Development of a Spherical Gear

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ABSTRACT

The use of ball and socket joints for control of machinery has been critical for many robotic manipulators. The commonly used universal joint has been studied extensively and alternative methods for such a joint have been proposed. Our process of achieving a 3-degree of freedom socket joint involves the use of a spherical gear driven by 2 custom-made driver gears arranged perpendicular to each other.

Keywords: *- Mechanical, Mechatronics, Gear, and 3D modeling.*

1. Introduction

There has been ongoing research on multi-DoF mechanisms, actuators, and integrated robot joints, which is driven by societal demands. Robots will become smaller, less expensive, and more functional if many degrees of freedom (DoF) can be operated in a single joint.

Several mechanisms and actuators that incorporate several degrees of freedom in a single joint (contact surface) have been proposed over the years. The classic friction-based force transmission device consists of a sphere and many strategically arranged friction wheels. Although classical mechanisms allow for limitless motions with three rotational degrees of freedom (RDoF), they have significant frictional losses. This difficulty has been remedied in recent years by replacing the friction wheel with an omni-wheel. However, without external three-dimensional sensors, slippage inhibits the effective transfer of high torque and precise placement. High-frequency vibrations from piezoelectric or magnetostrictive components are used in another method.
Because of their basic construction, these designs have a large velocity range and a compact design, but they do not solve the concerns mentioned above. Other methods of transmission through noncontact spherical actuators were also proposed. These were three-dimensional induction or stepping motors. They require a lot of electrical and computational resources despite having a high-power capacity. Furthermore, a gear reducer for high torque production at low speed is difficult to build for these actuators. Some scholars have proposed a linking mechanism with a spherical linkage or a slider linkage instead of spherical geometry.

2. Theory

The mechanism consists of an S-gear (spherical gear) supported by a holder and two driving modules driver-gear. The driver-gear was modeled to have a tooth pattern that can mesh with the S-gear. The gear is driven with 2 driver gear modules and each module has 2 motors controlling the movements. So, it’s a 4-motor-driven mechanism. The mechanism operates like an active ball joint with three RDoF between links B and H.

2.1 Spherical Gear (S-Gear):

The S-gear is modeled by taking two tooth patterns on perpendicular planes and then applying it as an engrave into a spherical structure. The first tooth profile is sketched on the x-y plane and is revolved around the x-axis. This shape is based on the profile of an involute gear. The next engraving is around the y-axis, with the pattern sketched on the y-z plane. Hence, a spherical tooth structure around both axes is formed on the spherical surface.

The module m_{sph} of the involute tooth profile of the S-gear is unconstrained. The number of teeth z_{sph} must be even. For easier convention, the x and y-axes are located in the center of the peak of the tooth, just as in the sketch of the tooth patterns.

This is necessary to avoid obtaining incomplete teeth due to the interference of the two tooth structures and to mesh with the driver gear. The pitch circle diameter d_{sph} mm, the addendum circle diameter $d_{a.sph}$ mm, and the tooth depth h_{sph} mm of an S-gear are defined as follows

$d^{sph} = 92mm$

$d^{asph} = 92mm$

$h^{sph} = 6mm$

Although multiple RDoF have been constructed from several planar and basic spherical gear-like structures, an equivalent S-gear engraved over the full surface of a sphere has not been previously reported.

Driver Gear: The driver gears have a unique tooth structure, the pole, which can mesh with the CS-gears When the z- and x-axes are aligned with the rotational axis and the pole, an driver gear is symmetric in the x–y plane and its cross-section has a typical involute gear profile. The module m_{mpl} and number of teeth z_{mpl} of the profile are, respectively, given by:

$$m_{mpl} = 1$$
$$z_{mpl} = 32$$

$$m_{mpl} = m_{sph}$$

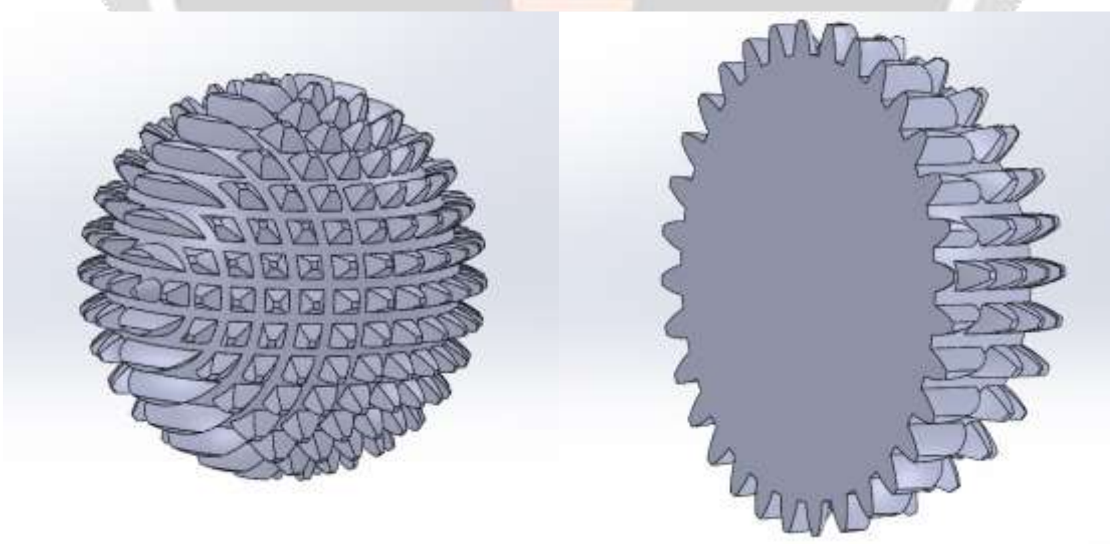

Fig -1: S-gear and its cross-section showing gear tooth profile

2.1 Driver Gear:

The interaction between an S-gear and a driver-gear would have motions like gearing, coupling, and sliding. In Figure, these three motions are invoked by a basic spherical gear and an driver-gear. As the driver-gear rotates around the y-axis, it interacts with the S-gear, and the driving force is transferred from the driver-gear to the S-gear, just like that of a regular involute gear system.

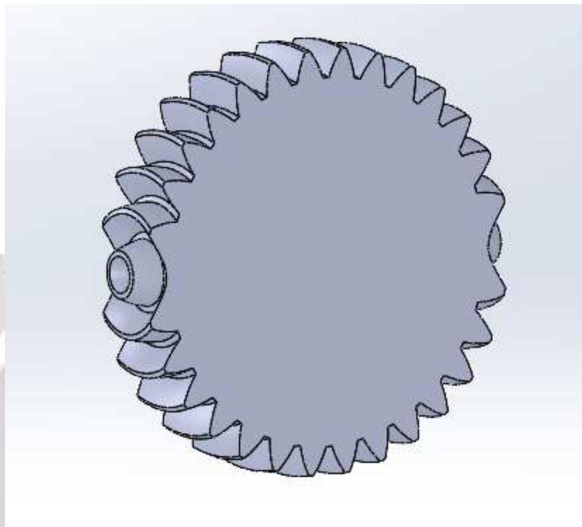

Fig -2: Driver gear

The coupling motion of the driver and Spherical-gear results in the transmission of the driving force through the rotation of the driver gear, which is connected to a motor. But passive sliding between the two gears does not transmit the motion. When the poles of the S-gear and driver gear are coincident, the rotation of the driver gear around the x-axis will not transfer any of the torque, and hence, any of the motion. But in this orientation, the driver gear can be rotated freely in any direction and then rotated in the perpendicular plane to give motion to the S-gear in the required direction.

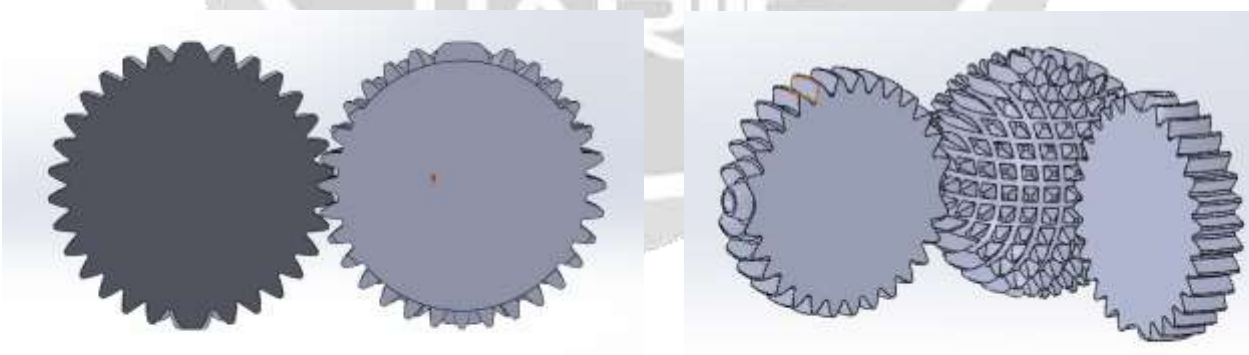

Fig -3: S-gear and driver gear meshing

Cross-section view of a driver gear with a driving module expressed as an equivalent linkage. The output link has the equivalent capability as the mechanism of the driving module as shown in the figure. The amount of rotation of the pitch axis is half that of roll axis and the direction is opposite to the structural axis. A single driver gear can constrain or drive two of the three RDoF of the S-gear. An S-gear with two crossed-tooth structures can superimpose the interactions of two driver gears. One driver gear meshes with the tooth structure of the S-gear structural axis. A constrains the S-gear's rotations except for the rotation around the structural axis A.

Similarly, the other driver gear constrains the rotation except around the structural axis B. Because structural axes A and B are orthogonal, the two driver-gears can constrain or drive all RDoF of the S-gear.

2. Development

Based on the interaction described in Section II-B1, the Image is replaced by the connection method shown in Figure, i.e., the relationship between S-gear and two driving modules can be displayed, with the equivalent, closed connection. This connection satisfies the following two conditions.

1) The rotating axes of all six joints meet in the center of the S-gear.
2) The angle between the axes of any two joints (but without the angle between the lower axes of the lower axis) is 90 deg.

This closed communication method is a type of circular path that becomes the most delayed under the condition. Therefore, from Gruebler's equation, the DoF number is given by

$$F = 3\,(N - J - 1) + \sum_{\square=\square}^{\square} f_i$$

where N is the number of links, J is the number of members, and F_i is - DoF joint ith. In the diagram, say N = 6, J = 6, and f_1 ... 6 = 1. The DoF number for this equilibrium is F = 3, which means that the output link in the Figure has three RDoF. This module is an RR-type model of the framework of the frame structure represented by the same connection. This same link method is made up of two methods shown in the diagram

The output link achieves a driving torque with three RDoF. a two-link serial arm with a joint as the end user. Since the connection is circular, the final drive gear motor controller module has two DoFs in a circular area centered on O. The same definition holds for another driving module. Therefore, the S-gear can be considered to be operated in conjunction with two consecutive arms. Since each arm is connected to the S gear via a synthetic joint and all joints are orthogonal, the output link receives three RDoFs. Interestingly, this similar correlation suggests that the mechanical strength is independent of the components, i.e., the relative angle between the driving modules should not be 90 [deg]. For example, modules can compete in a straight line. As shown in Figure, the possible positioning angles of the outlet in the equilibrium output network are largely limited to the mechanical interference between the connectors. Therefore, one of the most important achievements of this study was the achievement of an infinite range of motion by replacing this equilibrium with a gear-based machine.

3. Conclusion

The 3D model of the above-mentioned gear system is modeled and modeled on Solidworks. Modeled to work with 3 DOFs with 32 gears with spur teeth to transfer power in direct directions to each other. In determining the mechanical parameters, it is assumed a Perpendicular type.Opposite type. that a rod of length 300 mm and weight 0.5 kg is connected to the output link. The CS-gear's motion range allowed by the output link depends on the opening area of the holder. The contact surface area between the holder and the CS-gear is an important stabilizing factor in the mechanism.
Three RDoF can be actively driven by this method. The study first developed a quadrature spherical tooth structure S-gear and a novel shape driver-gear that allowed continuous meshing with the CS-gear. Through gearing, coupling, and sliding motions, the two gear types interacted during meshing, allowing a single driver-gear to limit or drive two

RDoF of the S-gear. The three RDoF of the S-gear are proposed to be achieved by driving two driver gears meshing with two phase-different tooth shapes.

5. REFERENCES

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