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TRANSMISSION INDEX BASED OPTIMAL DESIGN OF AN OCTA POD

A Kiran[1], S Jaya Krishna[2], Prof. G Satish Babu[3]

[1]Department of mechanical engineering, Jawaharlal Nehru Technological university Hyderabad.
Email id: kiran.annangi593@gmail.com
[2]Department of mechanical engineering, Holy mary Institute of Technology and Science
Email id: yellowjupiter@gmail.com
[31]Department of mechanical engineering, Jawaharlal Nehru Technological university Hyderabad.,
Email id: satishbabug.jntuhm@gmail.com

***Abstract*— Performance analysis of parallel manipulator is a standout among the most noteworthy and testing issues. Particularly in the investigation of parallel manipulators with particular movements, the Force transmissibility assessment is critical and stays to be fathomed. At the point when a parallel manipulator executes a given errand, for example, grinding, grasping, brushing and lifting up, it adjusts the contact forces and torques on its end-effector from joint space by the joint power/torque. Subsequently, the interior transmission powers in a parallel manipulator assume enter parts in controlling the end effector and opposing outer burdens. Fundamentally, the bigger of the actuator estimate, bigger outer Forces and torques the component could be a regardless of with the basic transmission execution at various designs. The transmission index ranges from zero to one.**

***Keywords*— Transmission index, Octa pod, Jacobian, Euler angles, Optimal design.**

I. INTRODUCTION

G.Sutherland and B.Roth [1] developed a general index of the quality of motion transmission for spatial; mechanism using the theory of screws. This index is related to the mechanical error possible in a linkage. A method for synthesizing spatial linkages with desirable motion transmission and mechanical error characteristics is developed. The problem of determining a RGGR function generator with optimum transmission and the error sensitivity characteristic is dealt with. Ya-Qing Zheng ,Xiong-Wei Liu[2] Force Transmission Index Based Workspace Analysis Of A Six Dof Wire-Driven Parallel Manipulator Asme 2002 Design Engineering Technical Conferences and Computer and Information in Engineering Conference Montreal, Canada This paper presents a novel six DOF wire-driven PKM. Its moving platform is supported by seven wires via spherical joints, and at the other end each wire is driven by a servo motor via a pulley mounted on a frame. The force transmission index is adopted to analyse the relationship of the force transmissibility between the wires and the moving platform. Moreover, the workspace analysis of the moving platform is investigated by means of force transmission index. Finally, a case study is presented to demonstrate the application of the algorithm to determine the workspace of two manipulators with different design parameters using Monte-Carlo technique under the Matlab environment. Wen-Tung Chang and Chen-Chou Lin [3] Force Transmissibility Performance of Parallel Manipulators Journal of Robotic Systems 20(11), 659–670 (2003) © 2003 Wiley Periodicals, Inc. Published online in Wiley Inter Science. In this paper, a new force transmission index called the mean force transmission index (MFTI) is proposed, and the force transmissibility analysis procedure is established for parallel manipulators. The MFTI is an extended definition of the force transmission index (FTI) introduced by the authors previously. It is shown that the FTI is a function of the input velocity ratio (IVR) for a multi-DOF mechanism of the same configuration. To represent the force transmissibility by a definite value, the MFTI is defined as the mean value of the normalized FTIs function over the whole range of the IVR. The force transmissibility analysis of two planar parallel manipulators is illustrated using the MFTI method. The result is compared with that of the Jacobian matrix method and the joint force index (JFI) method. It shows that, especially for symmetric parallel manipulators, an approximate inverse-proportionality relationship exists between the JFI and MFTI, and between the maximum input torque/force and MFTI. It is concluded that the MFTI can be used as a quantitative measure of the force transmissibility performance for parallel manipulators.

Pond and Carretero [4] introduced a dimensionally homogeneous Jacobian matrix, which is used to determine the dexterity of parallel mechanisms regardless of the number and type of degrees of freedom of the mechanism. A 3-PRS manipulator is analysed by using the new concept. Daxing Zeng et al. [5] analysed a 3DOF 3-PRUR Parallel Manipulator(PM). *It* is found that the PM can behave like a conventional X-Y-Z Cartesian machine and is completely decoupled on the initial position. After obtaining the corresponding atlases to these performance indices it is concluded that the mechanism's performance will not be influenced even if all links have the same length. Xinjun LIU,chao wu[7] ,fugue XIE proposed a local transmission index for the evaluation of motion / force transmissibility of non-redundant parallel manipulators with a single element. A non-redundant 3DOF 3-CPU is compared with 3DOF 4-CPU parallel manipulator and observed that by introducing an extra actuation redundancy the motion / force transmissibility is well improved and the singularity- workspace is also abruptly enlarged.

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Metin Toz and Serdar Kucuk [10] designed an asymmetric Generalized Stewart–Gough Platform (GSP) sort parallel manipulator by considering the sort blend approach. The awry six-Degree Of Freedom (DOF) manipulator streamlined is chosen among the GSPs ordered under the name of 6D. The dexterous workspace streamlining of Asymmetric Parallel Manipulator with ten Different Linear Actuator Lengths (AMEDLAL) subject to kinematics and geometric limitations is performed by utilizing the Particle Swarm Optimization (PSO). The condition number and Minimum Singular Value (MSV) of homogenized Jacobian matrix are utilized to acquire the dexterous workspace of AMEDLAL. Guanglei Wu, Stéphane Caro, Jiawei Wang [12] exhibited an asymmetrical spherical parallel manipulator and its transmissibility investigation. This manipulator contains an inside shaft to both produce a decoupled boundless torsion movement and bolster the portable platform for high situating precision. This work addresses the transmission examination and ideal outline of the proposed manipulator in light of its kinematic investigation. Haitao Liu, Tian Huanga, Andrés Kecskeméthy, Derek G. Chetwyndc , Qing Li [13] introduced a general and deliberate approach for force/motion transmissibility examinations of redundantly activated and over constrained parallel manipulators. An arrangement of standardized transmission indices are proposed for speaking to the closeness to singularities and in addition for dimensional advancement of the repetitively activated and over constrained parallel manipulators. Juan Diego Orozco-Muñiz, J. Jesús Cervantes-Sánchez [14] presents two novel dexterity indices to assess the kinematic execution of planar parallel manipulators. The proposed records depend on traditional ideas of unbending body kinematics and they don't rely upon having a dimensionally homogeneous grid or utilizing a similar kind of actuators.

II. KINEMATIC ANALYSIS OF AN OCTA POD

2.1 Transmissibility Index

A parallel manipulator must transmit the joint forces and torques to the output platform, resisting the external loads, through its mechanical structure. Amid the procedure of force transmission, the rising internal wrenches, particularly, the transmission wrenches, can be imparted by the TWS. It is understood that a TWS must be integral to the twist screws permitted by the segregated joints in the relating leg, when the dynamic joints are bolted. If all the parallel manipulators are considered as exactly constrained systems, then

$$EF=W \tag{2.1}$$

Where W is the unit wrench, F= [f_1, f_2,…. f_n], and E is termed as transmission matrix.

$$E=\begin{bmatrix} e_1 & e_2 & \dots\dots\dots & e_n \\ (c_1\times e_1)+h_1e_1 & (c_2\times e_2)+h_2e_2 & \dots\dots\dots\dots & (c_n\times e_n)+h_ne_n \end{bmatrix} \tag{2.2}$$

where $\mathbf{e_i}$ is the unit directional vector of the TWS, $\mathbf{c_i}$ is the vector pointing from the centre of the platform to the characteristic point of the i_{th} leg, $\mathbf{h_i}$ **is** the pitch of the TWS, $\mathbf{f_1}$ is the magnitude of the TWS in terms of force and σi are the singular values of E. The transmission index (TI) is given by

$$TI=\sum\frac{1}{\sigma_i^2}$$

2.2 Kinematic analysis

$$p_i = s + Qp_i' \qquad i = 1,2\dots\dots8 \tag{2.3}$$

Where $p_i' = [\,p_{ix}', p_{iy}', p_{iz}'\,]^T$.

Subtracting vector b_i from both sides of eq. (2.3), one obtains

$$p_i - b_i = s + Qp_i' - b_i \qquad i = 1,2\dots\dots8 \tag{2.4}$$

Where the left-hand side represents, in fact, a vector connecting point B_i to point A_i, along the i_{th} leg. Hence, taking the Euclidean norm of both sides of this equation leads to

$$\rho^2 = ||b_i-p_i||^2$$

$$\rho^2 = (s + Qp_i' - b_i)^T(s + Qp_i' - b_i) \tag{2.5}$$

When eq. (4.3) is differentiated with respect to time, a set of linear equations relating the joint rates to the Cartesian velocities is obtained. Following the formalism proposed in Gosselin and Angeles (1990) for parallel manipulators, two Jacobian matrices A and B are obtained and the velocity equations can be written as

$$At = B\rho, \tag{2.6}$$

Where t is the six-dimensional twist of the platform and $\dot{\rho}$ is the vector of joint velocities. These vectors are defined as

$$t = [\dot{s}^T, \omega^T]^T, \quad \dot{\rho} = [\dot{\rho}_1, \ldots, \dot{\rho}_8]^T, \tag{2.7}$$

in which the angular velocity of the platform is defined as ω and $\dot{s}=[\dot{x}, \dot{y}, \dot{z}]^T$ is the velocity of point O′. The aforementioned Jacobian matrices can then be written as

$$B = \mathrm{diag}(\rho_1, \ldots, \rho_8) \tag{2.8}$$

and

$$A = \begin{bmatrix} c_1^T \\ \cdot \\ \cdot \\ \cdot \\ c_8^T \end{bmatrix}, \tag{2.9}$$

with

$$c_i = \begin{bmatrix} d_i \\ (Qpa_i)\times d_i \end{bmatrix}, \quad i = 1\ldots,8 \tag{2.10}$$

where d_i is the vector connecting point B_i to point P_i, i.e.,

$$d_i = p_i - b_i, \qquad i = 1\ldots,8. \tag{2.11}$$

Finally, the rotation matrix Q representing the orientation of the platform with respect to the base can be written using Euler angles (Hughes 1986) as

$$Q = \begin{bmatrix} \cos\theta\cos\psi & \cos\psi\sin\theta\sin\phi - \sin\psi\cos\phi & \cos\psi\sin\theta\cos\phi + \sin\psi\sin\phi \\ \cos\theta\sin\psi & \sin\psi\sin\theta\sin\phi + \cos\psi\cos\phi & \sin\psi\sin\theta\cos\phi - \cos\psi\sin\phi \\ -\sin\theta & \cos\theta\sin\phi & \cos\theta\cos\phi \end{bmatrix} \tag{2.12}$$

Where ψ, θ, ø are three Euler angles defined according to the convention (Qz, Qy, Qx). Other representations of the rotation could also be used (e.g., quaternions, linear invariants, dual representations), which would not affect the algorithm presented.

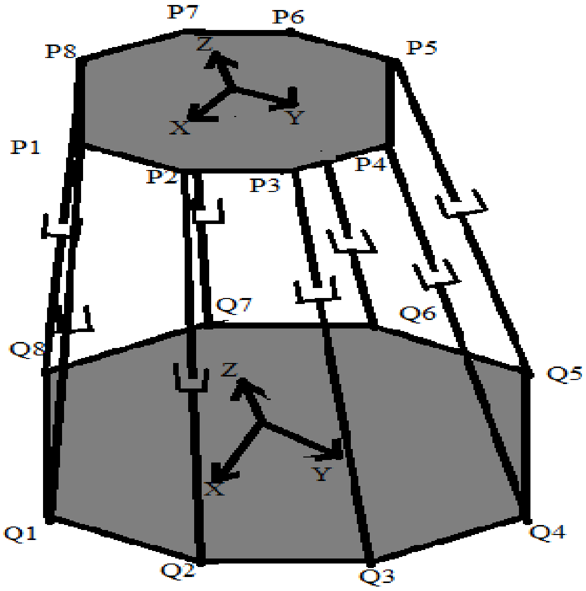

Fig 2. Kinematic model of 8-UPS parallel manipulator

III. RESULTS AND DISCUSSION

The results obtained by using the MATLAB code for the Transmission index discussed in the following sub sections. The graphs for Transmission index are obtained by considering a specified workspace of 8-UPS spatial parallel manipulator.

The Transmission index of the manipulator is dependent on the end effector 's position and orientation with in the specified workspace of the manipulator. For the optimal design, the parameters: fixed platform size (b), moving platform size (p), twist angle(Ψ), tilt angle about Y axis(θ) and tilt angle about X axis(Ǿ) are considered; it is implemented by evaluating the influence of these parameters on Transmission index.

As a part of Optimal design, the graphs showing the variation of Transmission index for different structures of the manipulator are developed. Only three structures m are finally selected based on the optimum values of the Transmission index. In each structure by fixing the twist and tilt angles the variation of the measures in a plane parallel to the base platform at different vertical reaches of the moving platform are developed.

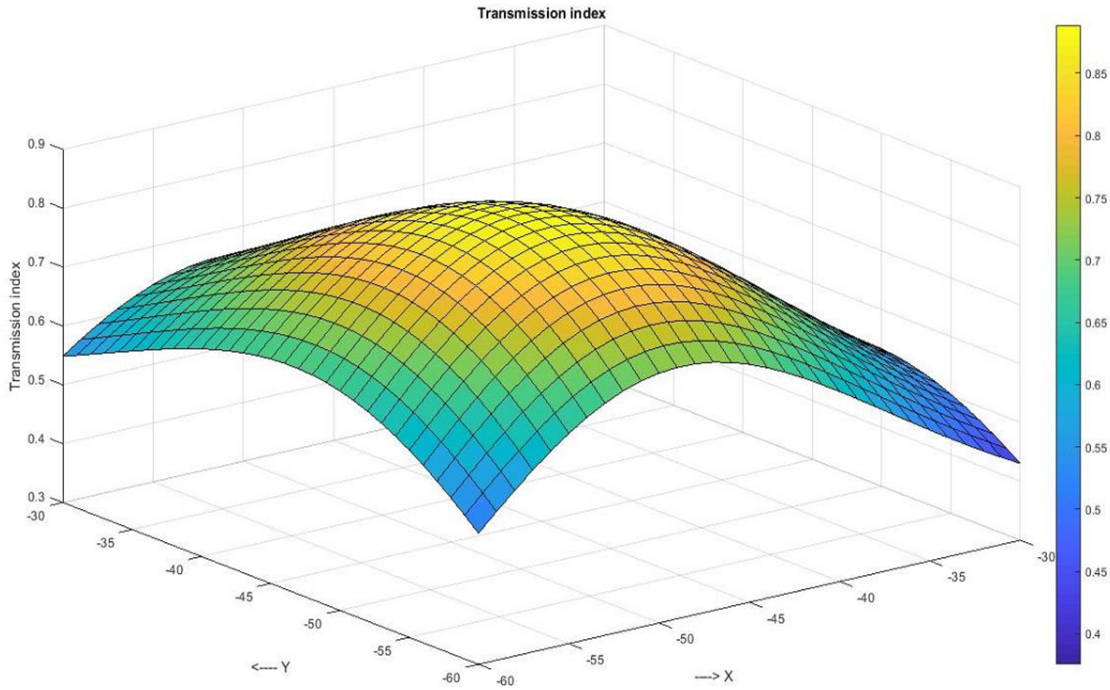

Fig.3 for R_b=70,R_p=30 & z=10, Twist angle Ψ=10^0, Tilt angles θ=10^0, Ǿ=10^0

For above structure specified by base platform and moving platform radius as 70mm and 30mm respectively with twist angle (Ψ)=10^0 , tilt angle about Y axis(θ)=$10^0$and tilt angle about X axis(Ǿ)=10^0 the value of transmission index increases in the vertical reach range of 5mm to 10mm and the maximum value of Transmission index is 0.88853 which occurs at x=-49mm, y=-49mm and vertical reach of 10mm as shown in fig. 3. At other values of vertical reach for this structure the obtained results shows that the jacobian matrix is ill conditioned which indicates the singular locations of the moving platform.

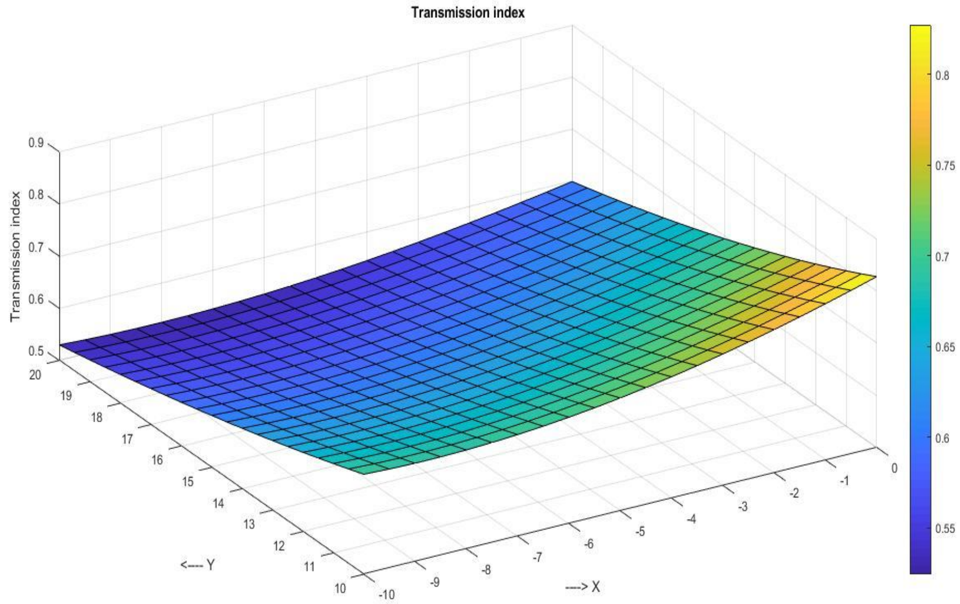

Fig.4 for R_b=60,R_p=30 & z=35, Twist angle Ψ=8^0, Tilt angles θ=9^0, Ǿ=9^0

For above structure specified by base platform and moving platform radius as 60mm and 30mm respectively with twist angle (Ψ)=8^0 , tilt angle about Y axis(θ)=9^0 and tilt angle about X axis(Ǿ)=9^0 the value of transmission index increases in the vertical reach range of 30mm to 35mm and the maximum value of Transmission index is 0.82721 which occurs at x=0mm, y=10mm and vertical reach of 35mm as shown in fig.4. At other values of vertical reach for this structure the obtained results show that the jacobian matrix is ill conditioned which indicates the singular locations of the moving platform

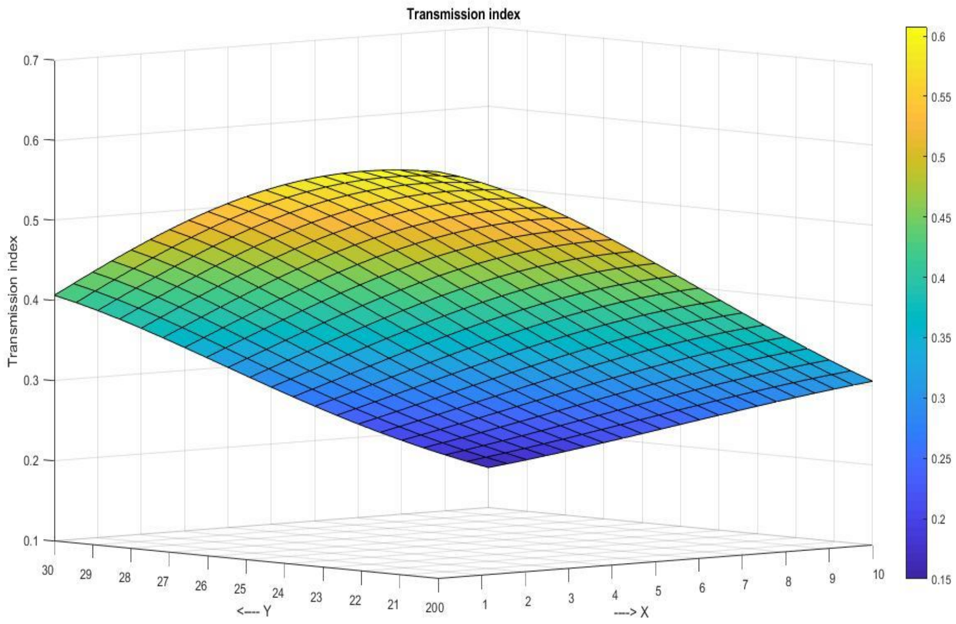

Fig.5 for R_b=30,R_p=20 & z=28, Twist angle Ψ=9^0, Tilt angles θ=7^0, Ǿ=9^0

For above structure specified by base platform and moving platform radius as 30mm and 20mm respectively with twist angle (Ψ)=9^0, tilt angle about Y axis(θ)=$7^0$and tilt angle about X axis(Ǿ)=9^0 the value of transmission index increases in the vertical reach range of 20mm to 28mm and the maximum value of Transmission index is 0.60782 which occurs at x=0mm, y=20mm and vertical reach of 28mm as shown in fig.5. At other values of vertical reach for this structure the obtained results show that the jacobian matrix is ill conditioned which indicates the singular locations of the moving platform.

IV. CONCLUSIONS

Present work has been focused on investigation of 8-UPS spatial parallel manipulator's kinematics and performance evaluation based on the Transmission index. The following conclusions were drawn from the results.

- Using the kinematic model, the loop closure equations are developed for 8-UPS manipulator.
- Jacobian matrices are derived for 8-UPS manipulator.
- The Transmission index considered in the present work is the function of the jacobian matrix.
- Graphs showing the variation of Transmission index in a specified workspace is developed.
- Maximum value of Transmission index i.e. 0.88853 is obtained for the manipulator with structure having base radius to moving platform radius of 2.33, the orientation of the moving platform specified by Ψ=10^0,θ=10^0&Ǿ=$10^0$and the position in the workspace : x=-49mm, y=-49mm and z=10mm. This posture is the best for force/torque transmission and can be used in assembly applications.

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