FINITTE ELEMENT ANALYSIS OF KNEE PAD

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Thesis submitted in partial fulfilment of the requirements
for the award of the degree of Bachelor of Mechanical Engineering

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JULY 2013

ABSTRACT

Knee is so vulnerable and sensitive to alignment, a good care of knee is needed to avoid the knee from any serious injuries. Knee pad was developed to protect the knee, but still there were limitation of knowledge to find the best materials for knee pad. The purpose of this study is to study the stress distribution on the knee while wearing and without wearing knee pad. The analysis was made on the basic of the Asian's soccer player that don't have a history of knee injuries. Three different angle and force were applied to the knee. The result shows the knee pad helps to distribute the stress on the knee. Thus, the stress distribution on the knee pad is better on the materials that have a high young modulus. Among all the materials that has been used for analysis, it is find out that kenaf fibre is the best materials to be used in knee pad because it can distributed and absorbed more stress compared to the other materials that has been analysed.

ABSTRAK

Lutut begitu lemah dan sensitif kepada penjajaran, penjagaan baik diperlukan untuk mengelakkan lutut daripada kecederaan yang serius. Pad lutut telah dicipta untuk melindungi lutut, tetapi masih terdapat had kepada pengetahuan mencari bahan-bahan terbaik untuk pad lutut. Tujuan kajian ini adalah untuk mengkaji taburan tekanan pada lutut ketika memakai dan tanpa memakai pad lutut. Analisis telah dibuat berasaskan pemain bola sepak Asia yang tidak mempunyai sejarah kecederaan lutut. Tiga sudut yang berbeza dan tenaga telah dikenakan pada lutut. Hasil menunjukkan pad lutut membantu untuk mengagihkan tekanan pada lutut. Oleh itu, agihan tegasan pada pad lutut adalah lebih baik pada bahan-bahan yang mempunyai young modulus yang tinggi. Antara semua bahan-bahan yang telah digunakan dalam analisis, di dapati bahawa serat kenaf adalah bahan terbaik untuk digunakan dalam pad lutut kerana ia boleh mengedarkan dan menyerap lebih banyak tekanan berbanding dengan bahan-bahan lain yang telah dianalisis.

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E	Young Modulus
N	Newton
MPa	MegaPascal
Pa	Pascal
°	Degree
%	Percentage
v	Poisson's Ratio

LIST OF ABBREVIATIONS

ABS	Acrylonitrile Butadine Styrene
EVA	Ethylne Vinyl Acetate
NIOSH	National Institute of Occupation & Safety
PU	Polyrethane

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Human knee joint is made up of bone, cartilage, ligaments and fluid. Muscles and tendons help the knee joint move. When any of these structures is diseased, it will result a knee injuries. Knee problems can cause pain and difficulty in locomotion. In some cases the doctor may recommend knee replacement.

In order to reduce the problems, knee pad are developed and the variation design of the knee pad will give a different effect to the user. Knee pad are design with various function on the basic of user demand. The knee pad are design for the athletes and person that always deal with heavy work and associate with their knee, for example lifting a heavy object.

The effect of wearing the knee pad are clinically proven that it can reduce the effect of having the knee problems. Knee problems is mostly effected by the aggressive activities. Athletes are one of the major user of the knee pad. As their activities requires movement and it will affect their knee condition. Some of the athletes that having a knee problem have to face the knee replacement and they are not qualified to play in their game. In this case their talented will be waste.

1.2 PROBLEM STATEMENT

In recent days, the use of knee pad in sport and everyday life has given a big impact to the user. Especially in sport field, the use of knee pad become one of the important in order to avoid injury. Different knee pad have their own ability with their own design and materials. But still there were limitation of knowledge to find the best materials for knee pad.

1.3 PROJECT OBJECTIVE

The aims of this study are to study the stress distribution on the knee while wearing and not wearing the knee pad and also the stress distribution on the knee pad. Besides, the characters of the knee pad are also being study as the design and the material use for the knee pad will give a different effect to the user.

1.4 SCOPE OF THE PROJECT

The analysis study will be applied to the Asian soccer player with a healthy knee conditions. The athletes must not have any medical record about the knee as this record may affect the result of the analysis for the knee and the knee pad. The scope of this study will involve three phases of work. The first step is to prepare the drawing and assemble the drawing using the solid work software. The second phases is to have the analysis of the stress by using the finite element method. The solid work drawing are transfer into the finite element software and being analysed. The finite element analysis will applied using the static stress with non-linear models test. Lastly, the result of the stress analysis will be compared and analysed and come out with a best knee pad design and materials to be produce or fabricate in future.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Knee injuries are among the most common complaints of individuals involved in sports and fitness activities. Unsurprisingly, since the knee is a weight bearing joint that must withstand large force (Fiscella, 2005). Soft tissue injuries of the knee are some of the most common and clinically challenging musculoskeletal disorders in patients presenting to the Emergency Department (Levy, 1998).

The invention of a knee pad is related for the athletes which has a cushion part which covers the front and side of the knee. Knee pad are usually be wear by the athletes that expose to regular contact and impact within the game. Knee pads such as sold for instance by the applicant under the name “protection indoor knee pad” have at least cushioned regions which surround the knee cap (patella), the lateral and medial epicondyles of the tibia lying below the knee cap on the shinbone (tibia), and the lateral and medial condyles (Gongea, 1996).

The knee joint functions as a stabilizer for the lower extremity during weight bearing and allows large range of motion for various functional activities. The two primary articulations of the knee joint are the tibia femoral joint and the patella femoral joint (Fiscella, 2005).

2.2 STRUCTURE OF THE KNEE

The knee is so vulnerable and sensitive to alignment because it is a shallow, basically unstable joint. Picture two long columns stacked atop each other, and got the thigh bone (femur) and the shin bone (tibia). The flat surfaces of the bones make the knee dependent on ligaments (which join bone to bone) and tendons (which join muscle to bone) to hold it together. Any side-bending or twisting forces endanger these supporting tendons and ligaments.

For example, standing poses done with improper alignment can put great strain on the knee. The best indicators of knee alignment in standing poses are the relative positions of the foot and kneecap. The foot acts like a pointer showing the rotation of the shin and lower leg, while the kneecap shows the rotation of the femur (Limtrakam, 2010).

The knee joint is composed of four bones: the femur (thigh bone), the tibia (shinbone), the fibula (thin long bone that runs from the side of the knee to the ankle) and the patella (kneecap) (Limtrakam, 2010).The important ligaments are the medial collateral (MCl), lateral collateral ligament (LCL), anterior cruciate ligament (ACL), and posterior cruciate ligament (PCL). The MCL connects the femur to the tibia on the inner aspect of the knee. It is typically injured when the knee is hit from the side. Conversely the LCL connects the femur to the tibia on the outer aspect.

The ACL and PCL cross in the middle of the knee. Both attach the femur to the tibia. The ACL limits rotation and forward translation of the tibia. The PCL limits backward translation of the tibia. PCL is the strongest ligament in the knee. There two types of cartilage in the knee, the articular cartilage and the meniscus. The articular cartilage covers the ends of the hyaline cartilage. Hyaline cartilage is composed in large part, water, and also of collagen and substances called proteoglycans (Limtrakam, 2010).

The front of the knee is protected by the patella or kneecap, which is attached to the quadriceps muscle by the quadriceps tendons and to the tibia by the tendons. The patella is a triangular shaped. The quadriceps muscle controls knee extension (straightening the knee), the knee flexion (bending the knee) is controlled by the hamstring muscles. The patella gives extra leverage and improves the efficiency of the quadriceps pull (Levy, 1998).

The risk for development of knee osteoarthritis is also increased in occupations requiring kneeling, squatting, climbing, and heavy physical workloads (Pollard, 2002).

FIGURE 2.1: Anatomy of the knee

Source: http://emedicine.medscape.com/article/826792-overview#a0104

Annually, around 1.9 million primary outpatient visit to the emergency department for their acute knee pain. The knee pain may derive either from the damage to the soft tissues structure that stabilize and also cushion the knee joint of the knee or infection to the knee structure or from the trauma of the bones. Every patient's will presenting the different symptom to determine the acuity of the pathologic process to detect the pain (Levy, 1998).

Knee is similar to a rolling cam. The knee symptoms arise from an alteration or disruption of the normal anatomic structures that impede normal knee function. The knee will undergoes movement as the knee proceeds from flexion to extension, a complex screw-type motion will takes place (Fiscella, 2005).

2.3 FLEXION ANGLE

The functions of the bones, articular cartilage, menisci, ligaments, and muscle units are transmitting load that acted on the knee and guide joint movement. The knee can have several conditions that effect the structure of the knee and the load distribution. Normally, there were four condition s of the knee:

a) Flexion is the movement of the bending joint that will resulting in a decreasing of an angel such as moving the lower leg toward the back of the thigh.

b) Extension is the movement of straightening the joint that will resulting in an increasing of an angle such as moving the lower leg away from the back of the thigh.

c) Medial rotation (internal rotation). It is the rotary movement of the bone around the longitudinal axis of the bone (toward the center of the body) such as knee bent and turning the lower leg outward.

d) Lateral rotation (external rotation). It is a rotary movement of the bone around the longitudinal axis of the bone (away from the center of the body) such as turning the lower leg outward from the body.

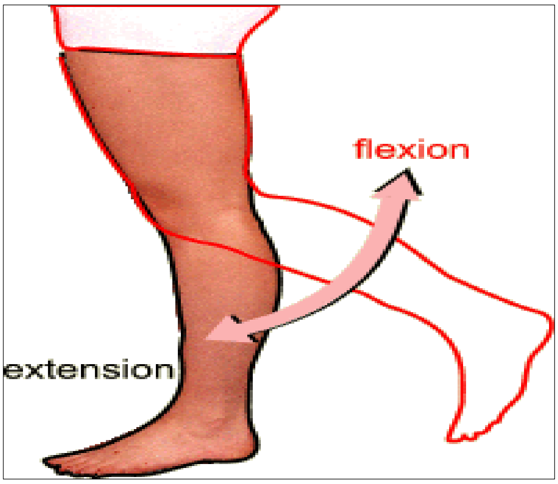

FIGURE 2.2: The movement of the extension and flexion of the knee

Source: http://www.gla.ac.uk/ibls/US/fab/tutorial/anatomy/kneet.html

Investigator have reported that internal or external rotation of the tibia is coupled to flexion or extension of the knee. As the knee is flexed, the tibia rotates internally, and as it is extended, this rotation is reversed in the classic `screw-home' a pattern (Wilson, 2000).

The tibia rotated internally with increasing flexion angle, with the peak rotation ranging from 14 to 363.These observations of internal/external rotation coupled to flexion support the argument that the tibia follows a path in passive flexion, although no study has as yet described the path completely (Wilson, 2000).

2.4 FORCE ACTING ON THE KNEE

The majority of the pressure was found to be transmitted to the knee via the combined patellar tendon and tibia tubercle rather than through the patella (Porter, 2002).

Previous studies have shown increased when kneeling in high flexion and squatting. Due to variability in computation methods, knee forces reported in literature exhibit wide variability and have been reported to be as high as 7 times body weight in deep flexion (Nagura, 2002).

Caruntu, (2003) modelled the behaviour of the knee in a deep squat (165^0 flexion) to determine the effect of thigh-calf contact. The authors found that neglecting thigh-calf contact resulted in 700 N overestimation in quadriceps force and a 50% underestimation in medial collateral ligament forces (Pollard, 2002).

2.5 FINITE ELEMENT MODEL OF KNEE

The stress distribution within the prosthetic components, the bone–implant interface, and the supporting bone are dependent on the kinematics of the replaced knee. The model analysis are dependent on a number of factors including the design of the implant, particularly of the articulating surfaces, the relative alignment of the components. A series of finite element simulations were performed to assess the influence of modelling-based parameters on the predicted kinematics and stresses, as outlined below: (Godest, 2002).

I. **Mesh density:** Two mesh densities were considered for the polyethylene component, the first having an average element edge length of 2 mm in the contact area, which will be referred to as the coarse mesh, and the second having an average element edge length of 1.2 mm, which will be referred to as the fine mesh.

II. **Time step:** In an explicit finite element analysis, not only the geometry is discretised but so is the time domain. The CPU time required is dependent on the size of the time step. Initial analyses were performed with a time step of 0.5 μs for the coarse mesh and 0.4 μs for the fine mesh. In order to reduce the CPU time, the initial time step was increased to 5 μs for the coarse mesh and 2 μs for the fine mesh.

III. **Influence of friction:** The magnitude of the coefficient of friction between cobalt-chrome and polyethylene has not been widely reported in the literature. Friction has been assumed to be as low as 0 and as high as 0.15 between a metallic femoral component and polyethylene. Therefore, analyses were performed with coefficients of friction of 0.01, 0.04 and 0.07. All other analyses were performed with a coefficient of friction of 0.04 unless otherwise stated (Godest, 2002).

2.6 DESIGN OF KNEE PAD

A protective knee guard includes first and second spaced members adapted to the tibial and femur portions of a knee joint. The invention relates to be wear by a participant in sports events in such as football has been a need for a practical and effective protective structure for various joint especially the knee joint. It has been found that during such sport events the knee joining has been highly vulnerable to injured or damage (Godshaw, 2003).

The knee guard of the instant invention is designed specifically to cushion lateral impact with the user’s knee and to transmit at least a portion of the impact cushioned by the guard to the thigh above the associated knee (Larson, 1979).

Protection for an athlete’s limb and joint is important in many sport. Protective pad, cover element and two elastic strips. Protective pad are wider than it is long. The top and bottom edges of the pad are substantially straight, while the central portion is cutaway. This cutaway opening extends a substantial distance into the pad. The pad is covered with stretchable fabric cover element (Hull, 1985).

Knee pad are designed to provide a knee guard which will also be operative to absorb rearward impact at the level of the associated knee (Larson, 1979).

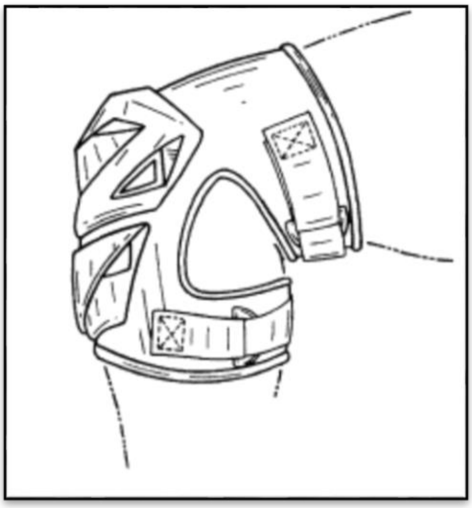

FIGURE 2.3: Knee Pad design

Source: Knee Guard by Kalvestran (1996)

The knee guard is in two different forms, one form being designed to guard the associated knee against lateral impact from the outside and the second form of guard being designed to protect the associated knee against lateral impact from both the inner and outer sides as well as from the front side (Larson, 1979).

The disadvantages of the knee guard is some of the knee guard are too heavy or rigid and do not allow a user to have sufficient flexibility for running as is required in most contact sports. The knee guard must allow full flexing of the knee for running, turning, and other movement. In addition, the knee guard also have to invent which is padded and attached to the leg above and below the knee which will distribute forces delivered towards the knee to shells located above and below the knee (Godshaw, 2003).

Protective knee guard are used to provided shield to the user‘s knee from injuries due to impact on the knee and twisting. This is the main reasons why the knee guard comprises a pair of rigid shaped. It may be used by any individual concerned over injury to a knee. Typical users include athletes with knee injuries, persons recovering from extensive knee surgery (Garcia, 1986).

Conventional protection has been provided in the form of various of pads which are usually attached over the knee by straps or other means. Such constructions are often very uncomfortable and not always efficient. The straps holding the pads in position may cut into the limbs of the person wearing them. An alternative to strapped-on are padded clothing, such as trousers with padded knees (McFarlane, 2001).

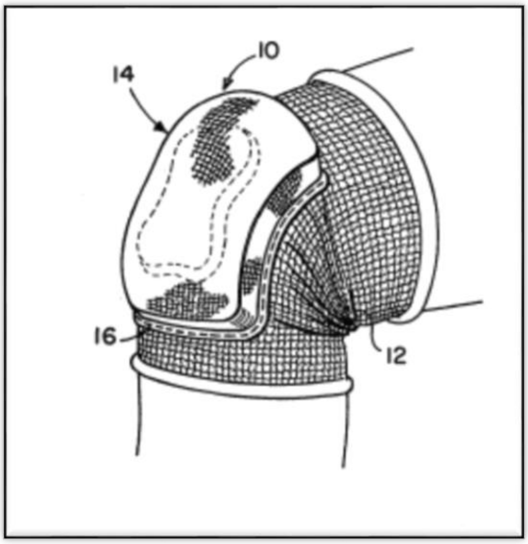

FIGURE 2.4: Knee pad

Source: Knee and elbow pad and method of making by Leighton (1983)

2.7 CHARACTERISTIC OF KNEE PAD

Portion of exterior surface material of the knee protection is covered with a treatment mix comprising four part of a polytetraflourethylene or resin dispersion, one part of an acrylic polymer resin and 5 % of a solution of ammonium sulphate. The treatment mix is the applied to the exterior surface material by silk screening process and cured by application of heat (Leighton, 1984).

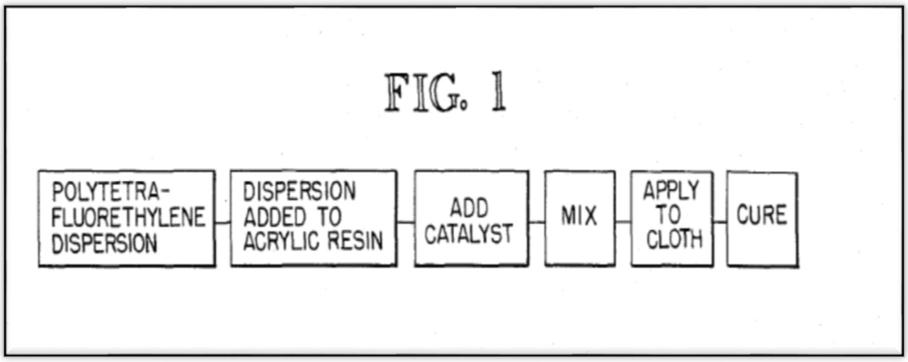

FIGURE 2.5: Flow chart for knee pad making

Source: Knee guard treated to increase durability and a process for producing same by Kelly, 1985

The treated portion of the resulting protective guard has a substantially lower coefficient of friction than the exterior surface material of an untreated protective guard (Kelly, 1985).

Knee pad are designed to protect the knee from contact impact. The contact is usually caused by diving attempts to keep the game. It creates a significant amount of stress on the fabric and produces such high temperatures that the melting point of the fabric. The fabric in the conventional knee guard typically frays, tears, or otherwise unusable in a short amount of the time, and must be replaced. Prior attempts to solve this problem have concentrated on using more durable materials, such as a heavier fabric with a roughened exterior surface, and a more durable protective pad, rather than treating existing materials (Kelly, 1985).

A knee pad construction includes a molded, elastomeric pad with a concave back side and a multi-segmented, integrally molded shape. A retention strap is positioned on the lower of the pad for holding the pad cover a knee (McFarlane, 2001).

The pad is an elasticized sleeve surround the joint to protect and a pad assembly fastened to the sleeve. The combination of the polyurethane foam and dense, modified polyurethane provides superior shock absorption and protection from impact (Leighton, 1983).Conventional protection has been provided in form of various types of pads which are usually attached over the knee by straps or other means. Such construction are often very uncomfortable and not always efficient (McFarlane, 2001).

Auxiliary non-elastic straps variously attached to the lateral and medial side members and to the two cross members are provided to resist traumatic forces acting on the wearer’s knee that causing anterior or posterior translocation of the tibia or either tibia condyle or hypertension of the knee joint (Cromartie, 1990).

2.8 KNEE PAD ANALYSIS STUDY

Application of knee pad has been use in other field such as in mine industries. Mine workers use kneepads to help redistribute and diminish the effects of the stresses applied to the knee while kneeling. However, the effectiveness of the kneepads is unknown. Despite the fact that nearly all low-seam coal mine worker wear kneepads, knee injuries continue to occur and are relatively severe as was discussed that without kneepads may provide insight into the injury mechanism (Porter, 1998).

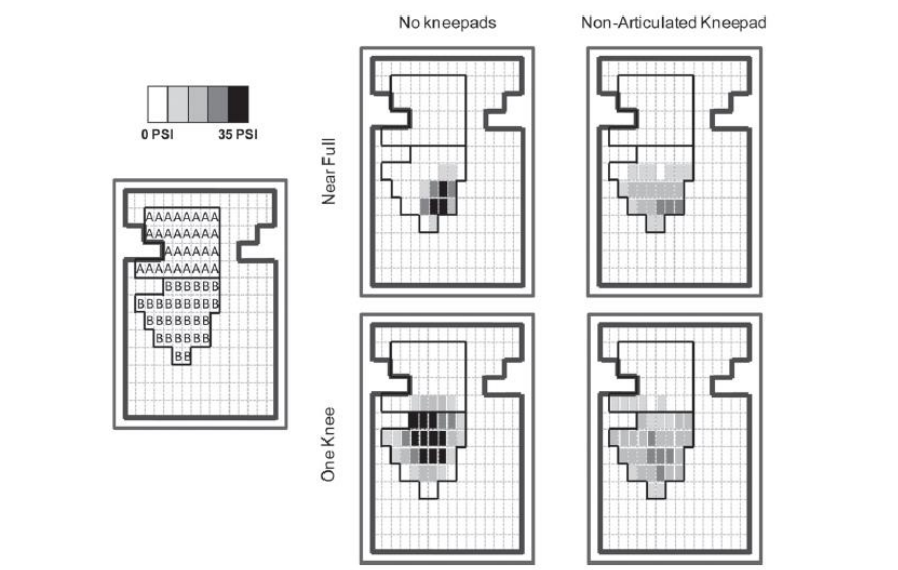

Fig. 2. Sensor pad layout with sensing units identified during palpation as the Patella (A) and the PTT (B) for a representative subject with the shaded cells identifying the pressure distribution during kneeling in full flexion (Near Full) and kneeling on one knee (One Knee) for the same subject.

FIGURE 2.6: Stress distribution on the knee

Source: Pressure distribution on the anatomic landmarks of the knee and the effect of kneepads by Porter

On further analysis as shown in figure 2.6, it was found that no significant difference existed between the no-kneepad state and the two kneepad states, while a significant difference existed within the two kneepad states with the articulated kneepad exhibiting a greater mean pressure (Porter, 1998).

The stress transmitted to the knee through the patella, patellar tendon, and tibia tubercle were determined while in static postures. The kneepads distributed the stresses at the combined patellar tendon and tibia tubercle region across a larger surface area, decreasing the maximum stresses experienced by these structures. However, peak pressures of greater than 25 psi were still experienced. These findings demonstrate that the kneepads tested had little affected on the overall application of stress to the knee. (Porter, 1998).