Controlling Performance Variation of Planar Mechanisms by Providing Scheme of Tolerance, Using Relative Velocity Method: An Approach

P. S. Thakare [1], Dr. C. C. Handa [2]

[1]Department of Mechanical Engineering, R.T.M.N. University, Nagpur
[2]Department of Mechanical Engineering, R.T.M.N. University, Nagpur

ABSTRACT

Machines / equipments consist of mechanism for their successful operation. These mechanisms are designed for desired output or required performance for specified input. Error in link lengths results in variation in the performance of the mechanism. The link length inaccuracies are due to number of factors like machining errors, deflection of links, clearances in joints, etc. Due to manufacturing defects and clearances, the link length varies. This variation in link length causes variation in desired performance of the mechanism. In this paper, a simple class I four bar linkage is analyzed assuming that links are rigid. Main objective of the analysis is to determine sensitivity of the mechanism to dimensional inaccuracies. In bulk manufacturing, it is not possible to verify functionally all the desired characteristics and if it is so, then it adds to the cost of production. Design engineering and manufacturing engineering are competing. Design engineer wants tight tolerances to assure accurate performance; while on the other hand, manufacturing engineers prefer loose tolerances to reduce cost. For this purpose, the paper proposes an approach to identify tolerance scheme which will help in controlling the performance of the mechanism at minimum cost. Also, instead of providing close tolerances on all the links in the mechanism, an attempt is made to design scheme of optimum tolerances for different links. This will allow designer to provide optimum tolerances on links in the mechanism. For iterative analysis process, software is developed to help manufacturing industries maximize performance at minimum cost.

Keywords **-** *Performance variation, angular velocity ratio, velocity, mechanism, tolerances.*

1. INTRODUCTION

Linkage mechanisms are used in variety of equipments/machines. These mechanisms are designed so as to get the desired output for specified input. This desired output is nothing but the performance required for successful operation of a machine. This performance is called as desired performance of the mechanism. Design performance is important in working of a mechanism. Accuracy of linkages passing through prescribed positions is paramount in mechanism design. Even with most precise design, when it is converted into prototype, unavoidable constraints such as manufacturing errors, deflection and thermal deformation of links, clearances in joints, etc. come into play, causing inevitable deviation of prescribed positions. This ultimately affects the design performance of the mechanism. Performance deviation is generally caused due by change in link lengths. Any change in one or more links will change in the performance of the mechanism. If one try to manufacture the mechanism with exactly or by giving closer tolerance to all the links, it increases the cost of production as it requires precision machining and highly skilled labour.

In this paper, a simple four bar class I mechanism is analyzed assuming that links are rigid. Main objective of the analysis is to determine sensitivity of the mechanism to dimensional inaccuracies. Different set of tolerances are proposed on various links in a mechanism for acceptable percentage variation of performance. Also, an attempt is made to identify sensitive link/s in a mechanism which is responsible for maximum variation in performance.

Many researches have been carried out on performance evaluation of a mechanism due to inadequate design of tolerance on link lengths and clearances in joint. In 1980, Taguchi proposed the concept of parameter design and tolerance design. F. C. Chen and H. H. Huange[3] use Taguchi method coupled with Fuzzy logic for tolerance sensitive analysis of a four bar function generator. C. C. Handa and H. T. Thorat[4,5] have tried to identify sensitive link/s tolerance and its effect on design tolerances of mechanism using instantaneous center. P. L. Bhagat and Dr. B. M. Domkundwar[6] use graphical approach for sensitive analysis of four bar linkage in terms of variation on link lengths and their effects on the curvature of the coupler curve.

2. CONCEPT USED

Angular velocity ratio i.e. ratio of angular velocity of output link and angular velocity of input link defines performance of the mechanism. This ratio can be predefined. If same ratio is obtained in fabricating mechanism, performance of the mechanism is ideal and mechanism is known as ideal mechanism. Any change in the ratio affects change in performance.

Change in performance = (Designed angular velocity ratio - calculated angular velocity ratio) / Actual angular velocity ratio.

Tolerable variation can be defined at the time of requirement of the mechanism. If calculated performance is within tolerable limit, mechanism can be accepted and possible set of tolerance can be identified. If performance is not within tolerable limit, further analysis is required to find out new acceptable set of tolerance.

3. ASSUMPTIONS

Following are the assumptions considered while evaluating performance of the mechanism.

1) Links are assumed to be rigid.
2) Assume one of the link lengths is variable and other three links are of constant length.

Or, all link lengths vary simultaneously.

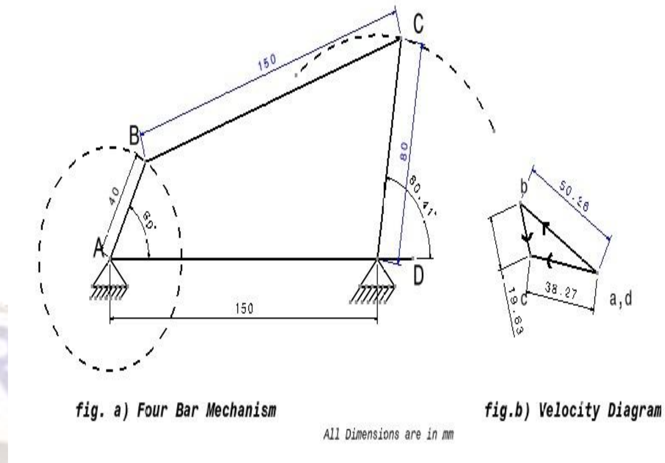

Fig. 1 four bar mechanism

4. Methodology:

Following methodology is adopted to identify sensitive link/s and evaluate performance variation considering variation in length of links due to machining capabilities of individual machines.

1) Consider machining tolerances on one of the links (say L_1) of the mechanism and other links are assumed to be constant. Calculate performance of the mechanism for every 1^0 interval through 360^0 rotation of the crank.
2) Consider machining tolerances on second link (say L_2) of the mechanism and other links are assumed to be constant. Calculate performance of the mechanism for every 1^0 interval through 360^0 rotation of the crank.
3) Consider machining tolerances on third links (say L_3) of the mechanism and other links are assumed to be constant. Calculate performance of the mechanism for every 1^0 interval through 360^0 rotation of the crank.
4) Consider machining tolerances on last link (say L_4) of the mechanism and other links are assumed to be constant. Calculate performance of the mechanism for every 10 interval through 360^0 rotation of the crank.

5. SOFTWARE DEVELOPMENT

Computer plays an important role in all engineering disciplines, including design synthesis and analysis. Analytical technique and graphical techniques are too cumbersome to carry out manually. With the help of computer, the work is easy.

For the above synthesis and analysis, software is developed which will be helpful for manufacturing industries to get accurate performance in minimum manufacturing cost.
The language used for programming is 'C #'. Flow chart of the computer program is as follows:

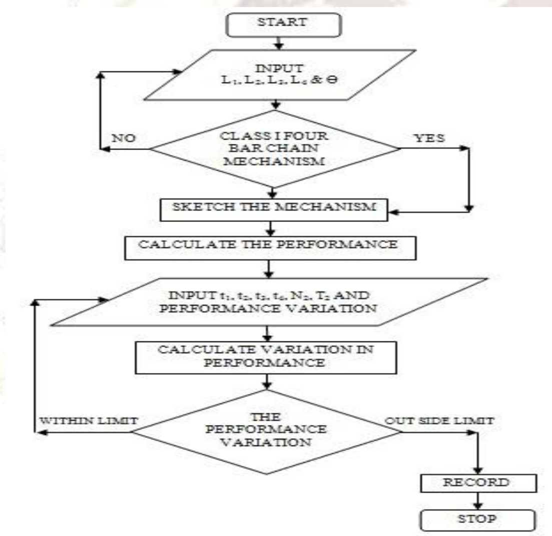

Fig 2. Flow chart

6. RESULTS

A computer program is prepared to evaluate the performance analysis of the Class I four bar mechanism. A 'Relative Velocity Method' is used for the same. Change in performance due to tolerances on each link is tabulated as follows. Tolerance on each link is considered to be 1 mm one by one keeping dimensions of other links is constant.

6.1 Input Data:Input Torque = 50 Nm Crank Speed = 120 rpm Input Angle = 60^0

SR. NO.	DIMENSION OF LINKS				MANUAL CALCULATIONS (A)	SOFTWARE CALCULATIONS (B)	STANDARD DEVIATION (σ)
	Link 1 (mm)	Link 2 (mm)	Link 3 (mm)	Link 4 (mm)	Output Torque (Nm)	Output Torque (Nm)	
1	150	40	150	80	131.58	131.31	0.672
2	151	40	150	80	132.63	132.14	
3	149	40	150	80	130.56	130.46	
4	150	41	150	80	127.26	126.97	
5	150	39	150	80	136.38	135.93	
6	150	40	151	80	130.21	130.25	
7	150	40	149	80	132.63	132.35	
8	150	40	150	81	132.63	133.97	
9	150	40	150	79	128.93	128.73	
10	149	39	151	81	136.23	136.67	

7. CONCLUSION

The proposed method is useful in determining the performance variation of the class I four bar mechanism taking into account tolerance on individual link. The mechanism studied shows that, performance of the mechanism varies maximum when tolerance on link 2 is ±1 mm keeping dimensions on other links remain constant. Thus, link 2 is identified as most sensitive link.
If you assume that error between the torques evaluated by the software and manually is assumed to follow normal distribution then, it can be estimated that if torque estimated by the software is T then, in 99.97 % of the cases, torque estimated by manually will lie in the range T±3σ, where value of sigma (σ) is 0.672 Nm.

REFERENCES:

[1] Hrishikesh V. Nene, "Effect of Link Length on Kinematics of Mechanisms",M. Tech Thesis, Indian Institute of Technology, Bombay.
[2] M. Y. Lee, A. G. Erdman, S. Faik, "A Generalized Performance Sensitivity Synthesis Methodology for Four Bar Mechanisms", Mechanism and Machine Theory vol. 34, pp 1127-1139, 1999
[3] F-C Chen, H. H. Huang, "Taguchi Fuzzy Based Approach for the Sensitivity Analysis of a Four bar Function Generator", Proc. IMECH. Vol. 220, C.JMES, 2006
[4] C. C. Handa, H. T. Thorat, "A Generalized Approach in Anticipating the Effect of Link Length Tolerances on Performance of Mechanism Using Instantaneous Center", Advances in Machines and Mechanisms; Proceeding 9th NaCoMM 1999, December 16-17, 1999
[5] C. C. Handa, H. T. Thorat, "A Generalized Approach in Identifying Control Link Tolerances and its Effect on Design Tolerances of Mechanisms Using Instantaneous Center", NaCoMM 2003.
[6] P. L. Bhagat & Dr. B. M. Domkundwar, "Sensitivity Analysis by Graphical approach"