



**Finite Element Analysis Of Type-7 Microcrack
Penetration Induced By Haversian System**

by

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
APDL	Ansys Parametric Design Language
BMD	Bone Mineral Density
CINT	Constrained Integration Numerical Technique
CMOD	Crack Mouth Opening Displacement
CTOD	Crack Tip Opening Displacement
DEM	Displacement Extrapolation Method
DELR	Radius of First Row Element about Keypoint
EPFM	Elastic Plastic Fracture Mechanics
FE	Finite Element
HC	Haversian canal
LCP	Locking Compression Plate
LSF	Lateral Screw Fixation
LEFM	Linear Elastic Fracture Mechanics
NTHET	Number of Elements in Circumferential Direction
SA	Stress Amplification
SERR	Strain Energy Release Rate
SETP	Strain Energy Transfer Parameter
SIF	Stress Intensity Factor
SS	Stress Shielding
SST	Stress Shielding Transfe
XFEM	Extended Finite Element Method

LIST OF SYMBOLS

a	Crack length
a/W	Crack-to-width ratio
E	Young's modulus
G_{LP}	Strain energy release rate for longitudinal primary
$G_{LP_A,P,M,L}$	Strain energy release rate for longitudinal primary anterior, posterior, medial, lateral
G_{LS}	Strain energy release rate for longitudinal secondary
$G_{LS_A,P,M,L}$	Strain energy release rate for longitudinal secondary anterior, posterior, medial, lateral
G_{TP}	Strain energy release rate for transverse primary
$G_{TP_A,P,M,L}$	Strain energy release rate for transverse primary anterior, posterior, medial, lateral
G_{TS}	Strain energy release rate for transverse secondary
$G_{TS_A,P,M,L}$	Strain energy release rate for transverse secondary anterior, posterior, medial, lateral
K_{IBS}	Stress intensity factor Mode I Brown and Srawley
K_{IGB}	Stress intensity factor Mode I Gross and Brown
K_{IT}	Stress intensity factor Mode I Tada
K_{ILP}	Stress intensity factor Mode I longitudinal primary
$K_{ILP_A,P,M,L}$	Stress intensity factor Mode I longitudinal primary anterior, posterior, medial, lateral
K_{IILP}	Stress intensity factor Mode II longitudinal primary
$K_{IILP_A,P,M,L}$	Stress intensity factor Mode II longitudinal primary anterior, posterior, medial, lateral
$K_{ILS_A,P,M,L}$	Stress intensity factor Mode I longitudinal secondary anterior, posterior, medial, lateral
$K_{IILS_A,P,M,L}$	Stress intensity factor Mode II longitudinal primary anterior, posterior, medial, lateral
K_{ITP}	Stress intensity factor Mode I transverse primary
$K_{ITP_A,P,M,L}$	Stress intensity factor Mode I transverse primary anterior, posterior, medial, lateral
K_{IITP}	Stress intensity factor Mode II transverse primary
$K_{IITP_A,P,M,L}$	Stress intensity factor Mode II transverse primary anterior, posterior, medial, lateral
$K_{ITS_A,P,M,L}$	Stress intensity factor Mode I transverse secondary anterior, posterior, medial, lateral
$K_{IITS_A,P,M,L}$	Stress intensity factor Mode II transverse secondary anterior, posterior, medial, lateral

p	Significance difference
$\langle p \rangle$	Stress traction
$\langle p_{HC} \rangle$	Stress traction Haversian canal
Y	Shape Correction factor
Y_{BS}	Shape correction factor Brown and Srawley
Y_{GB}	Shape correction factor Gross and Brown
Y_T	Shape correction factor Gross and Brown
ε	Elastic strain
σ_{max}	Maximum von Misess

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Analisis Tidak Terhingga Jenis-7 Penembusan Retakan Mikro Dicitus Oleh Interaksi Sistem Haversian

ABSTRAK

Kestabilan penetapan mutlak dan relatif menentukan pemulihan tulang sekunder utama dan tidak melalui pembentukan semula tulang dan osseointegrasi. Klinikalnya, dibawah bebanan mampatan, keadaan ricih dan kilasan, kestabilan penetapan implan terjejas oleh ketidakcukupan, kelebihan dan ketidaktetapan pemindahan perisai tekanan (SST) yang tidak konsisten antara permukaan implan-tulang. Lebih buruk, mekanisma pemindahan perisai tekanan (SST) boleh mencetuskan kegagalan penahan implan, pin implan atau kelonggaran skru dan patah tulang anatomi yang berpunca dari kerosakan tulang oleh pra-gerudi retakan mikro antara muka. Interaksi elastik mikromekanik penembusan retakan mikro ke dalam sistem Haversian yang berpunca oleh retakan mikro pada masa ini kurang dibincangkan berdasarkan prinsip mekanik patah. Oleh itu, penyelidikan ini bertujuan untuk menyelidik Jenis-7 penembusan retakan mikro tunggal terhadap pembentukan sistem Haversian bagi tulang primer dan sekunder spesifikasinya kepada patah tulang kortikal diafisis melintang dan menegak. Mekanisme patah elastik lurus (LEFM), mekanisme patah elastik plastik (EPFM) dan teori Kachanov terhadap lubang ellips dan interaksi retakan mikro digunakan untuk mencipta model patah tulang primer dan sekunder dengan menggunakan analisis unsur terhingga (FE) dalam ANSYS APDL bagi model penembusan retak Mod I dan Mod II Jenis-7 model penembusan untuk semua korteks melintang dan menegak dengan menggabungkan pendekatan singulariti tekanan retak dengan menggunakan kaedah ekstrapolasi anjakan (DEM) dan kadar keluaran tenaga tekanan (SERR) menggunakan kaedah J- integrasi. Kedua-dua pendekatan K_{ITP} , K_{ILP} dianalisis secara numerik dan disahkan dengan persetujuan teori yang baik oleh Brown & Srawley (0.2%), Gross & Srawley (0.4%) dan Tada (1.6%) formulasi analisis untuk retakan kelebihan tunggal dalam badan terhingga. Sensitiviti dan analisis statistik juga menunjukkan korelasi ketara ($p < 0.05$) antara parameter yang diukur untuk semua korteks. Model penembusan Jenis-7 dipertingkatkan untuk penilaian tulang primer. Kedua-dua kaedah DEM dan J - integrasi mempunyai ketepatan untuk menentukan Mod I $K_{ITS(A,P,M,L)}$ dan Mod II $K_{ITS(A,P,M,L)}$, tetapi SIFs kelihatan hanya J-intergrasi yang boleh menilai pengaruh Young's modulus terhadap retakan tulang primer. Oleh itu, untuk tulang sekunder, hanya analisis J-intergrasi diteruskan untuk menilai ketidaksamaan interaksi sistem Haversian kepada retak mikro melintang dan menegak Jenis-7 penembusan melalui matriks interstisial, garis simen dan osteon yang disebabkan oleh daya tarikan tekanan terusan Haversian. Kuantifikasi penguatan tekanan σ_{SA} , pelindung tres σ_{SS} dan daya tarikan tegangan $\langle p_{HC} \rangle$ dinilai dan disahkan oleh formulasi analisis dan teori Kachanov mengenai retakan elips dan interaksi retakan mikro. Keputusan menunjukkan pada melintang ($K_{ITS}/K_0 > 1$) dan menegak ($K_{ILS}/K_0 > 1$), σ_{SA} didominasi oleh tekanan interaksi pada kawasan matriks interstisial. Pemindahan σ_{SA} berlaku ketika penembusan barisan simen dan di dalam osteon selanjutnya kepada penembusan terusan Haversian, penembusan tersebut didorong oleh σ_{SS} pada ($K_{ITS}/K_0 < 1$) dan ($K_{ILS}/K_0 < 1$) Walaubagaimanapun, kedua-dua arah melintang dan menegak Jenis-7 mengalami intensiti dan kadar pelepasan tenaga berlainan σ_{SA} ke σ_{SS} apabila penembusan garis simen terhadap nisbah retak ke lebar a/W Kesimpulannya, model interaksi sistem Haversian telah berjaya menunjukkan Jenis -7 penembusan retakan mikro bagi pembentukan tulang primer dan sekunder.