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CONSTRAINT FORCE ALGORITHM FOR DYNAMICS MODELING OF FLEXIBLE MULTIBODY SPACECRAFT

Abstract

In recent years, multibody spacecrafts, such as the space manipulators, are getting increasingly attention. When designing the critical structures of a multibody spacecraft or optimizing a feed-forward controller, it is desirable to have the knowledge of the constraint forces at the joints during the operation. In most cases, the constraint forces are calculated by introducing unknown multipliers or auxiliary generalized velocities, or simply by substituting the system's responses into the equations of motion of each body, which would lead to undesirable increase of computational cost. Therefore, the recursive algorithms and the efficient algorithms based on high-performance computers and parallel computing were proposed. However, most of them fail in giving the explicit expressions of the system's motion or the constraint forces and helpless in designing a feed-forward controller. Thus some researchers presented the constraint force algorithm (CFA). The CFA can give an explicit expression of the constraint forces and provide the constraint forces before achieve the dynamic responses while meet the demand of a high efficiency. Yet this algorithm is only applicable to rigid chained systems, the way of handling systems with flexible bodies remain unsolved. In this study, the constraint force algorithm for multibody spacecraft with flexible bodies is developed. The cases of a rigid-rigid connection, a flexible-flexible connection, a rigid-flexible connection and a flexible-rigid connection are discussed separately. The vibration equations for flexible bodies are established by modal superposition method. The order of modes included in the dynamics can be chosen according to different requirements and characteristics of the actual systems. The transfer equations of vibration displacements and modal forces were introduced, so that the form of the global equations remains the same with the CFA for rigid multibody systems. Consequently, the explicit expressions of the system's motion and the constraint forces in the CFA are still tenable for a flexible multibody system. The reminder of the paper will be organized as follows. Section I is the introduction. Section II gives the system description and several basic concepts. The constraint force algorithm for flexible multibody systems (F-CFA) will be given in Section III. Section IV presents the numerical simulations to validate the accuracy of the proposed algorithm. Conclusions are made in Section V. By now, the theoretical derivation is finished. A space manipulator will be taken into consideration as the numerical example.