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Engineering

A STUDY ON TRANSITIVE MEASUREMENT OF BORE WEAR THROUGH RAMMER LOADING IN SMOOTH BORE TANK GUNS

Ramesh Shanmugam	Dept of Mechanical Sciences, Hindustan University, Padur, Chennai 603 103
D Dinakaran	Dept of Mechanical Sciences, Hindustan University, Padur, Chennai 603 103
D G Harris Samuel	Dept of Mechanical Sciences, Hindustan University, Padur, Chennai 603 103

ABSTRACT Among parameters that affect the accuracy of a gun, bore parameters are predominant. They are interdependent, significant and complex. Presently, very limited set of bore parameters are being measured, that too at logistic pauses during operations due to non-availability real time condition monitoring tools. Consequently, the accuracy levels of present day tank guns continue to remain sub-optimal. Further, monitoring of these parameters is equally vital to ensure crew safety through early failure predictions. Condition monitoring of tank guns in near real time thus is an impending need that has huge prospects in exponentially enhancing the combat potential of the Tank Formations. This paper presents a case study wherein a real time monitoring technique for Tank Gun Bore Wear, involving transitive measurement of bore wear through rammer load current, that has been successfully validated.

KEYWORDS :

INTRODUCTION

Condition Monitoring(CM) of Tank Guns towards enhancing accuracy and safety is a continuous and evolving process. Accuracy of a Tank Gun is dictated by many factors amongst which gun bore parameters are predominant. Wear is a mechanical effect that is the result of interaction between the Gun Barrel and the projectile as the latter traverses the bore[1]. Bore wear affects almost all other parameters of gun like muzzle velocity, accuracy, grouping, stability in-flight, fuze functioning, reliability of sensitive components, and life cycle cost[2]. Present measurement systems of bore wear include Bore scope, Star scope, Pullover gauges and laser optical devices. It is important to note that the fatigue life of the barrel which is statistically determined through live testing and simulations, are invariably longer than bore wear based life[2]. While this consideration may be arguably a safer practice, it sub-optimizes the useful life of the barrel. Bore wear is neither uniform nor linear through-out the barrel length. It was empirically proved that few sections of the barrel sustain more wear than the rest. Studies recommend measurement of bore wear at various lengths of the barrel and each of which has different coefficients of importance[3]. Jankovych, R., & Beer, S.[4] have carried out a detailed analysis of 2A46 Cannon fitted in Tank T-72 in this regard, and also developed a mathematical model for wear prediction for various types of ammunition. Beer, Stainslav and Hajn, Michael[5] have also presented a detailed study on correlation between bore wear and muzzle velocity. They successfully proved that range loss due to bore wear has two components, namely; (a) pressure loss due to gases escaping past obturating bands and (b) high projectile drag caused by yaw, due to increased bore clearance[6]. Muzzle velocity which is one of the major factors determining the trajectory, thereby the accuracy, has direct correlation with bore wear[7]. Presently, bore wear is measured with offline devices during lulls in the battle field after necessary cleaning, which is time consuming. There is no real time measurement of bore wear being undertaken for the tank guns.

RAMMING SYSTEM

Ramming System is used to position the projectile in the bore. As the bore wear increases, correct positioning of the projectile becomes a challenge. It also leads to fall back of projectile and cause premature explosion in the bore. Ramming process is also influenced by barrel thermal deformation. Jiri Bhalla et al[8] have carried out a detailed mathematical treatment of ramming kinematics and dynamics, covering all kinds of loading systems, for determining reaction forces. Important relationships between bore wear and ramming distance through resolving reaction forces, have also been established in the study, which recommends measurement of ramming forces through ejection forces. Although it is possible to measure these reaction forces on real time, presently there are no such devices available. The reaction forces measured in ibid study are vital in analyzing the muzzle velocity dynamics and are shown in Fig 1 and Fig 2 for New and Worn out barrels respectively from which following can be deduced :-

(a) Max reaction force is approx 31000 N for a new barrel and 10000 N for a worn out barrel (assuming the worn out barrel to be in last quarter, with say 3mm wear).
(b) This equation translates into 21000N for 3mm wear or in other words 700 N or 71.38 Kgf per 0.1 mm.
(c) Effectively, it is 2.8 x 10^{-4} mm per 200 gms force, which is the accuracy levels that can be achieved in the proposed method in the best case.
(d) In the worst case, if reaction forces of mid-pulse with 12000 N were considered, the accuracy becomes half i.e. approx 4N per micron. Since tolerance required is in the order of 0.1 mm, it will be approx 400 N per 0.1 mm which is approx 41 Kgs per 0.1mm.
(e) The impact distance from start to stop position, measures around 3 to 5 mm for a new barrel, whereas in the worn out barrel it is as high as 150 mm.

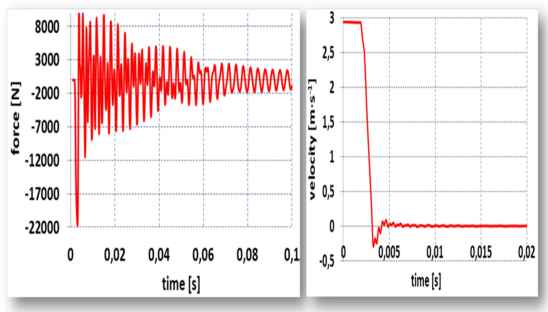

Figure 1: Reaction Forces in a New Barrel

Source:[8]

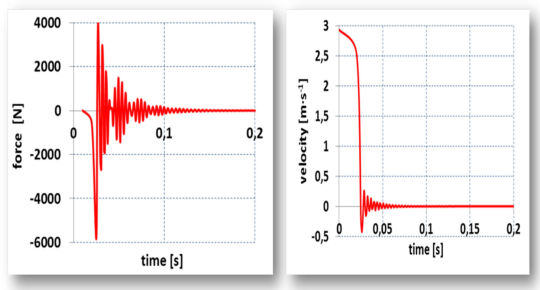

Figure 2: Reaction Forces in a Worn Out Barrel

Source:[8]

TRANSITIVE MEASUREMENT OF BORE WEAR

Based on the review, it could be inferred that accuracy of firing of tank guns can be improved by measuring of bore wear and applying corrections. If done in real time or near real time, accuracy of every round can be maintained at its best, thus improving First Round Kill Probability (FRHP) and First Salvo Effectiveness(FSE). The position of projectile in the barrel is affected by the bore wear and barrel temperature. Typically, these distances vary from 5 mm for a new barrel upto 150mm for a worn out hot barrel[8]. Thus there is an hypothesized correlation between bore wear and projectile position post ramming, that can be measured non-invasively through rammer travel and its forces.

EXPERIMENTAL SETUP

Experimental setup used is shown in Fig 3 below, that is self explanatory.

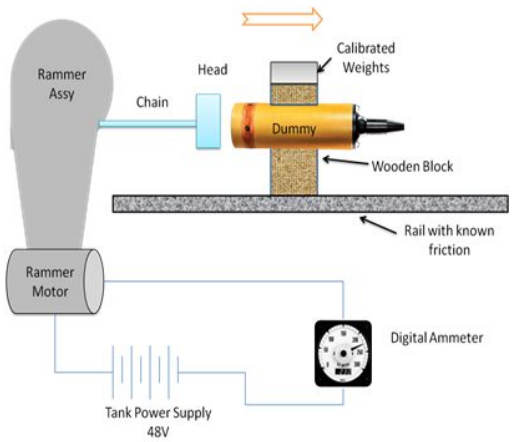

Figure 3: Experimental Set up for Measuring Ramming Force

RESULTS AND DISCUSSION

The rammer load has been simulated by placing a dummy projectile on a sliding block and the frictional force has been varied by placing calibrated weights. Using a simple spring balance, the slide has been calibrated for its frictional force and thereafter the current was measured through a digital ammeter, by increasing the load through adding calibrated load in the steps of 200 gms. The values obtained are shown in Table 1.

TABLE – 1 LOAD Vs RAMMER CURRENT

Added Weight Kgf	Total Load Kgf	Forward i1 mAmp	Return i2 mAmp
0	0	4.20	2.00
0.2	8.75	5.10	2.10
0.4	8.95	5.15	2.10
0.6	9.15	5.15	2.10
0.8	9.35	5.20	2.05
1.0	9.55	5.20	2.00
1.2	9.75	5.25	2.10
1.4	9.95	5.30	2.10
1.6	10.15	5.30	2.05
1.8	10.35	5.40	2.05
2.0	10.55	5.45	2.05
2.2	10.75	5.45	2.10
2.4	10.95	5.50	2.05
2.6	11.15	5.55	2.10
2.8	11.35	5.60	2.10
3.0	11.55	5.70	2.05
3.2	11.75	5.70	2.10
3.4	11.95	5.75	2.10
Constants			
Projectile Weight 7.05 Kgf			
Dead Weight 1.230 Kgf			
Friction 0.280 Kgf			

Source: Primary Data

Statistical Analysis indicate a very strong linear correlation between the load applied and load current which is very much in expected lines. The consistency and accuracy obtainable from rammer current for minimum load change factor of 200 gms is adequate in the light of findings deduced from reaction forces of New and Old barrel (Refer Figure 1 & 2 above). It can be inferred that bore wear can be transitively measured through rammer motor load current and rammer travel, for applying necessary corrections in Fire Control Systems to enhance accuracy.

CONCLUSION

Accuracy of tank gun decides its fire power effectiveness thereby its combat potential. There are many parameters that affect the accuracy of which Bore Wear is predominant. A transitive measurement of bore wear through rammer loading was evolved. The correlation between rammer load current and the bore wear has been successfully established for automatic measurement of rammer load current in real time and feeding of the same to FCS for correction, thereby increasing the accuracy.

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