ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, Vol 8(S1), 202–205, January 2015
10.17485/ijst/2015/v8iS1/57927

A Study on Fire Power Performances of Combat Vehicles with Suspension Systems

Hwan Il Kang1*, Jae Jeong Pyun[2] and Hyun Soo Kim[3]

[1]Deptartment of Information & Communication Engineering, Myongji University, Yongin, 449-718, South Korea; hwanilkang@naver.com
[2]Agency for Defense Development, Yuseong-Gu, Daejon, 305-600, South Korea; jjpyun@add.re.kr
[3]Deptartment of Information & Communication Engineering, Myongji University, Yongin, 449-718, South Korea; saints7777@naver.com

Abstract

When the combat vehicle runs on an off-road, the vertical displacement occurs. This vertical displacement variation affects fire power performance for a weapon system mounted on the combat vehicle. We focus on the hit probability which is one of the fire power performances. The combat vehicle is simulated with a quarter car system. We measure the vertical displacement using the quarter simulation model. The passive suspension system and the active suspension system with the use of the linear state feedback system are considered. The active suspension system with the feedback control has better performances for the hit probability than the passive suspension system has.

Keywords: Active Suspension System, Hit Probability, Passive Suspension System, Vertical Displacement

1. Introduction

The warfare feature is changing from the platform centric warfare to network centric warfare. The design of the future combat vehicle should satisfy the future warfare style. The future combat vehicle system consists of four hierarchical structures: systems of system, system, subsystem and components. To satisfy the requirement of operational capability, we determine which type of combat vehicle systems has the most effective system. The combat vehicle system is a level of systems of system. As a system level, the combat vehicle is considered.

The combat vehicles and mounted weapons should have some good performances for the mobility, fire power, the vulnerability and operability. The estimation method of the Measure of Performance (MOP) and the allowable error selection method for the design parameters satisfying the MOP should be obtained. The measure of performance for this paper is a hit probability for the weapons equipped with the combat vehicles. In addition, the range distance may be another MOP but we do not consider range distance for the MOP. Some error budgets affect the hit probability. The error budgets for the hit probability for the gunnery on the combat vehicle are four categories such as the mechanical errors, the specification of the combat vehicle and the weapon, the meteorological errors and the sensor errors. Among the mechanical errors, the muzzle velocity variation and the variation of the gun jump due to the off-road profile are included.

Using the vehicle dynamic mechanical model such as the quarter car, half car and full car model[1–3], the vertical displacement, pitch, and roll values are obtained, respectively. Using the error budgets and the external ballistics, the estimation of the hit probability is achieved. Besides the problem of estimation of the hit probability, the design of parameters is another problem for satisfying the minimum hit probability. We do not consider the design problem for design parameters.

*Author for correspondence

In this paper, the estimation method of the fire power for combat vehicle is considered. Especially, the estimation of hit probability is focused. The error budget is the vertical displacement for the gunnery. The vertical displacement is also a design parameter. Using the quarter car model and its analysis, the vertical displacement is determined. We assume that the pattern on the rectangular target forms a two dimensional normal distribution. So the hit probability is expressed as an integral of some distribution functions. By using the approximate error function, we may derive the hit probability given by Polya-Williams[4]. The combat vehicle has either a passive suspension system or an active suspension system. The active suspension may be obtained by the linear state feedback controller. In this paper, the estimation of the hit probability is considered for the combat vehicle for the passive suspension system and the active suspension system. Hit probability is higher for the active suspension system compared with that for the passive suspension system.

2. Quarter Car Model and Equations

1.1 The Quarter Car Model

The quarter car model is depicted in Figure 1 and some values for the quarter car models are tabulated in Table 1. The state variables of dynamic equations are $x_1 = x,\ \ x_2 = y,\ \ x_3 = z,\ \ x_1, x_5 = x_2$ and $x_6\, x_3$. Then, the state space representations using mass, spring and damping coefficients for the arm, body and wheel are made as follows:

$$x = Ax + Bu$$

$$y = cx$$

$$0 \,\&\, 0 \,\&\, 0 \,\&\, 1 \,\&\, 0 \,\&\, 0@0 \,\&\, 0 \,\&\, 0 \,\&\, 1 \,\&\, 0 \,\&\, 0@$$

$$0 \,\&\, 0 \,\&\, 0 \,\&\, 1 \,\&\, 0 \,\&\, 0@\frac{-(k_1+k_2)}{m_1} \,\&\, \frac{k_2}{m_1} \,\&\, 0 \,\&\, \frac{(h_1+h_2)}{m_2}$$

$$\& \frac{h_2}{m_2} \,\&\, 0@\frac{k_2}{m_2} \,\&\, \frac{(k_2+k_3)}{m_2} \,\&\, \frac{k_3}{m_2} \,\&\, \frac{h_2}{m_2} \,\&\, \frac{(h_1+h_2)}{m_2}$$

$$\& \frac{h_2}{m_2}@0 \,\&\, \frac{k_3}{m_2} \,\&\, \frac{k_3}{m_2} \,\&\, 0 \,\&\, \frac{h_3}{m_2} \,\&\, \frac{h_3}{m_2}$$

$$B = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ \frac{k_1}{m_1} & \frac{b_1}{m_1} & 0 \\ 0 & 0 & 0 \\ 0 & 0 & \frac{-1}{m_2} \end{bmatrix}, \quad c = \begin{bmatrix} 0\,1\,0\,0\,0 \end{bmatrix}, \quad u = \begin{bmatrix} y \\ \dot{y} \\ f \end{bmatrix}, \quad x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix}$$

In the above, r is a road profile, r is a differentiation with respect to t and f is a force pressing the arm as shown in Figure 1.

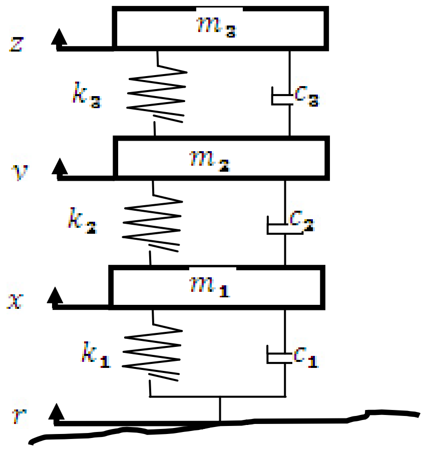

Figure 1. Quarter car model including arms.

Table 1. The parameters of the quarter car model

Parameters	Fixed values
passengers effective mass (m_3)	25 kg
passengers vertical stiffness (k_3)	19000 N/m
passengers damping coefficient (c_3)	1000 N.s/m
body mass (m_2)	500 kg
body stiffness (k_2)	16000 N/m
body damping coefficient (c_2)	1000 N.s/m
wheel mass (m_3)	205 kg
wheel stiffness (k_1)	10000 N/m
wheel damping coefficient (c_1)	2000 N.s/m

2.2 Active Suspension System

For the active suspension system, the linear feedback vector and state vector are

$k = [100\ 600\ -1000\ 200]$

$x = [z\ z\ y\ y\ x\ x]$

and the value $f = | Kx$ is feedback into the force of the input vector u in the state space representation. The implementation is shown in Figure 2.

2.3 Hit Probability

Hit probability[4] is expressible as

$$P_h \cong \sqrt{1 - exp\left(\frac{2h^2}{\pi\sigma_y^2}\right)}$$

where h and σ_y are the height of the target and the standard deviation for the vertical displacement. The value of h is given by 25cm.

3. Results

The vertical displacements are obtained for the passive quarter car system and the active quarter car system. For the passive system, the peak to peak value of the vertical displacement is 114mm as shown in Figure 3 and for the active suspension system; the vertical displacement is 24mm as shown in Figure 4. By using the external ballistics, the hit probability is 24.37 percent for the passive suspension system and 86.53 percent for the active sus

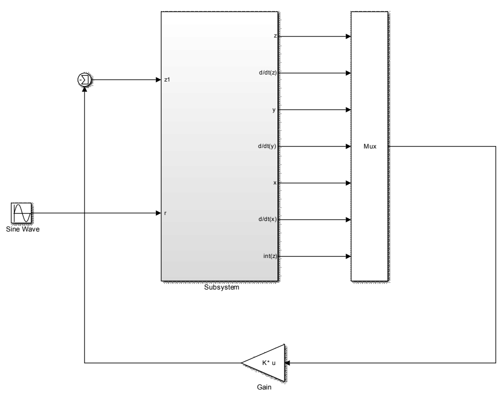

Figure 2. Combat vehicle with active suspension system.

Table 2. Performance comparison between two suspension systems

	Vertical displacement (peak value)[mm]	Hit probability (%)
Passive suspension	114	24.37
Active suspension	24	86.53

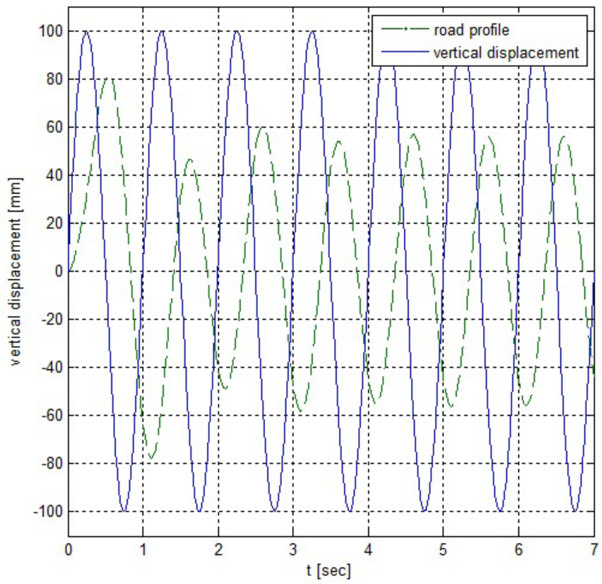

Figure 3. Road profile and the vertical displacement of arms (Passive).

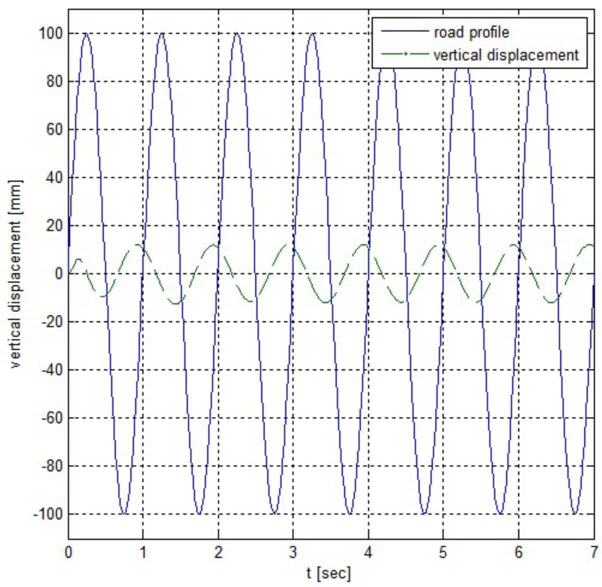

Figure 4. Road profile and the vertical displacement of arms (Active).

pension system. The off-road profile is the 200 mm peak to peak sine wave (1 Hz) as a modification of the real off-road profile. All the data are tabulated in Table 2.

4. Discussions

The estimation of the hit probability is considered for the combat vehicle for the passive suspension system and the active suspension system. Hit probability is higher for the active suspension system compared with that for the passive suspension system. In the future, the optimal design of state feedback and the study of the general off-road profile will be investigated.

5. Acknowledgements

This study was supported by the Research Program (the specialized research center for future ground system analysis (Contract No. 311165-911074201)) funded by the Agency for Defense Development in South Korea.

6. References

1. Han I, Choi K, Kim J, Lee Y, Kim S. Laboratory Test Results of Electro-Mechanical active Suspension Full Vehicle Model. Conference of Defense Science; 2013 Jul; Seoul.
2. Kim J. Half Car Active Suspension System with a Reduced Order State Feedback Control. J Mech Eng. 2009; 11(3).
3. Dixon JC. Suspension Geometry and Computation. USA: John Wiley & Sons Ltd; 2009.
4. Macfadzean, RH. Surface-Based Air Defense System Analysis. USA: Artech House Publishers; 1992.