GUN BEND SENSOR

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Filed Oct. 8, 1968, Ser. No. 765,893
Int. Cl. G01k 3/14, 7/24
U.S. Cl. 73—342

5 Claims

ABSTRACT OF THE DISCLOSURE

A gun bend sensor for indicating displacement of a gun barrel. The sensor includes a thermal model ring coaxially mounted about the gun barrel. Temperature responsive elements are mounted in the model ring. When the gun barrel is nonuniformly heated by the sun or the like, the free end of the barrel displaces an amount proportional to the temperature differential throughout the barrel. The thermal model ring is similarly heated and the temperature responsive elements provide an indication proportional to the temperature differential and the gun barrel displacement.

This invention relates to a displacement sensing device. More particularly, this invention relates to a device for sensing the displacement of a gun barrel.

The accuracy with which military weapons must be fired has become much more critical, because of the long distances, with which projectiles may now be fired. The target error caused by incorrect aiming is greatly exaggerated at these long distances. This problem becomes particularly acute when considered in conjunction with the "first round kill" requirements generated by military characteristics. Due to increased vulnerability from improved enemy countermeasures, a tank crew is not permitted to zero in on a target by trial and error but must have accurate first round capability of hitting the target. This requires the minimization of all error in the initial aiming of the projectile.

It has been found that one of the large sources of errors lies in the fact that the gun barrel is not pointing in the direction in which it appears to be pointing. There are and can be many reasons for this but the one which is of peculiar importance to this invention is due to the effects of nonuniform heating of the gun barrel. When a military tank remains in the sun for an extended period of time, the gun barrel will be nonuniformly heated due to the effects of solar radiation. For example, at high noon the top portion of the gun barrel will be of a higher temperature than the lower portion of the gun barrel, hence, the uppermost portion of the gun barrel will expand or elongate more than the bottom portion. The differential in strain caused by the differential temperature results in a sloping gun barrel. This resultant bend, if unknown to the operator, can greatly impair the firing accuracy. Hence, there exists a great need for a device which will sense the displacement of the gun barrel to provide a correction factor for the direction in which the gun barrel is aimed.

According to the invention, there is provided a gun bend sensor for sensing displacement of a gun barrel including a thermal model ring which is mounted about the gun barrel and which has a thermal conductivity proportional to that of the gun barrel. A plurality of thermal responsive elements are embedded in and isostatically spaced about the termal model ring. These thermal model elements are connected in an electrical bridge circuit. Each of the thermally responsive elements has an electrical property which varies in proportion to the temperature differential. Since the gun barrel displacement and the temperature differential of the model ring are proportional to the temperature differential of the gun barrel, the electrical signal output is proportional to the gun barrel displacement and may thereby be determined.

Other advantages of the present invention will become apparent to those ordinarily skilled in the art by the following description when considered in relation to the accompanying drawing of which:

FIGURE 1 is an elevational view, partly in section, of the gun bend sensor according to the invention.

FIGURE 2 is a cross sectional view taken along lines 2—2 of FIGURE 1.

FIGURE 3 is a circuit diagram showing the thermally responsive elements connected in an electrical bridge circuit.

Referring now to the drawing wherein similar numerals will refer to similar parts in the various figures, a gun barrel is shown in phantom at 10. This barrel is generally, though not necessarily, mounted on a military vehicle, such as the turret of a tank. The gun barrel is normally supported at one end like a cantilever beam.

The gun sensor shown generally at 12, is coaxially mounted about gun barrel 10 and comprises support member 14, thermal insulation means 16, model ring 18 and thermally responsive elements 20. Support member 14 has a generally cylindrical bore 24 therethrough which is adapted to receive a gun barrel 10. The support member 14 is mounted to the gun housing, turret, or vehicle hull by any suitable mechanical means such as screws or bolts. A support member is mounted such that the inner cylindrical surface of bore 22 is radially displaced from the outer surface of gun barrel 10. This enables the gun barrel to move without interference from the gun bend sensor.

Thermal model ring 18 is supported on support member 14 by means of radial spacer members 28 which are disposed at equal intervals about support member 14. Axial support for model ring 18 is derived from axial spacers 30 and 32. Spacers 30 are evenly distributed intermediate ring 18 and flange 32 of support means 14. Spacers 32 are mounted intermediate model ring 18 and end plate 36 which is secured to support means 14 by any suitable manner such as bonding.

Thermal model ring 18 is mounted coaxially with gun barrel 10 and may be formed of a material that is identical to the material of the gun barrel 10 in which case, of course, their thermal conductivities would be identical. The outer surface 38 of model ring 18 and the outer surface of gun barrel 10 should have similar emissivities, view factors, and surface roughness.

A plurality of thermal responsive elements 20 are shown embedded in thermal model ring at equidistant intervals. These thermal model rings will have an electrical property which will be proportional to the temperature thereof. A device which has been found to be suitable for this purpose is a thermistor, the resistance of which changes proportional to the temperature applied thereto.

Mounted intermediate thermal model ring 18 and support member 14 is thermal insulation means 16 for isolating the model ring 18 from the thermal effects of gun barrel 18 and support member 12. Thus the temperature of model ring 18 will be primarily dependent upon the external heat applied to external heat which is applied to surface 38 will be simultaneously applied to the exterior surface of gun barrel 10. If the thermal conductivity of the material forming model ring 18 and gun barrel 10 are proportional, the temperature distribution throughout ring 18 will be directly proportional to the temperature distribution throughout the gun barrel 10 provided the heat load is uniform along the axis of gun barrel 10. If as viewed in the drawing the upper half of gun barrel 10 is subjected to more heat than the lower half of gun barrel 10, this asym-
metrical heat input will also be applied to the model ring to create a time dependent temperature differential across the ring. The upper thermistor 20 will consequently be subject to a higher temperature than the oppositely disposed thermistor 20 on the lower half of the model ring. The resistance of each of the thermistors will change proportionally to the temperature difference across the ring. The temperature difference of the upper and lower thermistors will be indicative of the deflection of the gun barrel in the vertical plane whereas the horizontal deflection will be detected by the remaining two thermistors.

As shown in FIGURE 3, each of the thermistors 20 is connected in each leg of an electrical bridge circuit shown generally at 40. A source of suitable potential 42 is connected across the two oppositely disposed corners of bridge 40 whereas the load is shown by electronic cavity 44 connected across the two remaining oppositely disposed corners of the bridge circuit. Electronic cavity 44 is part of the vehicle fire control system which controls the direction in which the gun is aimed and fired. Suitable amplifiers may be incorporated to increase the signal as necessary.

In operation, when the gun barrel 10 is subjected to an asymmetrical heat input by the sun or the like, a significant dispersion results between groups of projectiles fired by the gun at different intervals. This disparity is due to non-uniformity in gun barrel heating which causes a bending effect and hence displaces the free end of the gun barrel an amount proportional to the temperature differential on opposite sides of the gun barrel. The asymmetrical heat input to the gun barrel is simultaneously applied to the model ring 18. The temperature differential of the thermal model ring 18 is proportional to the temperature differential of the gun tube 10 and hence the displacement of the gun tube 10 is sensed by thermistors 20 spaced about model ring 18. When the heat input to the gun barrel and model ring is symmetrical, the bridge 40 is balanced and no signal is provided to electronic cavity 44. When an asymmetrical heat input is supplied however, the resistance of the thermistors 20 vary and output current will flow from source 42 to load 44 proportional to the temperature gradient across model ring 18. Electronic cavity 44 can be connected to or may incorporate therein an electronic computer to which a signal is provided to correct the direction in which the gun barrel is pointing proportional to the amount of deflection and thereby correct for the error due to the asymmetrical heat input. If necessary, a differential bridge amplifier network could be connected to the input of the computer to suitably amplify the signal if necessary.

As will be readily apparent, if the asymmetrical heat input is along the horizontal plane, the temperature responsive means located on the horizontal planes will indicate the temperature difference which will be proportional to the deflection of the horizontal plane. It should be observed of course that although only four temperature responsive elements have been referred to, any number could be utilized depending on the accuracy required and the physical limitations of the thermal model ring.

It should be further noted that the outer surface of the gun barrel and the outer surface 38 of the thermal model ring are preferably exposed to similar ambient conditions such as fluid viscosity, temperature, radiating bodies, and fluid velocity. It should be realized that the diametrically opposed temperatures could also be used to determine angular displacement of the gun barrel in addition to linear displacement.

Since it is obvious that many changes and modifications can be made in the above-described details without departing from the nature and spirit of the invention, it is to be understood that the invention is not limited to said details.

I claim:

1. A gun bend sensor for sensing displacement of a gun barrel comprising:
   a support member having a bore therethrough which is adapted to receive said gun barrel,
   a thermal model ring mounted coaxially with said gun barrel and supported by said support member,
   a thermal responsive means located on said support means and said thermal model ring for isolating said thermal ring from the thermal effects of said support means and said gun barrel,
   and a plurality of thermally responsive means equidistantly spaced and connected with said model ring for indicating the temperature of said thermal model ring whereby the displacement of said gun barrel due to nonuniform heating is proportional to the temperature gradient of said model ring and may thereby be determined.

2. A gun bend sensor as set forth in claim 1 wherein the thermal responsive means, view factor, and surface roughness of the material forming said model ring and said gun barrel respectively are substantially equal.

3. A gun bend sensor as set forth in claim 1 wherein said thermally responsive means has an electrical property which is a function of the temperature being applied thereto.

4. A gun bend sensor as set forth in claim 3 wherein each of said thermally responsive means comprises a thermistor embedded in said model ring, said thermistors connected in each leg of a normally balanced electrical bridge circuit connected with a source of electrical power and a load whereby nonuniform heating of said gun barrel and said model ring will unbalance said bridge circuit permitting an output current to flow from said source to said load proportional to the temperature gradient of said model.

5. A gun bend sensor for indicating displacement of a cylindrical gun barrel due to exterior heating comprising:
   a support member having an outer surface and cylindrical bore coaxial with said gun barrel,
   a ring of thermal insulation mounted on the outer surface of said support member,
   a thermal model ring supported by said support member and embedded in said thermal insulation, said thermal model ring being coaxially mounted with respect to said gun barrel, and
   a plurality of thermistors embedded in said thermal model ring, each of said thermistors being connected in an electrical bridge circuit whereby the output of the bridge circuit will be proportional to the displacement of said gun barrel.

References Cited

UNITED STATES PATENTS
2,199,082 4/1940 Peters -------------------- 73—355
3,416,373 12/1968 Havens ------------------- 73—339
LOUIS R. PRINCE, Primary Examiner
F. SHOON, Assistant Examiner
U.S. Cl. X.R.
73—167, 339; 89—135