scallop does not only maximize the increment in burst height, but also ensures the strength of the gun body.

EXAMPLE 2

Figure 3 shows example 2 of the present invention, wherein the scallop 13 is an inner conical surface. The burst height H for a conventional perforating device with an external diameter of 102mm is 11mm and the resulting penetration depth L is 570.8mm. In the perforating device of example 2, the bottom surface for scallop 13 is conical and the burst height is 15mm; the resulting penetration depth is 618.7mm. The burst height increment of 4mm in the perforating device of the present invention had increased the penetration depth by 49.7mm; the length of the perforation channel had significantly increased.

EXAMPLE 3

Figure 4 shows example 3 of the present invention, wherein the scallop 14 has a cylindrical inner peripheral surface, and a conical bottom surface.

EXAMPLE 4

Figure 5 shows example 4 of the present invention, wherein the scallop 15 has a truncated-conical inner peripheral surface, and a flat bottom surface.

EXAMPLE 5

Figure 6 shows example 5 of the present invention, wherein the scallop 16 has a truncated-conical inner peripheral surface, and a conical bottom surface.
The scallops on the inner wall of the gun body comprising a stepped through hole and a sealing cap are illustrated in examples 6 and 7.

EXAMPLE 6

Figure 7 shows example 6 of the present invention, wherein the scallop comprises a stepped through hole 17 in the gun body and a sealing cap 171. There is sealant 172 outside the sealing cap 171 to fix the sealing cap 171 onto the step of the stepped through hole 17. The sealing cap 171 has a flat bottom surface.

EXAMPLE 7

Figure 8 shows example 7 of the present invention, wherein the structure of the scallop is the same as example 6 with the scallop comprising a stepped through hole 18 and a sealing cap 181 which has a concave spherical bottom surface.

The scallop on the inner wall of the gun body in the present invention can also be non-circular scallop, for instance, prismatic hole, pyramidal hole etc, that is, the cross-sectional view of the scallop is a regular polygon.

Figure 9 shows a schematic diagram indicating the burst height \( \frac{3}{4} \) of a perforating charge 2 in the gun body of a conventional perforating gun while Figure 10 shows a schematic diagram indicating the burst height \( H_1 \) of a perforating charge 2 in the gun body of example 3 of the present invention. The direction indicated by "A" in Figures 9 and 10 is the direction of the jet flow from the open end of the perforating charge to the inner wall of the gun body of the perforating gun; \( H_0 \) is the burst height of the perforating bullet 2 in the gun body of the conventional perforating gun; and \( H_1 \) is the burst height of the perforating bullet 2 in the gun body of the third embodiment of the present invention. \( H_1 \) is clearly larger than \( H_0 \). Do in figure 10 is the diameter of the shaped charge liner at the open end of perforating charge 2.
What is claimed is:

1. A composite perforating device comprising a gun body and one or more scallops on the inner wall of the gun body, wherein each of said scallop is located opposite to the open end of a perforating charge 2.

2. The composite perforating device of claim 1, wherein said scallop is for increasing the burst height of the perforating charge.

3. The composite perforating device of claim 1, wherein said scallop has a stepped-cylindrical inner surface, and flat or conical bottom surface.

4. The composite perforating device of claim 1, wherein said scallop has a conical inner surface.

5. The composite perforating device of claim 1, wherein said scallop has a cylindrical inner surface, and conical bottom surface.

6. The composite perforating device of claim 1, wherein said scallop has a truncated-conical surface, and a flat bottom surface.

7. The composite perforating device of claim 1, wherein said scallop has a truncated-conical surface, and a conical bottom surface.

8. The composite perforating device of claim 1, wherein said scallop comprises a stepped through hole in the gun body and a sealing cap mounted onto the step of said stepped through hole.

9. The composite perforating device of claim 8, wherein said sealing cap has a flat bottom surface.

10. The composite perforating device of claim 8, wherein said sealing cap has a concave spherical bottom surface.
INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/69607

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E21B 43/17 (201.3.01)
USPC - 89/1.15; 166/55

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - E21B 43/17 (2013.01)
USPC - 89/1.15; 166/55

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC - 166/297, 55.1, 55.2; 175/2, 3.5, 4.51, 4.6

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Pathbase, Google Patents, Google Scholar

search terms: Scallop, conical, flat, perforating, gun, charge, shape, jet, pressure, burst, passage, vent, set back, frusto, cone, taper, depression, detonet, cavity, aperture, cutout, step, edge, tier, terrace, apparatus, system, device, angle, slope, slant, shape, design, cross

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>us 20100276136 A1 (EVANS et al.) 04 November 2010 (04.1.1.2010), para [0023, Fig. 3 A]</td>
<td>1, 2, 4, 6</td>
</tr>
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<td>3, 5, 7, 8, 10</td>
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<tr>
<td>Y</td>
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<td>8, 10</td>
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</table>

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:
  
  "A" document defining the general state of the art which is not considered to be of particular relevance
  
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Date of the actual completion of the international search
28 January 2013 (28.01.2013)

Date of mailing of the international search report
28 FEB 2013

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1490, Alexandria, Virginia 22313-1490
Facsimile No. 571-273-2201

Authorized officer: Lee W. Young

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PCT OSP: 571-272-2774

Form PCT/ISA/2 10 (second sheet) (July 2009)