2. METHODOLOGY

The joint clearance and its impact on the accuracy of parallel mechanisms has been studied. So far, much research was conducted on kinematic structures with limited degrees of freedom which is used to mount the mechanism. In this paper two non-overconstrained architectures 3-RRS and 3-RSR are compared with overconstrained one from the accuracy point of view based on the joint clearance. First, a method to obtain a model of moving platform pose (position and orientation) error based on the joint clearance is introduced which leads to a standard convex optimization problem. Then maximum values of six components of the pose error are computed in more than 1000 different configurations within its workspace. It is shown that this displacement is configuration dependent. The obtained results revealed that the 3-RRS spherical parallel mechanism has better position accuracy while in the case of orientation, the 3-RRS SPM has the lowest maximum error between spherical parallel mechanisms under study in the prescribed workspace. It can be concluded that non-overconstrained structures can be used instead of the overconstrained structure. Finally, a comparison was made between the performance indices and the presented method.

1. INTRODUCTION

Spherical Parallel Mechanism (SPM) is one of the parallel mechanisms with limited degrees of freedom which is used to rotate a body around a fixed point. Different kinematic arrangements can be obtained for the robot with three degrees of rotational freedom. The most commonly used structure for this robot is the 3-RRR kinematic architecture which is an overconstrained parallel mechanism and causes several problems of mounting the mechanism. In this paper two non-overconstrained architectures 3-RRS and 3-RSR are compared with overconstrained one from the accuracy point of view. The maximum value of six components of the pose error is computed in more than 1000 different configurations within its workspace. It is shown that this displacement is configuration dependent. The obtained results revealed that the 3-RRS spherical parallel mechanism has better position accuracy while in the case of orientation, the 3-RRS SPM has the lowest maximum error between spherical parallel mechanisms under study in the prescribed workspace. It can be concluded that non-overconstrained structures can be used instead of the overconstrained structure.

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\[ \Delta \sigma_{i,j} = 0.1 \text{mm} \quad (6) \]
\[ \Delta \epsilon_{x,y} = 0.2 \text{ mm} \quad (7) \]
\[ \Delta \omega_{z} = 0.01 \text{rad} = 0.57' \quad (8) \]

Eventually, the maximum of each of the error components of the platform is obtained as follows:
\[ \max \Delta E_k = \max \{ \max \Delta E_{i,j} \} \quad i = 1, \ldots, m \quad k = 1, \ldots, 6 \quad (9) \]

2.2. Performance Indices

Various indices have been introduced to measure the accuracy of the robots that are all based on manipulator Jacobian [5] which the most well-known are as follows:

Manipulability:
\[ \mu = 1 / \sqrt{\text{det} \left( K' K \right)} \quad (10) \]

Dexterity:
\[ \alpha = \| K \| \| K^{-1} \| \quad (11) \]

Kinematic sensitivity:
\[ \sigma_{\epsilon,i} = \max_{\rho_{i,j}} \phi_j, \quad \sigma_{\rho,i} = \max_{\rho_{i,j}} \rho_j \quad (12) \]

One of the important weaknesses of these indices is that in robots which degrees of freedom are rotational and translational, in other words, then Jacobian is not homogeneous, the indices do not provide a significant physical quantity. Also, in robots with the same Jacobin, the situation we are facing in this paper, the indices cannot be used for comparison. Therefore, this paper presents a comparison between the proposed method and the kinematic sensitivity indices to determine the most suitable index for comparing robot precision.

3. RESULTS AND DISCUSSION

3.1. Under study workspace

In this paper, the Euler angles \([\phi, \theta, \psi]\) is used in order to show the workspace of the manipulator which is defined by
\[ \phi \in \left[ \frac{-\pi}{3}, \frac{\pi}{3} \right], \psi \in \left[ \frac{-\pi}{3}, \frac{\pi}{3} \right], \text{and} \ \theta = 0. \]

3.2. Comparison of introduced error model with performance indices

Fig. 1 shows the mentioned indices and maximum rotational error of 3-RRR SPM in the prescribed workspace. More graphs are provided in the full article. As shown in this figure, the kinematic sensitivity index is the most suitable indicator for displaying manipulator accuracy.

4. CONCLUSIONS

In this paper, an overconstrained SPM and two non-overconstrained SPMs were compared from the accuracy point of view and the results showed that the latter structures can be used and at the same time had the suitable accuracy.
Also, a comparison was made between kinematic sensitivity indices and the error model and results revealed that the kinematic sensitivity index is the most appropriate index for expressing the accuracy of parallel manipulators.

REFERENCES


