REVIEW OF SMART FLUID DAMPER FOR GUN RECOIL SYSTEM

Srinath Ingale[1], Siddhesh Nadgouda[2], Sandesh Patil[3], Yogesh Fathak[4], Vaijnath Patil[5] Pavan Shinde[6]

[1,] *Assistant Professor of Mechanical Department, Dr. A. D. Shinde Collage of Engineering, Gadhinglaj-416502, Maharashtra, India*

[2,3,4,5,6] *Students of Mechanical Department, Dr. A. D. Shinde Collage of Engineering, Gadhinglaj-416502, Maharashtra, India*

---***---

Abstract – *When a gun is fired, the burning propellant charge generates a blast of pressurized gases that impose enormous loads on the projectile as well as on the gun structure. Although the firing event has a short duration, the pressure forces impart a strong impulse load to the gun structure. To mitigate such a strong impulse and to maintain the displacement of recoil mass within specified limit the passive absorbers are not suitable. Also the passive system is unable to deal the changes in firing forces once it designed for particular load. To deal such 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.*

***Key Words*: Smart fluid; Smart damper; Gun recoil system;**

1. INTRODUCTION

In the current scenario of no use of nuclear weapons, the defense systems are strongly biased in favors of conventional armament. The end of Cold War has given a clear signal that in the future the key to success lies in the enhancement of precision of conventional armament, be it the internal security operation, domestic/international terrorism or low intensity conflict. Also the apparent success of high technology weaponry in the recent wars like in Iraq and Afghanistan, are indicative that the war is undergoing a profound transformation. Today, as in the past, technology is fundamentally changing the face and nature of warfare. The opportunities offered by these new or emerging technologies are boundless. There is a need to concentrate on those technologies that are important to the Indian Army for its modernization requirements. Hence the emphasis of Defence R&D on the development of conventional armament during the last fifty years showed the vision of policy makers in the Ministry of Defense and the Defense Research & Development Organization (DRDO).

Smart fluids are discovered long years back but many decades smart fluid remain in laboratory and with little practice use. As technology develops many scientist have worked in the field of smart materials and found out new properties and applications. Today still many people are working on smart fluid to find its applications. This literature gives the useful guideline and direction for further development in this era.

Recoil (often called knockback, kickback or simply kick) is the backward momentum of a gun when it is discharged. In technical terms, the recoil caused by the gun exactly balances the forward momentum of the projectile and exhaust gasses (ejecta), according to Newton's third law. In most small arms, the momentum is transferred to the ground through the body of the shooter; while in heavier guns such as mounted machine guns or cannons, the momentum is transferred to the ground through its mount. In order to bring the gun to a halt, to be ready for next fire a forward counter-recoil force must be applied to the gun over a period of time. To accomplish this task there is necessity of some mechanism called gun recoil system.

When a gun is fired, the burning propellant (chemical used in the production of energy or pressurized gas) charge generates a blast of pressurized gases that impose enormous loads on the projectile as well as on the structure on which gun is mounted. Although the firing event has a short duration, the pressure forces impart a strong impulse load to the gun structure. Such a short duration and with high amplitude impulse results in undesirable but controllable recoil load transmissions. If the gun is rigidly mounted on a structure such as an automobile or aircraft the resulting loads are directly transmitted to the host structure. The recoil forces can impart substantial vibrations and affect the fatigue life of the structure. Also, excessive vibrations can put a limit on the rate of fire so that mitigating or isolating these vibrations can dictate design requirements. Unless the load transmissions are controlled appropriately, these effects can lead to a design with large gun mount weight that can significantly reduce vehicle mobility.

2. LITERATURE SURVEY

Following are some of selected research papers which give the valuable information about gun recoil system its dynamics, Smart fluids and their applications.

Z C Li and J Wang [1] have made a research to design and control full scale gun recoil buffering system which works under real firing impact loading conditions. By replacing conventional gun recoil absorber with MR damper experimentation is carried out and found that optimal control is better than passive control as it produces smaller variation in recoil force while achieving minimum displacement of recoil body.

Hongsheng Hu, Juan Wang, Jiong Wang, Suxiang Qian and Yancheng Li [2] done an exhaustive study on gun recoil system. The primary purpose of this study is to identify its dynamic performance and controability of the artillery recoil mechanism equipped with MR damper. Based on traditional mechanism a recoil model is prepared. The effects of recoil resistance on the stability and firing accuracy of artillery are explored.

Harinder J. Singh and Norman M. Wereley [3] are investigated optimal control of a gun recoil absorber for minimizing recoil loads and maximizing rate of fire. An optimization problem is formulated by considering the mechanical model of the recoil absorber employing a spring and a magnetorheological (MR) damper. The gun recoil absorber performance is also analyzed for fluctuations in the firing forces.

Zekeriya Parlak, Tahsin Engin and Ismail Calli [4] are studied; a design optimization method for designing of MR damper. Finite element methods, electromagnetic analysis of magnetic field and CFD analysis of MR flow, have been used to obtain optimal value of design parameters. The new approach that is use of magnetic field and MR flow together and simultaneously has specified optimal design values. Two optimal design of MR damper obtained have been verified with experimental study by manufacturing and testing of the dampers.

G. Yang, B.F. Spencer Jr., J.D. Carlson and M.K. Sain [5] have studied large capacity MR dampers protecting civil infrastructures against earthquake and wind loading. They derived quasi-static axisymmetric model of MR dampers, which is then compared both simple parallel plate model and experimental results.

J. David Carlson [6] have studied the Experience in manufacturing MR fluids for commercial application has shown that some of the greatest barriers to commercial success are not factors or conditions normally considered in the laboratory. The present paper looks at conditions found in MR fluid devices operating in real-world applications where shear rates may exceed 105 sec-1 and devices are called upon to operate for very long periods of time. The problem of "In-Use-Thickening" wherein a MR fluid subjected to long-term use progressively thickens until it eventually becomes an unworkable paste is presented. The search for a solution to this heretofore unrecognized problem delayed commercial introduction of the Lord truck seat damper system for several years. Today, good fluids are able to operate for long periods with minimum in-use thickening.

Henri P. Gavin et al. [7] described the design, construction, testing and modeling of controllable damping devices utilizing electro-rheological (ER) materials. The rheological properties of ER materials (yield stress and viscoelasticity) are extremely sensitive to electric fields. Modulations of the electric field in electrorheological damper results in a corresponding change in device forces. The key feature of the ER devices described in this paper is a set of multiple concentric annular ducts through which the ER material flows. The annular ducts are formed by a set of concentric metallic tubes, which may be electrically charged with a high voltage potential, or electrically grounded. Three designs targeting different force levels (2kN to 6kN), are designed, tested and modeled. The device analyses used in the design incorporate a simplified closed form relation for the flow behavior of ER materials.

James C. Poynor [9] in his thesis introduced MR technology, MR devices and discussed their basics. Also includes a discussion of MR damper types, mathematical fundamentals, and an approach to magnetic circuit design. With the necessary background information covered, MR dampers for automotive use and designs for gun recoil applications are presented. Specifically, two different MR damper designs for gun recoil system are discussed along with live-fire test results for the first damper. Finally, two hybrid dampers that were based on a modified adjustable hydraulic damper are presented. He concluded that these hybrid dampers, if pursued further, may develop into controllable replacements for large hydraulic dampers such as those installed on large vehicles and field Howitzers.

Seval Genc [10] has described various types of smart fluids and their properties. He also describes the 'on' state and 'off' state behavior of smart fluids. The influence of the remnant magnetization of soft magnetic particulates on the redispersibility of MR fluids is investigated. He also studied the MR fluid under high temperature and its effect on properties of MR fluid.

S. B. Choi et al. [11] have presented experimentation of influence of electrode gap and electrode material on the yield stress of elecrorheological fluid. They tested two different ER fluids, water based Arabic gum ER fluid and dry based polyurethane ER fluid. Also he investigated time response for on-off states of an electric field and at different operating temperature.

T.Y. Lin et al. [12] have focused on the need of recoil system in artillery. They classified the available recoil mechanisms and discussed the components of recoil system. Researchers carried out response analysis for 150 mm gun. Also they discussed the optimization of recoil body displacement.

E. Kathe et al. [13] have mentioned in their technical report of U.S. Armament research need for recoil mitigation and basis of RAVEN propulsion. They also discussed the case study of 120 mm gun for determining venting time, estimation of impulse reduction, reduction in bore heating. Researchers also mentioned about the idea of recoilless operation.

Mehdi Ahmadian et al. [14] have studied the application of MR damper for controlling recoil dynamics, using a recoil demonstrator. Researchers have given the brief background on MR damper and Fire out of battery dynamics. They also carried out the tests with MR damper and result showed that MR dampers are capable of effective control in recoil dynamics.

3. CONCLUSION

Effect of magnetic field and electric field on smart fluid is discussed by different researchers in their work. Seval Genc describes various types of smart fluids and their properties. Z C Li and J Wang have developed recoil system with MR absorber. The results presented by them shows that there is improvement in absorption capacity of device. Harinder J. Singh and Norman M. Wereley are investigated optimal control of a gun recoil absorber for minimizing recoil loads and maximizing rate of fire. Zekeriya Parlak presented a design optimization method for designing of MR damper. The manufacturing difficulties of MR fluid and barriers to commercial success are discussed by J. David Carlson. Henri Gavin described the design, construction, testing and modeling of controllable ER damper. The MR damper types, mathematical fundamentals and an approach to magnetic circuit design are presented by James C. Poynor. S.B. Choi studied the influence of electrode gap and electrode material on the yield strength of ER fluid. T.Y. Lin discussed the need of recoil system in artillery. The application of MR damper for controlling recoil dynamics has been studied by Mehdi Ahmadin and Randall Appleton.

REFERENCES

[1] Z C Li, and J Wang, "A gun recoil system employing a magnetorheological fluid damper", Journal of smart materials and structure, vol.21, 2012.

[2] Hongsheng Hu, Juan Wang, Jiong Wang, Suxiang Qian and Yancheng Li, "Investigation on modeling and controability of a magnetorheological gun recoil damper", Second International Conference on Smart Materials and Nanotechnology in Engineering, October 20, 2009.

[3] Harinder J. Singh and Norman M. Wereley, "Optimal Control of Gun Recoil Using Magnetorheological Dampers", Journal of Mechanics and Behavior of Active Materials, vol.2 (2012) 441-450.

[4] Zekeriya Parlak, Tahsin Engin, Ismail Cali, "Optimal design of MR damper via finite element analyses of fluid dynamic and magnetic field", Journals of mechatronics, vol.22, (2012) 890-903.

[5] G. Yang, B.F. Spencer Jr., J.D. Carlson, M.K. Sain, "Large scale MR fluid damper: modeling and dynamic performance considerations", Engineering Structure, vol.24, (2002) 309-323.

[6] Fernando D. Goncalves, "Characterizing the Behavior of Magneto rheological Fluids at High Velocities and High Shear Rates", Virginia Polytechnic Institute and State University.

[7] Henri P. Gavin, "Multi-duct ER Dampers", Department of Civil & Environmental Engineering, Duke University, Durham NC 27708, U.S.A.

[8] Kuang Chi Hung, "Conceptual design of magnetic damper for Automotive Suspension System", University of technical Malaysia Melaka, April 2007.

[9] James C. Poynor, "Innovative Designs for Magneto-Rheological Dampers", Blacksburg, Virginia, August 2001.

[10] Seval Genc, "Synthesis and Properties of Magnetorheological (MR) fluids", University of Pittsburgh , July 18, 2002.

[11] S. B. Choi, Y. M. Han, J. W. Sohn, H. J. Choi, "Bingham Characteristics of Polymer-Based Electrorheological Fluids with Different Electrode Gaps and Materials" , Wiley InterScience, 12 August 2009.

[12] T. Y. Lin, H. C. Ping, T. Y. Yang, C. T. Chan, and C. C. Yang, "Dynamic simulation of the recoil mechanism on artillery weapons" , ICCES, vol.11, (2009) 115-121.

[13] E. Kathe, R. Dillon, S. Sopok, M. Witherell, S. Dunn, D. Coats, "Rarefaction Wave Gun Propulsion" ,US Army Armament Research, Development and Engineering, April 2001.

[14] Mehdi Ahmadian, Randall J. Appleton, and James A. Norris, "Designing Magneto-Rheological Dampers in a Fire Out-of-Battery Recoil System", IEEE Transactions on Magnetics, Vol. 39, (2003) 480-485.

BIOGRAPHIES

Prof. Srinath Ingale
Working as a assistant professor in Mechanical Department, Dr. A. D. Shinde College of Engineering, Bhadgaon.

Mr. Siddhesh Nadgouda

Last year student of Mechanical Department, Dr. A. D. Shinde College of Engineering, Bhadgaon.

Mr. Sandesh Patil

Last year student of Mechanical Department, Dr. A. D. Shinde College of Engineering, Bhadgaon.

Mr. Yogesh Fathak

Last year student of Mechanical Department, Dr. A. D. Shinde College of Engineering, Bhadgaon.

Mr. Vaijnath Patil

Last year student of Mechanical Department, Dr. A. D. Shinde College of Engineering, Bhadgaon.

Mr. Pavan Shinde

Last year student of Mechanical Department, Dr. A. D. Shinde College of Engineering, Bhadgaon.