A PHOTOELASTIC STUDY OF STRESSES IN THE FEMURE

Dr. Jamal A. Hassan,[*] Dr. Sadiq J. Abass,[*] Eng. Zainab majid,[**]

[*]College of Engineering, Al-Nahrain University

[**]Electrical Engineering Technical College , Middle Technical University

E-mail: engzainabmajid@gmail.com

Abstract

The femur bone is the longest bone in the human body. The proximal end of femur contacted at hip joint and in the distal end contacted at knee joint. Femur bone affected with muscles attached with it and with contacts at joints and weight bearing of body, all of these applied loads on femur and stresses effect result. In this study we will discuss stress analysis on the femur bone when a compressive load applied on the head of the bone at the contact region with acetabulum by using the photo elasticity transmission technique. The normal femur bone scaling to prototype according to material properties an polariscope load applied. The effect of load on the prototype with passage of polarized light through it give fringes pattern which Interpretation to show the stress at head of femur and at the shaft of femur. The study was done in Baghdad during 2016 from Al-Nahrain University.

Keyword: Photoelasticity, femur bone and stress analysis.

دراسه الاجهادات على عظم الفخذ

الخلاصه

عظم الفخذ هو أطول عظمة في جسم الإنسان. النهاية القريبه من عظم الفخذ تتصل بمفصل الورك و النهاية البعيدة تتصل بمفصل الركبة . عظم الفخذ تتاثر بالعضلات المتصله به وتتأثر بأتصالاته مع المفاصل و وزن الجسم الذي تحمله, كل هذه الأحمال المسلطه على عظم الفخذ والاجهادات تؤثر على النتائج . في هذه الدراسه سوف نناقش تحليل الاجهادات على عظم الفخذ عند تسليط قوة الضغط على رأس العظم في منطقة اتصال مع العظم الحقي باستخدام تقنية المستقطب الضوئي الناقل. عظم الفخذ الطبيعيه تدرج الى نموذج بقياسات معينه وفقا لخصائص الماده المستخدمه والاحمال التي تسلط من المستقطب الضوئي المستخدم. تأثير الاحمال على نموذج العظم مع مرور الضوء المستقطب من خلاله يعطي ترتيب هدبي يفسر لكي يظهر الاجهادات على رأس عظم الفخذ وعلى رمح العظم

.

الكلمات المفتاحية: المرونه الضوية, عضم الفخذ , تحليل الشد

INTRODUCTION

Photoelastic stress analysis is a technique that provides us with full field stress distribution at any examined model. It is based on the property of some transparent double refraction materials (birefringence material) [1]. If these materials are subjected to an applied load the refractive index of material change and the magnitude of the change is different in two plane of principal stress. This result in light passing through stressed material at different speed according to applied load [2].

The hip is a ball-and-socket joint as shown in figure (1). The socket is formed by the acetabulum, which is part of the large pelvis bone. The ball is the femoral head, which is the upper end of the femur [3]. The femur head subjected to compressive load that applied from the pelvis at contact with acetabulum region. Qualitative analyses of the stress distribution of the trabecular femoral head of a human femur by photoelasticity are presented and find that the porous bone model makes the stresses. Reduced at the contact with surface of the femoral head joint. That because of maximum stress concentration is shifted from the surface to the interior of the bone, results from the damping of external forces and diffused them towards the interior of the bone tissue [4]. The state of stress of an intact femur was analyzed using a three-dimensional finite element model and strain gauges for experimental measurements .several modes of loading, the deflections and the principal and comparison stresses were determined and compared. The upper one third and the diaphysis of the femur are differently affected in their state of stress. [5]

Use of photoelastic models to interpret and demonstrate biomechanical principles. Isochromatic fringes show bone stresses distribution in the femur is explained with respect to iliotibial tract loading, and he uses two-dimensional models to illustrate bone remodeling theories. [6]

Model from catalin made to femur bone with compressive load applied on the bone .the arrangement of stresses line markedly show the trabecular structure at longitudinal section of femur . The greater number of stresses line appears to be at medial side and shifted toward the line of mechanical axis of normal femur. [7]

In this work a qualitative analysis of the stress distribution of a cross section of the medial condyle of a human femur byphotoelasticity is presented. A model of the cross section was obtained by plaster casting, carefully maintaining the internal architecture of the Porous bone. The fringe patterns observed in the porous bone model showed that the maximum stress concentration is shifted from the surface to the interior of the bone and diffused [8].

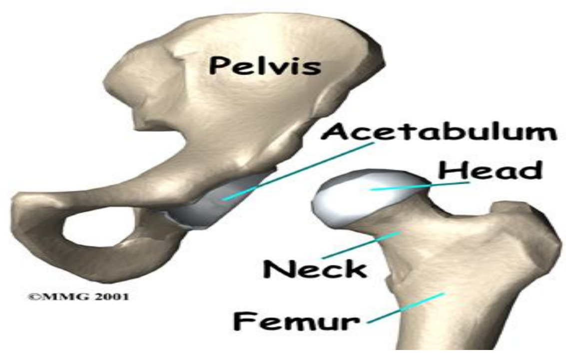


Fig.(1) Region of contact between femur head and acetabulum.

Aim of the study

In this study the photoelasticity used to find the stresses at femur bone of human body at hip joint. The stresses analyzed at different region in the femur bone and then compared with each other to find the higher stress which lead to fracture at some cases.

EXPERIMENTAL WORK

The first step on photoelasticity techniques calibration of material to find the material fringe values defined as number of fringes produced per unit load. Material fringe value used to accurately determine the stress distribution. The material fringe value depends on the type of birefringes material which used to make the prototype. The calibration method used at this study by tensile specimen which have a specific dimensions depend on the thickness of material. The width of specimen w, the thickness h, and the load applied p, fringe order n ,and the axial stress σ.

So, $\sigma 1=P/(wh)$ and $\sigma 2=0$ (1)

The birefringes material used at this study is the transparent polycarbonate. The load on tensile specimen increased gradually and order of fringes change with this increments as in figure(2). The material fringe value determined from equation (2).

$P/(wh) = nf/h$ or $f=P/(wn)$ (2)

*f=25.523/ (3.8 *1) = 6.7 N/mm fringes.*

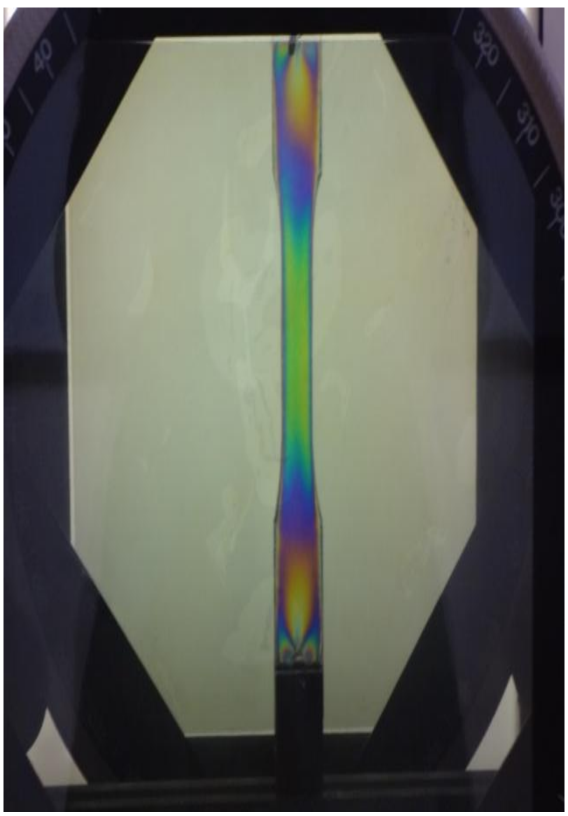
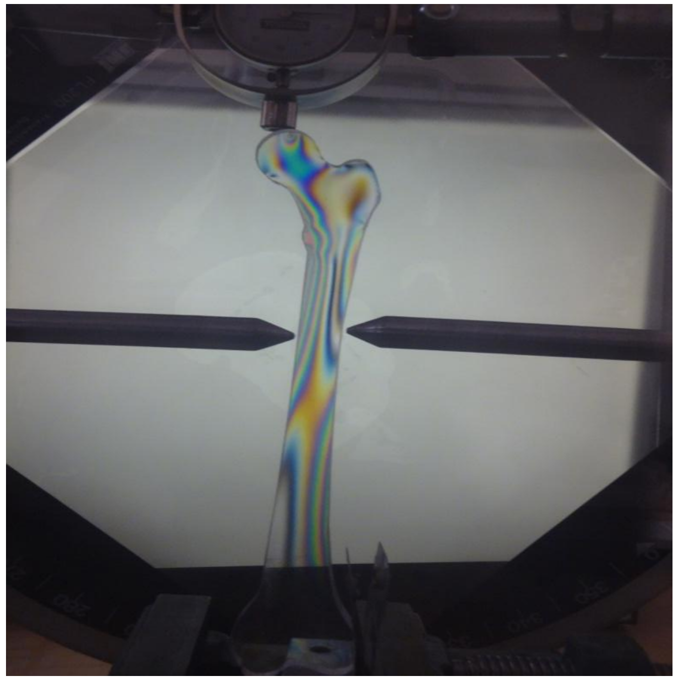


Fig.(2) Calibration of material by tensile specimen

After calibration the model of bone scaled to 2D prototype and the load applied on it founded as in figure(3). The prototype on polariscope with compressive load at 75degree on head of femur and passage of polarized light give a fringe pattern to find the stress distribution at region of contact with acetabulum and stresses at the shaft of the bone as in figure(4).



.

Fig.(3) Prototype of femur bone with applied load

Fig.(4) Fringes pattern on femur bone under load

The principal stress determined from fringe order appeared on the prototype with equation (3).

$\sigma_1 - \sigma_2 = f*n/h$ (3)

h is the thickness of prototype.

Then find the stresses on the head of femur and shaft of femur with each load applied by mohrs circle as in figure(5).

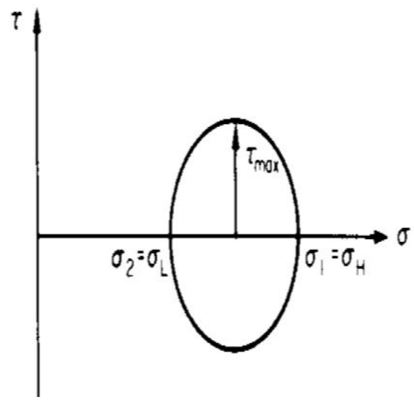


Fig. (5) Mohrs circle

Result:

The fringe order increase with the increasing of the load and find that the principal stresses and stresses in the femur head higher than the stress in the femur shaft as in table (1,2,3 and4).

Table 1: principal stresses on the femur head determined from fringe order

Load (N)	Fringe order(fringe)	Principal stresses on femur head(Mpa)
2.224	1	1.34
13.7322	2	2.68
17.9915	3	4.02
27.4646	4	5.36
31.7238	5	6.7
35.9830	6	8.04
40.24233	6	8.04
44.50159	7	9.32
48.76025	8	10.72
53.020111	9	12.06
57.2793	10	13.4
61.53862	10	13.4
70.5756	11	14.74

Table 2: principal stresses on the shaft of femur determined from fringe order.

Load (N)	Fringe order(fringe)	Principal stress on the shaft of bone(MPa)
2.224	0	0
13.7322	1	1.34
17.9915	1	1.34
27.4646	2	2.68
31.7238	2	2.68
35.9830	2	2.68
40.24233	3	4.02
44.50159	3	4.02
48.76025	3	4.02
53.020111	4	5.36
57.2793	4	5.36
61.53862	5	6.7
70.5756	6	8.04

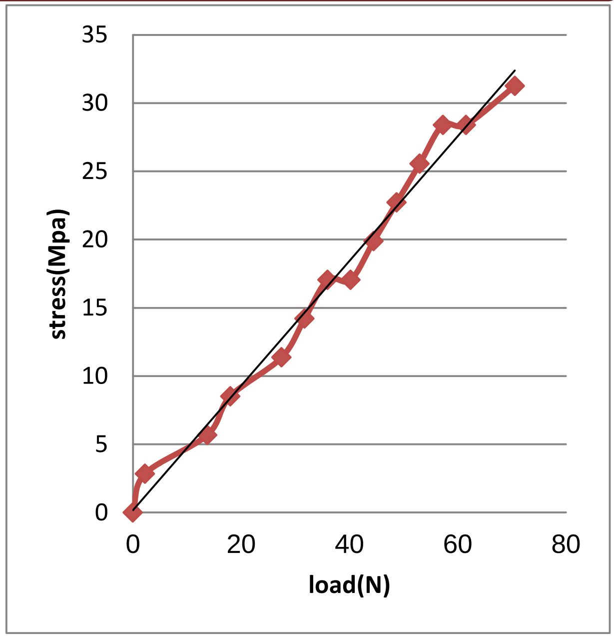


Fig. 6 Stress with load on head of femur

.

Table3: stresses on the head of femur from Mohr circle.

Principal stresses on the head of femur bone (MPa)	Stress(MPa)
0	0
1.34	2.84
2.68	5.68
4.02	8.52
5.36	11.36
6.7	14.2
8.04	17.04
8.04	17.04
9.32	19.88
10.72	22.72
12.06	25.56
13.4	28.4
13.4	28.4
14.74	31.24

Table 4: stresses from Mohr circle on shaft of femur

Principal stress on the shaft of bone(MPa)	Stresses(MPa)
0	0
1.34	2.84
1.34	2.84
2.68	5.68
2.68	5.68
2.68	5.68
4.02	8.52
4.02	8.52
4.02	8.52
5.36	11.36
5.36	11.36
6.7	14.2
8.04	17.04

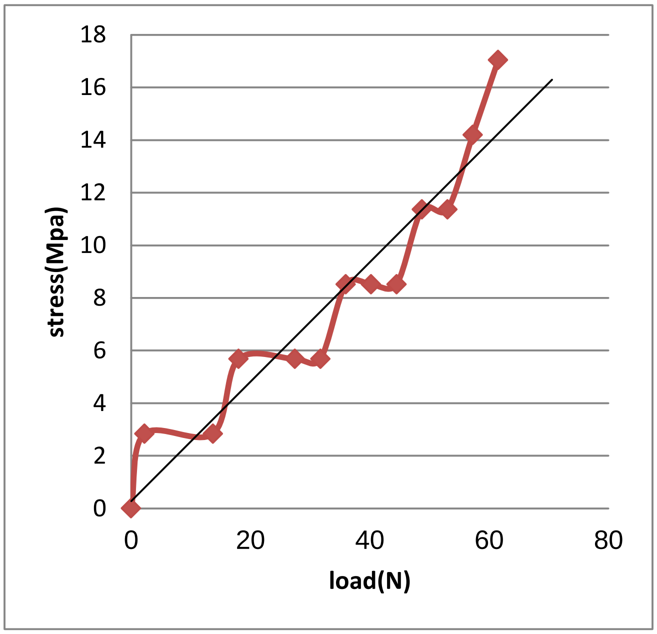


Fig. 7 Stresses with load on femur shaft

DISCUSSION

The fringe order on the head at contact more than the orders that reach at the shaft so , the stresses on the head of the bone higher than the stresses on the shaft of the bone .

Load applied directly from pelvis at contact region while the stresses on the shaft result from compression and decreased because of that the load not directly applied on it. So, with daily activity the hip joint may have arthritis or injury on the region of femur with hip contact or on the high stresses on the head of femur result from the load the femur neck that leads to hip replacement.

.

REFERENCES

[1] James F. Doyle and James W. Phillips, eds,**" Manual on experimental stress analysis"**

[2] J. W. Dally and W. F. Riley, *"**Experimental Stress Analysis**"* (New York: McGraw-Hill, 1978)

[3] Gerard J. Tortoraand Mark T. Nielsen, "**principles of human anatomy"** , 12th Edition

[4] Rodríguez Lelis J.M., Marciano Vargas Treviño, Navarro Torres J., Arturo Abundez P, Sergio Reyes Galindo, and Dagoberto Vela Arvizo ,"**A qualitative stress analysis of a cross section of the trabecular bone tissue of the femoral head by photoelasticity"** Vol. XXVIII, Núm. 2 ,Diciembre 2007 ,pp 105 – 109

[5] A. Rohlmann, U. Mössner , G. Bergmann, R. Kölbel," **Finite-element-analysis and experimental investigation of stresses in a femur".**

[6] 8th Samuel Haughton Lecture**," Images from Waves – photoelasticmodellingofBones"** January 2002 **.**Page 209**.**

[7] HENRY MILCH." PHOTO-ELASTIC STUDIES OF BONE FORMS" J Bone Joint Surg Am. 1940;22:621-626.

[8] J.M. Rodríguez-Lelis , A. Abúndez-Pliego, Marciano Vargas-Treviño, J. Navarro-Torres, Dagoberto Vela-Arvizo, G. Piña-Piña," A Qualitative Stress Analysis of a Cross Section of the Trabecular Bone Tissue of a Distal Femur by Photoelasticity"