ADAPTIVE AE TECHNIQUE FOR THE INTEGRITY ANALYSIS OF KNEE JOINT

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Adaptive integrity analysis of knee joint involves a detail study of anatomical parts of knee joint such as bones, cartilage, tendons etc. involving statistical and geometrical approaches for its correctness or wholeness in sound workability. The disorderness or damage of these anatomical parts causes several knee diseases, such as knee osteoarthritis (OA). The predominance of this disease mainly outbreaks in aging society due to damages in cartilage with increasing ages or some early unidentified knee injuries. In the present paper, adaptive acoustic emission (AE) technique has been applied for evaluating the disorderness of knee joint. The major objective of the present research is to early identify the damage initiation of cartilage so that the early preventive measure can be adopted for avoiding knee OA. Therefore, the present investigation focuses on the dynamical behavioral characterization of knee joint for its integrity analysis with AE based non-destructive imaging conditions. AE signals have been collected from different positions of tibia, patella, and femur for getting sufficient information about the condition of cartilage of knee joint. The result has been discussed and showed significant as a biomarker in knee condition analysis for preventing major knee diseases.

Keywords: AE technique, Non-destructive evaluation, Integrity analysis, Knee joint, Osteoarthritis.

1. Introduction

Adaptive integrity analysis of knee joint by acoustic emission (AE) technique deals with the adaptive parametric estimation of AE signals. As the basis of the proposed joint analysis is AE parametric analysis dependent, the adaptive AE events evaluation is largely influenced by the present knee evaluation technique for understanding about its integrity measure. The anatomy of knee joint is made up of three bones and a variety of ligaments. These three bones are named as the femur (the thigh bone), the tibia (the shin bone), and the patella (the kneecap). The motion control as well as the protection of the knee joint is done by several muscles and ligaments. Two ligaments called the medial and lateral collateral ligaments are located on either side of the knee joint for stabilizing the knee joint from side to side. Two other ligaments called anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) are crossed in a pair of ligaments in the center of the knee for stabilizing the knee from front-to-back during normal and athletic activities. The ligaments of the knee make sure that the weight which is transmitted through the knee joint must be centered within the joint for minimizing the amount of wear and tear on the cartilage inside the knee.
The dynamic analysis in the present research involves the integrity analysis of knee joint for a
detail study of its several anatomical parts during different movements such as sitting, standing and
so on. The major objectives of this study consist of finding any disorderness or damage of these
anatomical parts which may cause several knee diseases like osteoarthritis (OA). This disease in-
creases with age due to some damages in cartilage of knee joint. Several potential methods such as X-
rays, magnetic resonance imaging (MRI), some ultrasound oriented technique etc. for clinical diagnosis of knee joints. However, the sensitivity of the present clinical methods exhibits the mixed satisfaction of the patient. In all of the mentioned meth-
ods, external energy is need to insert to the examined parts of the patient which is not welcomed
always by the people. Moreover, almost all of the techniques are utilized for the diagnosis in static
mode. Although, a limited use of the dynamic MRI is recently introduced for the purpose of dynam-
ic analysis, however, the high cost and lack portability features of this system hinder its wide appli-
cation as well. In the context of this background, the potential application of acoustic emission

technique (AET) is considered for the dynamic analysis of knee joint.

AET is an important addition to NDT or NDE methods surveying actively a structure by
scanning for geometric defects as well as to visual inspection methods observing a material surface. Unlike to other NDT methods, the AET is often used during loading to a structure, not before or
after the loading like most of other techniques. Therefore, AET can be successfully applied to char-
acterize the failure of a structure or joint from a very beginning to its complete failure. In AET,
acoustic emission (AE) refers to the generation of transient elastic waves produced by a sudden
redistribution of stressing a material. When a structure is subjected to an external stimulus (changes
in pressure, load, or temperature), localized sources trigger the release of energy, in the form of
stress waves, which propagate to the surface and are recorded by sensors.

In the present research the integrity of knee joint is planned to be investigated by AE tech-
nique of in dynamic movements (sit-stand-sit) of the knee. Different aged people are considered to
be involved for the prediction of the mentioned disorderness in knee joint. In the next section, ex-
perimental methodology is discussed, after which results and discussion and finally conclusions and
references are presented.

2. Experimental methodology

The experimental methodology is defined in the paper based on the experimental apparatus
that have been used in the experiment and the procedures and the considerations that have been taken
in the measurement systems as follows.

2.1 Experimental set up

First of all, the apparatus and the acquisition system of present AE technique is designed and
visualized according to the schematic views as shown in Fig. 1. For getting emitted acoustic signals,
a pair of AE sensors of Physical Acoustics Corporation, Japan (Dim: 19x22; Peak: 75 dB; Direct: ±1.5) has been used. The operating frequency range and the resonant frequency of the AE sensors
are specified as 35 to 100 kHz and 55 respectively in the experiment. The sensors are connected to
the sensor pre-amplifiers and before entering to the data acquisition system, the signals are further
amplified in a four channel AE signals amplifier. The amplified signals are then acquired by digital
oscilloscope and saved in a storage device and finally, the data has been transferred to the personal
computer (PC) for analysis.

For getting dynamic measurements, the acquisition of angular movements of the knee during
sit-stand-sit, a two channel goniometer (SG150, Biometrics Ltd.) has been used and the correspond-
ing angular data has been recorded into the PC. The schematic of goniometer connection system is
also shown in the same figure (Fig. 1) as a block diagram.
2.2 Experimental procedure

Two sensors are attached to the knee joint as sensor, S1 to Tibia and sensor, S2 to Femur and mentioned in Fig. 2 (a). The AE signals that are generated during the dynamic movements of the knee joint have been received by the sensor 1 (S1) at Tibia portion. Similarly the AE signals that are generated at Femur portion have been received by the sensor 2 (S2). Any damage in cartilage as shown in Fig. 2(a) generates extra AE signals which are identified to the respective sensor. The method of attachment of sensors is shown in Fig. 2(b). According to the sensitive positions for the AE signals, as shown in Fig. 2(a), the AE sensors are attached to the positions of S1 and S2 with high elastic and non-harmful medical tape (Nichiban Co. Ltd., Japan). Due to the high elastic characteristics of the tape, the sensors are always attached to the skin of the knee at the desired position during sit-stand-sit movements. Therefore, undesirable noise in the dynamic knee experiments has
been avoided remarkably. Moreover, to ensure the continuous contact of the sensing surface of the sensor to the anatomical site of the knee, coupling gel is used between the surface of the sensor and the contact place site of the knee. For getting angular position of the movements, electronic goniometer is attached to the knee with double-stick tape so that it can be relaxed during the experiment. The position of the goniometer has been initialized to 90 degrees at the standing position, while at the sitting position it is initialized to 0 degrees. Thus, in one set of movements (sit-stand-sit) the measured angle has been recorded as 180 degrees. Ten set of movements has been considered as 1 cycle of movements while 5 minutes have been taken as intermittent rest time. For AE signals 1MHz and for goniometer 100 Hz sampling frequencies are used.

3. Experimental results and Discussion

Most sensitive positions for the placement of sensors to get the maximum levels of AE signals have been selected. Other several combinations of sensor positions have been analysed as well for clarifying the AE activities at each location of knee joints. However, as shown in Fig. 3, the sensor position 1 (S1) has shown more sensitivity compared to the position of sensor 2 (S2). The muscle volumes and patella movements create some noise in AE sensing to these positions.

Accordingly, experiments have been conducted to clarify the condition of the knee integrity based on the dynamic activities of knees among young people (20 ~ 29 years old) and middle aged people (40 ~ 49 years old). In this observations as shown in Fig. 4, AE events which are received for middle aged people are concentrated to a certain angular regions, whereas, for young people received AE events are distributed towards almost whole angular positions. These results are remarkably focus to the possibility of having some damage or started to have some damage to that particular region. Although, more parallel investigations are necessary for the confirmation about the focused possibilities. However, according to the present physical data which have been taken from the participants such that they never went to the hospital for knee pain treatment, it has been assumed that the knee conditions of aged people are also fine. But since the differences in acoustic emissions between young and aged people are identified, it has definitely concentrate to having the wear effects of knee joint due to getting ages. Of course, more data for 60 years people must be helpful in concrete forecasting about the wear effects of femoral condyle or bone-end cartilage for successful evaluation of osteoarthritis disease, the major disease of knee joint. Therefore, the present results show significant understanding about the knee problem as well. Furthermore, it is informed that for getting more complete results investigations are going on which may be informed in a near future.

![Figure 3. AE signals for two positions of sensors.](image1)

![Figure 4. AE events for two age groups.](image2)
4. Conclusions

An acoustic emission technique based on experiment has been set up has been evaluated to measure the integrity of knee joint. The results have successfully differentiated among the aging effects on knee joint problems, particularly a major cause of occurring osteoarthritis disease at knee. It has been noticed that more data of 60 years ages group must be helpful in finding the concrete related results and the authors are hopeful to inform that results in near future as well.

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