行政院國家科學委員會補助專題研究計畫成果報告

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※ 負回授格拉曼驅動力矩下陀螺機電系統非線性 ※
※ 動力分析及渾沌控制 ※
※ Nonlinear Dynamic Analysis and Chaos Control ※
※ of a Gyroscope Electro-Mechanical System with ※
※ Grammel Driving Torque as Negative Feedback ※
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計畫類別：■個別型計畫 □整合型計畫

計畫編號： NSC 90-2212-E-009-050-

執行期間： 89 年 8 月 1 日至 91 年 7 月 31 日

計畫主持人：戈正銘

共同主持人：陳恆輝

計畫參與人員：林宗南 (博士班研究生)、陳介程、楊吉雯(碩士班研究生)

執行單位：國立交通大學機械工程學系

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一、中文摘要

陀螺機電系統主要用途之一為導航。此系統為一帶有格拉曼回饋之機電系統。此非線性系統之響應藉由時間響應，相平面軌跡及龐加萊胞映射來描述。由不同數值分析技巧，如功率譜法、李雅普諾夫指數及李雅普諾夫維度可觀察其規則與渾沌行為。

在渾沌的控制上。延遲回授控制、適應控制等將系統之渾沌行為得以有效控制。在渾沌反控制上。外加定力矩控制、外加週期外力矩控制等將系統之渾沌範圍得以明顯增加。最後，在渾沌同步上。外加線性迴饋項、外加正旋函數項、外加指數函數項、適應迴饋等方法達成渾沌同步。本計劃不僅可提供日後設計時的根據，而其研究也具有本身的學術價值。

關鍵詞：陀螺機電系統，分歧，格拉曼，渾沌，渾沌控制、渾沌反控制、渾沌同步。

二、英文摘要

One of the main applications of a gyroscope Electro-Mechanical system is the guidance for vehicles. It is very important to analyze the stability of a gyroscope Electro-Mechanical system mounted in a wobbling space vehicle. This system is a gyroscope Electro-Mechanical system with Grammel feedback. The time evolutions of the response of the nonlinear dynamical system are described by time history, phase portraits and Poincaré maps. The regular and chaotic behaviors are observed by various numerical techniques such as power spectra, Lyapunov exponents and Lyapunov dimension.

For the controlling chaos purpose, the delayed feedback control, adaptive control algorithm (ACA) control are used to control chaos. For the chaos anticontrol purpose, the addition of constant torque, the addition of periodic torque, are used to anticontrol of chaos. Finally, attention is shifted to chaos synchronization, for this purpose, the addition of linear feedback term, the addition of sinusoidal feedback term, the addition of exponential feedback term and adaptive feedback method are used to chaos synchronization. Besides we must point out this project gives not only a theoretical basis for practical design but also present academic instrest by itself.

Keywords: Gyroscope Electro-Mechanical system, Bifurcation, Grammel, Chaos, Controlling Chaos, Chaos Anticontrol, Chaos Synchroniztion.

三、計畫緣由與目的

緣由:

陀螺的研究已有相當的成果, 國內張家歐、周傳心[1-3]及戈正銘, 國外 Alfriend [4, 5]等皆有專精的研究. 而渾沌現象之基本行為與背景理論在各領域已有甚多專書, Guckenheimer [6], Moon[7], Wiggins[8], Nayfey[9], Hilborn[10], 曾做了比較完整的回顧總結而國內董必正[11-14]也有相關研究。在渾沌尚未誕生前國內外對剛體運動之非線性研究已有相當可觀的成果[15-20], 但是目前對剛體系統的渾沌行為討論並不多見, Leipnik and Newton[21]曾研究過具有線性反饋控制之剛體運動的渾沌現象, 但 Leipnik and Newton 的研究僅指出其存在兩個怪吸引子, 最近戈正銘等對這方面之研究亦有不少成果, 這些成果並發表於國際著名期刊[22-34], 對於如此重要的問題亟需加以注意和研究討論。本計劃依此精神, 來延續先前之研究期使研究結果更完備, 以精確的非線性運動微分方程作為根據, 並以理論及數值分析, 故具有一定的實際與理論價值。此外, 關於陀螺體系統渾沌之控制、反控制及同步之研究皆屬創新之發展。

目的:

陀螺機電系統對於車輛、船舶、航空器以至於衛星的導航是非常重要的。之前對於陀螺儀的研究很少概括到機電系統, 至於陀螺機電系統的渾沌行為也未見有人研究過。現擬考慮精確之非線性動力方程, 以詳細研究規則與渾沌行為並利用不同的控制方法來加以控制渾沌現象。此結果對此種系統之設計與運轉有重大的實際指導意義。就對非線性動力學而言, 也有其一定的價值。此外, 陀螺系統渾沌之同步與反控制尤屬創新之發展。

四、結果與討論

結果:

1. 以數值計算法得出相圖、功率譜、分歧圖、龐加萊映射及李雅普諾夫指數。
2. 採用延遲回授控制、適應控制等將系統之渾沌行為得以有效控制。
3. 採用外加定力矩控制、外加週期外力矩控制等將系統之渾沌行為範圍得以有效明顯增加。
4. 採用外加線性迴授項、外加正弦迴授項、外加指數迴授項、適應迴饋方法等使得渾沌得以同步化。

討論:

對於負回授格拉曼驅動力矩下機電陀螺系統的行為已有一系列完整的探討。渾沌的同步化及渾沌反控制是門新的學問, 值得加強深入探討。

五、計畫成果自評

1. 所得結果可對未來設計陀螺體機電系統提供較可靠之理論依據。
2. 所得結果在非線性動力學方面具有學術價值。

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