Dynamic Modeling and Robust Motion Control of a 2D Compliant Pantograph for Micromanipulation

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***Abstract*—This paper investigates the dynamic modeling and robust motion controller for a compliant pantograph manipulator with/without guiding mechanism. The pseudo-rigid-body model is used to allow flexible elements to be modeled as rigid body mechanism. Afterward Euler-Lagrange formulation method is used to get the dynamic model of the compliant mechanism. The proposed controller consists of two loops, internal and external loops. The robust internal loop compensator strategy guarantees a robust stability and performance in the presence of uncertainty and external disturbances. On the other hand, the external loop is designed to meet the performance criterion. Simulation results are based on Co-simulation between MS-ADAMS and MATLAB. The nonlinear model is exported from MS-ADAMS to capture the dynamics of the manipulator while MATLAB is used to implement the controller algorithm. A disturbance input force is applied to the control input to test the robustness of the controller. The whole results show the efficiency of the proposed controller in tracking desired trajectory accurately to be used in micromanipulation.**

Keywords-compliant parallel mechanism; 2D pantograph; decoupled motions; micromanipulation; robust control introduction

I. INTRODUCTION

Micromanipulators are urgently required to manipulate minute objects for performing tasks as bio-cell manipulation, scanning tunneling microscope (STM), atomic force microscope (AFM), and part placement in micro-assembly. These tasks demand high dexterity and precision that enable an unprecedented level of manipulability [1]. The compliant mechanism instead of traditional rigid body endows a mechanism with several merits including no backlash, free of friction and lubrication, low cost and easy to fabricate. Additionally, it can overcome the shortcomings existing in conventional precision systems with sliding and rolling bearings, and implement positioning with the capability of smooth motion [2]. Compliant mechanisms are monolithic structures that provide the required motion from deflections by way of flexure hinges or flexible links inherent to the structure. The flexure hinges may be placed between relatively rigid members, referred henceforth to as links, to provide the desired motion of the mechanism, commonly determined by high precision actuators [3]. The most common modeling methods of compliant mechanisms are finite element method, elliptic integral solution and pseudorigid-body model (PRBM). The elliptic integral solution is frequently thought to be the most precise method however, it is viewed as a complex method. PRBM is considered as a straightforward method as it behaves adequately similar to a corresponding rigid-body mechanism [4]. Most of the traditional types of control topologies of compliant mechanisms are sensitive to uncertainties, measurements noise, disturbance inputs and non-modeled dynamics [5]. They assume an accurate knowledge for the manipulator dynamic matrices which are not available, unless an online estimation algorithm is involved which will increase the computation complexity. An alternatives approach is to use a robust control laws which is aimed at tuning the performance of the whole closed-loop system based on the worst case of uncertainty or external disturbances. One of the main concerns in micropositioning applications is to introduce a precise and efficient control strategy to realize its benefits. In this paper, the dynamic modeling of the compliant pantograph is developed with and without guiding mechanism. A robust motion controller is applied to both systems using the robust internal-loop compensator (RIC) framework [6]. This paper is organized as follows. The description of the 2D pantograph mechanism is presented in Section II. The kinematic modeling is introduced in Section III. Section IV introduces the dynamic modeling using Euler Lagrange. In Section V, motion control based on internal- loop compensation is designed. In Section VI. The simulation results and discussion. Finally, conclusions are drawn in Section VII.

II. DESCRIPTION OF THE 2D PANTOGRAPH

The typical 2D pantograph mechanism contains one parallelogram so that the movements of the actuators and the extreme point of the output link are pure decoupled translational motions in x and y directions. A 2D pantograph manipulator having end-effector with fixed orientation is obtained by adding a guiding mechanism to the 2D pantograph mechanism which consists of two parallelograms. The main pantograph mechanism and 2D manipulator with guiding mechanism have been built on CATIA software as shown in Fig. 1(a). The circular notch joint has been used in the design where, the thickness, radius and width are t, r and w respectively as shown in Fig. 1(b). Fig. 1(c) illustrates the