膝關節面間生醫替代材料之應力分析（II）

計劃編號：NSC 89-2212-E-002-102
執行期限：89/08/01~90/07/31
主持人：陳兆勛　國立台灣大學應用力學研究所教授

一、中文摘要：

膝關節面植間入 Polyetherene Orthoplastic 替代品，因受力造成磨耗面產生碎粒雜質而被骨髓吸收，則衍生出常久性問題，如關節面鬆脫及感染等問題。本期計劃乃針對裂縫存在於雙層不同材料之界面間，或存在於三明治型的試件中的中間層內層或層與層間時，當各種上述狀況的試件承受不同破壞模式，其裂縫的成長情形，以及其與界面能量的關係。試圖探討此生醫替代材料作為臀、膝替代品時之間密合性及其應力關係。

英文摘要

Debris resulting from damage to the surface of polyethylene components of total joint replacements has previously been shown to contribute to long-term problem such as loosening and infection. Surface damage has been associated with fatigue processes due to stresses arising from contact between the metal and polyethylene components in this.

In this study we will use the PE components of total joint replacements. and we try to use elasticity and finite-element solutions to find out these stresses under in vivo loading and check the stress concentration of the contact area .

二、　計劃緣由與目的：

膝關節面植間入 Polyetherene Orthoplastic 替代品，因受力造成磨耗面產生碎粒雜質而被骨髓吸收，則衍生出常久性問題，如關節面鬆脫及感染等問題。本計劃乃針對上述"膝關節面植間入 Polyetherene Orthoplastic 替代品"作應力分析。試圖探討此生醫替代材料作為臀、膝替代品時之間密合性及其應力關係。本期計劃乃針對裂縫存在於雙層不同材料之界面間，或存在於三明治型的試件中的中間層內層或層與層間時，當各種上述狀況的試件承受不同破壞模式，其裂縫的成長情形，以及其與界面能量的關係。

三、　研究方法及進行步驟：

在一般骨科臨床醫學上，人工關節常遇到有經某種原因所產生的破裂，而導致關節炎等現象。在醫學上，往往無法單獨解決這種複雜的力學問題。並且在一般骨關節處的接觸問題上，亦是一種複雜的接觸力學問題。因而本期的研究工作乃致力於臨床醫學上所遭遇到的移植人工關節之接觸破壞行為，交界面裂紋或材料自身內部裂縫產生後之破裂行為，從其基本的骨骼關節之接觸力學行為進而推衍其產生破裂之原因，以及如何改善以求能防止

破裂之產生，並希望從破裂產生後之力學行為作研究，以徹底瞭解在有破裂產生後，如何導致令病患痛苦不已之關節炎等症狀，以及尋求解決之道。

四、結果與討論

首先我們先對骨骼關節之運動行為作一深入分析，了解在肢体運動時關節的行為如何，針對此一行為我們配合全像術可對整個骨骼較大區域在受彎曲效應時的運動作量測藉以掌握整個大區域之基本運動現象。另外利用電子光斑干涉儀作近關節處之微觀變形量測之探討。尤其是在裂縫發生之後的延伸及路徑判斷所需訊息和裂紋尖端位移場效之下的應力強度因子都可由直接經由實驗觀察量測並由迅速之數位結果換算分析及推演其應變量及應力場，抑或再間接利用有限元素分析法作數值計算得到裂紋尖端鄰域的一些重要訊息。而且對於極受重視之人工關節因裝置失妥而導致之破壞的疾病原因都可以藉此分析技術之建立分析校正出來。

在理論分析部份，我們從接合力學(Mechanics of Adhesive Bonding)著手，先對人工關節之互鎖式(interlock)接合方式進行探討，並著眼六壬其特有之兩種現象(1)介面無滑動，無切向應力，(2)接合區(cohesive zone)近裂紋處對應力強度因子所造成弱化現象，以此二者為前題作為分析之基礎以設計力學模型，並參考前人所用之線性或非線性彈簧作模擬。在試片的測試工作上，亦參考前人所使用之純彎曲以及單軸拉伸兩種，分別可探討受張、壓兩種狀況之應力強度及破裂行學，和了解開口變位，互鎖式結合的近尖端之力學行為。至於理論修正則得藉以建立數值模型。

五、 參考文獻

1 J. S. Bradley, G. W. Hastings, and C. Johnson-Nurse, "Carbon fibre reinforced epoxy as a high strength, low modules material for internal fixation plates," Biomaterials, 1, 38-40 (1980)

2 L. Claes, W. Hüttner, and R. Weiss, "Mechanical properties of carbon fibre reinforced polysulfone plates for internal fracture fixation," in Biological and Biochemical Performance of Biomaterials, P. Christel, A. Meunier, and A. J. C. Lee (Eds.), Elsevier Science, Amsterdam, 1986, 81-86

3 N. Gillett, S. A. Brown, J. H. Dumbleton, and R. P. Pool, "The use of short carbon fibre reinforced thermoplastic plates for fracture fixation," Biomaterials, 6, 113-121 (1985)

4 S. A. Brown, "Biomechanical compatibility," in Biocompatibility of Orthopedic Implants, "Vol. 1, D. F. Williams (Ed.) CRC Press, Boca Raton, 1982, pp. 75-110.

5 R.S. Hastings, S. A. Brown and Moet, "Characterization of short fiber reinforced polymers for fracture fixation devices, "presented at the thirteenth Annual Meeting of the Society for Biomaterials, New York, June 3-7, 1987

6 D. F. Williams, A. McNamara, and R. M. Turner, "Potential of Poly-etheretherketone (PEEK) and carbon fibre-reinforced PEEK in medical applications, "J. Mater. Sci. Lett. 6(2), 188-190 (1987)

7 R. N. Cogswell and M. Hopprich, "Environmental resistance of carbon fibre-reinforced polyetheretherketone. "Composites 14(3), 1983, 251-253

8 ASTM F813 "Standard practice for direct contact cell culture evaluation of materials for medical devices," in Annual Book of ASTM standards 13.01 ASTM, Philadelphia, 1987

9 C. A. Behling and M. Spector, "Quantitative characterization of cells at the interface of long-term implants of selected polymers," J. Biomed. Mater. Res., 20, 1986, 653-666

10 M. Spector, "A high modulus polymer for porous orthopedic implants: biomechanical compatibility of porous implants," J. Biomed. Mater. Res., 12, 1978, 665-677

11 ASTM F619 "Standard practice for extraction of medical plastics" in Annual Book of ASTM Standards 13.01 ASTM, Philadelphia, 1987

12 ASTM F895 "Standard test method for agar diffusion cell culture screening," in Annual Book of ASTM, Philadelphia, 1987

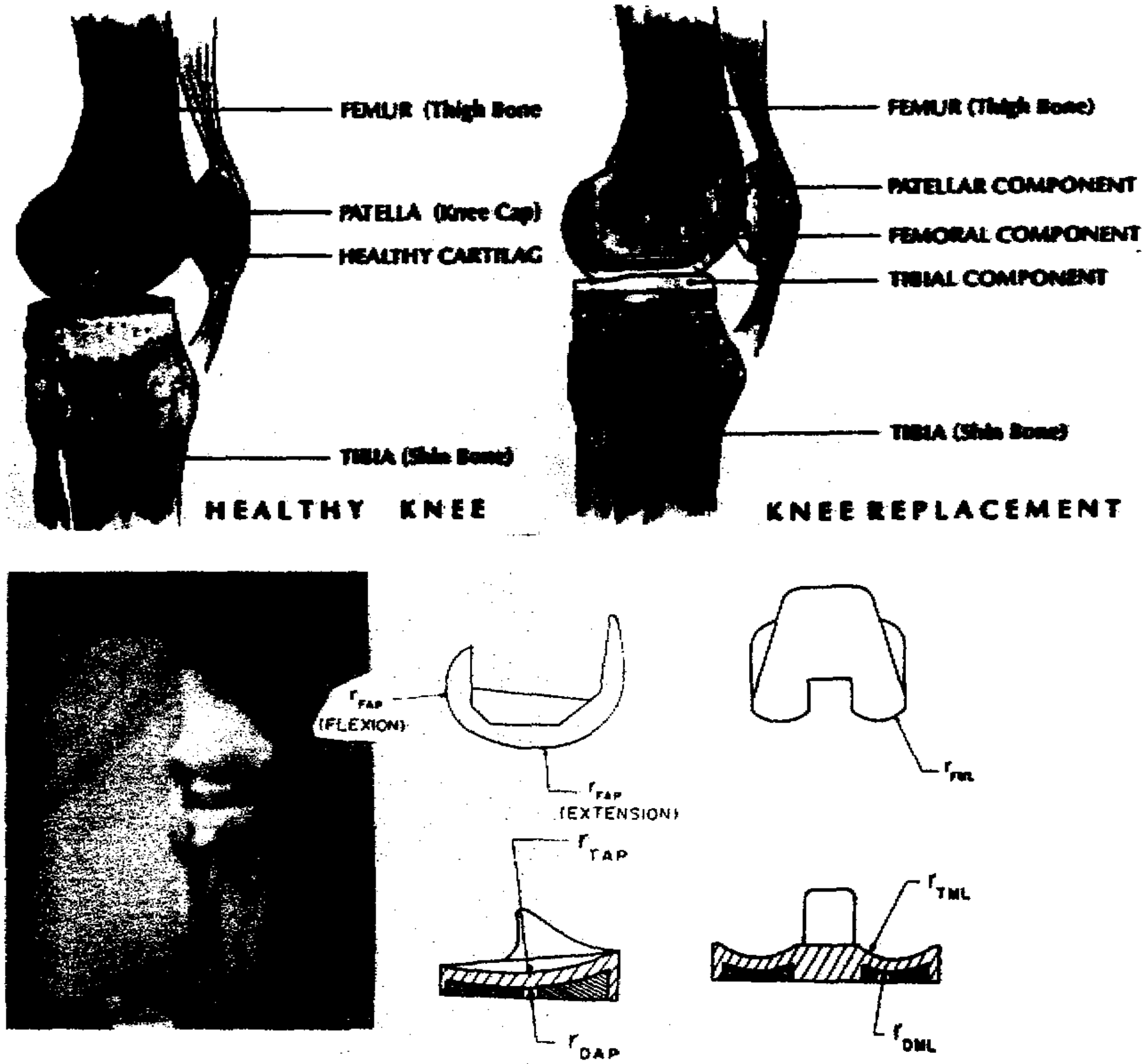


FIG. 1

The contacting surfaces for the total knee replacement were described by four radii: r_{FAP}, the radius of the femoral component in the anterior-posterior direction; r_{FML}, the radius of the femoral component in the medial-lateral direction; r_{TAP}, the radius of the tibial component in the anterior-posterior direction; and r_{TML}, the radius of the tibial component in the medial-lateral direction. The distal surface of the metal-backed polyethylene is described by radii r_{DAP} and r_{DML}, for the anterior-posterior radius and the medial-lateral radius, respectively. Note that the radius of the femoral component in the anterior-posterior direction has two values: one for contact in extension and one for contact in flexion.

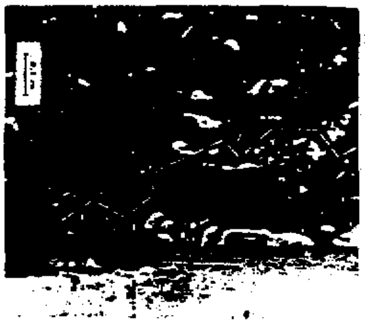
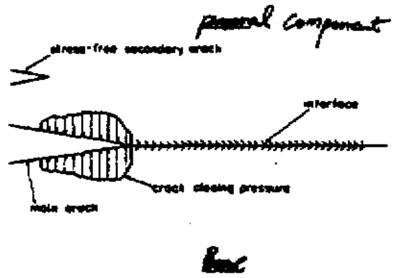


Fig. 1(c) [illegible]



2 Two interacting edge cracks, with closing pressure on the interfacial crack

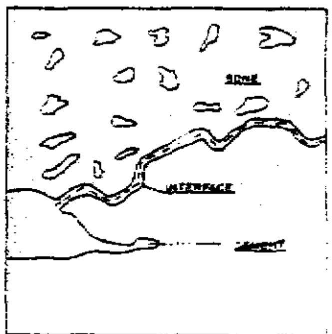


Fig. 1(d) Schematic of Fig. 1(c)

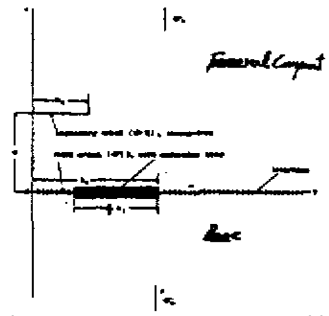


Fig. 3 Problem A: Two interacting edge cracks in a half-plane [illegible]

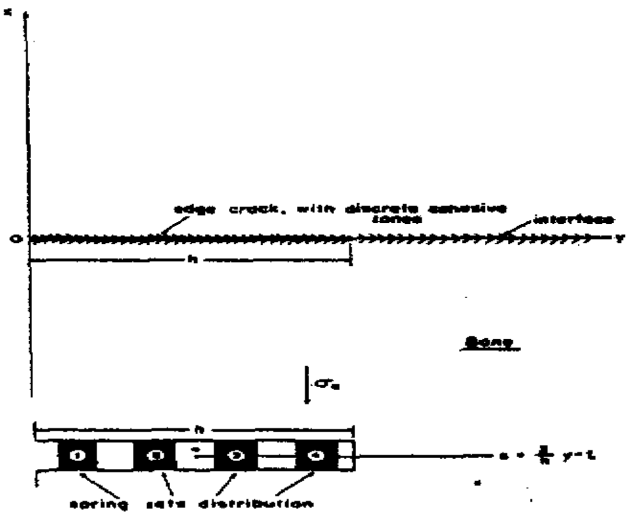


Fig. 4 Problem B: Interface edge crack with discrete distribution of springs. Cohesive zone: $S = (-0.7, -0.5] \cup (-0.3, -0.1] \cup [0.1, 0.2] \cup [0.6, 0.7]$.