Effect of Rocket Firing Pattern

On Launching Platform for Vibration Minimization

Attapon Charoenpon (Author)
Operation Military Vehicle Department
Defence Technology Institute of Thailand
Nonthaburi, Thailand
Email: attapon.c@dti.or.th

Sedthawatt Sucharitpwatskul
CAD/CAE Lab
National Metal and Material Technology Center
Pathum Thani, Thailand
Email: sedthaws@mtec.or.th

Abstract—The vibration of Rocket launched platform causing the aiming direction change. To minimize the vibration effect, the firing sequence to vibrate structure was considered. In this study, the model was defined as flexible body motion while subjected to load. The force generated while the rocket moves along the launched tube make the tube deformed and vibrated. This deformation was measured and transform into Gain-Frequency domain. The study results show the pattern of firing as Leap-Frog Scheme in every row of rocket housing and for overall the rocket pattern was recommended as zig-zag to minimize vibration on structure.

Keywords—vibration, Launched Platform, Firing, Sequence, Flexible Body, Leap-Frog, Pattern

I. INTRODUCTION

The launcher vehicle plays major role in the battlefield. It helps to defense the enemy forward to strategic territory or clearing the forward path of trooper by firing massive rocket to the target area. The covering area of target zone may vary from small building to entire Mountain. To focus on the specific target zone, the precise of rocket trajectory should be concerned. The launching vehicle is the origin of the trajectory of rocket motion. When the free flight rocket start to ignite the propellant, it generate thrust force to push the rocket forward. Usually rocket is set inside the launched tube or rail to guide the rocket in the desirable direction. The moving rocket causes the launched tube and structure that support them to be stressed and vibrated, causing the aiming angle change compare to the original state and the next firing rocket may miss the target. Thus in this study is aim to investigate the rocket firing sequence to minimize the structural vibration while the weight of structure is constrained.

II. MODELING METHODOLOGY

In this study, there are two analyzes were done. The first is rigid body motion and the second is stress analysis. This combination called the flexible body motion analysis. The equation of motion of the rigid body is expressed in equation (1)

$$\begin{bmatrix} M_{RR} & M_{RL} \\ M_{LR} & M_{LL} \end{bmatrix}\begin{bmatrix} \overset{\circ\circ}{U}_R \\ \overset{\circ\circ}{U}_L \end{bmatrix} + \begin{bmatrix} C_{RR} & C_{RL} \\ C_{LR} & C_{LL} \end{bmatrix}\begin{bmatrix} \overset{\circ}{U}_R \\ \overset{\circ}{U}_L \end{bmatrix} + \dots$$
$$\dots + \begin{bmatrix} K_{RR} & K_{RL} \\ K_{LR} & K_{LL} \end{bmatrix}\begin{bmatrix} U_R \\ U_L \end{bmatrix} = \begin{bmatrix} F_R \\ F_L \end{bmatrix} \quad (1)$$

Where subscript RL is defined as interface DOF and Interior DOF of the system. Apply the Craig Bampton transformation [1] expressed by equation (2) to the equation of motion (1) and rewritten,

$$[U_A] = \begin{bmatrix} U_R \\ U_L \end{bmatrix} = [B \quad \Phi]\begin{bmatrix} U_R \\ q_M \end{bmatrix} \quad (2)$$

$$[M][B \quad \Phi]\begin{bmatrix} \overset{\circ\circ}{U}_R \\ \overset{\circ\circ}{q}_M \end{bmatrix} + [C][B \quad \Phi]\begin{bmatrix} \overset{\circ}{U}_R \\ \overset{\circ}{q}_M \end{bmatrix} + [K][B \quad \Phi]\begin{bmatrix} U_R \\ q_M \end{bmatrix} = [F] \quad (3)$$

By multiply equation (3) by the transpose of Craig-Bampton transformation matrix to yield,

$$\begin{bmatrix} B^T & B^T M\Phi \\ \Phi^T MB & \mu \end{bmatrix}\begin{bmatrix} \overset{\circ\circ}{U}_R \\ \overset{\circ\circ}{q}_M \end{bmatrix} + \begin{bmatrix} B^T CB & B^T C\Phi \\ \Phi^T CB & \Phi^T C\Phi \end{bmatrix}\begin{bmatrix} \overset{\circ}{U}_R \\ \overset{\circ}{q}_M \end{bmatrix} + \dots$$
$$\dots + \begin{bmatrix} B^T KB & B^T K\Phi \\ \Phi^T KB & \mu\omega_0^2 \end{bmatrix}\begin{bmatrix} U_R \\ q_M \end{bmatrix} = [B \quad \Phi]^T [F] \quad (4)$$

Manipulate equation (4) the obtain the equation of motion with craig-bampton transformation is obtained

$$\begin{bmatrix} M_{BB} & M_{Bm} \\ M_{mB} & I \end{bmatrix}\begin{bmatrix} \overset{\circ\circ}{U}_R \\ \overset{\circ\circ}{q}_M \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & 2\xi\omega_0 \end{bmatrix}\begin{bmatrix} \overset{\circ}{U}_R \\ \overset{\circ}{q}_M \end{bmatrix} + \begin{bmatrix} K_{BB} & 0 \\ 0 & \omega_0^2 \end{bmatrix}\begin{bmatrix} U_R \\ q_M \end{bmatrix} = [F] \quad (5)$$

Where μ, ω_0 and ξ are generalized modal mass, eigen-value and critical damping respectively.

This equation is useful to reduce order of degree of freedom when calculation motion with stress analysis.

The launching platform shown in Figure 1 consist of 5 major components which are Rockets, Pod (housing of rocket with launched tube inside), Carriage (the structure for support the pod), Actuators (for aiming the pod to desired direction) and Base (to support all structures). The rockets in this study have 30 round and weight 63kg each.