行政院國家科學委員會補助專題研究計畫期中成果報告

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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 89-2212-E-009-068-

執行期間： 89 **年** 8 **月** 1 **日至** 90 **年** 7 **月** 31 **日**

計畫主持人：戈正銘

共同主持人：陳獻庚

計畫參與人員：**林宗南、鄭普建(博士班研究生)、林俊吉(碩士班研究生)**

執行單位：國立交通大學機械工程學系

中　華　民　國　九十 年 五 月　一　日

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主持人：戈正銘　國立交通大學機械工程學系教授

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一、中文摘要

陀螺機電系統主要用途之一為導航，當其裝置在晃動的飛行器上其穩定性的分析是極為重要的。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。由李雅普諾夫直接法可求得系統平衡點的穩定條件。一個餘維數一分歧分析應用於自治系統的退化點後，發現系統存在著 Hopf **分歧行為。系統之周期吸引子及奇異吸引子之吸引區可由改良式內插胞映射法求得。**

最後，將重點集中在渾沌的控制上。延遲回授控制、外加固定力矩控制、外加週期力矩控制、適應控制、最佳化控制、週期脈衝控制和 bang-bang 控制等將系統之渾沌行為得以有效控制。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，李雅普諾夫穩定性，改良式內插胞映射法，渾沌控制。

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. Lyapunov direct method is also applied to obtain conditions for the stability of the equilibrium point of the system. A codimension one bifurcation analysis for the autonomous system is carried out near the degenerate point. The domain of attraction of the periodic and strange attractors of the system are located by applying the modified interpolated cell mapping (MICM) method.

Finally, attention is shifted to the controlling chaos. For this purpose, the delayed feedback control, the addition of constant torque, the addition periodic force, adaptive control algorithm (ACA) control, optimal control, periodic impulse control and bang-bang control are used to control chaos. 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, Lyapunov Stability, Modified Interpolated Cell Mapping, Controlling Chaos.

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**[22-32]**，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。**

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。

四、結果與討論

結果:

1. **採用李雅普諾夫直接法研究系統平衡位置的穩定及不穩定條件。**
2. **採用中心流形理論在退化點研究分歧行為。**
3. **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。**
4. **改良式內插胞映射**(MICM)**法將系統做整體分析**(global analysis)**。**
5. **採用延遲回授控制、外加固定力矩控制、外加週期力矩控制、適應控制、最佳化控制、週期脈衝控制和** bang-bang **控制等將系統之渾沌行為得以有效控制。**
6. **採用外加線性迴授項、外加正弦迴授項、外加指數迴授項、系統偶合化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陀螺系統的自治與非自治行為已有一系列完整的探討。渾沌的同步化是門新的學問，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械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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