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Design Of Shoulder Joint Mechanism for Robots

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Abstract— The Industries have come a long way right from the era of manual labors to automations. In recent years, robotics have been an emerging technology in implementing Industry 4.0 objectives. This paper presents the design and development of a robotic arm occupied by an active ball joint mechanism. This mechanism is enhanced by interactions of spherical gears. The active ball joint mechanism can transmit high torque and reliable positioning in 3 DoF without an orientation sensor. This is applicable to robot joints. The driving module is being driven by an stepper motors which are being controlled by stepper motor drivers. The developed prototype is tested and program is being developed for user friendly interface.

Index Terms— Automation, Development and prototyping, mechanism design, spherical gear.

I. INTRODUCTION

The word robot originated from the Czech word robota, meaning work [8]. The definition of industrial robot has been evolved considerably in recent years. According to international standard ISO 8373:2012, the industrial robot definition is ‘a, multifunctional, reprogrammable, automatically controlled manipulator, programmable in three or more axes that can be fixed in one area or mobile for use in industrial automation applications. This paper is an understanding the issues related to the precision, accuracy, number of sensors used, etc. Robotic arms are in demand for industrial production, processing, and manufacturing roles i.e. any task which needs precise, fast and repeatable movement. Robotic arms are fast, accurate and reliable, and can collectively be programmed to perform an almost infinite range of different operations. Robotic arms are commonly comprised of 4 parts – mechanical body, controller, servomotor, and sensors [1]. In this paper we have used the active ball joint mechanism instead of servo motors as a solution for the current problems related to the robotic arms. In optimized future designs, the mechanism will gather the joints of a robot at one point (i.e., at an active ball joint), reducing the energy and resource consumptions and improving the economy of robot operation. [7].

II. MECHANISM

Active ball joint mechanism is a sophisticated technology used in various applications that require precise and controlled movements. The mechanism consists of a cross-spherical gear and 2 driving modules of a monopole gear. The monopole gear has tooth shape that meshes with the cross – spherical gear. The CS-gear has a quadrature tooth structure engraved over the entire surface of a sphere, and the MP-gear is able to mesh with the CS-gear. Based on nonslip gear meshing, the mechanism provides high-torque transmission and reliable positioning without requiring a three-dimensional sensor. In addition, because the actuator and output link can be flexibly arranged, the mechanism can take various configurations [7].

1) Cross Spherical Gear - The tooth structure is first engraved on the surface of the sphere around the x-axis Next, by additionally engraving around the y-axis a quadrature spherical tooth structure around both axes is formed on the spherical surface. The number of teeth zsph is subjected to two constraints:

i) The number of teeth zsph must be even. (zsph ∈ EVEN).

ii) The x and y-axes are located in the center of the valley or peak of the tooth.

These conditions are necessary to avoid obtaining incomplete teeth due to the interference of the two tooth structures and to mesh with the MP-gear.

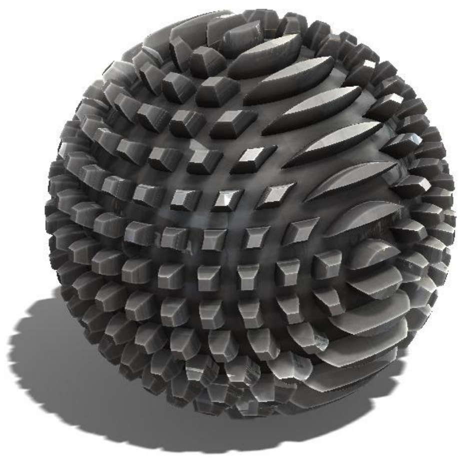

Fig. 1: Cross Spherical Gear

2) Monopole Gear - The tooth structure of the MP-gear, the spherical hobbing cutter is shaped similarly to a basic spherical gear and is formed by rotating a typical gear profile around a structural axis.

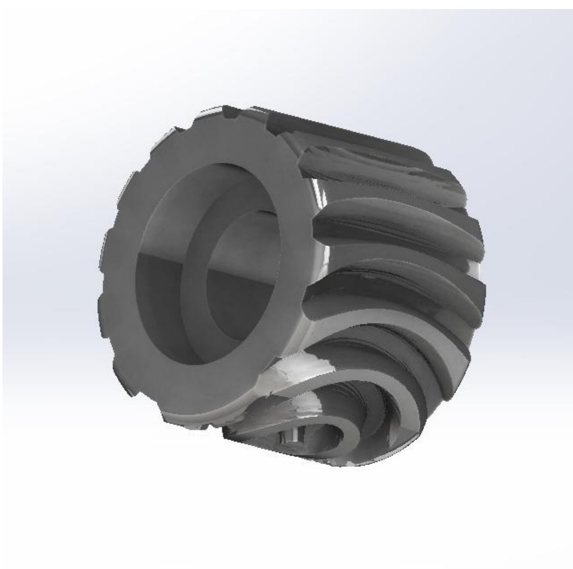

Fig. 2: Monopole Gear

When gear profiles of both the gears are arranged on the same plane, they mesh like a spur gear and if the center distances are fixed it behaves as a planetary gear mechanism. When they are assembled, a monopole gear drives the Cross spherical gear. The driving module is a mechanism of axis with its pitch and roll axis adjacent to each other. To enable 3 RDoF to the output link two driving modules are necessary.

The meshing of gears generates gearing, coupling and sliding motions. Since the structural axis of Cross spherical gear are orthogonal, the monopole gear can drive all the RDoF of the cross spherical gear.

The CS-gear can be considered driven in parallel by two serial arms. Since each arm is connected to the CS-gear via a passive joint and all joints are orthogonal, the output link acquires three RDoF. This linkage also says that this mechanism is independent of the positions of the two driving modules i.e. relative angle between them need not to be 90 [deg], they can also be placed facing each other in a straight line.

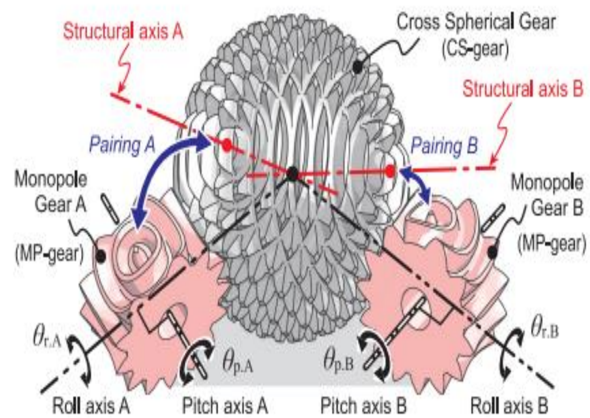

Fig. 3: Meshing of CS gear and Monopole Gear

III. DESIGN

The CAD design of the mechanism is shown in the Fig. driving modules are connected to the holder. Each driving module has a differential unit for pitch and roll rotations of the MP-gear that meshes with the CS-gear. This unit is composed of an inner rotor, a differential inner worm gear, a differential pinion, and the MP-gear. This driving module also has an ability to adjust the distance or backlash between the CS-gear and the MP-gear, which consequently corrects manufacturing and assembly errors [7].

1) Cross spherical gear parameters - The pitch circle diameter d_{sph} mm, the addendum circle diameter $d_{a.sph}$ mm, and the tooth depth h_{sph} mm of a CS-gears are defined as follows, just like the typical spur gears:

$d_{sph} = m_{sph} * z_{sph}$ ………. (1)

$d_{a.sph} = d_{sph} + m_{sph}$ …… (2)

$h_{sph} = 2.25m_{sph}$…… (3)

2) Monopole gear parameters - The module M_{mpl} and number of teeth Z_{mpl} of the profile are, respectively given by:

$M_{mpl} = M_{sph}$...... (4)

$Z_{mpl} = Z_{sph}/2$...... (5)

The length of the carrier mm, the revolution angle of the planetary gear rad around the sun gear, and the rotation angle of the planetary gear rad are, respectively, defined as:

$$R_{cr} = \frac{M_{sph}(Z_{sph} + Z_{mpl})}{2} = \frac{M_{sph}}{2} \times \frac{3Z_{sph}}{2} = 0.75d_{sph}$$

$$\varphi_{hb} = \frac{\varphi_{cr}}{2}$$

$$Where\ (0 \leq \varphi_{cr} < 2\pi)$$

The motors used in the driving module are Stepper motors (NEMA 17).

3) Material Selection – The material used for manufacturing the prototype is Polylactic Acid (PLA +). Polylactic acid exhibits certain mechanical properties, such as tensile strength, elastic or flexural modulus, elongation-at-break, Izod impact strength, and Rockwell hardness which determine its strength and ability to withstand various conditions.

Using a 3D printer is a good way to fabricate this mechanism. The prototype was manufactured by Fused Deposition Modeling (FDM). This is a technique in which, materials are extruded through a nozzle and joined to create 3D objects and models as per the CAD design. Fused deposition refers to the melted filaments that emerge from the nozzle and pile up to form a 3D object or model.

IV. HARDWARE DESCRIPTION

The commands from the user are given through the Graphical user interface which communicates with Arduino I/O board serially. Arduino I/O board on receiving the commands from the GUI controls the position of the motor shafts which in turn controls the roll and pitch axis of the monopole gear.

1) Arduino UNO - Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. Pins D2 to D13, A0 to A5 and all power pins including ground pins are used for interfacing of CNC shield.

2) CNC Shield - CNC shield V3 is an open-source hardware used to control stepper motors. Allows to control 4 motors simultaneously. It contains 4 driver sockets which allows diver modules to be inserted providing the ability to drive 3 stepper motor axis (XY& Z) plus an optional 4th auxiliary motor. Additional connectors provide easy connection of end stop sensors and control buttons. Stepper Motors can be connected with 4-pin Molex connectors or soldered in place. It Runs on 12-36V DC.

3)A4988 Stepper Motor drivers - The A4988 stepper motor driver has an output drive capacity of up to 35V and ±2A. This allows to control a bipolar stepper motor, such as the NEMA 17, at up to 2A output current per coil. There are two control pins, one for controlling the steps and the other for controlling the spinning direction. The A4988 is a complete Micro stepping Motor Driver with a built-in translator for easy operation. The breakout board from Allegro features adjustable current limiting, over-current and over-temperature protection and five different micro step resolutions. It operates from 8 V to 35 V and can deliver up to approximately 1 A per phase without a heat sink or forced airflow. It is rated for 2 A per coil with sufficient additional cooling.

4)Stepper Motor (NEMA 17) - NEMA 17 is a hybrid stepping motor with a 1.8° step angle (200 steps/revolution). Each phase draws 1.2 A at 4 V, allowing for a holding torque of 3.2 kg-cm.0 The motor has 6 lead wires and rated voltage is 12 V and hence the level of control is also high. These motors run on 12V and hence can provide high torque. These stepper motors consume high current and hence a driver IC like the A4988 is mandatory. NEMA 17 stepper motors typically have four wires, each connected to one end of two separate coils inside the motor. These four wires are often color-coded to help identify them. The color coding is not standardized across all manufacturers, but a common scheme is:

Black and Green wires: often correspond to one coil, which can be referred to as Coil A or Phase 1.

Red and Blue wires: often correspond to the other coil, which can be referred to as Coil B or Phase 2.

5) Software Implementation – Arduino IDE is the software used for controlling the stepper motors. The pins for connecting the Arduino uno, CNC shield, A4988 motor drivers and the stepper motors are initialized in Arduino IDE.

V. DESIGNED MODEL

The model is designed with the reference of [9]. Fig. shows the final designed module.

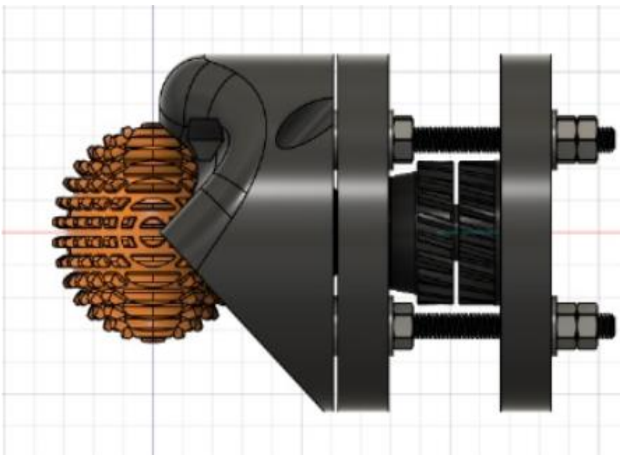

Fig. 4: 3D CAD Model

This design can be more optimized for various configurations and working conditions of a robotic arm. Moreover its software implementation can also be optimized for creating a user friendly GUI.

VI. RESULTS

The results of the mates of innovative gears are to create mechanism with three RDOF The challenge in multidegree of freedom mechanisms is the range of motion. In this mechanism there is two types of placing the two driving modules. First of them is opposite type 180[deg]. It provides a range of motion of 270, 90, 360 [deg] [3]. The second one is perpendicular type 90 [deg]. This range of motion is relatively high compared to other mechanisms and since our mechanism is a gear-based mechanism it reduces slippage and provide high position accuracy as well as high torque and reliable transmission.

CONCLUSION

This study proposes a new mechanism based on spherical gear meshing; this mechanism can actively drive three DOF. During meshing, the two gear types interacted through gearing, coupling, and sliding motions, allowing a single MP-gear to constrain or drive two DOF of the CS gear. This study proposes that the three DOF of the CS-gear are achieved by driving two MP-gears meshed with two phase-different tooth structures. This idea is reinforced by the mechanistic equivalence of the gear mechanism and a linkage mechanism. It also suggests that the mechanism’s capability of is independent of the positional arrangement driving modules.

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