A Computerised Methodology For Rating Of Simple Jointed Planar Kinematic Chain

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ABSTRACT

Existing literature shows that methods have been report to detect isomorphism and type of freedom among kinematic chains and mechanism. A thorough knowledge of kinematic chain is essential for a designer in mechanical engineering and persistent effort has made to know about kinematic chain as much as possible. In the present investigation a methodology is proposed based on the influence of type of links, type of joints and type of loop present in a kinematic chain to predict the performance of kinematic chains without carrying out the dimensional synthesis. The method has implemented for performance rating on catalogue of 8 – Link, 1 –degree of freedom and 9-link, 2- degree of freedom kinematic chain.

INTRODUCTION

Detection of distinct kinematic chain really becomes significant only when the designer is able to predict the behavior of the chain based on its kinematic structure. For example, one should know which of the chains would generate a function more accurately once its dimensional synthesis is completed. It is, of course, know that a chain with greater number of links will generate specified motion more accurately because more design parameters like link ratios are available to the designer, but out of distinct chains consisting of same number of links it is not known how the type of link and their layout affect the dimensional behavior of the chain in the sense of structural error.

As the number of linkages, increases at the same time the possible configuration increases i.e. more number of distinct kinematic chain are possible hence predicting the performance of a given category of kinematic chain is difficult. A methodology has developed and it has illustrated by taking examples for predicting performance of given kinematic chain without actually carrying out the dimensional synthesis. A proposed methodology uses of link assortment, joint value, primary Hamming number, secondary Hamming number & loop value of chain for predicting the performance. The methodology has divided in two parts. The first part involves finding link assortment, joint value, primary Hamming number, secondary Hamming number. Second part involves, finding loop value of chain, types of links in an individual loops and their values. Programming, based on the above methodology has developed in C and is implemented 8 – Link, 1 –degree of freedom and 9-link, 2- degree of freedom kinematic chain.

METHODS The method divided in two parts,

Part 1: The methodology and its formulation have illustrated by taking suitable examples. For example, let us consider 6-link, 1-degree of freedom simple jointed planar kinamatic chain. The chain having two configuration are shown in fig.1 and fig.2 below,

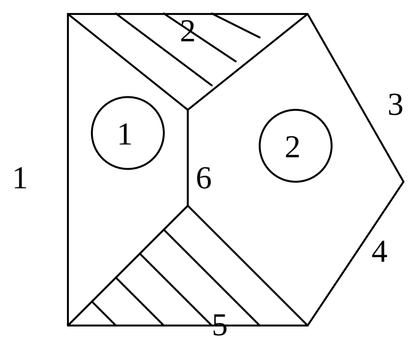


Fig. 1 Stephenson Chain

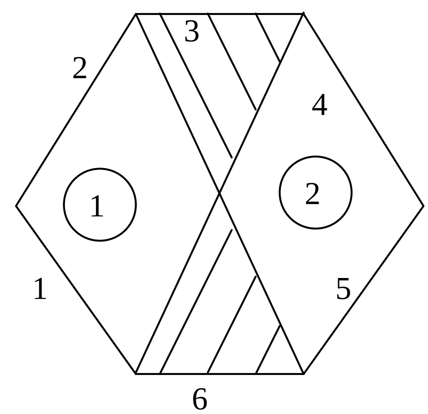


Fig. 2 Watt Chain

Connectivity of fig.1

1 – 2,5
2 – 1,3,6
3 – 2,4
4 – 3,5
5 – 1,4,6
6 – 2,5

Connectivity of fig.2

1 – 2,6
2 – 1,3
3 – 2,4,6
4 – 3,5
5 – 4,6
6 – 1,3,5

1 Step: Generating a Connectivity Matrix

The connectivity matrix is a square matrix, whose diagonal elements are zero. The size of matrix is equal to number of links in a given kinematic chain hence size of connectivity matrix for fig.1 and fig.2 is [6 x 6].The link which are directly connected are denoted as 1 and links which are separated denoted as 0.The connectivity matrix for fig.1 and fig. 2 are as shown below.

	1	2	3	4	5	6
1	0	1	0	0	1	0
2	1	0	1	0	0	1
3	0	1	0	1	0	0
4	0	0	1	0	1	0
5	1	0	0	1	0	1
6	0	1	0	0	1	0

Matrix 1 for Fig.1

	1	2	3	4	5	6
1	0	1	0	0	0	1
2	1	0	1	0	0	0
3	0	1	0	1	0	1
4	0	0	1	0	1	0
5	0	0	0	1	0	1
6	1	0	1	0	1	0

Matrix 2 for Fig.2

II Step: To Get the Link Assortment and Joint Value Form the Connectivity Matrix

Sum the elements of each row of matrix 1 and matrix 2, which gives type of link e.g. 1st link of matrix 1 is binary (2) and 2nd link of matrix is ternary (3)

As per definition of link assortment the type of link is given kinamitc chain gives the link assortment hence link assortment of fig 1 Stephenson chain is 4(2), 2(3) and for fig 2 4(2), 2(3) meaning there are four binary link and two ternary links each.

III Step: Generating Primary Hamming Matrix and to get Primary Hamming Number

The Primary Hamming matrix is generated form the connectivity matrix. The element of the i^{th} row has considered as the binary code representing i^{th} link. For example of matrix -1.

For link 1	0	1	0	0	1	0
For link 2	1	0	1	0	0	1

Primary Hamming number between any two links is the number of digit at which the corresponding codes differ. For example $h_{1,2}$ the hamming number between links 1 and 2 of matrix – 1 is 5. Link wise hamming number for all the links has computed and another matrix is generated the elements of which are h_{ij} has formulated.

0	5	2	2	5	0
5	0	5	3	2	5
2	5	0	4	3	2
2	3	4	0	5	2
5	2	3	5	0	5
0	5	2	2	5	0

Matrix 3 for Fig.1

0	4	1	4	2	5
4	0	5	2	2	1
1	5	0	5	1	6
4	2	5	0	4	1
2	4	1	4	0	5
5	1	6	1	5	0

Matrix 4 for Fig.2

Primary hamming number of chain is summation of all the elements of primary hamming matrix hence primary number for Stephenson chain is 100 and for watt chain is 100

IV STEP: Secondary Hamming Matrix And To Get Secondary Hamming Number

The Secondary hamming matrix is generated form the primary hamming matrix. The elements in the i^{th} row of primary hamming matrix may be considered as its hamming code for example the element of link 1 and 3 of matrix 1 of fig.1 are,

Link 1	0	5	2	2	5	0
Link 2	2	5	0	4	3	2

"The secondary hamming number between two links is defined as the sum of the primary hamming numbers off the entire digit at which they differ" i.e. secondary hamming number s_{ik} between links I and k for an n link chain is given by the relation.

$$S_{ik} = (h_{ij} + h_{kj})$$

It may be noted that $(h_{ij} + h_{kj}) = 0$, if $h_{ij} = h_{kj}$

Therefore, value between link 1 and link 3 is 20. Same way generate the matrix for a given chain

0	34	20	20	34	00
34	00	36	36	20	34
20	36	00	24	36	20
20	36	24	00	36	20
34	20	36	36	00	34
00	34	20	20	34	00

Matrix 5 for Fig.1

00	32	34	32	04	34
32	00	34	04	32	34
34	35	00	34	34	36
32	04	34	00	32	34
04	32	34	32	00	34
34	34	36	34	34	00

Matrix 6 for Fig.2

The Secondary hamming number of chain has defined as summation of all the elements of secondary hamming matrix. The value of Secondary hamming matrix for Stephenson chain is 808 and for watt chain is 888.

Part 2

With the understanding, some definitions a table is prepared for each chain, with loops as rows and the links as columns. On the top, each link its link value has to be written. Now refer to Table 1 and Table 2 respectively for applying this method, which is explained below stepwise

I Step: To Fill the Elements in the Rows of Independent Loop

Whether or not each link is participating in an independent loop has spelled out in the rows of independent loops. Whose elements are either '0' or '1' For example 1^{st} row of the table 1 which is [1,1,0,0,1,1] implies that links 1,2,5 and 6 of fig1.participating the independent loop (1) similarly the element of rows of other independent loop can be filled in.

Table -1 for Fig.1 [Stephenson chain]

L.V. →	2	3	2	2	3	2

Table -2 for Fig.2 [Watt chain]

L.V. →	2	3	2	2	3	2

Link → / Loops ↓	1	2	3	4	5	6	LS ↓
1	1	1	0	0	1	1	4
2	0	1	1	1	1	1	5
1-2	1	1	1	1	1	0	5
						lvc	14

Link → / Loops ↓	1	2	3	4	5	6	LS ↓
1	1	1	1	0	0	1	4
2	0	0	1	1	1	1	4
1-2	1	1	1	1	1	1	6
						lvc	14

II Step: To Fill the Elements in the Rows of Sub Loop

Consider the row of sub loop [1-2] of table -1. For filling the first element of the sub loop [1-2], add the first element of the independent loop [1] and [2]. If the sum is not equal to zero but less than the link value of link 1, the first element of the sub loop [1-2] is ‘1’. If the sum is zero or equal to or greater than the link value the first element of the sub loop [1-2] is 0.

For the case under consideration the sum is [1+0] = 1, which is less than the link value 2, so first element of sub loop is 1.Consider as another example to fill the sub loop value of sixth column sub loop i.e. the sum is [1+1] =2. Moreover, it is equal to link value of link six. So sixth element of the sub loop [1-2] is zero.

III Step: Loop Size

It has defined as the size of the loop it indicates the number of links participating on the periphery of any loop. In order to calculate loop size add all the elements of the rows of table 1 of fig. 1 the loop size are respectively 4,5,5 for loop 1,2 and 1-2.

Iv Step: Loop Value of Chain (L.V.C)

It is defined as the summation of all the loop size of a given kinematics chain for fig.1 the loop value of chain is 14 [4+5+5].

V Step: Loop Value of a Link (L.V.L)

It has defined for link as the summation of the size of loops in which it is participating. For example form table-1 for a link 1 loop value of a link is 09 which is the sum of loop size of loop [1] and [3] neglect [2] where link 1 is not participating.

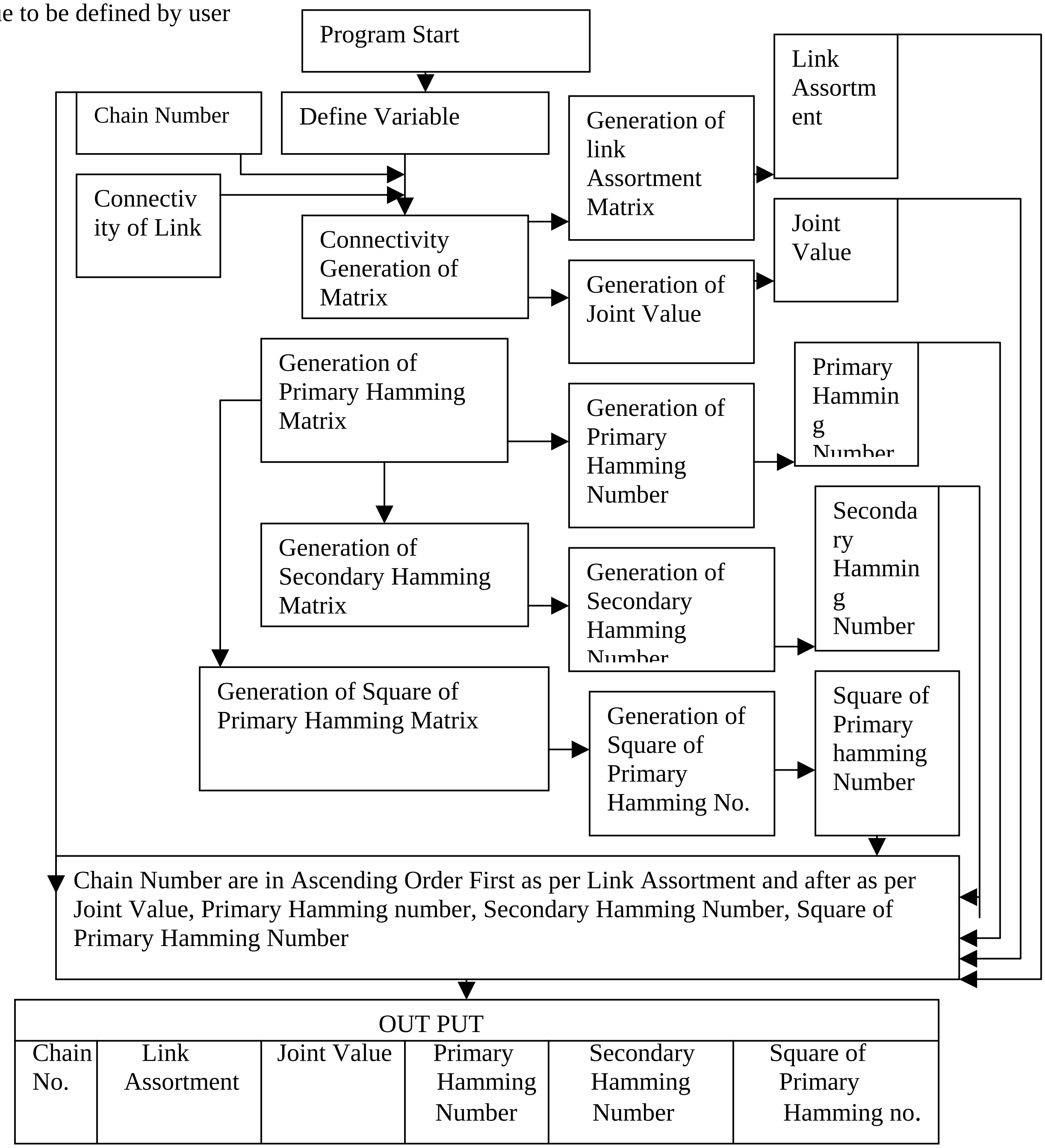
VI Step: Independent Loop Value

It has defined by summation of loop value of a link, which is participating in formation of independent loop.

In a given table-1 the independent loop-1 is form by link [1, 2, 5 & 6] hence sum the link value of loop of same link. The value become [09+14+14+09] =46.

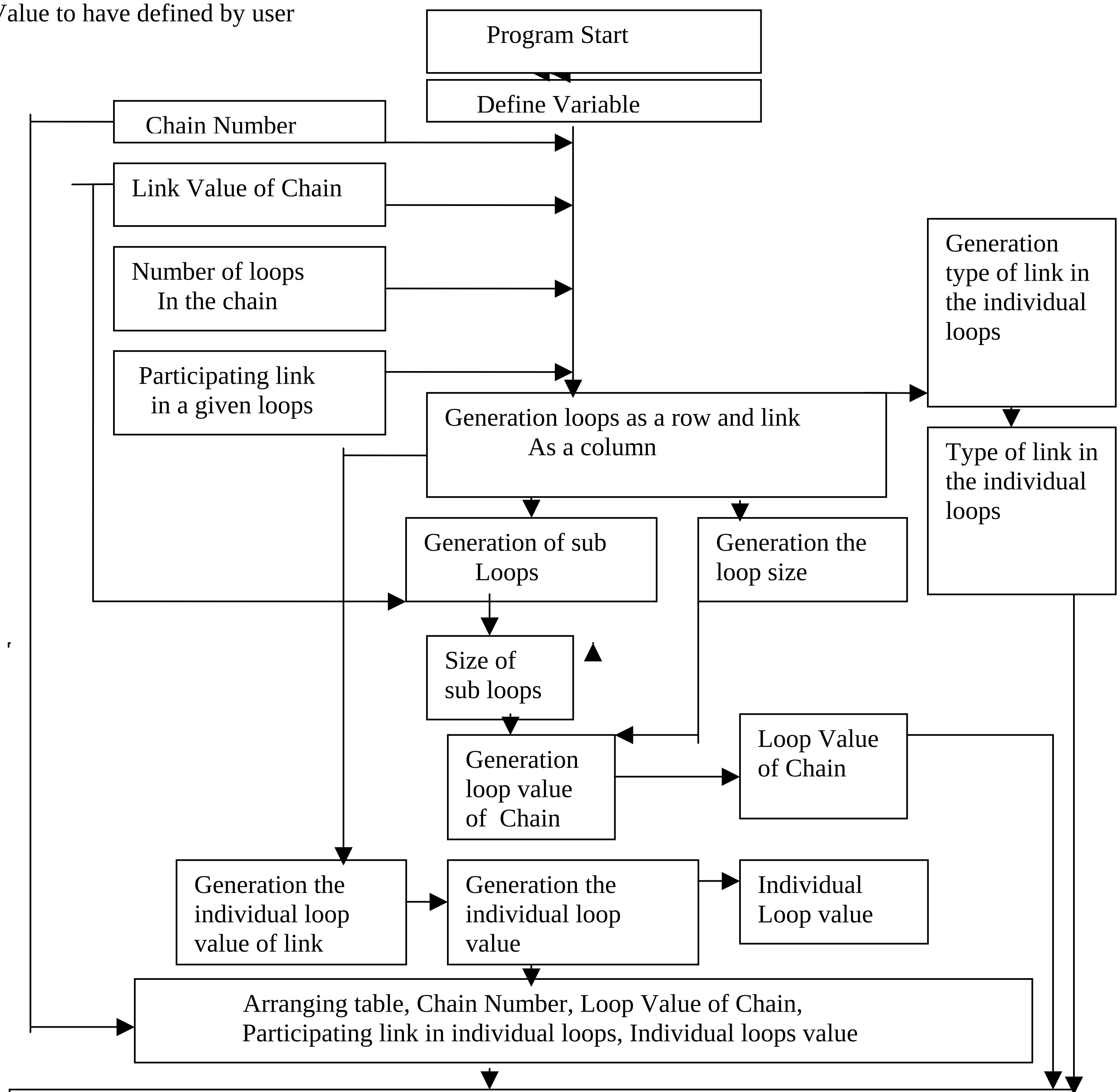
FLOW CHART FOR RATING, METHOD (PART-1)

Value to be defined by user



FLOW CHART FOR RATING METHOD (PART-2)

Value to have defined by user



OUT PUT

Chain No	Loop Value of Chain	Types of Link in Loop-1	Types of Link in Loop-2	Types of Link in Loop-3	Individual Loop-1 Value	Individual Loop-2 Value	Individual Loop-3 Value

APPLICATION

- Rating For 8-Link, 1-D.O.F. Simple Jointed Planar Kinamatic Chain on (Part-1&2)

Chain No.	Link Assortment	Joint Value	Primary Hamming Number	Secondary Hamming Number	Loop Value of Chain
4	4(2)4(3)	1(2+2)6(2+3)3(3+3)	216	2612	40
5	4(2)4(3)	1(2+2)6(2+3)3(3+3)	216	2656	40
6	4(2)4(3)	1(2+2)6(2+3)3(3+3)	216	2600	40
7	4(2)4(3)	1(2+2)6(2+3)3(3+3)	216	2456	40
8	4(2)4(3)	2(2+2)4(2+3)4(3+3)	216	2448	40
9	4(2)4(3)	2(2+2)4(2+3)4(3+3)	216	2576	40
1	4(2)4(3)	8(2+3)2(3+3)	216	2672	40
2	4(2)4(3)	8(2+3)2(3+3)	216	2424	40
3	4(2)4(3)	8(2+3)2(3+3)	216	2608	40
11	5(2)2(3)1(4)	1(2+2)4(2+3)4(2+4)1(3+3)	212	2448	39
12	5(2)2(3)1(4)	1(2+2)4(2+3)4(2+4)1(3+3)	212	2488	39
13	5(2)2(3)1(4)	2(2+2)3(2+3)3(2+4) 1(3+3)1(3+4)	212	2508	39
14	5(2)2(3)1(4)	2(2+2)4(2+3)2(2+4)2(3+4)	212	2464	39
10	5(2)2(3)1(4)	6(2+3)4(2+4)	212	2072	39
15	6(2)2(4)	2(2+2)8(2+4)	208	2096	38
16	6(2)2(4)	2(2+2)8(2+4)	208	2288	38

- Rating For 9-Link, 1-D.O.F Simple Jointed Planar Kinamatic Chain on (Part-1&2)

Chain No.	Link Assortment	Joint Value	Primary Hamming Number	Secondary Hamming Number	Loop Value of Chain
07	5(2)4(3)	1(2+2)8(2+3)2(3+3)	284	3748	44
12	5(2)4(3)	1(2+2)8(2+3)2(3+3)	284	3592	44
13	5(2)4(3)	1(2+2)8(2+3)2(3+3)	284	3520	44
14	5(2)4(3)	1(2+2)8(2+3)2(3+3)	284	3816	44
15	5(2)4(3)	1(2+2)8(2+3)2(3+3)	284	3880	44
16	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3640	44
08	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3656	44
09	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3792	44
10	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3668	44
11	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3808	44
03	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3664	44
05	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3752	44

06	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3544	44
02	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3784	44
17	5(2)4(3)	2(2+2)6(2+3)3(3+3)	284	3696	44
01	5(2)4(3)	3(2+2)4(2+3)4(3+3)	284	3784	44
04	5(2)4(3)	3(2+2)4(2+3)4(3+3)	284	3696	44
18	5(2)4(3)	10(2+3)1(3+3)	284	3696	44
19	5(2)4(3)	10(2+3)1(3+3)	284	3672	44
28	6(2)2(3)1(4)	1(2+2)6(2+3)4(2+4)	280	3396	43
32	6(2)2(3)1(4)	1(2+2)6(2+3)4(2+4)	280	3220	43
24	6(2)2(3)1(4)	2(2+2)5(2+3)3(2+4)1(3+4)	280	3320	42
21	6(2)2(3)1(4)	2(2+2)5(2+3)3(2+4)1(3+4)	280	3424	43
29	6(2)2(3)1(4)	2(2+2)5(2+3)3(2+4)1(3+4)	280	3508	43
33	6(2)2(3)1(4)	2(2+2)5(2+3)3(2+4)1(3+4)	280	3624	43
22	6(2)2(3)1(4)	2(2+2)4(2+3)4(2+4)1(3+3)	280	3468	43
34	6(2)2(3)1(4)	2(2+2)4(2+3)4(2+4)1(3+3)	280	3624	43
35	6(2)2(3)1(4)	2(2+2)4(2+3)4(2+4)1(3+3)	280	3492	43
30	6(2)2(3)1(4)	3(2+2)4(2+3)2(2+4)2(3+3)	280	3500	43
26	6(2)2(3)1(4)	3(2+2)4(2+3)2(2+4)2(3+3)	280	3444	43
23	6(2)2(3)1(4)	3(2+2)4(2+3)2(2+4)2(3+3)	280	3404	42
31	6(2)2(3)1(4)	3(2+2)3(2+3)3(2+4)1(3+3)1(3+4)	280	3492	43
25	6(2)2(3)1(4)	3(2+2)3(2+3)3(2+4)1(3+3)1(3+4)	280	3498	42
27	6(2)2(3)1(4)	3(2+2)3(2+3)3(2+4)1(3+3)1(3+4)	280	3552	43
20	6(2)2(3)1(4)	3(2+2)3(2+3)3(2+4)1(3+3)1(3+4)	280	3464	43
36	7(2)2(4)	3(2+2)8(2+4)	276	2832	42
37	7(2)2(4)	3(2+2)8(2+4)	276	2976	42
38	7(2)2(4)	4(2+2)6(2+4)1(4+4)	276	3056	42
39	7(2)1(3)1(5)	3(2+2)3(2+3)5(2+5)	272	3168	41
40	7(2)1(3)1(5)	4(2+2)2(2+3)4(2+5)1(3+5)	272	3206	41

RESULT

- Rating For 8 – Link, 1 – D.O.F. Simple Jointed Planar Kinamatic Chains (Fig 3)

Chain No. as per Fig	Rated Chain No.	Chain No. as per Fig.	Rated Chain No.
1	15	9	08
2	16	10	07
3	10	11	09
4	11	12	06
5	14	13	03
6	12	14	04
7	13	15	05
8	02	16	01

- Rating for 9 – Link, 2 – D.O.F Simple Jointed Planar Kinamatic Chains (Fig 4)

Chain Number as per Fig	Rated Chain Number	Chain Number as per Fig.	Rated Chain Number	Chain Number as per Fig.	Rated Chain Number	Chain Number as per Fig	Rated Chain Number
1	39	11	21	21	33	31	17
2	40	12	26	22	13	32	04
3	36	13	20	23	06	33	18
4	37	14	22	24	01	34	07
5	38	15	35	25	12	35	05
6	24	16	31	26	16	36	02
7	23	17	30	27	08	37	09
8	25	18	29	28	03	38	11
9	32	19	27	29	10	39	14
10	28	20	34	30	19	40	15

CONCLUSION

A computer methodology has reported for the rating of simple jointed planar kinematic chains without carrying out dimensional synthesis. The methodology is generic and can be implementing on n-link, f-degree of freedom chain with slight modification. The method is compatible for digital computers.

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