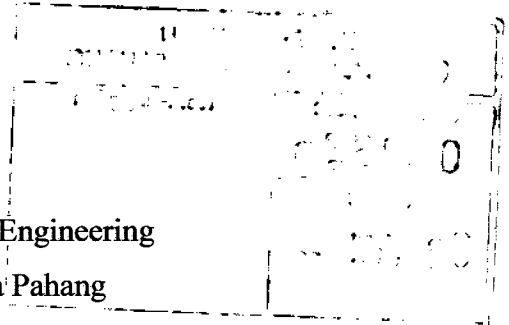


# DESIGN AND DEVELOPMENT OF LADDER NEW MECHANISM

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## **ABSTRACT**

Nowadays, people do not realize that current mechanism of ladder is unsafe and unstable. The statistics show that numerous number of ladder accident happen every year. This research is about to design and develop a new safer and stable mechanism of ladder in order to change the dangerous mechanism of current ladder. The project starts with reviewing the potential mechanism that can be applied and the most simple and effective mechanism will be selected. After finalized the best design among alternatives design, fabrication processes then followed. The structure was analyzed by using software in order to satisfy the strength of the design structure. The processes involved in this project are cutting process, drilling process, sheet metal process, joining process and surface finish process. After the product was fabricated, test run is applied in order to know the capability and ability. From the test run analysis, the new mechanism of ladder can successfully reach 2 meters height in stable condition. It also can withstand the applied maximum load. So, the objectives of the project have been successfully achieved. Thus, this project has provided a new mechanism of ladder that is more safe and stable during the application. Otherwise, there are some recommendations that can be applied to the new mechanism of ladder to improve the capability. The amplification system should be added to the mechanism in order to minimize the force consumption and optimize the reaction of the new ladder mechanism. Other than that, this type of mechanism can be applied for others system such as jack mechanism, cranes and trolley.

## ABSTRAK

Pada masa kini, orang ramai tidak sedar bahawa mekanisma tangga sedia ada yang mereka gunakan adalah tidak selamat dan tidak stabil digunakan. Statistik menunjukkan bahawa angka kemalangan tangga adalah sangat tinggi setiap tahun. Kajian ini adalah untuk membentuk dan menghasilkan sebuah mekanisma tangga yang selamat dan stabil bagi menggantikan mekanisma tangga sedia ada yang membahayakan pengguna. Kajian ini bermula dengan menganalisa semua mekanisma yang berpotensi sebagai mekanisma tangga yang baru dan mekanisma yang terbaik akan dipilih. Selepas memilih model yang terbaik antara model-model alternatif lain yang berpotensi, proses fabrikasi produk akan menyusul. Sebelum itu, struktur model akan dianalisa melalui perisian komputer untuk melihat kekuatan dan ketahanan struktur model tersebut. Proses fabrikasi yang terlibat dalam projek ini termasuklah proses pemotongan, proses membuat lubang, proses kepingan logam, proses peyambungan logam dan proses membaiki permukaan produk. Selepas prototaip tersebut siap, ia akan diuji untuk melihat keberkesanan dan kebolehan sebagai mekanisma tangga yang baru. Daripada ujian tersebut, didapati mekanisma tangga yang baru ini berjaya mencapai ketinggian 2 meter dengan stabil. Ia juga dapat menahan beban maksimum yang diberikan semasa ujian. Oleh itu, objektif projek ataupun kajian ini telah tercapai. Satu mekanisma tangga baru yang lebih selamat dan stabil berjaya dihasilkan dalam kajian ini dalam usaha menggantikan mekanisma tangga yang sedia ada. Walaubagaimanapun, terdapat beberapa penambahbaikan yang boleh dilakukan terhadap mekanisma tangga yang baru ini untuk meningkatkan keupayaan dan keberkesananannya. Sistem amplifikasi perlu ditambah untuk mengurangkan tenaga yang diperlukan dan mempercepatkan pergerakan mekanisma baru ini. Selain itu, mekanisma yang baru ini juga boleh diaplikasikan dalam sistem yang lain seperti mekanisma jek, kren, dan troli.

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## CHAPTER 1

### PROJECT DESCRIPTION

#### 1.1 Introduction

Do you really care about your safety? Can you ensure that the ladder used safe and will not slip or falling down? Nowadays, there are many peoples whose involve in a ladder accident either in domestics or in the working place. It shows that the design and condition of current ladder are not safe. This condition will causes negative effects especially to the person, company and country.

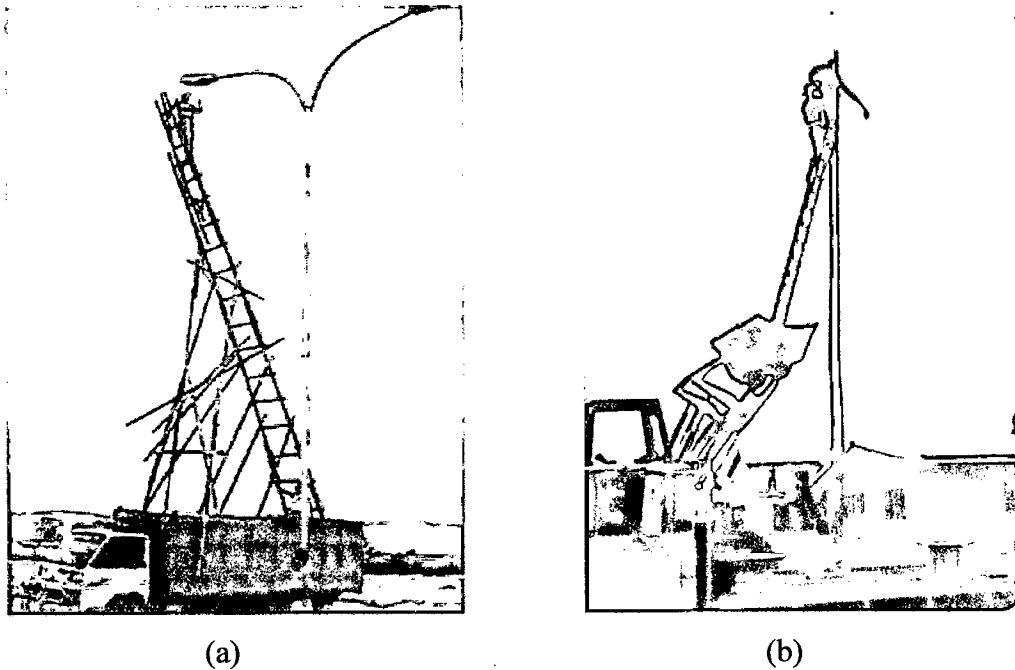


(a)



(b)

**Figure 1.1** (a) and (b) Example of common type of ladder  
((a).[www.safety first europe.co.uk](http://www.safetyfirsteurope.co.uk) and (b).[www1.istockphoto.com](http://www1.istockphoto.com))



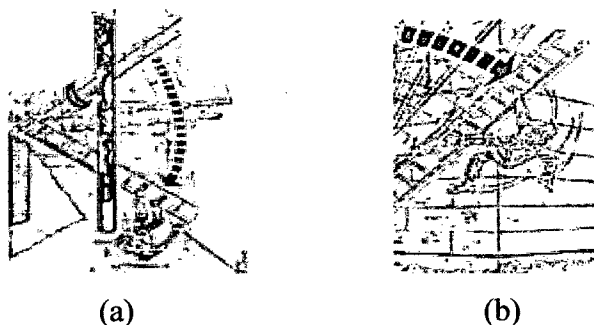
**Figure 1.2** (a) and (b) The workers threaten their health and life by working with dangerous ladder ([www.mainporttraining.com](http://www.mainporttraining.com))

Firstly, the unsafe design of ladder or mechanism can cause death life of people or workers. Every year, numerous people fall from ladders causing on average 50 deaths in the United Kingdom, 1000 serious injuries and 40,000 hospital visits ([www.safetyfirsteurope.co.uk\\_laddermate.htm](http://www.safetyfirsteurope.co.uk_laddermate.htm)). About 300 people in the United States die from ladder related injuries annually ([www.emsifl.com/fyi-lighting-ladder-accidents.html](http://www.emsifl.com/fyi-lighting-ladder-accidents.html)). The elevated fall accidents accounted for 661 deaths on the job in 1994. That is fourteen percent of total occupational death that year ([www.occupationalhazards.com](http://www.occupationalhazards.com)).

Secondly, unsafe design of ladder causes a serious injury of people or workers. According to the article from BBC News, Tuesday, 8 January, 2002, the number of people injured in domestic (United Kingdom) accidents involving ladders has soared by 62% over the last decade. The injuries can be severe, and include broken bones and damage to the head. On this news, figures from Rehab United Kingdom, a charity which helps people with head injuries, show that 48,000 people a year in the United Kingdom now attend hospital Accident and Emergency Departments following a ladder accident in and around the house. In year 1991 to 1992, the figure was 30,000 people involved in ladder accident. About a third

involves stepladders, fifth free-standing A-frame ladders and sixth portable leaning ladders. Reg Prole, a chief executive of Rehab United Kingdom, said, "Head injuries occurred in about 2,300 cases for the ladder accident".

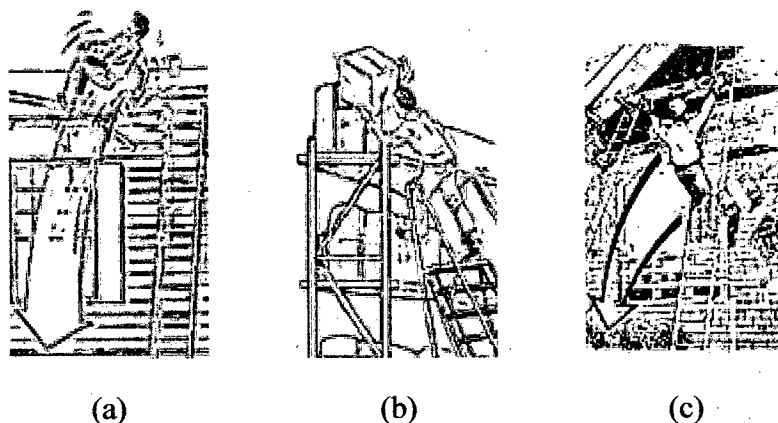
Other than that, The American Academy of Orthopedic Surgeons recently published some statistics that illustrate the dangers of ladder accidents. In the United States, more than 500,000 people a year are treated for ladder related injuries, and that number does not include people who suffered injuries but did not go to a medical care provider for treatment ([www.emsifl.com/fyi-lighting-ladderaccidents.html](http://www.emsifl.com/fyi-lighting-ladderaccidents.html)). An article on 21 November 2001, Attacking Ladder Falls One Rung at a Time, the falls from ladders injure is more than 20,000 American workers every year, according to the Bureau of Labor Statistics ([www.occupationalhazards.com](http://www.occupationalhazards.com)). The impact from sprains and strains, broken bones and other more serious disabling conditions resulting from falls from ladders reaches far beyond the injured worker's suffering ([www.occupationalhazards.com](http://www.occupationalhazards.com)).



**Figure 1.3** (a) and (b) Example of serious ladder accident  
([www2.worksafebc.com](http://www2.worksafebc.com))

Thirdly, unsafe design of ladder will cause financial lose to the government or country to spend for medical expenses. The Association of British Insurers has stated that £12 Billion a year is lost in the United Kingdom through accidents, and of these 25% are as a result of falls from height especially ladder accident ([www.safetyfirsteurope.co.uk\\_laddermate.htm](http://www.safetyfirsteurope.co.uk_laddermate.htm)). The estimated annual cost of ladder related injuries is \$11 billion, including work loss, medical, legal, liability, and pain and suffering expenses. These figures are staggering and highlight the need for employers to be concerned about ladder accident dangers and think how to solve this

problem ([www.emsifl.com /fyi-lighting-ladder-accidents.html](http://www.emsifl.com/fyi-lighting-ladder-accidents.html)). An article from Barrett Miller, MEd, OHST, shows that the Consumer Product Safety Commission reports that more than 90,000 people receive emergency room treatment for ladder accidents each year ([www.safetyengineer.com/ladder.htm](http://www.safetyengineer.com/ladder.htm)). In all, 111,300 persons were injured in elevated falls in 1994.



**Figure 1.4** (a), (b) and (c) Example of ladder accident that happen during work ([www2.worksafebc.com](http://www2.worksafebc.com))

Lastly, by using an unsafe design of ladder, it will cause financial loss to individual and the company where there working. The images and credibility of company whose involves in ladder accident can be contaminating. The direct compensation and medical treatments associated with falls from elevation cost American businesses \$4.6 billion, according to Liberty Mutual's 2005 Workplace Safety Index ([www.occupationalhazards.com](http://www.occupationalhazards.com)). The indirect costs associated with increased absenteeism, worker replacement and productivity loss can cost up to two times as much, according to a recent survey of corporate financial decision-makers ([www.occupationalhazards.com](http://www.occupationalhazards.com)).



**Table 1.1: Odds of Death Due to Injury, United States, 2003**

Type of Accident or Manner of Injury	Deaths	One Year Odds	Lifetime Odds
Fall on same level from slipping, tripping, and stumbling, W01	597	487,186	6,278
Other fall on same level, W00, W02-W03, W18	3,896	74,653	962
Fall involving bed, chair, other furniture, W06-W08	838	347,076	4,473
Fall on and from stairs and steps, W10	1,588	183,155	2,360
Fall on and from ladder or scaffolding, W11-W12	417	697,482	8,988
<u>Fall from out of or through building or structure, W13</u>	<u>600</u>	<u>484,750</u>	<u>6,247</u>
Other fall from one level to another, W09, W14-W17	701	414,907	5,347

(Table 1 taken from <http://www.nsc.org/lrs/statinfo/odds.htm>)

Assume that the same statistics and situation of ladder accident is happened in Malaysia. According to Occupational Safety and Health Act (OSHA) research, they concluded that 100% of ladder accidents might be eliminated with proper attention to the application of equipment, and the proper training of climbers. Human failure causes most ladder falls, but the preventable error is often administrative, not the fault of the victim. All the statistics showed that the portable ladder that we used nowadays was not safe.

The design and mechanism of ladder is not safe for application either for domestic or in working places. We must think about a new design and mechanism of ladder which provide more stable and safer ladder and decrease the large amount of ladder accident happened. So, this project proposes a development of new mechanism of ladder to ensure that we are in safe condition during works. Then, work can be done safely without an accident.

## 1.2 Problem Statement

Nowadays, many ladder accidents were happened causing by using a portable ladder which is unstable and unsafe of design and mechanism. These mechanical problems can influence our health and life. So, this project is to develop and design a new mechanism of ladder which is stable and safe to apply without worry about an accident. There are six problems or factor that's making or causing a ladder unstable and unsafe to use:

- i. The ladder is easy to slips out of its position. From the article on 21 November 2005, at <http://www.occupationalhazards.com>, the ladder base may slips out of position when the ladder is at wrong angle, workers climb too fast or the surface below the ladder is wet, bumpy or uneven. Ladder must be use at exactly preferred angle. Liberty Mutual researchers found that adjusting a ladder's angle a mere 10 degrees from 75 to 65 degrees almost doubles the friction required to hold the ladder in place. If you increase the worker's climbing speed, the friction required jumps again by 7 percent. However, in the real world, most workers have no way to measure ladder angle. In fact, several studies show that when workers set up a ladder at 75 degrees without a measurement device, resulting angles vary from 67.3 to 76.2 degrees. This condition can cause a ladder accident. The slip resistant feet also cannot work properly if the angles are wrong or the floor is in slippery condition.
- ii. Nowadays, ladders are less of stability during their applications. For example, we have to be careful for the whole of a job when using the ladder. We need to balance our body position on the ladder which has to limit our motions and movements. It's hard to make two jobs instantaneously. This situation will increase the probability of ladder accident.
- iii. All ladders today required the user to climb on it. We may lose our step or stability during climbing up the ladder especially when carrying a tools or materials. So this condition exactly will influence the users balancing and causing the ladder not stable and safe in design and mechanism. There are

many ladder accidents occur because of the ladder has not been secured and starts to slip. An unsecured ladder is often made more unstable by the practice of climbing while carrying loads and of overreaching and overbalancing ([www.consultnet.ie/Working%20at%20 Heights.Htm](http://www.consultnet.ie/Working%20at%20 Heights.Htm)). Climbers are frequently hit by passing carts, cars and even trains ([www.safetyengineer.com/ladder.Htm](http://www.safetyengineer.com/ladder.Htm)).

- iv. In some cases, federal codes require spotters and barricades. Ladders propped on top of another object to gain height or convenience often move. If the floor surface or the upper surface is slippery, the ladder may slide away from the climber ([www.safety-engineer.com/ladder.htm](http://www.safety-engineer.com/ladder.htm)). That's why the ladder mechanism is not safe to apply.
- v. When we climb up the ladder, an increasing of height level is constant due to the distance between the rungs of the ladder. We cannot reach the exactly height. Fixed height problem that occurs tends user to make much movement on the ladder in order to reach the desired level. This situation will make the ladder less stability and unsafe to use.
- vi. We also must fit a suitable dress such as a suitable shoe to prevent slippery or an accident. Grease, ice, mud, snow or water on the rungs can cause slips and falls if we do not used suitable shoes. Other than that, ladders which are badly positioned or set on uneven or unstable bases are also common factors in accidents ([www.consultnet.ie/Working %20at%20 Heights.htm](http://www.consultnet.ie/Working %20at%20 Heights.htm)).

All the condition causes a design and mechanism of ladder in unstable and unsafe condition. We cannot let this problem continuing and let the number of people suffering with ladder accident increasing without and taking an action to prevent on it. We have to take responsibility to solve the problems. Then, this project is to design and develop a new mechanism of ladder which is more stable and safe to be used.

### 1.3 Project Objectives

There are three objectives should be achieved from this project:

- i. To design a new safer ladder mechanism that is high stability and portable. For example, the ladder that we design uses different mechanism which not require user to climb on it. This will increase the stability of the ladder.
- ii. To analyze the new ladder design with a software. The software of SolidWorks and Algor will be applied for this project. The analyzing is to show the result of the structure of new ladder mechanism and proves whether the design is satisfy the desired objectives.
- iii. To fabricate and test the prototype of ladder new mechanism. The fabrication processes apply the conventional machining in faculty lab. The test run analysis of the new ladder mechanism done by apply load and try to lift it up. It will show whether the mechanism design can works effective and smooth or any problem occurs.

### 1.4 Project Scopes

- i. This project only fabricates the prototype of ladder only. The material that uses during fabrication process is not the recommended material. The mechanism parts also are not in original sizes. Otherwise, the shape and design of each part is closely similar with the original design. Since we only fabricate the prototypes, during the test section, the maximum load apply is lower than what we expect for the exact design.
- ii. This new design of ladder mechanism can reach maximum 2 meters only. The parameters and design of each part depends on these scopes. A mechanism which clearly can reach this scope level is select and chosen.

- iii. This new design of ladder mechanism is suitable for adults above 15 years old only. The shape and sizes of the design will consider for people above 15 years only. Energy and force requirement for the ladder mechanism suitable for people above 15 years.
- iv. This new design of ladder mechanism not for heavy-duty work. The design and selection of material element and parameters depends on this scope which can undergo light-duty work only. The cost and processing time can be decreasing due to this scope.
- v. This new design of ladder mechanism is suitable for domestic application only. Since the function is for light-duty work, we expect that this new ladder design suitable used indoor task such change lighting, wiring, or for painting in our home or room. So, home is the best place to apply this new design of ladder mechanism.
- vi. The user weight for this new design of ladder mechanism cannot exceed 80 kg. The design of the part element, joint and stability are not suitable for a person that has weight above 80 kg.

## **CHAPTER 2**

### **SURVEYING OF MECHANISM FOR A NEW LADDER DESIGN**

#### **2.1 Introduction**

This chapter will presents briefly about the surveying of the variety mechanism which can transfer a rotational motion into a linear motion in order to select as the new mechanism of ladder. This chapter also elaborates how that's mechanism works, their advantages and limitations. In the end of this chapter, we will summarize entirely all of the mechanism and proposed the most potential mechanism to be applied for this project.

#### **2.2 Definition of Terms**

##### **2.2.1 Machine**

From the Cambridge Advanced Learner's Dictionary, machine is define as a device with several moving parts which uses power to do a particular type of work. Machine also defines as a device to alter, transmit and direct force to accomplish desired objectives (Myszka, 2005). Machine refers as an apparatus that transmit energy through its pars to perform a desired task (Cleghorn, 2005). Machine also can be defines as system of element which is arranged to transmit motion and energy in a predetermined fashion. A machine typically contains mechanisms which are designed to provide significant power (Norton, 2001).

Other than that, the definition of machine is as an assemblage of parts that transmit force, motion and energy in a predetermined parameter ([www.engr.utexas.edu/dteach](http://www.engr.utexas.edu/dteach)). A machine also known as a combination of rigid bodies formed and connected so that they move with definite relative motions and transmit force from the power source to the resistance to be overcome ([www.engr.utexas.edu/dteach](http://www.engr.utexas.edu/dteach)).

### 2.2.2 Mechanisms

A Cambridge Advanced Learner's Dictionary defines mechanisms as a part of a machine, or a set of parts that work together. Mechanism is an assemblage of rigid member connected together by joints (Waldron and Kinzel, 2003). Mechanisms transfer motion and mechanical work from one or more actuators to another output members. For purpose, mechanism to kinematic linkage in which all members are assume perfectly rigid and connected by joints (Waldron and Kinzel, 2003).

Mechanisms also can be defines as a mechanical portion of machine that functions to transfer motion and forces from sources to output. Mechanism also considered as the arrangement of rigid parts that connected to produce the desired motion of machine (Myszka, 2005). For example, the purpose of mechanism to lift a platform is a machine such a lifting load.

Other than that, in kinematics, a mechanism is a means of transmitting, controlling, or constraining relative movement ([www.engr.utexas.edu/detach](http://www.engr.utexas.edu/detach)). The term of mechanism is applied to the combination of geometrical bodies which constitute a machine or part of a machine. So, a mechanism may therefore be defined as a combination of rigid or resistant bodies, formed and connected so that they move with definite relative motions with respect to one another. ([www.engr.utexas.edu/dteach](http://www.engr.utexas.edu/dteach))

Mechanism is a device which is transforms a motion to some desired pattern and typically develops very low forces and transmits little power (Robert L. Norton, 2001). The commonly definition of mechanism is a system of elements arranged to transmit motion in a predetermined output (Robert L. Norton, 2001). Movements which are electrically, magnetically, pneumatically operated are excluded from the concept of mechanism. The central theme for mechanisms is rigid bodies connected together by joints.

### **2.2.3 Machine and Mechanism**

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There are no clear-cut divider between machine and mechanism. They differ in degree rather than in kind. If the forces and energy levels within the device are significant, it will considered machine; if not, it considered a mechanism (Robert L. Norton). The similarity between machines and mechanisms is that they are both combinations of rigid bodies and the relative motions among the rigid bodies are definite([www.engr.utexas.edu/dteach](http://www.engr.utexas.edu/dteach)).The difference between machine and mechanism is that machines transform energy to do work, while mechanisms so not necessarily perform this function ([www.engr.utexas.edu/detach](http://www.engr.utexas.edu/detach)). The term machinery generally refers to machines and mechanisms.

### **2.2.4 Joint**

From Cambridge Advanced Learner's Dictionary, joint means a place where two things are fixed together. Joint also defines as a connection between two or more links (at their nodes), which allows some motion, or potential motion, between the connected links (Robert L. Norton, 2001). Joints can be classified in four ways:

- i. by the type of contact between element, line, point, or surface.