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Kinematic Analysis of Seven Degrees of Freedom Parallel Robot

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Abstract: ***A seven degree of freedom parallel manipulator is presented. Firstly, geometrical structure manipulator is addressed. Then the inverse kinematic problems are analysed, singularity analysis of the mechanism is performed based on the singular conditions of the direct Jacobian matrices, acceleration analysis and workspace analysis developed by the Jacobian matrix being identically Finally, a potential application of the mechanism is briefly described.***
Keywords: ***Degree of freedom, Parallel robot, kinematic analysis, inverse kinematics, workspace analysis***

I. INTRODUCTION

Parallel robots have incited various research exercises in the Academic people group for a long time now. In reality, from the primary thoughts proposed by Gough or Stewart, a great deal of fascinating mechanical gadgets or structure techniques have been widely examined. In the late 90'S, another field of both research and applications has been opened by Clavel who proposed the well-known Delta structure as a base for a "family" of parallel machines committed to fast applications. All the more as of late, the machine-apparatus industry found the potential points of interest of parallel mechanisms and most significant machine-instrument organizations are today during the time spent broad tests and assessment of their parallel robot machines for 5-pivot processing (Gidding&Lewis, Ingersoll, Hexel, Toyoda, Neos), for penetrating Hitachi, for 3-hub processing .Degrees of freedom, in a mechanics setting, are explicit, characterized modes in which a mechanical gadget or framework can move. degrees of freedom is equivalent 4 to the complete number of independent displacements or parts of movement. A machine may work in two or three measurements however have multiple degrees of freedom. The term is broadly used to characterize the movement capacities of robots.

A Gough–Stewart platform is a kind of parallel manipulator that has six prismatic actuators, ordinarily hydraulic jacks or electric direct actuators, appended two by two to three situations on the platform's baseplate, traverse to three mounting focuses on a top plate. Each of the 12 associations are made by means of general joints. Devices set on the top plate can be moved in the six degrees of freedom in which it is workable for an openly suspended body to move. These are the three straight developments x, y, z (parallel, longitudinal, and vertical), and the three revolutions (pitch, roll, and yaw). In view of its movements, it is additionally called a six hub platform or 6-DoF platform Regardless of whether a unimaginably enormous number of various structures have been proposed by Academic analysts in the last 20 years, some of them can be respected as increasingly famous to the extent mechanical use is concerned: the Delta robot is certainly a triumph, as well as the alleged "hexapod" with 6 UPS chains in parallel (U-P-S: Universal-Prismatic-Spherical). This robot has six-DoFs manipulation and grasping limits using straight stages arranged on the robot's base. The robot structure was inspected and its kinematic model made. For the confirmation of thought, a model was made and controlled. This robot had the alternative to viably achieve grasping, manipulation, and expansion exercises which affirms the proposed thought.

II. KINEMATIC STRUCTURE

The idea of the proposed structure is portrayed in the architectural plan showed in Fig. 1, where joints are represented by rectangles, and links between those joints are represented by lines. The robot is incited utilizing eight moving stages, symmetrically fixed on the base. Each moving stage underpins one swagger, which is appended to the platform and to the moving stage by mean of two round joints. The privilege some portion of the top platform is appended to one side one through a revolute joint so as to produce a collapsing portability.

This structure permits six-DoF movement and the collapsing of the top platform. The design of the platform is characterized by the directions (x, y, z) of the point Op situated in the focal point of the platform while three Euler edges (α,β,γ) are utilized to depict the overall direction of the platform with the base, as represented in Fig. 2. The relative point between the two pieces of the foldable platform is represented by θ. The gadget is needlessly impelled since the seven DoFs of the design are controlled by eight independent actuators.

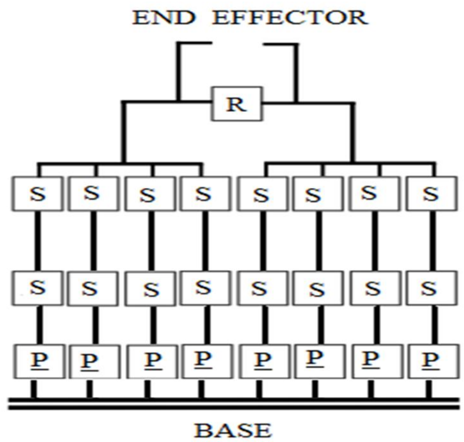

Figure 1. blocks R,S and P represent revolute, spherical, and prismatic joint respectively

III. METHODOLOGY

Each engineering design is dependent upon varieties that can emerge from an assortment of sources, including manufacturing operations, varieties in material properties, and the working environment. Point when varieties are disregarded, non-strong designs can result, which are costly to create or bomb in administration. Plus, the power of a mechanism is significant when alignment is essential in fact that the lower the affectability of the mechanism to dimensional varieties, the simpler its adjustment.

A. Investigation of Parallel Mechanisms

Investigation of Parallel mechanisms is the investigation of motion of various individuals establishing a mechanism and the mechanism all in all element while it is being worked or run. This investigation of motion includes direct just as angular position, velocity and speeding up of various focuses on individuals from parallel mechanisms. Investigation and union are two unique parts of parallel mechanisms and machine design. Prior design architects utilized drafting types of gear to graphically examine the mechanisms. The nonstop commitment by design builds for a considerable length of time has lead to improvement of numerous strategies and systems for examination of mechanisms. As of late, the improvement of PC methods has offered various suitable and appealing arrangements

B. Strategies and Techniques of Mechanism Analysis

Mechanism examination techniques are fundamentally of two sorts, graphical and explanatory. Every strategy has numerous strategies for examination of mechanisms, where every system is reasonable for a specific classification of mechanisms. With the advancement of complex PC projects design architects like to focus their exertion on expository methodology. Yet at the same time the graphical way to deal with mechanism investigation has not lost its utility, uncommonly at times where graphical method gives the most proficient arrangement and physical knowledge to picture working of the mechanism.

C. Graphical Method of Mechanism Analysis

Graphical strategy begins with position analysis by essentially attracting the linkage component to scale. At that point the velocity analysis is performed which requires the precise position of the connections to be resolved previously. So also, it is important to know rakish speeds of connections for acceleration analysis. Accordingly, the grouping for kinematic analysis of components is – position analysis, at that point velocity analysis and afterward acceleration analysis.

D. Various Techniques of Graphical Analysis

1) *Velocity and Acceleration Polygon:* Velocity and acceleration are vectors and, in this manner, their whole or contrast will keep vector polygon laws. In the event that velocity of one point on a connection is known, at that point the velocity of different focuses can be discovered utilizing the vector polygons. This strategy depends on vector polygon laws.
2) *Velocity and Acceleration Image:* This method is utilized for graphical analysis of components with more than one circle. On the off chance that the velocity and acceleration of two on a connection are known then the velocity and acceleration of third point on that connection can be resolved utilizing velocity and acceleration picture.

3) *Reversal Technique:* When it is preposterous to expect to break down the linkage straightforwardly utilizing vector polygon approach then Inversion Technique is utilized. In this method the determined and driver wrenches are traded to perform graphical analysis.
4) *Relative Velocity and Acceleration:* This strategy is utilized to break down systems with huge number of individuals. In this system the connections between relative direct/precise speeds and acceleration of focuses/individuals are utilized to investigate the instruments.
5) *Moment Center of Velocity:* For an unbending body moving in a plane, at each moment there exists a point that is immediately very still. Right now, focus of velocity for the given unbending body is discovered utilizing standard techniques. It is valuable for discovering input-yield velocity connections of complex systems.

IV. INVERSE KINEMATICS

The connection giving the incited joint coordinates for a given posture of the end-effector is known as the inverse kinematics, which is straightforward for parallel robots. The inverse kinematics comprises in building up the estimation of the joint coordinates relating to the end-effector arrangement. Setting up the inverse kinematics is fundamental for the position control of parallel robots. There are different approaches to speak to the posture of an unbending body through a lot of parameters X. The most old-style route is to utilize the coordinates in a reference edge of a given point C of the body, and three edges to speak to its direction. In any case, there are different ways, for example, kinematic mapping which maps the dislodging to a 6-dimensional hyperquadric, the Study quadric, in a seventh-dimensional projective space. The kinematic mapping may have an enthusiasm as conditions including dislodging are arithmetical (and the structure of mathematical assortments is preferable comprehended over other non-direct structures) and may have intriguing properties, for instance, expressing that a point submitted to a removal needs to lie on a given circle is effectively composed as a quadric condition utilizing Study coordinates (Merlet, 2006).

A. Analytic Method

For a fully-parallel mechanism, every one of the chains interface the base to the moving platform. In the event that B speaks to the end of the chain that is connected to the base, and A the end of the chain that is connected to the moving platform. By development the coordinates of B are known in a fixed reference outline, while the coordinates of A might be resolved from the moving platform position and direction. Subsequently the vector BA is principal information for the inverse kinematic issue, this is the reason it assumes a pivotal job in the arrangement.

1) Two edges are characterized, in particular B: a reference casing fixed on the base; A: an arrange casing fixed on the nacelle C_1, C_2
2) The actuators slide along manage ways arranged along a unitary vector,K_Z the solidarity vector along z pivot in the reference outline B, and the root is the point P_i , so the situation of each point An I is given by by $\mathbf{B}_I=\mathbf{P}_i+q_i+\mathbf{z}_i$, q_i, qi is the moving separation of the actuator. The number I =1,2,3,4 speaks to each combine of kinematic chains;
3) The parameters M_i , d and h are the length of the bars, the balance of the revolute-joint from the swiveling appendage, and the balance of each rotating conjuncture from the focal point of voyaging plate, individually;
4) The position of the end-effector, to be specific point A, is characterized by a position vector A = [x y z], and a scalar, speaking to the direction edge.

Without losing consensus, in this segment we consider balance of {B} from {A} along the heading of k_Z . $\mathbf{P}_i = a_i , b_i ,0$ for straightforwardness, Q_Z is the of B from A along the bearing of k_z .

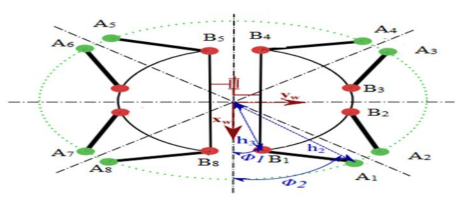

Fig 2 seven dof parallel robot

The situation of focuses C_1 and C_2 are given by:

$$C_1=A+Rot(v,\theta)(AC_1) \qquad C_2=A+Rot(v,\theta)(AC_2) \tag{1}$$

The position relationship would then be able to be composed as:

$A_1=C_1+C_1A_1 \qquad A_2=C_1+C_1A_1 \qquad (2)$

$A_3=C_2+C_2A_3 \qquad A_4=C_2+C_2A_4 \qquad (3)$

At that point for primary hub : $B_1A_1=[\ A+Rot(v,\theta)(AC_1)+C_1A_1-P_1]-q_1z_1$

$$(\mathbf{B}_1\mathbf{A}_1)^2=q^2_1-2q_1d_1\,z_1+d_1^2$$

Where $d_1=$ $\mathbf{A}(Rot(\mathbf{v},\theta)(\mathbf{AC_1})+\mathbf{C_1A_1}-\mathbf{P_1}$ .At long last, the two arrangements are given by

$$Q_1=d_1\bullet z_1\pm\sqrt{(d_1\cdot z_1)^2+M_1-d_1^2}$$

Comparable determinations give the answer for Q_2,Q_3. Q_4,Q_5 Q_6,Q_7 and Q_8

V. GEOMETRICAL METHOD

The geometrical way to deal with the inverse kinematics issue is to think about that the furthest points A, B of each chain have a known situation in 3D space. The leg can be cut at a point M and two unique mechanisms MA, MB comprised of the chain between A, M and the chain between B, M can be gotten. The free movement of the joints in these two chains will be with the end goal that point M, considered as an individual from MA, will lie on an assortment VA, while considered as an individual from MB it will lie on an assortment VB. In the event that expect the mechanism have just old-style lower combines, these assortments will be mathematical with measurements dA, dB. In the 3D space, an assortment of measurement d is characterized through a lot of 3-d independent conditions, and consequently VA, VB will be characterized by conditions. The arrangements of the inverse kinematic issue lie at the crossing point of these assortments. As the quantity of arrangements must be limited (generally the robot can't be controlled), the position of the crossing point assortment must be 0. As such, so as to decide the 3 coordinates of the focuses, should equivalent. The key issue about the geometrical method rests with the decision of the cutting point. For the structure appeared in Fig.10, Bi are picked as the cutting focuses. Focuses Bi needs to lie on a circle focused at Ai with span Mi, while for the nacelle, the coordinates of Points Bi can be portrayed as (8). Subsequently to acquire the crossing point of these 2 assortments the known separation between A, B of ought to be equivalent to Mi: this condition will give the joint ordinates qi. Similar outcomes can be acquired as portrayed

VI. JACOBIAN MATRIX

Jacobian matrix relates the activated joint speeds to the end-effector cartesian speeds, furthermore, is basic for the velocity and trajectory control of parallel robots. For parallel controllers, their opposite Jacobian matrix can be set up without an exceptionally high intricacy, however their Jacobian matrix can't be gotten legitimately, even with the assistance of emblematic calculation, aside from in some specific cases (Bruyninckx, 1997; Pennock and Kassner, 1990). Hypothetical scientific definitions of jacobians have been proposed, yet require muddled matrix reversals (Dutré et al., 1997; Kim et al., 2000). By and large, the trouble of the reversal doesn't lie in the multifaceted nature of the calculation however in the sheer size of the outcome (Merlet, 2006). The velocity of the nacelle can be characterized by falling back on a lines, the velocity of focuses C1 and C2 can be composed as pursues (Pierrot and Company, 1999)

$$\mathbf{V_{c1}=V_A+\theta\, v\times AC_1} \qquad \mathbf{V_{c1}=V_A+\theta\, v\times AC_1} \qquad \mathbf{(4)}$$

In addition, since the connections B_1 B_2 and B_3 B_4 move just in interpretation, the accompanying relations hold:

$$V_{A1}=V_{A2}=V_{C1} \qquad V_{A3}=V_{A3}=V_{C2}$$

Velocity to points B_i is given by:

$$V_{Ai}=q_iz_i$$

$$V_{Ai} \cdot B_iA_i = V_{Bi} \cdot B_iA_i \tag{5}$$

Can i=1,2,3,4…….8 and result is matrix such

$$J_q\, q = J_X\, x$$

Where

$$J_Q = \begin{bmatrix} B_1A_1 \bullet z_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & B_2A_2 \bullet z_2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & B_3A_3 \bullet z_3 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & B_4A_4 \bullet z_4 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & B_5A_5 \bullet z_5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & B_6A_6 \bullet z_6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & B_7A_7 \bullet z_7 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & B_8A_8 \bullet z_8 \end{bmatrix} \tag{6}$$

$$Q = [Q_1\ Q_2\ Q_3\ Q_4]^T$$

$$J_X = \begin{bmatrix} (B_1A_1)_X & (B_1A_1)_Y & (B_1A_1)_Z & (B_1A_1 \times BC_1) \bullet V \\ (B_2A_2)_X & (B_2A_2)_Y & (B_2A_2)_Z & (B_2A_2 \times BC_2) \bullet V \\ (B_3A_3)_X & (B_3A_3)_Y & (B_3A_3)_Z & (B_3A_3 \times BC_1) \bullet V \\ (B_4A_4)_X & (B_4A_4)_Y & (B_4A_4)_Z & (B_4A_4 \times BC_4) \bullet V \\ (B_5A_5)_X & (B_5A_5)_Y & (B_5A_5)_Z & (B_5A_5 \times BC_5) \bullet V \\ (B_6A_6)_X & (B_6A_6)_Y & (B_6A_6)_Z & (B_6A_6 \times BC_6) \bullet V \\ (B_7A_7)_X & (B_7A_7)_Y & (B_7A_7)_Z & (B_7A_7 \times BC_7) \bullet V \\ (B_8A_8)_X & (B_8A_8)_Y & (B_8A_8)_Z & (B_8A_8 \times BC_8) \bullet V \end{bmatrix} \tag{7}$$

$$X = [\, x \quad y \quad z \quad \theta \,]$$

On the off chance that the system isn't in a singular configuration, the converse Jacobian framework is portrayed as:

$$J^{-1} = J_q^{-1} J_x \tag{8}$$

Jacobian matrix

$$J = J_X^{-1}\, J_Q \tag{9}$$

At the point when the determinant of backwards Jacobian matrix equivalents to zero, the parallel controller is in a solitary configuration, which is a general strategy for distinguishing the particular configurations of parallel controllers. In any case, for a controller with n<6DOF, it ought to be noticed that it may not be proficient to recognize all the solitary configurations by deciding just the n×n reverse kinematic Jacobian that relates the incited joint speeds to the conceivable DOF speeds. Next area will talk about a backwards kinematic Jacobian that includes incited joints speeds and the full touch of the end-effector, which might be basic for peculiarity investigation. This kind of matrix is begat as by and large jacobian.

VII. ACCELERATION ANALYSIS

This segment will figure out what are the relations between the impelled joint increasing velocities and the cartesian and precise increasing velocities of the end-effector. presents phenomenal attributes as to speeding up which can arrive. For parallel robots it is commonly simple to get these relations straightforwardly. From the condition

$$q = J^{-1}\, X \tag{10}$$

The accompanying can be gotten by differentiation

For the different classifications of parallel controllers, the assurance of the speeding up conditions along these lines adds up to the assurance of the subsidiary of the reverse kinematic jacobian matrix (Merlet, 2006).

In any case, the technique portrayed above isn't intuitionistic. So we infer the relations between the activated joint increasing speeds and the increasing speeds of the end-effector utilizing geometric strategy.

The speeding up projection of focuses Bi and Ai on hold AiBi is equivalent. So, the q

$$\mathbf{a_{Ai}.B_iA_i = a_{Bi}.B_iA_i} \tag{11}$$

Condition can be composed for i=1… ,8 and the outcomes assembled in a matrix structure, for example,

where

$$Q=[Q_1 \quad Q_2 \quad Q_3 \quad Q_4]^T$$

$$J_B=\begin{bmatrix} (B_1A_1)_X & (B_1A_1)_Y & (B_1A_1)_Z & ((B_1A_1)XCos\,\theta + (B_1A_1)ysin\,\theta \bullet HE_{11}) \\ (B_2A_2)_X & (B_2A_2)_Y & (B_2A_2)_Z & ((B_2A_2)XCos\,\theta + (B_2A_2)ysin\,\theta \bullet HE_{12}) \\ (B_3A_3)_X & (B_3A_3)_Y & (B_3A_3)_Z & ((B_3A_3)XCos\,\theta + (B_3A_3)ysin\,\theta \bullet HE_{13}) \\ (B_4A_4)_X & (B_4A_4)_Y & (B_4A_4)_Z & ((B_4A_4)XCos\,\theta + (B_4A_4)ysin\,\theta \bullet HE_{14}) \\ (B_5A_5)_X & (B_5A_5)_Y & (B_5A_5)_Z & ((B_5A_5)XCos\,\theta + (B_5A_5)ysin\,\theta \bullet HE_{15}) \\ (B_6A_6)_X & (B_6A_6)_Y & (B_6A_6)_Z & ((B_6A_6)XCos\,\theta + (B_6A_6)ysin\,\theta \bullet HE_{16}) \\ (B_7A_7)_X & (B_7A_7)_Y & (B_7A_7)_Z & ((B_7A_7)XCos\,\theta + (B_7A_7)ysin\,\theta \bullet HE_{17}) \\ (B_8A_8)_X & (B_8A_8)_Y & (B_8A_8)_Z & ((B_8A_8)XCos\,\theta + (B_8A_8)ysin\,\theta \bullet HE_{18}) \end{bmatrix} \tag{12}$$

$$X= [x \quad y \quad z \quad \theta\ ]$$

For the structure and plan parameters depicted above, when the nacelle is in the starting point present and the impelled joint increasing velocities are Q=[9 -9 9 9]M/s^2, the direct speeding up of the nacelle can arrive at 24m/s2 and the rakish increasing speed can arrive at 2.5rad/s2.

VIII. WORKSPACE ANALYSIS

The workspace of a controller can be characterized as the volume that the robot can reach. This volume compares to the reachable 3D focuses by the robot end-effector with any direction of its foundation. The mechanical breaking points of the circular joints have not been considered since they can altogether change from one structure to another. The hypothetical workspace of the introduced robot is acquired numerically by considering a movement of 18 mm, which compares to the movement scope of the picked direct actuators. Clearly, the workspace volume depends additionally on the length of the robot's fingers. The all-out volume was assessed utilizing the six kinematic structure parameters exhibited in Table 1 and the structure parameters of the fingers displayed. The three-dimensional workspace of the two distal fingers of the controller is appeared. The red and the blue extents show the two reachable spaces of the two fingers of the gripper. With the picked parameters, the robot's workspace volume is around 157 cm^3 shows the greatest removals, revolution points, and opening/shutting edge of the configurable stage introduced in the point O.

IX. CONCLUSION

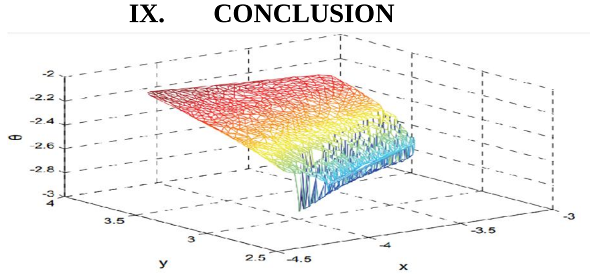

FIG.3 Singular Surface

In this paper, this robot has six-Degree of Freedom manipulation and grasping abilities utilizing straight stages situated on the robot's base. The robot structure was researched and its kinematic model created. A seven degree of freedom its kinematic analysis, Jacobian matrix and twist Accelerations analysis. One key point is the determination of a vital condition to acquire a revolution about guaranteed pivot. This robot had the option to successfully accomplish grasping, manipulation. The fundamental position of the robot is that it offers position, direction, and grasping abilities while every one of the chains are situated on the base**.**

X. FUTURE SCOPE

Further improvements of the robot will concentrate on the singularity examination of the proposed structure, plan improvement and, control abusing activation and detecting repetition, which will improve the robot capacities and exhibitions**.**

REFERENCES

[1] Wissem Haouas,2. Redwan Dahmouche, 3. Guillaume Jacques Laurent “A New Seven Degrees-of-Freedom Parallel Robot with a Foldable Platform” Article in Journal of Mechanisms and Robotics · March 2018

[2] Ozgur, 2.E., Dahmouche, R., Andreff, N., and Martinet, P., 2013. “High speed parallel kinematic manipulator state estimation from legs observation”. In Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on, IEEE, pp. 424–429.

[3] Pierrot, F., and Company, O., 1999. “H4: A new family of 4-dof parallel robots”. In Advanced Intelligent Mechatronics, 1999. Proceedings. 1999 IEEE/ASME International Conference on, IEEE, pp. 508–513.

[4] Yao, Q., Dong, J., and Ferreira, P. M., 2008. “A novel parallel-kinematics mechanism for integrated, multiaxis nano positioning: Part 1. kinematics and design for fabrication”. Precision Engineering, 32(1), pp. 7–19.

[5] Hoevenaars, A. G., Lambert, P., and Herder, J. L., 2014. “Kinematic design of two elementary 3dof parallel manipulators with configurable platforms”. In Computational Kinematics. Springer, pp. 315–322.

[6] Niccolini, M., Petroni, G, Menciassi, A., and Dario, P “Real time control architecture of anovel single port laparoscopy bimanual robot (sprint)”. In Robotics and Automation (ICRA), 2012 IEEE International Conference on, IEEE, pp. 3395–3400

[7] Abbott, D. J., Becke, C., Rothstein, R. I., and Peine, W. J., 2007. “Design of an endoluminal notes robotic system”. In Intelligent Robots and Systems, 2007. IROS 2007. IEEE/RSJ International Conference on, IEEE, pp. 410–416.

[8] Khalil, W., Bernard, S., Lemoine, P., Comparison study of the geometric parameters’ calibration methods, International Journal of Robotics and Automation, Vol.15, 2000, 56-67.

[9] Taguchi, G., On robust technology development, Bringing Quality Engineering Upstream, ASME Press, 1993.

[10] Kalsi, M., Hacker, K., Lewis, K., A comprehensive robust design approach for decision trade-offs in complex systems design, Transactions of the ASME, Journal of Mechanical Design, Vol.121, march, 2001, 1-10.