MAIN BATTLE TANK STABILISATION RATIO ENHANCEMENT USING HULL RATE FEEDFORWARD

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Abstract. Improvements in the Stabilisation Ratio (SR) of current Main Battle Tanks (MBTs) are due to the use of hull disturbance feedforward. For the predicted im1provements to be realised, it is shown that the effects of non-linear friction must be compensated for. Simulations of a linear and non-linear Weapon Control System (WCS) are used to show the benefits of hull disturbance feedforward and the necessity to cancel out the effects of real friction in the non-linear case.

INTRODUCTION

The primary objective of the Weapon Control System (WCS) on a Main Battle Tank (MBT) is to maximise the probability of hitting a stationary or moving target with the first round, in the shortest possible time, from a stationary or moving vehicle. The current method of improving the isolation of the gun from the hull motion (stabilisation) is to use disturbance feedforward. The feedforward signal is derived from the angular rates of the turret and hull in pitch and yaw respectively.

Linear theory predicts substantial improvements in Stabilisation Ratio (SR) using disturbance feedforward. For an MBT the SR is defined:

for sinusoidal motion:

$$\mathrm{SR} = \left|\frac{\omega_h}{\omega_g}\right| \text{ or } 20\log_{10}\left(\left|\frac{\omega_h}{\omega_g}\right|\right) \text{ dB} \tag{1a}$$

and, for random motion:

$$\mathrm{SR} = \frac{\mathrm{rms}(\omega_h)}{\mathrm{rms}(\omega_g)} \text{ or } 20\log_{10}\left(\frac{\mathrm{rms}(\omega_h)}{\mathrm{rms}(\omega_g)}\right) \text{ dB} \tag{1b}$$

where; ω_h and ω_g are the angular rates of the hull and gun respectively. Thus the SR is a measure of the WCS's ability to reject the motions of the vehicle hull and it ideally should be infinite. In Equation (1a), the SR varies with frequency and for an MBT with disturbance feedforward it will usually be over 30dB at 1Hz. It is possible to determine the variation of SR with frequency from the random motions by using the Fourier transform, but in this paper, Equation (1b) will be used as a quantitative measure of the SR over all frequencies. The angular rates of the gun are normally measured at the breech or cradle using a rate gyro.

In practice, the effectiveness is reduced because of non-linearities - notably friction. Non-linear friction has a detrimental effect on the performance of a WCS from both a stationary and moving MBT. This paper investigates the effect of non-linear friction on the SR in elevation of an MBT moving over random terrain with an all-electric WCS. The effectiveness of one method of compensating for the non-linear friction is investigated.

Descriptions of the types of WCS used on current MBTs are given in [1,2,3,4]. These give the historical development of the systems used and a discussion of their advantages and disadvantages, with some information on their relative performances. The modelling and control of linear gun systems are given in [5,6,7]. These concentrate on developing or extending WCS models and investigating the different methods of controlling them. The problem with using a linear model of the gun system is that it can give misleading results because of the level of non-linear friction. Non-linear models of gun control systems have been developed in [5,7]. In these references, the effect of kinetic (Coulomb) and static (stiction) friction are shown to be significant.

This paper uses a simulation technique to examine the effects of non-linear friction on the SR in elevation with feedforward and friction compensation. The non-linear model and closed-loop controller used in this study have been taken from [5]. The principal non-linearity in this model is static and kinetic friction. This model allows MBT motions to be coupled into the model via the hull pitch rate and vertical acceleration of the trunnions. The gun barrel is modelled as two rigid sections and is referred to in the paper as a Lumped Parameter Flexible Beam Model (LPFBM).

ELEVATION MODEL

A brief description of the elevation model is given here, the interested reader is referred to [5,7] for more detailed information. The description of the model is broken into two sections, linear and non-linear.

Linear Elevation Model

A diagram of the elevation channel is shown in Figure 1. The input to the elevation drive is a voltage to the servo-amplifier. The servo-amplifier produces a current, proportional to its input voltage. The prime mover is a dc servo-motor and in conjunction with the amplifier, can be considered as producing torque proportional to its input current [6]. The remainder of the drive-line consists of a gearbox, and rack and pinion. The servo-amplifier, motor and gearbox are represented by a single drive torque constant K_t. Sensors are used to measure the angular rate of the motor, and angular rate and position of the cradle.