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KINEMATIC ANALYSIS OF RSSR SPATIAL MECHANISM – A REVIEW

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Abstract— spatial mechanism is a mechanical system that has at least one body that moves in a way that its point trajectories are general space curves. In many applications spatial mechanism has clear advantage on parallel mechanism and robots. RSSR mechanism is used in application like landing gear of JAGUAR Strike air craft, used in place of bevel gears between two shafts in the space. Many method such as iterative technique based on Newton-Raphson method, force fluctuation number, Graphical methods, methods using exponential matrices, screw theory, complex number theory, dual algebra ,D-H parameters, PRBM and other methods used for kinematic analysis of spatial mechanism. D-H parameters are used widely for kinematic synthesis because it assist ease for computer programming. In this paper critical review on this methods has been carried out. As D-H parameters method can directly applied to mechanism having joints like Prismatic, revolute, cylindrical and helical but it cannot directly applied to mechanism consisting spherical joints. Study shows that there is scope of kinematic analysis using extended D-H parameters, and most of the work focus on path generation so work can also done in velocity and acceleration analysis. Present study motivate researchers to work on presented research work.

Keywords— spatial mechanism, D-H parameters, kinematic analysis, RSSR mechanism, velocity indices

I. INTRODUCTION

Machines are devices used to alter, transmit, and direct forces to accomplish a specific task. A mechanism is the mechanical portion of a machine that has function of transferring motion and forces from a power source to an output. Generally Mechanism classified in two sub systems (i) planar mechanism. (ii) Spatial mechanism. Spatial mechanism is a mechanical system that has at least one body that moves in a way that its point trajectories are general space curves. The motion of all points in planar linkage is restricted to a single plan or a set of parallel plane. Rotational axes of hinged joints are perpendicular to the ground plane where in spatial mechanism rotational axes of hinged joints lies in space that do not intersect and have distinct common normal[1][4]. Spatial mechanisms are classified by degree of freedom and joints used in it. The number of independent parameters required to uniquely describe the position in space at any instant is defined as Degree of freedom [1] [4]. Some common example of spatial mechanisms are 7R, RCCC, RCSR, RSCP, RSSR, RSSR-SC etc. Here R, C, P, S represents revolute joint, cylindrical joint, Prismatic joint, and Spherical joint respectively. [1][3][4] The degree of freedom of spatial mechanism is given by kutzbatch's equation. Eq. for mechanism having n number of link:

$$DOF = 6(n-1) - 5(R+P+H) - 4C - 3(S+E)$$

Where R, P, H, C, S and E are respectively, number of revolute, prismatic, screw, cylindrical, spherical and planar pairs[1][4]. For e.g. - RSSR mechanism has total 4 links having 2 revolute and 2 spherical joints. So it has two degree of freedom.

Kinematic analysis of various spatial mechanisms is subjects of interest of many researchers due to its advantages and applications. Its complex motion in space make this analysis and synthesis very challenging.

Spatial mechanisms, being purely mechanical single input devices tend to be more reliable and more energy efficient than electronically-controlled multi input devices such as robots. Also close-loop spatial mechanisms are known to be capable of running at higher speeds and carrying greater loads with more precision. It has also clear advantage in some situations like "pick and place" task that is used widely in assembly lines of mass production.so it is advantageous in repetitive tedious and complex task[5][6][7].

Due to its advantages explained above it has applications in aerospace industry, exercise equipment, and rehabilitation medical field. Engineers in aerospace industry are working on to make thing compact, lightweight and able to perform spatial task like satellite design and deployment. In bio-medical field engineers carries out research on to get mechanisms which are look-like human body as wrist etc. and equipment which are helpful for betterment of human life[2][6][7].

II. LITERATURE REVIEW

A. Literature review on Spatial mechanism:

In this section literature review regarding spatial mechanism is carried out. Lack of spatial mechanism in industry was because of its difficulty in visualization. Oldest design methods in planar kinematics involves graphical methods. Spatial mechanisms not possess the same ease of visualization as planar mechanisms. Two or more projections, using descriptive geometry, are necessary to represent a point, line, or arc in space. Therefore, graphical methods becomes difficult to use for spatial mechanism. The father of modern kinematics generally held by Freudenstein. The shift from graphical to analytical method is hall marked by his paper "Approximate synthesis of four bar linkages" (1955) later Freudenstien and sandor(1959) employed complex number theory and a programmed IBM 650 digital computer for synthesis of path generating mechanism [8][9] .

D.Segev (1972) introduces iterative proximity perturbation technique. Which is based on Newton-Raphson method. In this method set of non-linear equations of displacement of four bar spatial mechanism, solved. For small increment of input motion the roots of equation iterated in the proximity of their old values. These starting values taken those which are available. To show feasibility of this method FORTRAN programed introduce for spherical RRRR mechanism. Displacements of coupler point and output link are calculated. Also this method is applied to RSCR mechanism and kinematic quantities like displacement, velocity and acceleration are obtained and Cal comp-plots had been generated. Method is proved very rapid and consistent [10]. After that screw theory and vector analysis methods are used for kinematic analysis of spatial mechanism. The RSCR spatial mechanism studied by Ananthasuresh and Kramer (1994), illustrate the Genetic algorithm method. The function generation and the path generation are both solved for this type of mechanisms. Ananthasuresh and Kramer (1994) used the gradient method to solve the function generation problem for this mechanism.in this paper set of 12 design variables used to describe geometry of RSCR mechanism [11]. This number of design variables reduces greatly from 12 to 8 by the method introduced Denavit-Hartenburg in their work (1965) on the same mechanism. In this paper they used matrices method which contains 4 design parameters: link length, joint angle, link offset, and link twist [12]. This paper also illustrate the method of finding velocity and acceleration for RSPC mechanism. With the use of this D-H parameters Med-amini-Laribi and et al (2011).does analysis and optimal synthesis of single loop spatial mechanism. They used D-H parameters for geometric construction and Dialytic method for path generation and function generation. They uses RSPC and RSCR mechanism for illustration. [13]

Dual number vector and matrices methods for synthesis of spatial mechanism also used nearly after 2000[14] [15].After that trend start that used 4 x 4- homogenous matrices for kinematic analysis of spatialmechanism.

Bin Li, Yangmin Li, and Xinhua Zhao (2016) does analysis on a 2-RPU&SPR parallel spatial moving platform, which has 3-degree of freedom. Mobility of this mechanism had calculated using screw theory and forward and inverse kinematics and workspace analysis has been calculated using Jacobean matrix [16].

Amanpreet Singh, Ashish Singla and Sanjeev Soni(2014) found that in kinematic analysis of open spatial robotic chain consecutive links are at the right angles forward kinematics derived with help of classic D-H parameters will become inconsistent. There for they introduce concept of dummy frame for analyse the mechanism. This method is demonstrated with the help of manipulator for medical assistance having 7- degree of freedom [17]. Kinematic synthesis of the RSHR, RCCR and RSSR - SC spatial mechanisms is done by using DH parameter and exponential rotation matrices methods. Fariborz Soltani considered spherical joint as revolute joint to carry out kinematic analysis of RSSR – SC spatial mechanism. Structural and kinematic synthesis of over – constrained spatial mechanisms is carried out by Özgün SELVİ (2012) using screw theory [30].

B.Review on RSSR spatial mechanism

In this section literature review of RSSR spatial mechanism is carried out because it is most simple four bar version of spatial mechanism and less attention is given to this mechanism. So there is a future scope on working with RSSR spatial mechanism.

J.Guffi amd M.J Gilmartin work on RSSR spatial mechanism early in the 1978. They consider one spherical joint as a combination of two Revolute joint and second as a combination of three revolute joint so, they show RSSR mechanism as equivalent 7R mechanism. After that they do kinematic analysis with the help of screw theory and acceleration calculated with help of graphical method like polar quadrilateral and polar triangle coine rule. This method is simple yet it generates 28 design parameters. [6]

K.laxminarayana and L.V. Balaji rao shows RSSR spatial mechanism as crank-rocker mechanism and shows four possible ways of synthesis for prescribe oscillation angle and quick return ratios. They suggest that this graphical method is believed to be useful when critical demand not to be made or deviate somewhat from design catalogue and only ratios are important rather than absolute values. [18]

Yue-qing-yu (1992) used finite element method for kineto-elasto dynamic analysis and uses new multiplier technique for optimization of RSSR. FORTRAN computer language and IBM-4381 system is used for computation. Wen-yuan –chang (2004) has done mobility analysis of RSSR mechanism and maps are shown for the feasible region for the workspace is shown. In this method mobility is find out by solving equation of ellipse and unit circle with centre at origin. [19]

J.jasu and et al. (2005) has done kinematic analysis on RSSR-SC mechanism. They found out rotatiblity condition of this mechanism in two stage: first they make calculation for RSSR they solve quadratic equation numerically after getting roots of the quadratic equation they solve quartic equation of whole mechanism. Authors find full relatability without undesirable branching defects. This thing is beneficial when linkage is going to be driven by a unidirectional rotating actuator like in “pick and place” actuators. Mechanism that gain some or all of their motion through the deflection of flexible members are called complaint spatial four bar mechanisms [20]. The analysis and design of new type complaint four bar (RSSR) mechanism is carried out by Engine tank and Volkan parlaktas (2011). These authors introduces new method of analysis that is PRBM pseudo rigid body method. With this method analysis of multi axis flexural hinges can be simplified. Deflections and static forces calculated using virtual force method. Then method is verified with physical model. [21]

As the classical D-H parameter can be directly applied to the prismatic, cylindrical, revolute joints but it cannot directly applied to spherical pair so Jung-Fa-Hsieh (2010) introduces Extended D-H parameter method that can also applied to any spatial mechanism if it has spherical joints or not. For validation of this method they uses RSCP, CSSR, and CSSP mechanisms [22]. Haigang sun and Yong zohu (2010) is carried out design of RSSR mechanism by graphical method. 3-D motion simulation and analysis is also carried out in this paper [23]. The kinematic analysis of RSSR spatial

mechanism is carried out by David Ferng chyi using Tensor method. FORTRAN programme for IBM 360 data processing system is used for analyse the displacement of each joint pair, angular velocity and angular acceleration [19].

Fariboz sultani (2005) presented kinematic synthesis based on algebra of exponential rotation matrix. Major work in the thesis is focus on path and motion generation of a RSHR mechanism. In most of the work loop closure equation is solved by Mathcad programming software. In addition to that mobility analysis done for and RCCR mechanism and swing angle chart is also made for this mechanism [25].

Famous D-H method has limitation to apply for the branched mechanisms or close loop mechanisms, so to overcome this limitation Fatima Rodrigues and et. al presents modified D-H parameters method, which is also known as proximal variant of D-H parameter method. This method originally suggested by Khalil-Kleinfingerin their paper "A new geometric notation for open and close loop robots" (1986)

J.J Uicker (1964) present new unified method for kinematic analysis of spatial mechanism. This method after that successively used by V.K Gupta (1973) for analysis of RSSR and RCCC spatial mechanism [7]. Robert Williams (1985) uses same method suggested by J.J. uicker and further extends the study to path generation and function generation. H.B. wang and Z.huang presents the influence co-efficient method of kinematic and dynamic analysis. This method can be applied to any spatial mechanism. In this paper formula of velocity and acceleration of single degree of freedom spatial mechanism is deduced with the help of influence co-efficient method. Dynamic analysis for finding reaction forces also carried out in this paper [26]. J Gracia de Jalon (1982) presents simple numerical method for computer analysis of spatial mechanism. In this work study is limited to velocity and acceleration. Results obtained directly in the form of a set of velocities and acceleration of different points of the mechanism. In this study position of desired point is assumed to be known. [27]

III. CONCLUSION

From the above literatures, it can be stated that various researchers have carried out their work in kinematic analysis of spatial mechanism with different methods. Various iterative method is become very tedious and complex for spatial mechanism having spherical joint. Graphical methods have visualization problem with spatial mechanisms, so exponential matrices and D-H parameter method is widely used for kinematic analysis of spatial mechanism, but it observes certain limits spherical joint is considered as revolute joint, so multiple degree of freedom is constrained and considered as a single degree of freedom for simplification purpose. So here it is a scope to do kinematic analysis of RSSR mechanism with extended D-H parameter. Also kinematic analysis can be done with the help of proximal variant of the D-H parameter.

From the above literature, it can also be seen that less work done in the field of velocity and acceleration with the help of matrix method or dual number methods, so here it is also a scope for the velocity and acceleration analysis by matrix method and dual number method.

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