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DESIGN AND CONSTRUCTION OF REMOTE CENTERED COMPLIANCE(RCC) USING DOUBLE PARALLEL MECHANISM FOR AUTOMATED POLISHING OF 3D SURFACES.

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Abstract An automatic system which serves as a remote centered compliance(RCC) for polishing 3 dimensional surfaces using a passively compliant end effector (double parallel manipulator) mounted on the wrist of the industrial robot is focused in this paper. For enlarging workspace and avoiding singularity, a double parallel manipulator has been designed by combining two parallel mechanisms with respect to central axis. The motion of the device is decoupled and constrained by the central axis. This leads to simplicity in geometric constraints but needs a novel strategy in mechanism analysis. The passive compliant end effector is used to modify the trajectory of the robot based on the contact geometry and end point forces. The end effector is specially designed to suit the operation to be performed. The system can be used for polishing sculptured surfaces such as dies for sheet metal forming is one area where application of industrial robot can load to significant increase in productivity. The design and fabrication of double parallel manipulator is also done and is presented here in this paper.

Keywords: Double parallel manipulator, spherical pair, compliance.

INTRODUCTION

Manufacturing manipulators require mechanical interaction with the environment or with the object being manipulated. Robot manipulators are subjected to interaction forces when they maneuver in a constrained workspace. In constrained maneuvers, one is concerned with not only the position of the robot end point but also the contact forces. If we define compliancy as a measure of the ability of the manipulators to react to the interaction forces and torques. The objective is to assure compliant motion (active or passive) for the robot end point in the Cartesian coordinate frame for manipulators that must maneuver in the constrained environments. The contact forces between the part and robot arising from the robot oscillations, robot programming error and part fixturing errors. Hence a passive end effector is used because the elements that generate compliancy are passive and no external energy is flowing into the system.

RCC SYSTEM

A compliant system is one that complies with external generated forces, that is, one that modifies its motion in such a way as to minimize some particular forces. If the robot uses force sensors and modifies its, control strategy based on the sensor's output, the term active compliance is used to describe the behaviour. On the other hand, if the robot's gripper is constructed in such a way that the mechanical structure deforms to comply with these forces, the term passive compliance is used. The compliance of the robot manipulator refers to the displacement of the wrist end in response to a force or torque exerted against it. A high compliance means that the wrist is displaced a large amount of a relatively small force. The term "springy" is sometimes used to describe a robot with high compliance. A low compliance means that the manipulator is relatively stiff and is not displaced by a significant amount.

Robot manipulator compliance is a directional feature. That is, the compliance of the robot arm will be greater in certain directions than in other directions because of the mechanical construction of the arm. Compliance is important because it reduces the robot's precision of movement under load. If the robot is handling a heavy load, the weight of the load will cause the robot arm to deflect. If the robot is pressing a tool against a work part, the reaction force of the part may cause deflection of the manipulator. If the robot has been programmed under no load conditions to position its end effector, and accuracy of position is important in the application, the robot's performance will be degraded because of compliance when it operates under loaded conditions.

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REMOTE CENTERED COMPLIANCE

Remote center compliance is a device, which is used to correct the problems of lateral and angular errors that occur during assembly. This device is typically mounted between the wrist of the robot and its gripper. The RCC device is capable of accommodating the lateral errors encountered in an insertion operation and in other operation requiring limited compliance.

RCC's are typically constructed using elastomer springs rather than the mechanical linkages. This has resulted in designs that are simple, small and lightweight.

DESIGN OF DOUBLE PARALLEL MECHANISM

The double parallel mechanism is obtained by coupling two 3 degrees of freedom parallel manipulators. The mechanism consists of one base plate, one end plate and several parallel links, that connects the base plate and end plate which are joined by providing spherical pairs.

The advantage of using parallel mechanism is

1. higher payload to weight ratio since the payload is carried by several links in parallel.
2. higher accuracy due to non cumulative error.
3. higher structural rigidity since the load is usually carried by several links in parallel.
4. location of actuators (motors) at or close to the base
5. simpler solution of inverse kinematic equations.

KINEMATIC ANALYSIS

Kinematics deals with the geometry and the time dependent aspects of motions without considering the forces causing action. In robotics mapping from joint space to Cartesian space is referred to as direct or forward kinematics and mapping from Cartesian space to joint space is referred as inverse or backward kinematics.

DIRECT & INVERSE KINEMATICS

In direct kinematics the joint variables are given and the position and the orientation of the moving platform are to be found. The forward transform finds the Cartesian configuration corresponding to a given set of joint angles. For parallel manipulators this problem is explicit and can be modeled only by a system of non linear equations. A solution of which requires either a conversion to a suitable polynomial system or the numerical techniques.

In inverse kinematics the positions and the orientation of the moving platform are given and the joint angles are to be found. Inverse kinematics transformation finds the joint angle that corresponds to that position. Inverse kinematics is more interesting in the robot control point of view since in most robot application tasks are specified in Cartesian coordinates and inverse kinematics is computed to arrive at the joint co-ordinates to be used at the lower level joint controllers.

POSITION OF ONE LINK MOVEMENT

In the RCC mechanism three rigid links are connected to the Base and top platforms by means of a spherical joint and universal joint respectively. The position of one link movement is shown in in Fig 1 where θ is the angular tilt of the link and the corresponding position of the link after an angle of tilt θ is given by the relations shown in Fig.1.

PRINCIPLE OF OPERATION

The end effector incorporates rotational compliance in all directions. During operation, the parallelogram mechanism allows angular orientation to the surface and the polishing tool remains normal to the surfaces and the normal forces remain approximately constant, regardless of the robots wrist movement. The principle of operation of RCC is shown in Fig. 2

The potentiometers continuously measure the translational displacement and angular misalignment between the robot wrist axis and the surface normal. The ball bearing castor allows free rotation around vertical and horizontal axis. These bearings minimize frictional forces between the probes and surface.

EDGE DETECTION

The fundamental method of exploring the surface leads to the simple method of detecting of the edges of the surface when one of the probes encounters a sharp edge or discontinuity and leaves the surface; there is a significant increase in displacement X and Y, which is reflected on the sensory data. The change is intensified at an edge because of the preloaded spherical joint.

CONCEPTUAL DESIGN

The geometry of end effector is chosen to give the polishing tool a virtue center of spherical rotation about a point on or near to the surface being polished. Considerable orbital vibration may be excised by a high-speed tool during polishing enough to reduce this vibration to an acceptable level. The photograph of the fabricated model is shown in Fig .3. The spatial mechanism is kinematically over constrained if the links are rigid and the joints are free from backlash.

The polishing tool holder is attached to three arms through spherical joints and three probes are fixed under the tool holder. Each probe is comprised of a ball bearing castor, which allows free rotation around vertical and horizontal axis. The bearings minimize frictional forces between the probes and the surface friction tends to cause stick slip motion as the end effector is moved across the surface. The polishing disc is attached to the air motor which runs at 1440 rpm and this is connected to the end platform which is movable.

ELECTRONIC CIRCUITS

The end effector can be made to trace the required path by measuring the misalignment of the robot's wrist from the surface normal or by prodefining the path via a "Teach pendant" of the robot. The angular value must be calibrated using software since the signal obtained from the sensor will be a value corresponding to the voltage variation.

The link movements of the end effector are sensed by three rotary feed back potentiometers. The analog signal from each of the rotary potentiometers is amplified using a variable gain amplifier using IC741. The purpose of using a variable gain amplifier is to calibrate the analog signal to required digital value. An analog switch namely CD4066 shown in Fig .4 is used to select any one of the three analog signals at a instant depending on the control voltage being applied to its control pin. A +5V on the control pin selects the appropriate signal. The analog signal is then given to an 31/2 digit A/D converter IC7107. The circuit diagram of IC7107 is shown in Fig .5. This will directly drive an instrument size light emitting diode.

The scanning of the analog signal (or) the selection of the analog signal is varied by using a decade counter CD4017 and a 555 timer circuit arrangement. The 555 timer acts in the stable mode and it triggers during a low to high transition. A light emitting diode display is used to indicate which potentiometers are being currently selected.

CONCLUSION

A Robotic system for polishing three-dimensional surfaces has been developed and analyzed. The main advantage of the system is that it is passive and can therefore used with a standard industrial robot without making any hardware modifications. The large range of compliant movement afforded by the end effector enables the robot to move in point to point manner, thereby simplifying the robot control algorithm. A large step length can be used during the polishing processes provided, that the angular and transactional errors do not exceed the range of compliant motion. The system can be used for polishing the turbine blades, components having both concave and convex surfaces, Fan blades etc.,

Prismatic joints can be provided on the links to have large extension in such a way maximum angular tilt will be achieved and this leads to the mechanism a larger compliance.

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