

Investigation of Single Segment Side-Polished Optical Fiber Sensor for Shoulder Joint Monitoring

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Abstract— Shoulder monitoring is an important stage in the diagnosis and treatment process of affected patients. Current devices available in the clinical environment for this application are focusing on flexible ruler or manual goniometer, which are prone to measurement error. Alternative approaches including accelerometer, magnetometer, strain sensor and inertial measurement unit (IMU) are subject to reading error, susceptible to output drift, has bulky overall size and difficult to be attached on the human body (via adhesive or garment). To solve this issue, this paper presents the use of an optical fiber sensor (OFS) based on intensity modulation technique via single segment side-polished fiber. Based on the experimental study, the proposed method can be utilized to measure an angle between 0 deg. and 90 deg. Additional optical sensors can be added to increase the sensor's range of motion that is sufficient for shoulder joint measurement.

Keywords—optical fiber sensor, shoulder joint monitoring, health monitoring

I. INTRODUCTION

Human joint is defined as a point where two bones are connected for the purpose of moving body parts. Based on studies, there are more than 300 joints in the human body. Based on their movement ability, most joints can be categorized into three groups, namely immovable joint (called synarthroses), slight movement (amphiarthroses) and freely movable joints (diarthroses) [1]. The human shoulder joint is one example of diarthroses type human joint. Based on typical shoulder functions, various range of motions is possible such as flexion (arm forward), extension (arm backward), adduction (arm back-sideway), abduction (arm away-sideway), internal rotation (shoulder turns-in towards the front), external rotation (shoulder rotates out), horizontal flexion (arm away-horizontal), horizontal extension (arm backward-horizontal) and 360° circumduction in the sagittal plane.

The shoulder joint connects the upper arm to the shoulder blade via a ball-and-socket connection. It consists of three bones, which are the upper arm bone (called humerus), shoulder blade bone (scapula), and collarbone (clavicle) [2]. This type of connection makes the shoulder the most mobile joint in the body as the small and shallow socket allows the ball-shaped head of the humerus to move freely. However, it has a drawback, where the shoulder joint is also unstable and prone to injuries.

Generally, most shoulder problems fall into four main categories, which are tendon inflammation (tendon tear), instability, arthritis and fracture/broken bone [3]. Tendon inflammation can be divided into bursitis and tendinitis. Bursitis is commonly due to the inflammation and swelling of the bursae (small and fluid-filled sacs located in the

shoulder joint) between the rotator cuff and the acromion. Meanwhile, tendinitis refers to inflammation of the tendon that function as a cord that connects muscle to bone.

The second problem related to the shoulder instability is due to sudden injury or from overuse when the head of the upper arm bone is forced out of the shoulder socket. In other case, the instability of the shoulder may be due to the partial or complete dislocations (the ball comes out of the socket). Another common shoulder problem is known as wear and tear arthritis or called osteoarthritis. This condition may be related to the work injuries, inflammation or infection of the joint lining, rotator cuff tears or chronic wear and tear.

The symptoms of shoulder pain may vary between individuals and can significantly reduce their ability to carry out daily activities. Among common symptoms for shoulder pain are random pain at neck, arm or back areas as well as muscle stiffness and weakness at shoulder area. According to survey carried out by researchers in this area, the shoulder pain affects a range of 18% to 26% adults at all time [4]. Most of the patients who suffered from shoulder pain are due to sport activities or work related to physical activities.

This paper proposes an alternative method to provide continuous measurement data of the shoulder movement. Aside from conventional devices such as flexible ruler, tape measurement and two-arm goniometer, other monitoring devices such as accelerometer, gyroscope, magneto and inertia sensors have also been applied for shoulder monitoring application with various working range and measurement performance. In this work, a plastic-based optical fiber sensor is proposed as shoulder monitoring device via intensity modulation technique. The measurement of the shoulder joint angle is based on intrinsic approach where the light variation of the light intensity detected at the detector represent the degree of angle of the shoulder motion.

II. MAIN SOURCES OF SHOULDER PAIN

A. Shoulder Pain due to Sport Activities

In terms of shoulder pain related to sport activities, a study on the prevalence of shoulder pain among female artistic gymnast in the United States [5] was carried out, where shoulder injury prevalence was higher among international level gymnasts (29.2%) as compared to national contestant gymnasts (20%). Out of one thousand participated volunteers, about 33% to 37% of them suffered from shoulder instability and 26% to 90% suffered from tendinitis (musculotendinous). Out of this number, 80% caused symptoms post-retirement. In another study among 336 elite football players [6], 50% of them had a history of shoulder