Design Improvements of Theo Janson Mechanism

Hitesh Rana[1] Nilam Soni[2] Bharat Gajera[3]
[1,2,3]Department of Mechanical Engineering
[1,2,3]G.D.E.C., Navasari, Gujarat, India

Abstract— The purpose of this work is to contribute to the area of mechanism design and optimization of a single-degree-of-freedom leg mechanism. The leg mechanism is considered to be very energy efficient especially when walking on rough terrains. Furthermore, the mechanism requires very simple controls since a single actuator is required to drive the leg. In this work parametric study is carried out and best combination of linkages is recommended. Gait analysis is performed to study the walking pattern and improve the stability of the mechanism. In addition, effort is given to increase the length of path of contact with ground and it is found that it increases about 23% by attaching one extension link at the end of leg.

Keywords: Theo Janson Mechanism, Geogebra Software, Single-Degree-Of-Freedom Leg Mechanism

I. INTRODUCTION

It has been established that legged, off-road vehicles exhibit better mobility, obtain higher energy efficiency and provide more comfortable movement than those of conventional tracked or wheeled vehicles while moving on rough terrain [1]. In the last several decades a wide variety of leg mechanisms have been researched for the applications of legged locomotion, such as planetary exploration, walking chairs for the disabled and for military transport, rescue in radioactive zones for nuclear industries and in other hostile environments. Because these leg mechanisms require a fairly large number of links to pro- vide high mobility, it is extremely complicated for the type selection and dimensional synthesis of leg mechanisms. Although significant progress has been made in the last few decades, there are still a number of design problems that remain unsolved, and thus requires further research.

A number of six-link and seven-link leg mechanisms have been designed with one degree-of-freedom [2, 3, 4, 5, 6]. Rigorous research has been carried out on their mobility and energy loss through kinematic and structural analysis. Two important findings have been documented: (1) a crank as an input link with continuous rotation motion should be used to achieve fast motion with minimum control [2, 3, 4, 5], and (2) an ovoid foot path is necessary to step over small obstacles without raising the body too much [3, 4, 5]. These two requirements are important for designing single-DOF (SDOF) leg mechanisms for mobility and energy efficiency.

While legged walking mechanisms have been designed and built based on engineering theories, they have also attracted much attention from the art fields. The kinetic sculpture “Wind Beast” is a multi-legged walking mechanism powered by wind. It was created by Mr. Theo Jansen, a Dutch kinetic sculptor. The mechanism has many advantages from the design viewpoint, such as: it has a SDOF, a crank as an input link and an ovoid foot path. Also, two legs are in pair and are mirrored, where they share the same crank as the input link. This is beneficial because a central shaft can be used to operate all the legs without adding extra actuators.

II. DESIGN OF LINKAGES

Janson linkages are prepared in Geogebra software with following dimensions and parametric study is performed. From Fig.1 it can be seen that locus of point i is of ovoid shape which is one of the conditions to be fulfilled for a walking mechanism. Different combinations of linkages dimensions are checked but the best trajectory is obtained in following combinations of linkages.

Link	Dimensions (mm)	Link	Dimensions (mm)
Crank (CD_1)	30	EF	111.6
D_1E	100	FH	78.8
D_1G	123.8	AG	78.6
BA	76	HG	73.4
BC	15.6	HI	131.4
AE	83	GI	98
AF	80.2		

Table 1: Dimensions of links.

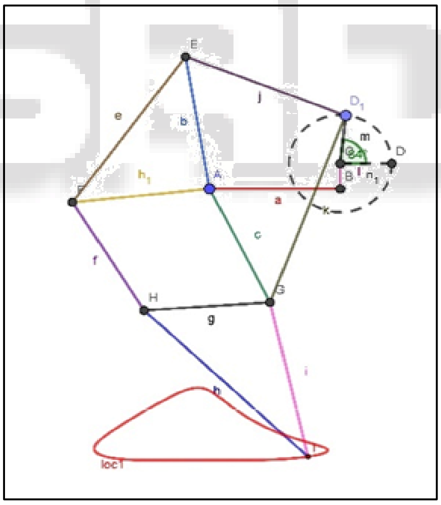

Fig. 1: Jansen Linkages prepared in Geogebra.

III. STABILITY ANALYSIS

Janson originally used number of legs in the mechanism so there was no issue of stability. But if number of legs are reduced to 4 then there is a problem of stability. In 4 legs, leg 1 and 3 is in sync & leg 2 and 4 is in sync. Condition for stability is that at a time 3 legs must be on ground while one leg is in air. To do so the crank angle between leg 1 and 4 was kept 120o same combination is replicated for leg 2 and 3. Another way of improving stability is by increasing the time period of contact of leg with ground which can be achieved by attaching an additional link at the end of the leg (see sec. III.II).

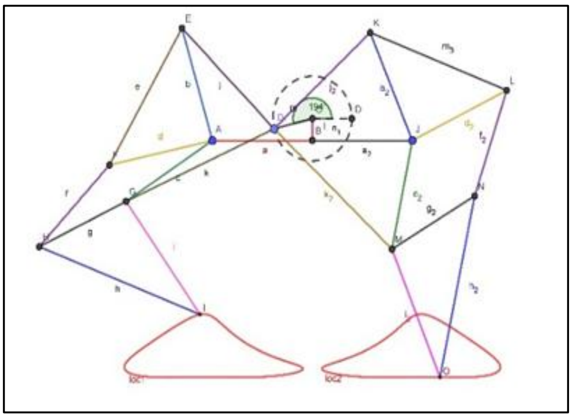

Fig. 2: Path traced by front and back leg

A. *Without Extension Link*

Fig. 4 shows the displacement of point i with respect to crank angle. From figure it can be seen that the end point of the leg is in front most position when crank angle is 257o and back most position when crank angle is 118o. And the leg is lifted at the crank angle of 192o. Fig. 5 shows the trajectory of the end point i of the leg. It can be seen that the foot path is of ovoid shape which is the condition for mechanism to move over obstacles. From Fig. 5 it can be seen that displacement of point i in x direction is 135.81mm and in y direction is 44.91mm.

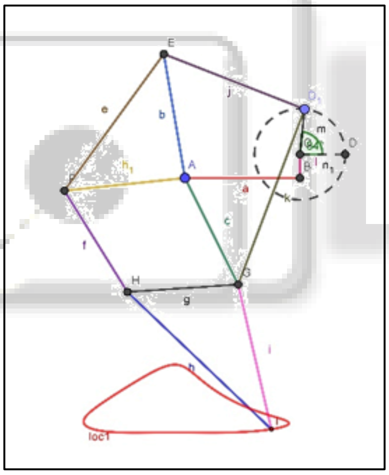

Fig. 3: Without extension link.

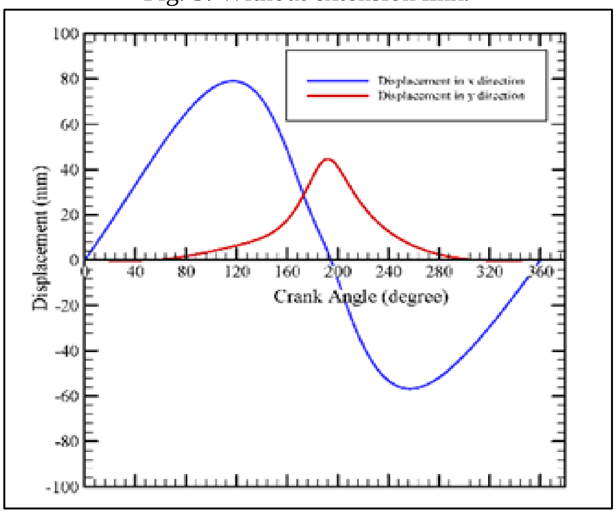

Fig. 4: x and y displacement with respect to crank angle

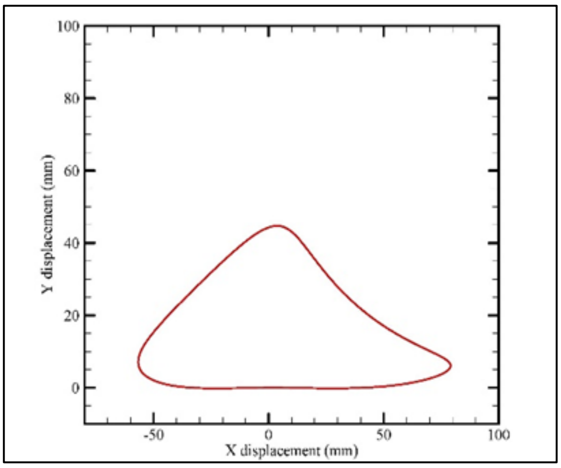

Fig. 5: Locus of end point of leg.

B. *With Extension Link*

Below figure shows the improved mechanism with an extension link attached to the end of the leg. It can be seen that bigger foot trajectory can be achieved with the same dimensions of the other linkages. Fig. 7 shows the comparison of x displacement of improved design and old design. It can be seen that front most position is achieved at crank angle 267o and back most position is achieved at 125o and leg is lifted at an angle of 190o. it can be seen from Fig. 9 that displacement of end point in x direction is 166.95mm which is 23% more than old mechanism and in y direction is 52.85mm which is 18% more than old mechanism. As the leg is in contact for greater time, it improves stability of the mechanism.

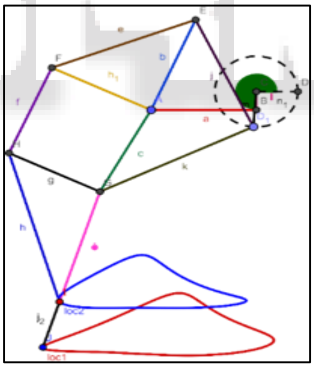

Fig. 6: With extension link

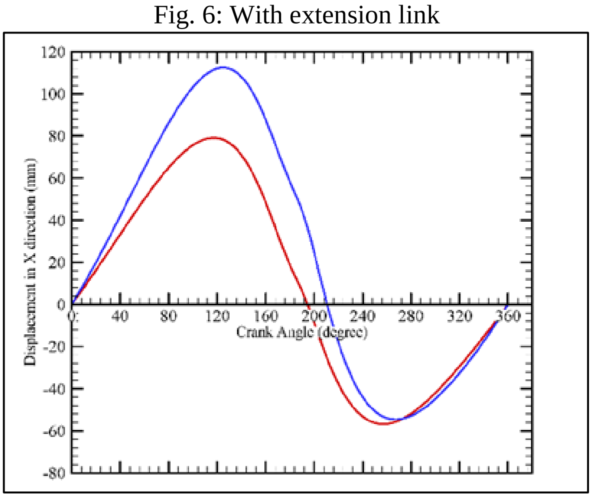

Fig. 7: Comparison of x displacement without and with extension link

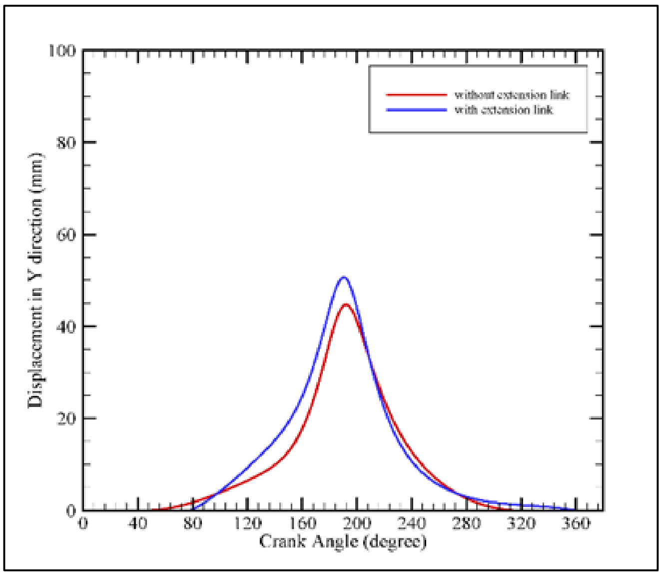

Fig. 8: Comparison of y displacement without and with extension link

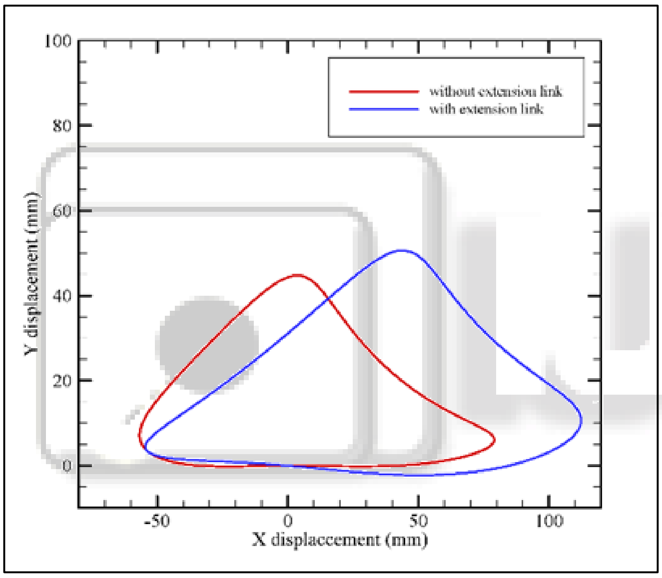

Fig. 9: Comparison of locus of end points

IV. Conclusion

Legged off-road vehicles have better mobility, higher energy efficiency and are easier to control as compared with those of conventional tracked or wheeled vehicles while moving on rough terrains. Synthesis of Jansen mechanism was carried out in this work and modified mechanism is proposed with one more link attached to the end of the leg. It is observed that the path of contact with ground increases by 23% and the leg lift distance increases by 18% without changing any other linkages. As the distance for which the leg is in contact with the ground increases, the stability of the mechanism improves.

References

[1] D.-I. M. G. Bekker, D.-I. M. G. Bekker, Mechanics of off-the-road locomotion, Proceedings of the Institution of Mechanical Engineers: Automobile Division 16 (1) (1962) 25–44.

[2] R. Williams, L. Tsai, S. Azarm, Design of a crank-and-rocker driven pan- tograph: A leg mechanism for the university of maryland’s 1991 walking robot, Tech. rep. (1991).

[3] W.-B. Shieh, L.-W. Tsai, S. Azarm, Design and optimization of a one- degree-of-freedom six-bar leg mechanism for a walking machine, Journal of Robotic systems 14 (12) (1997) 871–880.

[4] W. Shieh, S. Azarm, L. Tsai, A. Tits, Optimization-based design of a leg mechanism via combined kinematic and structural analysis, in: The 1994 ASME Design Technical Conferences. Part 1(of 2), 1994, pp. 199–209.

[5] S.-M. Song, K. J. Waldron, G. L. Kinzel, Computer-aided geometric de- sign of legs for a walking vehicle, Mechanism and Machine theory 20 (6) (1985) 587–596.

[6] W.-B. Shieh, L.-W. Tsai, S. Azarm, A. Tits, Multiobjective optimization of a leg mechanism with various spring configurations for force reduction, Journal of Mechanical Design 118 (2) (1996) 179–185.