行政院國家科學委員會專題研究計畫　成果報告

對稱陀螺儀的渾沌反控制及渾沌同步

計畫類別：個別型計畫
計畫編號：NSC91-2212-E-164-004-
執行期間：91 年 08 月 01 日至 92 年 07 月 31 日
執行單位：修平技術學院工業管理系

計畫主持人：陳獻庚

報告類型：精簡報告

處理方式：本計畫可公開查詢

中　華　民　國 92 年 10 月 30 日

行政院國家科學委員會補助專題研究計畫成果報告

※※※※※※※※※※※※※※※※※※※※※※※
※ 對稱重陀螺儀的渾沌控制及渾沌同步 ※
※ Anti-control of Chaos, Synchronization of a ※
※ Symmetric Gyroscope ※
※※※※※※※※※※※※※※※※※※※※※※※

計畫類別：■個別型計畫 □整合型計畫
計畫編號：NSC 91-2212-E-164-004-
執行期間：91 年 8 月 1 日至 92 年 7 月 31 日

計畫主持人：陳献庚
計畫參與人員: 鄭鴻文、孟憲虹

成果報告類型：■精簡報告 □完整報告

執行單位：修平技術學院工業管理系

中 華 民 國 九十二 年 十 月 二十 日

行政院國家科學委員會專題研究計畫成果報告

對稱重陀螺儀的渾沌控制及渾沌同步
Anti-control of Chaos, Synchronization of a Symmetric Gyroscope

計畫編號：NSC 91-2212-E-164-004
執行期限：91 年 8 月 1 日至 92 年 7 月 31 日

主 持 人：陳献庚　修平技術學院工管系 助理教授
參 與 人 員：鄭鴻文　修平技術學院工管系 講師
孟憲虹　中華大學機械系 碩士班研究生

一、中文摘要

陀螺儀的主要用途之一為現代太空載體、火箭、飛彈及戰艦等的導航儀器。本報告針對一對稱陀螺儀作渾沌反控的動力分析及渾沌同步研究。首先以渾沌反控制的方法將規則的陀螺運動轉而為渾沌狀態。以數值方法研究此非線性系統的規則與渾沌行為。

最後，將重點集中在渾沌同步化的研究上。在兩個處於渾沌運動的系統，利用系統偶合方式使兩系統達成渾沌同步化。同時計算次李雅普諾夫指數且應用其正、負號來判斷渾沌同步化是否實現。此外，亦研究渾沌同步時間。本報告不僅提供日後陀螺儀設計時之依據，而其研究本身也具有相當的學術價值。

關鍵詞：陀螺儀，渾沌反控制，渾沌同步，次李雅普諾夫指數，偶合，同步時間

Abstract：

One of the major applications of gyroscope is the guidance of modern space vehicles, rockets, missiles, warships etc. This report provided the nonlinear dynamic analysis of a gyroscope with anti-control of chaos. The report has controlled a stable gyroscope into a chaotic motion by the anti-control of chaos method. In this project, modern numerical methods have been used t to observe periodic and chaotic motions.

Finally, attention is shifted to the synchronization of chaos in the two identical chaotic motions of symmetric gyros. The results show that one can make two identical chaotic systems to synchronize through applying coupling. The sign of the sub-Liapunov exponents is also applied as a criterion for this. Furthermore, the synchronization time is also examined. Besides we must point out this report give not only a theoretical basis for practical design but also present academic interest by itself.

Keywords：gyroscope, anti-control of chaos, synchronization of chaos, sub-Liapunov exponent , one-way coupling, synchronization time

二、緣由與目的

非線性動力學近年來取得突破性之

進展，確定性非線性動力系統的渾沌運動之發現，揭示了一個全新世界，被視為與相對論、量子力學並論的二十世紀理論科學三大偉大成就之一。近年來在廣度與深度方面皆以空前的速度發展。

渾沌動力學在 1970 年代才開始萌芽發展，而到目前受到科學家之重視，主要係在科學之各領域中皆存在渾沌現象，甚至造成神秘猝死的主要原因都可由人類心臟所產生的渾沌找到令人訝異不已的秩序。渾沌運動是確定性系統中出現類似隨機的過程，這種過程對初值的微小擾動極為敏感，初值即使只有很小的差別，經過一段時間後，兩條軌線已沒有任何相關性可言。這是當前國際科技界非常活躍的研究領域。

自從 1963 年大氣學家 E. N. Lorenz 以著名的 Lorenz's equation 發表渾沌理論，三十多年來，很多努力皆放在找尋及預測渾沌現象，而避免使用產生渾沌運動的參數，因為渾沌運動意味著該系統行為的不可預測，所以研究渾沌運動的學者，總是想辦法抑制渾沌運動的發生。有時渾沌反而是有用的，例如混合過程或熱傳等，但對一般機械系統是不受歡迎的。

因此，渾沌控制是根據系統需求而定的。近年來，控制渾沌的研究已有很好的進展，許多渾沌控制方法也已陸續被學者研發出來。控制渾沌運動軌道，使其進入類似週期運動區域內，進而轉換成我們可以預測其運動行為的規則運動；或者控制類似週期運動軌道，使其進入渾沌吸子內，進而轉換成渾沌軌道，使該系統的運動行為變成不規則的運動，以上兩者都是渾沌控制研究的重要範籌。渾沌控制亦可以運用到娛樂設備或醫療上。尤其醫學上的應用，例如將不規則的心跳（心臟病發作）轉換成規則的韻律跳動、或者將發送規則訊號的腦波（癲間），轉換成不規則的腦波（正常腦波）。產生規則運動，可以達成預測系統運動行為的目的，但有時為了增加娛樂設備的效果或者醫學上病情的控制，反而希望不規則的渾沌運動，所以渾沌的控制，應可朝實際生活應用上發展。本報告針對一對稱陀螺儀作渾沌反控制的動力分析及渾沌同步化的研究。研究本身具有相當學術價值也具有獨特意義，更期許國內的動力學之研究在較短期間能進入國際先進水準之行列。

三、結果與討論：

本報告首先以渾沌反控制的方法將規則的陀螺運動轉而為渾沌狀態。以數值方法研究此非線性系統的規則與渾沌行為。***本報告有極為重大的發現，著名的 Lorenz's equatuon 及 Chen's Attractor 皆為本研究的一個特例。***另外，利用系統偶合方式使兩個處於渾沌運動的系統達成渾沌同步化。同時計算次李雅普諾夫指數且應用其正、負號來判斷渾沌同步化是否實現。研究證實發現偶合常數具有關鍵的影響地位，只要適當的選定就能使兩系統達到渾沌同步。此外，亦研究渾沌同步時間，同時亦以數值方法證明初始條件並不影響渾沌的同步時間。

註：Chen's Attractor 為香港城市大學陳關榮(GUANRONG CHEN)教授所發現。GUANRONG CHEN received the M.Sc. degree in Computer Science from the Sun Yatsen (Zhongshan) University, China, in Fall 1981 and the Ph.D. degree in Applied Mathematics from Texas A&M University, USA, in Spring 1987. He worked at Rice University as Visiting Assistant Professor 1987-1990, at University of Houston through tenure track till became Full Professor thereafter, and then at City

University of Hong Kong as Chair Professor and founding Director of Centre for Chaos Control and Synchronization since 2000. He is a Fellow of the IEEE, awarded in 1996, for his fundamental contributions to the theory and applications of chaos control and bifurcation analysis.

Dr. Chen's main research pursuit is in one of the focusing areas in Electrical Engineering - Nonlinear Systems Control and Dynamics, with applications in related areas such as encryption and secure communication, intelligent systems, chaos generators design, and nonlinear circuits. He is the (co)author of more than 250 refereed journal papers, 180 some conference proceedings abstracts, and 15 research monographs and advanced textbooks.

四、計畫成果自評：

摘要中所列研究重點皆獲得預期結果。所得結果可對陀螺儀的設計提供理論的依據。所得的結果具本身的學術價值。培育力學新領域(如計劃中之渾沌反控制、渾沌同步化…等)的研究人力。期使更多的優秀人才投入這方面的研究。提昇我國在此領域的學術地位，使我們也能夠跟得上新時代的腳步。***計畫成果分為兩部分：其中渾沌同步化已發表於ImechE Part C：Journal of mechanical Engineering Science[28]; 另外，渾沌反控制也已被Chaos, Solitons & Fractals [29]接受同意刊登。上述兩種期刊皆為SCI所收錄，因此，本計畫共產出兩篇SCI論文。***

五、參考文獻：

1. Chang, C. O. 2001 “The Rotational Dynamics and Control of a Rigid-Body with Internal Wheels,” Journal of the Chinese Society of Mechanical Engineers, Vol. 22, No. 5, pp. 361-369.
2. Chang, C. O. and Chou, C. S. 1989 “Partially Filled Nutation Damper for Freely Processing Gyroscope,” AIAA Journal of Guidance, Control, and Dynamics, Vol. 14, No. 5, pp. 1046-1055.
3. Chang, C. O. and Liu, L. Z. 1996 “Dynamics and stability of a Freely Precessing Spacecraft Containing a Nutation Damper,” Journal of Guidance, Control and Dynamics, Vol. 19, No. 2.
4. Alfriend , K. T. and Spancer, T. M. 1983 “Comparison of Filled and Partially Filled Nutation Damper,” Journal of Astronautical Sciences, Vol. 31, No. 2, pp. 198-202.
5. K. T. Alfriend 1975 “Magnetic Attitude Control System for Dual-Spin Satellites,” Am. Inst. Aeronaut. Astronaut. J., Vol. 13(6), pp. 817-822.
6. Guckenheimer, J. and Holmes, P. 1983 Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vectors Fields, Springer-Verlag, New York.
7. Moon, F. C. 1992 Chaotic and Fractal Dynamics, John Wiley & Sons, New York.
8. Wiggins, S. 1990 Introductions to Applied Nonlinear Dynamical Systems and Chaos, Springer-Verlag, New York.
9. Nayfeh, A. H. and Balactandran, B. 1995 Applied Nonlinear Dynamics, John Wiley & Sons, New York.
10. Hilbron, R. C. 1994 Chaos and Nonlinear Dynamics, Oxford University press, Inc. New York.
11. Tung, P. C. and Shaw, S. W. 1998 “A Method for Improvement of Impact Printer Performance,” Trans. ASME, Vol. 110, pp. 528-532.
12. Tung, P. C. 1992 “Dynamics of a Non-harmonically Forced Impact Oscillator,“ JSME Int. J., Series III 35, PP.378-385.
13. Tseng, C. Y. and Tung, P. C. 1995

"Dynamics of Nonlinear Structure with Magnetic Actuator," Japanese Journal of Applied Physical, Vol. 34, pp. 374-382.
14. Tseng, C. Y. and Tung, P. C. 1995 "Stability, Bifurcation, and Chaos of a Structure with a Nonlinear Actuator," Japanese Journal of Applied Physical.
15. Leipink, R. B. and Newton, T. A. 1981 "Double Attractors in Rigid Body Motion with Linear Feedback Control," Physics Letter, November, pp.63-67.
16. Ge, Z. M. and Chen, H. H. 1996 "Bifurcations and Chaos in a Rate Gyro with Harmonic Excitation," Journal of Sound & Vibration, Vol. 194, No. 1, pp.107-117.
17. Ge, Z. M., Chen, H. K. and Chen, H. H. 1996 "The Regular and Chaotic Motion of a Symmetric Heavy Gyroscope with Harmonic Excitation," Journal of Sound & Vibration, Vol. 198, No. 2, pp.131-147.
18. Ge, Z. M. and Chen, H. K. 1996 "Stability and Chaotic Motions of a Symmetric Heavy Gyroscope," Japanese Journal of Applied Physics, Vol. 35, No. 3, pp.1954-1965.
19. Ge, Z. M. and Chen, H. H. 1996 "Bifurcations and Chaos in Rate Gyro with Harmonic Excitation," Journal of Sound & Vibration, Vol. 194, No. 1, pp.107-117.
20. Ge Z. M., Lee, C. I., Chen, H. H., and Lee S. C. 1998 "Nonlinear Dynamics and Chaos Control of a Damped Satellite with Partial-filled Liquid," Journal of Sound and Vibration, Vol. 217, No. 5.
21. Tong, X. and Mrad, N. 2001 "Chaotic Motion of asymmetric Gyro Subjected to a Harmonic Base Excitation", Trans. ASME Journal of Vibration and Acoustics, Vol. 68, pp. 528-532.
22. Peng, J. and Liu, Y. 2000 "Chaotic Motion of a Gyrostat with Asymmetric Rotor," International Journal of Non-Linear Mechanics, Vol. 35, pp. 431-437.
23. Kuang, J., Tan, S., Arichandran, K. and Leung, A. Y. T. 2001 "Chaotic Dynamics of an Asymmetrical Gyrostat," International Journal of Non-Linear Mechanics, Vol. 36, pp. 1213-1233.
24. Ge, Z. M. and Lin, T. N. 2001 "Chaos, Chaos Control and Synchronization of Gyrostat System," Accepted by Journal of Sound & Vibration.
25. Hsien-Keng Chen 2002, "Chaos and Chaos Synchronization of a Symmetric Gyro With Linear-Plus-Cubic Damping," Journal of Sound & Vibration, Vol. 255, pp. 719-740.
26. Chen, H. K. 2001 "Synchronization in Chaotic Symmetric Gyros By Simple Coupling," Automation Science & Technology Application Conference, Macau, pp. 98-104
27. Wang, X. F., Chen, G. and Yu, X. 2000 "Anticontrol of chaos in continuous-time systems via time-delay feedback," Chaos, Vol. 10, No. 4, pp. 771-779.
28. Chen, H. K. and Lin, T. N. 2003, "Synchronization of Chaotic Symmetric Gyros By One-Way Coupling Conditions," ImechE Part C: Journal of Mechanical Engineering Science, Vol. 217, pp. 331-340
29. Chen, H. K. and Lee, C. I. 2003, "Anticontrol of Chaos in Rigid Body Motion," Chaos, Solitons & Fractals (Accepted).