VACUUM DAMPED RECOIL SYSTEM: A REVIEW

Pankaj W. Wanjari¹, Dr. C. C. Handa² and Prof. A. P. Ninawe³

¹M.Tech Student, Department of Mechanical Engineering K. D. K. College Of Engineering, Nagpur, Maharashtra, India.
²Professor, Department of Mechanical Engineering K. D. K. College Of Engineering, Nagpur, Maharashtra, India.
³Assistant Professor, Department of Mechanical Engineering K. D. K. College Of Engineering, Nagpur, Maharashtra, India.

Abstract—Recoil is the backward momentum of barrel when it is discharge. Due to certain damping system it move inward and return its original position. Conventional recoil system basically consists of hydraulic type system, stiff spring, damper etc. which make it more complex and unreliable due to more moving parts. By using such a system time required for canon to come its initial position is large for canon. It is important that time between consecutive firing of shell should be minimum as possible. A review of the related work done in the past in the area of vacuum damped recoil system is present, in this paper some of important papers are discussed below.

Keywords—Recoil length, Recoil time, MR damper, Nonlinear Hydraulic Damper, EM damper.

I. INTRODUCTION

Recoil is the rearward movement of the tube and connecting parts after the weapon has been fired. It is caused by the reaction of the tube to the forward motion of the projectile as the projectile is the weapon driven through the tube by the expanding gases of the powder charge. Recoil follows Newton’s law of motion, which states that for every action there is an equal and opposite reaction.

The function of a recoil system is to moderate the firing load on the supporting structure. This moderation is accomplished by prolonging the time of resistance to the reaction force caused by the action of the gun on the propellant gases. If no resistance is offered, the reaction force will be as great as the action force caused by the propellant gas. In other words, if the gun tube is rigidly fired to the gun mount/carriage, the supporting structure is subjected to the full force of the propellant which is very high for large guns.

To withstand such a force, the structure has to be not only strong and heavy but also wide-based to prevent tip over.

As the gas pressure propels the projectile toward the muzzle, it exerts an equal and opposite force on the breech, which tends to drive the gun backward. The recoil system suppresses this force gradually and also limits the rearward movement.

II. LITERATURE REVIEW

Tomas Lucak, Roman Vitek, Linh Do Duc, Vladimir Horak,¹ present a paper on “Experimental mechanical device for recoil simulation” presented experimental mechanical setup was designed to provide an experimental data for the purpose of the research and development of the device for the gun’s recoil simulation.

The main idea for the design and development is to simulate gun’s recoil and behavior as realistically as possible and therein make the training shooting more faithful. Mechanical setup was designed for the purpose of acquisition of the force diagrams provided by the present pneumatic and electromagnetic recoil simulation devices, which use the mechanical impact for the recoil force generation.

Obtained force diagrams provide the image of the behavior and dimension of the generated force from the mechanical impact.
Deepak C. Akiwate, S. S. Gawade,\textsuperscript{[2]} present a paper on “Design and Performance Analysis of Smart Fluid Damper for Gun Recoil System” this paper describes to deal variations in loads the smart fluid damper is designed. For designing the damper thorough study of smart fluid and gun recoil dynamics is carried out, as the MR fluids have higher yield strength than that of ER they are selected for this applications. During designing of damper the effect of various parameters on damping force and dynamic range are studied. The trade-off between number of coils and dynamic range has been found out. Once the damper is designed the mathematical modeling of gun recoil system is formulated.

Galal A. Hassaan,\textsuperscript{[3]} present a paper on “On Dynamics of a Cannon Barrel-Recoil Mechanism with Nonlinear Hydraulic Damper and Air-Springs” this paper describe the dynamics of the barrel assembly-recoil mechanism of military cannons when using air springs and hydraulic dampers of nonlinear characteristics in their recoil mechanisms. The nonlinear characteristics of the damper and spring and the recoil mechanism orientation introduce extra nonlinearity to the dynamic model of the system. An extremely nonlinear model of the barrel assembly is derived and solved using Runge-Kutta 4 method to provide the dynamic response of the barrel assembly upon firing. The performance of the recoil mechanism is evaluated through the minimum and maximum displacements of the barrel assembly, the settling time of its response upon firing and the steady-state error of its time response.

Edward M. Schmidt,\textsuperscript{[4]} present a paper on “Comparison of the recoil of conventional and electromagnetic cannon” this paper describe the recoil from an electromagnetic (EM) rail gun is discussed and compared with that from conventional, propellant gas driven cannon. It is shown that, under similar launch conditions, the recoil of the EM gun is less than that of the powder gun; however, use of a muzzle brake on a powder gun can alter this relative behavior.

Ju-Ho Choi, Sung-Soo Hong, and Joon Lyou,\textsuperscript{[5]} present a paper on “A Development of Recoil & Counter Recoil Motion Measurement System Using LVDT” this paper describes a recoil and counter recoil motion measurement system using linear variable differential transformers (LVDT). The output of the LVDT is obtained from the differential voltage of the secondary
transformers. Since a transducer core is attached to the motion body, the output is directly proportional to the movement length of the core. Displacement, velocity and acceleration are measured from the LVDT. With a comparison between the measurement result and the reference value obtained by the highly accurate Vernier calipers, it is proved that the measurement system with the LVDT is applicable to the test of the moving part of the mechanism with better accuracy.

Aleksandar Kari, Momcilo Milinovic, Olivera Jeremic, Zoran Ristic,[6] present a paper on “Redundant stiffness absorbing system for redesigning of recoil forces profiles” this paper describes serial and parallel combination of wire rope absorbers junctions provide better absorbing of shock forces and external impulses. This performance is acceptable to be taken for different purposes including recoil force dumping. Paper considers relations of deviation caused by nonlinearities and hysteretic behavior as consequence of absorbing energy dissipation. This hysteretic behavior orientated threshold displacements required in application of this system to be employed in the design of composed hydraulic and wire rope weapon barrel brakes and recuperators. Main experimental parameters represented differences of mentioned serial and redundant junctions. Performances are estimated based on experimental static tests realized in this paper. Attempt of comparison with ideal elastic model is also performed.

Yuliang Yang, Changchun Di, Junqi QIN, Yanfeng Yang,[7] present a paper on “Mechanism - hydraulic Co-simulation Research on the Test Bed of Gun Recoil Mechanism” this paper describes the test bed of recoil mechanism, recoil mechanism completed the recoil and counter recoil process, pushed by hydraulic cylinder. The test bed consisted of the mechanical system, the
hydraulic system and the electrical system. The dynamic model and hydraulic system model of test bed were respectively built. On the basis of these models, mechanism hydraulic co-simulation model of test bed was built, and co-simulation analysis was developed. The movement curves of piston rod and pressure curves of accumulators were obtained. The study will provide a theoretical basis for the engineering application of test bed.

Figure 5. Test bed of recoil mechanism

1-recoil mechanism 6-front support bushings
2-test bench 7-sleeve
3-back support bushings 8-connecting seat
4-back support 9-force sensor
5-front support 10-high speed hydraulic cylinder

Mehdi Ahmadia, James C. Poynor, present a paper on “An evaluation of magneto rheological dampers for controlling gun recoil dynamics” this paper describes the application of magneto rheological dampers for controlling recoil dynamics is examined, using a recoil demonstrator that includes a single-shot 50 caliber BMG rifle action and a MR damper. The demonstrator is selected such that it can adequately represent the velocities that commonly occur in weapons with a recoil system, and can be used for collecting data for analyzing the effects of MR dampers on recoil dynamics. The MR damper is designed so that it can work effectively at the large velocities commonly occurring in gun recoil, and also be easily adjusted to reasonably optimize the damper performance for the recoil demonstrator. The test results show that it is indeed possible to design and use MR dampers for recoil applications, which subject the damper to relative velocities far larger than the applications that such dampers have commonly been used for (i.e., vehicle applications). Further, the results indicate that the recoil force increases and the recoil stroke decreases nonlinearly with an increase in the damping force. Also of significance is the fact that the adjustability of MR dampers can be used in a closed-loop system such that the large recoil forces that commonly occur upon firing the gun are avoided and, simultaneously, the recoil stroke is reduced. This study points to the need for several areas of research including establishing the performance capabilities for MR dampers for gun recoil applications in an exact manner, and the potential use of such dampers for a fire out of battery recoil system.

Figure 6. Transducer placement for MR gun recoil demonstrator
Z C Li, J Wang\(^9\) present a paper on “A gun recoil system employing a Magneto rheological fluid damper.” This research aims to design and control a full scale gun recoil buffering system which works under real firing impact loading conditions. A conventional gun recoil absorber is replaced with a controllable magneto rheological (MR) fluid damper. Through dynamic analysis of the gun recoil system, a theoretical model for optimal design and control of the MR fluid damper for impact loadings is derived. The optimal displacement, velocity and optimal design rules are obtained. By applying the optimal design theory to protect against impact loadings, an MR fluid damper for a full scale gun recoil system is designed and manufactured. An experimental study is carried out on a firing test rig which consists of a 30 mm caliber, multi-action automatic gun with an MR damper mounted to the fixed base through a sliding guide. Experimental buffering results under passive control and optimal control are obtained. By comparison, optimal control is better than passive control, because it produces smaller variation in the recoil force while achieving less displacement of the recoil body. The optimal control strategy presented in this paper is open-loop with no feedback system needed. This means that the control process is sensor-free. This is a great benefit for a buffering system under impact loading, especially for a gun recoil system which usually works in a harsh environment.

Mahmudur RAHMAN, Zhi Chao ONG, Sabariah JULAI, Md Meftahul FERDAUS, Raju AHAMED\(^10\) present a paper on “A review of advances in magneto rheological dampers: their design optimization and applications.” In recent years, Magneto rheological (MR) Fluid technology has received much attention and consequently has shown much improvement. Its adaptable nature has led to rapid growth in such varied engineering applications as the base isolation of civil structures, vehicle suspensions and several bio-engineering mechanisms through its implementation in different MR fluid base devices, particularly in MR Dampers. The MR damper is an advanced application of a semi-active device which performs effectively in vibration reduction due to its control ability in both on and off states. The MR damper has the capacity to generate a large damping force, with comparatively low power consumption, fast and flexible response, and simplicity of design. With reference to the huge demand for MR dampers, this paper reviews the advantages of these semi-active systems over passive and active systems; the versatile application of MR dampers; the fabrication of the configurations of various MR dampers; and provides an overview of various MR damper models. To address the increasing adaptability of the MR damper, its latest design optimization and advances are also presented. Because of the tremendous interest in self-powered and energy-saving technologies, a broad overview of the design of MR dampers for energy harvesting and their modeling is also incorporated.

![Figure 7. MRF magnetic particles chain-like formation with applied magnetic field](image)

\(^9\)Li, Z. & Wang, J. (2017). A gun recoil system employing a Magneto rheological fluid damper. *International Journal of Modern Trends in Engineering and Research (IJMTER)*, 04(8), 88.

\(^10\)Rahman, M. & Ong, Z. C. (2017). A review of advances in magneto rheological dampers: their design optimization and applications. *International Journal of Modern Trends in Engineering and Research (IJMTER)*, 04(8), 88.
III. PROBLEM IDENTIFICATION

The conventional recoiling system are used in canon consist of spring-mass-dashpot system, which is more complex and less reliable. Today's artillery weapons may fire about one-quarter of the time and spend about another quarter of the time in moving about the battlefield. The remaining time is spent resolving RAM-D (reliability, availability, and maintainability durability) problems. To overcome such problems more reliable and simple recoil system of vacuum damped type can be used.

IV. CONCLUSION

After studying various papers it is come into understand that work on recoil system is done in limited area like hydraulic and hydro-pneumatic type system and on smart fluid dampers. Such systems are complex and required more time to sort out maintainability problems. So that here attempt is made to design and develop vacuum damped recoil system which is simple and more reliable.

REFERENCES

[1] Tomas Lucak, Roman Vitek, Linh Do Duc, Vladimir Horak, “Experimental mechanical device for recoil simulation,” Scientific research and education in the air force doi: 10.19062/2247-3173.2016.18.1.46
[2] Deepak C. Akiwate, S. S. Gawade, “Design and Performance Analysis of Smart Fluid Damper for Gun Recoil System,” International Journal of Advanced Mechanical Engineering, Volume 4, Number 5 (2014), pp. 543-550.
[3] Galal A. Hassaan, “On Dynamics of a Cannon Barrel-Recoil Mechanism with Nonlinear Hydraulic Damper and Air-Springs,” IJRIT International Journal of Research in Information Technology, Volume 2, Issue 9, September 2014, Pg. 704-714.
[4] Edward M. Schmidt, “Comparison of the recoil of conventional and electromagnetic cannon,” Army Research Laboratory. Aberdeen Proving Ground, MD 21005-5066, USA, pp.141-145.
[5] Ju-Ho Choi, Sung-Soo Hong, and Joon Lyou, “A Development of Recoil & Counter Recoil Motion Measurement System Using LVDT,” ICASE: The Institute of Control, Automation and Systems Engineers, KOREA Vol. 2, No. 3, September, 2000,pp.214-219.
[6] Aleksandar Kari, Momcilo Milinovic, Olivera Jeremic, Zoran Ristic, Redundant stiffness absorbing system for redesigning of recoil forces profiles,” 5th International scientific conference on defense technology OTEH 2012, Belgrade, 18 – 19 Sept. 2012.
[7] Yuliang YANG, Changchun DI, Junqi QIN, Yanfeng YANG, “Mechanism - hydraulic Co-simulation Research on the Test Bed of Gun Recoil Mechanism,” WSEAS TRANSACTIONS on APPLIED and THEORETICAL MECHANICS, Volume 10, 2015,pp.142-147.
[8] Mehdi Ahmadia, James C. Pynor, “An evaluation of magneto rheological dampers for controlling gun recoil dynamics” Shock and Vibration 8 (2001) ISSN 1070-9622 IOS Press. pp. 147–155
[9] Z C Li, J Wang, “A gun recoil system employing a Magneto rheological fluid damper” IOP publishing smart materials and structures , Smart Mater. Struct. 21 (2012) 105003 doi:10.1088/0964-1726/21/10/105003.
[10] Mahmudur RAHMAN, Zhi Chao ONG, Sabariah JULAI, Md Meftahul FERDAUS, Raju AHAMED, “A review of advances in magneto rheological dampers: their design optimization and applications” Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering) ISSN 1673-565X (Print); ISSN 1862-1775.