OPTIMUM TRUNNION PULL

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ABSTRACT

Attempt has been made to find out an optimum value of the trunnion pull which will give a minimum carriage weight. By a general theoretical analysis it is observed that the ratio trunnion pull to the square of the distance of recoil should be a constant for a minimum weight. This constant has been analysed from the study of the existing equipments.

Introduction

For any ballistic effect combined with a specified minimum weight of the equipment, the outstanding factors are:—

(*a*) Length of recoil

(*b*) Total trunnion pull.

The product of these two quantities govern the amount of energy absorbed in any recoil system. Therefore, to absorb a given amount of recoil energy of the recoiling mass, any value of trunnion pull and a corresponding value of the length of recoil could be selected. The assumption of a long recoil would reduce the trunnion pull (resistance to motion) and consequently decrease the strain on the carriage and permit its parts to be made lighter. However, the necessary increase in the length of recoil slides, trails and other members of the carriage might over-balance the saving and add to the weight. The object of this analysis is, therefore, to estimate an optimum value of the trunnion pull and the length of recoil to dissipate a given amount of recoil energy such that the carriage weight is a minimum.

Analysis

If it is assumed that the force acting on any member of the carriage is proportional to the trunnion pull (R) and its length is proportional to the length of recoil, (Z), which is generally true, it can be shown that the weight of the carriage (W) is given by the expression:

$$W=\sum^{n_1} K_1\, R\, Z + \sum^{n_2} K_2\, R^{\frac{1}{2}} Z^2 + \sum^{n_3} K_3\, R^{2/3}\, Z^{5/3}$$

where the first term represents the weight of all the members in tension and members in short compression, the second of the long members in compression and the third of members in torsion or bending, n_1, n_2, and n_3, the number of members in the respective group and K_1, K_2, K_3 are constants involving the yield strength, modulus of elasticity and density of the material, factor of safety, the ratio of force coming on the member to the trunnion pull and its length to distance of recoil.

From the above equation, it can be easily shown that for a minimum weight $R/Z^2 = \left(\overset{n_2}{\Sigma} K_2 / 2\overset{n_1}{\Sigma} K_1\right)^2$ which is constant. It is therefore obvious, that to get a minimum carriage weight in a new design, the optimum value of the trunnion pull could be determined from the equations:

$R \times Z$ = Energy of the recoiling masses and R/Z^2 = Constant.

A theoretical evaluation of this constant is almost impossible and, therefore, a statistical analysis of the variation of carriage weight per unit recoil energy, with R/Z^2 was done for a large number of equipments. These were divided into three groups viz. Antitank, Light field, and Heavy field because of the geometric and operational similarity of guns in any group. A/A Guns could not be analysed because of insufficient data. Mean trunnion pull at zero elevation was calculated and used in the above analysis. The following formulæ were used in case complete ballistic data for the equipment was not available.

(*a*) Estimation of charge weight[1]:

$$\tfrac{1}{2}(1\cdot05w + C/3)v^2 = \frac{\eta\, C \times 11 \times 10^6}{0\cdot26}$$

(*b*) Estimation of recoiling mass[2]:—

$$W_r = 1/2 \cdot W/g \cdot v^2 \times 10^{-3}$$

(These formulae assume that the recoiling mass is 10% higher than the ordnance weight)

(*c*) Estimation of mean trunnion pull[3]:—

$$R = \frac{(wv + 4700C)^2}{1200 W_r\, Z}$$

In the above formulæ w, C and W_r are the weights of projectile, charge and the recoiling mass in lbs, v the muzzle velocity in ft/sec, R the trunnion pull in tons, Z the recoil length in inches and η the gun efficiency which was assumed to be 0·3 for low and 0·25 for high muzzle energy guns. The relevant data for various guns is given in table attached[4]. Curves in figures 1 to 3 indicate the variation of W_c/RZ with R/Z^2.

TABLE

Nomenclature and origin		R/Z^2 tons/ in²	W_c/RZ lbs/ton in
Light Field			
7·5 cm Field Gun (Feldkanone 18)	Germany	0·00125	18·1
7·5 cm Feldkanone 38	Do	0·00198	17·8
7·5 cm Mountain Howitzer—Model 15	Do	0·00566	11·2
7·62 cm Infantrie—Kanonenhaubitze 290 (*r*)	Do	0·00225	12·1
Q.F. 25 pr short Mk I	Australia	0·0224	13·3
95 mm Inf How	Britain	0·0065	9·5
100/17 How Model 14 and 16	Italy	0·00283	8·55

TABLE—*contd.*

Nomenclature and origin		R/Z² tons/in²	Wc/RZ lbs/ton in
	Light Field—contd.		
105 mm How M2 and M2A1 on carr M2	USA	0·00378	11·35
10·5 cm Gun/How 1. F.H. 18	Germany	0·00303	12·9
Q.F. 4·5 in How Mk I and II on carr Mk I P	Britain	0·00318	8·8
B.L. 4·5 in Gun Mk II on carr Mk I and II	Do	0·00321	15·35
Q.F. 25 pr Mk II on carr Mk I	Do	0·00372	16·0
QF 3·7 in How Mk I on carr Mk IV P	Do	0·002	16·15
	Heavy Field		
B.L. 60 pr Mk I to I^{xx}	Britain	0·00354	9·15
B.L. 60 pr Mk II and II^{x}	Do	0·00366	12·35
12·8 cm (5 in) Guns bearing the model No 81	Germany	0·02593	8·2
15 cm S.I.G. 33	Do	0·00983	4·83
B.L. 6 in Mk XIX gun on Mk VIII and VIII A tarv car	Britain	0·01525	9·25
B.L. 6 in 26 cwt How Mk I on carr Mk I to IR	Britain	0·00557	8·53
155 mm Gun M1 and M1A1 on carr	USA	0·00485	15·6
155 mm How M1917 and M 1918	Do	0·00845	6·7
17 cm K on carr 21 cm Mk 18	Germany	0·0357	13·9
B.L. 8 in How Mk VIII on VIIA and VII AP carr	Britain	0·01238	7·07
12·2 cm S.F.H. 396 (r)	Germany	0·00641	6·87
B.L. 5·5 in Mk III on carr	Britain	0·0045	11·9
B.L. 7·2 in How Mk I on carr Mk I	Do	0·01386	7·55
	Anti Tank		
37 mm Gun M3 on carr M4	USA	0·0026	34·7
3·7 cm pak	Germany	0·00193	36·1
4·2 cm Pak 41 (Taper bore)	Do	0·00169	46
4·7 cm Model 1	Japan	0·00596	34·5
5 cm Pak 38	Germany	0·0012	52·5
7·5 cm pak 40	Do	0·0033	15·1
8·8 cm Pak 43/41	Do	0·01145	37·8
7·5 cm Pak 41	Do	0·00511	31
17 pr Mk I on carr Mk I	Britain	0·0043	10·3
6 pr 7 cwt Mk II on carr Mk I	Do	0·0026	25·1

Conclusions

It can be seen from the curves in figures 1 to 3 that there is an optimum value of R/Z^2 for which the carriage weight per unit recoil energy is a minimum. The optimum, however, cannot be defined from these curves because of the incomplete geometric similarity of design even within its own group and slight variations of materials and factors of safety employed by their designers. It can, therefore, be stated broadly that the ratio of trunnion pull to square of distance of recoil in a new design for least weight may be taken as follows:—

(*a*) A/Tk guns 0·0035 to 0·0055.

(*b*) For light field guns 0·006 to 0·012.

(*c*) For heavy field guns 0·008 to 0·012.

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LIGHT FIELD GUNS

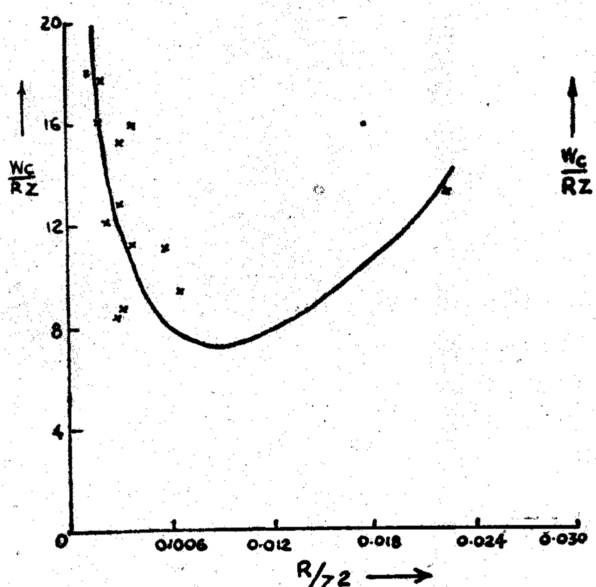

FIG:-1

HEAVY FIELD GUNS

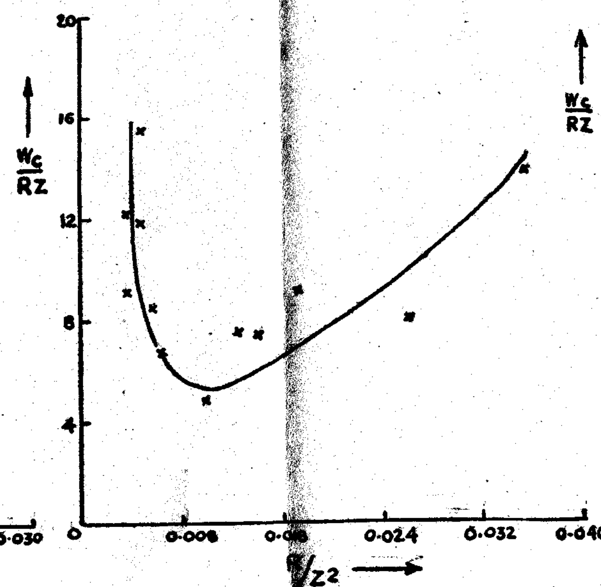

FIG:-2

ANTI-TANK GUNS

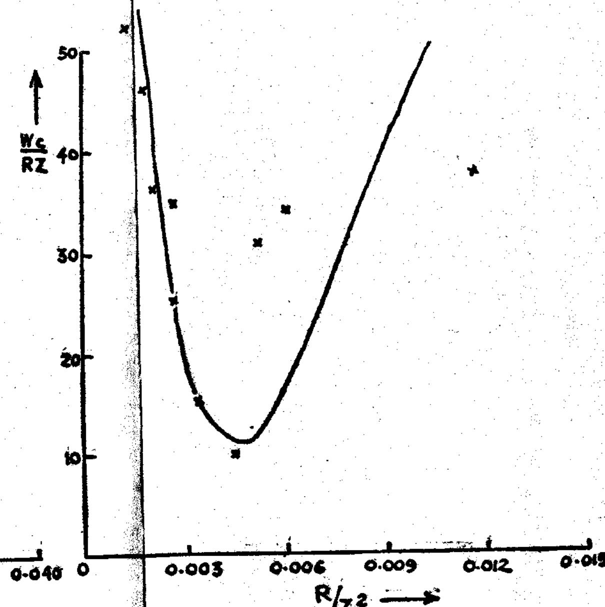

FIG:-3

CURVES SHOWING VARIATION OF Wc/RZ WITH R/Z²