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ON THE DEPLOYMENT OF A SUBSATELLITE IN A SPACE ELAVATOR SYSTEM

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The initial stage of construction of a space elevator system is a critical stage in many aspects, including the system's energy consumption. The deploy craft can be deployed in various rate strategies which lead to different costs. Modelling a space elevator system, this paper analyzes the dynamics and energy cost of the system in its initial construction stage. Librational motion of the long tether and the difference between the three centres of the system - center of mass, center of gravity, and center of orbit - are considered in the analysis. This paper completes the previous study of the authors where, using a three degrees-of-freedom model with no librational motion, the near optimum deployment strategy was studied through a set of optimization problems. In that analysis, it was concluded that a cost effective deployment occurs in an orbital station-keeping phase. This paper analyzes the effect of librational motion on the results and the difference between the energy required to enforce each of the above three centres to move in a geocentric orbit.

I. INTRODUCTION

Discussion of a space elevator dates back to 1895 when Konstantin Tsiolkovsky proposed a free-standing "Tsiolkovsky Tower" reaching from the surface of the Earth to the geostationary orbit [1]. 65 years later, Artsutanov [2] proposed the modern idea of the space elevator. One can mention the paper of Pearson on the 'orbital tower' [3] as the first research which focused on the details of the subject. Later, Edwards addressed different aspects and various problems of a space elevator [4].

Deployment of the initial elevator ribbon is the first stage of the construction of a space elevator system. It is the most challenging stage of the construction of the system, both from the practical point of view and the analysis point of view. So far, two different approaches have been proposed to deploy the initial elevator ribbon [5]. Both start with a spacecraft containing all the components. They differ in terms of the starting point and manoeuvre strategies; starting with the spacecraft at GEO and deploying the ribbon downward, and starting with a spacecraft in LEO and deploying the ribbon and ballast mass upward. It is clear that this initial stage plays an important role in the construction of a space elevator system.

In order to evaluate the more effective approach and to understand the system operation, we need to analyze the system dynamics. McInnes [6] obtained analytical results for a simple case of a space elevator: a point-mass climber traversing a stationary ribbon. Woo and Misra [7] studied the dynamics of a partial space elevator with multiple climbers, while Cohen and Misra [8] attempted to develop a realistic yet simple planar model to study the effect of the climber transit on the space elevator dynamics purpose.

Assuming no librational motion in the system, its dynamics during the initial stage of space elevator construction has been studied by several researchers [5, 9-11]. It has been shown that, in this stage, the space elevator may fall to the ground before achieving the full deployment. Takeichi [10] aimed to develop a feasible orbital control strategy for the geostationary station keeping of the initial space elevator during its deployment. He considered librational motion in his analysis.

This paper will elaborate on the modelling and analysis of the dynamics of a space elevator system during the deployment phase starting from the main spacecraft at GEO. It is mainly concerned with the effect of librational motion as well as the differences of the system centres on the deployment strategy.

Structure of the paper is as the following. After this introduction section, the problem statement is expressed in Section 2. Dynamical model of the system during its deployment stage is developed in Section 3. Section 4 reviews the previous study on the cost effective deployment. Effects of librational motion and differences of the system centres on the results are