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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※ **帶彈簧之六邊形調速器的旋轉機械非線性** ※
※ **動力學及渾沌控制** ※
※ Nonlinear Dynamics and Control of Chaos for a ※
※ Rotational Machine with a Hexagonal Governor ※
※ with a Spring ※
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計畫類別：■個別型計畫　　□整合型計畫
計畫編號：
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
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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

行政院國家科學委員會專題研究計畫期中成果報告

計畫編號：NSC 89-2212-E-009-069
執行期限：89 年 8 月 1 日至 90 年 7 月 31 日

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一、中文摘要

帶有離心調速器之旋轉機械(如透平)是重要的，常見的旋轉機械。申請人於去年度之國科會專題研究計畫「帶離心調速器之旋轉機械的規則與渾沌動力分析」，(計畫編號NSC89 -2212-E-009-005)，則對其簡化模型作了研究，其中略去了實際上存在的懸軸距離及彈簧的作用。本計畫擬對更精確的動力模型進一步作詳盡之研究。我們探討一考慮彈簧(且彈簧係數為變量)及懸軸距離之離心調速器之旋轉機械受到外界干擾所產生的動態行為。由李亞普諾夫直接法可求得系統平衡點的穩定條件。中心流型分析應用於自治系統的退化點後，發現系統所存在的分歧行為。此外，藉相位圖、功率譜法、龐加萊映射法(Poincaré map)及李亞普諾夫指數可觀察到周期性、擬周期性及渾沌運動。

接著，在全局分析中,系統每個吸子之吸引區由戈正銘與李三祈 1997 年得出的改進式內插胞映射法(modified interpolated cell mapping)求得，採用此法，對系統作全局分析時于計算時間大為縮短，精確度提高甚多。

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：調速器，旋轉機械，動力分析，渾沌，渾沌控制

二、英文摘要

Rotating Machines with centrifugal governor, e.g. turbines, are important and familiar rotating machines. The National Science Council project “Regular and Chaotic dynamics of the Rotational Machine with Centrifugal Governor” applied by applicant had studied for the simplified model this year. It neglected the distance of suspension joint and the action of spring in actual fact. This project will study detail for the accurate dynamical model. The dynamics behaviors of a rotational machine with centrifugal governor with a spring (the stiffness of spring is a variable) which is subjected by external disturbance are studied in the thesis. The Lyapunov direct method is applied to obtain conditions of stability of the equilibrium points of the system. The center manifold analysis for the autonomous system is carried out near the degenerate point. It is founded that bifurcation occurs in the system. Besides, phase diagrams, power spectra, Poincaré maps, and Lyapunov exponents are presented to observe periodic, quasiperiodic and chaotic motions.

For global analysis, the basins of attraction of each attractors of the system are located by

employing the modified interpolated cell mapping (MICM) method given by Zheng-Ming Ge and Sann-Chie Lee in 1997. It can shorten the computational time and enhance the accuracy by using this method for global analysis.

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 interest by itself.

Keywords: governor, rotating machine, dynamic analysis, chaos, controlling chaos

三、計畫緣由與目的

緣由:

渾沌現象是學術界晚近的一項重大發現。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[1]**，**Moon[2]**，** Wiggins[3]**，** Nayfey[4]**，** Hilborn[5]**，曾做了比較完整的回顧總結而國內董必正**[6-9]**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**[10-17]**，但是目前對剛體系統的渾沌行為討論並不多見，**Leipnik and Newton[18]**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**[19-28]**，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:

帶離心調速器之旋轉機械為重要的且常見的。前人或以線性化方程加以粗略研究，或雖以非線性方程研究，但卻過於簡化。至於渾沌行為也鮮見有人研究過。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。

帶離心調速器之旋轉機械多為價值昂貴之巨大機械系統，故其動力行為之精確性與可靠性要求甚高，如運動穩定性，週期解之存在性及求得，特別是其分歧行為之分析尤為必要。因為唯有先了解其動力行為且若能有效的控制渾沌行為，方可避其所害，用其所利，以達經濟而有效率之設計與運轉。

四、結果與討論

結果:

1. **採用拉格朗日運動方程式導出帶離心圓調速器的旋轉機械的運動微分方程組，它們是三個一階非線性微分方程所組成的非自治系統，再將此方程組無因次化。**
2. **採用李雅普諾夫直接法得出系統平衡位置的穩定與不穩定的條件。**
3. **用中心流形及標準型理論在自治系統的退化點得出其** Hopf **分歧行為。**
4. **以數值計算法得出相圖，功率譜，分歧圖，龐伽萊映射及李雅普諾夫指數，用來研究周期運動，準周期運動和渾沌運動的行為。最後用戈正銘與李三祈發展的改良式內插胞映射**(MICM)**法將系統做整體分析**(global analysis)**，得到各個吸引子的吸引區圖，其中包括碎形**(fractal)**圖。**

討論:

本研究得出一個新的三維自治系統(autonomous system**)之渾沌現象，十分可**

喜。我們知道由常微分方程表達的連續自治系統中出現渾沌現象者不多。故此一自治系統之渾沌值得做進一步之研究。

五、計畫成果自評

1. 所得結果可對未來設計與運轉帶離心調速器之旋轉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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