Mechanical vibration affects Gatling weapon shooting accuracy

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Abstract. To using the Gatling fire mode to the fire accuracy, the Gatling gun fire mode was researched and it was found that the advantage of even Gatling gun. The firing mode of the Gatling weapon is clearly a turn round, several tubes firing several rounds. There are drawbacks that the faster the launch, the more the gun body tubes group shift in the direction, and resulting in the weapon missing a lot from the shooting target. There was no choice but to make compensatory moves on the firepower system. this paper the launch even mode proposed is still rotating, but it is indeed the upper and lower parts of the projectile. And the pipes are divided into two groups, and one group moves from the left, the top is in the launch state; and the other group enters from the right side, and the bottom is in the launch state. the horizontal displacement in the barrel mouth is 0.0028142m but the new methods is 1.168e-6m, and While 2000m the Gatling old scheme has 80m layout and the new Gatling gun has only 5m. The comparison with the single-tube weapon, and the even tube (4,6,8,10) has an advantage over odd tube (3,5,7,9), and it is more convenient to supply the bullet left and right or up and down.

1. Introduction

Gatling weapons can be divided into external energy Gatling weapons and internal energy Gatling weapons. The barrels of Gatling gun are arranged in a circle, and only one shot can be fired at a certain time. Therefore, it will bring an unbalanced state of force in circular motion, so it needs to be studied to find the right way to launch.

US's Gatling weapons are mainly external energy sources. Generally, the initial speed is higher, and some can reach more than 1000m/s, but the rate of fire is not high, and generally not more than 6,000 rounds/min (RPM). Russia's Gatling weapons are mainly energy, which are generally high rate of fire, such as Gsh-6-23M's rate of fire up to 10,000 RPM, but the initial speed is lower, and generally about 700m / s to 900m / s.

Nowadays, Gatling weapon occupies a very important position in air defense and anti-missile, and it defends the structure of the country. However, its shooting accuracy has to be studied carefully. The launch of single barrel not only produces recoil, but also the torque that reverses the body [1], and it is worth studying. Compared with the single-tube weapon, and it can be loaded up and down or left and right, which can realize the symmetry of the upper and lower forces, and it does not generate torque, which is favorable for shooting accuracy.
2. **Analysis of the Loadings on the Gatling weapon**

Because Gatling weapon is stressed on the circumference of the body tube, it can be forced backward along the axial direction of the body tube. The force on the body tube is shown in Figure 1, and the force is $F$. The body support point is $o$. It can be drawn as shown in Figure 2. The center $o$ is also stressed by $F$, but with a torque $FR$. This torque causes the transfer weapon to have an upward offset.

Since $F$ is determined by the pressure of the magazine, and if the speed of the projectile is constant, $F$ is not variable, then it can be seen whether $R$ can be reduced, and $R$ is determined by the revolution radius of the movement group, and the possibility of $R$ reduction is also compared. So $FR$ determines the size of the offset.

![Figure 1. Gatling firing mode with four barrels.](image1)

![Figure 2. Conversion of Gatling gun of four barrels.](image2)

Now we study it and draw a structural diagram as shown in Figure 3:

![Figure 3. Barrels and body frame.](image3)

Basically, the body tube group and the frame are regarded as the structure shown in Figure 3. The body tube group length is $a$, and the EI of the neutral axis; and the length of frame seat is $b$, and the moment of inertia of the neutral axis is $EI_1$, the body tube and the frame when the joint is applied with the $FR$ moment, the end of barrels will be raised, and the left part will rise and it will be deformed. The following section can be used to draw the deformation in Figure 4:

![Figure 4. Deformation of barrels and body frame with FR and F.](image4)

It can be seen that the angle caused by the $FR$ at the first fulcrum can be expressed as [2]:

$$\theta_1 = \frac{FRb^2}{2EI_i}$$

(1)

The maximum deflection occurs at the first pivot point and the second pivot point. The maximum deflection is expressed as:

$$f_{\text{max}} = \frac{FR*b^3}{16EI_i}$$

(2)

It can be seen from the two Equations (1) and (2), that increased EI and shortening $b$ value can not only reduce the value but also reduce the maximum deflection. It can be known from Equation (1) that if gravity is not considered, and the body tube group will prevail, the distance from the original axis of the body tube is:

$$x_1 = b \tan \theta_1$$

(3)
This is the basic offset [3] when the turret is launched. The value of $x_1$ can only reduce the $\theta_1$, and it can not reduce $\theta_0$ because it affected by the initial velocity of the projectile, and $b$ can not be reduced.

The $F$ can load $a$, the cantilever beam also follows the bending change as Figure 5, only the deformation of cantilever beam of $a$ is calculated:

$$x_2 = \frac{Fa^3}{3EI}$$

Figure 5. The cantilever beam of length $a$.

That the barrel mouth maximum deformation can be load:

$$x = x_1 + x_2$$

Part of the $b$ deformation and part of the cantilever beam $a$ deformation, the two combined maximum deformation, and $x$ should be the maximum deformation.

As the launch speed increases and the FR swings above, it can oscillate continuously, and it causes the difference between the direction of the shot and the direction of the aiming. This aspect can be compensated for in the numerical solution of the aiming direction. There is also a scheme to carry out the even-tube Gatling weapons, such tubes as 4, 6, 8, and 10 Gatling weapons. It can also make up for this problem from the aspect of the supply of ammunition. As shown in Figure 6, the 4 pipes are divided into two groups, and one group moves from the left, the top is in the launch state; and the other group enters from the right side, and the bottom is in the launch state. In this case, the two $F$ forces are placed in equilibrium for the body tube group, the $o$ point is transformed into a force of $2F$, as shown in Figure 7.

In this case, the body tube group is in the backward $2F$ power, and there is no swing, which is good for shooting [4-5]. For the M134 Gatling gun which is with the new supply method, if the 6 barrels keep 6000 rpm, then the barrels rotating speed from 1000 RPM to 500 RPM; if it is still 1000 rev/min and it rises to 12,000 rev/min. This reduces the collision of the Gatling components, and 500 rpm is possible, it maintains the characteristics of 6000 rpm which reduces the collision of the supply mechanism.

3. Simulation of M134 Gatling gun

US Army model is called M134 Gatling rapid-fire machine gun, and the 6-tube 7.62 mm ammunition rapid gun (Minigun) is widely used. It is called GAU-2 B/A by US Air Force model, and it is called GAU-17. /A type by US Navy model, as it was showed in Figure 8, and it was used NATO's 7.62*51mm caliber standard ammunition and shown in Table 1:
Figure 8. Air force M134 Gatling gun.

Table 1. M134 Gatling gun data.

| Whole gun weight | 15.9Kg (does not include motor and the bomber) |
|------------------|-----------------------------------------------|
| Gun length       | 801.6mm                                       |
| Barrel length    | 559mm                                         |
| Tube lines       | 4                                             |
| Wrapping distance| 254mm                                         |
| Warhead Quality  | 9.75g                                         |
| Theoretical rate of fire | 6000rpm                             |
| Initial velocity | 838m/s                                        |
| Maximum pressure | 345MPa                                        |
| Range            | 800m                                          |
| Error            | 800m 0.2-0.8m                                 |
|                  | 5000m 1.5-3m                                  |

As we know the whole gun weight, and the gun length, the barrel length, we draw the barrel and stand of M134 as shown in Figure 9:

Figure 9. M134 imitation barrels and body frame.

NATO’s standard ammunition of 7.62mm caliber cannot be found. As described in Reference [4], in general military bombs have higher spring pressure and has larger shell walls. The depth is slightly deeper than the rifle of the civilian gun (approximately 0.33mm). According to the internal ballistic equation, the P value can be determined:

\[ SP(l + l_r) = f_0v \omega^2 - \frac{\theta}{2}mv^2 \]  

(6)

In terms of gunpowder and barrel length, the trajectory curve as shown below is obtained, the end point can be calculated: P = 73Mpa. After the calculation of interior ballistics, the pressure is obtained separately as shown in Figure 10:

Figure 10. M134 ballistic curve.
After processing by Ansys Workbench [6-8], we mesh and apply the Figure 10 force to the barrel and the results are obtained with Figure 11 and Figure 12, and the results unit are mm and s:

**Figure 11.** Displacement of single shot barrel in traditional way.

**Figure 12.** Velocity of single shot barrel in traditional way.

The other is the displacement and speed of the barrel for the new feeding method as shown in Figure 13 and Figure 14:

**Figure 13.** Displacement of the barrel in the new way of feeding the projectile.

**Figure 14.** Velocity of the barrel in the new way of feeding the projectile.

Comparing these four figures, it can be seen that comparing Figure 11 with Figure 13, although the overall deformation of the new feeding mode is large in the deformation, the muzzle is compared, and Figure 13 has an advantage in the muzzle portion and a small deformation. Comparing Figure 12 with Figure 14, we find that the deformation speed is larger in Figure 14, but the deformation speed of the muzzle portion is smaller and takes priority.
This is to say that the new method takes advantage [9-11], which is a kind of weapon that combines the Gatling weapon and Puckle’s gun. Compared with Russia's Gsh23mm, it is double-tube, but it is rotated in the left and right. As shown in Figure 15, it can also be shot at the same time as the left and right, and also has a moment on the central axis.

**Figure 15.** Russian Gsh23mm gun.

Let’s calculate the two models projection angle of the bullets, these two models, not including the wind speed and the others as Figure 16 and Figure 17. From the Figure 16 we can see that the barrel offset and from the Figure 16 we can see that the two-bullet deviation distance while bullet flew 2000 meters:

![Figure 16. Two barrels initial offset.](image)

From the Figure 11 the horizontal displacement in the barrel mouth is 0.0028142m but from Figure 13, the displacement of nozzle is 1.168e-6m, from the Figure 16, the direction of the bullet flying on the basis of 2000 meters by Newton's second theorem is shown in Figure 17.

![Figure 17. Two models calculation flying 2000 meters.](image)

The old scheme is about 80m and the new scheme is about 5m. The new method can make the projectile fly near the target, which is better. And the superiority of the program is reflected.

4. **Conclusions**

1. The comparison with the single-tube weapon, and the even tube (4,6,8,10) has an advantage over odd tube (3,5,7,9), and it is more convenient to supply the bullet left and right or up and down. It can realize the symmetry of the upper and lower forces, and it does not produce torque, and it is advantageous for shooting accuracy. A weapon that combines Gatling and turning technology takes advantage. Even barrel is good for even shot.
2. Under high radio frequency, in order to maintain the specified rate of fire, the left and right or upper and lower supply can slow down the speed of the body tube group and become half of the original speed, which is superior to reducing the collision of the supply.

3. For new weapons, even pipe transfer weapons need to promote the two-side feed technology.

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