

BORESIGHTING DEVICE AND METHOD

Subject-matter of the invention

The present invention relates to a method and device for aligning the line
5 of sight with the firing line, commonly called boresighting device, for weapons
systems, preferably large caliber (75 mm to 140 mm).

Technological background and state of the art

On a weapons system, a misalignment between the firing line and the line
10 of sight is detrimental to hit a target with precision. There are two main sources of
misalignments. A first misalignment source is the physical deformation of the barrel,
commonly called deflection, which appears naturally and inevitably, both horizontally
and vertically, as a result of the relatively heavy weight of the barrel and the outside
conditions (rain, wind, sun, etc.). This deformation causes a parallelism flaw between
15 the firing line from the shaft of the barrel and the firing line from the muzzle of the
barrel. A second source of misalignment lies in the impacts and vibrations experienced
during driving and shot firings that cause a deviation relative to the alignment
previously calibrated.

Different devices exist for aligning the firing line with the line of sight, or in
20 other words, boresighting a weapons system.

There are traditional boresighting techniques where the device is based on
the cooperation between two operators, the first being located in the turret while the
second, outside the turret, stays close to the muzzle of the barrel. The principle is
based on optical collimator and described in document US 1,994,177. The collimator is
25 placed inside the tube of the barrel by the second operator and gives the first operator
a view aligned with the firing line. In other words, the second operator informs the first
operator how it is necessary to move the barrel so that he can see, through the
observation hole, how the reference target is positioned. One major drawback of this
device is that it requires two operators, including one outside the vehicle, i.e., directly
30 exposed to an outside threat. Furthermore, it requires a ladder in order for the second
operator to be able to reach the muzzle brake.

There are also devices of the "Muzzle Reference System" (MRS) type. These devices, described *inter alia* in document US 4,665,795, are generally made up of a laser transceiver situated at the base of the barrel and a mirror placed at the muzzle of the barrel. The transmitter sends an infrared laser ray toward the mirror, which is next
5 reflected toward the receiver. Based on the position of the laser received by the receiver, a piece of electronic equipment allows the automatic calculation of the azimuth and elevation corrections, which are next added to the ballistic corrections at the shot firing control system. One drawback of these devices is that the mechanical stability of the mirror is very complex to provide. Furthermore, detecting the arc lines
10 of the barrel via laser measurements can make the system detectable by the enemy. Next, although devices of the MRS type make it possible to correct the variations in the arc lines of the barrel, an initial alignment remains necessary.

Similarly, the document FR 2 505 477 discloses a boresighting device which comprises on the barrel a deflection target formed by a mirror on which a crosshairs is
15 projected, a housing comprising optics systems and an image sensor, the images are, on the one hand, the reflected image of the crosshairs and, on the other hand, in the presence of a filter, the reflected image of a distant object. It is again a precarious system wearing out with low stability and with the risk of deterioration of the precision of the optics systems in the long run.

20 Other, less widespread devices may also be cited.

Document EP 1,510,775 describes a device with a camera having two focusing levels. This camera is inserted in the chamber of the barrel during the boresighting operations. A first focusing at the muzzle of the barrel makes it possible to estimate its angular deviation (X,Y). A second infinity focusing makes it possible to
25 observe an object situated at a far distance, and therefore to bring the view of the optical system back onto the same reference. The boresighting is done by combining these two operations.

Document EP 1,616,145 discloses a boresighting device done by a single operator located inside the turret. A camera is pushed to the muzzle of the barrel from
30 the inside of the latter. Since this camera is situated at the muzzle of the barrel, it implicitly takes the arc line of the barrel into account.

These two devices have the drawback of having to position a camera inside the barrel. In the case of document EP 1,616,145, deploying the camera is a time-consuming and tedious operation, especially if it must be done by a single operator situated in the turret. Furthermore, it is not possible to guarantee that the orientation
5 of the camera pushed to the muzzle will systematically be the same upon each boresighting operation.

Aims of the invention

The present invention aims to provide a boresighting device and method
10 that require only one operator located inside the turret.

It further aims to develop a device not requiring an optics system inside the barrel. It thus aims to develop a device which is stable and precise.

It also aims to develop a boresighting method that is quick, while also being repeatable.

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Brief description of the figures

The present invention will be better understood in light of the following description, referring, as an example, the Figures 1 to 3.

Figure 1 schematically shows a turret provided with the boresighting device
20 according to the invention, in the presence of the shaft, the barrel and the sighting optics, as well as the optical axes of the two cameras of the boresighting device.

Figure 2 schematically shows the optics systems inside the housing according to the invention.

Figure 3 illustrates the movement of the geometric figure over the
25 deflection target following deflection of the barrel.

Legend

- (1) Turret
- (2) Housing
- 30 (3) Deflection target
- (4) Barrel

- (5) Shaft
- (6) Muzzle brake of the barrel
- (7) Optics system provided with the deflection camera
- (8) Optics system provided with the boresighting camera
- 5 (9) Geometric figure on the deflection target
- (10) Optics of a sight system of the turret

Main features of the invention

The present invention relates to a boresighting device to equip a turret provided
 10 with a barrel and one or several sight system(s) each with an optical system, said device comprising:

- a deflection target intended to be positioned outside the barrel, at the muzzle brake of said barrel,
- a housing intended to be positioned outside the barrel, at the shaft of said barrel,
 15 said housing including:
 - a first optics system provided with a deflection camera, said first system being used to determine a parallelism error between a firing line from the shaft and that from the muzzle brake,
 - a second optics system provided with a boresighting camera, said second system
 20 being used to determine a parallelism error between the firing line from the shaft and an optics line from the sight system(s).

According to specific embodiments of the invention, the device includes at least one or a suitable combination of the following features:

- each camera has fixed focusing, the boresighting camera having infinity focusing and
 25 the deflection camera being configured to have focusing adjusted on the deflection target;
- the deflection target includes any geometric material figure serving as a reference point for the first optics system, said geometric figure preferably being a circle.

The present invention also relates to a weapons system comprising the
 30 boresighting device as described above, wherein the housing is positioned on the shaft of the barrel and said deflection target is positioned near or on the perimeter of the

muzzle brake of the barrel. Furthermore, in this weapons system, the deflection target can be attached or integrated with respect to the muzzle brake.

The present invention also relates to an armored vehicle provided with this weapons system.

5 The present invention also relates to a boresighting method using the device described above, said method comprising the following steps:

- Calculating the displacement ΔX and ΔY of the geometric figure relative to a reference position of said figure, said calculation being done based on image processing from the deflection camera, the parallelism error between the firing line
- 10 from the shaft and that from the muzzle brake next being determined via a mathematical model based on calculated ΔX and ΔY values,
- Comparing an image taken by the boresighting camera with an image taken by an optical system of the sight system(s) in order to determine the parallelism error between the firing line from the shaft and the optics line from the sight system(s),
- 15 - Accumulation of two parallelism errors and displacement of said optics line accordingly.

According to specific embodiments of the invention, the method includes at least one or a suitable combination of the following features:

- the calculation of ΔX and ΔY is done using an algorithm based on a contour detection
- 20 according to the Canny method and using a Hough transform;
- the reference position of the geometric figure is calculated during a calibration following an installation of the boresighting device on a weapons system;
- the calibration is done using a muzzle bezel, said calibration comprising a step for aligning a position of a crosshairs of the boresighting camera with a point observed
- 25 through the muzzle bezel;
- after the step for calculating the parallelism error between the firing line from the shaft and that from the muzzle brake, the crosshairs of the boresighting camera is moved by a same angle along the X and Y coordinates;
- the method can be implemented during a mission.

Lastly, the present invention relates to a computer program suitable for implementing the method described above and by recording data readable by a computer comprising this program.

5 **Detailed description of the invention**

The present invention relates to a boresighting device and the method implemented using said device. The device according to the invention is preferably intended for large caliber weapons systems (75 mm to 140 mm). It could nevertheless be used for small and/or medium caliber weapons systems subject to certain
10 developments related to the steric bulk in the riggings associated with said calibers.

The boresighting device according to the invention is shown in Figure 1 on a turret **1**. The device is made in two parts positioned in separate locations. It includes a housing **2** on the one hand, and a deflection target **3** on the other hand. The housing **2** is positioned outside the barrel **4**, and preferably mounted on the shaft **5** of the
15 barrel **4**. The housing **2**, visible in more detail in Figure 2, includes two optics systems **7, 8** each provided with a camera. A first camera **7**, called deflection camera, is intended to correct the misalignment resulting from the deflection of the barrel, i.e., the misalignment between the firing line from the shaft and that from the muzzle of the barrel. A second camera **8**, called boresighting camera, is intended to correct the
20 misalignment between the firing line from the shaft of the barrel and the optical axis of the sight system. In the housing, the two cameras are mounted in a single block. The boresighting and deflection cameras have the feature of having fixed focusing, respectively infinity focusing and focusing at the muzzle brake, as illustrated in Figure 1. Mounting in a single block with fixed focusing for each camera has the advantage
25 that no moving part is required in the housing, which makes it possible to ensure mechanical stability thereof relative to the impacts and vibrations related to shot firings. Furthermore, the housing is designed athermally so that the position of the optics axis of the cameras is not sensitive to temperature variations. In addition to the housing, the device includes the deflection target **3**, which is located at the muzzle
30 brake **6**, i.e., at the end of the barrel where the ammunition exits. This deflection target **3** can be either an additional part that is placed at the fastening of the muzzle

brake, or it can be integrated directly on the perimeter thereof. The latter alternative is favored to guarantee the mechanical stability of the device. The deflection target is provided with any geometric figure serving as a reference point for the optics system 7. This figure is physical, or tangible in other words, on the target which means that it is integrated on the target. It is thus not a projected figure on a mirror acting as a deflection target.

The boresighting method according to the invention takes into account both of the aforementioned misalignment causes, i.e., the deflection of the barrel and the deviation between the firing line and the sight line following impacts caused by the use of the vehicle and its weapons system.

To that end, the method is based on three steps.

In a first step, the optics system provided with the deflection camera is used to determine the parallelism error between the firing line from the shaft and that from the muzzle brake. More specifically, the first optical system 7 of the housing detects the position of the deflection target via image processing such that the system can deduce, vertically and horizontally, the deflection of the barrel relative to a reference position obtained during calibration of the device. The movement along X and Y, i.e., the delta X (ΔX) and delta Y (ΔY), is calculated relative to a reference embodied by the geometric figure that is preferably a circle 9 on the deflection target 3 (see Figure 3). It is possible to consider other geometric forms, having previously made several specific modifications to the algorithms used. A ΔX and ΔY are thus calculated relative to the starting position of the center of the circle. Through a mathematical model, the system produces the parallelism error therefrom between the firing line at the shaft and the firing line at the muzzle brake. The algorithm used to detect a geometric figure is based on a contour detection according to the Canny method. A Hough transform makes it possible to obtain a first estimate of the position of the reference circle. Next, an algorithm makes it possible to refine the obtained results at the sub-pixel level.

In a second step, the optics system provided with the boresighting camera is used to determine the parallelism error between the firing line at the shaft and the sight line. The camera whose axis is parallel to the firing line at the shaft and which

uses infinity focusing provides an image of a distant object that is directly compared to the image provided by the optics system(s) **10** of the sight system(s) of the turret (Figure 1). It is thus possible to deduce the parallelism error between the firing line at the shaft and the optics line of the sight system(s).

5 In a third step, the two parallelism errors are accumulated and sent directly to the sight system(s) of the turret.

Prior to these steps, the device must be calibrated. This calibration is done when the housing and the target are mounted on the turret. Subsequently, no new calibration is required as long as the housing and the deflection target are not moved.

10 The calibration is done from a conventional muzzle bezel. This calibration consists of aligning the position of the crosshairs in the boresighting camera with the point observed by the muzzle bezel. This operation is done by one of the occupants of the turret via his control monitors. When this alignment is achieved, the reference position of the geometric figure is calculated and stored by the device. During subsequent
15 boresighting operations, in the first step, the device measures the displacement of the geometric figure relative to that obtained during the calibration. This difference is next reflected in the boresighting camera by moving the position of its crosshairs thereto.

Advantages of the invention

20 The precision of the boresighting in the presence of the device according to the invention is equivalent to that encountered with the prior art devices, but without the drawbacks.

 Thus, the boresighting is done by a single operator located inside the turret, without deploying any tools. There is therefore no heavy, and therefore slow,
25 manipulation. This absence of manipulation also guarantees better repeatability of the measurements. Furthermore, this allows the boresighting to be done mid-mission.

 According to the invention, the deflection target and its geometrical figure are physical. It is not a mirror on which a crosshairs is projected. Thus, the device according to the invention does not require layers of mirrors causing
30 desynchronization risks and requiring systematic calibrations.

CLAIMS

1. A boresighting device to equip a turret (1) provided with a barrel (4) and one or several sight system(s) each with an optical system (10), said device comprising:

- a deflection target (3) intended to be positioned outside the barrel (4), at the muzzle brake (6) of said barrel (4),
- a housing (2) intended to be positioned outside the barrel (4), at the shaft (5) of said barrel (4), said housing (2) including:
- a first optics system (7) provided with a deflection camera, said first optics system (7) being used to determine a parallelism error between a firing line from the shaft (5) and that from the muzzle brake (6),
- a second optics system (8) provided with a boresighting camera, said second optics system (8) being used to determine a parallelism error between the firing line from the shaft (5) and an optics line from the sight system(s), the device being characterized in that the deflection target (3) is devoid of mirror and integrates a geometric figure (9) serving as a reference point for the first optics system (7);

wherein the method of using the device comprises the following step:

- Calculating the displacement ΔX and ΔY of the geometric figure (9) relative to a reference position of said geometric figure (9), said calculation being done based on image processing from the deflection camera, the parallelism error between the firing line from the shaft (5) and that from the muzzle brake (6) next being determined via a mathematical model based on calculated ΔX and ΔY values,
- Comparing an image taken by the boresighting camera with an image taken by an optical system (10) of the sight system(s) in order to determine the parallelism error between the firing line from the shaft (5) and the optics line from the sight system(s),
- Accumulation of two parallelism errors and displacement of said optics line accordingly.

2. The device according to claim 1, wherein each camera has fixed focusing, the boresighting camera having infinity focusing and the deflection camera being configured to have focusing adjusted on the deflection target (3).

3. The device according to claim 1 or 2, wherein the geometric figure (9) is a circle.

4. A weapons system comprising the boresighting device according to any one of claims 1 to 3, wherein said housing (2) is positioned on the shaft (5) of the barrel (4) and said deflection target (3) is positioned near or on the perimeter of the muzzle brake (6) of the barrel (4).

5. The weapons system according to claim 4, wherein the deflection target (3) is attached or integrated with respect to the muzzle brake (6).

6. An armored vehicle provided with the weapons system according to claim 4 or 5.

7. The device using the method according to claim 1, wherein the calculation of ΔX and ΔY is done using an algorithm based on a contour detection according to the Canny method and using a Hough transform.

8. The device using the method according to claim 1 or 7, wherein the reference position of the geometric figure (9) is calculated during a calibration following an installation of the boresighting device on a weapons system.

9. The device using the method according to claim 8, wherein the calibration is done using a muzzle bezel, said calibration comprising a step for aligning a position of a crosshairs of the boresighting camera with a point observed through the muzzle bezel.

10. The device using the method according to any one of claims 1 or 7 to 9, wherein, after the step for calculating the parallelism error between the firing line from the shaft and that from the muzzle brake, the crosshairs of the boresighting camera is moved by a same angle along the X and Y coordinates.

11. The device using the method according to any one of claims 1 or 7 to 10, able to be implemented mid-mission.

12. A computer program suitable for implementing the method according to any one of claims 1 or 7 to 11.

13. A means for recording data readable by a computer comprising the program according to claim 12.