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Dynamic Sensitivity Analyses of Projectile Muzzle Velocities

Zhong-feng Luo[1], Xiao-rong Guan[2], Cheng Xu[3]

School of Mechanical Engineering, Nanjing University of Science and Technology, Nanjing, 210094, China

1) 360523644@qq.com

2) gxr@njust.edu.cn

3) xucheng62@mail.njust.cn

Abstract: To decrease uncertainties of projectile muzzle velocities is one of important ways to improve gun firing accuracy. In order to solve the problem above, the influences on the uncertainties of projectile muzzle velocities should be calculated, which are caused by the variations of artillery structure parameters, but there is no effective method. We will provide a valid solution in this paper, taking a wheeled self-propelled gun for example. Firstly test scheme is designed and computed in inter-outer array. Subsequently the influences of barrel and projectile's parameters on the fluctuations and means of projectile muzzle velocities are discussed based on experimental results. Then in the next analysis their contribution rates to the fluctuations and means of projectile muzzle velocities are calculated and these parameters are classified further to improve gun firing accuracy better. At last, test scheme and results are proved to be reasonable and feasible.

Key words: gun firing accuracy; dynamic sensitivity analysis; projectile muzzle velocity; rate of contribution; significance

1 Introduction

Improving firing accuracies is one of the most important problems in the development of cannons. To reduce the fluctuations of projectile muzzle velocities, and to improve the accuracies of their means could help to improve the firing accuracies of cannons. The related research status is: with the help of the firing table, the changes of firing accuracies caused by the changes of projectile muzzle velocities are calculated in the single factor error method or the comprehensive parameters method [1-4]; but the changes of projectile muzzle velocities caused by the fluctuations of cannons' parameters could not be calculated because of the lack of effective methods. Due to the above problem, it is necessary to find a suitable method for sensitivity analyses of projectile muzzle velocities. To take a cannon as an example, this paper would study the influences of the relevant parameters of gun tube and projectile on the fluctuations of muzzle velocities and their means under different loading levels, which provides an effective method to improve the firing accuracies of cannons by adjusting cannons' parameters.

2 Ideal Function

According to the purpose of the design, actual projectile muzzle velocities should be equal to their design values respectively. In fact, it is not possible that actual projectile muzzle velocities are equal to their design values accurately, due to the fluctuations of cannons' parameters. In the paper the fluctuations of actual projectile muzzle velocities under different loadings could be described in the S/N ratio, while the changes of their means be described in the sensitivity coefficient. (The larger the S/N ratio, the lower the fluctuations of projectile muzzle velocities; the larger the sensitivity coefficient, the easier to change the means of projectile muzzle velocities.) In order to calculate the S/N ratio and sensitivity, the ideal function of the cannon is set up, which is shown as following:

$$y - y_S = \beta(M - M_S) \quad (1)$$

where y_S is the mean values of actual projectile muzzle velocities, β is the sensitivity coefficient, M_S is the design values of projectile muzzle velocities.

3 Controlled Factors and Their Levers

Based on the experimental purpose and obtained test dates, 11 parameters are selected as controlled factors, which are shown in Table.1. Each controlled factor is considered 3 levels, which are level 1, level 2 and level 3 in order respectively.

TABLE 1. Analytical factors and their levels

Analytical Factors \ Levels		1	2	3
Controlled Factors	A.Chamber Volume	A_1	A_2	A_3
	B.Barrel Length	B_1	B_2	B_3
	C.Rifling Depth	C_1	C_2	C_3
	D.Gun Groove Diameter	D_1	D_2	D_3
	E.Groove Land Ratio	E_1	E_2	E_3
	P.Forcing Cone Half Angle	P_1	P_2	P_3
	G.Projectile Weight	G_1	G_2	G_3
	H.Axial Inertia	H_1	H_2	H_3
	I.Band Diameter	I_1	I_2	I_3
	J.Band Length	J_1	J_2	J_3
	K.Band Density	K_1	K_2	K_3
Error Factors	N. Initial powder temperature	N_1	N_2	

4 Error Factors and Their Levers

Error factors mainly come from powders in the paper. The fluctuations of powers' structure parameters and physical properties are very small, because of the improved processing technologies. At the same time, environments in the actual emissions, plus transportations, storage conditions and storage times would cause initial powder temperatures to deviate from their set values, which may make projectile muzzle velocities increased or decreased. The powder in the study is mixed charge, so error factors may be integrated by different initial powder temperatures (as shown in Table 1): N_1- the negative side of the worst condition (making projectile muzzle velocities small); N_2-the positive side of the worst condition (making projectile muzzle velocities large).

5 Computational Model

Due to the limitation of the experimental conditions, it is not possible to carry out relevant physical tests in strict accordance with test settings. Based on some exiting experimental data, a neural network model is conducted, which is used to predict the cannon's projectile muzzle velocities in different situations. After testing, the credibility of the model is 0.945, which is greater than the setting value (0.9).So it is believed that the approximate model can be used to predict the cannon's projectile muzzle velocities accurately.

6 Design of Inner (outer) Tables

6.1 Design of the Inner Table

In the paper test schemes are designed in the inner/outer method, to reduce the number of tests and accurately to evaluate the effects of controlled factors on projectile muzzle velocities. The inner table is used to design test schemes. The outer tables are used to simulate the effects of error factors on projectile muzzle velocities under the given test scheme. According to the number of controlled factors and their levers, the inner table is compiled (as presented in Table 2), which provides 27 test schemes.

6.2 Design of Out Tables

After the inner table is established, outer tables will be designed for each scheme in the internal table, which are used to simulate the influence of error factors in the given test scheme. For example, Table 3 is an outer table, which is corresponding to the first test scheme in the inner table (Table 2).Because the power has 4 class, there are 4 signals in Table 3 (M_1, M_2, M_3, M_4) .Then different projectile muzzle velocities could be calculated based upon controlled factors' levers in the first scheme and the related lever of error factors.

TABLE. 2 Inner table and test results

Factors / No.	A	B	C	D	E	P	G	H	I	J	K	S/N ratios	Sensitivities
1	1	1	1	1	1	1	1	1	1	1	1	-15.073	0.29746
2	1	1	1	1	2	2	2	2	2	2	2	-13.987	0.21373
3	1	1	1	1	3	3	3	3	3	3	3	-13.339	0.24564
4	1	2	2	2	1	1	1	2	2	2	3	-15.247	0.02180
5	1	2	2	2	2	2	2	3	3	3	1	-14.271	0.01918
6	1	2	2	2	3	3	3	1	1	1	2	-14.631	0.58836
7	1	3	3	3	1	1	1	3	3	3	2	-15.604	-0.0810
8	1	3	3	3	2	2	2	1	1	1	3	-15.575	0.54592
9	1	3	3	3	3	3	3	2	2	2	1	-14.908	0.38368
10	2	1	2	3	1	2	3	1	2	3	1	-12.313	-0.2343
11	2	1	2	3	2	3	1	2	3	1	2	-15.063	-0.0179
12	2	1	2	3	3	1	2	3	1	2	3	-14.545	0.22913
13	2	2	3	1	1	2	3	2	3	1	3	-13.804	0.08009
14	2	2	3	1	2	3	1	3	1	2	1	-15.170	0.13455
15	2	2	3	1	3	1	2	1	2	3	2	-14.571	0.28161
16	2	3	1	2	1	2	3	3	1	2	2	-11.453	0.12199
17	2	3	1	2	2	3	1	1	2	3	3	-12.898	0.03550
18	2	3	1	2	3	1	2	2	3	1	1	-13.292	0.41118
19	3	1	3	2	1	3	2	1	3	2	1	-13.233	-0.4033
20	3	1	3	2	2	1	3	2	1	3	2	-13.494	-0.1315
21	3	1	3	2	3	2	1	3	2	1	3	-15.617	0.25265
22	3	2	1	3	1	3	2	2	1	3	3	-12.698	0.17341
23	3	2	1	3	2	1	3	3	2	1	1	-11.957	0.00332
24	3	2	1	3	3	2	1	1	3	2	2	-12.897	-0.0894
25	3	3	2	1	1	3	2	3	2	1	2	-12.336	-0.0514
26	3	3	2	1	2	1	3	1	3	2	3	-11.743	-0.0608
27	3	3	2	1	3	2	1	2	1	3	1	-13.071	-0.0325

TABLE 3 Test results of projectile muzzle velocities (Out table 1)

Signals / Error Factors	898.62	977.97	1055.58	1133.04
N_1	922.78	1003.16	1082.52	1161.82
N_2	930.35	1012.80	1094.44	1176.16

TABLE 4 Table of projectile muzzle velocities adjusted in table 3

Correction Signals / Error Factors	-117.68	-38.34	39.28	116.74
N_1	-125.27	-44.89	34.47	113.77
N_2	-117.70	-35.25	46.39	128.48

6.3 Calculation of S/N Ratios and Sensitivities

On basis of test results in Table 3 and the ideal function(Eq.(1)), the S/N ratio and sensitivity of the first test scheme could be computed in Eq.(2)~Eq.(14).

Datum points:

$$y_{S1} = (922.78 + 1003.16 + \cdots + 1176.16)/8 = 1048.05, \tag{2}$$

$$M_S = (898.62 + 977.97 + \cdots 1133.04)/4 = 1016.03, \tag{3}$$

where y_{s1} is the mean of test results in Table 3, M_s is the mean of signals in Table 3.Then all test results are subtracted from the mean of test results in Table 3, while the signals are subtracted from the mean of signals. The results are shown in Table 4.

Total sum of squares (S_{T1}) and its freedom (f_{T1}):

$$S_{T1} = (-125.27)^2 + (-44.89)^2 + \cdots + 128.48^2 = 65593 \ (f_{T1} = 8), \tag{4}$$

where S_{T1} is the square sum of corrected projectile muzzle velocities in Table 4, f_{T1} is the number of corrected projectile muzzle velocities in Table 4.

Linear expressions:

$$L_1 = (-117.68)\times(-125.27) + (-38.34)\times(-42.89) + \cdots + (116.74)\times(113.77) = 31098.12, \tag{5}$$

$$L_2 = (-117.68)\times(-117.70) + (-38.34)\times(-35.25) + \cdots + (116.74)\times(128.48) = 32023.39, \tag{6}$$

where L_1 is the sum of product the corrected signal and their corresponding corrected projectile muzzle velocity influenced by error factor N_1 in Table 4, L_2 is the sum of product the corrected signal and their corresponding corrected projectile muzzle velocity influenced by error factor N_2 in Table 4.

Effective divisor (r_1):

$$r_1 = 2\times\sum_{i=1}^{4}(M_i - M_S)^2 = 60980.33. \tag{7}$$

Fluctuation of proportional item ($S_{\beta 1}$) and its freedom ($f_{\beta 1}$):

$$S_{\beta 1} = (L_1 + L_2)^2/r_1 = 65337.87(f_{\beta 1} = 1). \tag{8}$$

Square sum of fluctuation ($S_{\beta * N1}$) and its freedom ($f_{\beta * N1}$):

$$S_{\beta * N1} = (L_1 - L_2)^2/r_1 = 14.04(f_{\beta * N1} = 1). \tag{9}$$

Fluctuation of error (S_{e1}) and its freedom (f_{e1}):

$$S_{e1} = S_{T1} - S_{\beta 1} - S_{\beta * N1} = 241.10(f_{e1} = f_{T1} - f_{\beta 1} - f_{\beta * N1} = 6). \tag{10}$$

Variance of error (V_{e1}):

$$V_{e1} = S_{e1}/f_{e1} = 40.20. \tag{11}$$

Variance of total errors (V_{N1}):

$$V_{N1} = (S_{e1} + S_{\beta * N1})/(f_{e1} + f_{\beta * N1}) = 31.89. \tag{12}$$

Because $V_{N1} < V_{e1}$, the S/N ratio and sensitivity of the first test scheme may be calculated in Eq.(13) and Eq. (14) respectively.

$$\eta_1 = 10 * \log(S_{\beta 1} - V_{e1})/(r_1 * V_{e1}) = -15.073(\text{dB}). \tag{13}$$

$$S_1 = 10 * \log(S_{\beta 1} - V_{e1})/r_1 = 0.29746(\text{dB}). \tag{14}$$

The S/N ratios and sensitivities of the other test schemes could be computed by referring to the above method. All results are presented in Table 2. The interpretation of the S\N ratio and sensitivity can refer to literature [8].

7 Average Effect Analyses

7.1 Average Effect Analyses for S/N Ratios

The average S/N ratios of controlled factors at different levels may be calculated, according to S/N ratios in Table 2.

They could be obtained in the following way: firstly the S/N ratios are added at the same level of the given controlled factor; then the sum is divided by the number of test schemes involved. To facilitate the analyses, Figure 1 and Figure 2 are used to show controlled factors' average S/N ratios at different levers. In Figure 1 and Figure 2, the average S/N ratios of controlled factors are different at different levels, i.e. the influences of controlled factors at different levels are different on the fluctuation of projectile muzzle velocities.

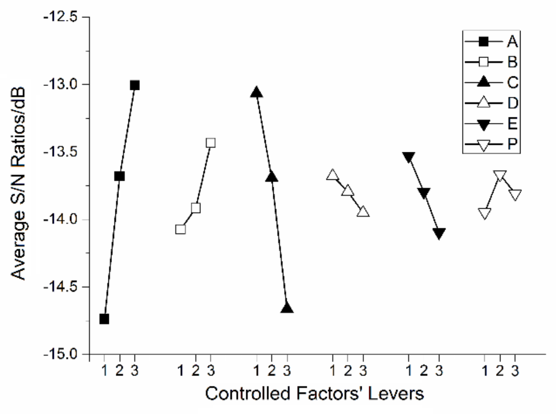

Fig.1 Average S/N ratios vs. levels (a)

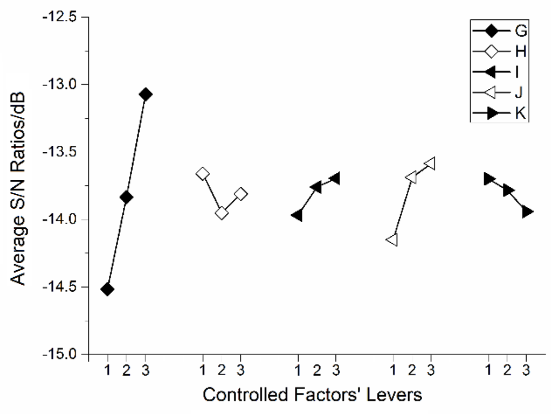

Fig. 2 Average S/N ratios vs. levels (b)

At the same time, Figure 1 and Figure 2 also show that the average S/N ratio increases with the increases of chamber volume (A), barrel length (B), projectile mass (G), band diameter (I), band length (J) in the given intervals; and decreases with the increases of rifling depth (C), gun groove diameter (D), groove land ratio (E), band density (K), while it does not increase or decrease monotonously with the increase of forcing cone half angle (P), projectile axial inertia (H).From the view of the S/N ratio, the best levers of controlled factors are: $A_3B_3C_1D_1E_1P_2G_3H_1I_3J_3K_1$. Under this condition, the best S/N ratio would be calculated in Eq. (15):

$$\eta_{\text{best}} = \overline{A_3} + \overline{B_3} + \overline{C_1} + \overline{D_1} + \overline{E_1} + \overline{P_2} + \overline{G_3} + \overline{H_1} + \overline{I_3} + \overline{J_3} + \overline{K_1} - 10 \times T_\eta = -10.010(\text{dB}) \quad (15)$$

where T_η is the average value of all S/N ratios in Table 2. The rationality of S/N ratios may be verified by the test of the best S/N ratio.

7.2 **Average effect analyses for sensitivities**

The average sensitivities of controlled factors at different levels can be calculated in the part, according to sensitivities in Table 2.They may be obtained by referring to the calculated method of the average S/N ratios in Part 6.1 . To facilitate the analyses, Figure 3 and Figure 4 are made, which are used to show controlled factors' average sensitivities at different levers.

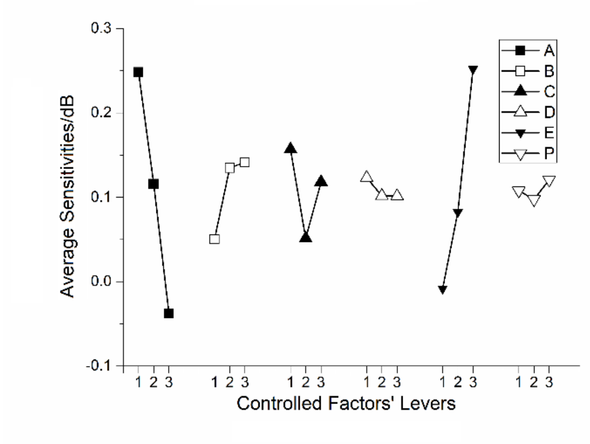

Fig.3 Average sensitivities vs. levels (a)

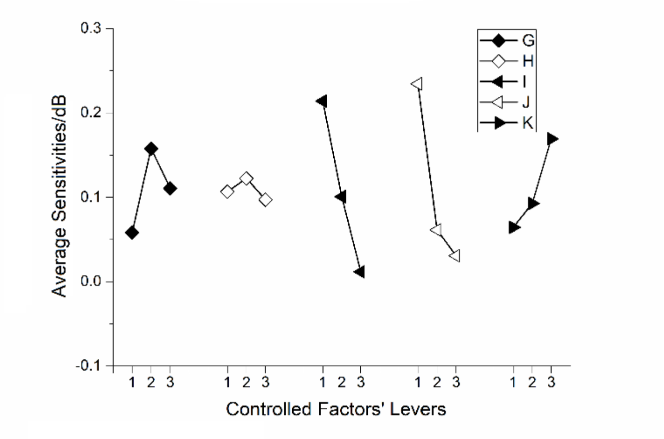

Fig.4 Average sensitivities vs. levels (b)

In Figure 3 and Figure 4, the average sensitivities of controlled factors are different at different levels, i.e. the influences of controlled factors at different levels are different on the means of projectile muzzle velocities. Meanwhile Figure 3 and Figure 4 also show that the average sensitivity increases with the increases of barrel length (B), groove land ratio (E), band density (K)in the given intervals; and decreases with the increases of chamber volume (A), gun groove diameter (D), band diameter (I), band length (J), while it does not increase or decrease monotonously with the increases of rifling depth (C),forcing cone half angle (P), projectile mass (G), axial inertia (H).From the view of the sensitivity, the best levers of controlled factors are: $A_3B_3C_1D_1E_1P_2G_3H_1I_3J_3K_1$.Under this condition, the best sensitivity would be calculated in Eq. (16):

$$S_{\text{best}} = \overline{A_3} + \overline{B_3} + \overline{C_1} + \overline{D_1} + \overline{E_1} + \overline{P_2} + \overline{G_3} + \overline{H_1} + \overline{I_3} + \overline{J_3} + \overline{K_1} - 10 \times T_S = -0.29085(\text{dB}), \quad (16)$$

where $T_S$is the average value of all sensitivities in Table 2. The rationality of sensitivities may be verified by the test of the best sensitivity.

8 Variance Analyses

According to the data supplied in Table 2, variance analyses of S/N ratios and sensitivities would be conducted in the part, to further calculate analysis factors' contribution rates and significances.

8.1 Variance Analyses for S/N Ratios

Sum of S/N ratios $(T)$and Correction term (CT):

$$T = \sum_{i=1}^{n} \eta_i = -372.78708, \quad (17)$$

$$CT = T^2 / n = 5147.04462, \quad (18)$$

where n is the number of test schemes in Table 2.
Square sum of the fluctuation of S/N ratios $(\eta_T)$and its freedom(f_T):

$$\eta_T = \sum_{i=1}^{n} \eta_i^2 - CT = 41.96684(f_T = n - 1 = 26), \quad (19)$$

(The following only provides the calculated methods of the related indexes of both controlled factor A and error factors. The indexes of the other controlled factors could be computed by referring to the above method.)

Average S/N ratios of controlled factor A:

$$T_{1A} = \sum_{i=1}^{9} \eta_i = -132.63417, \quad (20)$$

$$T_{2A} = \sum_{i=10}^{18} \eta_i = -123.10726, \quad (21)$$

$$T_{3A} = \sum_{i=19}^{27} \eta_i = -117.04565. \quad (22)$$

Square sum of SRN fluctuation of controlled factor A (η_A) and its freedom (f_A):

$$\eta_A = \left(T_{1A}^2 + T_{2A}^2 + T_{3A}^2\right) / (n/3) - CT = 13.72250\left(f_A = K_A - 1 = 2\right), \quad (23)$$

where K_A is the number of the levers of controlled factor A.

Square sum of SRN fluctuation of error factors (η_e)and its freedom(f_e):

$$\eta_e = \eta_T - \left(\eta_A + \eta_B + \cdots + \eta_K\right) = 0.34782\left(f_e = f_T - \left(f_A + f_B + \cdots + f_K\right) = 4\right). \quad (24)$$

Variances for S/N ratios of controlled factor A (V_A) and error factors (V_e):

$$V_A = \eta_A / f_A = 6.86125, \quad (25)$$

$$V_e = \eta_e / f_e = 0.08696. \quad (26)$$

Contribution rate of controlled factor A (ρ_A):

$$\eta_A^{'} = \eta_A - f_A V_e = 13.54858, \quad (27)$$

$$\rho_A = \eta_A^{'} / \eta_T = 32.28\%. \quad (28)$$

Contribution rate of error factors (ρ_e):

$$\eta_e^{'} = f_T V_e = 2.26086, \quad (29)$$

$$\rho_e = \eta_e^{'} / \eta_T = 5.39\%, \quad (30)$$

F value of controlled factor A (F_A):

$$F_A = V_A / V_e = 78.91. \quad (31)$$

Because of$F_A = 78.91 > F_{0.01}(2，4) = 10.92$, controlled factor A is a highly significant factor, marked by "**". (If $F_A > F_{0.01}(2，4)$, controlled factor A is a highly significant factor, marked by "**"; if$F_{0.05}(2，4) \le F_A \le F_{0.01}(2，4)$, controlled factor A is a significant factor, marked by "*"; if $F_A < F_{0.05}(2，4)$, controlled factor A is not a highly significant factor or a significant factor, marked by" ".)

Analysis of variance

All the above results are given in Table 5. According to table 5, chamber volume, rifling depth have larger contribution rates on the fluctuation of the S/N ratio while the other controlled factors have relatively low contribution rates. What's more, controlled factors' influences on the fluctuation of S/N ratios could be compared quantitatively with the help of their contribution rates. Meanwhile it is not enough to merely know the contribution rates of controlled factors, which does not consider the relationships between controlled factors and error factors. In order to solve the above problem, F analyses between controlled factors and error factors are conducted, which would show the significances of all controlled factors under the influence of error factors. Based on the above result, the highly significant and significant factors are chosen as optimization variables in the subsequent improvement.

TABLE 5 ANOVA table for S/N ratios

Sources of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Contributions (%)	F	Significances
A. Chamber Volume	13.72249	2	6.86124	32.28	78.91	**
B. Barrel Length	2.01821	2	1.00910	4.40	11.61	*
C. Rifling Depth	11.67411	2	5.83705	27.40	67.13	**
D. Gun Groove Diameter	0.34026	2	0.17013	0.40	1.96	
E. Groove Land Ratio	1.45250	2	0.72625	3.05	8.35	*
P. Forcing Cone Half Angle	0.35778	2	0.17889	0.44	2.06	
G .Projectile Weight	9.39500	2	4.69750	21.97	54.02	**
H. Axial Inertia	0.38363	2	0.19182	0.50	2.21	
I. Band Diameter	0.36757	2	0.18379	0.46	2.11	
J. Band Length	1.63492	2	0.81746	3.48	9.40	*

K. Band Density	0.27254	2	0.13627	0.24	1.57
Pooled error	0.34782	4	0.08696	5.39	

8.2 Variance analyses for sensitivities

The variance analysis of sensitivities could be conducted by referring to the variance analysis of S/N ratios, whose results are shown in Table 6. The contribution rates of gun groove diameter, forcing cone half angle and axial Inertia are not shown in Table 6, because they are too small.

Table 6 shows that in the variance analysis of sensitivities the contribution rates of controlled factors are coincident with the information presented in Figure 3 and 4; the contribution rate of error factors is the largest among all analysis factors, which means that if the conditions of powder preservation are improved, the fluctuation of sensitivities would decrease, without any adjustments of controlled factors. After the conditions of powder preservation are improved, the contribution rates of all controlled factors could be computed again, which may help to obtain more the highly significant factors and the significant factors. If the conditions of powder preservation could not be improved firstly, the next optimization only would be conducted on the basis of the results shown in Table 6.

8.3 Significances compares

The significances of controlled factors are shown in Table 7. It is known from Table 7 that chamber volume and groove land ratio in the variance analysis of both S/N ratios and sensitivities are highly significant factors or significant factors; barrel length, rifling depth, projectile mass, band length are highly significant factors or significant factors only in the variance analysis of S/N ratios; gun groove diameter , forcing cone half angle , axial inertia , band diameter , band density are not highly significant factors or significant factors in the variance analysis of S/N ratios and sensitivities.

These mean that chamber volume and groove land ratio have obvious influences on the fluctuations of projectile muzzle velocities and the changes of their means in a given ranges; barrel length, rifling depth, projectile mass and band length only affect the fluctuations of projectile muzzle velocities; gun groove diameter, forcing cone half angle, axial inertia, band diameter, and band density have tiny influences on the fluctuations of projectile muzzle velocities and the changes of their means in a given ranges. According to the above analyses, the fluctuations of projectile muzzle velocities could be adjusted by barrel length, rifle depth, and band length in the subsequent optimization; the means of projectile muzzle velocities may be adjusted by chamber volume and groove land ratio; gun groove diameter, forcing cone half angle, axial inertia, band diameter, band density can be temporarily unchanged. This would make the subsequent optimization simpler.

TABLE 6 ANOVA table for sensitivities

Sources of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Contributions (%)	F	Significances
A. Chamber Volume	0.36884	2	0.18442	24.58	10.68	*
B. Barrel Length	0.04657	2	0.02328	0.88	1.35	
C. Rifling Depth	0.05144	2	0.02572	1.24	1.49	
D. Gun Groove Diameter	0.00279	2	0.00140	/	0.08	
E. Groove Land Ratio	0.31502	2	0.15751	20.63	9.12	*
P. Forcing Cone Half Angle	0.00249	2	0.00125	/	0.07	
G .Projectile Weight	0.04488	2	0.02244	0.76	1.30	
H. Axial Inertia	0.00294	2	0.00147	/	0.09	
I. Band Diameter	0.18552	2	0.09276	11.10	5.37	
J. Band Length	0.21730	2	0.10865	13.44	6.29	
K. Band Density	0.05301	2	0.02650	1.36	1.54	
Pooled error	0.06908	4	0.01727	33.02		

TABLE 7 Comparisons of controlled factors' significances

Controlled Factors	S/N ratios	Sensitivities
A. Chamber Volume	**	*
B. Barrel Length	*	
C. Rifling Depth	**	
D. Gun Groove Diameter		
E. Groove Land Ratio	*	*
P. Forcing Cone Half Angle		
G .Projectile Weight	**	
H. Axial Inertia		
I. Band Diameter		
J. Band Length	*	
K. Band Density		

9 Test

Because the conclusions of the paper cannot be tested directly, the credibility of the test method and results would be tested indirectly from the following two aspects: the accuracies of projectile muzzle velocities and the rationalities of S/N ratios and sensitivities. The accuracies of projectile muzzle velocities are sure, due to the credibility of the computational model. According to projectile muzzle velocities supplied by the computational model, the conclusions of effect analyses and variance analyses are believable, if S/N ratios and sensitivities are reasonable in Table 2.The rationalities of S/N ratios and sensitivities are obtained, if the actual values of the best S/N ratio and sensitivity are consistent with their predicted values respectively. After computation, the actual values of the best S/N ratio and sensitivity are 10.05 dB and 0.2906 dB, which are very accordant with their corresponding predicted values in Part 6 respectively. So the test method and results provided in the paper are believable, due to the credibility of the computational model and the rationalities of S/N ratios and sensitivities.

10 Conclusion

Taking a cannon as an example, this paper provides a method, which is used to compute the influences of cannons' parameters on the fluctuations of projectile muzzle velocities and their means in the given internals.

1) The out (inner) tables are established to design test schemes, meanwhile S/N ratios and sensitivities are calculated in different test schemes.
2) The influences of controlled factors in different levels are computed on the fluctuations of projectile muzzle velocities and their means on the basis of the average S/N ratios and the average sensitivities. The best S/N ratio and sensitivity are predicted at the same time.
3) Thirdly the contribution rates and significations of all analysis factors are calculated through variance analyses of test results, then according to the above results, the suggestions are provided, which are used to improve the firing accuracies of the cannon.
4) The test method and conclusions are verified to be credibility.

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