GUN BARREL MODELS FOR USE IN WEAPON CONTROL SYSTEM INVESTIGATIONS

David J. Purdy[1]

Abstract. In the design of Weapon Control Systems (WCS) for main battle tanks there is a requirement for low-order models of the elevating mass and barrel. In this work two models suitable for this requirement are put forward. The two models under consideration break the barrel down into rigid sections that are connected by frictionless pin-joints and linked by torsional springs and dampers. This model is referred to as a Lumped Parameter Flexible Beam Model (LPFBM) in this work. These models consider the barrel being broken down into two and three rigid sections. The lengths of the rigid sections and spring stiffnesses are selected to preserve the resonances (poles) and anti-resonances (zeros) of the system. This is achieved by using a novel scheme based on equations derived for the cantilever mode frequencies for the zeros and on optimising the lengths of the rigid sections for the poles. The responses from these two models, in the frequency and time domain, are compared to a finite-element barrel version, which is used as the base model and a non-optimised two-section LPFBM. Recommendations are then made on the appropriate model to use in the design of a WCS based on the required frequency range of the model and whether muzzle motion predictions are needed.

NOMENCLATURE

$\mathbf{A}$	System matrix
$\mathbf{B}$	Input matrix
$\mathbf{C}$	Damping or output matrix
c	Damping coefficient
$\mathbf{D}$	Transmission matrix
f	Force
$\mathbf{I}$	Input or unit matrix
J	Performance index
$\mathbf{K}$	Stiffness matrix
k	Stiffness
l	Length defined in Figure 1
$\mathbf{M}$	Mass matrix
m	Mass
R_p	Pinion radius
T_d	Drive torque
$\mathbf{u}$	Input vector
W	Weight
X_{tp}	Length defined in Figure 1
$\mathbf{x}$	State vector
x	Coordinate defined in Figure 1
y	Trunnion vertical motion
β	Proportional damping coefficient
η	Length defined in Figure 1
θ	Angular rotation
ω	Angular velocity or frequency
Superscript	
fe	Finite element
II, III	Two-section, three-section LPFBM model
o	Optimised
Subscript	
$1, 2, 3$	LPFBM section
$\mathbf{2}, \mathbf{3}$	Two-section, three-section LPFBM model
$12, 23$	Between sections 1 and 2, 2 and 3
b	Barrel or beam
c	Cantilever
d	Drive
m	Model, elevation
p	Platform

INTRODUCTION

For Weapon Control System (WCS) investigations for Main Battle Tanks (MBTs) a model of the gun barrel/elevating mass is required that faithfully reproduces the motions of the system up to the highest frequency of interest, commonly 50–100 Hz. In this work two optimised barrel models are proposed for such studies and compared with both finite-element and non-optimised barrel models.

Three of the models consist of breaking the barrel down into two or three rigid sections that are pin-jointed together and linked by rotary springs and dampers. In this work these models are referred to as Lumped Parameter Flexible Beam Models (LPFBMs). A diagram for the elevation axis of an electrical drive MBT is shown in Figure 1, which has a three-section LPFBM. The modelling method proposed for the barrel can be applied to the traverse and elevation axes, the resulting order of the models, including the drive and turret inertias, being in the range from six to ten. With this relatively low order of model it is possible to run them in real time, as part of a prediction or estimator algorithm.

The modelling and control of flexible structures has received considerable attention [1–13], with the finite-element method having become the most common for gun dynamics investigations. The problem with finite-element models for control system studies is their relatively high order, which necessitates some form of model order reduction, though it does result in high-fidelity models [6–8].

For an insight into the dynamics of flexible structures it is possible to generate analytical models for simple structures [1,3,5,6]. These models show that the response consists of both resonances (poles) and anti-resonances (zeros). The poles are independent of where on the structure a measurement is made. While the zeros are dependent on the measurement position and can be thought of as resonances (poles) of a constrained sub-structure [9]. This can be explained as follows; consider a balanced elevating mass, which is pivoted at its trunnions and has no damping. The frequencies at which the motion of the breech is stationary (zero or anti-resonance) correspond to the cantilever frequencies of the elevating mass, this is a constrained sub-structure of the system. Also if measurements are made at the

[1] Engineering Science Department, Defence College of Management and Technology UK, Cranfield University, Shrivenham, SN6 8LA, UK.

ISSN 1440-5113