A Novel Algorithm to Find Distinct Mechanisms of a Planar Kinematic Chain

Venkata Kamesh Vinjamuri[#1]
[#]Professor of Mechanical Engineering,
Aditya Engineering College (A), SURAMPALEM-533437 AP, INDIA
[1]kameshvv@gmail.com

***Abstract*— In the structural synthesis of kinematic chains development of distinct mechanisms is an important task to be analysed. After finding the distinct kinematic chains resolving the problem of isomorphism, it is necessary to find distinct mechanisms. Earlier, many researchers developed methods based on topological characteristics based on link and joint connectivity. In this paper, a novel algorithm is proposed based on adjacency of each link mixed with the 'degree of vertex' concept in Graph theory. Distinct kinematic mechanisms or inversions are found for 8-link 1-degree of freedom kinematic chains. All the results are in agreement with earlier results. The proposed method can be extended to higher linkages and degree-of-freedom.**

***Keywords*— kinematic chain, inversion, link, joint, adjacency**

I. INTRODUCTION

In structural synthesis of kinematic chains it is important to find distinct mechanisms. Earlier many researchers [1-11] developed several methods to find distinct mechanisms or inversions. In this paper, 8-link 1-dof planar kinematic chains are studied to find distinct mechanisms.

II. FUNDAMENTAL CONCEPTS

In a planar kinematic chains, distinct kinematic mechanisms are found by fixing one of the link as ground link. If input is given to one of the other links output will be found at another link in movement. This mechanisms are developed for each link fixed. Some of the mechanisms behave similar, are found to be same mechanisms or same type of inversions. Any of those links when fixed results the same inversion or mechanism.

LINK CONNECTIVITI INDEX

Link connectivity index is defined as the summation of degree of vertices of pair of links. For a pair of links 'i' and 'j', if 'i' is a ternary link and 'j' is a binary link, 'link connectivity index' will be 3+2 =5.

TOTAL LINK CONNECTIVITY INDEX

Total link connectivity index is defined as the summation of link connectivities of all pairs of primary link concerned.

NET CHAIN CONNECTIVITY INDEX

Net chain connectivity index is defined as the summation of total link connectivity indices of all the links.

DISTINCT LINK INDEX

Distinct link index of a link is defined as the summation of Net chain connectivity indices when the primary link and its adjacent links are made fixed i.e. movement is arrested. In other words, the link connectivity indices are made zero.

ALGORITHM TO FIND DISTINCT MECHANISMS OF A KINEMATIC CHAIN

The steps involved in the algorithm are as follows:

Step 1: Link Connectivity Index of each pair of links is found.

Step 2: For each link, total link connectivity index and net chain connectivity index are found.

Step 3: To find the distinct mechanisms of chain, each link is made fixed i.e. movement is made zero for the primary link and its adjacent links. Net chain connectivity index is found each time.

Step 4: The Distinct link index for each link is found.

Step 5: If any two links have same Distinct Link Index they are said to have same distinct mechanisms or same inversions.

EXAMPLE 1:

An 8-link 1-dof kinematic chain (Chain No. 12 in Appendix I) is considered.

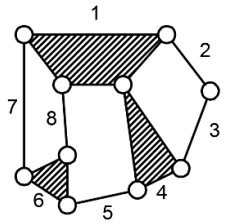

Fig. 1 Chain No. 12

The link connectivity indices are represented as follows:

Link	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total link connectivity index**
1	0	6			7		6	6	25
2	6	0	4						10
3		4	0	5					9
4			5	0	6			5	16
5	7			6	0	5			18
6					5	0	4		9
7	6					4	0		10
8	6			5				0	11
				Net chain connectivity index					108

If the link 1 is taken as primary link, the total connectivity index of link 1 and its adjacent links 2,5,7 and 8 are made zeros.

Then the resulting values are as follows.

Link	1	2	3	4	5	6	7	8	Total link connectivity index
1									0
2	0	0	4						4
3	0	4	0	5					9
4	0		5	0	6			5	16
5	0			6	0	5			11
6	0				5	0	4		9
7	0					4	0		4
8	0			5				0	5
				Net chain connectivity index					**58**

The net chain connectivity index for link 1 is found to be 58. Similarly for all other links computations are done. The values are expressed as a string like: 58-88-90-76-72-90-88-86. The distinct link index values are calculated and are expressed as a string like: 392-236-254-324-296-250-236-220. In the string link 2 and link 7 are have same value 236 but the sub string compositions are different. Hence, as the string values are all different, the chain no. 13 will have 8 different distinct mechanisms or inversions.

In the same way, the distinct mechanisms of all the 16 chains of 8-link 1-dof are found.

III. RESULTS & CONCLUSIONS

Distinct mechanisms of all the 16 no. 8-link 1-DOF kinematic chains based on the algorithm is shown in the Table I.

TABLE I

DISTINCT MECHANISMS OF 8-LINK 1-DOF KINEMATIC CHAINS

Chain No.	Number of Distinct Mechanisms
1	2
2	2
3	8
4	4
5	4
6	5
7	6
8	2
9	2
10	4
11	7
12	7
13	8
14	5
15	2
16	3
Total	71

According to the procedure described, all the distinct mechanisms of 8-link 1-dof kinematic chains in Appendix I are found. This method can be extended to higher linkages and DOF.

REFERENCES

[1]A.C. Rao, Raju D. Varada, "Application Of The Hamming Number Technique To Detect Isomorphism Among Kinematic Chain S And Inversion", Mech. Mach. Theory, Vol.26 (1) ,pp.55-75, 1991.

[2] A.C.Rao, "A Genetic Algorithm for Topological Characteristics of Kinematic Chains", J of Mech.Des., ASME, Vol. 122, pp.228-231,June 2000.

[3] Sanyal S, Bedi G.S., "Joint Connectivity: A new approach for detection of Isomorphism and Inversions of Planar Kinematic Chains", J. Institution of Engineers (India), Vol. 90, pp. 23 – 26, 2010.

[4] Sanyal S, Bedi G.S, "Modified Joint Connectivity approach for identification of topological characteristics of Planar Kinematic Chains", Proc. IMechE, Part C: J. Mechanical Engineering Science, Vol. 225, pp. 2700 – 2717, 2011.

[5] V.V. Kamesh, A.B.S. Rao, K.M. Rao, 2012, "A computer based technique for structural comparison of in-parallel robotic manipulators applicable for higher pairs too", International Journal of Mechanical Engineering Robotics & Research1(1):107-119

[6] Venkata Kamesh Vinjamuri, Mallikarnuna Rao Kuchibhotla, Balaji Srinivasa Rao Annambhotla, "A Novel Method to Detect Isomorphism in Epicyclic Gear Trains", imanager's Journal of Future Engineering and Technology, Vol. 12(1), pp. 28-35, 2016.

[7] Venkata Kamesh Vinjamuri, Mallikarnuna Rao Kuchibhotla, Balaji Srinivasa Rao Annambhotla, "Topological Synthesis Of Epicyclic Gear Trains Using Vertex Incidence Polynomial", J. Mech. Des. ASME, Vol. 139 (6), pp. 062304 (1-12), June 2017.

[8] Venkata Kamesh Vinjamuri, Mallikarjuna Rao Kuchibhotla, Balaji Srinivasa Rao Annambhotla, "Detection of Degenerate structure in Single Degree-Of-Freedom Planetary Gear Trains", J. Mech. Des. ASME, Vol. 139 (8), pp. 083302-083302-5, August 2017.

[9] Venkata Kamesh Vinjamuri, Mallikarnuna Rao Kuchibhotla, Balaji Srinivasa Rao Annambhotla, "An innovative approach to detect isomorphism in planar and geared kinematic chains using graph theory", J. Mech. Des. ASME, Vol. 139 (12), pp.122301-122301-11, December 2017.

[10] Venkata Kamesh Vinjamuri, "Rating of Kinematic chains using Genetic algorithm", International Journal of Innovative Research Explorer, 5(1): 90-94, January 2018.

[11] Vinjamuri Venkata Kamesh, "Isomorphism in planar kinematic chains-A case study in Graph theory algorithm", International Journal of Advance Research in Science and Engineering, 7(1): 165-171, January 2018.

APPENDIX I: 8-LINK 1-DOF KINEMATIC CHAINS

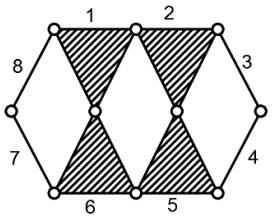	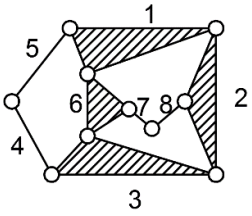	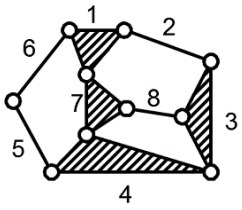	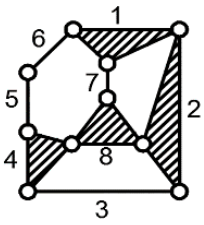
Fig. 1: Chain No.1	**Fig. 2:Chain No.2**	**Fig. 3:Chain No.3**	**Fig. 4:Chain No.4**
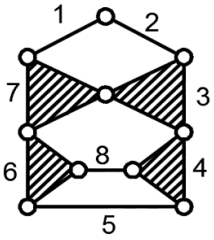	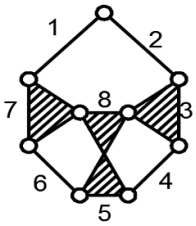	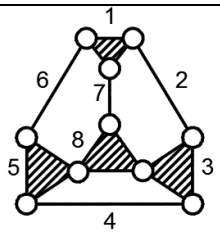	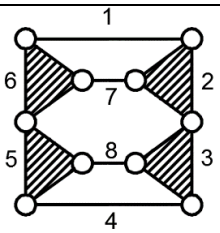
Fig. 5:Chain No.5	**Fig. 6:Chain No.6**	**Fig. 7:Chain No.7**	**Fig. 8:Chain No.8**
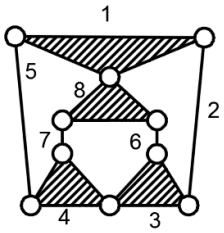	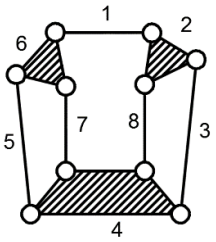	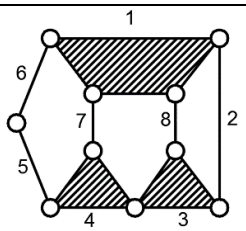	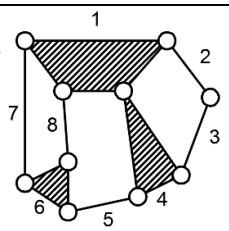
Fig. 9:Chain No.9	**Fig. 10:Chain No.10**	**Fig. 11:Chain No.11**	**Fig. 12:Chain No.12**
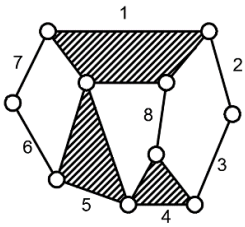	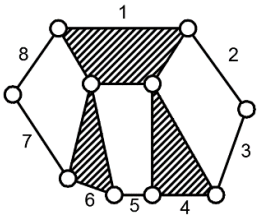	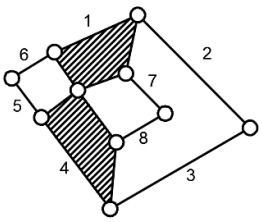	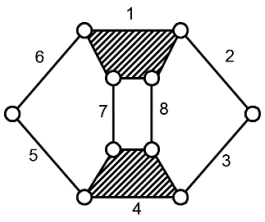
Fig.13:Chain No.13	**Fig. 14:Chain No.14**	**Fig. 15:Chain No.15**	**Fig. 16:Chain No.16**