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The Impact of Material Light-Weighting and Positioning of Headband of the Barrel in Gatling Gun

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Abstract. Aiming to an asymmetric cantilever rotor, its works with a series of axial high-speed moving mass, that is the Gatling gun. The changes of mass of bullet and barrel and the changes the effective distance X of the headband of the barrel and changes caused by material changes of headband, the mass of the bullet is relatively small and can be fired at a higher speed and the headband of steel and aluminum shows that the aluminum is good to steel, The muzzle X of steel is only 1/13 of the muzzle X of aluminum, the muzzle Y of steel is only to aluminum of muzzle Y. The basic numerical values of the two are consistent. The aluminum is good to steel. The effective distance X of the headband from three perspectives, it does the same thing. The Gatling gun imitation is very good, then it is not distributed of firearms at the 6.5 secret level, and the space is 100m.

Keywords: Asymmetric Cantilever Rotor(ACR); Headband; Light-weighting; Firing dispersion; Rounds Per Minute(RPM).

1. Introduction

The physical processes [1-4] such as the movement of the bullet in the barrel and the driving of the car on the bridge can be simplified as the vibration of the elastic beam under the moving load. Vibration problems of beams under moving load are the mode superposition method and finite element method. For the discrete multi-hypothesis piecewise time invariant in the time domain, the commonly used methods [5-9] are Newmark-β method, wilson-θ method, and so on.

Rotating machinery and rotor balancing [1], Mostafa P2 acts as a Timoshenko beam[10-14] with moving mass, there is something like the weapon. There is a moving mass (a bullet) that moves from the barrels.

A Gatling gun is a cantilever rotor with bullets flying in the middle. The trajectory of the bullets flying is the same as the axis direction of the rotor, resulting in an asymmetric rotor, and with different firing speeds, the muzzle of the gun barrel has different deformation.

2. Gatling gun

United States has a 6-barrel gun, such as Minigun [15]. It is to kill and assemble living targets and air defense. The U.S Navy GAU-17/A is used on the UH-1N, H-3 , and H-60 helicopters, It now provides 2000/4000 rounds for the crew, with two shooting modes.

The M134 Gatling gun, as shown in Fig.1, is composed of several barrels arranged in a ring, its engineering drawing was drawn and meshed in Fig. 2:

Fig. 1 Gatling gun

Fig. 2 Engineering draw and mesh

The Gatling gun has an rpm from 300 to 6000, and the time interval is 200ms to 10ms. The Gatling gun rotation rate is in Table 1:

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Table 1.M134 Rotation rate

Gatling gun/rpm	Revolution/(round/s)	Rotor speed(rad/s)	Frequency/ (Hz)
300	0.83	5.21	1.2053
500	1.38	8.66	0.7251
1000	2.77	17.39	0.3611
2000	5.55	34.9	0.1799
3000	8.33	52.3	0.1200
4000	11.11	69.77	0.0900
5000	13.88	87.17	0.0720
6000	16.66	104.62	0.0600

By the time the second bullet was started, the first bullet was already out of the gun. There is no interaction between the first and second bullet. And two bullets do not appear in the barrels at the same time. And the model of Gatling gun[10-12] was processed by ANSYS[6-7], the rotor dynamic controls were also called, and the Coriolis effect was set on, and the Campbell diagram was gotten from ANSYS. The eight number of points rotor speeds as Table 1 and the modal analysis is Table2：

Table 2. Mode Frequency and rotation speed

No	Frequency/(HZ)	Whirl Direction	ω/(rad/s)
1	21.737	BW	136.50
2	26.138	FW	164.14
3	28.286	FW	177.63
4	57.88	BW	363.48
5	112.81	BW	708.44
6	122.13	BW	766.97
7	125.15	FW	785.94
8	216.52	FW	1359.75

When the front and rear diameters D1 and D2 of the Gatling weapon are not equal, the seta is equal to:

$$\tan\,(\mathrm{seta}) = \quad |(\mathrm{D1}-\mathrm{D2})/(2\mathrm{L})| \tag{1}$$

The front and rear diameters D1 and D2 of the Gatling weapon are equal, the anglesetais equal to 0. According to the internal ballistic equation, the P value can be determined:

$$\mathrm{SP}\left(\mathrm{l}+\mathrm{l}_{\psi}\right) = \mathrm{f}\omega\psi - 0.5\theta\mathrm{mv}^2 \tag{2}$$

When the 7.62×51mm NATO in the Minigun , a driving edge force N [7] is calculated with:

$$\mathrm{N} = \frac{1}{\mathrm{n}}\left(\frac{\rho}{\mathrm{r}}\right)^2 \frac{\mathrm{SP_d tg\alpha} + \phi_1 \mathrm{K_a mv^2}}{\phi_1(\cos\alpha - \mathrm{f}\sin\alpha)} \tag{3}$$

The N is calculated as showing Fig.3:

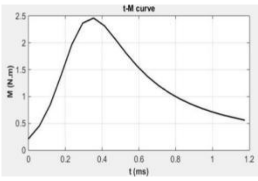

Fig. 3 value of N

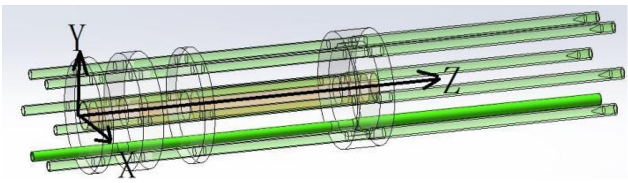

Fig. 4 Gatling gun’s 6 barrels and headband

3. Centroid Position of Gatling Gun Barrels With Bullets

3.1 Changes in Mass of Barrel

There is some centroid position of Gatling gun barrels as Fig.4:

From Fig.8, it needs 1.173ms, the bullet comes into the muzzle position. It needs 6 times to lead the 6 bullets to come to muzzle, that is 7.038ms, that is:

$$\mathrm{Nmax}=60*1000/7.038=8525\mathrm{rpm} \tag{5}$$

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The Minigun higher than 2000 and 4000, but Nmax is 8525rpm. The 2000 and 4000, just one less than 1/4, one exactly 1/2. Z axis is barrel, X and Y are perpendicular t the axis of the barrel, and mass of the bullet is Table 1， mass of bullet is 9.75g. Suppose n rounds are fired, and the Gatling gun finally stops at the angle of α, Matlab[19] round functions were used.

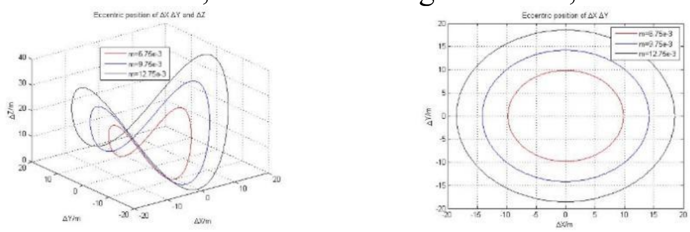
There is some calculation of 6 barrels in XYZ direction by formula. The centroid position of the barrel group is basically unchanged, which should be because the bullet mass is too small for the barrel, as shown in the Fig.5.

(a) ΔXΔY and ΔZ (b) ΔX and ΔY

Fig. 5 ΔXΔYΔZ basically unchanged

3.2 Changes in Mass of Bullet

The changes in the mass of the bullet, we see the changes in XYZ, as shown in Fig.6:



(a) ΔXΔY and Δ (b) ΔX and ΔY

Fig. 6 ΔXΔYΔZ changes in bullet mass

In this case, if the mass of the bullet decreases a bit, it has huge benefits for shooting and can enhance density. However, the mass of the bullet is relatively small and can be fired at a higher speed, making it more powerful for enemy aircraft.

3.3 Changes caused by material changes of headband

These materials were changed from steel to aluminum, as shown in Fig.7, and the coordinate is shown in Fig.8.

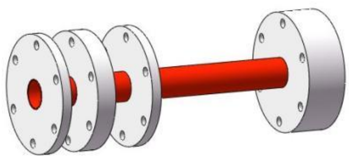


Fig. 7 Headband of the barrel

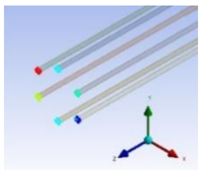


Fig. 8 Muzzle's XY

Changing the exterior from steel to aluminum will result in the following changes, from the X and Y in the muzzle position[20-23], as shown in Fig 9-12:

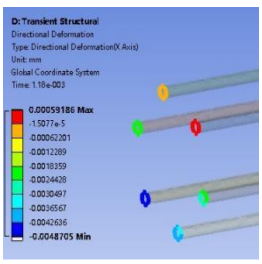


Fig. 9 Steel of Muzzle X

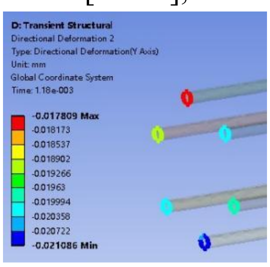


Fig. 10 Steel of Muzzle Y

Fig. 11 Aluminum of Muzzle X

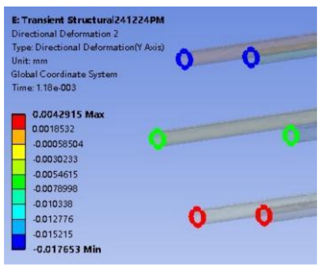


Fig. 12 Aluminum of Muzzle Y

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From the Fig.9-12, we can see that if we use the steel of headband, the muzzle displacement is so small to the aluminum of headband. The muzzle X of steel is only 1/13 of the muzzle X of aluminum, the muzzle Y of steel is only to aluminum of muzzle Y. The basic numerical values of the two are consistent. The aluminum is good to steel.

3.4 Changes the Effective Distance X of the Headband of the Barrel

Let's change the distance from the muzzle to headband of the barrel, as shown in Fig.13, the X distance from the 319mm, on this basis, it adds or subtracts 25mm.

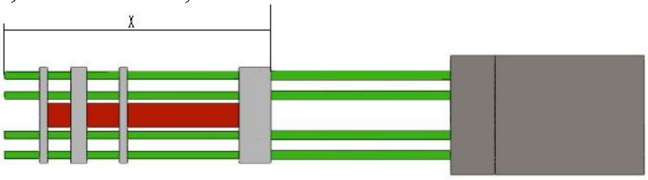


Fig.13 Effective distance X

The frequency from the X changes is from the ANSYS Workbench, the frequency is the list in Table 3:

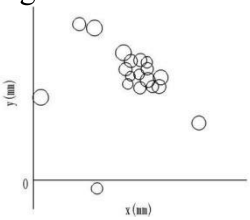
Table 3. X value brings the frequency of Weapon

X	1	2	3	4	5	6	7	8
294	19.477	19.658	61.735	61.911	72.52	166.31	200.43	200.63
319	20.018	20.215	56.419	58.168	65.615	165.17	166.63	178
344	18.489	18.664	54.895	55.108	63.652	165.89	219.77	220.01

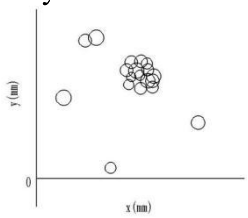
4. Experiment

The Gatling gun imitation was fired, with a tube length of 559mm and an initial velocity of 838m/s. because when the rotational speed[24-26] of the star body still reaches a stable rotational speed, it is fired. When the speed reaches a stable speed, the dispersion of bullets is relatively concentrated and 20 consecutive shots in 2000rpm and 4000rpm

R50 is about 10mm, and the included angle of dispersion is about 0.2mil, indicating that the muzzle bounce is small and the firing stability is good when the rotary tube machine gun fires at a high frequency. And Fig. 14 shows that 4000rpm target density is better than 2000rpm.



(a) 2000rpm



(b) 4000rpm

Fig. 14 100m vertical target density at 20 consecutive shots

The Gatling gun imitation is very good, then it is not distributed of firearms at the 6.5 secret level, and the space is 100m.

5. Conclusion and Results

These three factors are different firing rates, machine error of half cone angle and delay times. They can all affect machine gun firing. In addition to the different firing rates, the other two have to be further controlled.

(1) Minigun can give a shoot of 8525 rpm, it is higher than 2000 and 4000. That is 2000 and 4000, it is more barrel to be empty and it won't launch once in a while.

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(2) The aluminum headband is good to steel: the muzzle displacement is so small to the aluminum of headband. The muzzle X of steel is only 1/13 of the muzzle X of aluminum, the muzzle Y of steel is only to aluminum of muzzle Y. The basic numerical values of the two are consistent.

(3) Effective distance X of the headband of the barrel is not important.

(4) Bullet mass can be further reduced, and the initial velocity can be increased to strike the enemy.

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