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POSITIONING ACCURACY IMPROVEMENT OF DELTA PARALLEL ROBOT

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ABSTRACT

In recent years, Delta Parallel Robot have been in centre of attraction in the academic and industrial communities because of potential applications not just limited to robot manipulators only but also as mechanisms and machine tools. Mostly, the parameters used to evaluate the performance of traditional serial robots and parallel robots are the workspace, the payload to the robot mass ratio, accuracy of manipulator, and its dynamic properties. Apart from that, the reduced coupling effect between joints, parallel robots bring the benefits of much higher payload robot mass ratios, superior accuracy and greater stiffness; qualities which lead to better dynamic performance. The main drawback with parallel robots is the relatively small workspace. A great research work has been carried out globally on Delta Parallel Robot and a large number of parallel mechanism systems have been built for numerous applications, such as material handling, machine tools, medical robots, flight simulators, MEMS robots, and humanoid robots. In this project a novel approach to design and to develop a Delta Robot has been carried out

Keyword: *delta parallel robot, coupling effect, parallel mechanism system*

I. Introduction

Parallel robot show better stiffness, positioning accuracy and load-carrying capacity than serial robot. They can operate at a higher velocity and acceleration. In recent years, more attention has been paid to the increasing number of possible industrial application, such as manipulation, packing, assembly processes, motion simulation and milling machines. Now there are many other promising applications in medical robotics and the machine-tool industry, which require high positional accuracy. In other words, more precise reproduction of predetermined end-effector positions, which is strictly related to a higher manufacturing accuracy. For this purpose, in the present study, a new method of geometrical calibration is developed, which takes to account the elasticity of links.

II. Problem statement

The aim of geometrical calibration is to identify the real values of the parameters of a geometrical model which allows the improvement of the positioning accuracy of the robot. The positioning errors of the end-effector have two principal origins :

- Lack of knowledge of the real robot geometry due to the manufacture tolerances and assembly errors of all its components.

- Some physical aspects such as the elasticity of links, the clearance in the joints and the temperature variations.

At the first, the robot structure is considered a rigid-body system. The end-effector location is calculated by the forward kinematic model. The initial calibration process consists of the determination of the vector K of the geometrical parameters which minimizes the difference: Zr - Zm(K), where Zr is the real moving plate altitude measured by an external device and Zm(K) is the nominal altitude calculated by the forward kinematic model. Such a calibration is a nonlinear optimization problem which is solved for $k=3p$ number of measurement points, where p is the number of the identified parameters of the examined structure. Then, the errors produced by the elasticity of links are used in the geometrical calibration process and final correction is achieved by taking into account these errors.

III. Modelling of the Delta robot

Fig. 1 Delta Robot

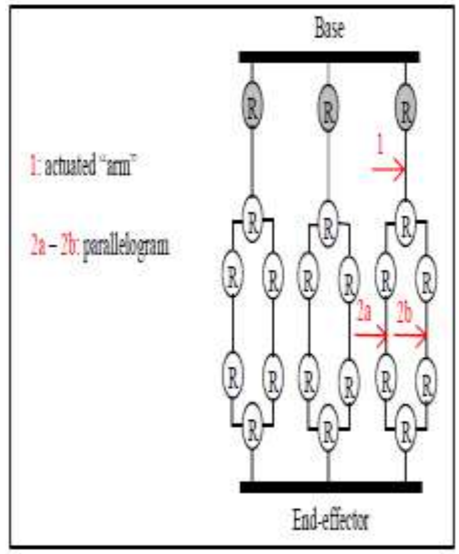

Fig. 2 Joint-and-loop graph of the Delta robot.

The displacement of the end-effector of the Delta robot is the result of the movement of the three articulated arms mounted on the base, each of which are connected to a pair of parallel rods [5,6] (Fig.1,2). The threeorientations are eliminated by joining the rods in a common termination and the three parallelograms ensure the stability of the end-effector.

This configuration of the robot has three degrees of freedom. The plate end-effector stays constantly parallel to a reference plane (base) and cannot rotate about the axis perpendicular to this plane. To simplify the model of the robot let us consider that the parallelograms are perfect which allows us to describe the structure with a complete and independent model having 18 geometrical parameters (7 parameters which describe the link length errors and 11 parameters which describe the orientation errors) [7].

STEP 1. Calibration of the Delta robot: rigid body model

First, we carried out a geometrical calibration with 82 measurement points, uniformly distributed in the restricted area of the robot workspace (700x500x400 mm). In this case, the calibration was realized without taking into account the elasticity of links. A comparative analysis was accomplished for the end-effector positions along the Z axis. The measurements after calibration were compared with the forward kinematic model, which was calculated for the nominal and corrected parameters. The

- End-effector displacement due to the elasticity of links:
  - ΔX = 439 µm
  - ΔY = -57 µm
  - ΔZ = -1126 µm

obtained results show a significant improvement in the robot accuracy (Table 1, see Step 1). The comparative analysis of these results also showed that the difference between the identified and real values is important (see Table 2) . It is obvious that such an important difference cannot be due only to the geometrical effects, so we decided to get to the root of this problem and take into account the elasticity of links.

Table 1

Before calibration (Not corrected FK)	Geometric calibration (Step 1)	Corrected calibration (Step 2)
1060 µm	13,8 µm	12,6 µm

Table 2

Arms length	L1 (mm)	L2 (mm)	L3 (mm)
Nominal values in mm	950	950	950
Geometric calibration (Step 1)	953,58	955,21	953,12
Corrected calibration (Step 2)	952,32	954,11	952,31
Identification improvement	35%	21%	26%

STEP 2. Corrected calibration of the Delta robot: flexible model

In this case, we introduced the flexibility of links in the calibration process. For this purpose, the displacements of the end-effector were calculated by taking into account the elasticity of links (see Fig.3). A finite element model developed on the Castem software, allowed us to calculate the deviation of the end-effector positions along the Z axis with great precision. This deviation represents the errors due to the elasticity of links. The geometrical model of the robot was then studied, which took into account this deviation and allowed us to improve the calibration process. Such a modification shows, that for the second step, the vector **K** of estimated parameters better corresponds to the structure image.

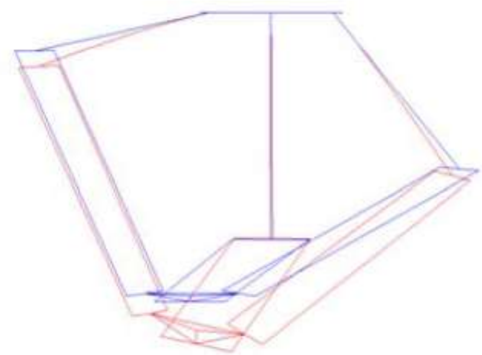

Fig.3. Rigid-body and flexible models.

Thus, by compensating for elastic deformations, the positioning accuracy is improved by 9% (Table 2). Also, the difference between identified and real parameters is significantly reduced, meaning that the obtained robot model is more realistic.

IV. Conclusions

This paper deals with a solution to the problem of improving the positioning accuracy of the Delta robot. The suggested approach is based on the geometrical calibration, which is carried out by the integration of the elastic deformations structure in the calibration process. Such a solution allows us to obtain a more exact geometrical model and consequently, to improve the positioning accuracy of the robot. We hope that this new solution will find a broad application in high-accuracy robotics.

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