出國報告(出國類別：國際會議並發表論文)

出席 2011 美國實驗力學年會

2011 Society for Experimental Mechanics Annual Conference

服務機關：國立高雄應用科技大學 機械與精密工程研究所
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報告日期：2011.11.02
出國期間：2011.06.10~2011.06.18

一、摘要

本次出席國際會議，將關節軟骨與半月板組織於動態壓縮負荷下的機械特性研究於實驗力學年會會議中發表。會議中參與報告並出席晨間聚會，與國內外學者交流，聽取並學習相關領域學者之研究，擴展國際視野。此行主要目的為發表本實驗室研究成果，探討半月板與關節軟骨組織於動態負荷下的機械性質量測，並以準靜態壓縮試驗探討不同應變率負荷下的影響。而在該研討會中，除本身研究報告之外，亦參加該協會舉辦之應變量測課程研討，聽取應變量測相關課程”Methods of Strain Data Analysis”，學習相關的應用與分析，取得研習證書。經此出席國際會議後，順利報告研究內容，亦從此行參訪中了解到本研究發展之價值，但對於其完整性尚須進行更深入的研究分析。

目錄

二、目的

本次出國參訪舉辦在美國康乃狄克州之實驗力學年會學術研討會(Society for Experimental Mechanical Annual Conference)針對實驗力學及生物力學等方面研討。為促進國際合作交流、擴展國際視野、推動生醫科技之發展，分享關節軟骨與半月板生物組織力學特性研究之成果，促進國內外雙向學術交流發展。

三、過程

本次行程由蔡立仁老師協助下，將實驗結果投稿於實驗力學協會舉辦的力學年會研討會，並接受出席會議報告之邀請，前往美國康乃狄克州參加國際會議。由於班機臨時取消更動之原故，於 2011 年 6 月 10 日出發，當日晚間抵達日本成田機場，前往由航空公司所安排之飯店住宿。隔日，11 日下午六點抵達紐約甘迺迪國際機場(JFK)，氣溫乾爽，基於預算有限，住宿安排於紐約皇后區民宿過夜，以利於研討會中保持良好的學習狀態。

12 日晨間轉赴安卡斯維爾(Uncasville)的金神大飯店(Mohegan Sun)，參加該研討會舉辦之應變量測研討課程。應變量測研討課程中與些許國外學者相互討論應變規相關實驗技術，體會到研究領域之廣闊，並接觸其他相同領域之學者，相互交流研究成果。當日晚間前往該研討會會場，與多位學者共同聚會，除學術上交流之外，亦拜訪到霍普金森桿領域上的重要學者 Bo Song，交流該實驗之設置空間與設備建立原則，吸取該試驗技術之經驗。13、14 日，參加個別領域之學術報告，學習力學相關之實驗原理與技術。15 號報告當日，參加晨間聚會，針對當日報告之流程，在晨間餐會中與主持人確認所需之物品與注意事項，以利當日報告進行。亦於非報告時間針對其他學者之衝擊負荷相關實驗報告，學習他人之研究。報告結束後，該力學之研討尚有一天之報告，把握 16 日之研討會議，與其他報告學者交流。研討會議結束後，於隔日返回紐約，當晚於甘迺迪國際機場前往日本成田機場轉機，返回台灣。

四、心得

此次出國研討會議本人參加重點在於擴展學術觀點與本實驗室研究成果的展現，除了觀察其他人的研究表現之外，其他如成果展現的技巧也相當多樣化，看到許多不同的展現方式。以研討會的規模來說，相較國內研討會的舉辦仍有許多需要改進的地方，如會議的場地、主持人對於報告者的安排等，些許的執行方式可考慮跟進他國的做法。參訪行程上的安排雖是順利，但行程過於緊湊，消耗不少體力。

於研討會中，有關關節軟骨與半月板組織相關的研究不虞匱乏，本研究對於

該生物組織研究偏向機械性質分析。研究上實行的分析往往限制於經費上，若有經費或權限使用相關儀器，對其他相關研究如生物保存之軟骨細胞生存率、酵素分析等方式亦可多加參考。雖然本研究中對於兩類軟骨組織的組成亦有些許探討，但對於生物力學上化學組成對於機械性質的相關內容應可多加研究，待研究內容更加完整後，應可投稿至相關期刊發表。

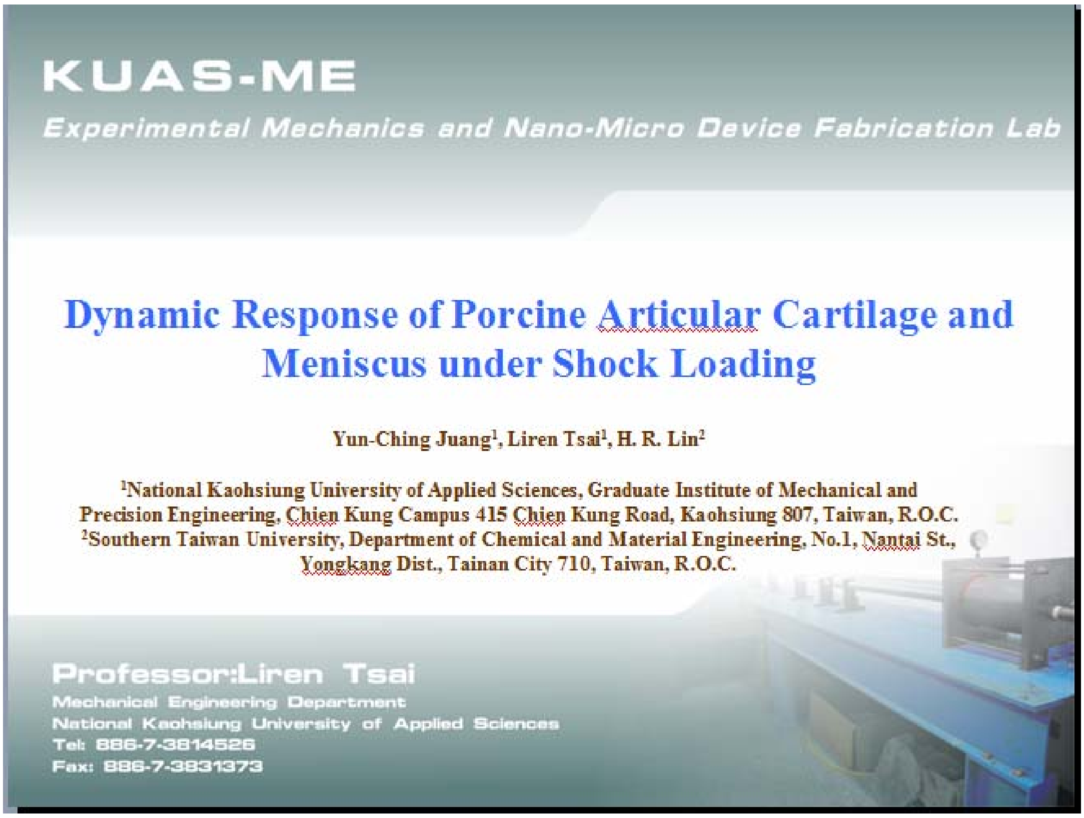
有關國外學者之研究，看到更多樣的成果敘述技巧，本實驗的數據可以再進一步分析，且對於樣本於本實驗中以 4℃預冷，隨後移置-30℃之環境保存至試驗前。保存狀態雖是保存良好，但倘若能獲取更高階之保存儀器，以-80℃之環境於活體取出後立即保存，使其達到對於組織試驗保存之要求。

五、建議事項

本次行程前往美洲地區出席國際會議並發表論文，針對其不足處提出以下幾點建議事項：

1. 本行程過於緊湊，進而影響學習之成效，研討會後應可以多停滯幾天以對於此行收穫內容重整。
2. 對於此次研討會過程中，該場主持會議的學者會於早宴中與報告者見面，說明出場順序，並詢問報告中的物品需求，以確保會議順利進行。對於該項辦理方式應可以些許參考。
3. 此行研討會中所舉辦的應變規課程，該內容的講述偏向廣泛的應用，對於相關的深入知識應把握機會並主動與演講者請教，雖然演講者非所有領域都精通，但對於應用上的細節影響能有所幫助，如黏貼的介面、溫度、預先負荷等量測精度修正問題。

六、附件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Experimental Mechanics and Nano-Micro Device Fabrication Lab
Dynamic Response of Porcine Articular Cartilage and Meniscus under Shock Loading
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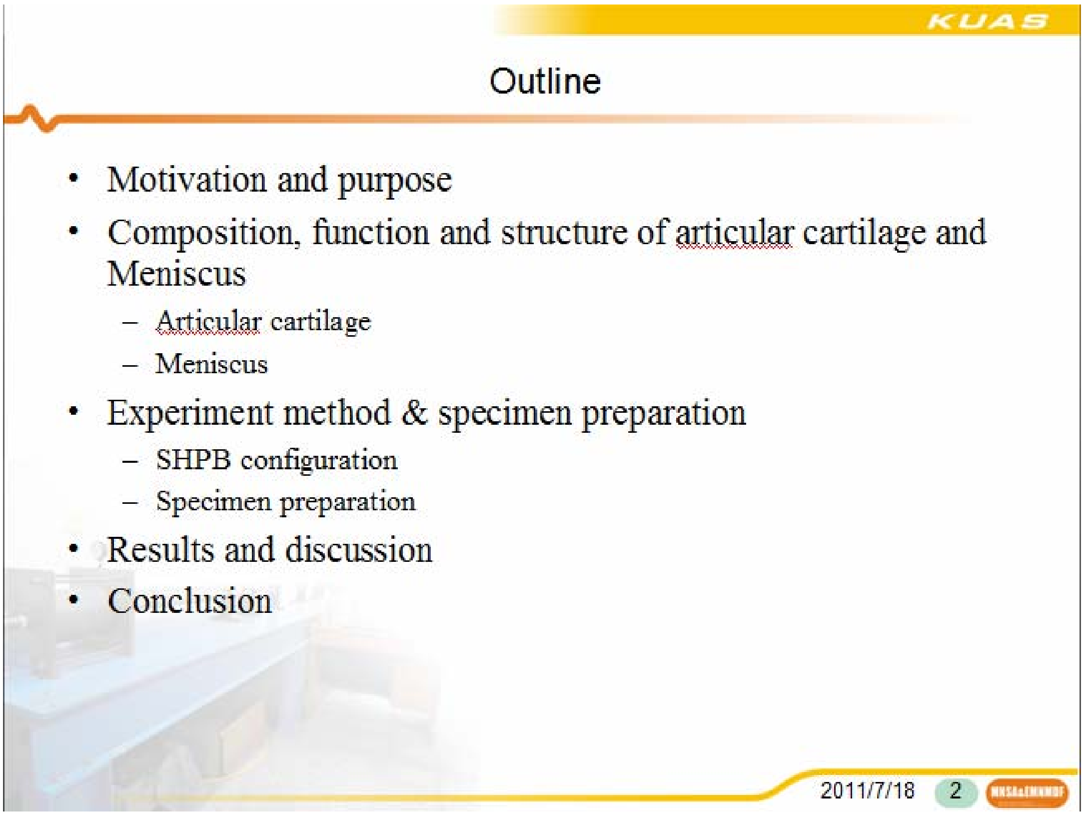
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Outline
• Motivation and purpose
• Composition, function and structure of articular cartilage and Meniscus
– Articular cartilage
– Meniscus
• Experiment method & specimen preparation
– SHPB configuration
– Specimen preparation
• Results and discussion
• Conclusion
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Motivation and Purpose

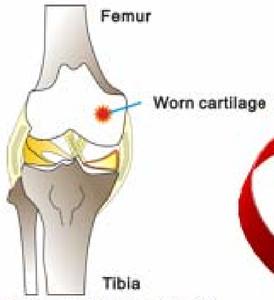

Fig. 1 Schematic diagram of the osteoarthritis in knee

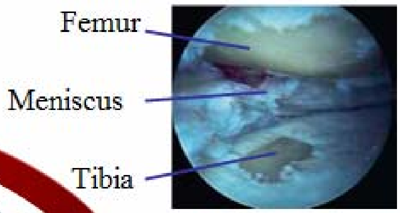

Fig. 2 An image of osteoarthritis [1]

Osteoarthritis

Degenerate with age

>45 years old	27.8%	[2, 3]
>60 years old	37.4%	[2, 3]
25~74 years old	12.1% in US	[2]

Understand the weight-bearing limit of the structures

SHPB experiment

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Introduction for Articular cartilage, Meniscus

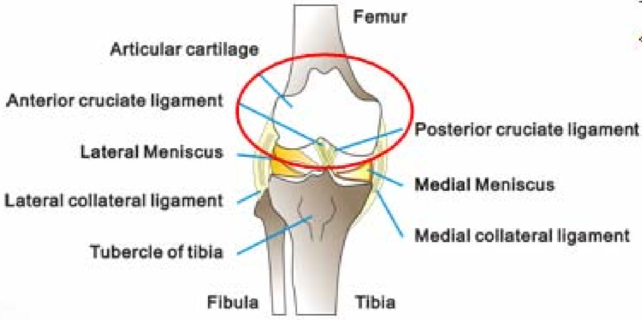

Fig. 3 Schematic diagram of knee

- Primary composition of Articular cartilage [2, 4, 5]
  - 30% of solid matrix
    - Type II collagen
    - proteoglycans
  - 70% of interstitial fluid
    - Contain Na^+, K^+, Ca^+ ion…

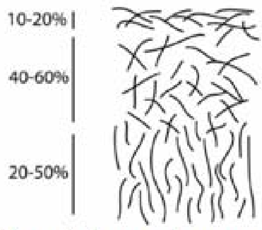

Fig. 4 Schematic diagram of structure of articular cartilage [2]

- Function
  - Lubrication, Low friction
  - Weight-bearing

Introduction for Articular cartilage, Meniscus

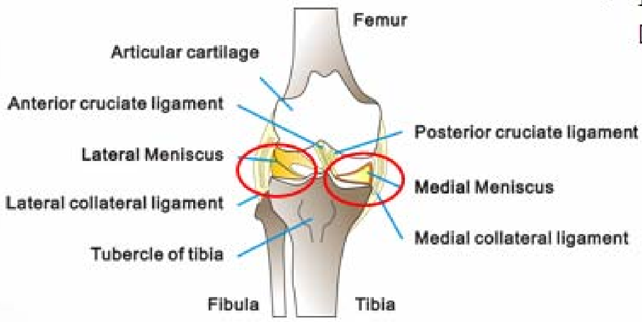

Fig. 3 Schematic diagram of knee

- Primary composition of meniscus [6, 7, 8]
  - Water 72%
  - Collagen 22%
    - 90% of type I collagen
    - Minor types II, III and IV
  - Glycosaminoglycans 0.8%
  - DNA 0.12%

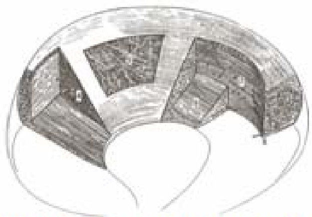

Fig. 5 Schematic diagram of structure of menisucs. [1]

- Function
  - Keep knee stable
  - Distribute loading
  - Absorb vibration

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Method

- Dynamic Experiment
  - The dynamic response of Meniscus tissue, articular cartilage in compression were studied using the split hopkinson pressure bar.
  - Modifications
    - Pulse shaper, PMMA bar, Semi-conductor strain gage

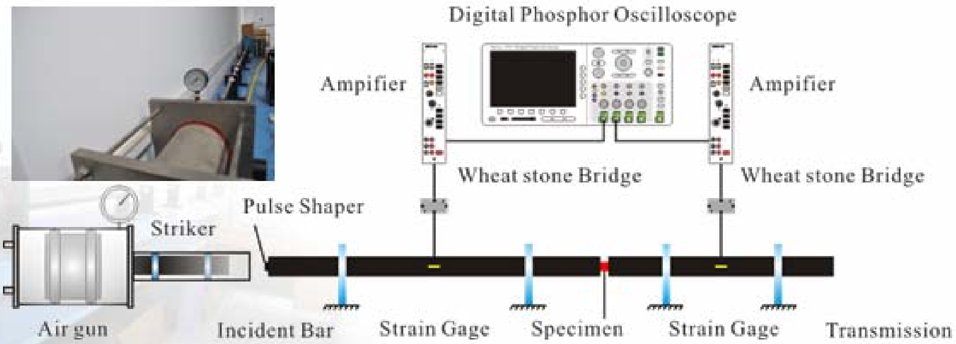

Fig. 6 Schematic diagram of SHPB

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Specimen preparation

Fig. 7 Cutting articular cartilage specimen

- Procedures-Meniscus
  - Using a scalpel and circular saw to cut off both tissue form the knee.
  - Seal up with sealing bags.
  - Pre-froze it in 4℃ environment for 2 hours, and freeze it in a -30℃ fridge until tested.
  - Maintain the length-diameter ratio of the sample between 0.1~0.3
  - Complete the experiment in 24 post-mortem hours for the articular cartilege, 60 post-mortem hours for the meniscus.

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Specimen preparation

Fig. 8 Cutting meniscus specimen

- Procedures-Meniscus
  - Using a scalpel and circular saw to cut off both tissue form the knee.
  - Seal up with sealing bags.
  - Pre-froze it in 4℃ environment for 2 hours, and freeze it in a -30℃ fridge until tested.
  - Maintain the length-diameter ratio of the sample between 0.1~0.3
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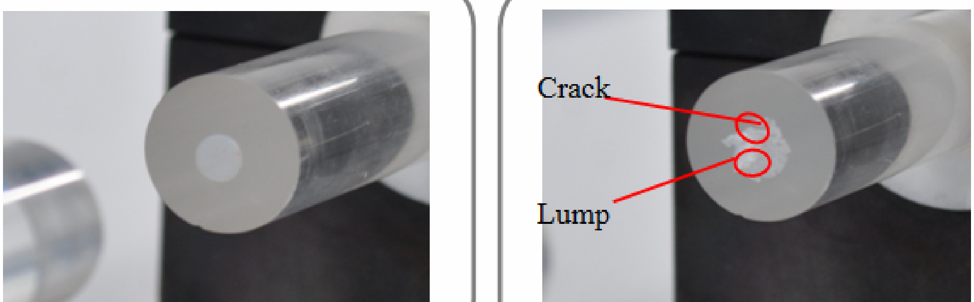
Result and Discussion

- Macroscopic -Articular Cartilage



(a) (b)

Fig. 9 (a) Native porcine articular cartilage
(b) The articular cartilage after shock loading at strain rate 1500s^{-1}

Raw- Smooth, Low friction

Damage feature- Lump, Crack

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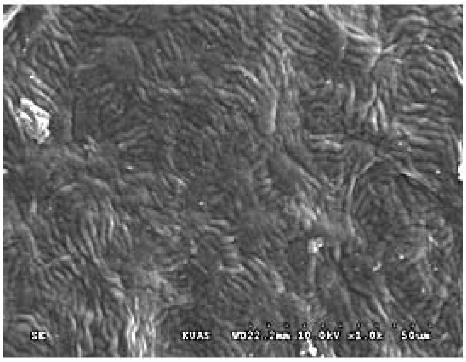
Result and Discussion

- Microscopic -Articular Cartilage (Before tested)



- Native
  - Random undulate-like structure
  - cellular debris
- Damage feature
  - Uniform agreement
  - Fiber-like damage.

Fig. 10 The SEM image of native porcine articular cartilage at magnification 1000X.

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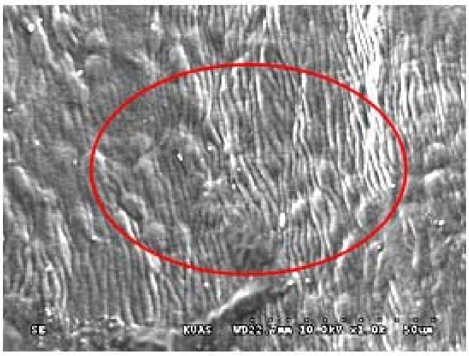
Result and Discussion

- Microscopic -Articular Cartilage (After tested)

Uniform agreement



Fiber-like damage

Fig. 11 The SEM image of compressed porcine articular cartilage at strain rate 1000s-1, magnification 1000X.

Fig. 12 The SEM image of compressed porcine articular cartilage at strain rate $1000s^{-1}$, magnification 3000X.

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Result and Discussion

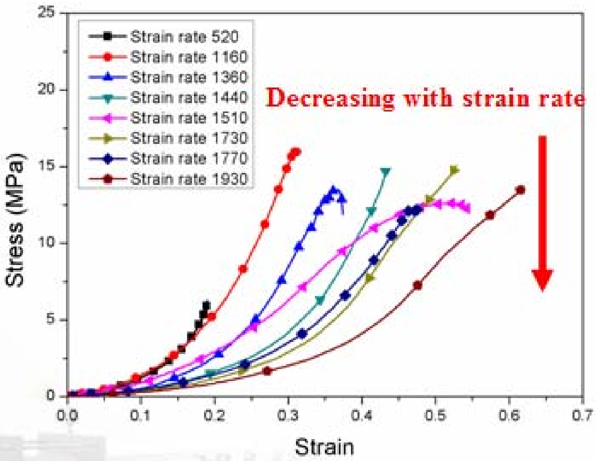


Fig. 13 Stress-strain curve of articular cartilage with different strain rate.

Table. 1 Young's modulus and strength of articular cartilage with different strain rate.

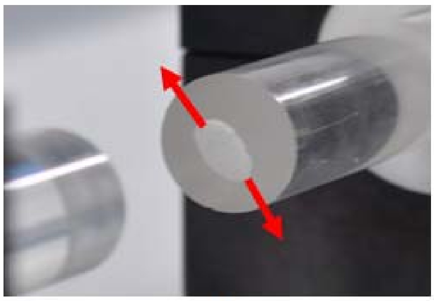
Strain Rate (1/s)	Young's Modulus (MPa)	Strength (MPa)
520	10.6	6.3
1160	8.57	16.06
1360	8.29	13.50
1440	7.11	14.76
1510	6.77	12.62
1730	6.37	15.07
1770	5.65	12.26
1930	5.41	13.76

Articular cartilage

Result and Discussion

- Macroscopic -Meniscus

(a)



(b)

Fig. 14 (a) Native porcine Meniscus
(b) The articular cartilage after shock loading at strain rate $1000s^{-1}$

Native meniscus tissue

Lateral tensile behavior

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Result and Discussion

- Microscopic -Meniscus

Before tested

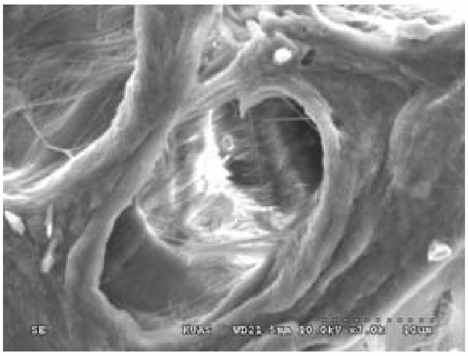

Fig. 15 The SEM image of native porcine meniscus at strain rate 3000s^{-1}, magnification 3000X.

After tested

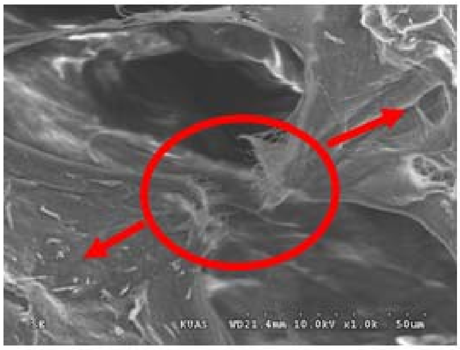

Fig. 16 The SEM image of compressed porcine meniscus at strain rate 1000s^{-1}, magnification 1000X

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Result and Discussion

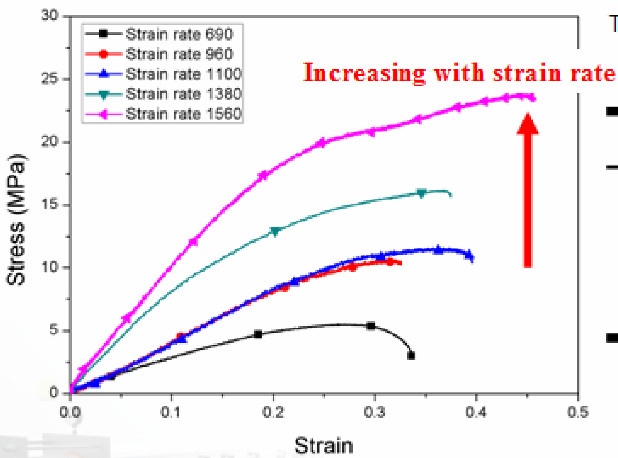
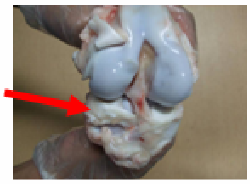


Fig. 17 Stress-strain curve of axial meniscus with different strain rate.

Table. 2 Young's modulus and strength of meniscus with different strain rate.

Strain Rate (1/s)	Young's Modulus (MPa)	Strength (MPa)
690	35.63	5.55
960	36.55	10.67
1100	44.85	11.59
1380	73.21	16.16
1560	148.14	23.83

Meniscus



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Conclusions

- Articular cartilage
  - Low friction.
  - Collagen agreement with horizontal direction at superficial zone, change to radial direction at deep zone.
  - J-shape stress-strain curve.
  - The strength and Young's modulus increasing with strain, and decreasing with strain rate form the strain rate range 1000~2000s^{-1}.
  - The arrangement of collagen was changed into uniform direction.
  - Lump, crack and fiber-like damage
- Meniscus
  - Collagen agreement with peripheral direction for the inner meniscus tissue and agreement with random direction for outer meniscus tissue.
  - r-shape stress-strain curve.
  - The strength and young's modulus increasing with strain rate form the strain rate range 1000~2000s^{-1}.
  - Lateral extension behavior and tensile damage under axial loading

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七、研習證書

Society for Experimental Mechanics, Inc.

An International Scientific and Educational Society

SEM

Certifies that

Yun Ching Juang

successfully completed the course

Methods of Strain Data Analysis

June 12, 2011

Uncasville, Connecticut USA

Paul Gloeckner

Cummins, Inc