



智慧機械基石-
流體傳動技術人才培訓
(氣壓與真空篇)

氣壓/真空電子控制技術

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氣壓/真空電子控制技術

(a) 挑戰與展望：

- (1) 大功率輸出---伺服(比例)液壓系統。
- (2) 中低功率輸出---伺服(比例)氣壓, AC/DC 伺服馬達系統。
- (3) 簡單軸(1~2軸)之驅動上, 氣壓比例系統較 DC 伺服馬達系統低成本。
- (4) 氣壓比例系統較機械控制系統為優(成本、空間等之比較)。
- (5) 應用領域：醫藥工業, 食品工業(飲料等), 包裝機械業, 3C 產業, 半導體無塵室等。

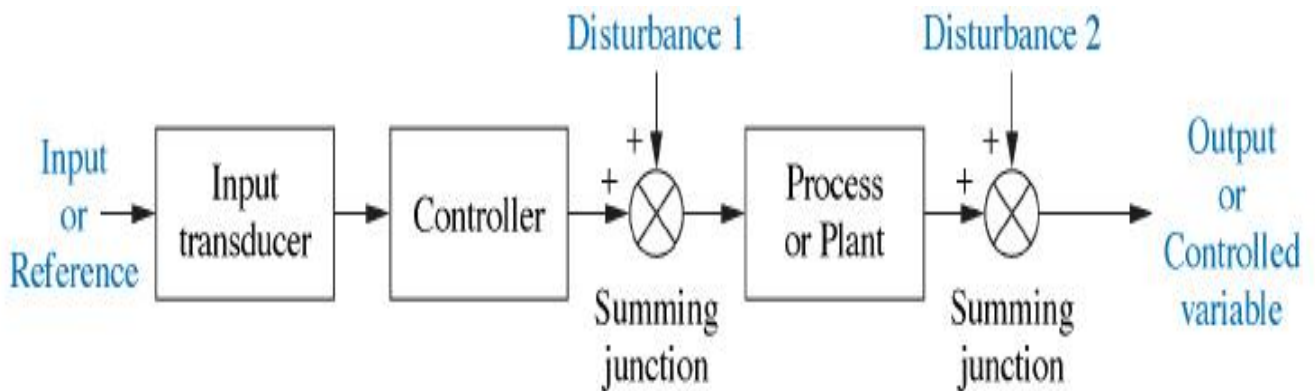
(b) 未來驅勢：

- (1) 微小化
- (2) 電控電路整合化(微電腦控制)
- (3) 模組化
- (4) IoT 網路控制化(例如：IO-Link)

(c) 開迴路及閉迴路控制：

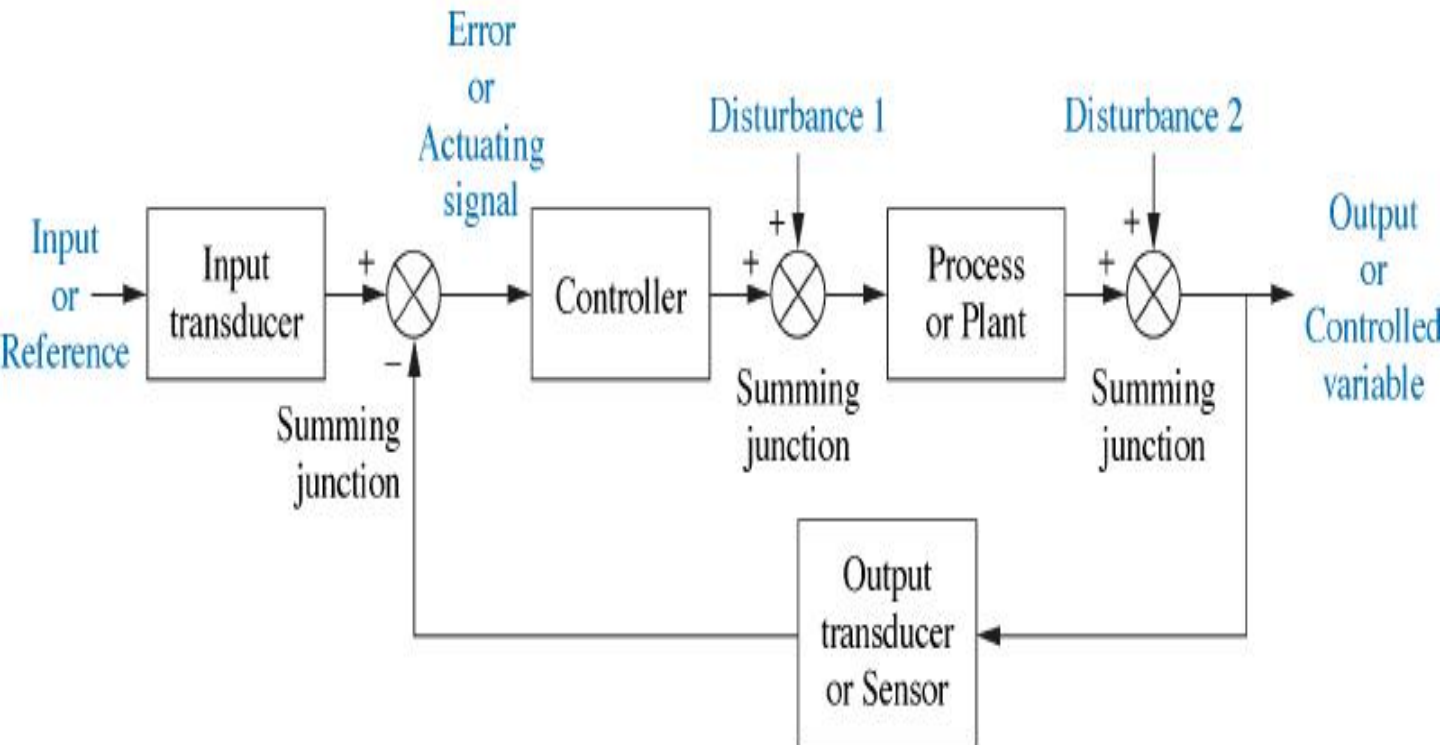
- (1) 開迴路：PLC 控制器 + On-Off 閥。
- (2) 閉迴路：PC-Based 控制器 + 比例閥。

■ Open-Loop Systems



- (1) **Can not** compensate for any disturbances
- (2) Are simply commanded by the input
- (3) Simpler and less expensive than closed-loop systems

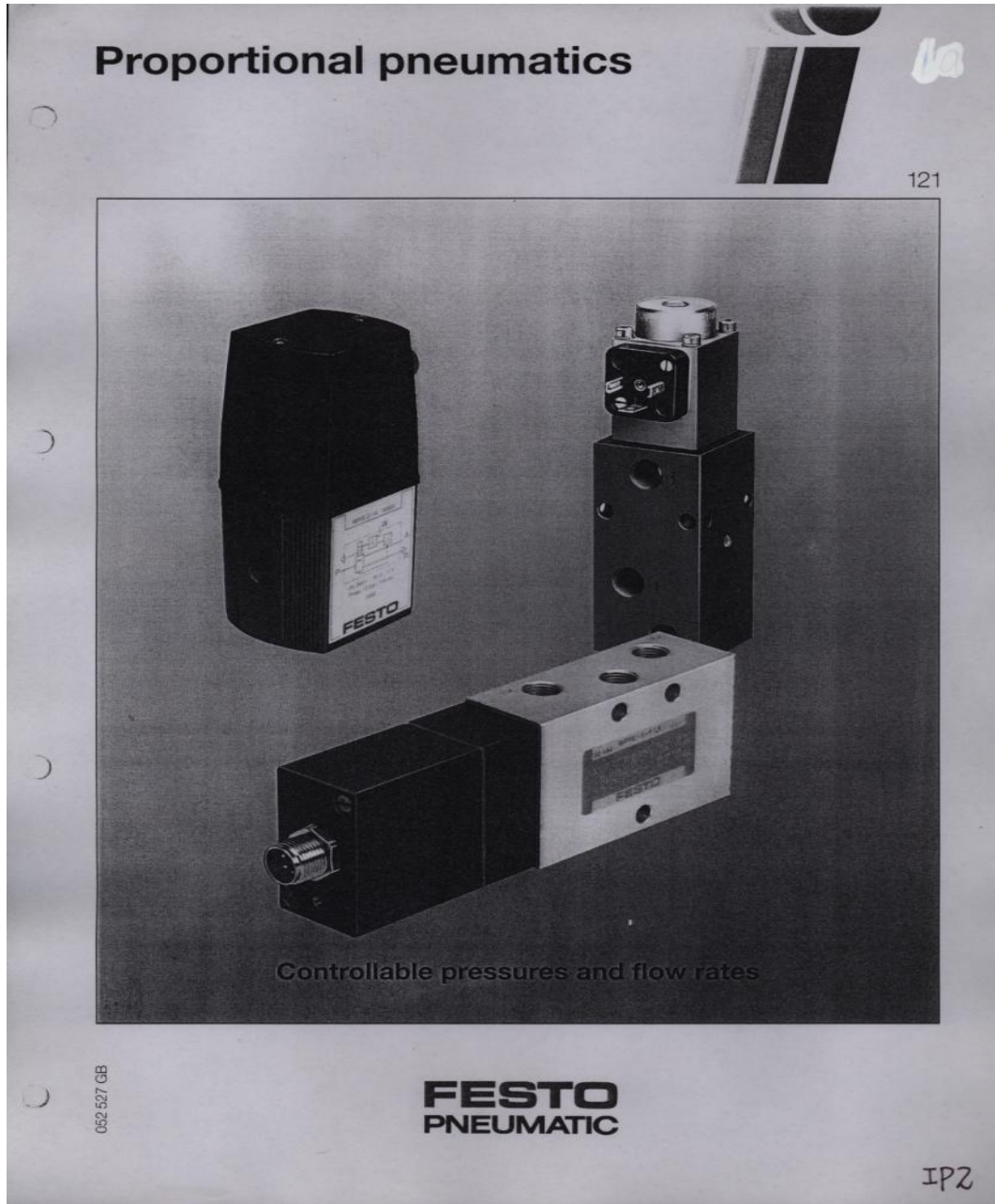
■ Closed-Loop (Feedback Control) Systems



- **Advantages:**

- (1) Greater accuracy (compared to open loop sys.)
- (2) Less sensitive to noise, disturbances and changes in the environment.
- (3) Transient response and steady-state error can be controlled more conveniently.
- (4) Adjustment of gain of compensator with greater flexibility.

氣壓比例閥



包含：比壓(左上)、比流(右上)及比方(下)閥

數位式PWM控制氣壓比例壓力閥

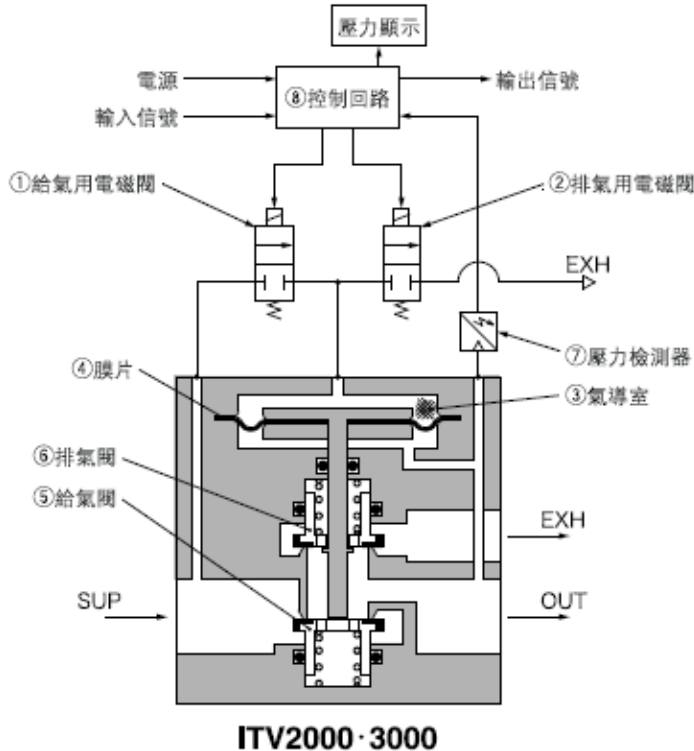
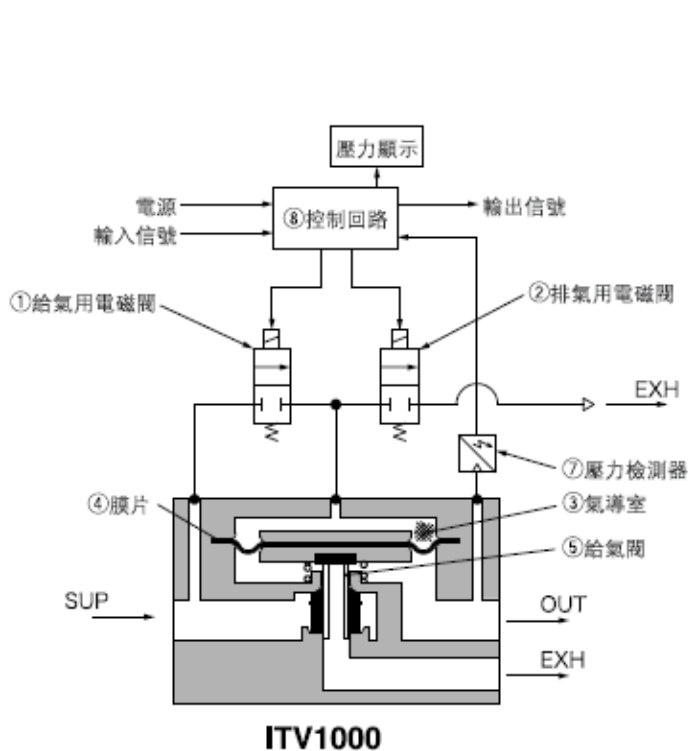


數位式PWM控制氣壓比例壓力閥原理

動作原理

輸入信號一增大，①給氣用電磁閥變為ON狀態，②排氣用電磁閥變為OFF狀態。由此，供給壓力通過①給氣用電磁閥作用在③氣導室。並且，③氣導室的壓力上升，作用在④膜片的上面。

由此結果，與④膜片連動的⑤給氣閥打開，一部分供氣壓力成為輸出壓力，通過⑦壓力檢測器反饋至⑧控制回路。在這裏，由於會進行修正動作，直到輸出壓力與輸入信號成比例，因此通常會得到與輸入信號成比例的輸出壓力。



圖形符號

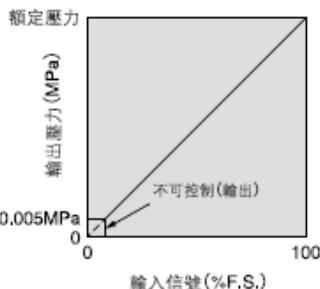
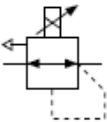
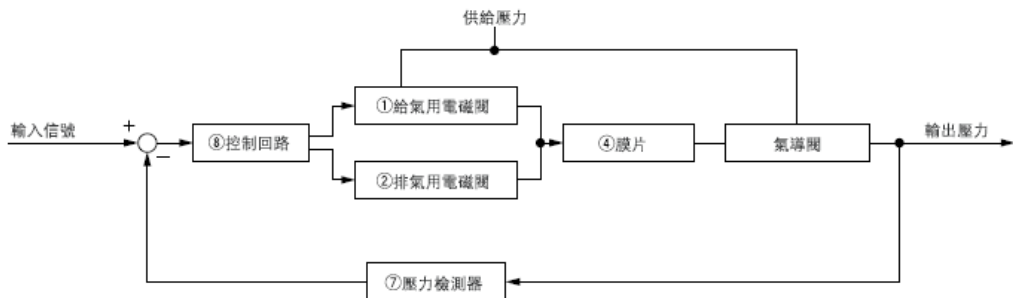


圖1.輸入輸出關係圖





氣壓/真空電子控制 實例介紹

(Applications)

A -1 主動式氣壓避震器系統

機械式主動氣壓避震器：目前氣壓減振平台大多使用機械式氣壓水平控制閥調整高度，達到平台自動水平校準的功能。以德國CFM氣壓避震器產品為例：

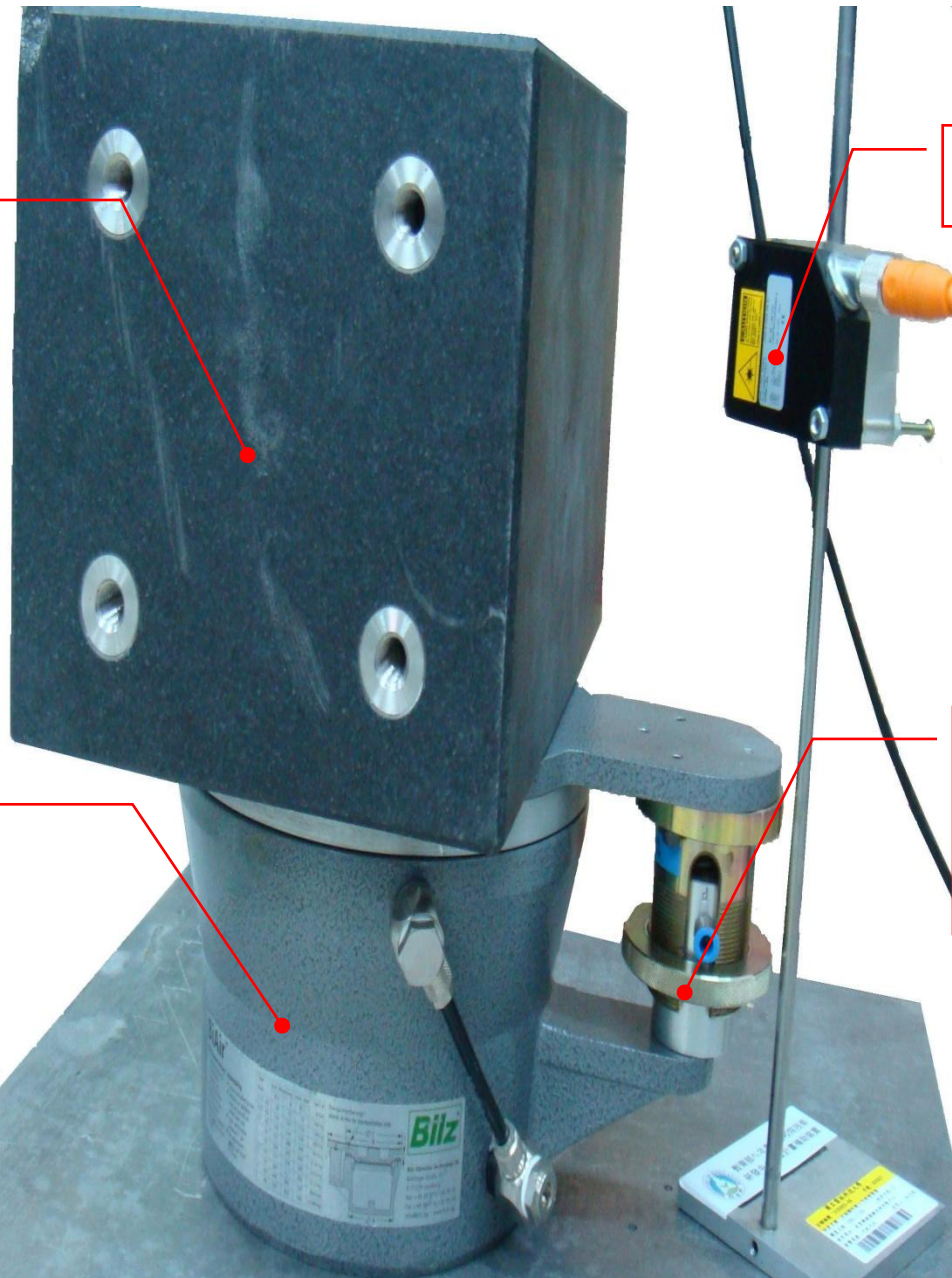


文獻回顧

關於主動式氣壓避震器系統之研究，隔振系統有**主動（Active）**與**被動（Passive）**之分：

- **主動隔振系統**：主要應用在隔離低頻振動或去除直接負載干擾。
- **被動隔振系統**：對隔離高頻振動的性能較好，被動式隔振設計簡單。

被動式的缺點：對於乘載重量及低頻的隔振效果有限，因此對於**低頻振動**可以用**主動控制**來進行。



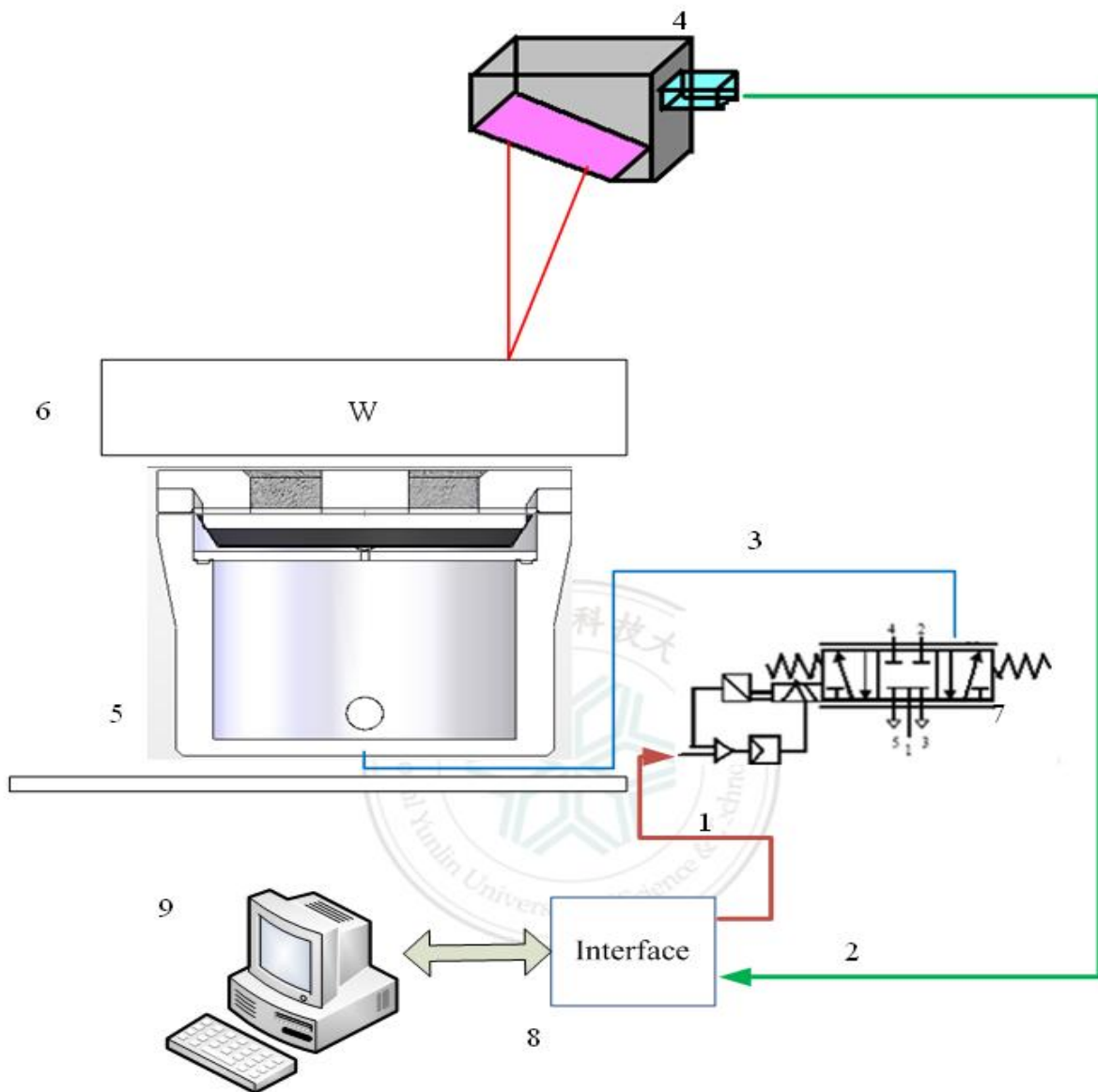
負載
(30kg
w)

主動式
氣壓避
震器

雷射位
移計

機械式
氣壓水
平控制
閥

閉迴路控制的研究將再加上比例方向閥、雷射位移計、資料擷取卡與電腦等相關研究設備進行閉迴路定位控制。



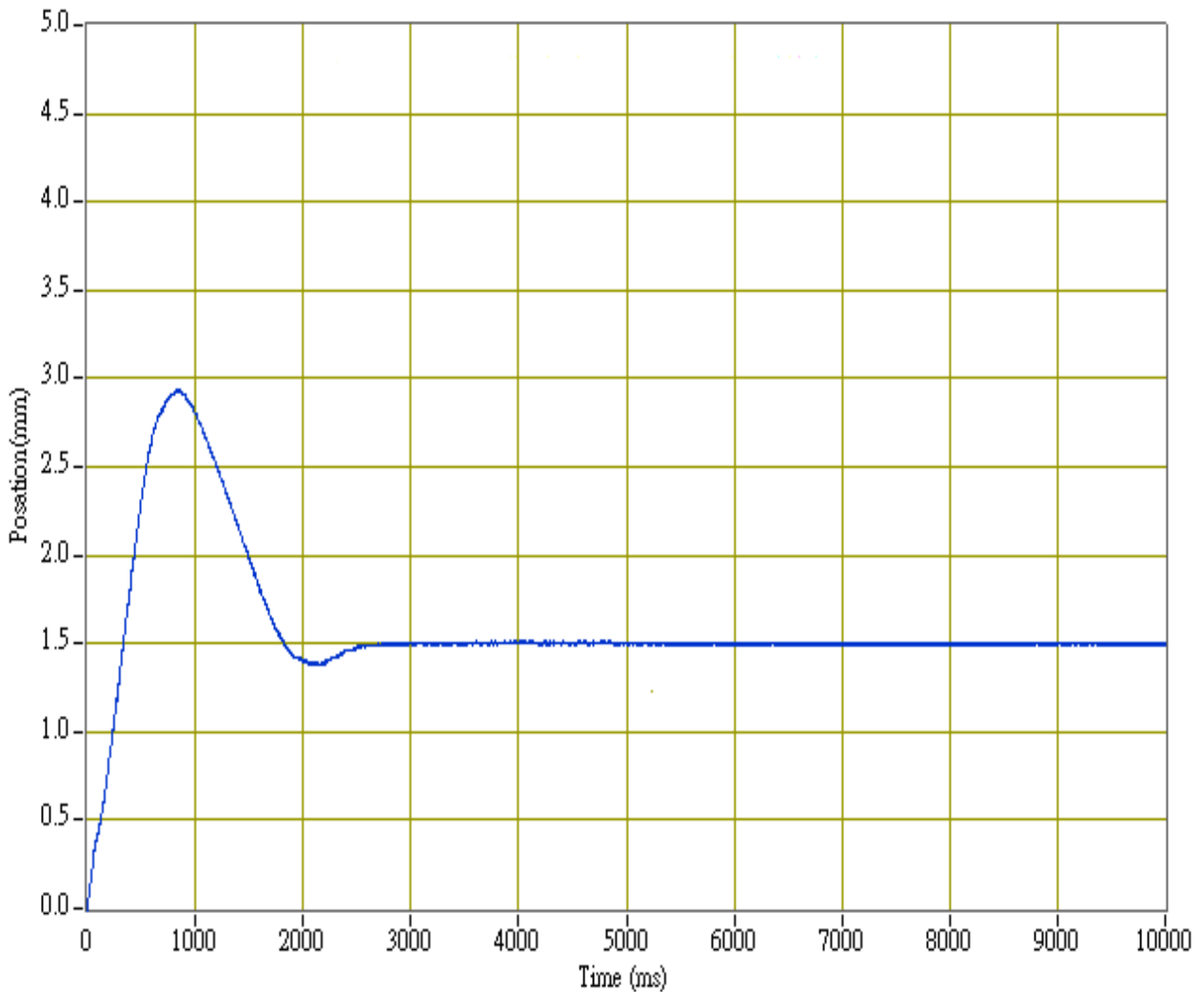
主動式氣壓避震器閉迴路控制系統流程圖



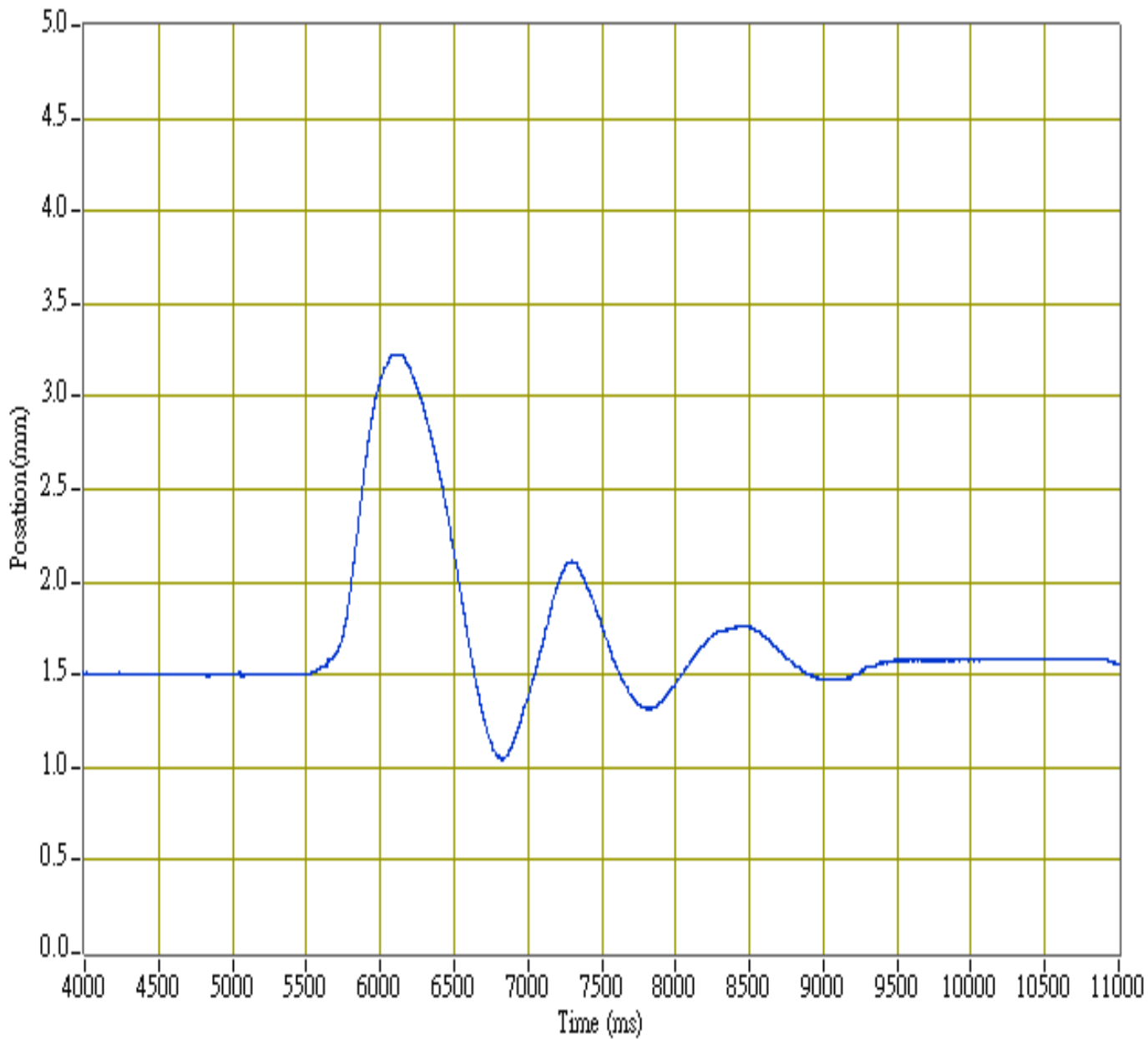
主動式氣壓避震器系統模擬分析 與實驗討論

主動式氣壓避震器系統實驗結果

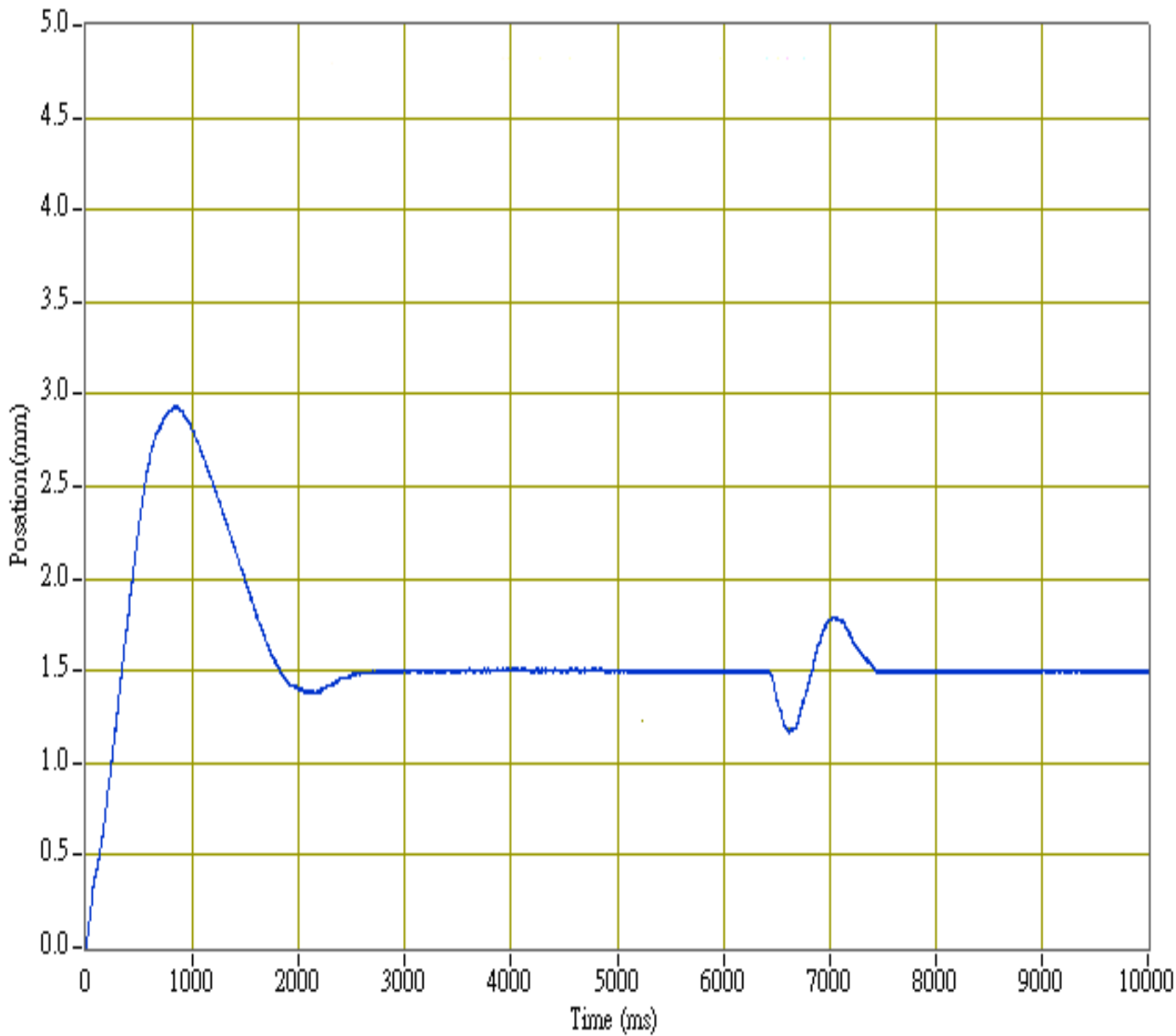
如圖所示為利用機械式氣壓水平控制閥輸入氣壓至氣壓避震器本體使上蓋及負載（30Kgw）往上撐起，直到機械式氣壓水平控制閥達到所設定的位置1.5mm後停止。



氣壓避震器定位控制響應圖(目標值1.5mm)



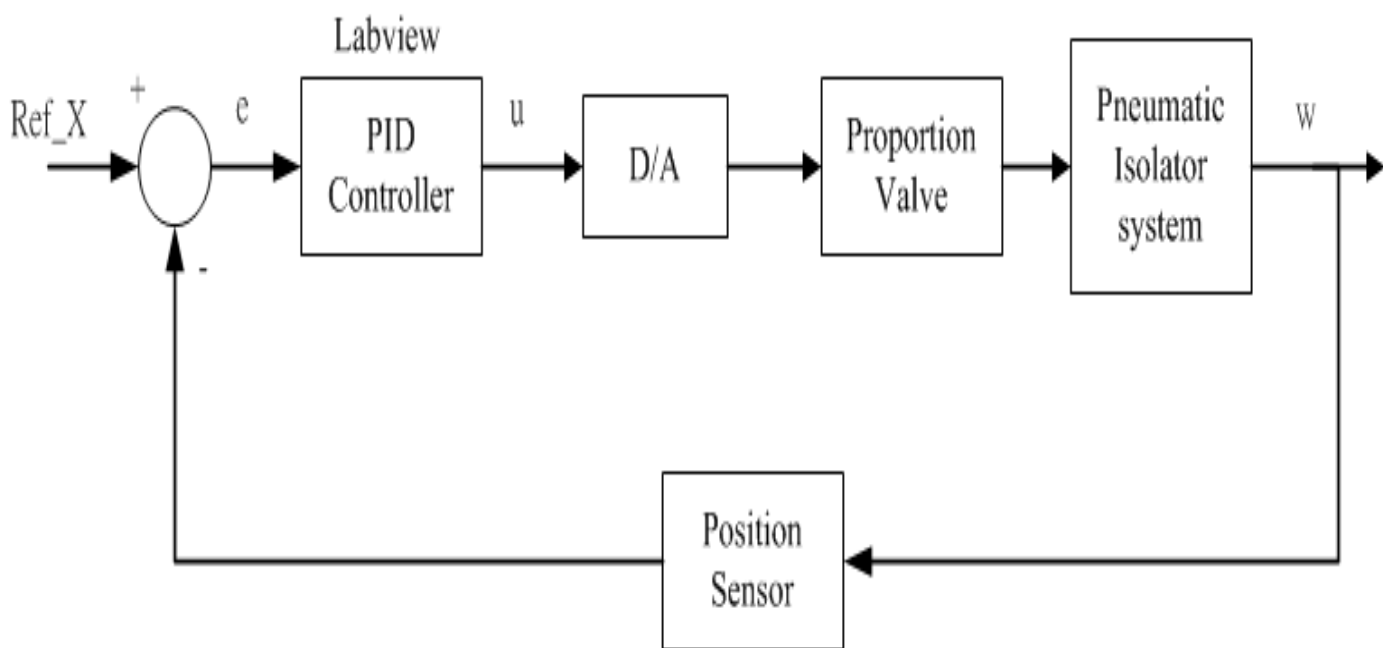
氣壓避震器釋放重量30Kgw後之動態響應圖



氣壓避震器施加重量2kgw之動態響應圖

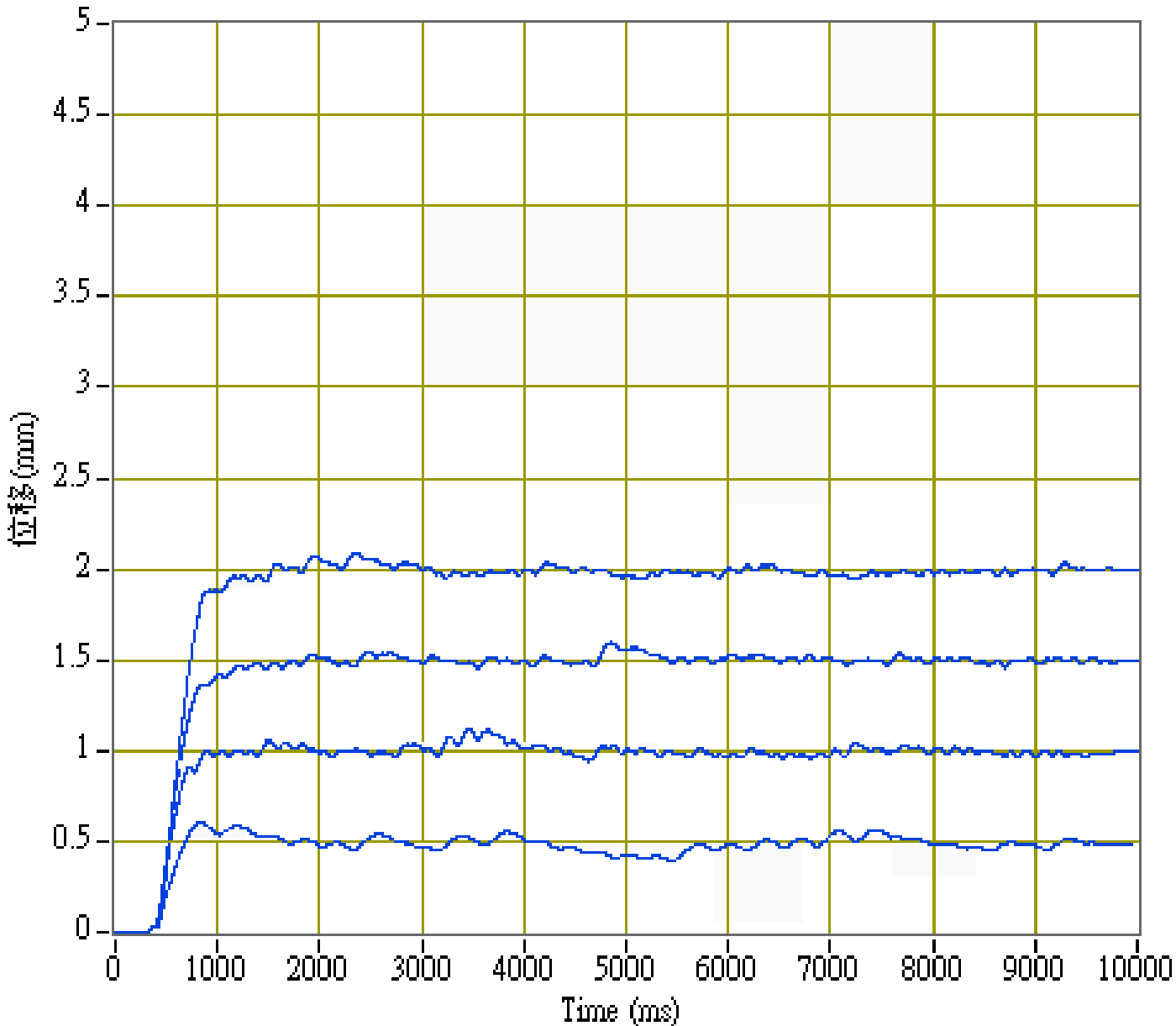
PID控制主動式氣壓避震器系統實驗結果

閉迴路控制研究另外將加上比例方向閥、雷射位移計等設備來組成並由透過電腦控制，將**比例方向閥**來取代**機械式氣壓水平控制閥**，改善機械式氣壓水平控制閥的缺點。

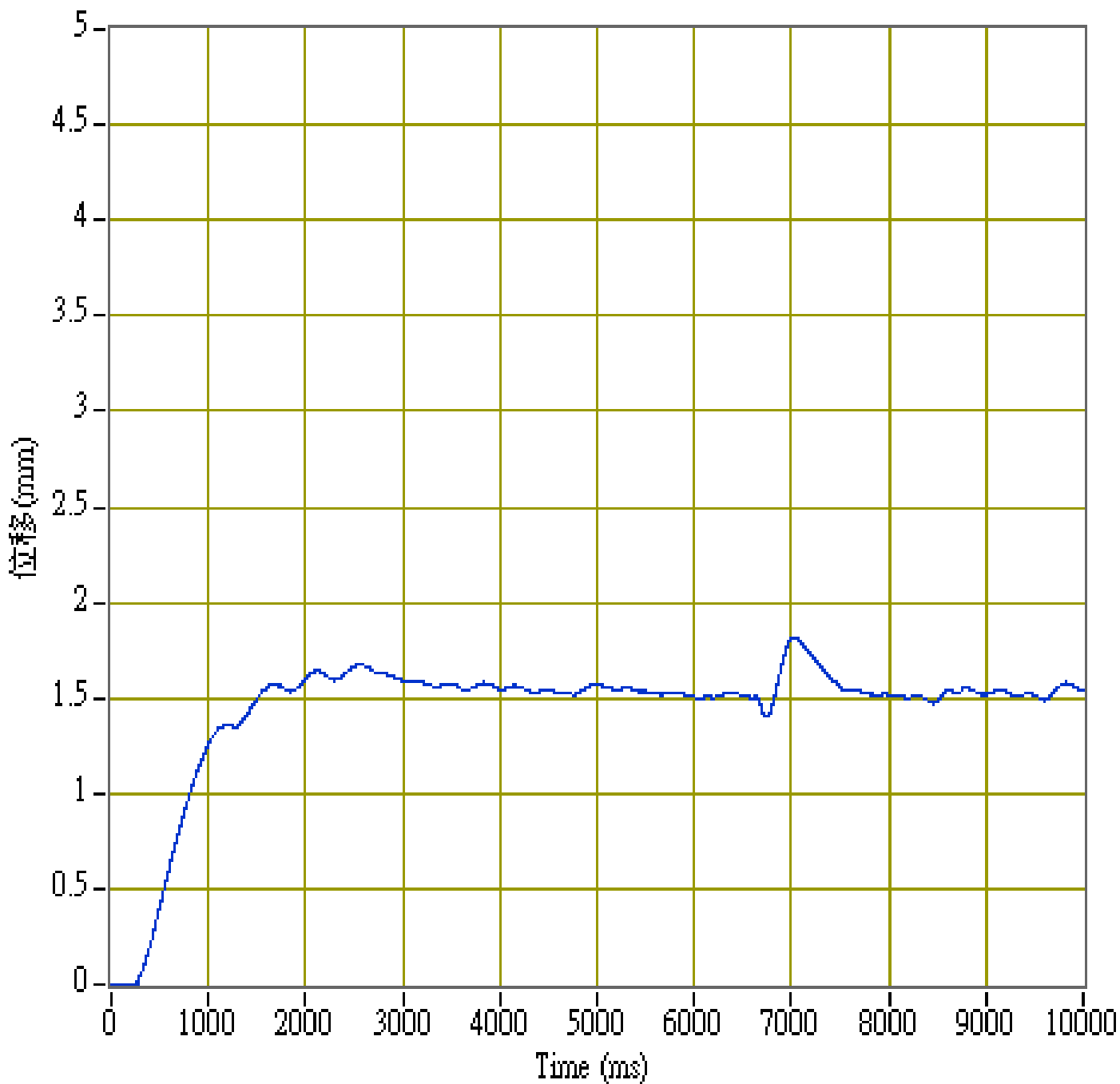


氣壓避震器位置PID控制系統方塊圖

如圖所示為使用比例方向閥分別定位於0.5mm~2.0mm之四種不同的位置做定位控制，其優點為可控制氣壓避震器在任何位置高度。



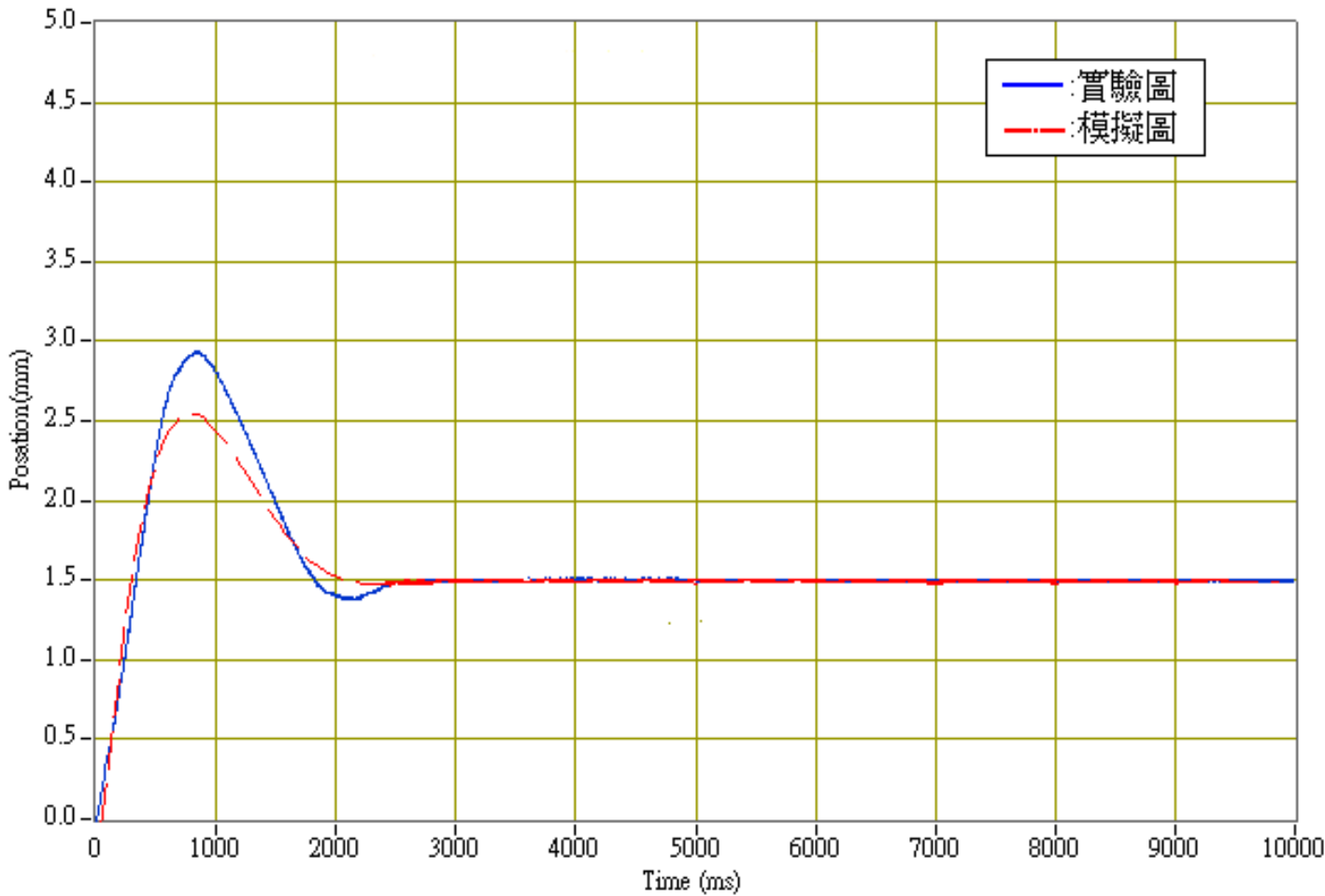
PID控制氣壓避震器分別定位0.5mm~2.0mm之動態響應圖



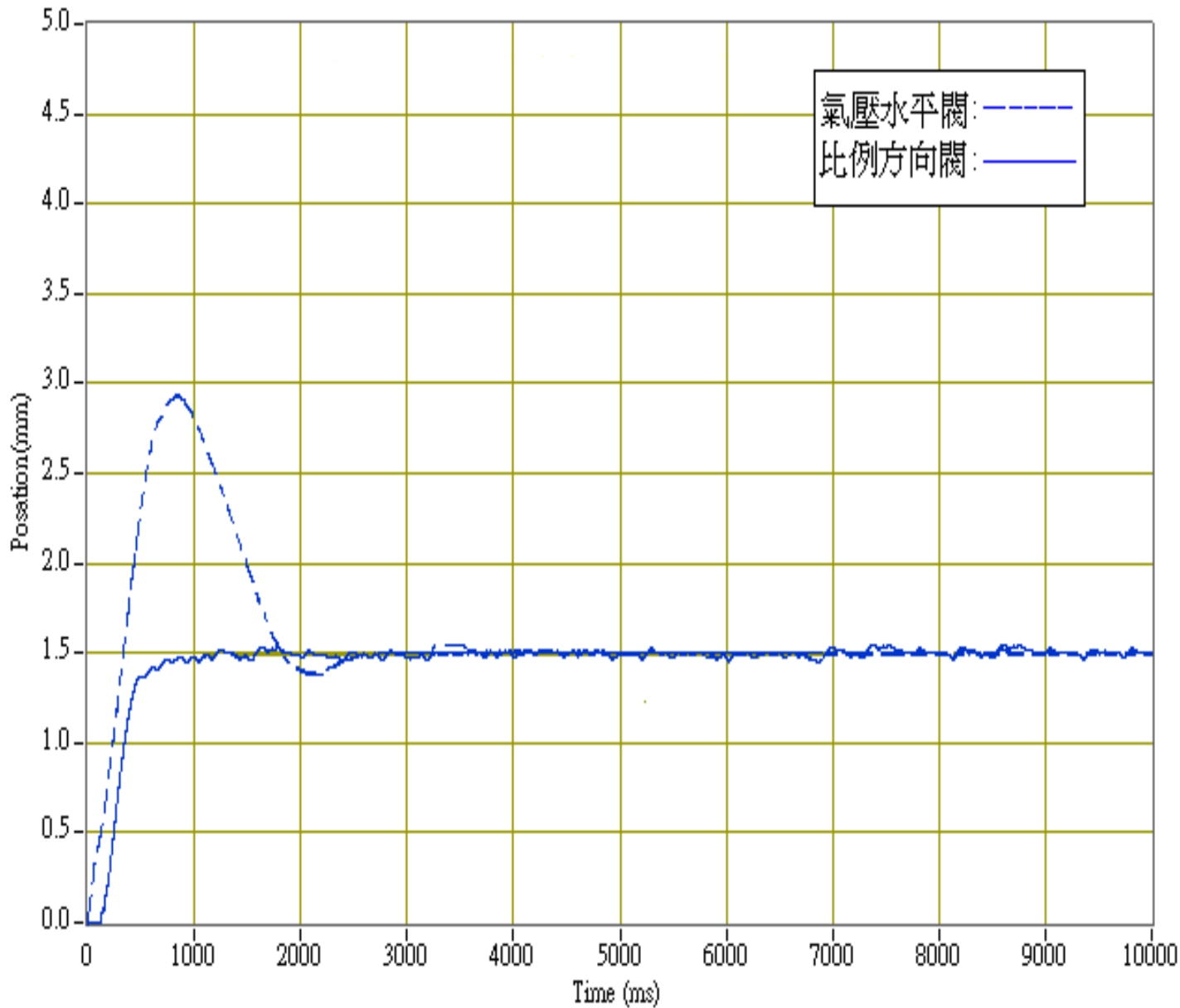
PID控制氣壓避震器施加重量 (2Kgw)
之動態響應圖

模擬與實驗結果討論

針對實際氣壓避震器內小孔節流口孔徑為0.5mm，進行模擬與實驗結果比較。

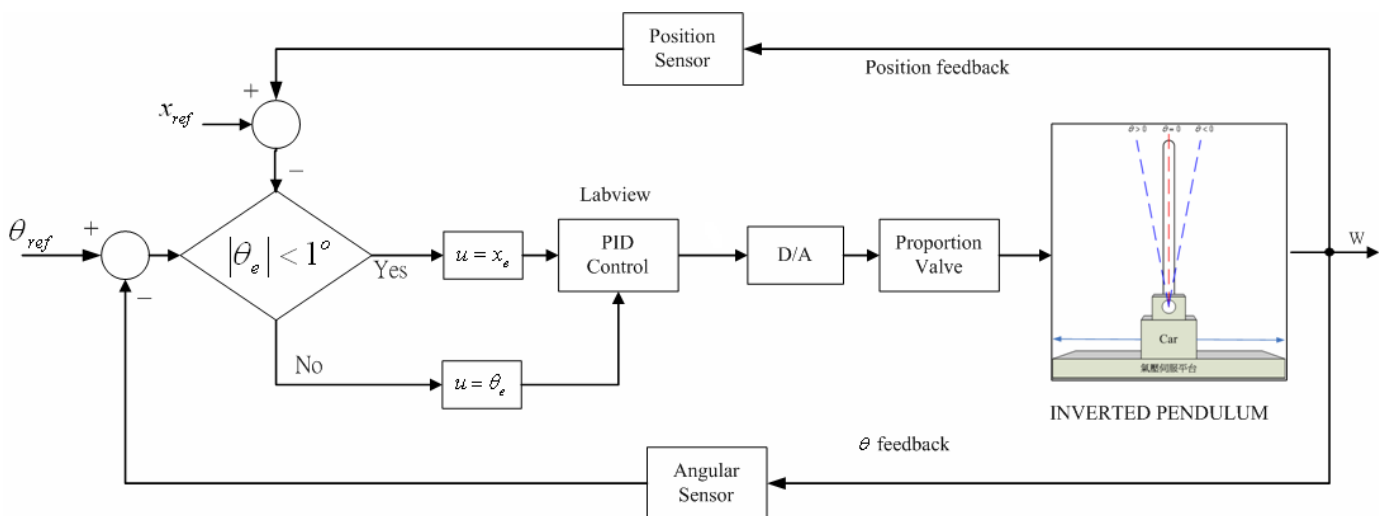


目標值	上升時間 t_r	安定時間 t_s	穩態誤差 e_{ss}
模擬 1.5mm	700ms	2100ms	0mm
實驗 1.5mm	800ms	2500ms	<0.1mm

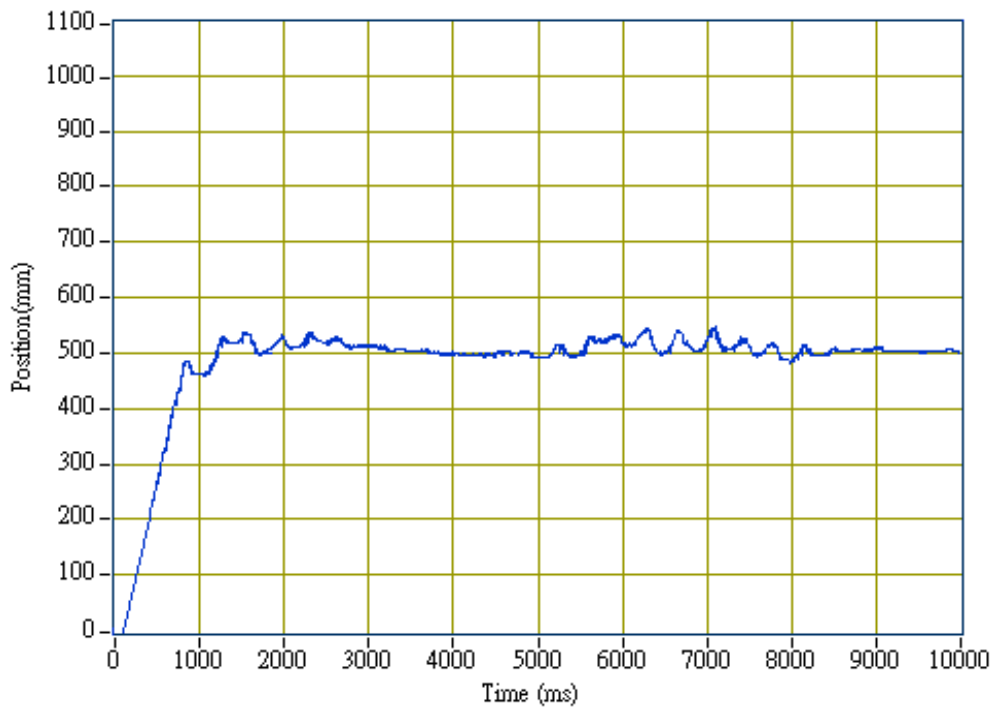
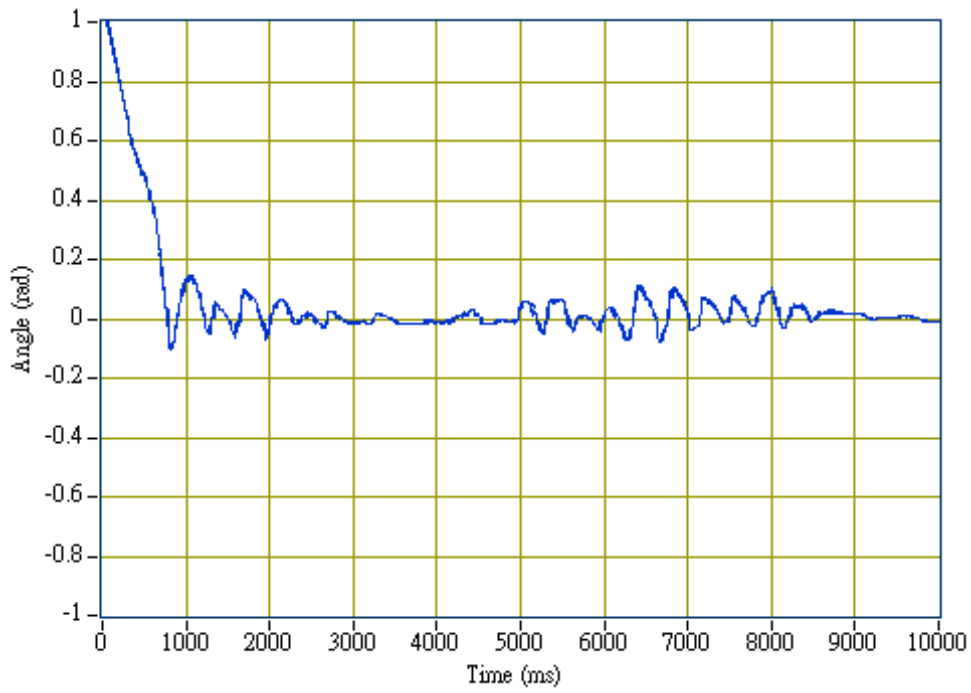


比例方向閥與機械式氣壓水平控制閥
定位1.5mm實驗值之比較圖

A -2 伺服氣壓倒單擺

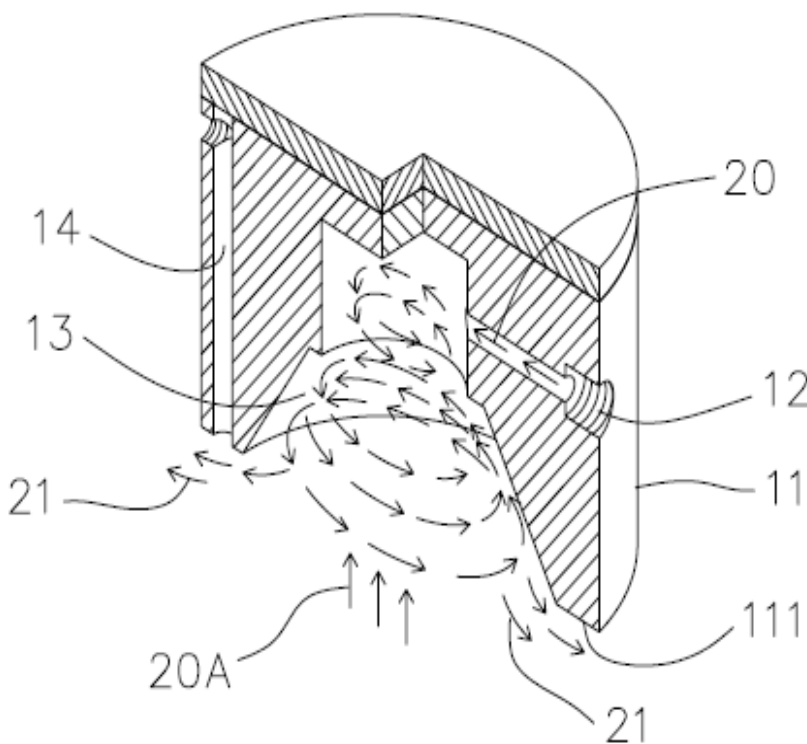


★控制邏輯順序是以角度控制為優先，接下來才是定位控制



A-3 無碰撞氣壓真空吸盤

旋轉氣場 (Vortex Levitation)

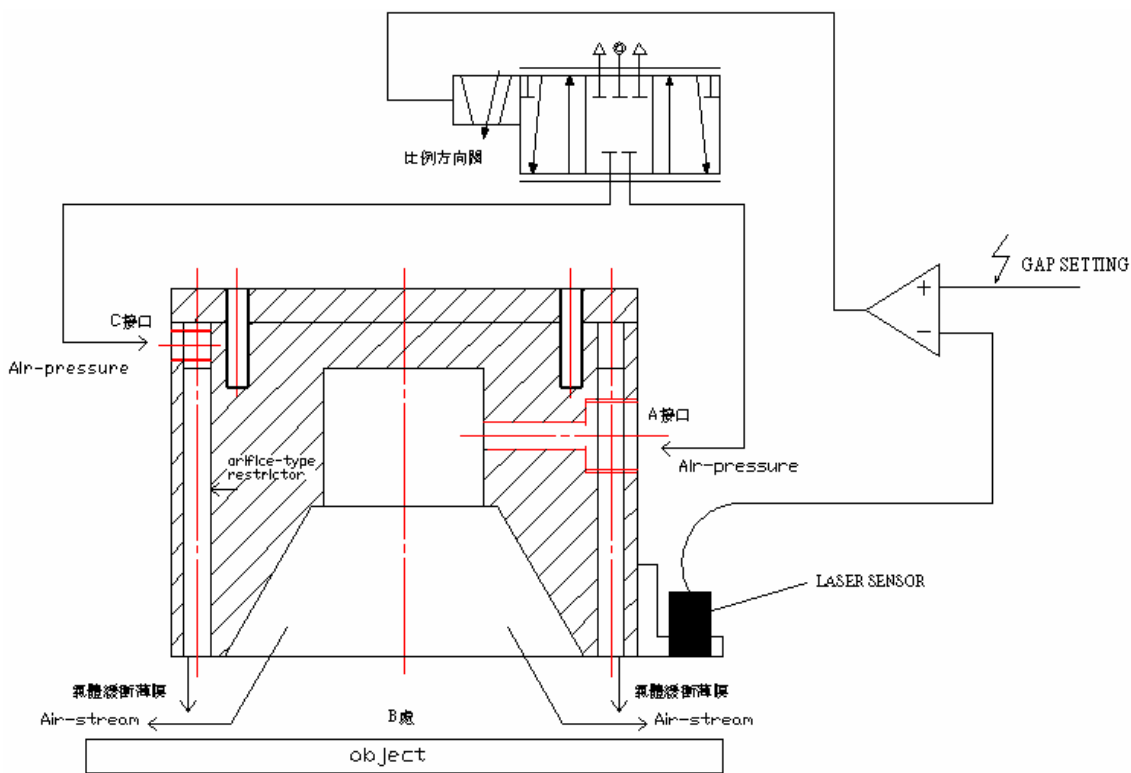


[1] 中華民國新型專利 M275054.

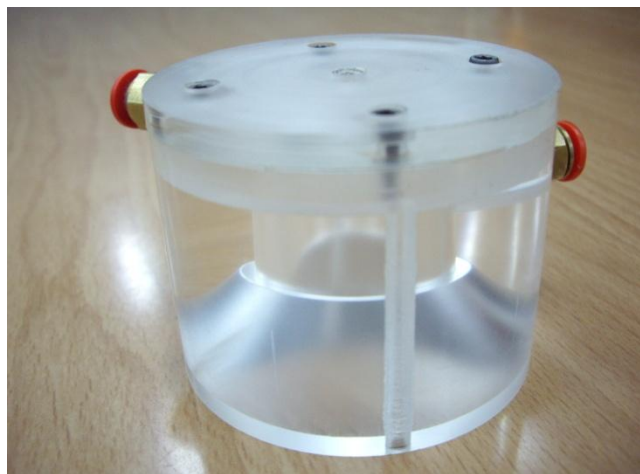
[2] 中華民國新型專利 M275053.

[3] 中華民國發明專利 I338084.

(3-1) 無碰撞氣壓真空吸盤

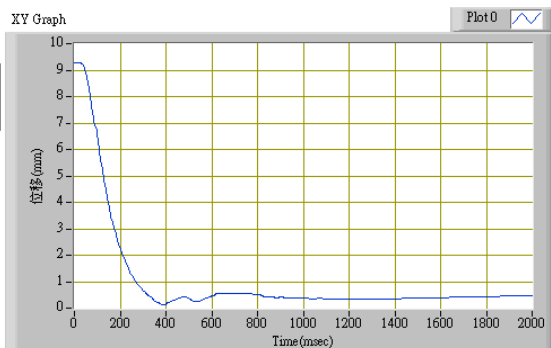


★利用氣壓比例方向閥切換吸盤吸力輸出或小孔斥力輸出



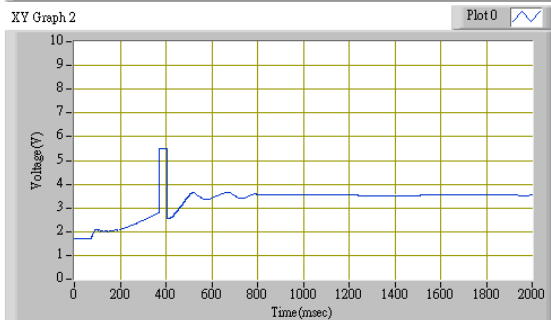
Gap

0.55

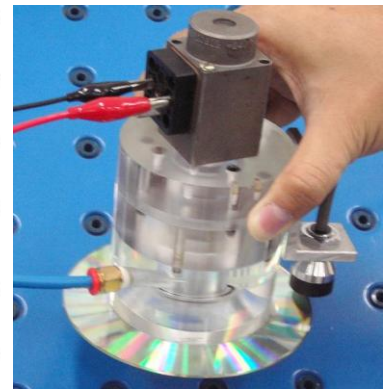
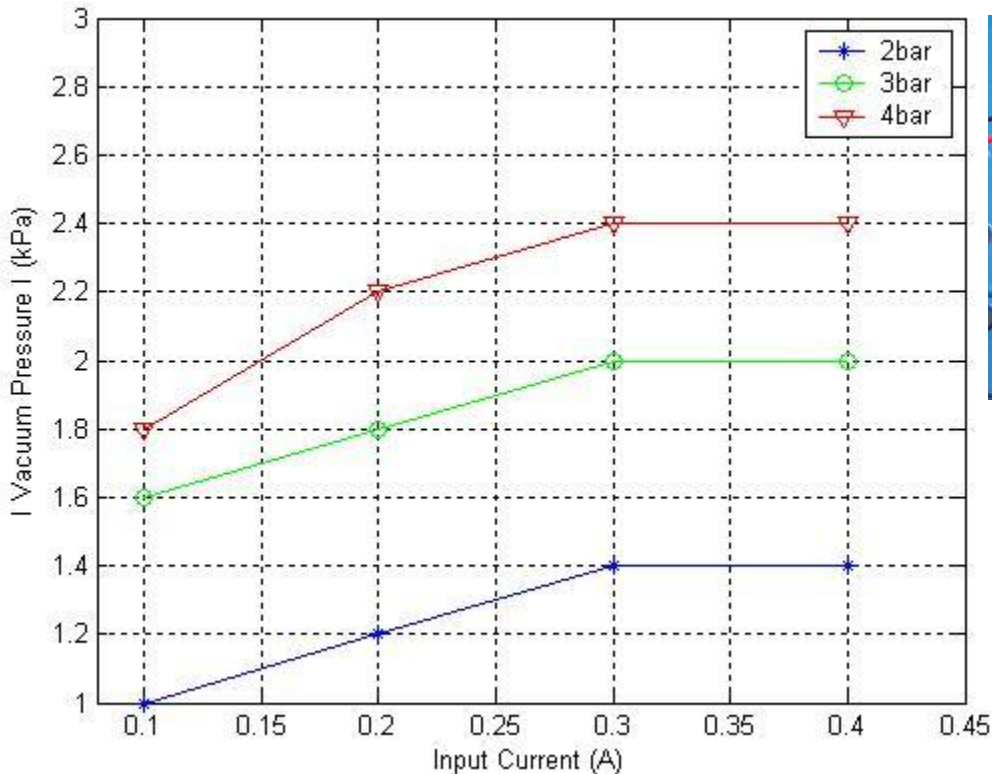
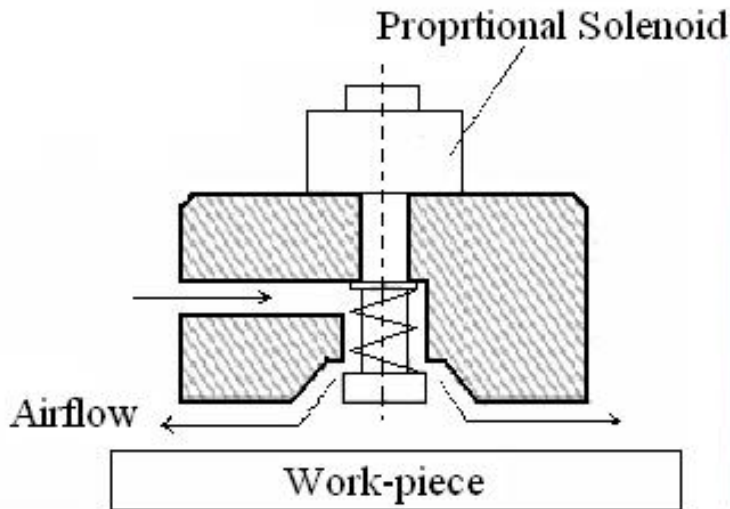


Voltage

3.5



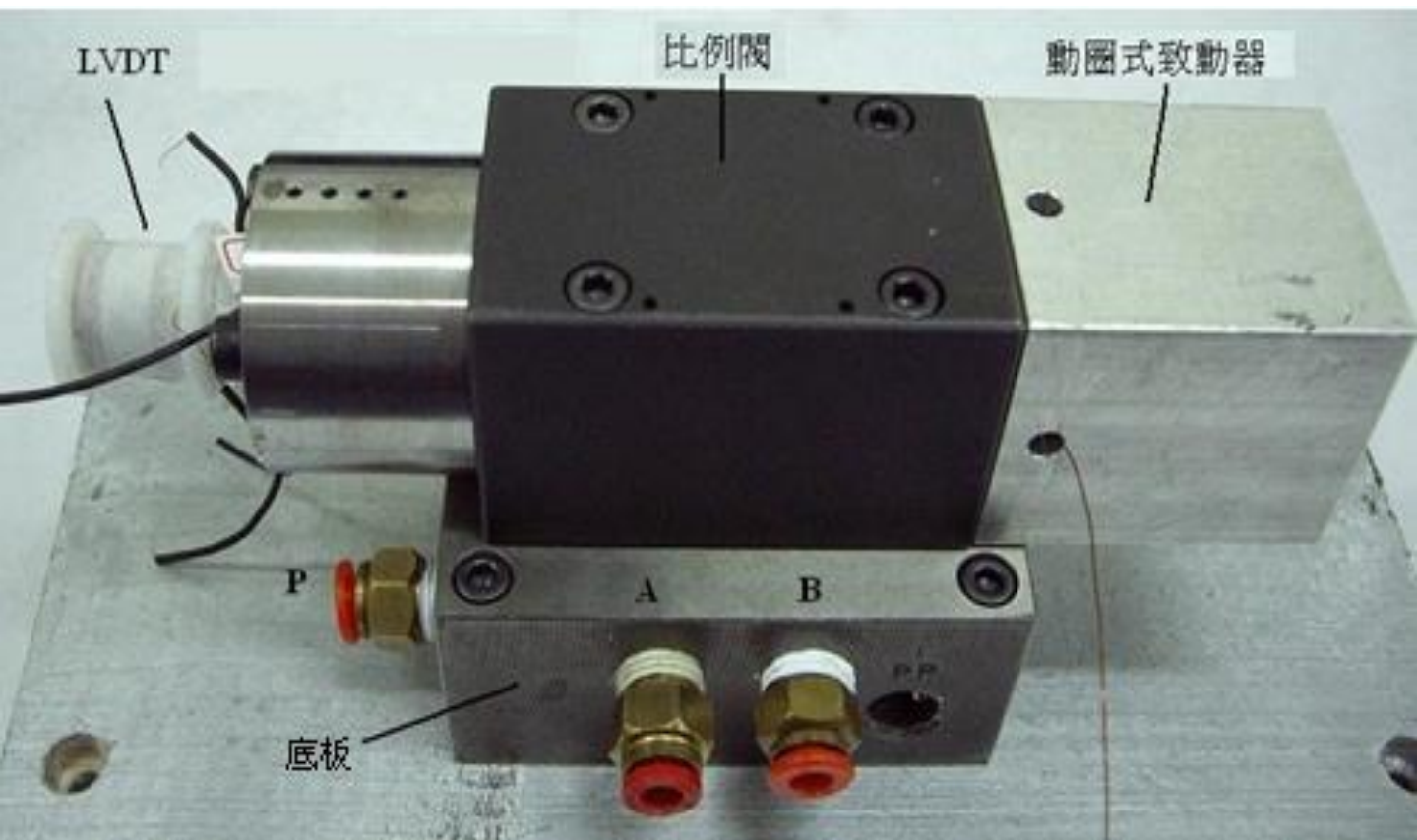
(3-2) 比例控制氣壓真空吸盤



Absolute value of vacuum pressure versus
input excitation current

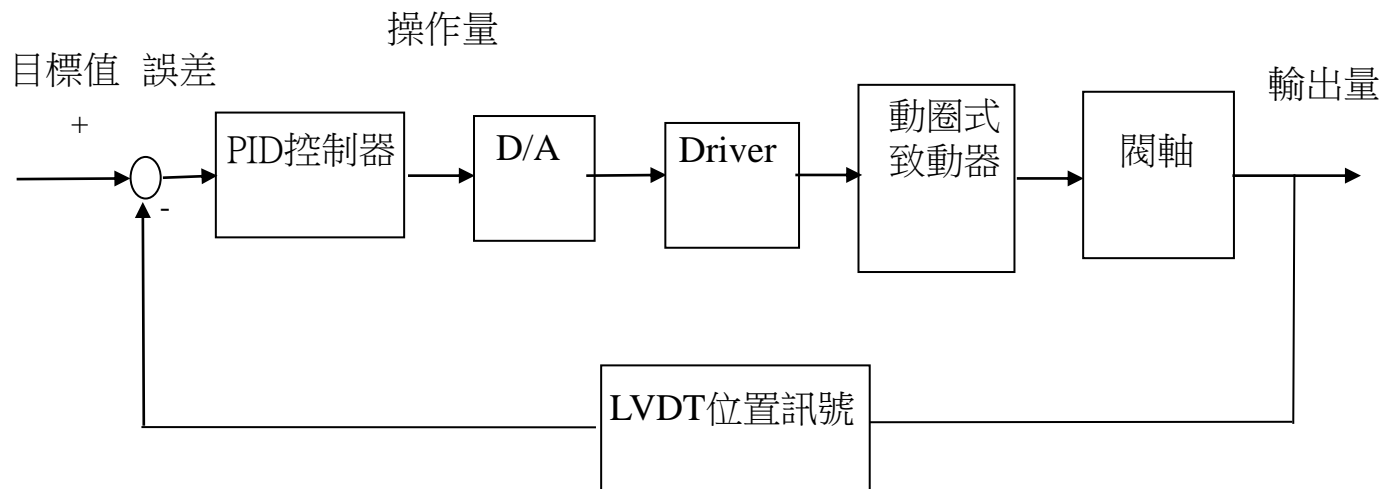
A-4 閉迴路動圈式氣壓比例閥

- ★ 自行設計之動圈式致動器搭配型號NG03比例閥閥體
- ★ 結合自行製作之LVDT(線性行程為0~6 mm)作為閉迴路控制
- ★ 達成具有高速響應及高定位精度雙重功能之動圈式氣壓比例閥

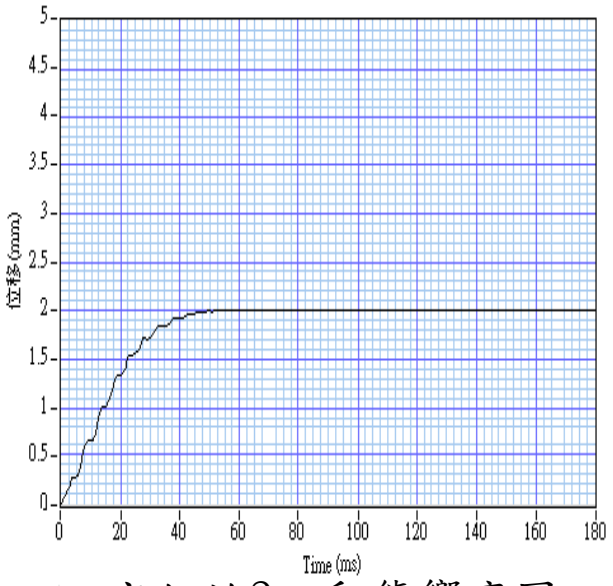


閉迴路動圈式氣壓比例閥之實體圖

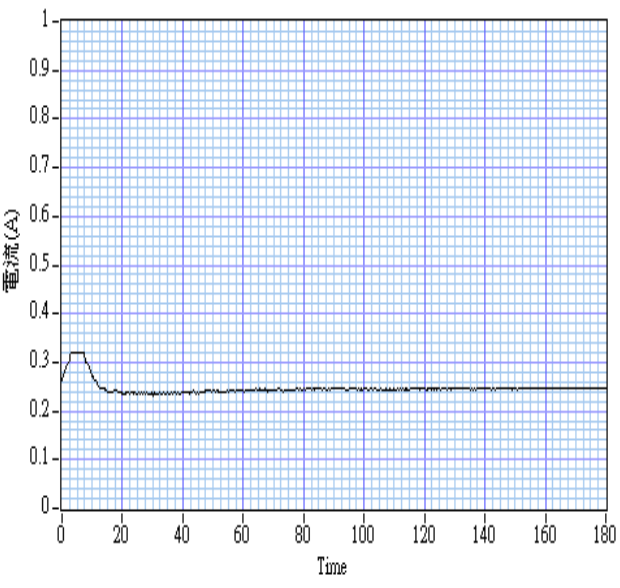
利用電腦 LabView 圖控程式將激磁訊號透過資料擷取卡數位類比 (D/A) 傳輸至驅動器 (Driver) 產生電流後，激磁動圈式致動器，進而推動閥軸，利用LVDT讀取閥軸移動之距離值做為迴授訊號，來進行 PID 控制，動圈氣壓比例閥PID控制系統方塊圖如下圖所示，其中輸入給 PID 控制器的訊號為目標值減去LVDT之位置迴授所得到之誤差訊號。



動圈式氣壓比例閥 PID 控制系統方塊圖



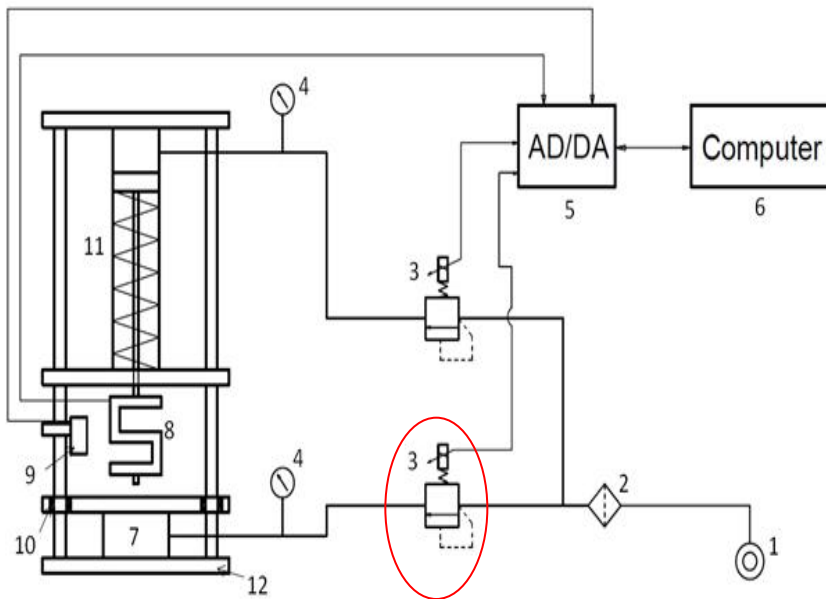
定位於2mm動態響應圖
(空載下)



定位於2mm電流圖
(空載下)

目標值	4mm	3mm	2mm
延遲時間 $t_d (0 \sim 50\%)$	23.7 4ms	17.8 9ms	16.5 3ms
安定時間 $t_s (e_s < 1\%)$	73.2 5ms	62.2 3ms	50.0 2ms
穩態誤差 e_{ss}	<10μm	<10μm	<10μm

A-5 精密比例式氣體軸承

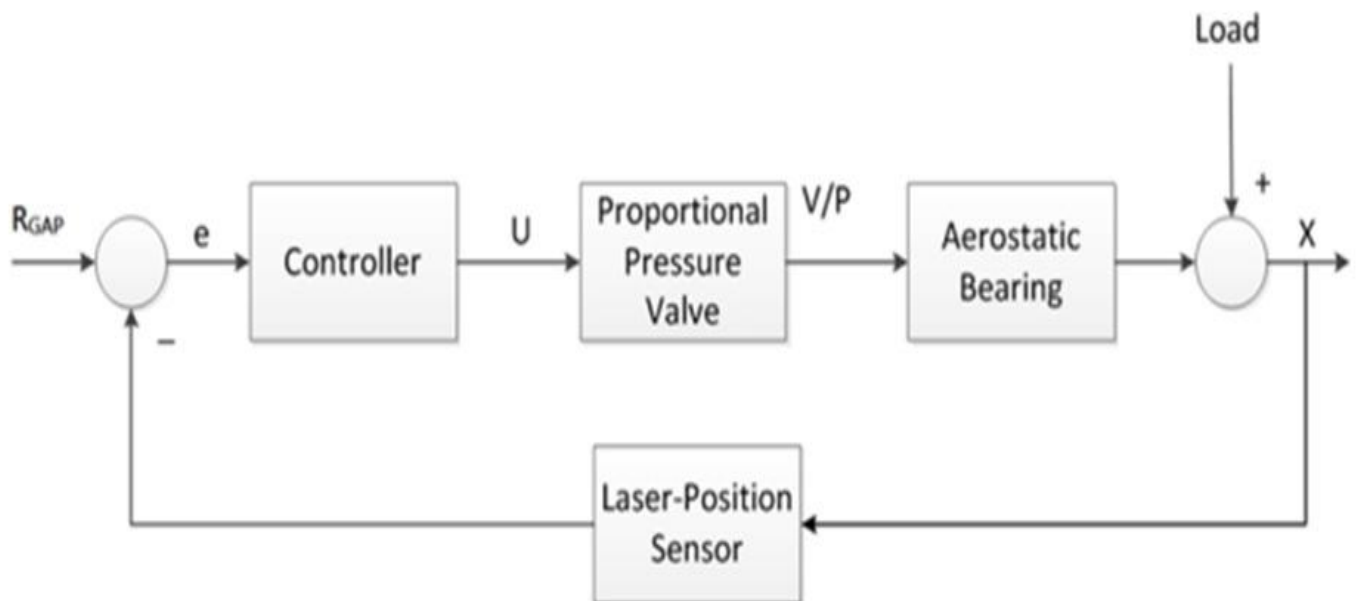
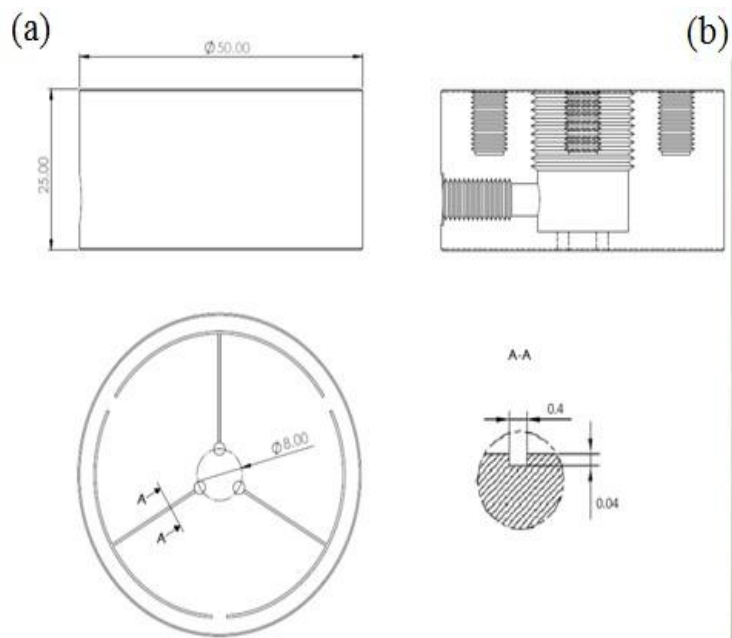


- | | |
|--|--------------------------------------|
| 1. Air Supply | 7. Tested Aerostatic Bearing |
| 2. Filter | 8. Load Cell |
| 3. Proportional Pressure Control Valve | 9. Laser Position Sensor |
| 4. Pressure Gauge | 10. Linear Ball-Screw Bearing |
| 5. Data Acquisition Interface Card | 11. Single-Acting Pneumatic Cylinder |
| 6. PC-based Controller | 12. Ground Platform |

(a)

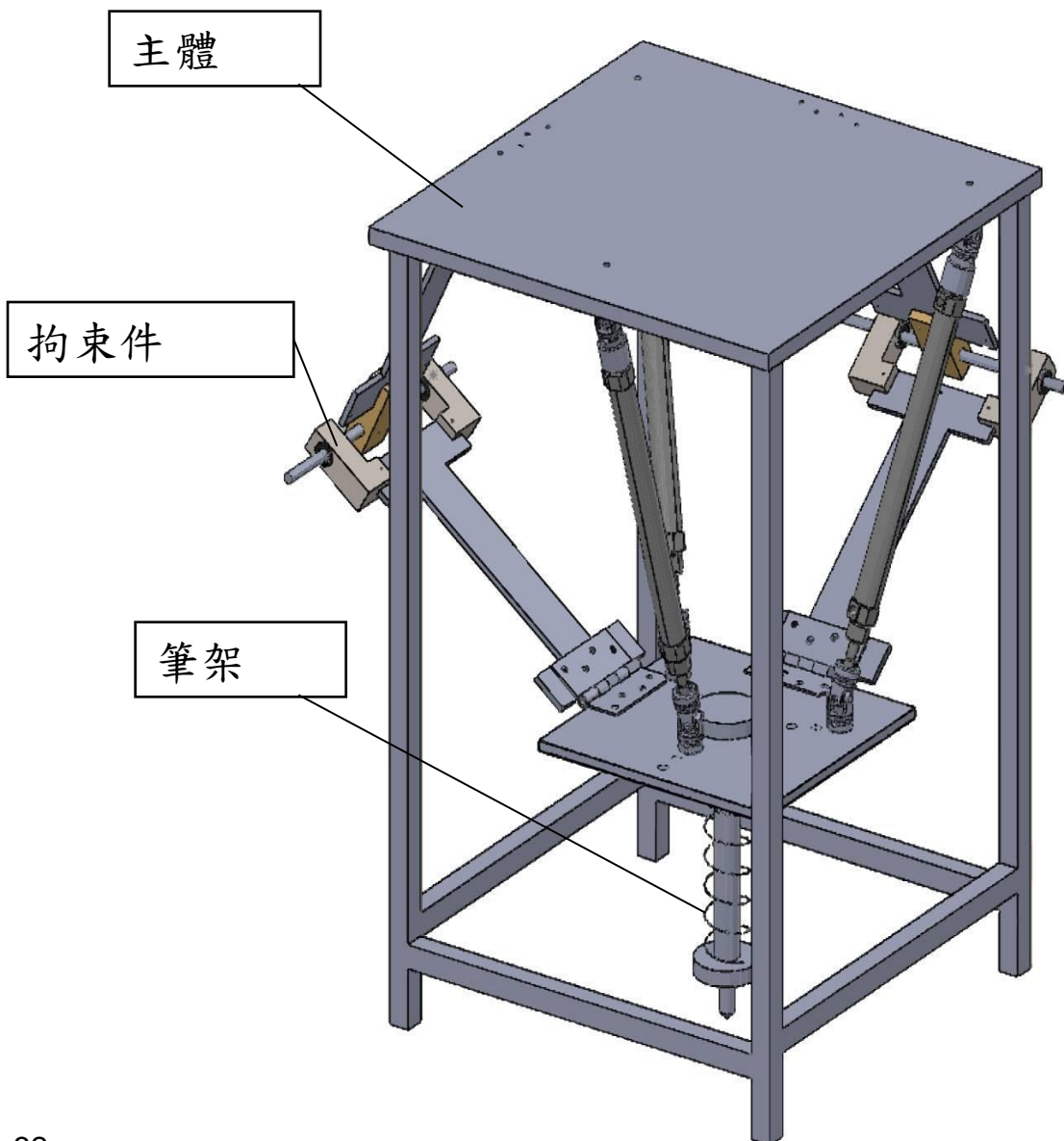


(b)

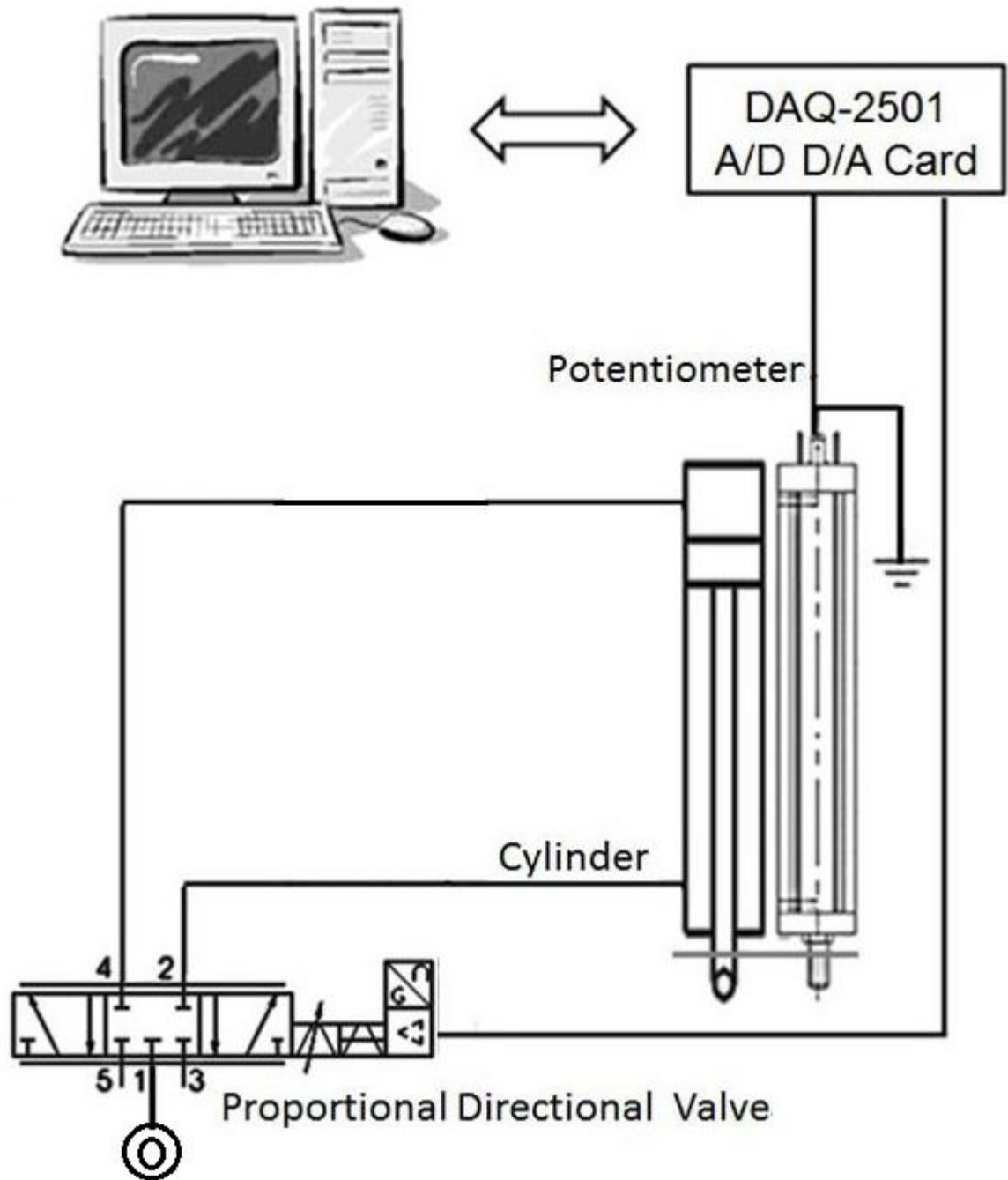


A-6 伺服氣壓三軸平台

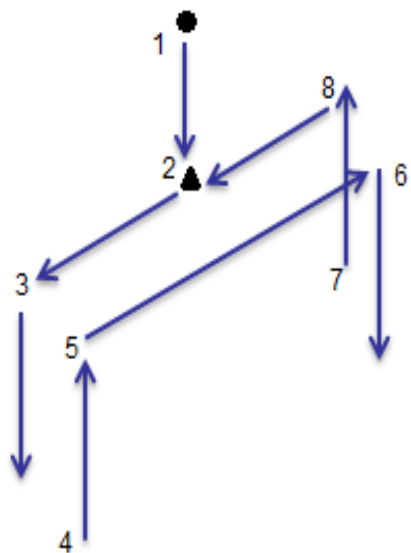
- 伺服氣壓三軸平台為一封閉並聯式連桿機構，其機構分為主體、拘束件和紀錄軌跡用之筆架。



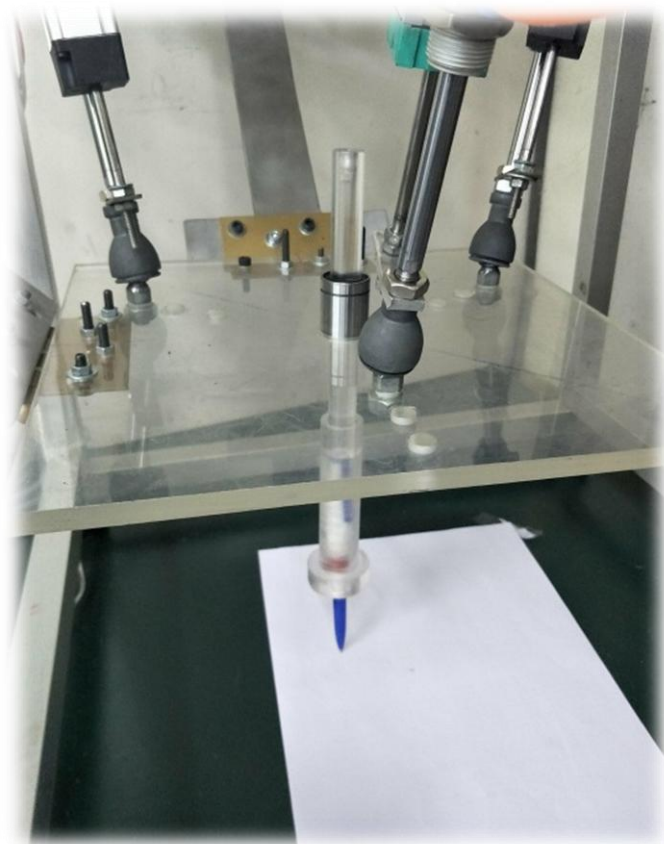
單軸控制之硬體迴路架構圖



取放動作之示意圖

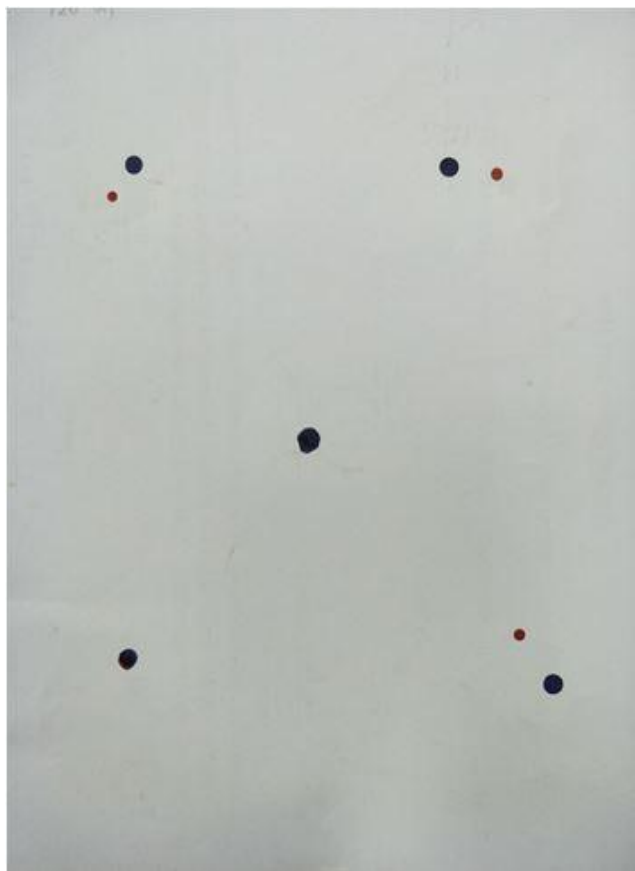


影片之依序動作



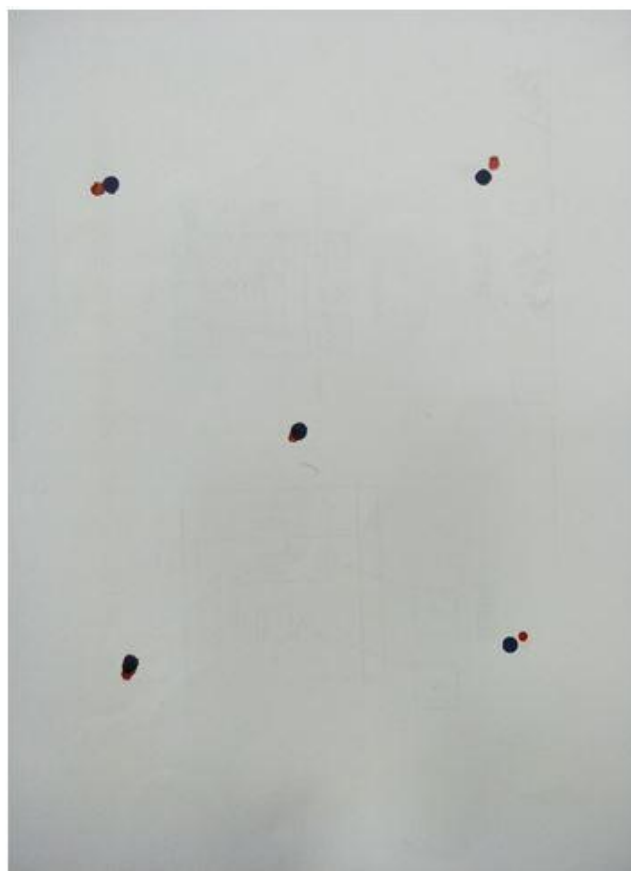
閉迴路取放(Pick and Place) 位置控制

平均誤差為9.1%



(a)最高速度為80mm/s

平均誤差為4.85%

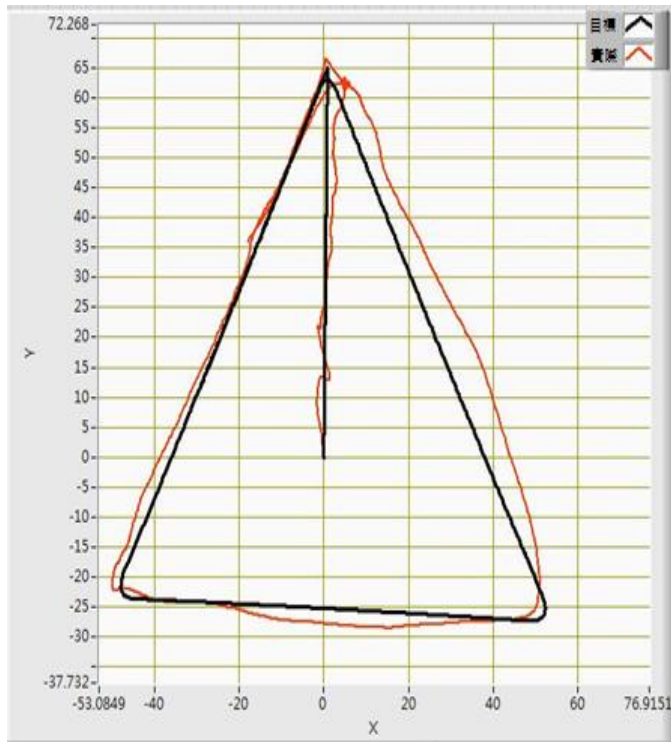


(b)最高速度為55mm/s

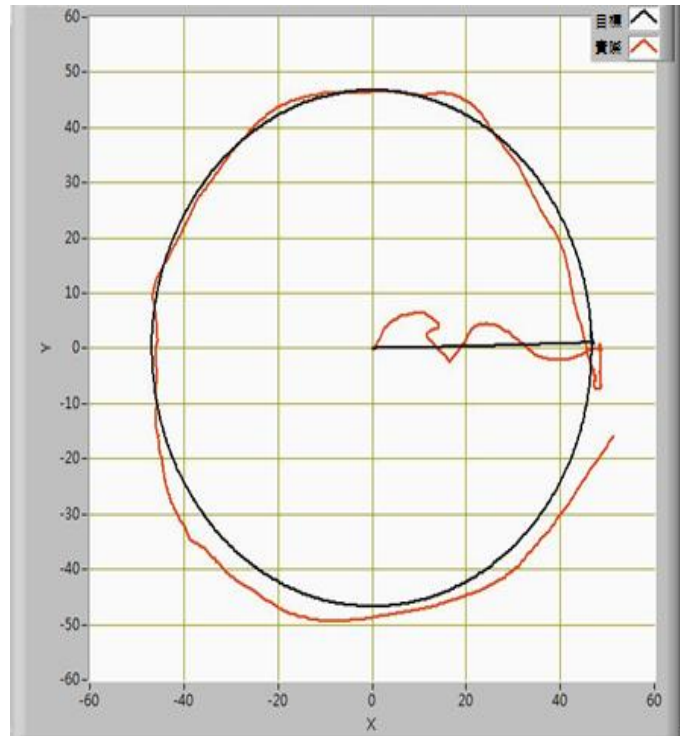
不同速度下在四個象限的移動結果

閉迴路軌跡控制

平均誤差為6.4 %



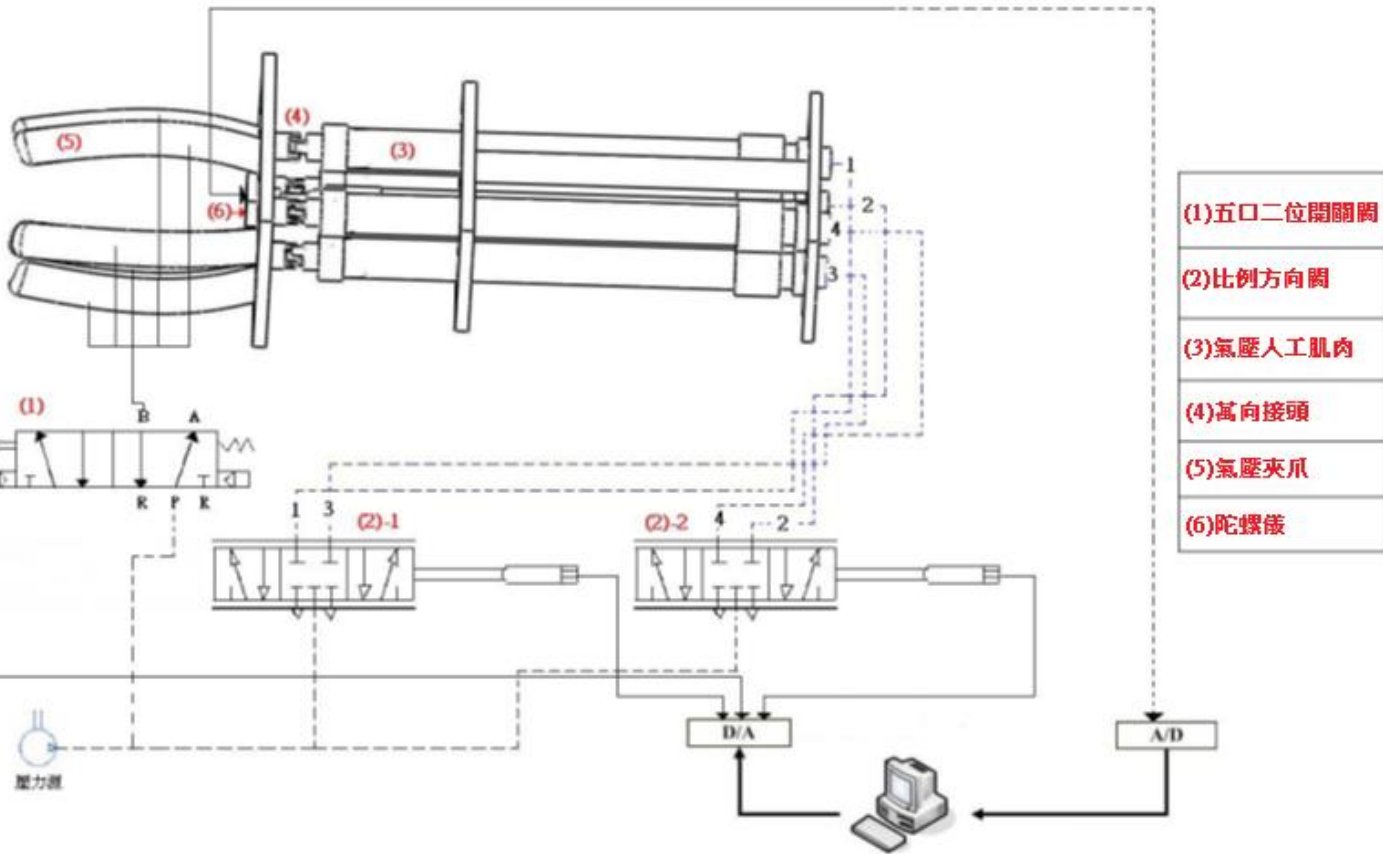
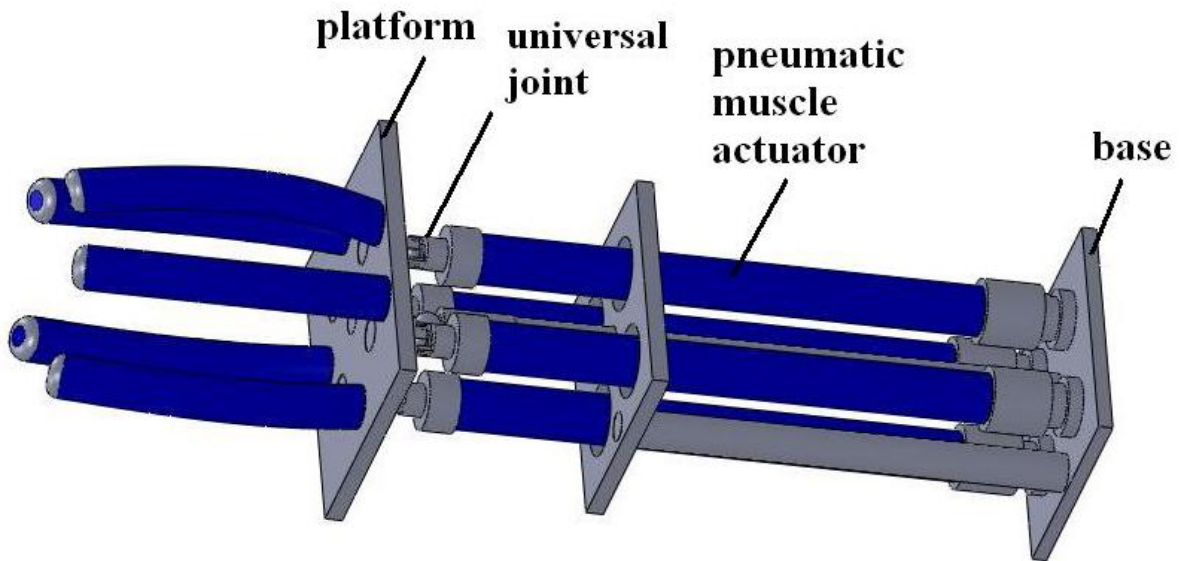
平均誤差為4.2%



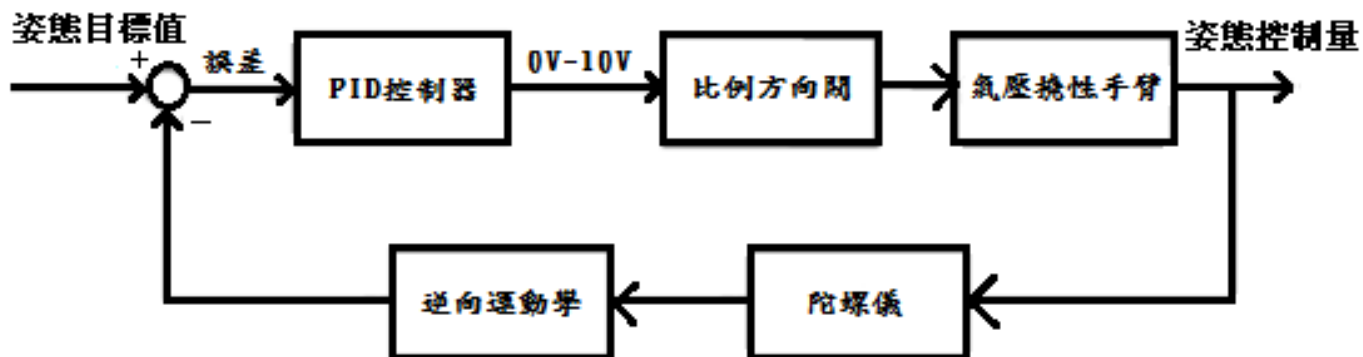
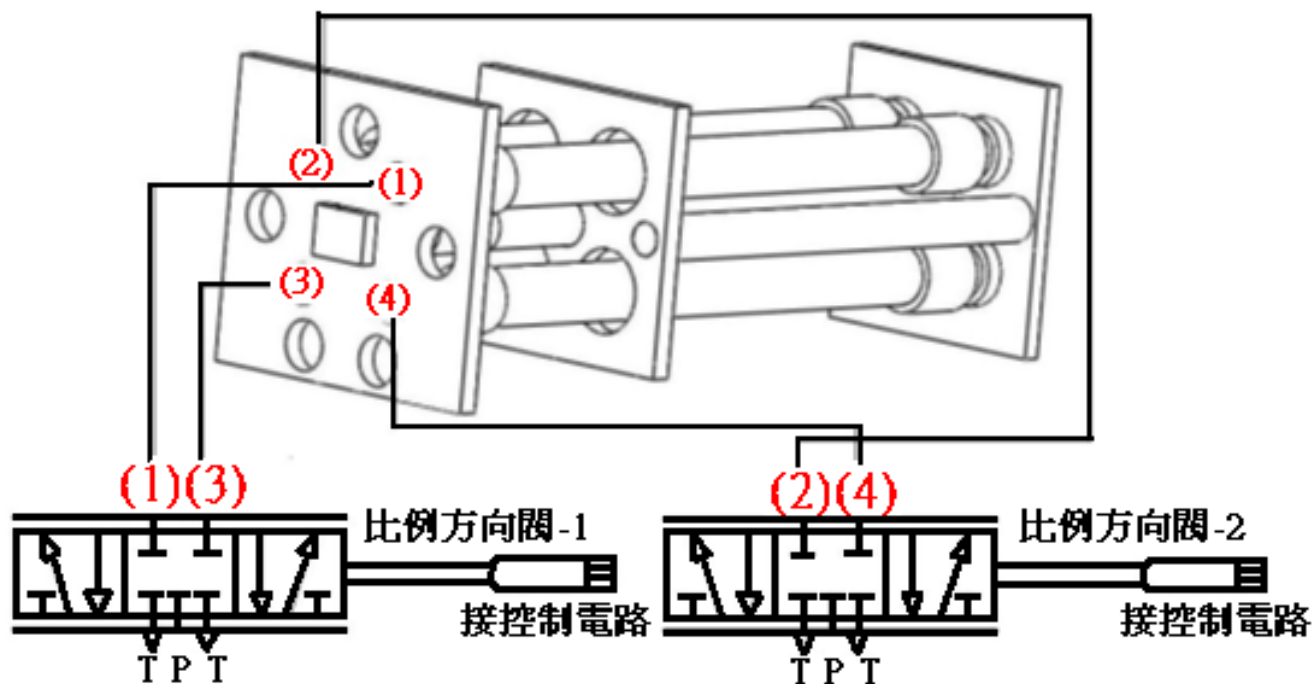
軌跡為三角形平面的實測圖
平均速度為58.6mm/s

軌跡為圓形平面的實測圖
平均速度為42.86mm/s

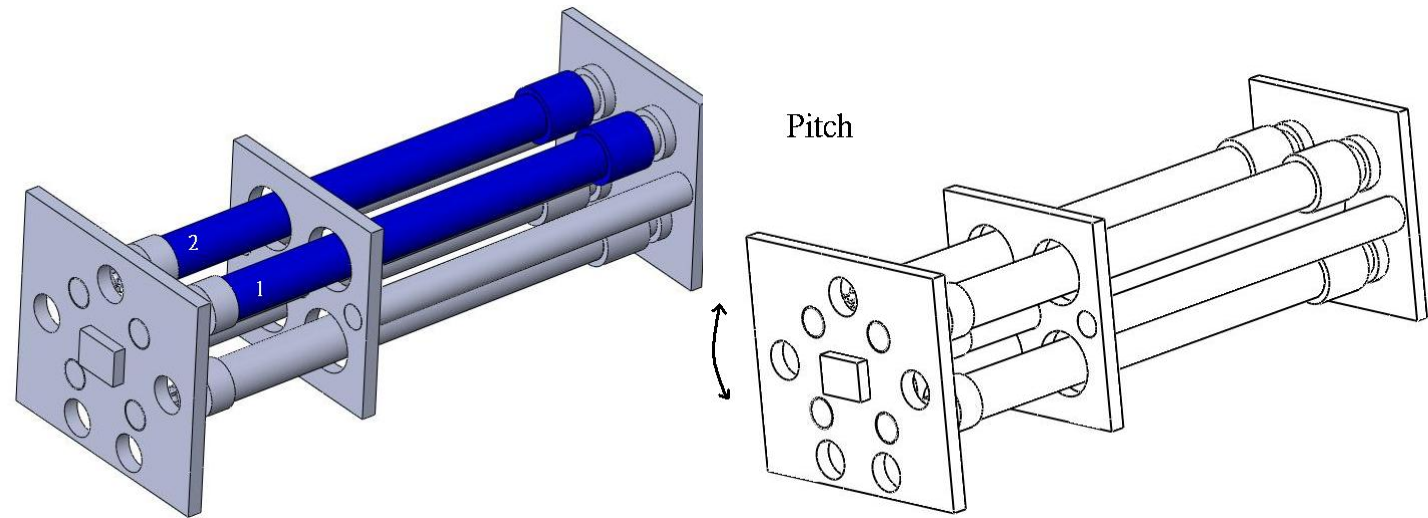
A-6 並聯式氣壓撓性手臂



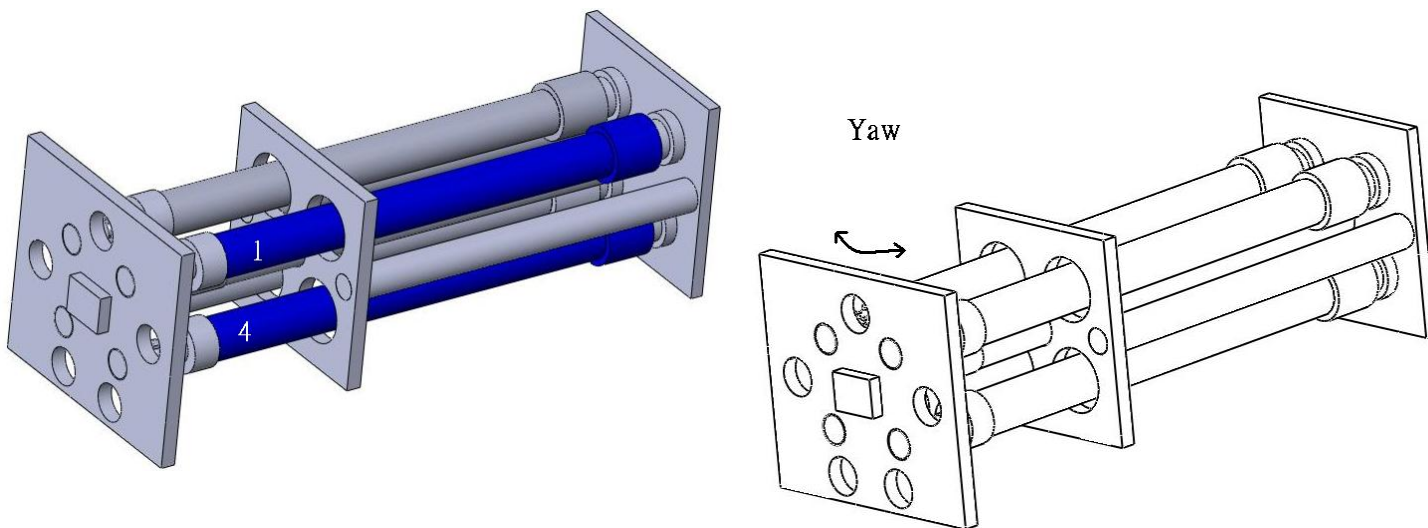
Scheme and Block Diagram:



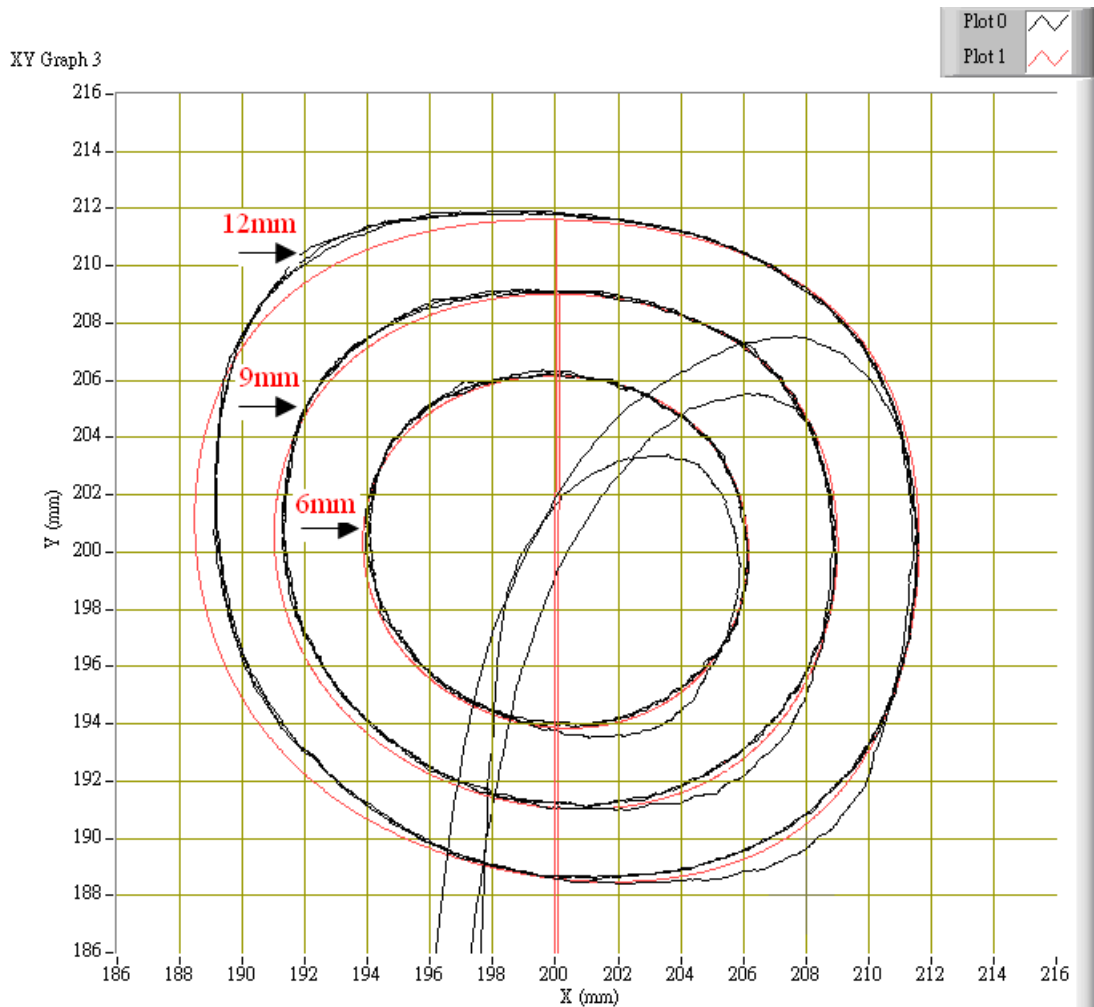
★ Pitch (上下) Control : 控制第1支及第2支



★ Yaw (左右) Control : 控制第1支及第4支

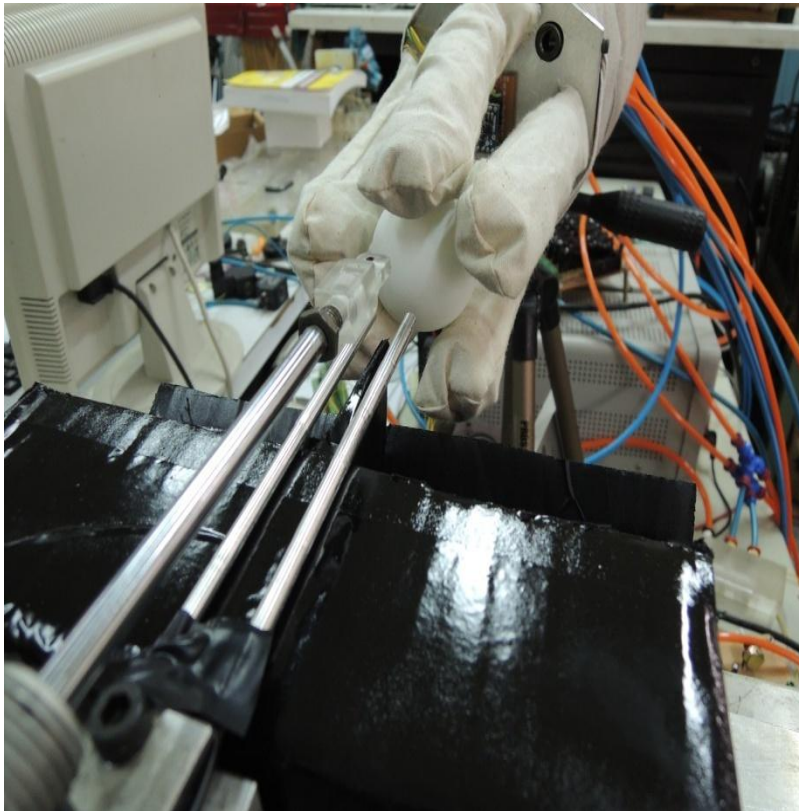
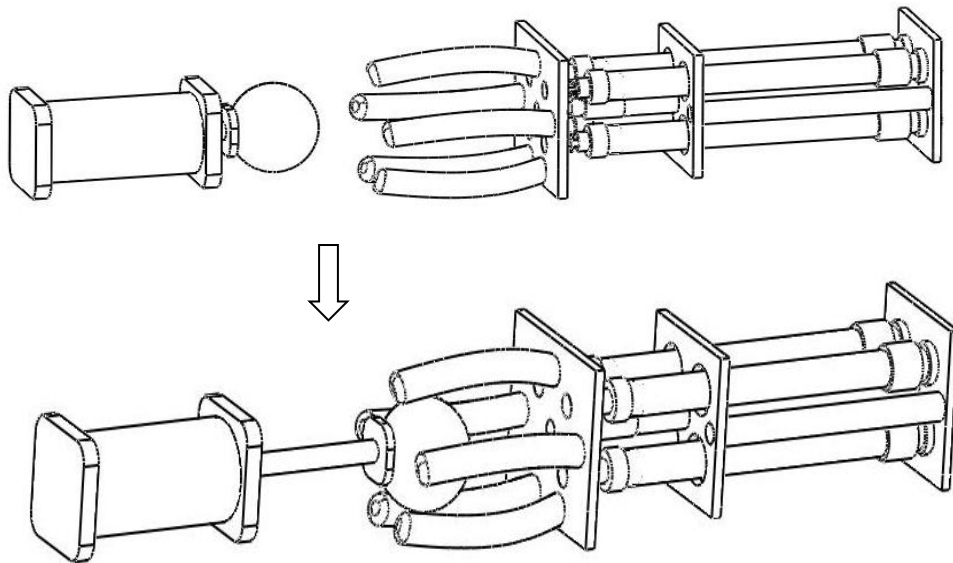


★以中心點為圓心半徑6, 9, 12mm之循圓實驗圖



氣壓夾爪設計

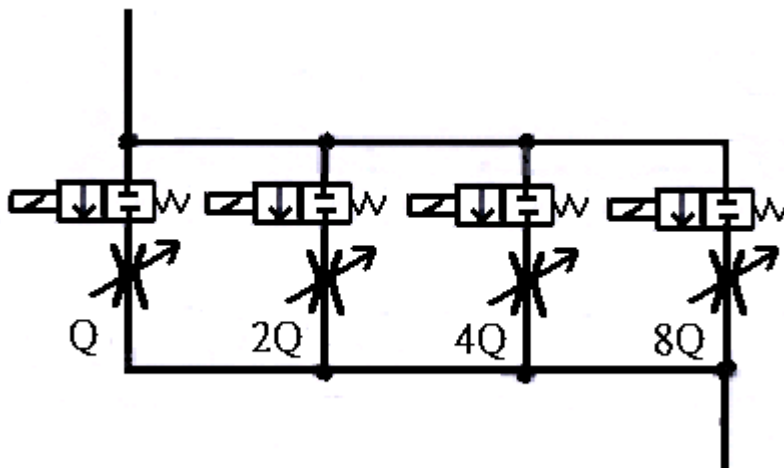
氣壓夾爪主要是由一5/2開關閥來控制，氣壓夾爪統一使用4 bar的壓力來控制其夾取，**彎曲角度大約可達30度**



A-7 全數位化控制技術

(Full-digital Proportional Control)

- Features: 1.First developed in 1980s
2.Further developed in Finland since 2000
3.Alternative of closed-loop servo control
4.Successful application in fluid power control (including pneumatic, hydraulic and water-hydraulic systems)
- Surveying some previous reports, it can be confirmed that the concept of full-digital control structure can be found in early 1980s. However, this control structure was not considered to be promising because the global digital revolution just began and was not fully developed at that time. Therefore, it was definitely not suitable for the realization of the full-digital proportional fluid power control system. Nowadays, however, the digital revolution covers all fields of technology, entertainment and other aspects. In addition, some 2/2 switching valves are well-developed with small dimension. Thus, it may be concluded that the full-digital control structure is ready for the application to the fluid power servo control system.
- Basic theory :
Ex: The Binary Coding System



- The details of binary coding :

BinaryDFCU					
Net flow	valve 1,Q	valve 2,2Q	valve 3,4Q	valve 4,8Q	State
0	0	0	0	0	0
1xQ	1	0	0	0	1
2xQ	0	1	0	0	2
3xQ	1	1	0	0	3
4xQ	0	0	1	0	4
5xQ	1	0	1	0	5
6xQ	0	1	1	0	6
7xQ	1	1	1	0	7
8xQ	0	0	0	1	8
9xQ	1	0	0	1	9
10xQ	0	1	0	1	10
11xQ	1	1	0	1	11
12xQ	0	0	1	1	12
13xQ	1	0	1	1	13
14xQ	0	1	1	1	14
15xQ	1	1	1	1	15

Pneumatic motor speed control using binary coding system

Experimental Device :

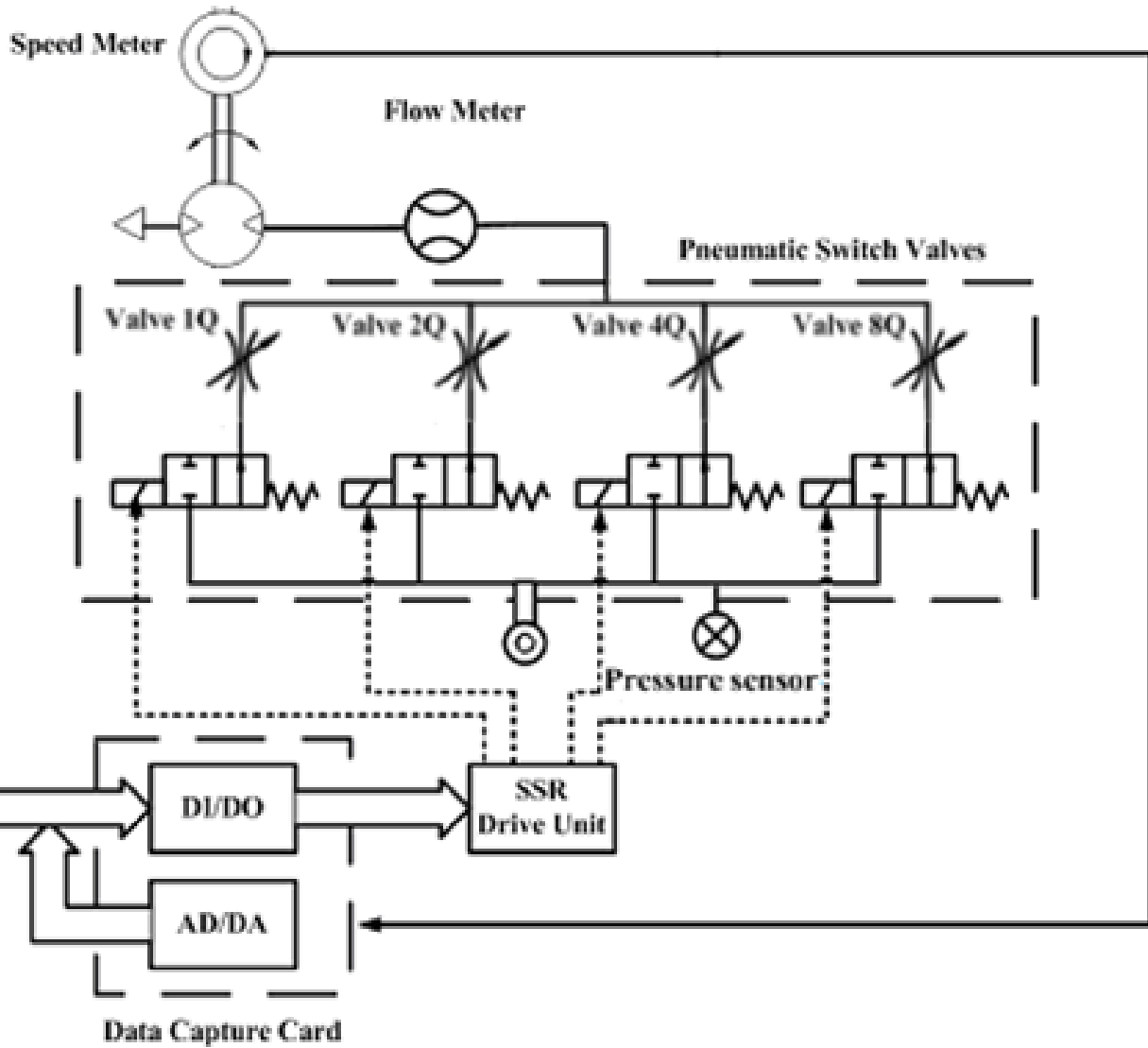


Pneumatic motor

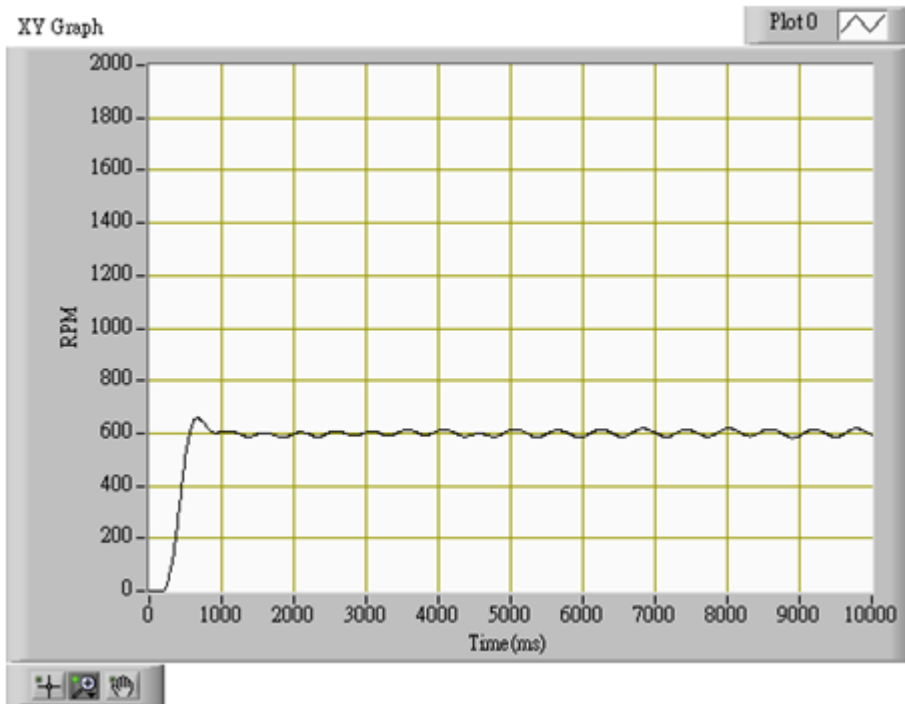


2/2 Switching valve

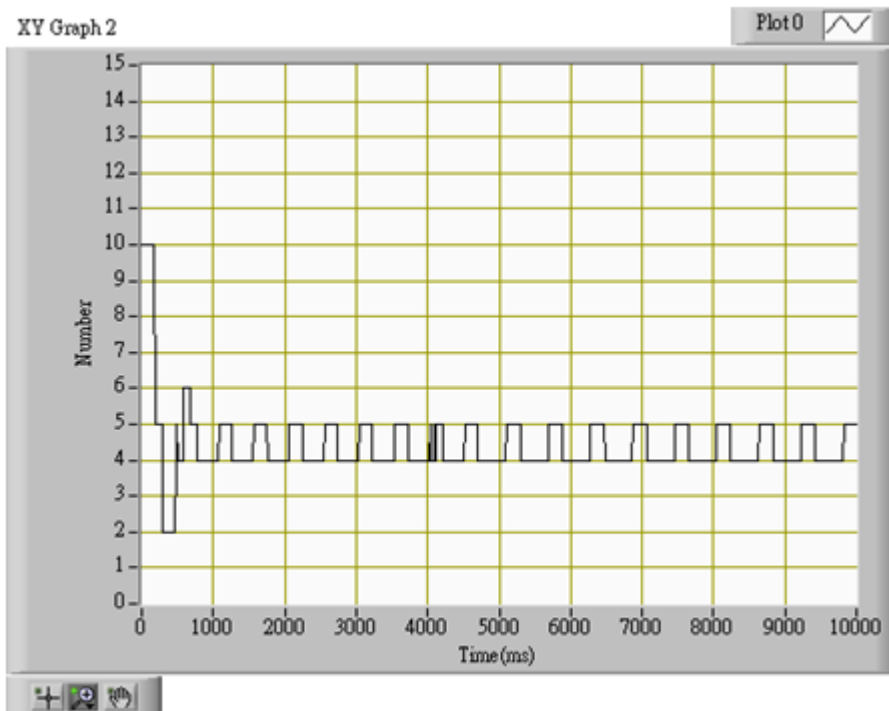
Circuit diagram



Experimental results (1) – Time response

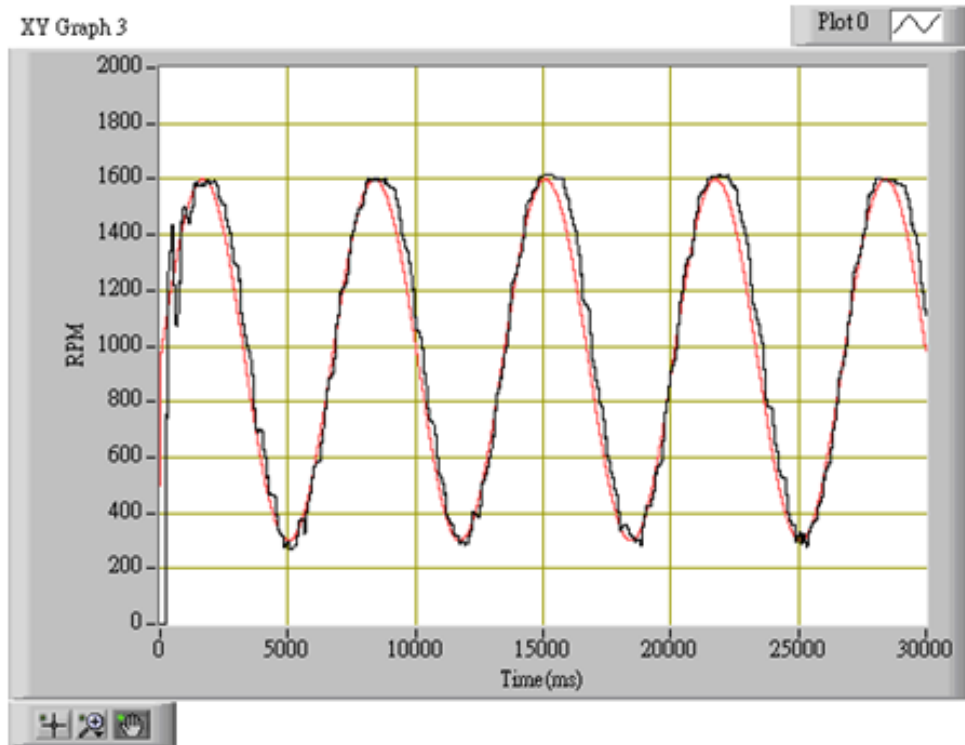


Desired speed : 600 rpm

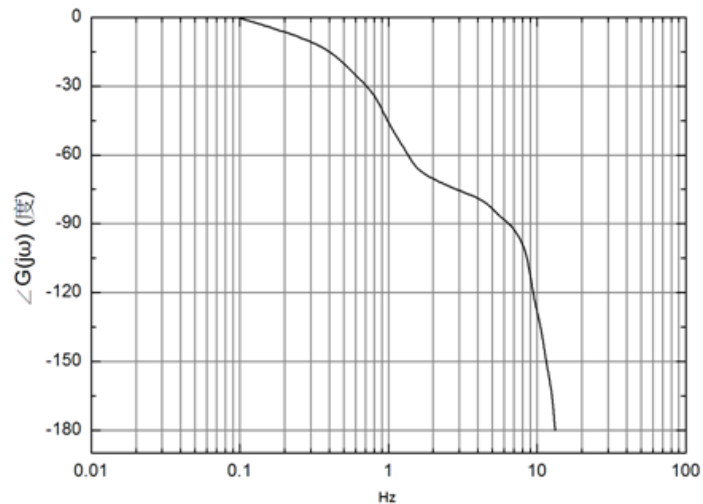
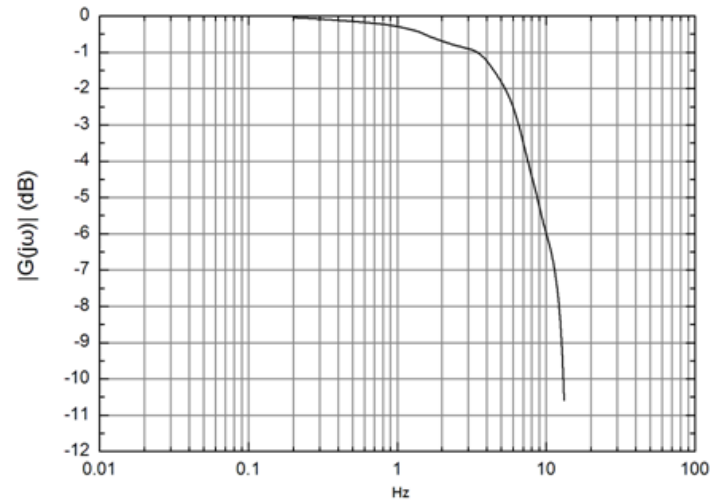


Number of resolution steps

Experimental results (2) – Frequency response



$$f = 0.83\text{Hz}$$



-3db所對應的頻寬為6.5Hz



課程結束

謝謝

Q & A