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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計畫類別：☑個別型計畫　　□整合型計畫

計畫編號：NSC 89－2218－E－041－003

執行期間： 89 年 8 月 1 日至 90 年 7 月 31 日

計畫主持人：徐宏修

共同主持人：黃永茂

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- ☑出席國際學術會議心得報告及發表之論文各一份
- □國際合作研究計畫國外研究報告書一份

執行單位：嘉南藥理科技大學資訊管理系

中 華 民 國 90 年 10 月 1 日

行政院國家科學委員會專題研究計畫成果報告

齒栓與齒輪近淨形鍛造製程之研究

A Study on Near Net Shape Forging of Spline and Gear

計畫編號：NSC 89-2218-E-041-003

執行期限：89 年 8 月 1 日至 90 年 7 月 31 日

主持人：徐宏修　嘉南藥理科技大學資訊管理系

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一、中文摘要

本研究以上界限法來對圓柱形胚料鍛製齒栓和正齒輪時作一理論解析。在建構齒栓和正齒輪精密鍛造的數學模式時，使用剛塑性變形模式，考慮了齒形模的幾何形狀、以及胚料在齒形模內，受模摩擦影響產生的非均勻變形及桶狀效應，並預估圓柱胚在齒栓和正齒輪精密鍛造時所承受之負載。本文詳細地探討了磨擦因數、初始半徑、高度比、齒數等加工參數對齒栓和正齒輪鍛造時鍛造功率、無因次化鍛造壓力以及齒栓和正齒輪形狀之影響。所獲得鍛造負載與其他研究者的實驗數據相較，可提供實施齒栓和正齒輪的精密鍛造時模具設計之一有用的參考資料。

關鍵詞：齒栓、齒輪、精密鍛造、上界限法

Abstract

In this research, a theoretical analysis for the precision forging of spline and spur gear from an original cylindrical billet specimen is proposed by using upper bound method. The geometric of tooth shape for forging mold during precision spur gear forging is introduced into mathematical modeling for simulating non-uniform deformation and the barreling effect of billet specimen. In this paper, several parameter such tooth number of spur gears, friction factor and aspect ratio of billet effect on forging power, non-dimensional forging pressure and billet deformation are investigated in detail. It offers a useful knowledge in mold design for precision forging of spur gear.

Keywords: Spline, Gear, Precision forging, Upper Bound Method

二、引言

最近利用精密鍛造的加工程序來製造齒栓和正齒輪的方法以被發展出來。與切削加工法及閉模鍛造法比較，利用某些形態的精密鍛造法製造齒栓和正齒輪時，可獲得節省切削成本、節省生產時間、較低的消耗功率、較佳的齒部強度、較長的模具壽命和較低的沖頭壓力的種種優點[1-3]。

在正齒輪形（齒栓）的導引形精密鍛造製程方面，Abdul[4]利用上界限法，探討了圓柱鍛胚在鍛模內的變形時金屬流的速度分佈。Choi[5]曾利用內部鬆弛型精密鍛造法製作正齒輪，當內部空心的圓環胚在鍛模內受壓而變形時，金屬流會向壓力較小的圓環胚內部空心處移動，因而降低鍛造所需沖頭壓力，為說明此現像，Choi 使用 FEM 分析鍛模所承受的壓力分佈，對內部鬆弛型精密鍛造法提出一理論依據。Chitkara[6] 曾應用切片法分析齒栓的導引型精密鍛造，獲得鍛模表面上的壓力分布及沖頭壓力，並和實驗數據相比較，作為設計鍛模的參考資料。Nakano[7] 和 Ohga[8]亦提出可改善齒栓機械性質的分流鍛造加工方式，此法的優點包含了節省加工機負荷的輸出功率、鍛胚內有較低的塑流應力、以及胚料和鍛模間有較少的摩擦功率損失。

上述文獻中所有的數學模型，均假設鍛胚在任一瞬間皆為均勻變形，也就是不考慮鍛壓過程中，胚料受壓力與摩擦所產生的非均勻變形及桶狀效應。本文將保留齒形輪關函數，以引用於數學模式中，並假設在鍛胚中所有塑性範圍內任一質點的軸向速度為非線性分佈，來模擬非均勻變形及桶狀效應，對齒栓和正齒輪的精密鍛造做三維的解析與探討。

三、數學模式

在速度場的推導過程中有如下的一些假設：

(1) 圓柱胚為一剛塑性材料；
(2) 疏忽沖頭和金屬鍛模的彈性變形；
(3) 圓柱胚是等方性的材料；
(4) 所有摩擦因子均為定值；
(5) 沖頭的速率為定值。

圖1中鍛胚的變形為上下對稱，若圖2之塑性域1,2,3區中，塑性流的軸方向速度皆相同，則 V_z 可假設如下：

$$V_z(z,H)=\frac{V_0}{2}\pm\left[1+C_1\left(\frac{z}{H}-1\right)\right]\frac{V_0 z}{2H} \tag{1}$$

其中 V_0 為沖頭速率在符號"±"中，"+"代表鍛胚上半部，"−"為下半部。各塑性區域的速度場之數學模式如下：

$$V_{r1}=0 \tag{2}$$

$$V_{\theta 1}(r,\theta,z,H)=\pm r(\alpha-\theta)\left[1+C_1\left(2\frac{z}{H}-1\right)\right]\frac{V_0}{2H} \tag{3}$$

$$V_{r2}(r,z,H)=-r\frac{\alpha}{2\beta}\left[1+C_1\left(2\frac{z}{H}-1\right)\right]\frac{V_0}{2H} \tag{4}$$

$$V_{\theta 2}(r,\theta,z,H)=r\theta\left(\frac{\alpha}{\beta}-1\right)\left[1+C_1\left(2\frac{z}{H}-1\right)\right]\frac{V_0}{2H} \tag{5}$$

$$V_{r3}(r,z,H)=-\frac{1}{r}\left(\frac{f(r)}{B(r)}\right)\left[1+C_1\left(2\frac{z}{H}-1\right)\right]\frac{V_0}{2H} \tag{6}$$

$$V_{\theta 3}(r,\theta,z,H)=-\theta\left(\frac{B'(r)f(r)}{B(r)^2}\right)\left[1+C_1\left(2\frac{z}{H}-1\right)\right]\frac{V_0}{2H} \tag{7}$$

上述式(1)-(7)中，H 為齒胚在鍛壓時間 t 之瞬時高度，$B(r)$ 是齒栓的齒部形狀函數。而本文引入的虛擬獨立參數 C_1，可模擬非均勻速度分佈及鍛胚的桶狀效應。另外，$B(r)$ 在積分範圍 $[0,r]$ 的積分結果表示為 $f(r)$。

以上各參數符號或函數可定義如下；

$$H\equiv H(t)=\frac{H_0+V_0t}{2} \tag{8}$$

$$B(r)=\arcsin\left(\frac{D_m}{r}\right) \tag{9}$$

$$B'(r)=\frac{\mathrm{d}B(r)}{\mathrm{d}r} \tag{10}$$

$$f(r)=\int_0^r s\cdot B(s)\mathrm{d}s \tag{11}$$

其中 D_m 為齒栓的一半寬度。式(8)中分母為2乃因鍛胚上下對稱本文取其上半部之故。從式(11)得到 $f(r)$ 和 $B(r)$ 之關係。就物理意義而言，$f(r)$ 代表任一垂直於鍛壓軸之平面上的齒胚斷面積。

參數 ξ 為無因次化的鍛造壓力，具有大小的指標作用，其定義如下：

$$\xi=\frac{J}{\sigma\cdot A_0\cdot V_0} \tag{12}$$

其中，A_0 為鍛胚的初始斷面積。

本文尚研究正齒輪的導引形精密鍛造與齒栓類似，僅齒形輪廓函數 $B(r)$ 不同。漸近線齒形常使用於正齒輪的製造中，其函數如下：

$$B(r)=\frac{\alpha}{2}-\sqrt{\left(\frac{r}{R_0}\right)^2-1}+\arctan\sqrt{\left(\frac{r}{R_0}\right)^2-1} \tag{13}$$

四、結果與討論

圖1為齒栓鍛造最佳化速度場計算例，僅取鍛胚上半部之速度場示之，其中矢線及長度指示速度方向的大小，從圖中得知在Zone 1中，任一質點的圓周方向速度大小與其座標 r 值成正比，塑性流從邊界 Γ_1 開始呈圓弧狀。通過邊界 Γ_2 後開始有徑向速度，Zone 2中任一質點的徑向速度大小向與其座標 r 值成正比。再通過圓弧狀邊界 Γ_3。因所有鍛壓下的胚料均往齒形部份流動，故明顯地，Zone 3中塑性流的速度大於Zone 1，2者。由圖可知，速度場滿足所有的邊界條件。

圖2表示本文模式與Abdul[4]模式在鍛造壓力之分析比較圖，其中齒栓數 $n=22$。一般而言，Abdul模式為均勻變形速度場，在本研究中，倘若 $C_1=0$ 亦代表鍛胚均勻變形，然而 C_1 不為零，即為非均勻變形之速度場，因此本文模式動可容速度場，涵蓋了Abdul之模式。能量最小化之搜尋範圍，亦包含了Abdul計算鍛造功率之範圍，經本研究計算結果後，C_1 往往不為零，故表示鍛胚在精密鍛造時應存在非均勻變形才能使鍛造功率最小。因此如圖所示，本文模式比Abdul[4]模式更能找出較小之鍛造壓力。在潤滑效果不佳時(摩擦因子較大)，鍛造壓力隨壓縮率的增加而增加；若潤滑效果佳時(摩擦因子較小)，鍛造壓力隨壓縮率的增加並無明顯增加，甚至略為減少。

僅改變齒栓數而固定其它加工參數時，齒栓數愈大表示鍛胚/鍛模摩擦接觸面愈多，摩擦功率受壓縮率之影響愈增加，從圖3可得知鍛造壓力隨壓縮率增加的趨勢在 n 愈大時愈明顯。

圖4為不同的摩擦因子對鍛胚桶狀效應之影響。其中 R_2 為鍛胚赤道面之半徑，R_1 為頂面半徑。當 m 愈大，則鍛胚頂面與底面，分別受沖頭面與鍛模內部底面之摩擦影響愈明顯，故 R_2/R_1 愈大，即桶狀效應愈明顯。

本文將以其它研究者之實驗結果，來對照說明本文數學模式於預測分析鍛造壓力、鍛造功率之適用性。圖5中顯示本文解析模式和Chitkara[3]實驗數據的比較。其實驗為齒栓的精密鍛造，齒胚數 $n=4$，實驗用碲-鉛為一圓柱胚試片，其半徑接近鍛模內徑 $R_0=19mm$，齒栓寬度 $D_m=3.5mm$，高度 $H_0=19mm$，置入一齒栓形鍛模內，上面沖頭以 $V_0=-0.042mm\cdot s^{-1}$ 緩慢移動，齒胚受壓後逐使的移動進入被成形鍛模的齒模並向齒部成形。Chitkara 以Alvania油脂當做一潤滑劑。在鍛胚/鍛模界面提供好的潤滑避免鍛模上刮痕。試片的應變-應力關係如下：

$$\sigma=\left(7.41+23.31\left(1-e^{-6.41\varepsilon}\right)\right)MN/m^2 \tag{14}$$

$$\varepsilon=\ln\left(\frac{H_0}{H}\right) \tag{15}$$

從圖5解析值和碲-鉛的齒栓鍛造實驗數據的比較中得知，本文模式和Chitkara在估計齒栓鍛造壓力的分析上的差異很少。兩估計值者及所預測鍛造壓力隨壓縮率增加而增加的趨勢都接近實驗結果，說明了考慮桶狀效應之速度場適用於齒栓導引形精密鍛造之解析。

五、參考文獻

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$R_0 = 20mm$, $H_0 = 40mm$, $V_0 = 1mm/s$,
red. $= 10\%$, $D_m = 4mm$, $n = 4$, $m = 0.2$,
$\sigma = 1\text{MPa}$, $C_1 = -0.075$

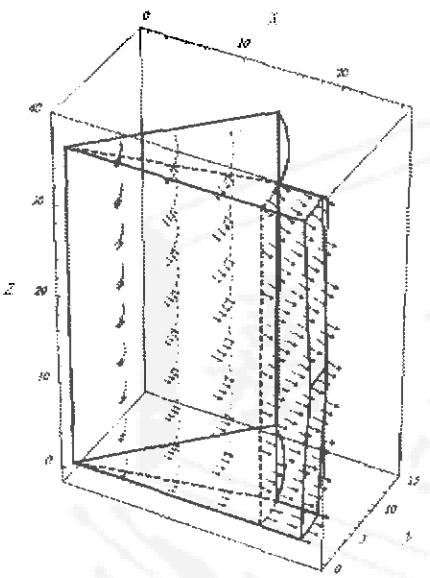

圖 1 齒栓鍛造之最佳化速度場計算例

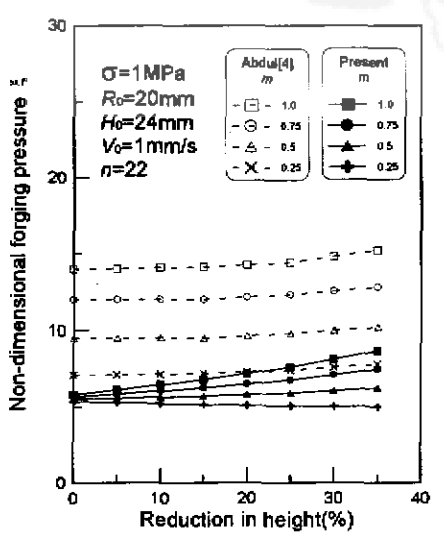

圖 2. 齒栓鍛造中摩擦因子對無因次化鍛造壓力之影響

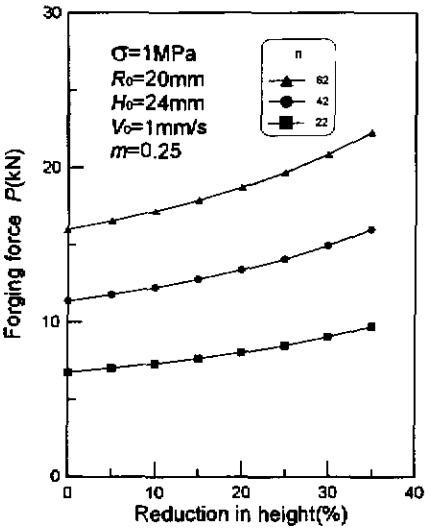

圖 3 正齒輪鍛造中齒數對無因次化鍛造壓力影響

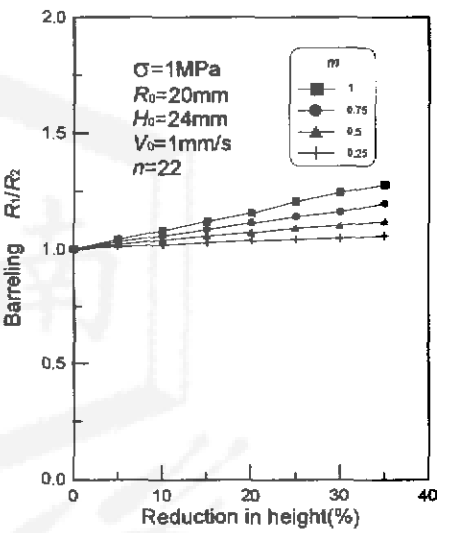

圖 4 齒栓鍛造摩擦因子對桶狀效應之影響

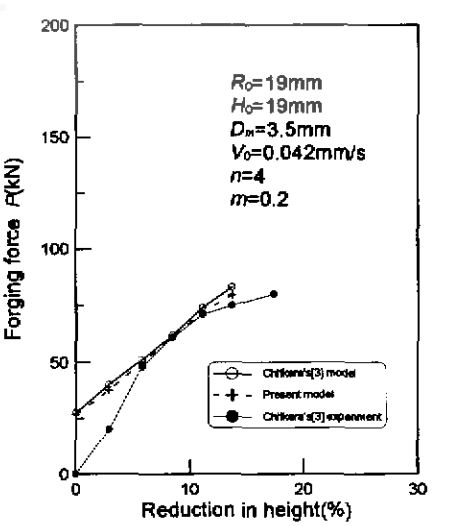

圖 5 齒栓鍛造解析值與 Chitkara 實驗值之比較

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

90 年 7 月 6 日

附件三

報告人姓名	徐宏修	服務機構及職稱	嘉南藥理科技大學 資訊管理系 助理教授
會議時間 會議地點	90 年 6 月 27 日~29 日 美國加州聖地牙哥	本會核定補助文號	90-2914-1-041-004-A1
會議名稱	(中文) 2001 力學與材料學會議 (英文) 2001 MECHANICALS AND MATERIALS CONFERENCE		
發表論文題目	(中文) 利用上界法於正齒輪精密鍛造之研究 (英文)A Study on Precision Forging of Spur Gear by Upper Bound Method		

一、參加會議經過

本人自六月二十六日下午搭機赴中正機場，轉長榮 BR12 國際航班經長達十二小時直達洛杉磯，再轉 American Eagle 飛往聖地牙哥。此季節當地氣候非常溫和，許多觀光客選擇聖地牙哥渡假，途中遇到參加相同會議的新加坡南洋科技大學（Nanyang Technological University）的劉國罡教授，雙方交換兩校彼此的概況及研究的方向。抵達聖地牙哥之後，經一夜的休息後，六月二十七日早上抵達會場－Sheration San Diego Hotel and Marina。在現場註冊後得知，研討會在兩棟相距約一五〇公尺的大樓同時舉行，為免於奔波，於是決定在 East Tower 活動。本人場次安排在下午三點三十分至三點五十分於 East Conference Center 3A，其餘時間參觀其他學者的論文宣讀。各論文重點摘要如下：

一篇由 California Institute of Technology 的 Luoyu Roy Xu 宣讀，內容為三明治結構的動態破裂特性探討在聚合物和金屬板的三層板系統中基本的破壞模式，由一系列不相長寬比試片的實驗中得知，大部分試片在衝擊下，層間的破裂先將發生並傳遞，所有的傳遞均被攝影並詳細探討。

來自 Wright State University 的 Nathan W.Klingeil 的研究為雙金屬層在自由端邊的介面破

裂的行為，他指出一個短的層間裂縫不一定造成層間分離，需配合雙金屬層的結構及尺寸比例。此研究目的在找出不造成層間分離及延伸的最大裂縫長度，即安全長度，作為設計雙層板的參考依據。

University of Utah 的 E.S.Folias 推導出一複合板的層間裂縫應力場，並仿造 Griffith 的推衍方式，獲得一破壞準則，並與實驗結果相比，得到一個具參考價值的理論。紐約 SUNY at Stony Brook 的 Raman P.Singh 研究研性層在易碎材料中的破裂增長的力學機構。此力學區分為靜態與動態負荷兩種條件。試片在 4m/s 和 8m/s 的衝擊速度下，以高速攝影拍攝到裂縫增長的情形。此一系列的實驗結果和理論值比較後，可用來設計防止裂縫在層間增長的參考資料。

北京石油化工學院機械系的原紅教授針對三層板中黏著層的強度與層間介面的應力分佈提出一套數學模式。此模式所獲得黏著層在端點及自由面的剪應力並無奇異解，可完全滿足邊界條件。此解析模式與常用的估算法相互照對，結果相近，適合用來設計三層板的黏著層。來自 Germany, Universitaet Siegen 的 Joerg Hohe 針對六角形蜂格狀單元在三層板結構中的應立場提出解析解並和 FEM 解析相比較。他指出 Stress intensity factor 和單元的彈性係數及有效應變的強度有關。此研究對以往無法正確預測的部分奇異解提出一較佳的預測值。

由於曲線型的平板型的積層複合材在低速衝擊下的損壞完全不同，Inha University，Korea 的 Oh-Yang Kwon 認為和曲率有關。在固定的衝擊能量下，曲線型積層材的曲率愈大則最大接觸力愈大，即愈易受到損害。此現象經由 FEM 和 Graphite/epoxy 的實驗對照下得到合理的佐證。

University of Washington 的 Paul E.W. Labossiere 則對雙層材介面端的破壞力學提出 2D 與 3D 的分析。由一系列 2D Silicon/glass 和 2D、3D 的 aluminum／epoxy 的實驗中發現，相關應力強度與施加的負荷及 far-field 的幾何形狀有關。由理論推導亦可獲得相同結論，並可得到破壞時的初始準則可供參考。

UCSD（University of California ,San Diego）的 Sai Sarva 研究高速衝擊下 Al203 的破壞現象。實驗中使用鎢合金的子彈，由瓦斯槍高速射入有限厚度的 Al203 中，並觀察其應力波傳遞的現象。Brown University 的 Jeffrey W. Kysar, 則對鋁的雙晶結構在微小的裂縫下的延性破壞做一有系統的實驗分析，並與 Rice 的理論做比較，歸納出雙晶結構下的破壞判斷法則。

UCSD 的 Robert E.Skelton 對結構的剛性及不同等級的結構轉換有一完全的數學模型。此理論限於所有結構組成僅受軸向張力或壓力，而每一個節點受固定之軸向壓力的情形下。該研究並舉 class 1 及 class 2 為例，說明力平衡條件的計算過程 Skelton 亦發表另一篇有關平面結構物之剛度最佳化的論文。UCSD 的 Hidenori Murakami 研究雙球型結構的靜態與動態特性

並以自製模型說明結構物的活動自由度。以上三篇論文均屬於機構學的研究領域。

本人發表 A Study on Precision Forging of Super Gear by Upper Bound Method，針對正齒輪精密鍛造時之旁凸效應提出一數學模型，並探討不同齒數，摩擦因子等對鍛造負荷的影響，並與 Abdul 及 Chitkara 的實驗值比較，得到較接近實驗值之結果。

Hyundai Heavy Industries Co. Ltd., Korea 的 H. T. Lee，針對板材在焊接下變曲現象提出 FEA 解析，與實驗值對照的結果可知：板材的變曲程度和加熱時的強度，板的厚度及外部拘束條件有關，而內部的拘束條件則可忽略。

二、與會心得

ASME, ASCE, SES 均為全球最著名之專業工程協會，其學術期刊亦列為國科會之 A 級期刊。本次會議由 ASME 之 MD, AMD 和 ACSE 以及 SES 於 UCSD 擴大舉辦，分 42 個討論會，涵蓋固體力學、製造力學、材料學等多項議題，開放給學界、產業界人士參加。研討重點在於機械、製造和材料之學術知識的結合，達到跨領域整合的目地。本次會議三天的時間內，發表七百多篇論文。範圍涵蓋複合材料、破壞力學、疲勞力學、塑性力學、實驗研究、塑性加工等，其中以複合材料為主，與會研究者多數均有理論與實驗對照，而研究設備也較國內先進，值得學習。根據統計來自中華民國的論文僅有十二篇，約 1.6%，雖主辦國佔大多數，而法國、大陸、日本等均發表二十至三十篇，殷切盼望日後能在國際會議中多看到國內學者的研究成果。

三、建議

本國籍航空公司於 6 月初即大幅提高票價，而本次會議時間又訂在旅遊旺季，使機票補助不足以支付本國籍航空公司與 American Eagle 聯航的來回票價。但若選擇非本國航空則機票花費較少，同時可節省公費支出。建議放寬出國必須搭乘本國籍航空公司的條件限制，使執行時更有彈性選擇的空間。

四、攜回資料名稱及內容

2001 MECHANICALS AND MATERIALS SUMMER CONFERENCE TECHNICAL PROGRAM AND BOOK OFABSTRACTS, 2001, UCSD, CA, USA。內容為大會程序，各討論會時程及論文摘要。

五、其他

無

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Processing and Manufacturing

MMC2001-469 —Wednesday, June 27, 3:30 PM

A Study on Precision Forging of Supr Gear by Upper Bound Method

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Precision forging of spur gear is a important process of manufacturing spur gear, this forging process of spur gear include several advantage such as less tolerance, more improved strength, cost billet savings and energy. In this paper, a numerical analysis for the precision forging of spur gear from an original cylindrical billet specimen was proposed by using upper bound method. The geometric shape of mold during precision spur gear forging was simplified for computation and the barreling effect for free surface of the workpiece influenced by the nonhomogeneous deformation was considered in present mathematical model. The mathematical model of the kinematically velocity field was simulated for the nonuniformed deformation of billet forged in the mold. This rigid-plastic model was developed to estimat the power, loading force for the billet during precision forging of spur gear. Several parameter such tooth number of spur gears, friction factor and aspect ratio of billet in forging process upon the forging power, load-stoke diagram and billet deformation were be investigated in detail. The estimated forging load obtained by this model was compared with experimental datas of other paper. It offer a useful knowledge in mold design for precision forging of spur gear.

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Cutting Performance of BN-based Ceramic Inserts Correlated to their Hot Hardness Properties

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Cubic Boron nitride (CBN) cutting inserts are considered to be the ideal solution to machine ferrous alloy. In this paper, the results of tool steel machining with Cubic Boron Nitride (CBN) are presented. The temperature dependence of the micro-hardness (hot hardness) of the CBN materials was investigated from room temperature up to 14000C. The hot hardness results are correlated with the deformation mechanisms and micro-structural properties of the CBN ceramics which control the response of the tool materials in service conditions. The contribution of abrasion to the crater wear up to a critical cutting speed is related to absolute differences in hardness and to the hardness temperature coefficient. The matrix phase plastic deformation is taken to be responsible for the drastic decrease of strength both in the high temperature hardness test and in limiting the cutting speed.

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MMC2001-508 —Wednesday, June 27, 4:06 PM

A Study on Equivalent Model for Prediction of the Distortions Caused by Line Heating with Flame Torch

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G. G. Byun, Production Engineering Development Department, Hyundai Heavy Industries Co. Ltd., Ulsan, Kyungnam, Korea

The purpose of this study is to clarify the relation between heating condition and induced distortions, and to propose a equivalent model mounted to the heating line automatic marking system by FEA and experiment. The variables used in this study were the plate thickness, internal/external restraint condition and heating parameters including combustion gases, nozzle type, stick out and cooling method.

The results obtained in this study are as follows

1. The angular distortion and transverse shrinkage induced by line heating depends on the heat intensity and bending/in-plane rigidity of the plate.

2. The equivalent model to predict the amount of angular distortion and shrinkage induced by line heating was formulated as a function of heating parameters, plate thickness and external restraint condition with plate theory.

3. The effect of external restraints on the curvature of the heated plate was very large, while the effect of internal restraints could be neglected.

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MMC2001-533 —Wednesday, June 27, 4:24 PM

A New Workability Criterion and Ductile Fracture Prediction in the Forging of Sintered Powder Compacts

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Powder forging combines powder metallurgy and forging technologies and thus possesses the advantages of both processes that result in stronger yet versatile products. Voids in sintered preforms exert a damaging effect on the mechanical properties, reducing the cavities can significantly increase their strength and workability. However, fracture will occur on the workpiece for the improper blank profiles and incorrect die design. The main purpose of this study is aimed at investigating the forgability of sintered compacts. A new ductile fracture criterion for porous media was developed in this form

行政院國家科學委員會補助專題研究計劃成果報告

※※※※※※※※※※※※※※※※※※※※※※※※※

※ 長期運動對中樞甲型 2-正腎上腺受器與 Imidazoline 受器 ※

※ 的影響及血壓下降可能之機制 ※

※※※※※※※※※※※※※※※※※※※※※※※※※

計畫類別：■個別型計畫　　□整合型計畫

計畫編號：NSC89-2320-B-041-007

執行期間：89 年 8 月 1 日 至 90 年 7 月 31 日

計畫主持人： 陳 麗 珠

執行單位：嘉南藥理科技大學

中 華 民 國 90 年 9 月 30 日

行政院國家科學委員會補助專題研究計劃成果報告

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一、中文摘要

本實驗探討長期有規則的運動對延腦內的甲型 2-正腎上腺受器(α2-adrenergic receptor)和 imidazoline 受器的影響。將雄性大白鼠(Wistar 品系，15 週齡)任意地分成控制組和運動組兩組。運動組的老鼠從四週齡開始訓練它們在滾筒式的跑步機上運動，每天跑一個小時，每週跑五天，共運動十週。為了避免殘留急性運動的效果影響到長期運動的效果，運動組的老鼠在實驗的前兩天停止做運動。控制組和運動組的老鼠均以斷頭的方式犧牲。先將前腦取出，再將橋腦剝除，從而在錐體交叉(pyramidal decussatio)處橫斷切下取得腦幹(brain stem)。再將腦幹豎起在乾冰上，縱切去除其背部(dorsal part)，留下腹面(ventral part)的延腦部位。最後只切下外側(lateral part)的延腦部位，並以此當作實驗的材料。每一次實驗所需的膜蛋白均需要 24 隻老鼠的腦幹一起混合製備使用才夠。

延腦的頭側，腹面外側的部位(rostral ventrolateral medulla, RVLM)是一個整合反射神經機制的重要區域。也就是說，在運動期間，它負責調控心臟血管的運作，並且，在中樞它也是抗高血壓藥劑有感受性的主要區域。長久以來，可羅尼丁(clonidine)被認為是一種抗高血壓的藥劑，並且認為它是藉著和位於腦幹上的中樞甲型 2-正腎上腺受器結合而降低交感神經的作用，最後導致降血壓的效果。但是最近相繼有証據顯示，在 RVLM 內還存在非甲型 2-正腎上腺受器而它對 imidazoline 有感受性，並且參與血管舒縮張力的調控。除此以外，它對可羅尼丁類的抗高血壓的藥劑也有感受性而呈現降低血壓的效果。

一般來說，長期有規則的運動可以降低血壓及心跳，而此種效果是否由於長期運動而使得在中樞的一些神經傳導物質增加或增加這些神經傳導物質的受器，以致有降低血壓及心跳的效果，可惜對這方面的研究，目前還很欠缺。所以在這個實驗設計中，長期運動訓練的老鼠和控制組的老鼠的腦幹內的甲型 2-正腎上腺受器和 imidazoline 受器的數目和對受質的親和力將被分析、比較，期能得到一個合理解釋的機制，以了解長期運動是否真能影響這些受器的數目和對受質的親和力，導致血壓下降的功效。實驗結果顯示長期運動訓練的老鼠和控制組的老鼠的腦幹內的甲型 2-正腎上腺受器和 imidazoline 受器的數目和對受質的親和力並未有明顯的差異。可能的解釋是生物長期處於一個壓力下慢慢會產生調適作用。

關鍵詞：長期運動、中樞甲型 2-正腎上腺受器、中樞 imidazoline 受器、延腦

ABSTRACT

The effects of chronic exercise on central noradrenergic and imidazolinergic systems were investigated. Male Wistar rats (16~20 weeks old) were divided into control and exercise groups. The exercise animals ran on a drum exerciser from age week four, one hour per day and five days a week for ten weeks. The speed started from 0.15 m/sec and gradually increase every two weeks. Before experiment, the exercised animals rested for two days to avoid the acute effect. Both control and chronic exercised rats were sacrificed by decapitation. The brains were removed and the brain stem isolated by trans-section at rostral and caudal limits of the pontomeduallary junction and the pyramidal decussatio. The ventral part of the medulla, including the RNL region, were isolated by discarding the dorsal part of the medulla. Crude membrane preparations were prepared from 24 pooled brain stems.

The rostral ventrolateral medulla (RVLM) plays a crucial area of integration for reflex neural mechanism, which plays an important role in regulating the cardiovascular system during exercise and is major site of action for centrally acting antihypertensive agents. Clonidine has traditionally been thought to exert its hypotensive effect via stimulation of central α2-adrenergic receptors in the brain stem leading to a reduction of sympathetic drive and consequently a fall in blood pressure. More recently, some studies have proposed the existence of non-adrenergic receptors in the RVLM specifically sensitive to imidazolines and are involved in the regulation of vasomotor tone and in the hypotensive effect of centrally acting antihypertensive agents of clonidine type. Receptor assay were performed to see if there were any change of α2-adrenergic receptors and / or imidazoline receptors in the rat brain stem after chronic and acute exercise. Results showed that the Bmax and Kd of the α2-adrenergic receptors and the imidazoline receptors in the rat brain stem after chronic exercise were not significantly different. The reason for that is due to the long term under a stress the animals will adapt itself to fit the condition. If a time course experiment was done the affinities and Kd of the α2-adrenergic receptors and the imidazoline receptors in the rat brain stem after chronic exercise may show transient exchange.

Key words: chronic exercise central α2-adrenergic receptor
hypotention central imidazoline receptor RVLM

INTRODUCTION

The modulation of peripheral sympathetic activity by the central nervous system may involve various pathways, neutrotransmitters and receptors. The main site for the vasodepressor response to clonidine and related compounds has been located within the medullary nucleus reticularis lateralis (NRL) of the rostroventrolateral medulla (RVLM) region of various species (Bousquest et al., 1981; Wolf and Mohrland, 1984; Ernsberger et al., 1990). Clonidine has traditionally been thought to exert its hypotensive effect via stimulation of central α2-adrenergic receptors in the brain stem leading to a reduction of sympathetic drive and consequently a fall in blood pressure (Timmermans and van Zwieten, 1982). More recently, Bousquest et al.(1984,1992) have proposed the existence of non-adrenergic receptors in the RVLM specifically sensitive to imidazolines and are involved in the regulation of vasomotor tone and in the hypotensive effect of centrally acting antihypertensive agents of the clonidine type. Thus it has been suggested that the hypotensive effect of clonidine-like compounds was mediated via imidazoline receptors (IRs)(Bousquest et al.,1984; Feldman et al., 1990).

The apparent heterogeneity of the imidazoline-preferring sites has resulted in the destination of the I1-receptor subtype (located in the RVLM, kidney, and suprarenal gland) and the I2-receptors (found in hepatocytes, fat cells, and the cortex) (Michel and Ernsberger, 1992; Ernsberger, 1992). The blood-pressure-lowering effect of centrally acting antihypertensive is predominantly due to the stimulation of I1-imidazoline receptor (Michel and Ernsberger, 1992). Radioligand binding and functional studies have indicated that clonidine has affinity for both α2- and I1-receptors in the central nervous system (Tibirica et al., 1991; Ernsberger et al., 1993). Clonidine's central antihypertensive activity is counteracted by yohimbine, a selective α2-adrenoceptor antagonist (Timmermans and van Zwieten, 1982; Tibirica et al., 1991). It is still controversial that the central antihypertensive activity of clonidine is mediated by central I1-and/or α2-adrenoceptors.

Recently studies have been shown that chrronic exercise training lowers blood pressure (Jennings et al, 1984; Tipton et al, 1991; Wiley et al, 1992), attenuate baroreflex (DiCarlo and Bishop, 1988), and enhance agonist-induced vasodilation and modulate α-adrenergic vasoconstruction (Pavlik et al., 1976; Bennet and Kotchen, 1989; Chen and Li, 1993; Delp et al., 1993; Chen et al.,1994; Chen and Chiang, 1996). These may be part of mechanisms for protective effect of regular exercise from cardiovascular diseases. Besides, physical exercise may affect central monoaminergic mechanism, the data from Gordon et al.(1996) indicated that exercise accelerates noraderenaline (NA) turnover. The influence of exercise training has also been investigated; indeed, Browwn et al. (1979) reported an increase in whole

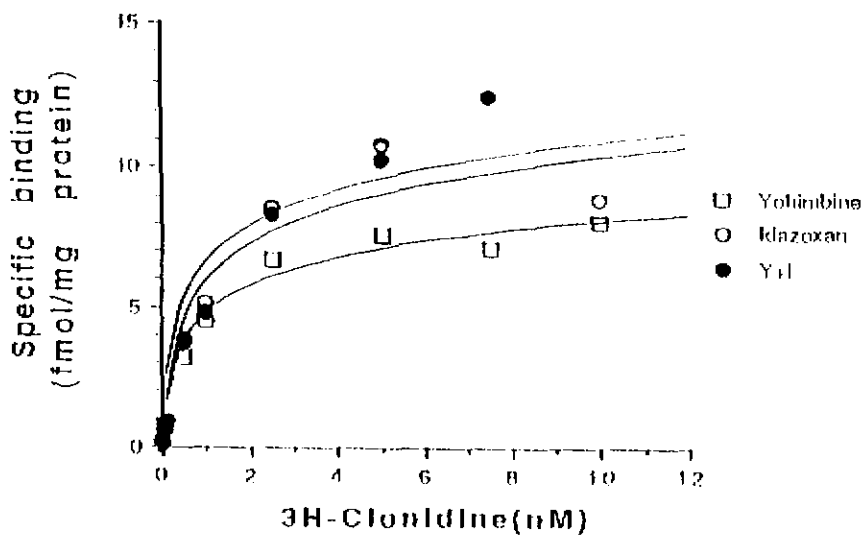
brain, midbrain and cortex NA level following repeated running (30 min per day for 40 days), a result that resembles that obtained following a single bout of exercise (Brown and van Huss, 1973). However, data related to the consequences of exercise on brain adrenergic and imidazoline systems and their receptors are still lacking. Nontheless, whether chronic or acute exercise can increase or decrease central α2-adrenoceptors and/ or imidazoline receptors, which in turn plays an important role in lower blood pressure, is still unknown. In this study, two antagonist were used for radioreceptor binding assays, yohimbine, an antagonist for α2-adrenoceptors and idazoxan, a mixed antagonist for α2-adrenoceptors and imidazoline receptors. The affinities (Kd), the maximal binding sites (Bmax) of α2-adrenoceptors and imidazoline receptors in the preparations of rat' RVLM were analyzed and compared between control and exercised groups.

Results and Discussion

Results showed that the Bmax and Kd of the α2-adrenergic receptors and the imidazoline receptors in the rat brain stem after chronic and acute exercise were not significant. The reason for that is due to the long term under a stress the organism will adapt itself to fit the condition. If a time course experiment was done the affinities and Kd of the α2-adrenergic receptors and the imidazoline receptors in the rat brain stem after chronic and acute exercise may show transient exchange.

Figure 1. An example showing specific binding of ^{3}H-Clonidine to the membrane of RVLM from (1a) the control group, and (1b) the chronic exercise group.

(1a)



(1b)

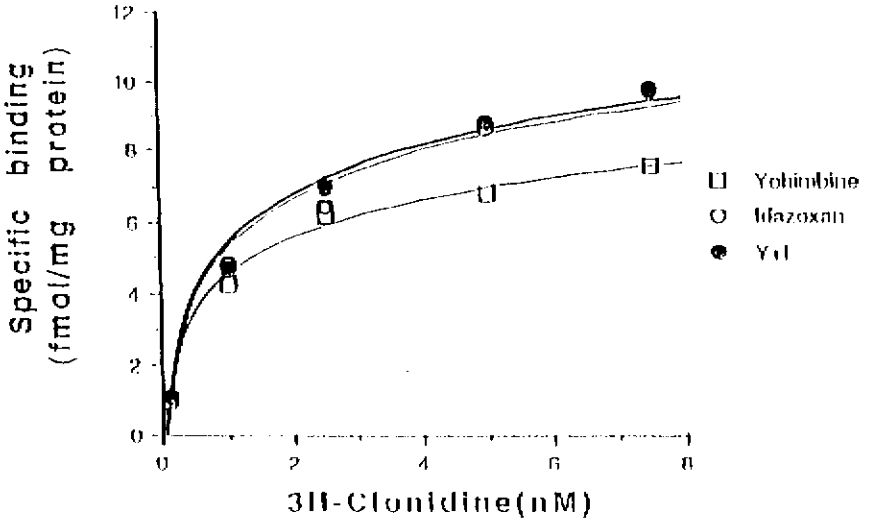
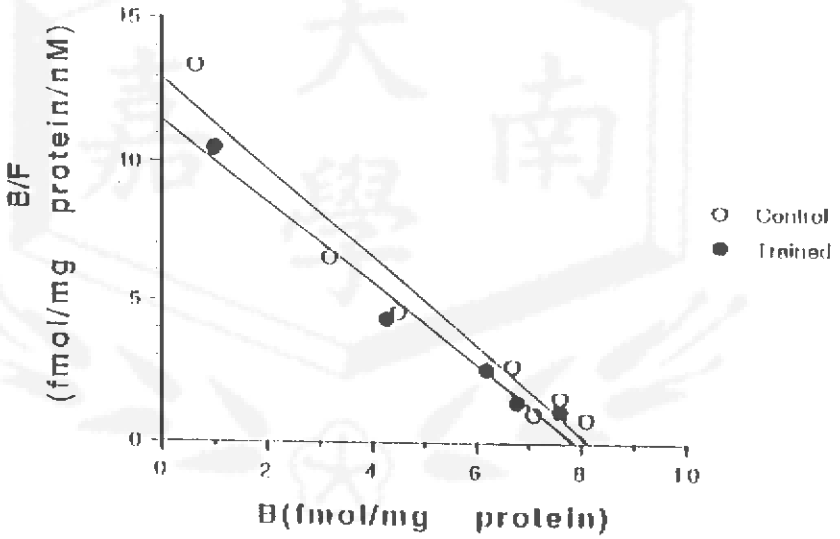
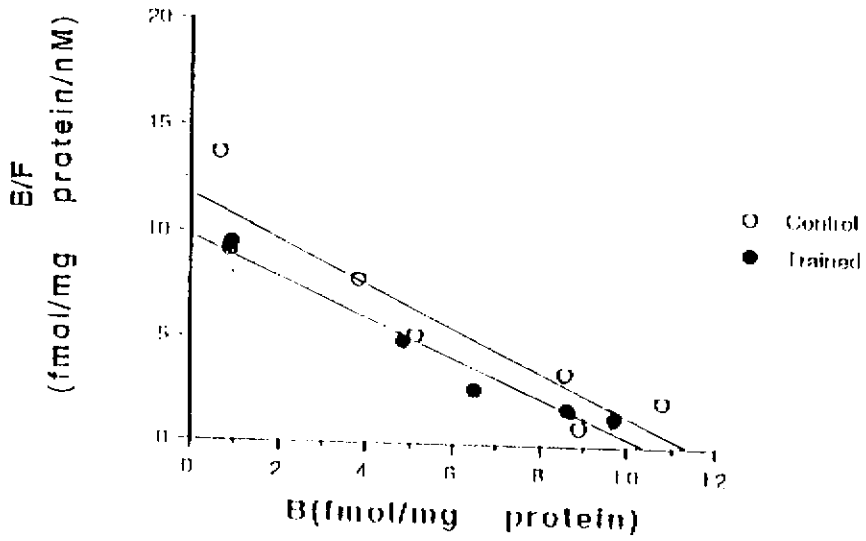


Figure 2. Comparison of Scatchard plots of ^{3}H-Clonidine binding assay in the present of different antagonists between control and chronic exercise groups. (2a) in the present of 10 μM yohimbine; (2b) in the present of 10 μM idazoxan; and (2c) in the present of 10 μM yohimbine and 10 μM idazoxan.

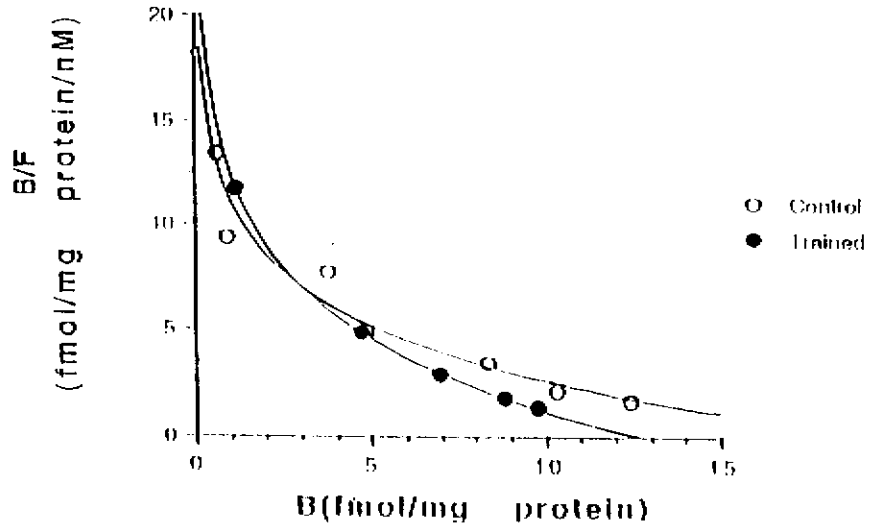
(2a)



(2b)



(2c)



計畫成果自評：

本實驗探討長期有規則的運動對延腦內的甲型2-正腎上腺受器(α2-adrenergic receptor)和 imidazoline 受器的影響。延腦的頭側，腹面外側的部位(rostral ventrolateral medulla, RVLM)是一個整合反射神經機制的重要區域。也就是說，在運動期間，它負責調控心臟血管的運作，並且，在中樞它也是抗高血壓藥劑有感受性的主要區域。長久以來，可羅尼丁(clonidine)被認爲是一種抗高血壓的藥劑，並且認爲它是藉著和位於腦幹上的中樞甲型 2-正腎上腺受器結合而降低交感神經的作用，最後導致降血壓的效果。但是最近相繼有証據顯示，在 RVLM 內還存在非甲型 2-正腎上腺受器而它對 imidazoline 有感受性，並且參與血管舒縮張力的調控。除此以外，它對可羅尼丁類的抗高血壓的藥劑也有感受性而呈現降低血壓的效果。

一般來說，長期有規則的運動可以降低血壓及心跳，而此種效果是否由於長期運動而使得在中樞的一些神經傳導物質增加或增加這些神經傳導物質的受器，以致有降低血壓及心跳的效果。所以在這個實驗設計中，長期運動訓練的老鼠和控制組的老鼠的腦幹內的甲型 2-正腎上腺受器和 imidazoline 受器的數目和對受質的親和力將被分析、比較，期能得到一個合理解釋的機制，以了解長期運動是否真能影響這些受器的數目和對受質的親和力，導致血壓下降的功效。實驗結果顯示長期運動訓練的老鼠和控制組的老鼠的腦幹內的甲型 2-正腎上腺受器和 imidazoline 受器的數目和對受質的親和力並未有明顯的差異。可能的解釋是生物長期處於一個壓力下慢慢會產生調適作用。雖然沒有達到預期的結果，但是我們已預測 PGE2 的量在長期運動訓練及急性運動鼠腦幹區域與血清中的表現，結果在長期運動訓練鼠腦幹區域與血清中的表現與控制組的老鼠無異；而在急性運動鼠腦幹區域與血清中的表現與控制組的老鼠有明顯的差異。我們會繼續尋求急性運動的老鼠和控制組的老鼠的腦幹內的甲型 2-正腎上腺受器和 imidazoline 受器的數目和對受質的親和力是否有差異，以了解急性運動引起的猝死。

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