"I hereby declare that I have read through this report entitle "Design Framework to Optimize the Walking Curve of Klann Mechanism." and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechatronics Engineering.

Signature : .....

Supervisor's Name : .....

Date : .....

DESIGN FRAMEWORK TO OPTIMIZE THE WALKING CURVE OF KLANN MECHANISM

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

I declare that this report entitles “Design Framework to Optimize the Walking Curve of Klann Mechanism.” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : .....

Date : .....

To my beloved mother and father

ACKNOWLEDGEMENT

First, I would like to thank my family and friends for their support leading up to and throughout this project. They helped me communicate my ideas more clearly and gave important feedback throughout my project. I am grateful for my supervisor Mr Nik Syahrim Nik Anwar for his guidance, ideas and time that made this project possible. I am also thankful for Faculty lab for giving me the incredible opportunity to use 3D printer in producing my Klann Prototype A as an undergraduate. I would also like to thank both my panel Pn. Irma Wani Binti Jamaludin and PM Dr Muhammad Fahmi for giving me many suggest to make the project a better success. Finally, I would like to give thanks to those who had help me in my project.

ABSTRACT

Wheels always have major disadvantage on uneven terrains especially those with short instant evaluation changes surface, such as stairs and steep or jagged rock. These surfaces are not a problem to normal human but for the disables who are using wheelchair, they avoid these surfaces. Therefore, legged mechanisms are recommended as an alternative for the purpose of accessing areas that wheels cannot. The most important aspect of the planar mechanism as legged mechanism is that it does not need large number of actuators for movement. All it need are a rotating motor or crank. There are many types of legged mechanism that fit the above description and the most effective mechanism are Theo Jansen Mechanism, resemble a human leg and Klann Mechanism, resemble a spider leg. In this project, Klann mechanism is chosen as it has more advantages. By creating this framework for Klann Mechanism, others are able simulate an operating or moving Klann mechanism easily. Furthermore, it can be used to determine the limitation of the walking curve, meaning the x step and y step for Klann. In addition, modification on the parameter of mechanism can easily be done by just using this Deign Framework of Klann Mechanism. Finally, if possible, by doing more simulation, a new understanding on Klann mechanism can be obtained.

ABSTRAK

Roda sentiasa mempunyai kelemahan yang besar terhadap rupa bumi yang tidak rata terutamanya mereka yang mempuyai permukaan perubahan yang mendadak, seperti tangga dan curam yang berbatu dan bergerigi. Permukaan ini tidak menjadi masalah kepada manusia biasa tetapi untuk manusia yang kakinya lumpuh dan perlu gunakan kerusi roda, mereka cuba mengelakkan permukaan ini. Oleh itu, mekanisme berkaki disyorkan sebagai alternatif untuk tujuan mengakses kawasan yang tidak mampu diakses oleh roda. Aspek yang paling penting dalam mekanisme satah sebagai mekanisme berkaki adalah ia tidak perlukan penggerak dalam jumlah yang besar untuk pergerakan. Apa yang perlu adalah motor berputar atau engkol. Terdapat banyak jenis mekanisme berkaki yang sesuai dengan huraian di atas dan mekanisme yang paling berkesan adalah Mekanisme Theo Jansen, menyerupai kaki manusia dan Mekanisme Klann, menyerupai kaki labah-labah. Kami memilih mekanisme Klann kerana ia mempunyai lebih banyak kelebihan. Dengan mewujudkan rangka kerja ini untuk Mekanisme Klann, orang lain dapat mensimulasikan mekanisme Klann yang beroperasi dengan mudah. Tambahan pula, ia boleh digunakan untuk menentukan had keluk berjalan kaki, bermakna langkah x dan langkah y. Di samping itu, pengubahsuaian pada parameter mekanisme mudah boleh dilakukan dengan hanya menggunakan Rangka Kerja ini untuk Mekanisme Klann. Akhir sekali, jika boleh, mereka yang menggunakan juga boleh mencipta jenis baru mekanisme.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

The title for my Final Year Project (FYP) is Design Framework to Optimize the Walking Curve of Klann Mechanism. As most of us know, Klann mechanism purpose is to be used on uneven surface. According to general knowledge, one-third of the earth is made out of land. In those one-third of land, there are different terrain such as rocky terrain, muddy terrain, grass terrain, sand terrain and many more. The common similarities these terrains share is their surface, which are naturally uneven. In these modern days, there are many ways to travel on or across the uneven terrain. The land on earth are uneven to begin with and it is through human creativity and innovation that we are able to use technology to make the surface smooth, flat and paved for our tracks and to be blunts, it is the fastest method for traveling, as speed is the most effective way to travel. But, creating tracks for wheeled vehicle need to go through the process called reforming, which include destruction and creation. One of the best example of tracks that we use for travelling daily is the roads.

For a road, paved surface or pathway which all can be called tracks to be constructed, a few procedures are required which involve destruction and reforming in general. The clearing of the surface and land is done by remove and clear a path. In general, activities such as deforestation and blasting is done to change the natural surface to the desired surface, which is will form clear and clean surface without obstacle. Plants are cut down; tree roots are remove; blasting and many more are done with the help of big machinery and tools. All these works are just to achieve one goal, to make a long and free obstacle path for wheeled vehicle. Then, the flattening and paving is done and all these cost resources and our Malaysia Government Works Ministry spend RM1.037 billion for federal road maintenance in 2014 [5][6].

Road construction are normally done of soft soil but it is done on other type of surface too such as rocky surface, sandy surface, muddy surface and many more. But by doing that, it is cost more resources, man power and process. Therefore, I believe that legged robot, in my case legged robot with Klann mechanism is a good alternative for travelling and exploration without the need of creating paths.

1.1 Motivation

The main motivation for the development of legged mechanism, which is Klann mechanism are the following. Disable with wheelchair cannot get access to stair, surface with short instant evaluation changes and government of nations spending billion on road construction. Wheeled vehicles are able to travel on different type of surface, depending on their type of tires, but, there are still one limitation, which is wheeled robot cannot move through all type of uneven surface and the most obvious is stairs.

Figure 1. 1: Wheelchair.

Figure 1. 2: Prosthetic leg.

Wheelchairs, Figure 1.1 have severe limitations in building and urban roads, so there is a need for new concepts of chairs for disable. [1] This is true, wheels have limitation as the earth terrains are mostly uneven as they are made out of rocky terrain, muddy terrain, grassing terrain, sandy terrain and many more. March 2011, earthquake and tsunami struck Japan and one of the surviving victim was a disable and been confine since young age. When tsunami happened, he recalls the sound of the tsunami alert just minutes before the water rushed into his home. He remembers the feeling of helplessness, and how his family helped him up the stairs to safety. His electric wheelchair was destroyed by surging water. “The whole neighbourhood became like a dark, black lake and everything disappeared in it,” he says. [2]. May 2008, earthquake hit China and a surviving girl need to use wheelchair for life as both of her legs were amputated above the knee. She gave a statement saying "My mother carries me and the wheelchair and I can help a little bit,"[3] when she need to attend her classes which are up three flights of stairs.

Some may suggest prosthetic leg, Figure 1.2 but do they know it cost from $5000 to $50 000. Even the most expensive limb can only withstand 3 to 5 year due to wear and tear, meaning it need to replace over the course of time, it is not a onetime thing but the wheelchair is. You just to need to buy one wheelchair can use it until it breaks down and it is way cheaper. In addition, wearing new prosthetics hurts and they need time to get used to it every single time. [4]

When talked about motion, we thought of cars as we use them daily. Governments spend billion in road construction and maintenance, creating tracks for vehicle with wheels, which is a very big sum. With billion, it can be used for other welfare such as building hospitals and schools or even, free education for the children. Malaysia is also included in spending billion in road construction and maintenance as in 2014, the Works Ministry allocates RM1.037 for federal road maintenance [5,6]. The main reason we still building road due to the world are still using technology from the caveman era, the wheels. Technology have improved since then and we should have make some changes as we are spending billion in road construction and maintenance. The concept of track and wheel had been widely use since 19th century and 20th century where the steam engine and the internal combustion engine were invented [7] mainly for train and car.

Figure 1. 3: The Tarim Desert Highway of China [8].

Figure 1. 4: Road construction of Dubai in Arab [9].

With wheeled vehicle, there must be tracks and that can only be done by destroying and reforming the naturally beautiful uneven terrains. The situation has become even worst as in the name of development, more cities and roads are build all over the world and process is still continue at an even faster pace. Tall building and roads are popping up fast everywhere all around the world and more terrains are reformed and developed into roads to connect all these cities. Many resources, man power and process are wasted on creating road and paved surface for wheeled vehicle.

Country which made out of dessert also spend many of their resources in making road to connect cities and the example are The Tarim Desert Highway of China and road construction of Dubai in Arab, [8][9] which is shown in Figure 1.3 and 1.4. Governments, Rulers of Nations, States, Cities and Town spend resources, man-power and process in building roads but not in the research to improve the vehicle moving on it. People have been constructing roads for centuries, since the 19th century and for decades many still doing research on enhancing roads quality or better road construction method. In state of improving the tracks, we should improve the vehicle or object traveling on it.

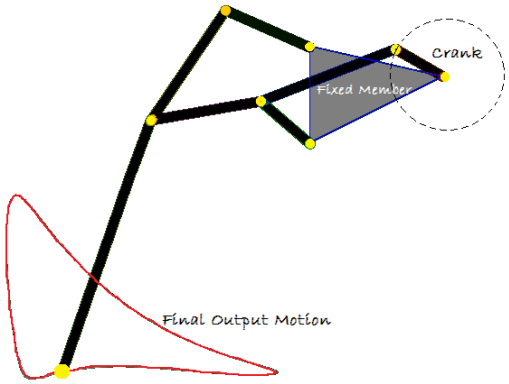

Figure 1. 5: Klann Mechanism [12].

Do not let the surface, limit the movement of the object. In state, the object build must have the ability to move on any surface. We should change our perspective and move forward by focusing on the object that travel on the surface, which is the vehicle. Do not change the natural uneven surface of the terrain but change the design of the vehicles which allow the vehicle travel on the uneven surface, the object design should adapt to the surface. In addition, it should have more function, such as moving on uneven surface, not paved path as the modern world now command products that can multitask. To reduce and prevent more tracks to be build, and the continuation of reforming the surface of our earth terrain, legged mechanisms are proposed for the use of mobile transportation. For this project, the focus will be on legged robot that uses planar mechanism and to be more precise, Klann Mechanism, Figure 1.5.

1.2 Problem Statement

The following are the problem statements for this project.

1.2.1 To identified the mechanism of crawler robot (legged robot) base on Planar Mechanism that can move on surface with short instant elevation.

For this project to start, the mechanism of the crawler robot that can move on surface with short instant elevation changes must first be identified and research. In addition, the mechanism need to consist the features of planar mechanism such as rotating cranks, linkages and connecting joints.

Short instant elevation changes surface, for example stairs are the most obvious surface that wheels cannot move on therefore, legged robot or crawler robot are suggested as alternative. For legged robot, they are normally made out of 2 type of mechanism which are planar mechanism and spatial/ complex mechanism. In a planar mechanism, all of the relative motions of the rigid bodies are in one plane or in parallel planes. If there is any relative motion that is not in the same plane or in parallel planes, the mechanism is called the spatial mechanism. [10]. In short, mechanism that are moving in 2-dimensional direction, which is x axis and y axis is planar mechanism, while more than 2-dimension direction is called spatial or complex mechanism.

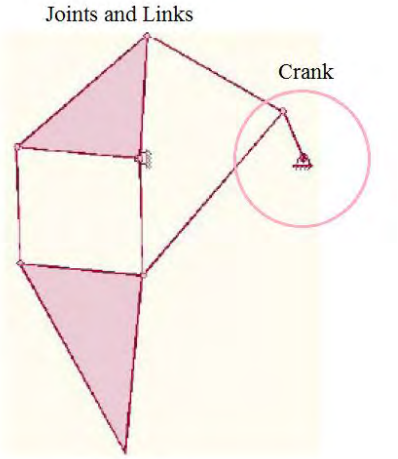

Figure 1. 6: Theo Jansen Mechanism (crank) [1].

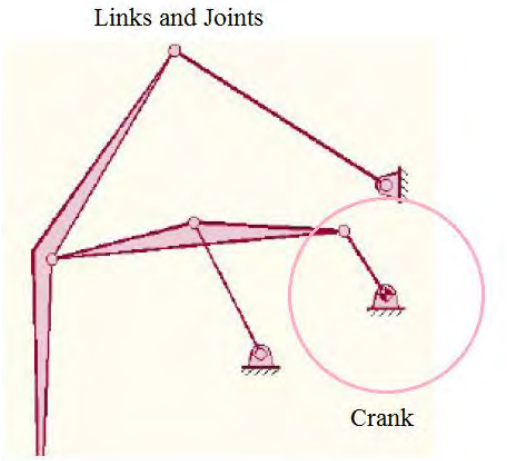

Figure 1. 7: Klann Mechanism (crank) [1].

For this project, planar mechanism is use for the crawler robot, where the links and joints are connected to a rotating crank. There are many types of mechanism that can be use and the following are a few examples that we going compare in the literature review. [14]

i. Klann Linkage

ii. Theo Jansen Linkage

The most effective and popular comparison of planar mechanism for crawler robot are Theo Jansen Mechanism, Figure 1.6, mimic human leg and Klann Mechanism, Figure 1.7, mimic spider Legged. Both these mechanisms follow the principle of having a rotating crank, linkages and connecting joints. But for this project, Klann mechanism is favour as it had more advantages and the detailed comparison can be seen in Literature Reviews.

1.2.2 To identified the limitation of the crawler robot mechanism in horizontal step distance (x step), and vertical step distance (y step) base on planar mechanism.

In this project, Klann linkage will be mainly use as example as it is the favoured and consist many advantages.

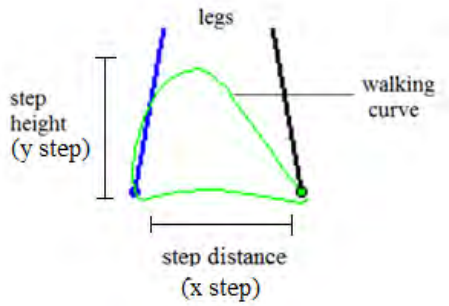

Figure 1. 8: Step Height and Step Distance [11].

The action of walking is first described as the lifting of leg. Next, move the leg forward or backward and finally move the leg downward. The action is repeated for each leg and the motion is mostly planar. The action of lifting your leg upward and downward is called step height (Height overcome with each step) and the action of moving your leg forward and backward is called step distance (distance move with each step), which is shown in Figure 1.8. For this project, the horizontal step is defined as step distance and the vertical step is defined as the step height.

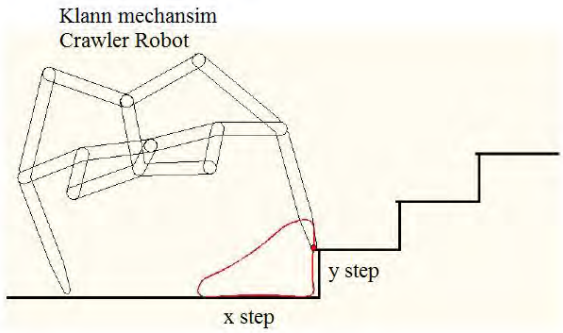

Figure 1. 9: Klann mechanism moving on a stair[1].

For each mechanism, there is a limitation for each taken step, in height and size. Since this project had decided on using Klann mechanism, Figure 1.9 will show Klann mechanism moving on a stair as we stated in our motivation, the mechanism need to move on surface with short evaluation changes that is stair, which step distance and step height. The step distance (x step) and step height (y step) are affected by many factor, mainly by the design of the mechanism which in this project consist of mainly linkages, joints and cranks and gears. Different length of linkages, position of joints, dimeter of cranks or no of teeth at gears should have effect on the on the walking curve, which will affect the x step and y step.

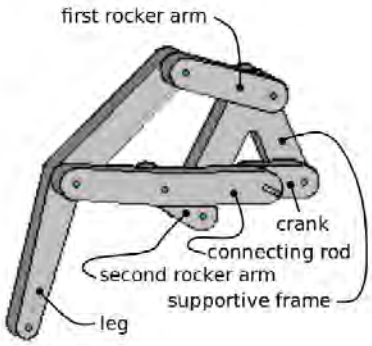

Figure 1. 10: Klann Legged mechanism for Crawler Robot [13].

For this modification, whether on the length of links, position of joints or radius of crank, Matlab will be use as simulation tool for creating the Framework for Klann mechanism. At this points, all the design will base on Klann mechanism. The modification of link will be done on the main linkages. The main linkages that may be modified are shown in Figure 1.10. The parts that will be modified will be determine after derivation of formula is done on the kinematic modelling of Klann mechanism.

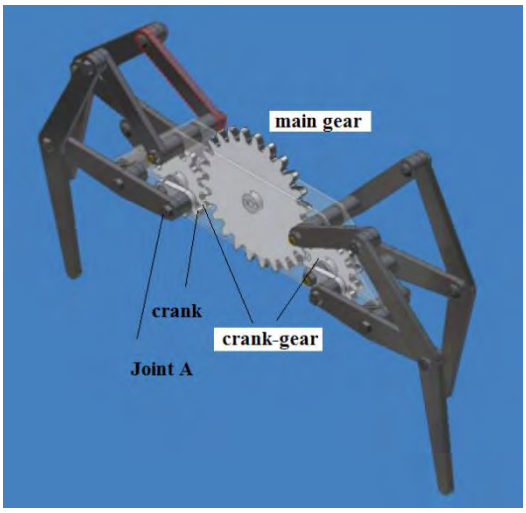

Figure 1. 11: The design of Klann mechanism crawler robot [18].

For the crank, which can be refer in Figure 1.11, show a design of Klann mechanism that are connected to the cranks clearly. The position of the joint connection (joint A) will affect two aspects which are,

i. The shape of walking curve, x step and y step.
ii. The time taken to complete one cycle of walking curve of the mechanism.

The changes of position at joint A can only be done by changing the diameter of the crank-gear. The difference in lengths from point A to the center of crank-gear (r-crank, Radius of Crank) will affect the shape of walking curve, the x and y step as the rotating point A had changed. Next, since the r-crank of rotating joints has changed, the time taken to complete one rotation cycle for crank will also change which will affect the time taken to complete a cycle of walking curve. In simple word, the moving speed of the robot will be change either faster of slower depending on r-crank. The bigger the radius, the slower the robot as it takes longer to complete one cycle of walking curve. The affect is vice versa for smaller Radius of crank. The position of Joints at the crank-gear, r-crank will have effects on shape and speed of walking curve. Therefore, joints and crank must be taken in consideration while designing and building the crawler robot mechanism as it will determine x step, y step and speed of one complete cycle rotation of walking curve.

Since the rotation of the of the crank that allow translational motion of the crawler robot, therefore, a transferring medium or parts is needed. For, this project, gears will use the transfer medium for rotational force of motors. In Figure 1.11, both the side cranks are modified to gears. For these crank-gear, it has both the characteristic of crank and gear. It still acts as a crank for the mechanism but is modified to crank-gear as the gears objective is to receive rotational motion from the main gear, which is connected to the motor. In gears, the diameter and number of teeth will affect the angular velocity. This will affect the translational movement of the crawler robot. Therefore, changes in gears must be taken as consideration in the development of the mechanism.

In this project, the main focus will be given to x step and y step as the main objective is to move on uneven surface, speed in not the main focus. Therefore, in the design, the changes are going to be done at the links first. This is to determine the relationship between length of links toward x step and y step. The modification of the position of Joints, Rcrank and Gears will be secondary. With the data obtained for the Matlab simulation, limitation on the walking curve, x step and y step of crawler robot will be determined. This is the original plan; other parts may also be change after more research is done.

1.3 Objective

i. To design a walking mechanism that can overcome an obstacle of 2 cm height.
ii. To determine the design parameters that influent the x step and y step in walking mechanism.

1.4 Scope

The title of the project is Design Framework to Optimize the Walking Curve of Klann Mechanism. Since we are going to design the framework for the Klann mechanism, therefore, must focus on walking curve. This result in analysing of two parts, which are

i. The mechanism of crawler robot, the Klann mechanism.
ii. The uneven surface, related to walking curve.