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Analysis of Jansen walking mechanism using CAD

Florina Moldovan[1, a], Valer Dolga[1, b]

[1] Politehnica University of Timisoara, Mechanical Engineering Faculty, Mechatronics Department, 1 Mihai Viteazu Blvd., 300222 Timisoara, Romania

[a]florina19martie@yahoo.com, [b]valer.dolga@mec.upt.ro

Keywords: walking robots, legged locomotion, CAD, kinematics, four bar mechanism

Abstract. In this article is presented a short classification for walking robots that are based on leg locomotion and the main objectives that walking robots designers must achieve. The leg configuration of the walking robot is essential for obtaining a stable motion. Computer aided design process offers certain advantages for designers who attend to realize competitive products with fewer errors and in a short term. The aim of this article is to present the graphical results of the kinematic analysis of a new type of walking mechanism designed by Dutch physicist and sculptor Theo Jansen using Pro Engineer program and SAM, in order to compare the results.

Introduction

The study of legged locomotion represents a great reliance for building various kinds of walking robots for different purposes such as land exploration, military purposes, mines detection, research purposes and transport in unstructured environments.

After some researchers' opinion nature is the best source of inspiration for building walking robots due to the fact that living creatures developed great performances in walking and climbing over uneven terrains and inclined surfaces [1], [2], [3]. The goal of most researchers in studying walking robots it consists in obtaining energy efficient structures with improved performances in traversing challenging terrains using optimized leg configuration. For this purpose new types of leg designs are studied and optimized for obtaining capabilities comparable to biological walkers [4].

A new type of walking mechanism design introduced by Dutch physicist and kinetic sculptor Theo Jansen it consists of a twelve bar linkage powered by the wind that walks similar to a crab and it appears in studies of few researchers [5, 6].

The present paper it consists of five parts: in the first part is presented a short introduction, second part illustrates few aspects about leg locomotion, in the third part is described the importance of using CAD simulation tools before building a real model, in the fourth part are presented the graphical results of kinematic analysis of the new type of walking mechanism and in the last part the conclusions.

Walking robots

Walking robots developed in the field of robotics research that are using legs for traveling have few advantages instead wheel locomotion: less energy consumption, no need for roads, capable to cross obstacles, the contact with soil is minimized at a discrete point, don't destroy surfaces of the ground, climbing abilities and maintaining the body at a specific height [7], [8], [9].

In the study of legged robots design and locomotion, researchers from all over the world are trying to achieve stable motion. For this reason researchers used nature inspired leg configurations in order to fulfill specific mobility and walking tasks such as stability, adaptability to the environmental challenges, control of forward velocity and ability to climb and walk on rough terrain and incline slopes [10].

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Till now there have been built various kinds of walking robots structures that can be classified, for example, like in the figure 1.

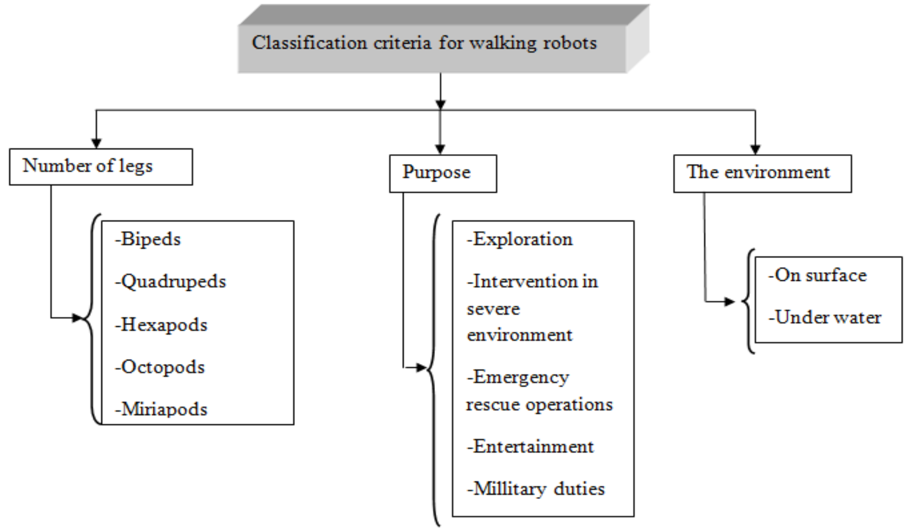

Fig.1 Classification criteria for walking robots

Legged locomotion

Depending on the purposes and functional roles initially established for, researchers are using different types of legs in building walking robots: crab type leg is useful for walking over sand, insect type leg (cockroach) are useful for traversing obstacles, ditches, gaps and uneven surfaces, as well as travel up and along inclines by slow, the mammalian type of leg for carrying large and heavy loads, the reptile type of leg for moving faster [1, 3].
In the study of legged robots an important issue is represented by the type of walking gait it develops during walking such as the tripod gait that it usually appears at insect types of legged robots and human like gait or compass like gait at biped robots. Depending on the type of walking gait selected it can be chosen the number and configuration of legs that are necessary for building the robot.
Another important issue in studying leg locomotion at walking robots it deals with the number of legs assigned to the robot structure so that it can maintain stability during walking phase which means that at least three points of contact with the ground must be assured. This refers to the fact that it must exist a control of the position of the center of gravity by assuring that its vertical projection always falls within the polygon of support [5].
It is also important for the builder of the walking robot to consider the dynamics of walking, the shapes of trajectory described by the feet during walking phase and the optimal leg configuration in order to walk smooth and stable [6].

Computer aided design process

CAD environment offers certain advantages for analyzing different types of structures and simulating their behavior in certain conditions before building a real model. The advantages consists in minimizing the errors in product design, easily usage because of the electronic format data, in accelerating the design process and in viewing in real time the results of the analysis and simulations. The facilities offered by CAD for the design process are forming a useful tool for obtaining competitive products and are based on object oriented characteristics and expert systems.
The shape, functions and functionality of a product usually interacts and condition each other and form the main three attributes of CAD process. For this reason CAD impose the condition of gathering information regarding the functionality of the model. The relation between this three attributes is presented in figure 2 [11].

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The object oriented design is specific in general to team working projects and provide an efficient communication between members of different groups who must accomplish the project tasks. It can be consider that object oriented design is a strategy in which the system is focused on objects instead of functions and operations. The design operation phase it situates between analysis and implementation process

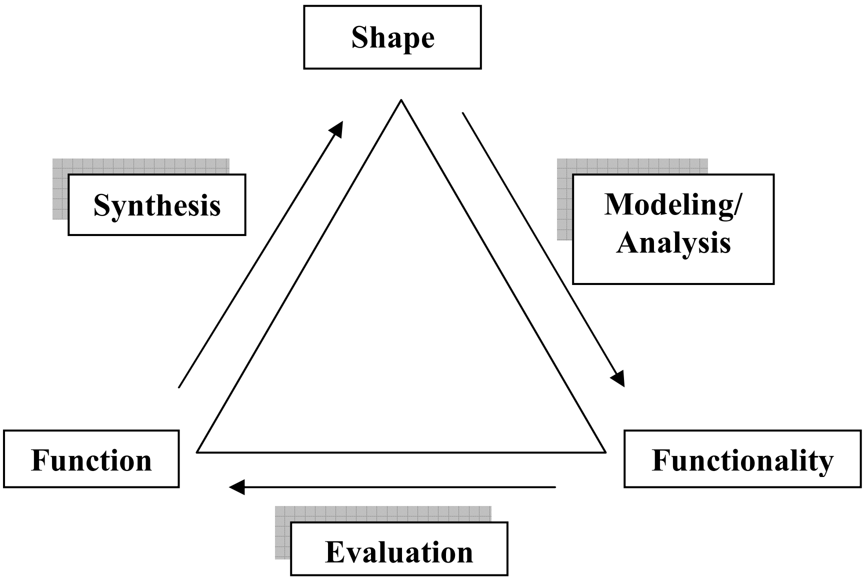

Fig.2 The relation between shape, function and functionality

For simplifying the design, analysis and simulation operations that a design engineer must accomplish were developed various types of integrated environments such as CAD. In figure 3 is presented the main structure of a working environment for design process [11].

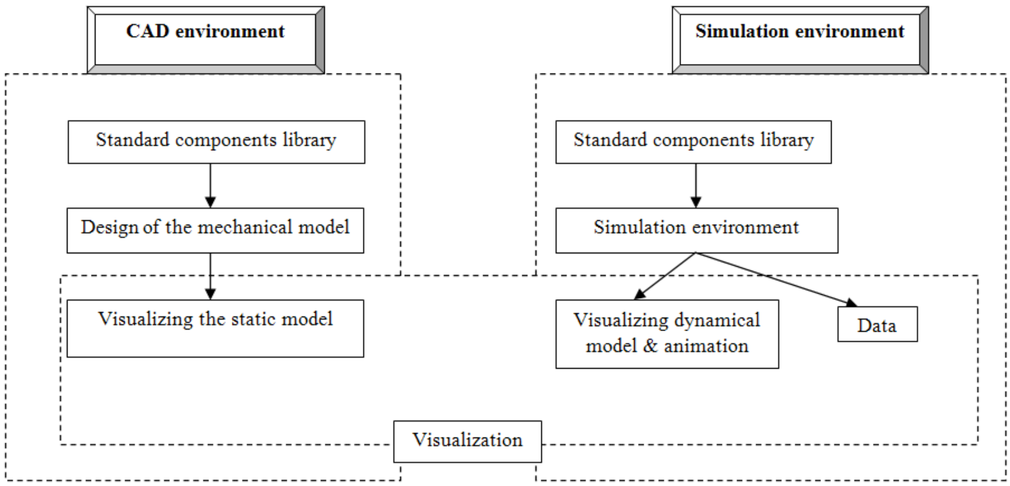

Fig.3 The main structure of a working environment for design process

Kinematics of a new type of walking mechanism using CAD approach

The new type of walking mechanism designed by Mr. Theo Jansen it is particularly analyzed by few researchers who claim that this type of mechanism is an optimal structure for building a walking machine [5, 6]. For this purpose a new design of leg configuration is proposed in figure (4a) using the proportions established by the artist and in figure (4 b) are presented the principal elements of the walking mechanism designed in Pro Engineer program. Kinematical analysis results

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using Pro Engineer software, for point A of the four bar mechanism is presented in figure 5 in which: a)- a sketch view of the four bar mechanism with the point A marked with a black box; b)- graphical result for velocity kinematic analysis using ProE; c)-graphical result for acceleration kinematic analysis during seventy seconds of walking cycle.

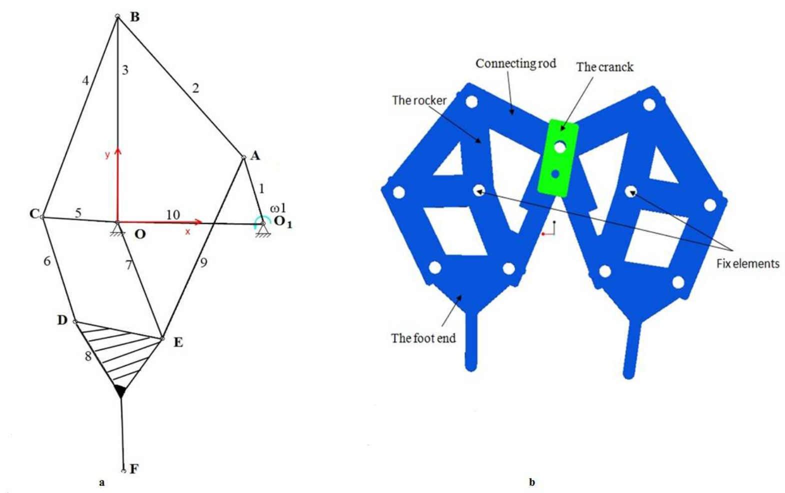

Fig. 4 The sketch view of leg design (a) and the walking mechanism design in ProE using the proportions proposed by Jansen (b)

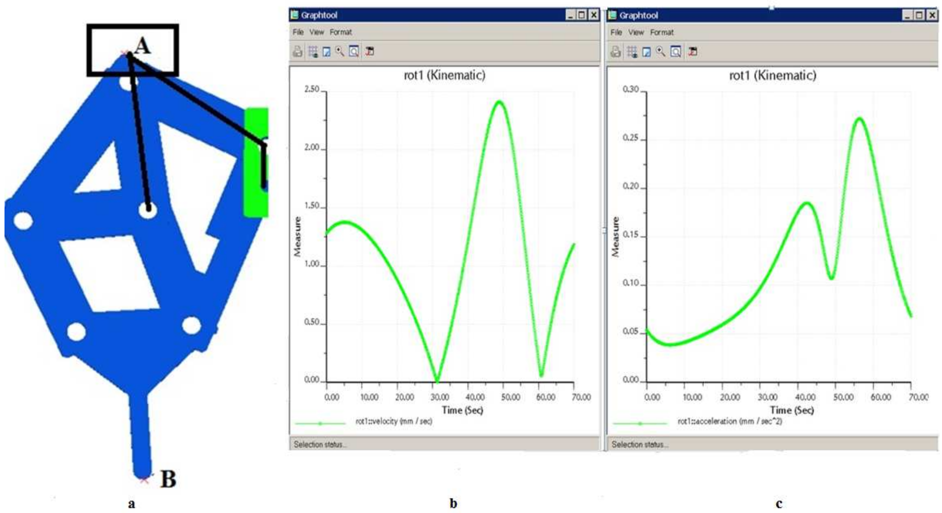

Fig. 5 The sketch view of the four bar mechanism (a) and the graphical results of kinematic analysis using ProE (b)

For comparing the results of the kinematic analysis of the four bars mechanism presented in figure (5a) we used another CAD program special designed for mechanism analysis in 2D. The kinematic sketch view of the four bar mechanism and the trajectory shape described by the point A, marked with the black box in figure (5a) is presented in figure (6a) this time in 2D view. In figure (6b) is presented the graphical result of kinematic analysis effectuated in SAM program.

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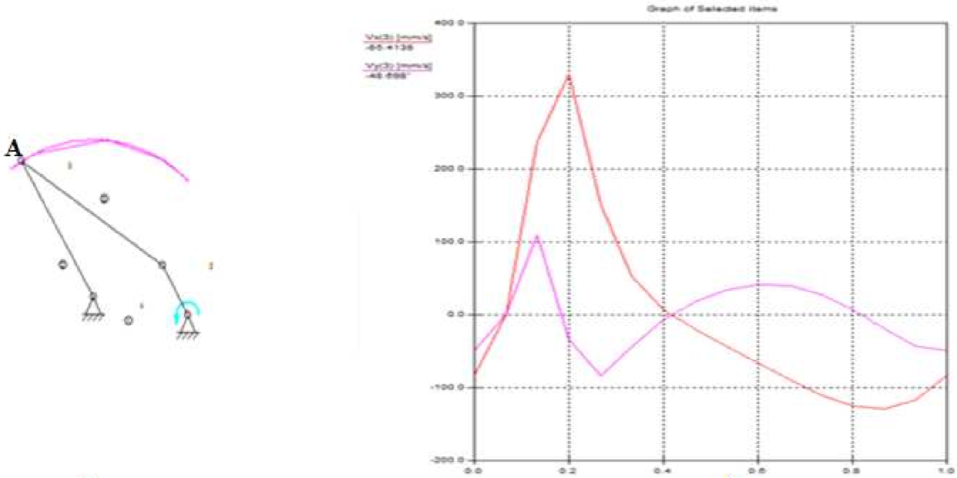
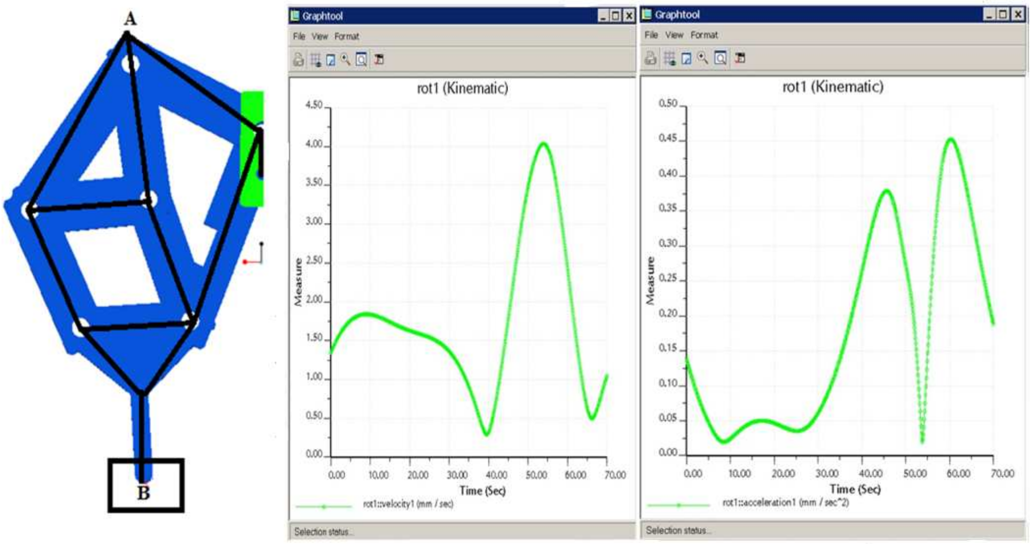


a b

Fig. 6. The four bar mechanism designed in SAM (a) and the graphical result of velocity and acceleration of the point A (b)

The results obtained from the four bars kinematic analysis is significant when are treated separately for each type of computing used by ProE and SAM programs. The initial conditions are not the same because the input angle of primary movement ω_1 is different from one form to another. The main disadvantage of using SAM analysis program it results from the representation form of the mechanism which consists in the planar view frame. For complex mechanism design analysis and simulation the tridimensional view offered by ProE program is more suitable.
The figure (7a) presents the kinematic sketch view of the walking mechanism with the end point of the foot B marked with a black box of which analysis results are presented in figure (7b) and (7c).



a b c

Fig. 7. The sketch view of the mechanism with the end point of the foot B marked (a) and the graphical results of velocity (b) and acceleration of the end point of the foot (c)

For the end point of the foot it is important to obtain a low acceleration value. This way the walk it will be more smooth and without shocks at the contact with ground.

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In figure 8 is presented a CAD model of a walking robot based upon Jansen walking mechanism that it can be developed for studying the locomotion and analyzing the suitability grade of this structure under specific environmental conditions.

CAD is a useful tool for analyzing and simulating the movement of a structure such as the walking mechanism investigated in this article, to interpret in an easier form the graphical results, to minimize errors and to save time during the design process.

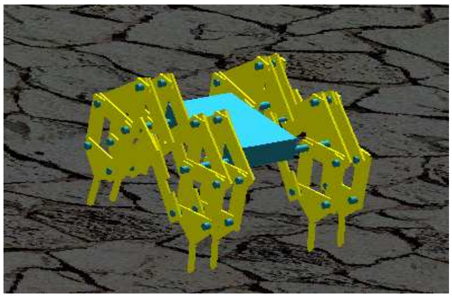

Fig. 8. The CAD model of new type of walking robot that uses Jansen type of leg configuration

Conclusions

Before building a walking robot prototype like the one proposed above it is necessary to analyze and simulate the structure design using CAD facilities and to optimize the proportions of the legs for obtaining an optimal design in order to walk smooth and stable through a certain environment.

Acknowledgements

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