DESIGN AND DEVELOPMENT OF PORTABLE PINEAPPLE PEELER: AN ERGONOMICS APPROACH

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2010

AHMAD HISYAM MOHAMAD BACHELOR OF MECHANICAL ENGINEERING 2010 UMP

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **DESIGN AND DEVELOPMENT OF PORTABLE PINEAPPLE PEELER: AN ERGONOMICS APPROACH**

SESI PENGAJIAN: 2010/2011

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DESIGN AND DEVELOPMENT OF PORTABLE PINEAPPLE PEELER: AN ERGONOMICS APPROACH

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

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DECEMBER 2010

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I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Dedicated to my beloved family & friends

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation and sincere gratitude to my supervisor, Madam Nurul Shahida Binti Mohd Shalahim, for her wisdom, invaluable guidance and professionalism from the beginning to the end in making this research possible. Madam Nurul Shahida has been an excellent mentor and has provided continuous encouragement and constant support throughout my project. It should be recognized that the success of this thesis was through her cooperation and assistance from the initial to the final level which enabled me to develop an understanding of the subject.

I also would like to extend my heartiest thanks to my colleagues who have rendered assistance and support in one way or another to make this study possible. My gratitude also goes to the staff of the UMP Mechanical Engineering Department, especially Mr Imran Sairaji, the person in charge for the Rapid Prototyping. I am grateful for their support and invaluable help.

Special thanks to my beloved parents and siblings whose endless support and understanding have been profound throughout the difficult times of this project. Without your love and support I am sure that I would not have been able to achieve so much. Lastly, it is a pleasure to thank those who supported me in any respect during the completion of the project. Without the generous help of these individuals, this research would not have been possible.

ABSTRACT

This thesis is about designing a portable pineapple peeler using ergonomics approach in order to avoid or minimize the risk of developing Musculoskeletal Disorders (MSD) among workers in pineapple industry. The workers especially in the small and medium enterprise still use the manual technique to peel the pineapple. MSD happens due to the products or tools that is not ergonomics. Some of physical activity risk factors related to MSD are application of force, repetitive movement and awkward posture. Working tools that is not ergonomics combining with the physical activity will results in MSD to develop and resulting pain in a long term period. There are three objectives for this study. The first objective of this study is to design a portable pineapple peeler with ergonomics approach using SolidWorks. The second objective is to make a prototype of the designed pineapple peeler using Rapid Prototyping (RP) and the third objective is to simulate the designed pineapple peeler using Algor Simulation software. While performing this project, the exclusions and the things known but not attempted to solve are the developed pineapple peeler is only prototype and is not readily functional as a commercial product and the simulation of the pineapple peeler using Algor Simulation software is considered precise. In designing process, two designs with different handle diameter were developed using SolidWorks. The design with handle diameter of 50 mm has been named as Design A while the design with handle diameter of 38 mm has been named as Design B. The designs have been analyzed using Algor Simulation software to evaluate the force distribution on the critical part of the pineapple peeler when it is used by the workers. Based on the results of the simulation, both Design A and Design B can withstand the extended allowed number of force. However, Design A can withstand higher forces and provides higher level of safety to the user compared to Design B. Thus, the chance to prevent MSD from occurring by applying Design A is higher than Design B. In the end, it can be decided that Design A should be used in designing the portable pineapple peeler. The usage of ergonomics in producing a product will helps to save life. The MSD will affect people in long term period and before they know it, it has gotten worst. Thus, the designed pineapple peeler will minimize and reduce the risk of having MSD among workers in pineapple industry.

ABSTRAK

Tesis ini adalah berkenaan merekabentuk pengupas nenas mudah alih menggunakan pendekatan ergonomik bagi mengelakkan atau mengurangkan risiko kejadian *Musculoskeletal Disorders* (MSD) di kalangan pekerja industri berasaskan nenas. Pekerja terutamanya di industri kecil dan sederhana masih mengamalkan teknik manual untuk mengupas nenas. MSD berlaku disebabkan oleh produk atau alatan bekerja yang tidak ergonomik. Antara aktiviti fizikal berisiko yang berkaitan dengan MSD adalah penggunaan daya, pergerakan berulang dan postur yang janggal. Alatan bekerja yang tidak ergonomik ditambah pula dengan aktiviti fizikal berisiko akan menyebabkan MSD berlaku dan membawa kepada kesakitan dalam jangka masa panjang. Terdapat tiga objektif bagi kajian ini. Objektif pertama kajian ini adalah merekabentuk pengupas nenas mudah alih dengan pendekatan ergonomik menggunakan perisian *SolidWorks*. Objektif kedua adalah menghasilkan prototaip pengupas nenas mudah alih yang telah direkabentuk dengan menggunakan proses *Rapid Prototyping* (RP) dan objektif ketiga adalah mensimulasikan penggunaan pengupas nenas mudah alih yang telah direkabentuk dengan menggunakan perisian simulasi *Algor*. Ketika menjalankan projek ini, pengasingan dan perkara yang telah diketahui tetapi tidak cuba untuk diselesaikan adalah pengupas nenas yang telah direkabentuk hanyalah prototaip dan tidak bersedia untuk berfungsi sebagai produk komersial dan simulasi pengupas nenas dengan menggunakan perisian simulasi *Algor* adalah tepat. Dalam proses merekabentuk, dua bentuk dengan diameter pemegang berbeza telah direka menggunakan *SolidWorks*. Bentuk dengan diameter pemegang 50 mm dinamakan Bentuk A manakala bentuk dengan diameter pemegang 38 mm dinamakan Bentuk B. Bentuk-bentuk itu telah dianalisis menggunakan perisian simulasi *Algor* untuk menilai pengagihan daya pada bahagian kritikal pengupas nenas ketika digunakan oleh pekerja. Berdasarkan kepada keputusan simulasi, kedua-dua Bentuk A dan Bentuk B boleh menahan jumlah daya yang dibenarkan. Walaubagaimanapun, Bentuk A boleh menampung daya yang lebih tinggi dan menyediakan tahap keselamatan yang lebih tinggi kepada pengguna berbanding Bentuk B. Oleh itu, peluang untuk mengelakkan MSD daripada berlaku dengan mengaplikasikan Bentuk A adalah lebih tinggi berbanding Bentuk B. Pada akhirnya, ia boleh ditentukan bahawa Bentuk A harus digunakan dalam merekabentuk pengupas nenas mudah alih. Penggunaan ergonomik dalam menghasilkan produk akan membantu menyelamatkan nyawa. MSD akan memberi kesan kepada manusia dalam jangka masa panjang dan sebelum mereka mengetahuinya, ia telah menjadi sangat teruk. Oleh itu, pengupas nenas yang telah direkabentuk akan mengurangkan risiko mengalami MSD dikalangan pekerja industri berasaskan nenas.

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LIST OF ABBREVIATIONS

CAD	Computer-aided design
CTDs	Cumulative trauma disorders
CTS	Carpal tunnel syndrome
DOSH	Department of Occupational Safety and Health
IEA	International Ergonomics Association
ILO	International Labour Organization
ISO	International Organization for Standardization
LPNM	Lembaga Perindustrian Nanas Malaysia
LPNTM	Lembaga Perusahaan Nanas Tanah Melayu
MMH	Manual materials handling
MSD	Musculoskeletal disorders
NIOSH	National Institute of Occupational Safety and Health
RP	Rapid prototyping
RSIs	Repetitive strain injuries
SME	Small and medium enterprise
SOCSO	Social Security Organization
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Malaysia is one of the world major producers of pineapple other than Hawaii, Brazil, Philippines, Taiwan, Thailand, Australia, Mexico, Kenya, South Africa and Caribbean area. Canned pineapple fruit have high market demand in countries like Japan, United States, European Union, Middle East and Singapore. This industry has the second highest export after watermelon in the tropical fruit category. Before the rise of other commodity, the pineapple industry in Malaysia was the main contributor of the country's economy. This industry played a role in contributing to the country’s economy and provides direct job opportunities in the plantation and processing industry and indirectly in the transportation and manufacturing industry.

Malaysian pineapple industry is supported by the government in aspect of land development policy. The small and medium enterprise (SME) is given priority by the government through the implementation of development and industrial support program. Due to that, Pekan Nenas Johor has been dedicated to grow and produce pineapple product such as jams, pineapple juice and many more. In this industry, the workers still use the traditional peeling method, by using bare hand and knife to peel of the fruit skin. The pineapple skin is thick and it is not easy to peel the skin off. Due to that, after one pineapple is peeled, a person will feel the pain around the hand and the upper body including the arms. The pain that a person experienced is called musculoskeletal disorders (MSD). The peeling process also involved the upper body of a person thus making the body vulnerable to back pain and other MSD symptoms. For workers that repeatedly peel the pineapple, the most infected part would be the hand or known as the carpal. Gripping the tools or knife to peel and also the force experienced by the hand due to the effect of cutting force will eventually resulting in pain around the hand area. This is the reason why the manual work, particularly work involving manual materials handling (MMH) tasks, is a primary cause of MSD in industry.

The pineapple industry has experienced a widely publicized increase in the reported incidence of disorders associated with the upper extremities such as hands, wrists, arms, and shoulders. This increase affects both worker and company. Whether the disorders result from single overexertion or from repeated micro trauma over a period of time, the direct and indirect costs of the disorders are very high. For example, a study of workers' compensation claims initiated in the United States in 1989 found that the mean direct costs of compensable low-back pain cases are approximately $8,300 per claim with medical costs comprising about 32% of the direct costs, and indemnity payments comprising about 68% (Webster and Snook, 1994). There are direct financial costs to the company, such as increased workers' compensation costs and health insurance premiums. The worker feels the cost in lost wages. However, there are also indirect financial costs that are potentially much greater, although they are not as easily documented. They include high turnover and absenteeism rates, increased training requirements, as well as the reduced efficiency and decreased product quality that go along with continually changing personnel.

For a company that involves a lot of their employees working for long hours such as in the pineapple industry, ergonomics is something that they would ideally take into consideration. Ergonomics on a big scale can have a striking effect on employees working for long hours. This is where ergonomics is considered and can aid such issues and allow the employees to work more comfortable, and also more efficiently. Many injuries and illness could be prevented if hand tools were designed or redesigned to optimize the relationship between the worker and hand tool. Improvements in job design, proper selection of hand tools, and implementation of safe operating procedures can further reduce the incidence of hand tool-related injuries and illnesses especially MSD.

1.2 PROBLEM STATEMENT

This project is to prevent the musculoskeletal problems among workers who manually peel the pineapple. Currently, there are very few studies have been done for such a function. A pineapple peeler will be designed by adapting the ergonomics criteria. In doing this, some of the problems associated with the musculoskeletal disorders are tackled. Other problems are not tackled in the duration of this project.

1.3 PROJECT OBJECTIVES

The objectives of this study are:

(i) To design a portable pineapple peeler with ergonomics approach using SolidWorks.
(ii) To make a prototype of the designed pineapple peeler using Rapid Prototyping (RP).
(iii) To simulate the designed pineapple peeler using Algor Simulation software.

1.4 PROJECT SCOPES

Without considering unforeseeable problems that might crop up later, these are the exclusions and the things known but not attempted to solve:

(i) The developed pineapple peeler is only prototype and is not readily functional as a commercial product.
(ii) The simulation of the pineapple peeler using Algor Simulation software is considered precise.

1.5 THESIS ORGANIZATION

There are five chapters in this thesis and each chapter has its' own sub topics. The first chapter introduced the idea of this project. It also contained a brief explanation of the pineapple industry especially in Malaysia and the peeling method used by the workers. The risk faced by the workers such as MSD and the important of ergonomics approach at workplace are discussed as well. The problem statement, project objectives and the scopes of this project are also included in this chapter.

The literature review about the words or terms that are regularly used during this project are discussed in chapter two. Ergonomics, musculoskeletal disorders, pineapple and peeler are the terms that need to be explained according to the established sources such as books, journal articles, websites, technical reports and newspaper articles. The explanation focuses on the history and the definition of the selected terms. The principle of ergonomics and the relation of peeling and MSD are also highlighted in this chapter.

In chapter three, the methods on how the project is conducted were discussed and explained. Each stage of the project such as preliminary design, computer aided design drawing, prototyping and simulation of the design were presented in details. The methodology flow chart is also included in this section.

The result of this project were discussed and analyzed in chapter four. The information that we get from the literature review previously was used to evaluate the data collected from the simulation of the design. The discussion was concentrated on the effectiveness of the performed design from the ergonomics aspect.

In the last chapter, the discussion whether the objective of the project is achieved or not was made. Besides that, the suggestion on how to improve the project and its' product were pointed out. All of the problems occurred during this project was briefly explained and the solution to overcome the problems were included as well.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter contains a review of information about the issues related to this project. The definition of ergonomics, musculoskeletal disorders, pineapple, pineapple peeler and other selected terms will also included in this chapter. All of the information is gathered from books, journals, articles and websites. This literature review not only attempts to collect and categorize previous researches, but also attempted to analyze and evaluate previous works leading to this project's framework.

2.2 ERGONOMICS

2.2.1 History of Ergonomics

We may have just heard the word "ergonomics" in recent years, and as a formal field of study it is relatively new, but the concepts have been around for a long time. In fact, in many ways ergonomics is 40,000 years old, ever since that first humanoid picked up a rock to use as a tool to overcome a human limitation. The 19th Century is particularly full of contraptions that correspond to good application of the principles of ergonomics, even though the word was never used at the time (Macleod, 2006).

Ergonomics developed into a recognized field during World War II, when for the first time, technology and the human sciences were systematically applied in a coordinated manner. Physiologists, psychologists, anthropologists, medical doctors, work scientists and engineers, together addressed the problems arising from the operation of complex military equipment. The results of this interdisciplinary approach appeared so promising that the cooperation was pursued after the war, in industry. Interest in the approach grew rapidly, especially in Europe and the U.S, leading to the foundation in England of the first ever national ergonomics society in 1949, which is when the term ergonomics was adopted. This was followed in 1961 by the creation of the International Ergonomics Association (IEA), which represents ergonomics societies that are active in more than 40 countries or regions, with a total membership of some 19000 people (Dul and Weerdmeester, 2008).

Some experts define the objective of ergonomics and human factors engineering as designing machines to fit human operators. However, it is also necessary to fit operators to machines in the form of personnel selection and training. It is probably more accurate, then, to describe this field as the study of human-machine systems, with an emphasis on the human aspect (Lehto and Buck, 2008).

2.2.2 Ergonomics Definition

In 2000, the council of the International Ergonomics Association have been approved that ergonomics or human factors is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system performance (Chaikumarn, 2005).

Ergonomics emphasizes designing the workplace to fit the employee rather than the employee fitting the workplace. Table 2.1 shows various definitions of ergonomics. From the previous research, we can conclude that ergonomics is an approach which puts human needs and capabilities at the focus of designing technological systems. The aim is to ensure that humans and technology work in complete harmony, with the equipment and tasks aligned to human characteristics.

Table 2.1: Various definitions of ergonomics

Year	Title	Author	Content
1996	Occupational Ergonomics : Theory and Applications	Amit Bhattacharya, James D. McGlothlin	The ability to apply information regarding human character, capacities, and limitations to the design of human tasks, machines, machine systems, living spaces, and environment so that people can live, work, and play safely, comfortably, and efficiently.
2006	Extra-Ordinary Ergonomics	Karl H.E. Kroemer	I use the term ergonomics to encompass all the deliberate efforts to design the world around us that it fits and accommodates human beings, in order to make our daily life and the performance of tasks safe, efficient, and easy. Accordingly, ergonomics is the application of scientific principles, methods, and data drawn from a variety of discipline to the design of engineered systems in which people play a significant role.
2008	Introduction to Human Factors and Ergonomics for Engineers	Mark R. Lehto, James R. Buck	The term “ergonomics” connotes diverse body knowledge about human abilities, limitations, and other uniquely human characteristics which are relevant to design.
2009	Introduction to Ergonomics (Third Edition)	R.S. Bridger	Ergonomics is the study of the interaction between people and machines and the factors that affect the interaction. Its purpose is to improve the performance of systems by improving human-machine interaction.

Practitioners of ergonomics, ergonomists, contribute to the planning, design and evaluation of tasks, jobs, products, organizations, environments and systems in order to make them compatible with the needs, abilities and limitations of people. In recent years, ergonomists have attempted to define postures which minimize unnecessary static work and reduce the forces acting on the body. In Figure 2.1, the "neutral posture" is recommended for a person who is using the computer as working tools. It shows how the seating and the workers position is adjusted according to ergonomics principle. The worker's seating position should be a series of right (90 degree) angles. For example the knees should be at a right angle, so should the hips and legs, and the elbows. It also shows that the screen should be at eye level and at a comfortable distance, usually about the same distance as the position of the hands for. From this figure, we realized that there are a lot of factors must be concerned to prevent occupational diseases such as MSD.

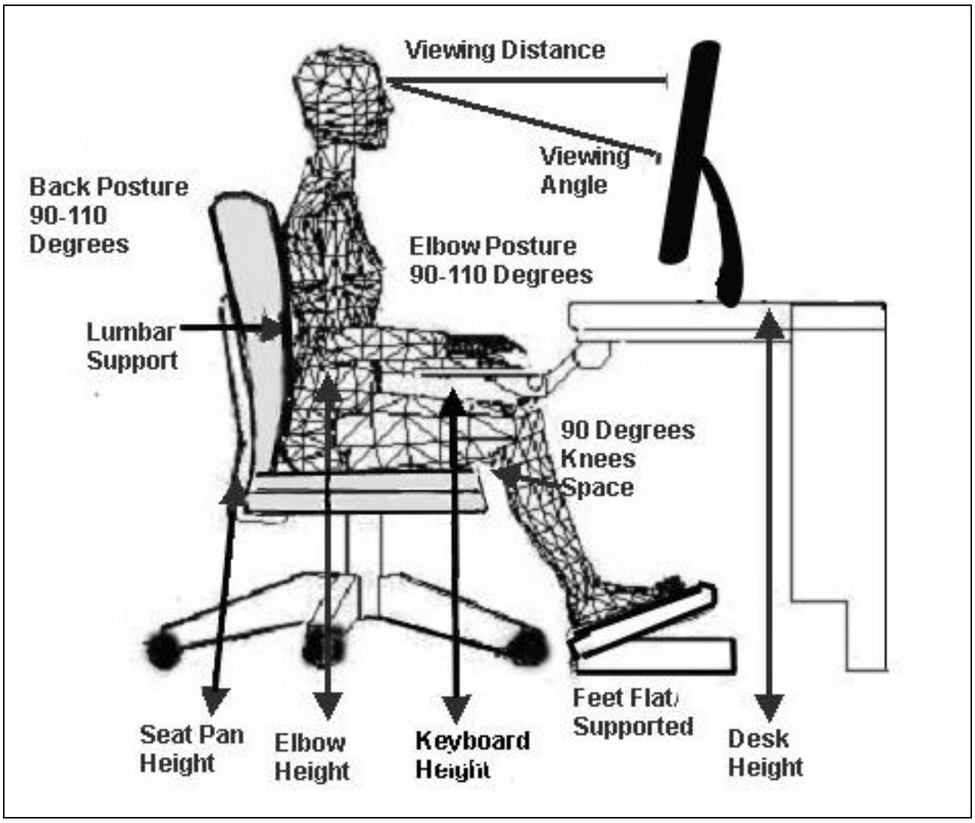

Figure 2.1: Neutral seated position

Source: http://uabf.asu.edu/ergonomics/February 2010

Malaysia has several national agencies collecting data on occupational accidents and diseases. The Department of Occupational Safety and Health (DOSH) under the Ministry of Human Resources, the National Institute of Occupational Safety and Health (NIOSH), the Occupational Health Unit under the Ministry of Health, the Social Security Organization (SOCSO), the Department of Labor and other agencies all collect surveillance data related to occupational health. Table 2.2 displays the number and types of occupational diseases reported to SOCSO in the years 1999, 2002 and 2003. The numbers of work-related diseases are small compared to occupational accidents, and may reflect underreporting due to failure to recognize the work-relatedness of medical diagnoses, non-reporting of diagnosed occupational diseases to the appropriate agencies or failure to capture occupational morbidities occurring among workers in small and medium-sized enterprises and the informal economy.

Table 2.2: Occupational diseases reported to SOCSO

Occupational Diseases	**Year**		
	1999	**2002**	**2003**
Cancer	61	65	86
Noise induced hearing loss	8	59	1
Respiratory disease	14	17	8
Skin disease	40	10	5
Musculoskeletal disorders	1	8	0

Source: Hashim et al. (2005)

We must always aware and take the effective ways to avoid these occupational diseases especially MSD from occurring. For this project, we are required to design a pineapple peeler by implementing the ergonomics approach. In order to come out with the best result, the design must obey the principles of ergonomics.

2.2.3 Principles of Ergonomics

To assess the fit between people and their technological tools and environments, it takes account of the ergonomics principles. The principles are safety, comfort, ease of use, productivity or performance, and aesthetics (Dul and Weerdmesster, 2001).

The first principle is safety and considered as the most important one. Safety includes the working environment and also the working tools. For working environment, a safe environment is essential. Many factors need to be considered to make workplaces safe and without unnecessary risks to health. Some of the factors are cleanliness, space and lighting. Premises and fittings should be kept clean and maintained good standards of housekeeping while each employee must have sufficient working space to enable them to do their work safely and without risks to their health. A good standard of general illumination should be provided and sustained by regular cleaning and maintenance. Certain work activities such as work with display screens, machinery and very close work require special attention to lighting. For working tools, they must be freedom from danger, injury, or damage under reasonable conditions by all who may be expected to handle, use, or operate them.

The second ergonomics principle is comfort. Comfort is significant aspect in designing a product. In market view, users always choose to buy products with physically comfortable. Comfort environment such as proper ventilation, comfortable working temperature and sufficient toilet accommodation tends to motivate the workers to work hard. Furthermore, it can relax the workers and release the stress that can cause ergonomics failure among the workers. Vibration is another common problem that can benefit from evaluation. As an example, vibrating tools can be dampened. Working accessories like chair, work bench, tooling apparatus are also need to be comfortable to be used. If the workers need to adjust the chair for a certain period of time before starting the work, this will cost the time of productivity for the company. For a big company that involves a lot of their employees working long hours on a computer, ergonomics is something that they would ideally take into consideration. Ergonomics on a big scale can have a striking effect on employees working long hours on a computer. For example, employees working on computer for long hours may face problems which can include discomfort in posture and loss of concentration. This is where ergonomics is considered and can aid such issues and allow the employees to work more comfortable, and also more efficiently.

Another principle is ease of use. The definition of usability in the ISO 9241 standard is the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use. This definition can be expanded, and made more comprehensive, by including five characteristics which must be met for the users of a product. They are effective, efficient, engaging, error tolerant and easy to learn. Effectiveness is the completeness and accuracy with which users achieve specified goals. It is determined by looking at whether the user’s goals were met successfully and whether all work is correct. It can sometimes be difficult to separate effectiveness from efficiency, but they are not the same. Efficiency is concerned primarily with how quickly a task can be completed, while effectiveness considers how well the work is done. An interface is engaging if it is pleasant and satisfying to use. The visual design is the most obvious element of this characteristic. The style of the visual presentation, the number, functions and types of graphic images or colors especially on web sites, and the use of any multimedia elements are all part of a user’s immediate reaction. Another characteristic is error tolerant. The ultimate goal is a system which has no errors. But, product developers are human, so errors may occur. An error tolerant program is designed to prevent errors caused by the user’s interaction, and to help the user in recovering from any errors that do occur. Easy to learn is also important characteristic in ease of use. Learning goes on for the life of the use of a product. Users may require access to new functionality, expand their scope of work, explore new options or change their own workflow or process. These changes might be instigated by external changes in the environment, or might be the result of exploration within the boundary.

Ergonomic workstations are created to enhance employee productivity and performance through increased alertness, and improved health and comfort. Increasing differentiation in the workplace leads manufacturers to offer workstations that meet the key requirements of functional and ergonomic performance. Studies by leading health and safety experts have repeatedly emphasized the health and productivity benefit of changing one’s work posture from time to time during the day. For example, height adjustable ergonomic office desk and chairs not only increase comfort, but also supports your commitment to providing a safe, comfortable and productive environment that is responsive to individual needs. In today’s increasingly diverse competitive market, a more ergonomically sound workstation is one of the essential ways to attract and retain employees.

The final principle of ergonomics is aesthetics. The term 'aesthetics' concerns our senses and our responses to an object. If something is aesthetically pleasing to us, it is 'pleasurable' and we like it and vice versa. Aesthetics involves all of our senses such as vision, hearing, touch, taste, and smell and our emotions. At the aesthetic level, we consider a product’s capacity to delight one or more of our sensory modalities. A product can be beautiful to look at, make a pleasant sound, feel good to touch, or even smell nice. The degree to which a perceptual system manages to detect structure, order, or coherence and assess a product's familiarity typically determines the affect that is generated (Desmet and Hekkert, 2007). While designing a product, There are four different 'pleasure types' to consider:

(i) Physio-pleasure - pleasure derived from the senses from touch, smell and sensual pleasure.
(ii) Socio-pleasure - pleasure gained from interaction with others.
(iii) Psycho-pleasure - pleasure from the satisfaction felt when a task is successfully completed. Pleasure also comes from the extent to which the product makes the task more pleasurable.
(iv) Ideo-pleasure - pleasure derived from entities such as books, art and music. This is the most abstract pleasure.

Outside of the discipline itself, the term 'ergonomics' is generally used to refer to physical ergonomics as it relates to the workplace. Workplaces may either take the reactive or proactive approach when applying ergonomics practices. Reactive ergonomics is when something needs to be fixed, and corrective action is taken. Proactive ergonomics is the process of seeking areas that could be improved and fixing the issues before they become a large problem. Problems may be fixed through equipment design or task design. Equipment design changes the actual, physical devices used by people. Task design changes what people do with the equipment. Environmental design changes the environment in which people work, but not the physical equipment they use. Table 2.3 shows recent studies on ergonomics.

Table 2.3: Recent studies on ergonomics at work

Year	**Title**	**Author**	**Content**
2001	Applied Ergonomics	David C. Alexander, Randall A. Rabourn	Covers a range of topics related to applications in engineering, medicine, and health and safety.
2006	Extra-Ordinary Ergonomics	Karl H.E. Kroemer	Explores designing for population groups that do not meet the customary standards in age, size &

Table 2.3: Continued

Year	Title	Author	Content
			abilities. This book also illustrates various approaches to measuring the characteristics, capabilities, and limitations of those who differ from the norm.
2006	Ergonomics Experiment for Thumb Keyboard Design	Xiong Yunfei	Study on how to improve the already made products, implement ergonomics principle on the product.
2009	Vibration Reduction of Pneumatic Percussive Rivet Tools: Mechanical and Ergonomic Re-design Approaches	John G. Cherng, Mahmut Eksioglu, Kemal Kizilaslan	Presents a systematic design approach to ergonomic re-design of rivet tools. The investigation was carried out using both ergonomic approach and mechanical analysis of the rivet tools dynamic behavior.

Ergonomics in the workplace has to do largely with the safety of employees, both long and short-term. Ergonomics design will prevent occupational disease such as MSD and many more in working area. Thus it can help reduce costs by improving safety. This would decrease the money paid out in workers' compensation. For example, over five million workers sustain over extension injuries per year. Through ergonomics, workplaces can be designed so that workers do not have to overextend themselves and the manufacturing industry could save billions in workers' compensation.

2.2.4 Principles of Handle Design

In order to design the portable pineapple peeler using ergonomics approach, the most important part is the handle part. The design of the handle must be compliance to several aspects such as:

(i) Grip type
(ii) Grip shape
(iii) Grip size
(iv) Grip material

The first aspect that must be considered in designing the handle is the grip type. It is important to know that there are many types of grips used when holding objects. The best type of grip for a tool depends upon its function. One common grip is power grip, used to hold tools involving large force exertion. In all power grips, the fingers are wrapped around the handle and the thumb place over the first finger, but the force may be applied in different directions relative to the forearm. Regardless of the direction the force is applied, a large portion of the hand surface is placed in contact with the tool handle. This allows forces and impacts to be distributed over the entire hand. Power grip involves large muscle groups, whereas a precision grip involves smaller muscles. There are some situations that require a combination of precision and power grip for example, when serving in tennis. In industrial work, such combination grips are not recommended because the use of control muscles which are smaller, to produce power can accelerate fatigue (Mital and Kilbom, 1992b). Therefore, tool designed primarily for exertion of force, such as hammer, mallets and saws should use a power grip and tool designed for manipulation, such as a surgical knife, should use a precision grip. However, grip design should be based on the maintenance of comfortable finger joint angles for optimum grasping and finger control (Kim et al., 1996). In order for a tool grip to be function, Yun and Freivalds (1995) concluded that it must:

(i) Be able to give the user complete control and manipulation capability.
(ii) Provide the user with a proper surface for exertion the force necessary to operate the tool.
(iii) Minimize the muscle effort needed to maintain this grip for extended period.

The shape and size of hand tools have major effects on both performance and stresses on the upper extremities (Aghazadeh and Mital, 1987). There are steps that can be taken to reduce stresses in the upper extremities and improve performance. Generally, hand tools should be designed to reduce excessive wrist deviation, shoulder abduction, and grip force requirements. Also, they should utilize the proper muscle groups, avoid static loading, and prove finger clearance. The grip shape should maximize the area of contact between the palm and the grip. Maximizing the area of contact leads to better pressure distribution and reduces the chances of forming pressure ridges or pressure concentration areas (Mital and Kilbom, 1992a). This is particularly important for tools that require a power grip. Generally, the tools available in the market have a cylindrical-shape grip. According to Bridger (2009), cylindrical handles are better than handles with finger grooves since these cause pressure hot spots and blistering of the skin of hands they do not fit. Pheasant and O'Neill (1975) reported that the shape of the handle is not relevant as long as the hand did not slip while around it. Since the friction characteristics of tool surface vary with the pressure exerted by the hand, some designers add grooves and indentation to the handle to prevent hand from slipping. The main problem with the grooves is that they do not fit people's different anthropometric measurements, either the grooves are big or small. Therefore, they sometimes cut into the palm and create pressure ridges (Mital and Kilbom, 1992b). In general, grooves and indentations are undesirable (Mital and Karwowski, 1991). Slight and uniform surface indentations, however, are desirable as they allow greater torque exertion capability (Tichauer and Gage, 1977). Pheasant and O'Neill (1975) found that screwdrivers with cylindrical and knurled surfaces provided greater torque exertion capability than smooth-surface cylindrical handles due to the increase in friction at the hand-handle interface. Guards in front of the grip can prevent injury when the hand slips or when the hand and tool collide against a rigid surface. The guard, in such cases, prevents the hand from slipping and shields the hand against the impact. This protection can be obtained by enlarging the grip cross section in front of the hand position. When users pull the tool towards them, similar features can be provided to keep the tool from slipping out of the hand if the gripping force is relaxed. That is, the grip behind the hand can be made larger. According to Cochran and Riley (1986), guards of 15.2 mm height provide adequate safety.

When deciding the optimum grip size, the diameter and length of the handle are considered as the important elements to be focused on. The handle size effect was found to be statistically significant with the larger handle most often resulting in higher torque strength (Deivanayagam and Sethi, 1993). Up to a certain grip diameter, grip strength increases with grip diameter, but beyond a certain point the grip strength starts decreasing as the grip diameter increase (Mital and Kilbom, 1992b). Herzberg (1973) reported an increase in grip strength with grip diameter up to 65 mm and then a decrease. Pheasant and O'Neill (1975) investigated handle design in a gripping and turning task. They found that strength deteriorated when handles greater than 50 mm in diameter were used and that, to reduce abrasion of the skin, hand-handle contact should be maximized. Johnson (1988) investigated the design of powered screwdrivers in relation to operator effort and concluded that grip diameters should be at least 50 mm. According to Petrofsky (1980), the optimum hand grip span should be between 50 to 60 mm. Greenberg and Chaffin (1977) recommended that a power grip diameter between 50 and 85 mm preferably 50 mm. Ayoub and LoPresti (1971) found a grip diameter of 50 mm produced minimum electromyographic (EMG) activity. Pheasant and O'Neill (1975) reported that, for screwdrivers, increasing the diameter from 18 to 40 mm enables a power grip to generate greater force. A grip shape that is circular or oval with a diameter of 31 to 44 mm is recommended (Attwood et al., 2004). All the hand and fingers should comfortably fit onto the grip. Eastman Kodak Company (1983) recommended a power grip diameter of 40 mm. The Technical Research Center of Finland (1988) circular handles should be between 28 and 38 mm in diameter. For powered screwdrivers, Johnson and Childress (1988) recommended grip diameter is 38 mm. This recommendation was based on EMG activity that was lower for the 38 mm grip diameter compared to the 28 mm grip diameter for a screwdriver. Based on anthropometric data, Konz (1990) recommended a minimum grip length of 102 mm preferably 127 mm grip length. The Technical Research Center of Finland (1988) suggested that the handle length should be at least 100 mm. Eastman Kodak Company (1983) recommended a grip length of 122 mm. Handle lengths should be at least 115 mm plus clearance for large (95th percentile) hands and an extra 25 mm should be added if gloves need to be allowed for (NIOSH, 1981). Lindstrom (1973), on the other hand, recommended a handle length of 112 mm for men and 102 mm for women. In reality, it is impractical to provide different handle length tools for the same work done by males and females. In general, the grip length should be selected to avoid excessive compressive forces or pressure on the tender parts of the palm in a way that would not limit the tool head opening.

The grip is where the hands and fingers apply force to the tool, so it should be covered with a soft material that reduces hard edges and pressure points. Konz (1990) recommended the use of compressible grip material that dampens vibration and allows better distribution of pressure across the palm or grip contact area. Either wood or medium hard rubber is recommended. In general, metallic handles should either be avoided or encased in a rubber or plastic sheath. Mital and Karwowski (1991) indicated that the grip material should not absorb oil or other liquids and should not permit conduction of heat or electricity.

2.3 MUSCULOSKELETAL DISORDERS

Work-related musculoskeletal disorders are impairments of bodily structures such as muscles, joints, tendons, ligaments, nerves, bones and the localized blood circulation system, that are caused or aggravated primarily by work and by the effects of the immediate environment in which work is carried out (European Agency for Safety and Health at Work, 2007).

Repetitive tasks are of interest to ergonomists because of their potential to cause musculoskeletal pain, to cause injuries, or to make the pain worsen from existing musculoskeletal conditions (Bridger, 2009). There is a variety of conditions, differing greatly in the extent that they are work related, all of which are characterized by musculoskeletal pain. At one extreme, certain shoulder, hip, and knee disorders are strongly related to specific work exposures, which, if removed by ergonomic redesign, would greatly reduce the risk.

MSD can affect workers’ productivity and efficiency. This is because when a worker is having MSD, they would not be able to perform to the best of their physical ability. Since physical discomfort could largely affect mental health, efficiency and productivity could well decline. Furthermore, he or she has to take a leave in order to recover from MSD. Individual sick leaves accumulated overtime can affect the total productivity of the workers. The number of days lost from one worker alone won't make such a big decrease in company’s productivity. However if we take into account, all the accumulated absences from all the workers due to sick leaves then the statistics would be quite alarming. The worst case scenario would be the company would have to pay compensation to the workers. Macleod (2006) also stated that the commons MSD symptoms are:

(i) Cumulative trauma disorders (CTDs)
(ii) Repetitive strain injuries (RSIs)
(iii) Occupational overuse symptoms

MSD generally develop over periods of weeks, months, and years. Physical activity risk factors related to MSD includes (Attwood et al., 2004):

(i) Application of force. Higher forces translate into higher loads on the muscles, tendons, and joints, which can quickly lead to muscular fatigue.
(ii) Repetitive motion. This is defined as performing the same motion every 30seconds or less or where 50% of the work cycle involves similar upper extremity motion patterns.
(iii) Awkward posture. An awkward posture requires more muscular force because muscles cannot work as effectively.
(iv) Contact stress. Tools, objects, or equipment that create pressure against the body (usually the hands and arms) can inhibit nerve function and blood flow.
(v) Overall muscular fatigue. Insufficient recovery time between muscular contractions may lead to overall muscular fatigue.

The magnitude of risk associated with a specific quantity of exposure to these factors is not well defined, but there is agreement that exposure to high levels or combinations of these risk factors increase the risk of the MSD. For example, force and repetition are recognized multiplicative factors; that is, if they are simultaneous risk factors, the interaction between them likely results in an increased risk of MSD compared to a single factor. Also, tasks with high repetition and high forces are 14 times as likely to be associated with type of MSD in the wrist called carpal tunnel syndrome (CTS) than low-repetition, low-force tasks (Silverstein et al., 1987).

Because there can be multiple confounded causes of an MSD it is often difficult to determine whether a condition is work or non-work related. The ergonomist’s goal is to identify the most critical risk factors that may be present in the work setting that could aggravate or contribute to the cause of an injury. The critical risk factors are those that the ergonomist believes are most important to address for the best possibility of reducing the risk of an injury.

Formal expectations were established about the programs and the processes that would be used to focus on proactively improving workplace environment and concomitantly reducing the risk of MSD. In order to meet this, company’s performance standard encompasses the following basic tenets (Chengular et al., 2004):

(i) Employees should receive training in basic ergonomics principles. The aspects covered in the training depend on the work environment they have.
(ii) Employees whose activities impact the work environment such as engineers, supervisors, maintenance groups, and health and safety professional should receive in depth training commensurate with their activities.
(iii) Newly designed or modified workplace, processes, and equipment should meet established ergonomics or human factors guidelines.
(iv) A continuous improvement process should be used to reduce fatigue and human error, as well as the risk of injury associated with the existing workplaces, processes or equipment.
(v) Affected employees should be involved in the planning and implementation of changes of workplace, equipment, or processes.
(vi) Reports or work related injuries and illness should be followed up with root cause analyses, and the workplace, process, or equipment should be modified accordingly.

To identify the critical risk factors, an ergonomist conceptually categorizes the physical work activities into two types, those that consist mainly of single exertions involving the entire body and those that are more repetitive and most likely involve more intensive use of the upper body or arms and hands. The physical work activities that involve whole body exertions typically involve carrying or moving an object, so they are called manual handling tasks. The ergonomist uses different approaches for assessing the risk factors depending on whether the task is a manual handling task or a more repetitive task.

Table 2.4: Recent studies on musculoskeletal disorders (MSD)

Year	**Title**	**Author**	**Content**
1998	Ergonomics in Manufacturing	Waldemar Karwowski, Gavriel Salvendy	Provide some case studies on reducing work-related musculoskeletal disorders.
2004	Ergonomics Solutions for the Process Industries	Dennis A. Attwood, Joseph M. Deeb, Mary E. Danz-Reece	Explain that the two primary types of physical work tasks on which to focus in petrochemical operations are manual handling tasks and repetitive tasks. Also includes an overview of the main tools for assessing risk factors in manual handling and repetitive task.
2007	Introduction to Work-related Musculoskeletal Disorders	European Agency for Safety and Health at Work	An integrated management approach is necessary to tackle MSD. This approach should consider not just the prevention of new disorders, but also the retention, rehabilitation and reintegration of workers who already suffer from MSD.
2008	Introduction to Human Factors and Ergonomics for Engineers	Mark R. Lehto, James R. Buck	Explain that muscle strains occur when muscles or tendons are stretched too far. In minor cases, this results in stiffness and soreness. In more severe cases, the muscle may tear or the tendon may tear loose from the bone. This results in intense pain and requires a long time for recovery.
2009	Posture and Muscle Activity of Pregnant Woman During Computer Work and Effect of an Ergonomic Desk Board Attachment	Genevieve A. Dumas, Tegan R. Upjohn, Alain Delisle, Karine Charpentier, Andrew Leger, Andre Plamondon, Erik Salazar, Michael J. McGrath	Comparing posture and muscle activity in the back and upper extremity of late pregnancy and non pregnant controls. The research also evaluates the effect of concave desk board on the back and upper extremity of woman in late pregnancy.
2009	Force in Measurement in Field Ergonomics Research and Application	Stephen Bao, Peregrin Spielholz, Ninica Howard, Barbara Silverstein	Explain the effect of pulling/pulling, lifting, pinch and power gripping, measure force when performing task.

Table 2.4: Continued

Year	Title	Author	Content
2009	Introduction to Ergonomics (Third Edition)	R.S Bridger	Study on measurement of musculoskeletal pain in the workplace.

2.4 PEELING AND MUSCULOSKELETAL DISORDERS

Currently, the most commonly method to peel a pineapple is by using bare hand and knife or known as traditional peeling method. This method requires a person to move their hand up and down by applying force into it. Since the pineapple skin is thick, more forces are needed to be applied by the person. Due to that, after the pineapple is peeled, the person will feel the pain around the hand and the upper body including the arms. The pain that a person experienced is called musculoskeletal disorders (MSD). MSD are the most common work-related health problems in the industrialized world. Physical activity risk factors related to MSD include application of force, repetitive motion, awkward posture, contact stress and overall muscular fatigue (Attwood et al., 2004).

The workers at the pineapple industry including the small and medium enterprise (SME) are the most risky group to suffer from MSD since they still practice the traditional peeling method. The workers perform the same motion to peel the pineapple and for every work cycle, they need to apply some forces. Higher forces translate into higher loads on the muscles, tendons, and joints, which can quickly lead to muscular fatigue. Poorly designed hand tools increase the amount of vibration transmitted to the hands, increase the forces required to operate the tool, and increase the awkward postures and positions taken when using them. Workers who routinely handle tools, parts, and materials subject their hands to a variety of mechanical forces. Forceful exertion, especially if repetitive, can cause damage to underlying structures such as tendons, tendon sheaths, and nerves (Armstrong et al., 1987). Duration and repetitiveness of work can affect muscle efficiency. Mital and Kilbom (1992b) concluded that the duration and repetitiveness of use of hand tool profoundly increase the risk of occupational injury. Working with a high degree of repetitiveness and high manual force exertions the prevalence of carpal tunnel syndrome was 15 times higher than in jobs with low repetitiveness and low force exertions. Chengular et al. (2004) indicated that, for repetitive operations that require finger pinches, keep the forces below 10 Newtons while for gripping actions, keep the required forces to 21 Newtons. These represent that if the forces acting on the hands are higher than 21 Newtons, there will be a chance of MSD to occur. So when using the designed portable pineapple peeler, we must make sure that the forces experienced by the user must not exceed 21 Newtons.

MSD can result in significant suffering, various costs, and decreased productivity and product quality. Therefore, it is important that management take a proactive role in trying to eliminate, or at least minimize these disorders. Although the exact causes of MSD are sometimes difficult to ascertain, risk factors associated with them are fairly well identified in the literature. In addition, several approaches are available to assist the safety or ergonomics specialist in implementing an effective strategy for the identification and control of MSD. By changing the peeling technique from up and down to a cyclic movement, it will ease the hand movement and equally distribute the force around the handle and the hand palm making less force experience around the hand.

2.5 HISTORY OF PINEAPPLE

Pineapples, or *Ananas comosus* in their botanical name, are native to South America, and were named after the resemblance to a pine cone, and the taste of the flesh being similar to an apple's. We have to go back to 1398 to find the first printed reference to its similarity to a pine cone, and the term *pinappel* to define it only appeared in print three centuries later, in 1664. Christopher Columbus and his shipmates saw the pineapple for the first time on the island of Guadeloupe in 1493 (Morton, 1987), during his exploration of the Caribbean, who called it *piña de Indes*, or "pine of the Indies". He brought some of them back to Spain as a gift for Queen Isabella, who apparently was very fond of them, since Spaniards tried to cultivate them with little success. Guarani and Tupi Indians in South America had already cultivated pineapples for centuries, and they called them "nana'" or "anana'", literally meaning "excellent fruit".

In 1903, James Drummond Dole began canning pineapple, making it easily accessible worldwide. Production stepped up dramatically when a new machine automated the skinning and coring of the fruit. The Dole Hawaiian Pineapple Company was a booming business by 1921, making pineapple Hawaii's largest crop and industry. Today, Hawaii produces only ten percent of the world's pineapple crops. Other countries contributing to the pineapple industry include Mexico, Honduras, Dominican Republic, Philippines, Thailand, Costa Rica, China, and Asia.

Pineapple is known as *nanas* locally in Malaysia. The pineapple industry of Malaysia is the oldest agro-based export-oriented industry. The industry is reputed to have started in 1888 by a European in Singapore. It was then brought to Malaya (West Malaysia) particularly Johor since it is geographically located nearest to Singapore. In those days, production of canned pineapple was by no means mechanized and even the tin containers had to be made by hand (Lim, 1973). Since then, from those humble beginnings through a chequered history of destruction and rehabilitation due to war and communist insurgency, the development of the industry to its present position can be regarded as one of the country’s success stories. The pineapple industry in Malaysia is unique because nearly 90% of the crop is planted on peat soil which is considered marginal for most other agricultural crops. In other states such as Kedah, Perak, Kelantan, Terengganu, Negeri Sembilan and Sarawak, pineapples are planted specially for domestic fresh consumption.

On 1957, Lembaga Perusahaan Nanas Tanah Melayu (LPNTM) was established under the 1957 Pineapple Industry Ordinance, currently known as Lembaga Perindustrian Nanas Malaysia (LPNM) / Malaysian Pineapple Industry Board which carries the role to manage and develop Malaysian pineapple industry. With the existence of agency responsible to carry out pineapple industry research and development, Malaysia is capable of producing high quality product that can survive in the mainstream market. Malaysian pineapple industry is supported by the government in aspect of land development policy. The small and medium enterprise (SME) is given priority by the government through the implementation of development and industrial support program. Though relatively small compared to palm oil and rubber, the industry also plays an important role in the country's socio-economic development of Malaysia, particularly in Johor. In 1997, the industry has contributed RM70.53 million to Malaysia's export earnings. The industry provides employment for people in the canneries, estates and small holder families. In addition, it also contributes towards the growth of other supporting economic activities such as tin plating industry, packaging, transportation and labeling.

In their natural form, every variety of pineapple has a rough, diamond-pattern skin. Their tastes vary slightly, though they all basically have the same juicy, tart taste. Depending on variety, the fruit can be up to 30 cm long and weigh more than 4 kg while the averages diameters would be 12 to 15 centimeters (http://www.fama.com.my/April 2010). Pineapples are grown all year long in the warmer climates. The pineapple plant is an herbaceous perennial that grows to be two to five feet high, and three to four feet across. It has a short, thick stem with waxy leaves.

There are basically five different kinds of pineapple, the Kona Sugarloaf, the Natal Queen, the Perambuco, the Red Spanish, and the Smooth Cayenne. Pineapples contain Vitamins A and C, but most importantly, they are a great source of an enzyme called Bromelain. Bromelain helps the body's digestive system and it also has anti-inflammatory properties as well. It has been used to treat a number of medical problems, including heart disease, arthritis, and upper respiratory infections. When taken with antibiotics and chemotherapy drugs, Bromelain has been found to increase the actions of these drugs. This remarkable enzyme is found in all types of pineapples.

2.6 PINEAPPLE PEELER

The purpose of the peeler is to skin root crops, vegetables even fruits smoothly and safely. It is easier to peel with a peeler because user just has to hold on to the handle provided. The blade that cuts through the skin is on the end of the handle, so there is virtually no risk of cutting through the skin of the user. Potato peeler and apple peeler are the peelers usually found in the market. Unlike potatoes and apples, the sizes of the pineapples are bigger and their skins are thick. So to peel a pineapple, an improved design with an ergonomics approach is needed.

The peeler comes in three most common types. They are the Y peeler, the Lancashire and the Dalson Classic Aussie peeler (http://www.peeler.com.au/April 2010). The Y peeler, or the yoke peeler, looks and operates like a razor. As opposed to the Lancashire Peeler, the user has to push it away instead of towards their body when peeling. Although, pushing is more difficult than pulling, it reduces the friction that it meets on the surface of the fruit or vegetable. The Lancashire peeler is basically the most "old school", though still useful, of all peeler varieties found in the market. It is a peeler in which the blade is extended from the handle. The vegetable or fruit is held with one hand and the peeler with the other. The blade is dragged on the vegetable or fruit towards the user when peeling. This is a very basic model that can be used on fruits or vegetable with tender skins. However it is not as efficient on thicker, harder skin. The third peeler which is called the Dalson Classic Aussie peeler requires the user to peel fruit or vegetable using upward and circular motions. Figure 2.2 shows the domestic pineapple peeler which can be categorized as the Dalson Classic Aussie peeler. Figure 2.3 shows commercial pineapple peeler developed by REITECH Co.

Figure 2.2: Domestic pineapple peeler

Source: http://www.kingarthurflour.com/March 2010

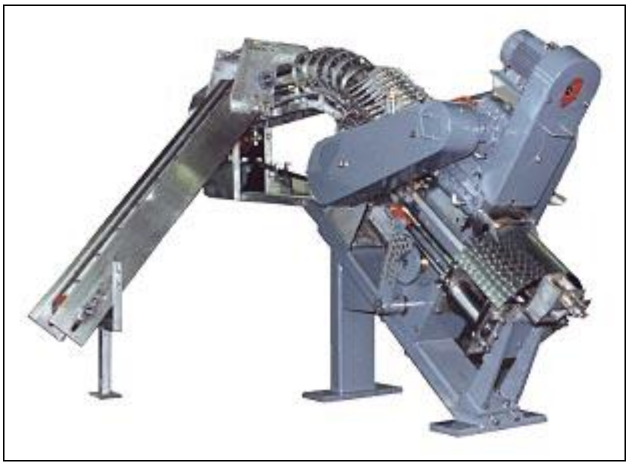

Figure 2.3: Commercial pineapple peeler

Source: http://www.reitech.co.za/March 2010

2.7 RAPID PROTOTYPING

Rapid prototyping (RP) is a freeform manufacturing process that allows users to fabricate a real physical part directly from computer-aided design (CAD) model. The CAD model is sliced into many layers by any number of software packages that can also prepare the part for whichever layered manufacturing machine is to be used. The part is then built layer-by-layer without extraneous tools. This process allows us to quickly build geometrically complex parts (Liou, 2008).

Rapid prototyping processes can be classified into three major groups. They are subtractive, additive, and virtual (Kalpakjian, and Schmid, 2006). As the names imply, subtractive processes involve material removal from a workpiece that is larger than the final part. Additive processes build up a part by adding material incrementally to produce the part. Virtual processes use advanced computer-based visualization technologies.

Prototypes enable the product development team to think, plan, experiment, and learn the processes while designing the product. For example, in designing appropriate elbow-support for an office chair, several physical prototypes can be developed to learn about the feel of the elbow-support for an office chair, several physical prototypes can be developed to learn about the feel of the elbow support when performing typical tasks in the office chair. Since physical prototypes in RP are developed with speed and are accurate, many of these roles can be accomplished quickly and effectively, together with other productivity tools.

RP is the physical modeling of a design using a special class of machine technology. It involves adding and bonding materials in layers to form objects, and thus is also called “layered manufacturing” or “solid freeform fabrication”. The advantages of RP include the fact that objects can be formed with any geometric complexity or intricacy, reducing the construction of complex objects to a manageable, straightforward, and relatively fast process. In some processes, materials can even be varied in a controlled fashion at any location in an object.

2.8 SOLIDWORKS

SolidWorks is a 3D mechanical CAD (computer-aided design) program that runs on Microsoft Windows. SolidWorks is a parametric feature-based solid modeler, using the Parasolid geometric modeling kernel. SolidWorks has a quite simple approach to modeling and assembling. All dimensions define the geometry, and not backwards as it happen in most CAD programs. To create volume and modifications, SolidWorks employs a feature-based system that can be rolled back to previous states in case something must be changed or multiple configurations of the same part must be handled. To assemble components, mates are created, which define the relative positions of the components to each other.

Drawings can be created either from parts or assemblies. Views are automatically generated from the solid model, and notes, dimensions and tolerances can then be easily added to the drawing as needed. The drawing module includes most paper sizes and standards (ANSI, ISO, DIN, GOST, JIS, BSI and GB).

For this project, this software was used to visualize the 3D image of the pineapple peeler. Using SolidWorks as the platform to develop the design gives a lot of advantages in terms of animation, view and needs to complete the design. The animation feature can give basic view of how the design will function. It is also essential to design the pineapple peeler in SolidWorks before we can use it in the rapid prototyping process and in the simulation using Algor software.

2.9 ALGOR SIMULATION SOFTWARE

The Autodesk Algor Simulation software is part of the Autodesk solution for Digital Prototyping. This software provides a broad range of analysis tools that enable designers and engineers to bring product performance knowledge into early stages of the design cycle which help to improve collaboration, design better and safer products, save time, and reduce manufacturing costs.

Simulation enables critical engineering decisions to be made earlier in the design process. With Autodesk Algor Simulation software, designers and engineers have the tools to more easily study initial design intent and then accurately predict the performance of a complete digital prototype. When working with CAD geometry, automatic meshing tools produce high-quality elements on the first pass, ensuring simulation accuracy within the areas of greatest engineering concern and helping to predict product performance in less time. Built-in modeling capabilities enable designers and engineers to directly edit the mesh to help with the accurate placement of loads and constraints or to create simplified geometry for proof-of-concept studies. In addition to increased productivity through modeling flexibility, design concepts can be quickly validated before resources are invested in significant design changes or new products.

2.10 SUMMARY

From the literature review, we have gathered a lot of information and understand various terms related to this project such as ergonomics, MSD and pineapple peeler. Besides that, we also have identified basic yet very important knowledge such as the principles of ergonomics and the risk factors related to MSD from the previous research. Repetitive movement and application of force are recognized as the main factors that cause MSD. Based on that, workers who involved in pineapple peeling process which use traditional peeling method or with tools that are not ergonomics are definitely exposed to MSD problems.

There is strong relationship between MSD and ergonomics. Ergonomics emphasizes designing the workplace to fit the employee rather than the employee fitting the workplace. To prevent MSD, the work is designed to be ergonomics in terms of working procedure and working tools. In order to do that, we must follow all of the ergonomics principles stated before. Ergonomics is also related to the health aspect. Ergonomics in the workplace has become much more of a popular subject in order to improve the safety and productivity of employees and employers. Effective implementation of ergonomics can lead to substantial benefits in terms of increased productivity, improved product quality, reduced absenteeism and lower turnover rates, as well as lower occupational safety and health costs. This also helps save billions of dollars in workers’ compensation claims.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, every method related in achieving the objective of this study is discussed. The gathered information is used to obtain the best design of the pineapple peeler according to ergonomics approach. Figure 3.1 shows the flow chart for the entire project.

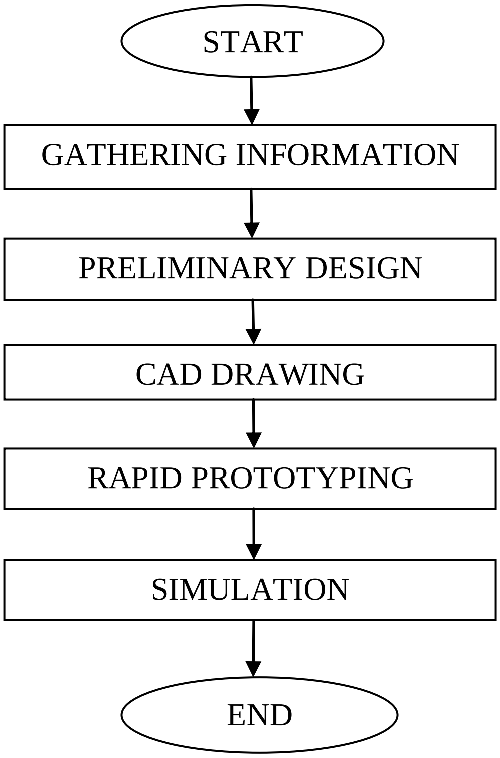

Figure 3.1: Project flow chart

3.2 GATHERING INFORMATION

Before the information collection process started, first the product requirement is needed to be defined. For this project, a portable pineapple peeler with ergonomics approach is needed to be designed. By doing this, the musculoskeletal problems among workers who manually peel the pineapple are able to be solved. Some of the criteria should be features in this product are safety, comfort and ease of use.

All of the information related to this project was gathered from the internet, journal, reference book and other sources. Further research has been done about the design and technique used on the development of pineapple peeler.

3.3 PRELIMINARY DESIGN

The design consideration must be done carefully so the design is functioning and most importantly, it can avoid MSD from occurring. In order to achieve those goals, the designed portable pineapple peeler must focus on ergonomics features. In the present context, the concentrated ergonomics aspects is the pineapple peeler’s handle. From the chapter 2, it is known that the design of the handle must be compliance to several aspects such as the grip type, grip shape, grip size and the grip material

Peeling the pineapple involve large force exertion. So for this project, power grip is selected as the grip type. A cylindrical-shape grip with slight and uniform surface indentations is used to prevent hand from slipping and allow greater torque exertion capability. In order to attenuate vibration expose to the hand, the handles encased in a rubber sheath was chosen. Besides insulating the hand from vibration, these materials are compressible, which helps distribute loads from the tool evenly over the hands. It is also important that the grip material be smooth and conforms closely to the hand, because ridges tend to transmit vibrations to localized regions of the hand. Furthermore rubber is effective insulating materials thus it protect the hands from the temperature of the tool or electricity. For the grip length, it can be concluded that the handle of 122 mm in length is the suitable for the designed pineapple peeler. The type, shape and material of the handle have been chosen, however the optimum size of the grip cannot be finalized since the optimum handle diameter is still undecided. This is because, from the information gathered, the grip diameters recommended can be divided into two groups. According to Table 3.1, it can be concluded that the first group or Group A suggested the grip diameter to be 50 mm whereas the Group B recommended the handle should be 38 mm in diameter. As a result, the designed pineapple peelers with different grip diameter are picked as Design A and Design B. Table 3.2 shows the dimensions of Design A while Table 3.3 shows the dimensions of Design B.

Table 3.1: Recommendations of the grip diameter

Author	Recommended grip diameter
Group A	
M.M. Ayoub, P. LoPresti	50 mm
S.L. Johnson	At least 50 mm
Jerrold S. Petrofsky	From 50 to 60 mm
L. Greenberg, Don B.Chaffin	From 50 to 85 mm, preferably 50 mm
Group B	
S.L. Johnson, L.J. Childress	38 mm
S.T. Pheasant, D. O'Neill	From 18 to 40 mm
Dennis A. Attwood, Joseph M. Deeb, Mary E. Danz-Reece	From 31 to 44 mm
Eastman Kodak Company	40 mm
The Technical Research Center of Finland	From 28 to 38 mm

Table 3.2: Dimensions of Design A

Part	Dimensions (mm)
Handle diameter	50
Handle length	122
Blade diameter	110
Top base	315 x 130 x 70
Bottom base	315 x 130 x 135
Guards of the handle	15.2

Table 3.3: Dimensions of Design B

Part	Dimensions (mm)
Handle diameter	38
Handle length	122
Blade diameter	110
Top base	315 x 130 x 70
Bottom base	315 x 130 x 135
Guards of the handle	15.2

3.4 COMPUTER AIDED DESIGN DRAWING

After all of the dimensions have been selected for both Design A and Design B, the next step is drawing the designs using SolidWorks application. In this stage, solid modeling method was used. Part by part solid modeling created according to the dimension done before. After all parts were created, the 3-D model was assembled with each other based on the design and then converted into orthographic view to get its engineering drawing details. Figure 3.2 shows the blade which has been transferred into solid modeling using the SolidWorks software. The isometric and front views of the Design A are shown in Figure 3.3 and Figure 3.4 while for the Design B, it is shown in Figure 3.5 and Figure 3.6.

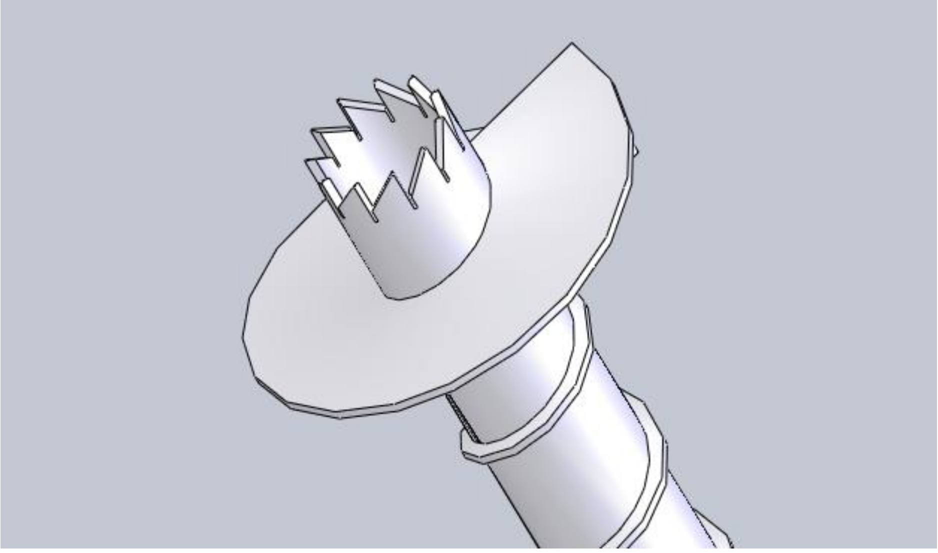

Figure 3.2: Blade

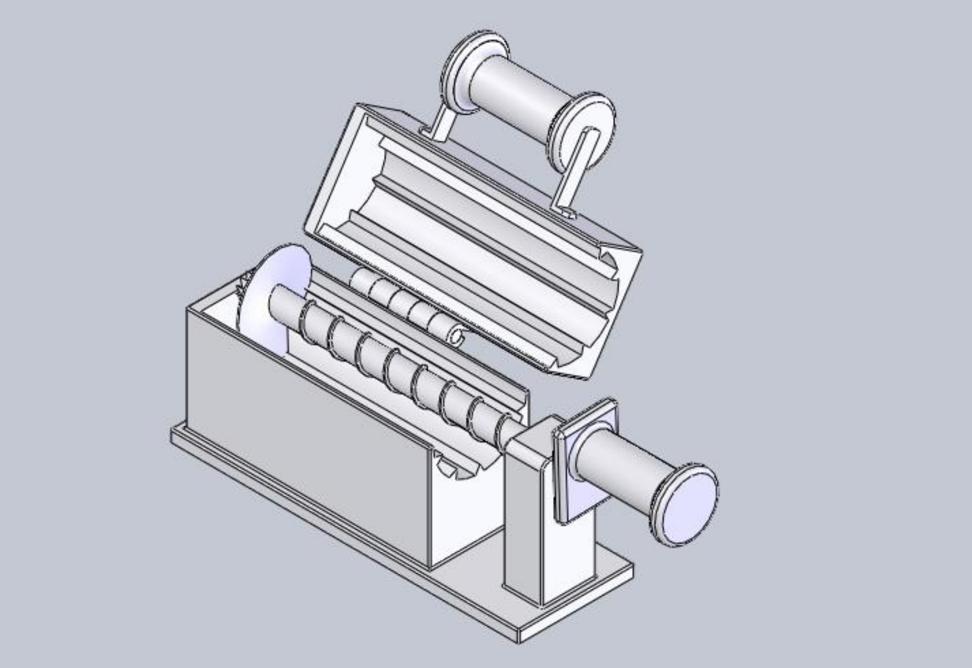

Figure 3.3: Design A (isometric view)

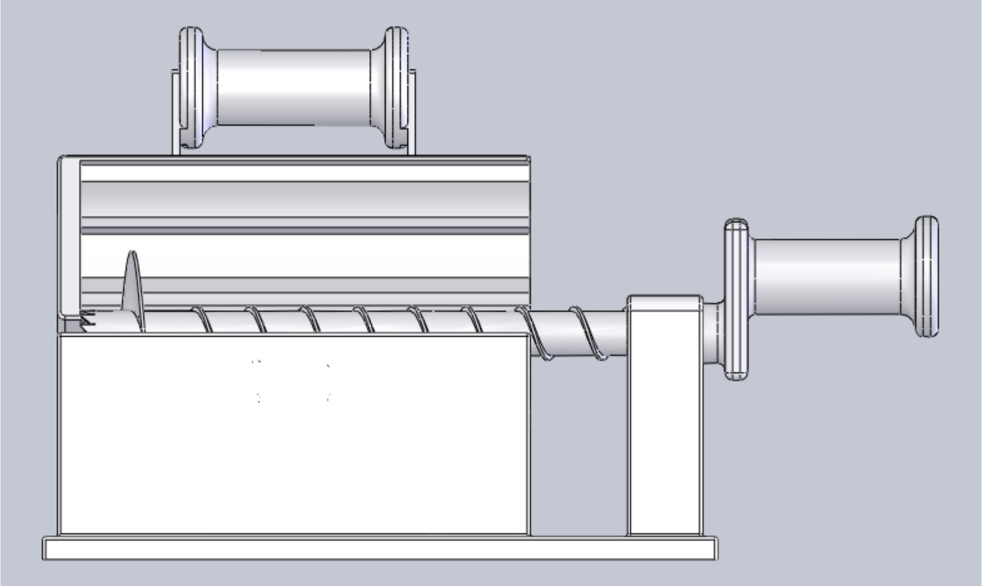

Figure 3.4: Design A (front view)

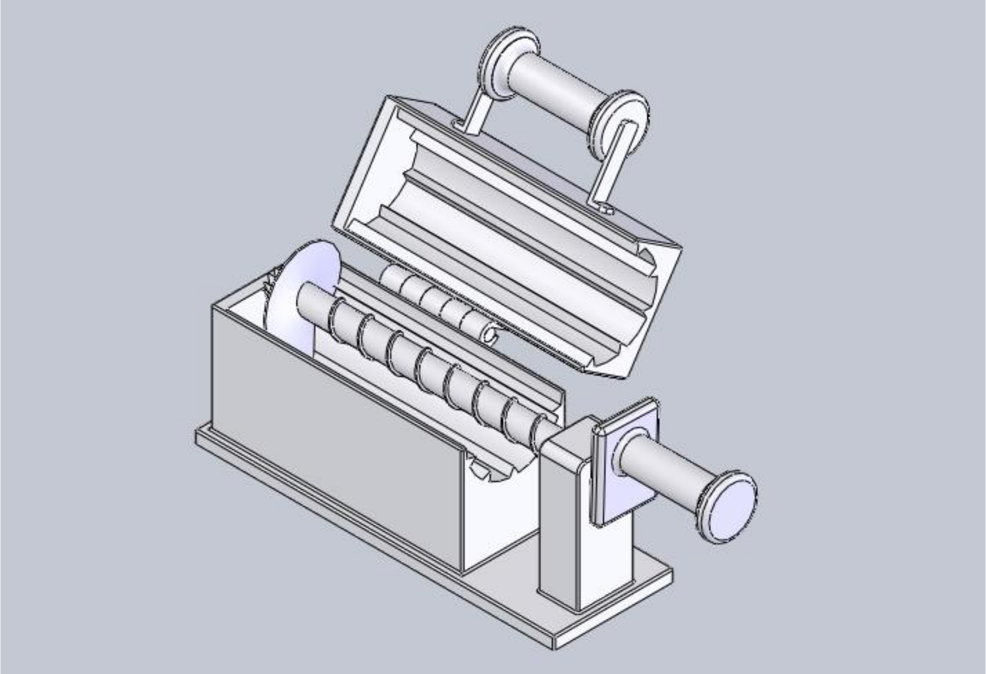

Figure 3.5: Design B (isometric view)

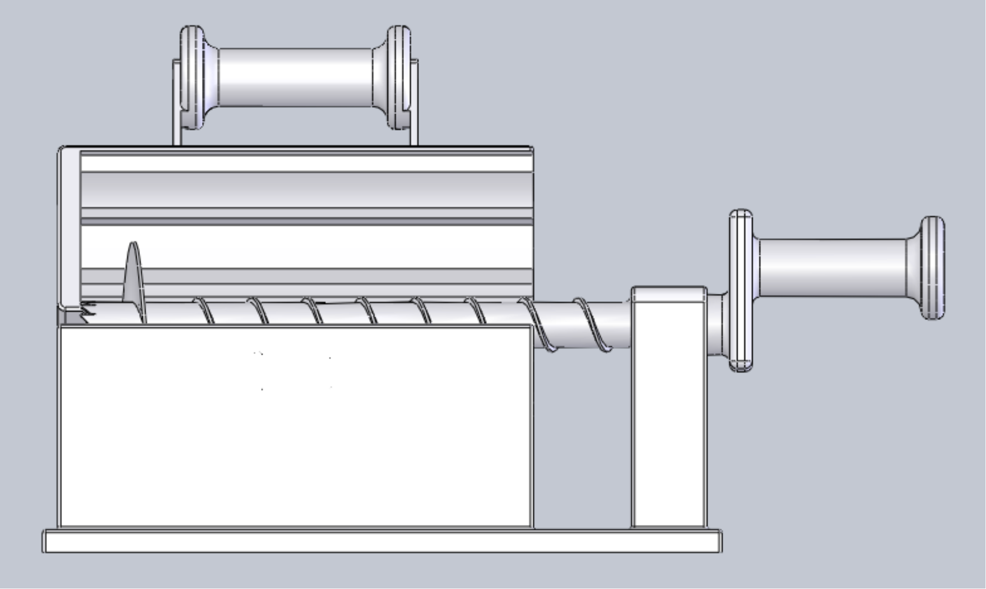

Figure 3.6: Design B (front view)

3.5 RAPID PROTOTYPING

For this project, a prototype by using the Rapid Prototyping (RP) method is built. The 3D printer model that we used to make the prototype is Spectrum Z510/DESIGNmate Cx. The 3D Printer System is based on the Massachusetts Institute of Technology's patented 3DP technology. It is designed to be used by design engineers and other professionals in the production of early-stage 3D appearance models and prortotypes. With the supervision of Mr Imran Sairaji, the person-in-charge for the rapid prototyping process, the prototype of the designed pineapple peeler was able to be produced. The procedure to get a print job running on the printer is divided into 3 sections. The first section is preparing the 3D printer. Firstly, the feed box is filled with powder. With the printer offline, the powder was spread over build area by pressing the *Spread* button on the control panel for four spreads. The printer will automatically spread powder over the build area. Next the service station is cleaned by rinsing and wiping the parking caps and rubber wiper. Then the binder bottles and the wash fluid and the waste fluid are checked. Lastly, the printer is put online by pressing the *Online* button on the control panel.

The second section is preparing the build in ZPrint software. First, the ZPrint is needed to be launch and the selected file is opened. The design is needed to be scale into 50% from the original size because the original design is quite big. Next the *File* menu is opened and *3D Print Setup* is selected. In the *3D Print Setup* dialog, the *Printer, Powder Type*, and *Layer Thickness* options are selected. Then the *3D* icon on the Toolbar is clicked and the settings are chosen in the *Printing Options* dialog. Proceed through the series of preparation dialogs that appear before the build start.

The last section is removing the part. Firstly, the part is checked whether the printing is completed or not by using the software for part orientation. Next, when the printing is completed, the part was grossed depowder and removed from build area. The last step is fine depowder part and post-process as needed. This process is done at the ZD5 Powder Recycling System. The figures below show some of the steps taken while producing the prototype.

Figure 3.7: Filling the feed box with powder

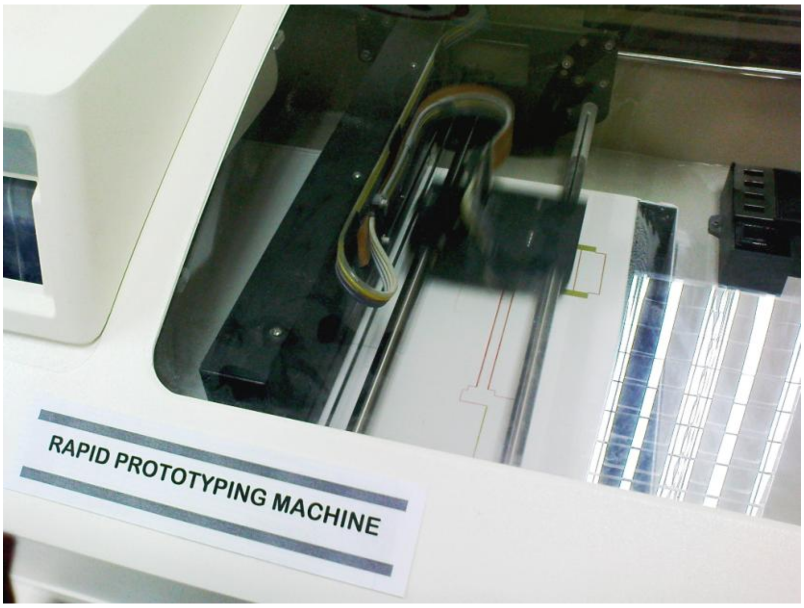

Figure 3.8: Printing process

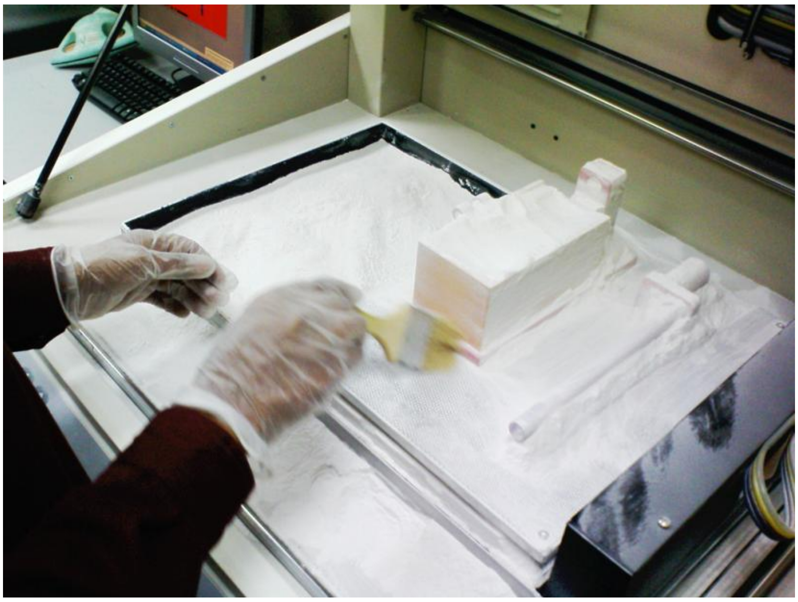

Figure 3.9: Gross depowder the part

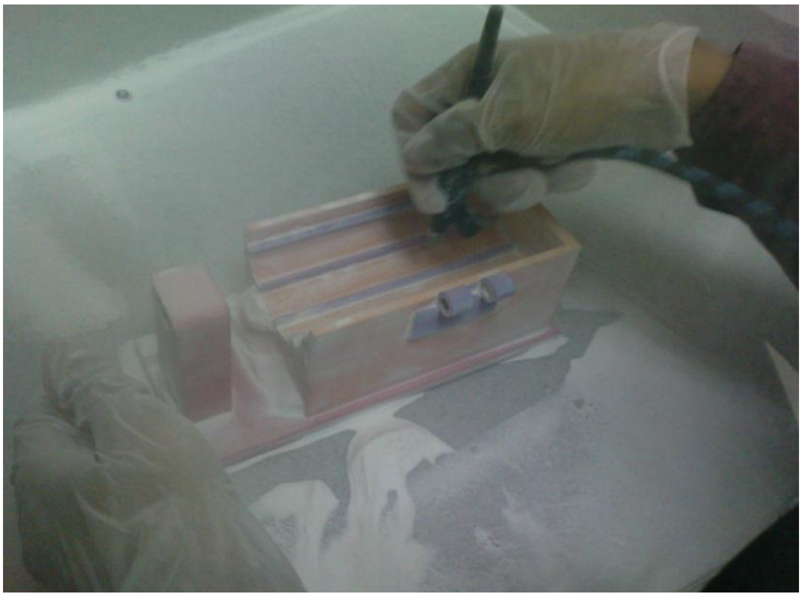

Figure 3.10: Fine depowder part

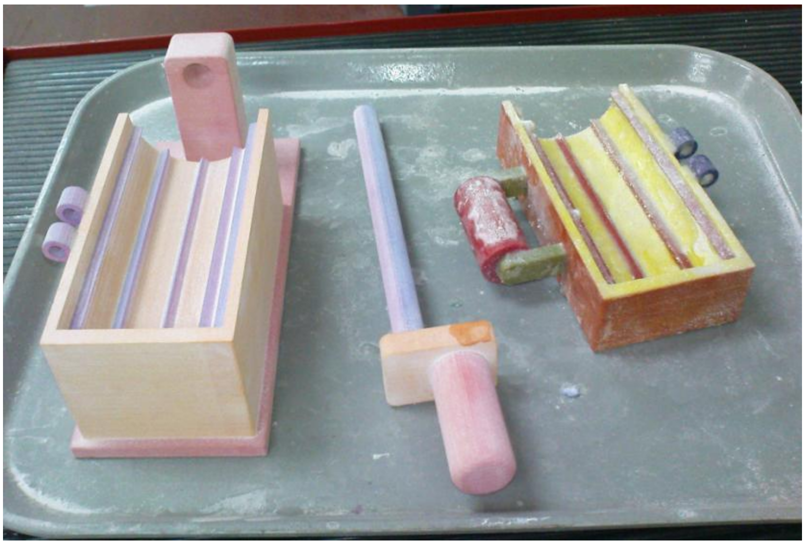

Figure 3.11: The finished prototype

3.6 SIMULATION

In this project, the simulation is performed to evaluate the critical parts of the design that is subjected to the force exerted during movement. The critical parts of the system consist of two primary parts. The first part is the crank handle and the second part is the handle of the top base. The critical parts of the portable pineapple peeler using Design A are showed in the Figure 3.12 while for the portable pineapple peeler using Design B, the critical parts are showed in the Figure 3.13. Knowing the critical part is important because we need to minimize the force effect and keep the design to be safe for use. Using the Algor Simulation software, we can determine the maximum stress the design can hold. Knowing the maximum stress distribution is important so that we can enforce the critical part to withstand such force.

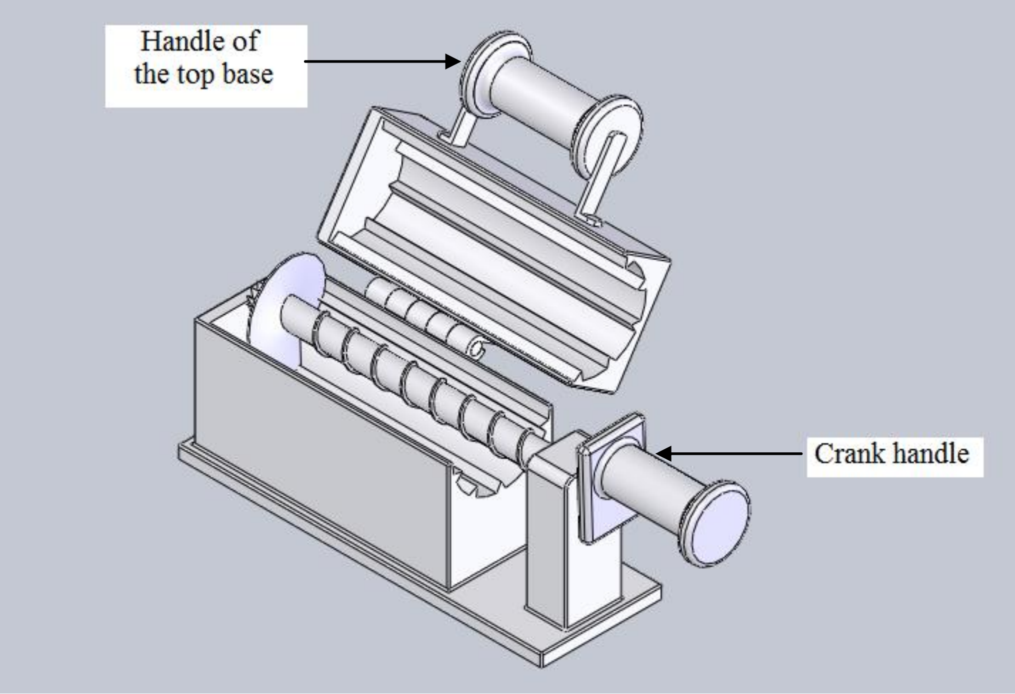

Figure 3.12: The critical parts for Design A

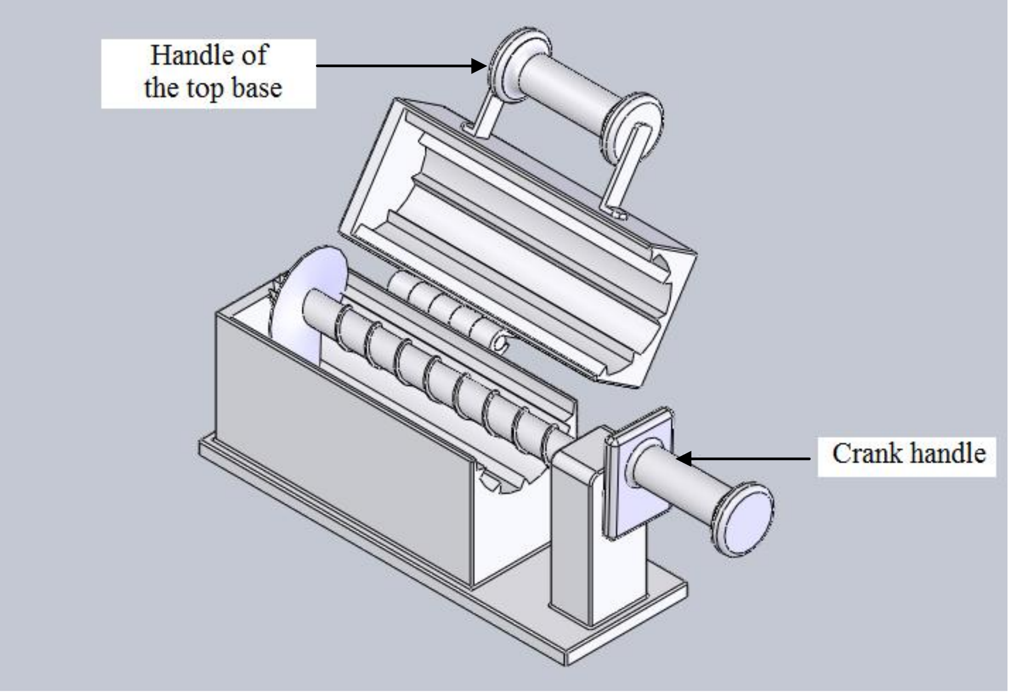

Figure 3.12: The critical parts for Design B

Using the .igs compatible mode, the model from SolidWorks is imported to Algor Simulation software. The type of analysis is static stress with linear material models. Since the stress through the thickness of a part is important for this testing, brick elements are used as the element type. The material is defined as Aluminium 6061-0 while the force has been distributed in Von Misses stress distribution.

Since the previous studies indicated that the forces allowed is between 10 to 21 Newtons, thus the simulation in Algor Simulation software is performed with the value of 10N, 20N, and 30N. Since we cannot ensure that the user will follow the instructions, an additional force of 40N had been applied to analyze the effect of the force on the critical parts of the design.

3.7 SUMMARY

The core of this chapter is the project flow chart which summarizes the whole method acquired for this project. It also makes this project more organized so that each step can be easily followed by referring the flow chart. It is essential to have proper method in performing a project to make sure that at the end of this project, the required outcome can be attained. For this project, the best design to be used in designing the portable pineapple peeler is determined according to the results from the Algor Simulation software. The designed pineapple peeler is also expected to obey the principles of ergonomics and also able to prevent MSD.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

The purpose of this chapter is to show the results and provide further discussion based on the developed prototype and the simulation using Algor that had been done during this project. Therefore this chapter is divided into two sections. In the first section, the discussion is focused on the benefits achieved from the developed prototype. The analysis of the critical parts that are simulated using Algor Simulation software was discussed in the second section. In this section, the data of stress obtained were recorded. The stress analysis is used to investigate about the maximum distribution of force acting on the designed pineapple peeler. By doing that, it can be determined whether the design will fail or not when the selected value of force is applied. The results obtained are discussed to decide whether the designed pineapple peeler can be use to prevent the development of MSD among users.

4.2 PROTOTYPING

RP applications are commonly used for communication process. Since the designed pineapple peeler is still in the development process, it is still not available in the market. Thus, when a drawing of the designed pineapple peeler is introduced, some of them cannot understand the concept of the design. However, by having the developed prototype, it will be a much more effective communication tool than plain drawings. As a result, these persons will be able to visualize and understand the design much better. This is because most people tend to learn more in a shorter amount of time from physical model than from drawings. For this project, as a designer, the author needs to make sure that the panels or anyone who involved in this study to understand the exact concept of the designed pineapple peeler.

The developed prototype can also be used to verify CAD database, especially misaligned holes, interferences, improper mating of parts and whatever was forgotten in creating the model. The designed pineapple peeler has 3 major parts and each part contains a lot of different shapes and dimensions. Because of that, some error may occur while dimensioning the design. Sometimes these errors are difficult to detect in CAD model, but can easily be spotted with a physical RP part.

4.3 RESULTS OF THE SIMULATION IN ALGOR

4.3.1 Results for the Crank Handle (Design A)

The simulation results of crank handle for the forces of 10N, 20N, 30N and 40N are shown in Figure 4.1, Figure 4.2, Figure 4.3, and Figure 4.4 respectively. Table 4.1 summarizes the Von Misses stress of the crank handle for Design A.

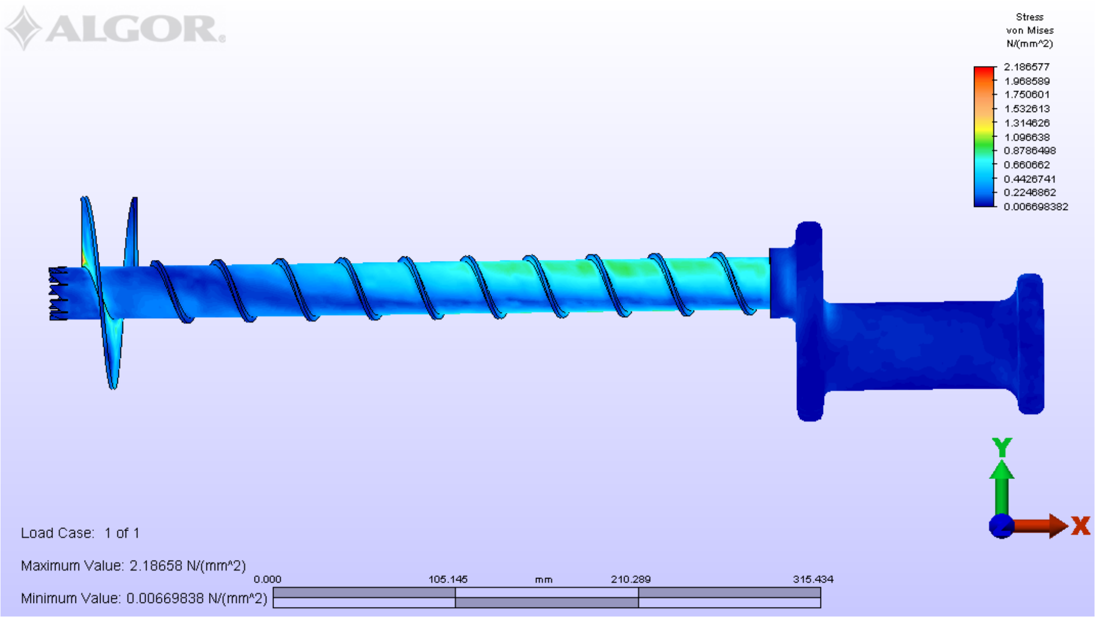

Figure 4.1: Von Misses stress of crank handle (Design A) for 10N

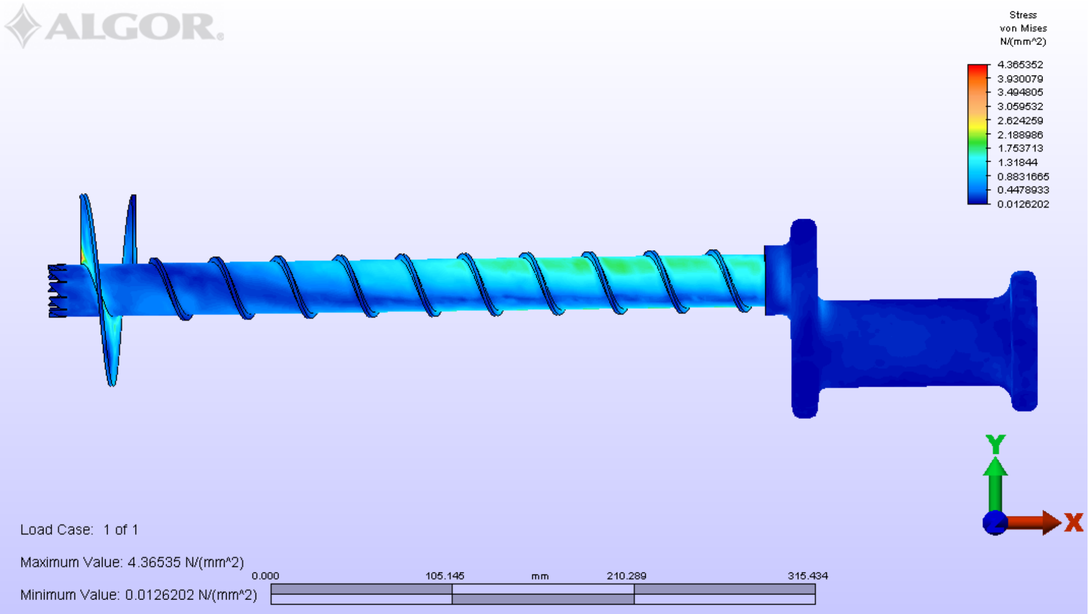

Figure 4.2: Von Misses stress of crank handle (Design A) for 20N

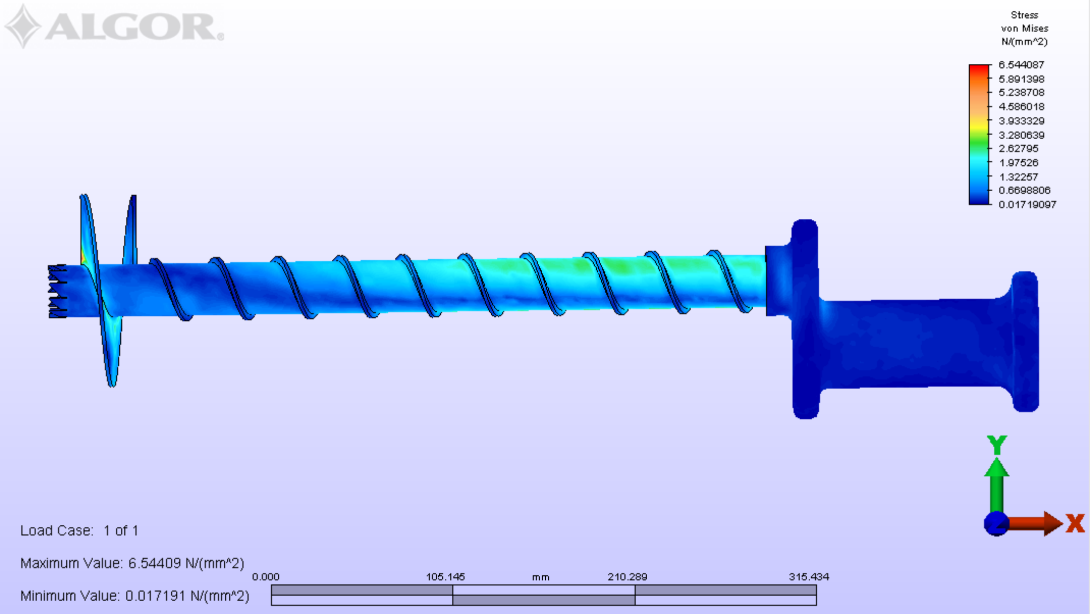

Figure 4.3: Von Misses stress of crank handle (Design A) for 30N

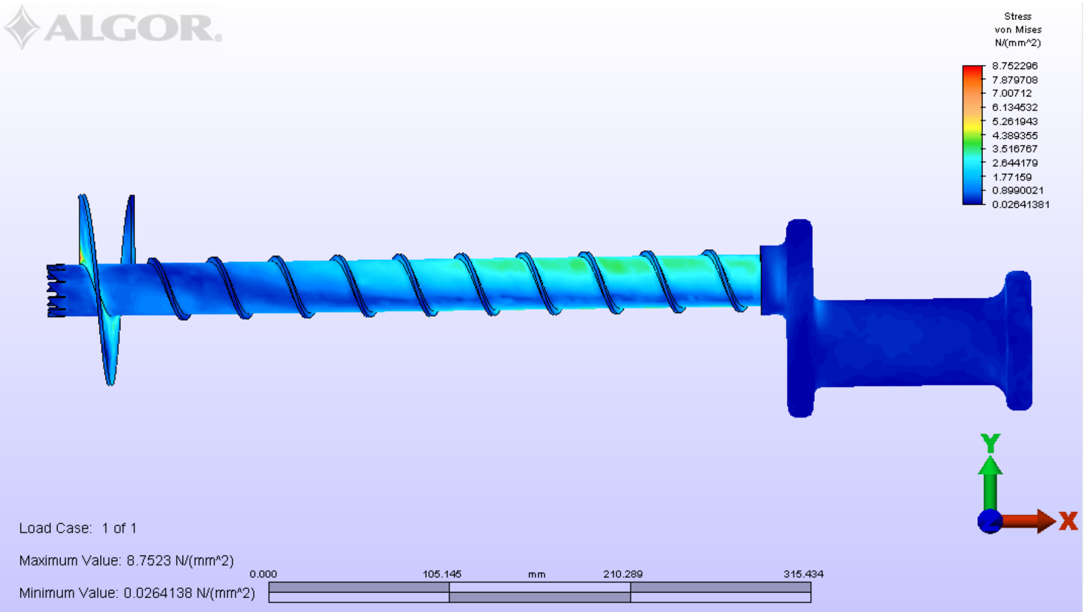

Figure 4.4: Von Misses stress of crank handle (Design A) for 40N

Table 4.1: Von Misses stress of the crank handle (Design A)

Load (Newton)	**Von Misses stress**	
	Minimum Value (N/mm²)	**Maximum Value (N/mm²)**
10	0.0066984	2.18658
20	0.0126202	4.36535
30	0.0171910	6.54409
40	0.0264138	8.75230

4.3.2 Results for the Crank Handle (Design B)

Figure 4.5, Figure 4.6, Figure 4.7 and Figure 4.8 showed the simulation results of the top base handle for the forces of 10N, 20N, 30N and 40N respectively. Table 4.2 summarizes the Von Misses stress of the crank handle for Design B.

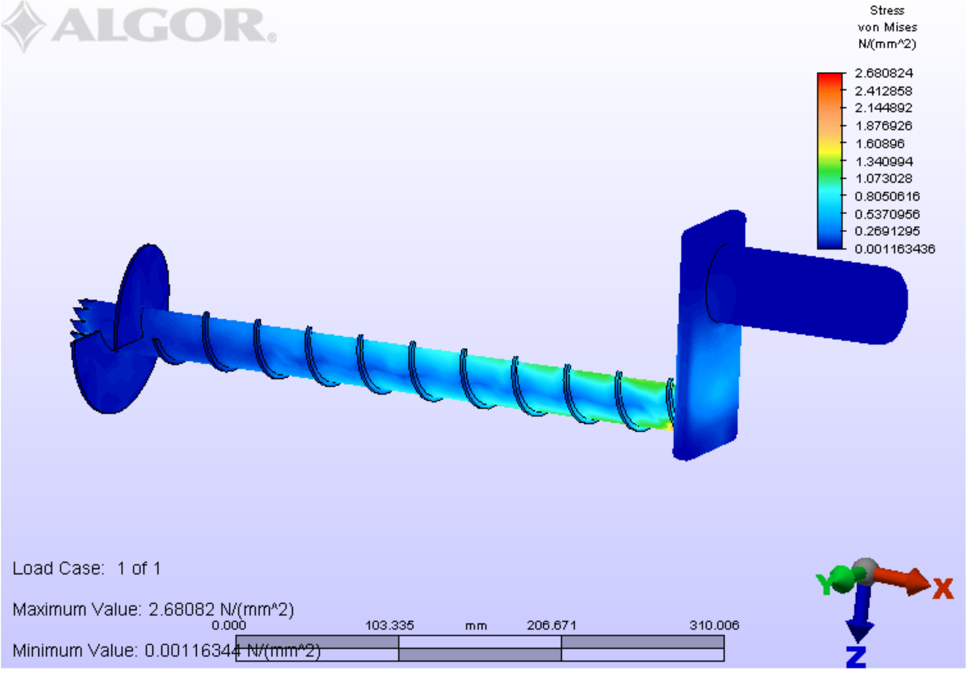

Figure 4.5: Von Misses stress of crank handle (Design B) for 10N

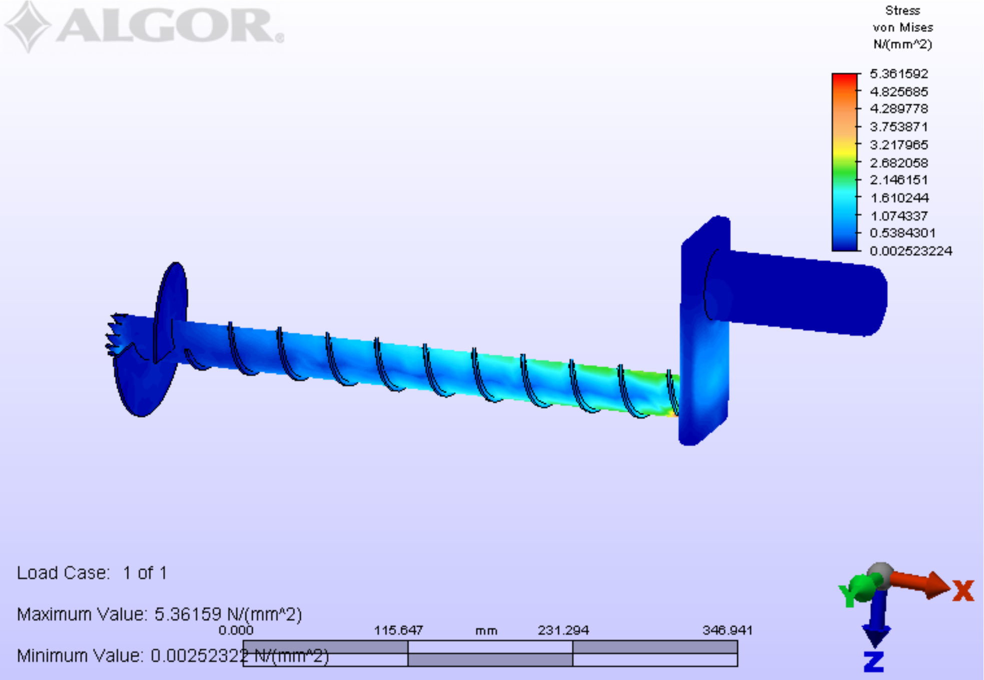

Figure 4.6: Von Misses stress of crank handle (Design B) for 20N

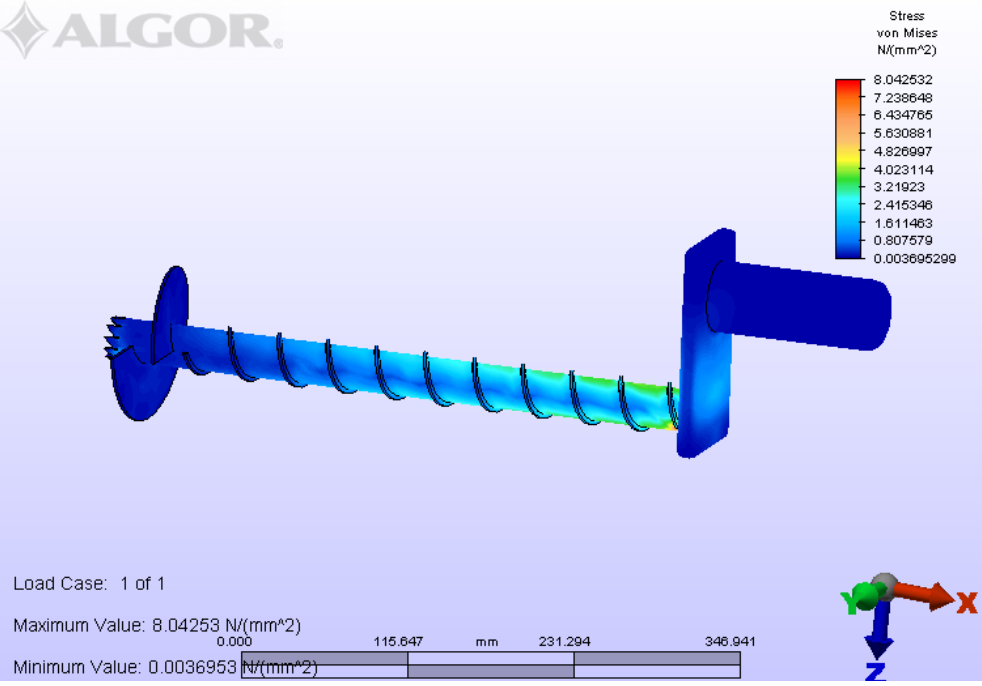

Figure 4.7: Von Misses stress of crank handle (Design B) for 30N

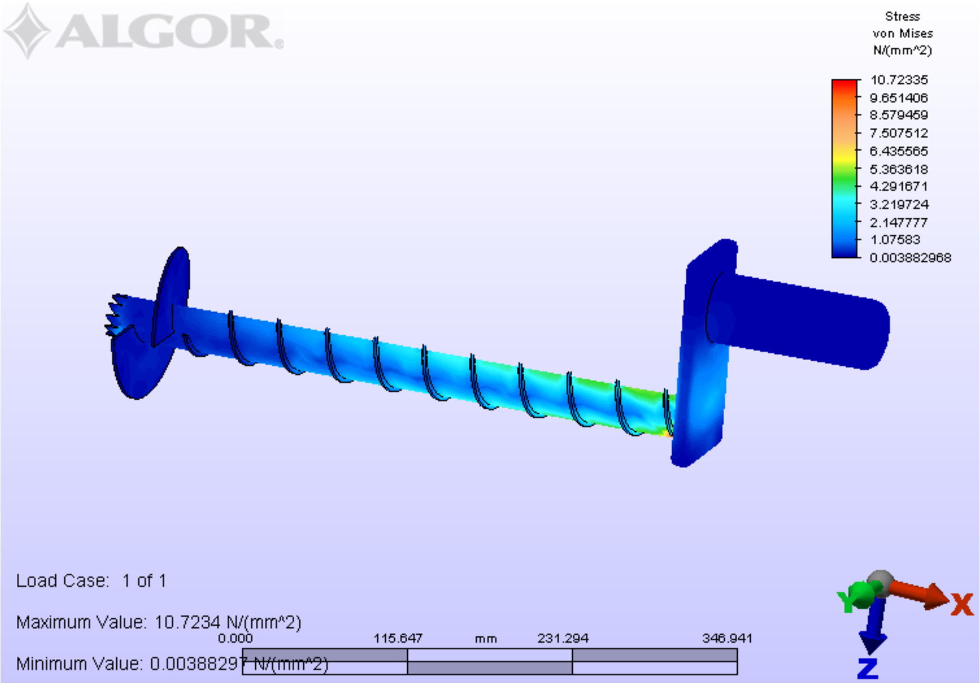

Figure 4.8: Von Misses stress of crank handle (Design B) for 40N

Table 4.2: Von Misses stress of the crank handle (Design B)

Load (Newton)	**Von Misses stress**	
	Minimum Value (N/mm²)	**Maximum Value (N/mm²)**
10	0.00116344	2.68082
20	0.00252322	5.36159
30	0.0036953	8.04253
40	0.00388297	10.7234

4.3.3 Results for the Top Base Handle (Design A)

The simulation results of crank handle for the forces of 10N, 20N, 30N and 40N are shown in Figure 4.9, Figure 4.10, Figure 4.11 and Figure 4.12 respectively. Table 4.3 summarizes the Von Misses stress of the top base handle for Design A.

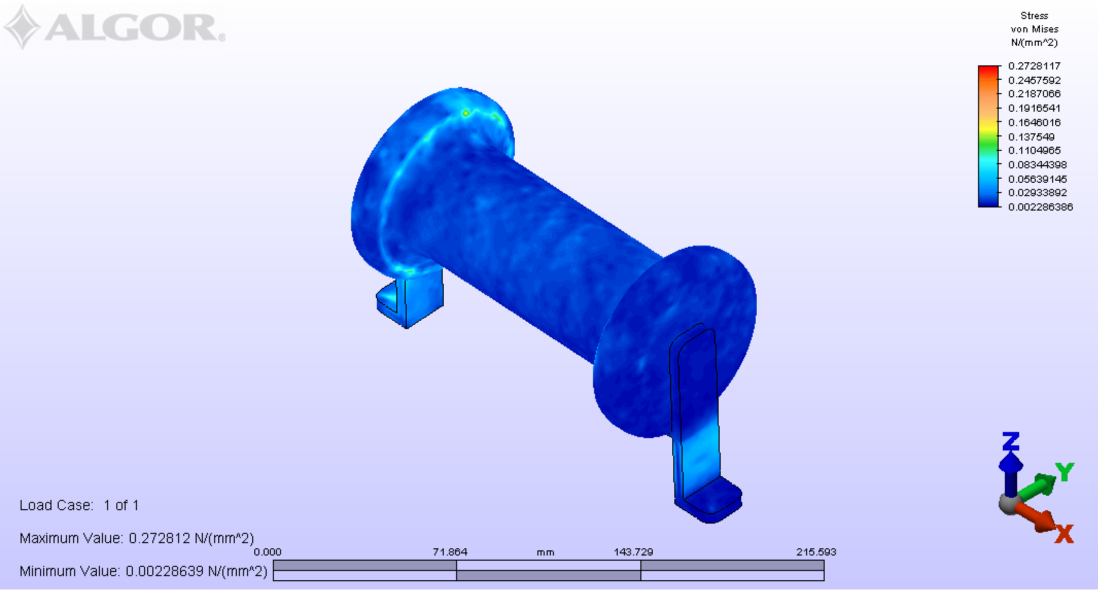

Figure 4.9: Von Misses stress of the top base handle (Design A) for 10N

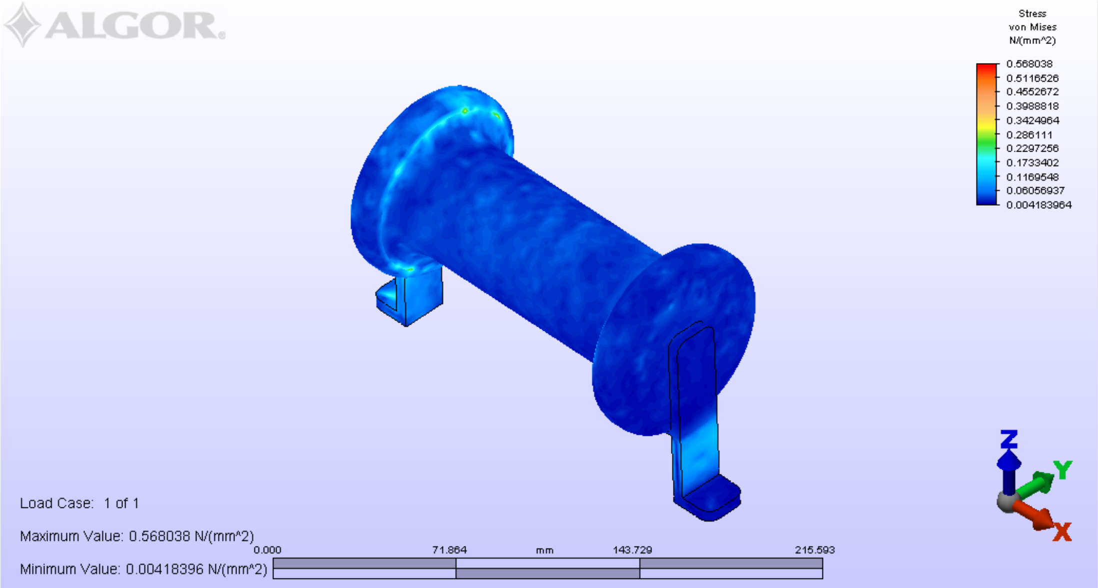

Figure 4.10: Von Misses stress of the top base handle (Design A) for 20N

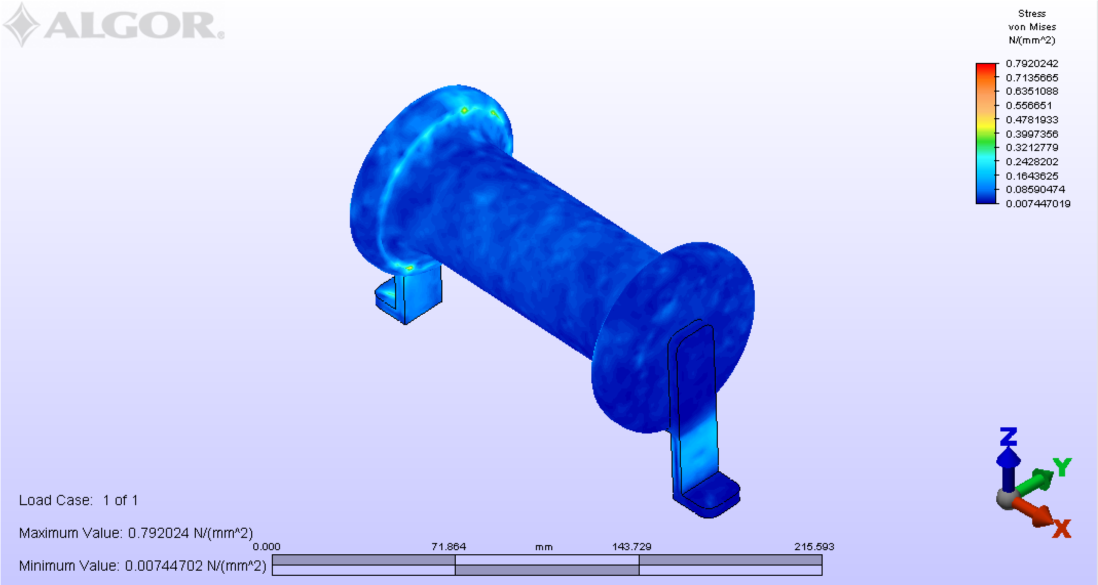

Figure 4.11: Von Misses stress of the top base handle (Design A) for 30N

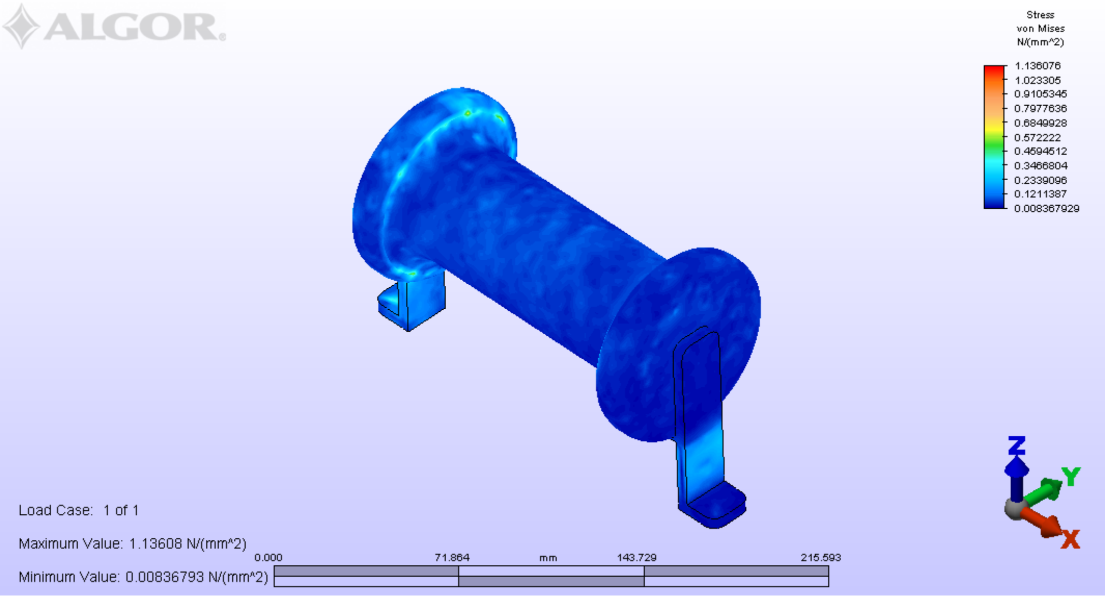

Figure 4.12: Von Misses stress of the top base handle (Design A) for 40N

Table 4.3: Von Misses stress of the top base handle (Design A)

Load (Newton)	**Von Misses stress**	
	Minimum Value (N/mm²)	**Maximum Value (N/mm²)**
10	0.00228639	0.272812
20	0.00418396	0.568038
30	0.00744702	0.792024
40	0.00836793	1.136080

4.3.4 Results for the Top Base Handle (Design B)

Figure 4.13, Figure 4.14, Figure 4.15 and Figure 4.16 showed the simulation results of the top base handle for the forces of 10N, 20N, 30N and 40N respectively. Table 4.4 summarizes the Von Misses stress of the top base handle for Design B.

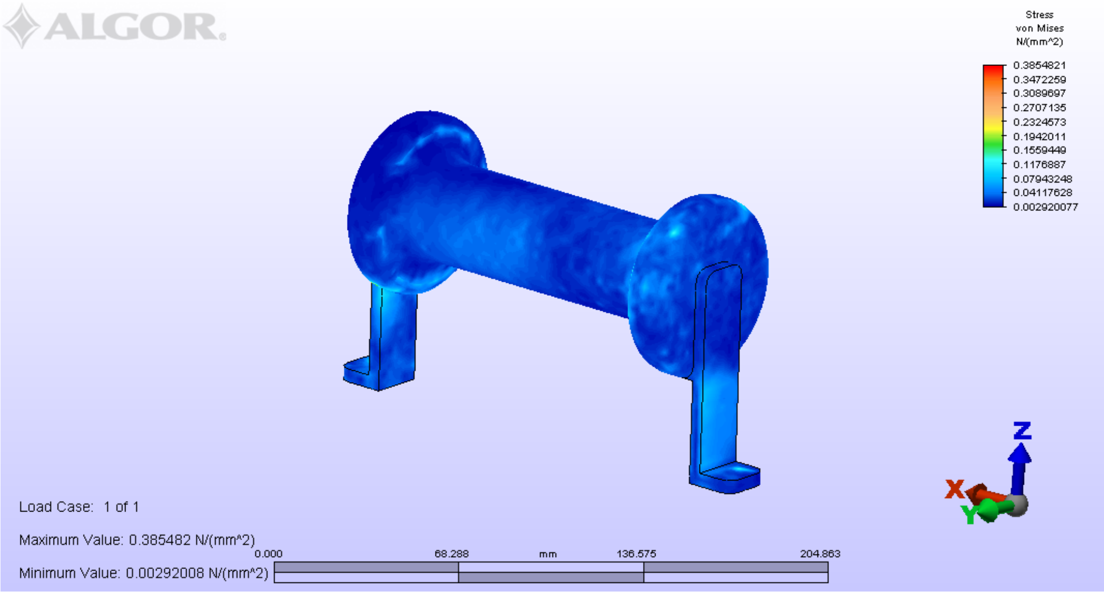

Figure 4.13: Von Misses stress of the top base handle (Design B) for 10N

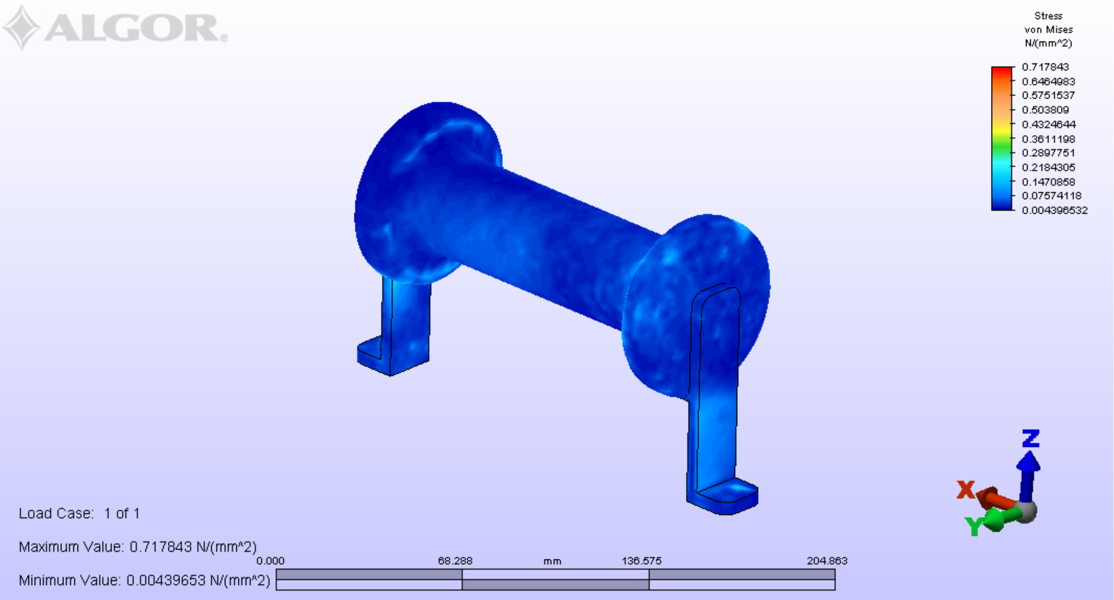

Figure 4.14: Von Misses stress of the top base handle (Design B) for 20N

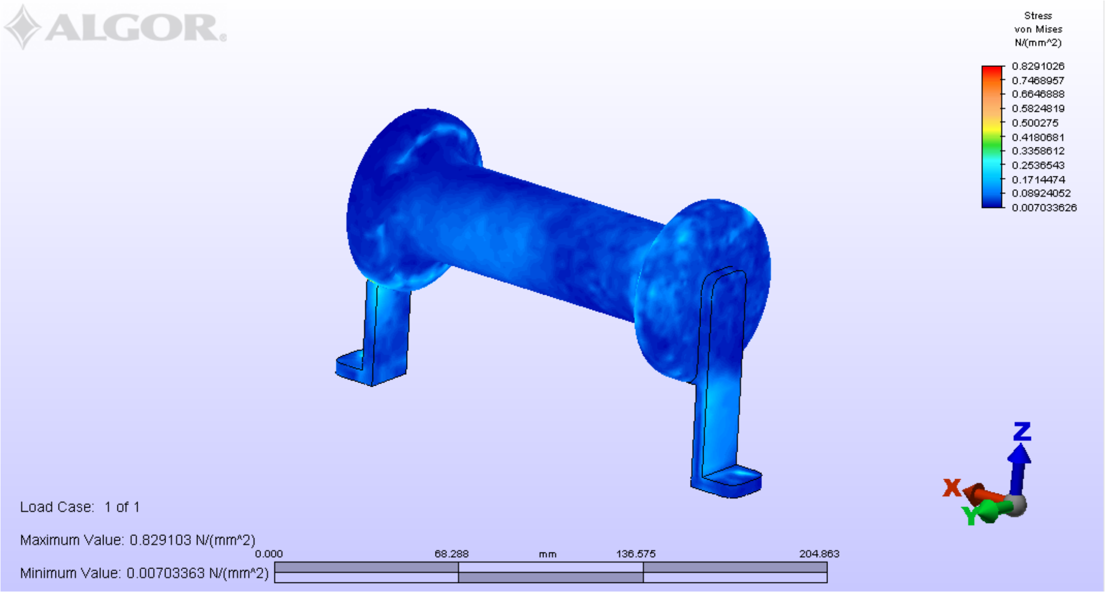

Figure 4.15: Von Misses stress of the top base handle (Design B) for 30N

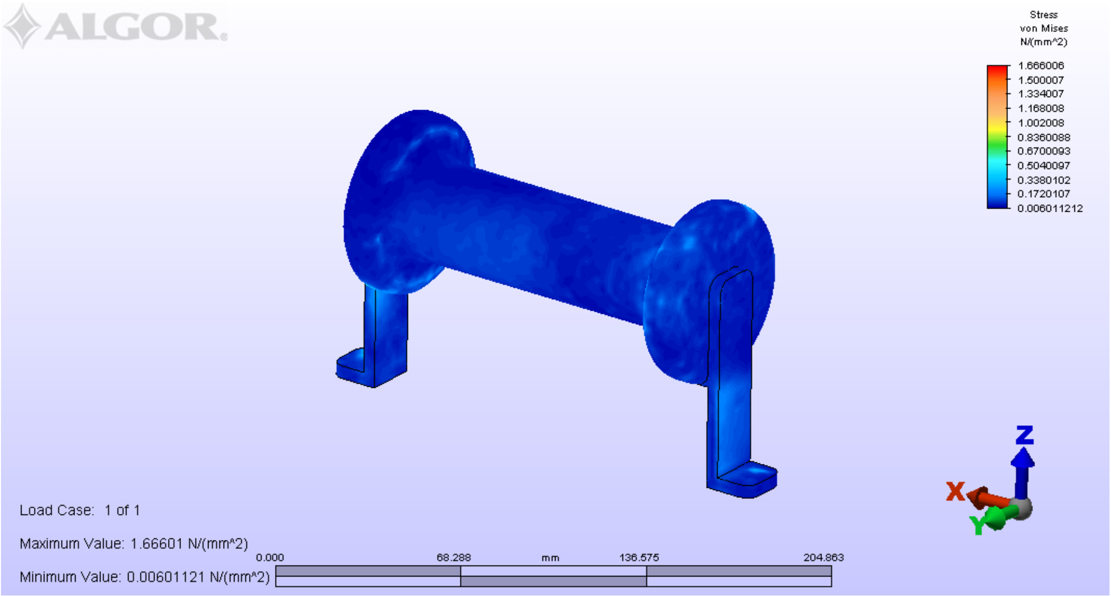

Figure 4.16: Von Misses stress of the top base handle (Design B) for 40N

Table 4.4: Von Misses stress of the top base handle (Design B)

Load (Newton)	Von Misses stress	
	Minimum Value (N/mm²)	**Maximum Value (N/mm²)**
10	0.00292008	0.385482
20	0.00439653	0.717843
30	0.00703363	0.829103
40	0.00601121	1.666010

4.4 DISCUSSION OF THE ANALYSIS

For this project, the analysis is concentrated on the critical parts of the designed pineapple peeler. The critical parts are the crank handle and the top base handle. The simulation using Algor Simulation software is performed for both Design A and Design B. So, there are four sets of the results that need to be interpret. The simulation for the crank handle is started with the load of 10N. According to the maximum value of Von Misses stress which is 2.18658 N/mm² for Design A and 2.68082 N/mm² for Design B, the subjected force only translate a small effect on the handle. The values obtained for Design A and Design B when 20N forces loaded on the crank handle are 4.36535 N/mm² and 5.36159 N/mm² respectively. Next, the testing load is increased to 30N. From the test, the value of 6.54409 N/mm² is obtained for Design A and 8.04253 N/mm² for the Design B. Although the forces allowed for gripping action are in between 10 to 20N, there is a possibility that the user will not follow the instruction. Hence an additional force of 40N is also executed. When the highest loading force is applied, the force output is only 8.75230 N/mm² for Design A and 10.7234 N/mm² for Design B. According to the results, the Von Misses stress indicates that there are no sign of failure may occurred for both designs. However, Design A is considered as a better design because for every load, their value of the maximum Von Misses stress is lower than design B. The comparison of the maximum values of Von Misses stress for the crank handle between Design A and Design B can be observed in Table 4.5.

Table 4.5: Comparison of the maximum values of Von Misses stress for the crank handle between Design A and Design B

Load (Newton)	**Maximum Value of Von Misses stress (N/mm²)**	
	Design A	**Design B**
10	2.18658	2.68082
20	4.36535	5.36159
30	6.54409	8.04253
40	8.75230	10.7234

The results also show the stress distribution on the top base handle. When the handle is subjected to the load of 10N, the maximum value of Von Misses stress for Design A is 0.272812 N/mm² while for Design B, the value is 0.385482 N/mm². The applied load used for the next analysis is 20N. The result attained for Design A is 0.568038 N/mm² while for Design B is 0.717843 N/mm². For 30N of applied force, Design A provided a result of 0.792024 N/mm² in the maximum value of Von Misses stress whereas 0.829103 N/mm² of maximum value of Von Misses stress are recorded for Design B. When the load of 40N is subjected to the handle, the results are 1.136080 N/mm² for Design A and 1.666010 N/mm² for Design B. From the analysis, it is proven that when the loads are increased, the maximum values of Von Misses stress are also increased regardless the design type. The results also proved that both Design A and Design B does not show any sign of failure. For example, when the designed pineapple peeler is subjected to the forces as high as 40N, both designs produced small value of Von Misses stress. Nevertheless, the maximum values of Von Misses stress for Design A are smaller compared to the Design B. The only different between Design A and design B is its' handle diameter. The handle diameter of Design A is 50 mm which is bigger compared to the Design B which the handle diameter is 38 mm. The higher diameter of the handle means, there are more area of contact between the handle and the users' palm. Thus the force will be distributed fairly across the handle area. Therefore, as a conclusion, the Design A is better than the Design B and no doubt that it is able to prevent the development of MSD.

Table 4.6: Comparison of the maximum values of Von Misses stress for the top base handle between Design A and Design B

Load (Newton)	**Maximum Value of Von Misses stress (N/mm²)**	
	Design A	**Design B**
10	0.272812	0.385482
20	0.568038	0.717843
30	0.792024	0.829103
40	1.136080	1.666010

4.5 SUMMARY

As a conclusion, based on the results of the simulation, when a maximum force which is 40N is applied, the Von Misses stress indicates that there are no sign of failure may occurred for both designs. It means that, both Design A and Design B can withstand the extended allowed number of force. However, based on the maximum value of Von Misses stress, Design A provided better results compared to Design B. Design A can withstand higher forces and provides higher level of safety to the user compared to Design B. Thus the chance to prevent MSD from occurring by applying Design A is higher than Design B. In the end, it can be decided that Design A should be used in designing the portable pineapple peeler.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

In the last chapter, a conclusion was made based on the results and discussion that had been carry out during the duration of this project. The most important elements that must be concluded are the objectives of the project. The objectives which were stated at the beginning of the study are decided whether they have been successly achieved or not. In addition, the contributions of the study and the limitations while performing this project are stated and discussed thoroughly. Besides the objectives stated, the purpose of this study is to prevent the musculoskeletal problems among workers who manually peel the pineapple by designing a portable pineapple peeler with ergonomics approach. Therefore the recommendations on how to enhance the research are pointed out. This is essential so that this research can be improved in the future study for the benefits of the workers in pineapple industry, specifically and human being, generally.

5.2 OBJECTIVES ACHIEVED

There are three objectives that have to be achieved at the end of this study. The first objective is to design a portable pineapple peeler with ergonomics approach using SolidWorks. During this study, two complete designs were created. Both of the design have the same dimensions except for its' handle. For Design A, the handle is 50 mm in diameter while for Design B, the diameter for its' handle is 38 mm. So, the first objective is considered successfully achieved. The second objective is to make a prototype of the designed pineapple peeler using Rapid Prototyping (RP). This objective is already achieved before the presentation of Final Year Project 1. It takes two weeks to make the prototype of the designed pineapple peeler. The RP process is done under the supervision of the RP person in charge, Mr Imran Sairaji. The third objective of this study is to simulate the designed pineapple peeler using Algor Simulation software. This method is performed to analyze whether the design obey the principles of ergonomics or not. If the forces resulted from the simulation are not exceed the allowed forces stated by previous studies, it can be considered that the designed pineapple peeler obeyed the principles of ergonomics and can prevent the development of MSD.

5.3 LIMITATIONS

During the study, a number of limitations had occurred. Some of them are:

(i) Lack of ergonomics software. Instead of using the Algor Simulation software to analyze the designed pineapple peeler, there are other software which is specifically built to analyze the design according to ergonomics aspects. The ergonomics software surely more user friendly and can provide more accurate data. For example, the ErgoFellow software has 17 ergonomic tools to evaluate and improve workplaces conditions, in order to reduce occupational risks and increase productivity. The software was developed by FBF SISTEMAS in 2009 and it is very useful for ergonomists and for all professionals in the area of occupational safety and health. It's also very good for educational purposes particularly for this kind of project.

(ii) Money constraint. Fabrication of a product is essential in determining the fuctionality and performance of the product in real case situation. However to fabricate the product, a great amount of money is needed to be spend. According to the panels during Final Year Project 1 presentation, to fabricate the mold alone will cost about RM 30,000. Therefore, it is impossible to fabricate the design in small production scale.

(iii) Limitation of getting the design validation by ergonomics expert. Ergonomics expert is a person who has a wide ranging experience in ergonomics field. To ensure the design conforms to defined user needs and intended uses, it must be validate by the ergonomics expert. The ergonomics expert will consult the designer to do the appropriate testing or correction to the design. The ergonomics factors, durability and function of the pineapple peeler also will be considered.

5.4 RECOMMENDATIONS

There are several recommendations are pointed out for the improvement in future studies:

(i) Use ergonomics software to analyze the design. For this project, the analysis process were done by using the Algor Simulation software. Although there is a result obtained from the simulation, the data obtained is not as precise as the data provided if the ergonomics software is used. One of the examples of ergonomics software that focus on reducing the occupational risk is ErgoFellow.

(ii) Fabricate the design. Fabrication is a vital process to be performed. By having the fabricated product, the actual concept of the design can be verified. It also can be used to get a feedback from the potential user, for this case, the workers at the pineapple industry. It is already known that the cost is high but the benefit that can be gained from the fabricated product is absolutely valuable.

(iii) Design validation by ergonomics expert. It is essential to get validation for the designed pineapple peeler from the ergonomics expert because they are capable to tell the designer about the advantages and disadvantages of the design. Ergonomics expert also can guide the designer and choose the appropriate method that should be performed based on their broad experience.

5.5 CONCLUSION

At the end of this study, it can be concluded that all of the objectives for this project are achieved. In the scope of this project, it has been stated that the simulation of the pineapple peeler using Algor Simulation software is considered precise. Thus, it can be conclude that the designed portable pineapple peeler has successfully developed. The design also proved to be able to prevent the development of MSD among workers who manually peel the pineapple.

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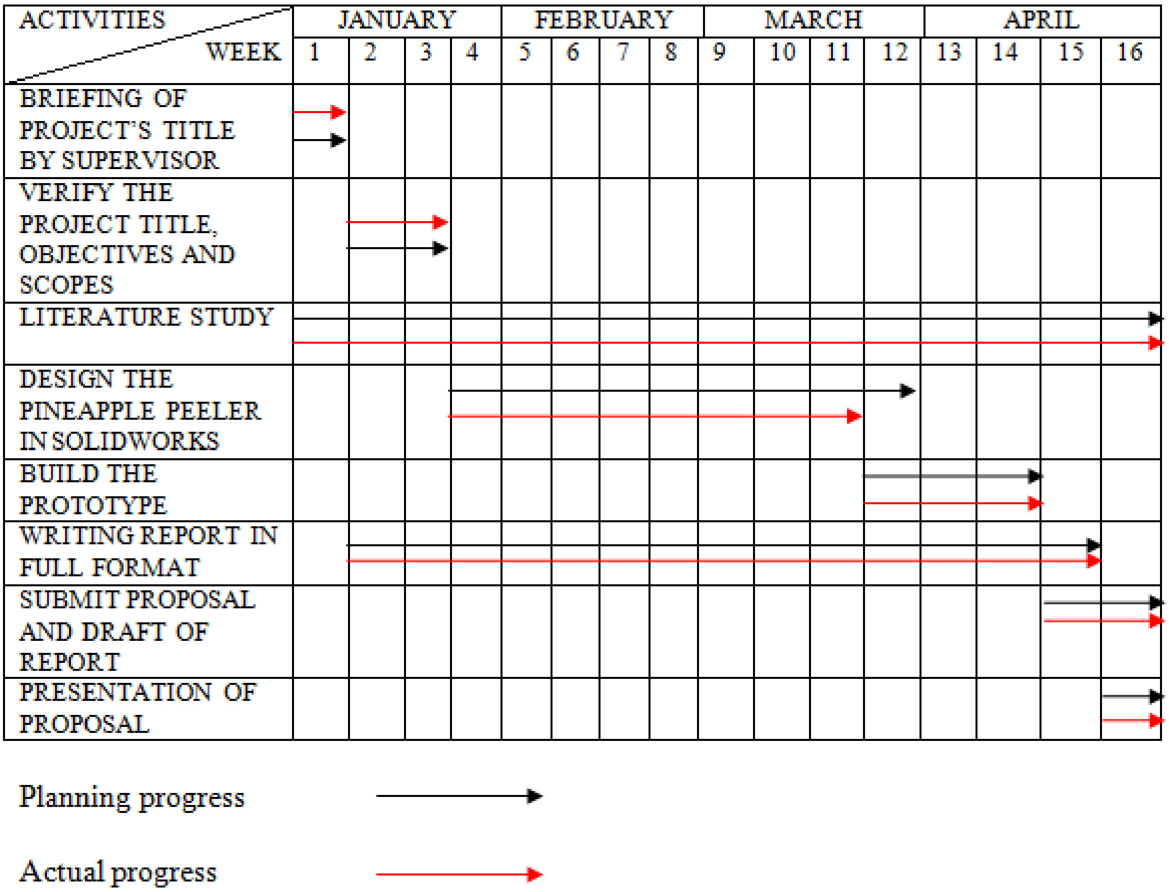
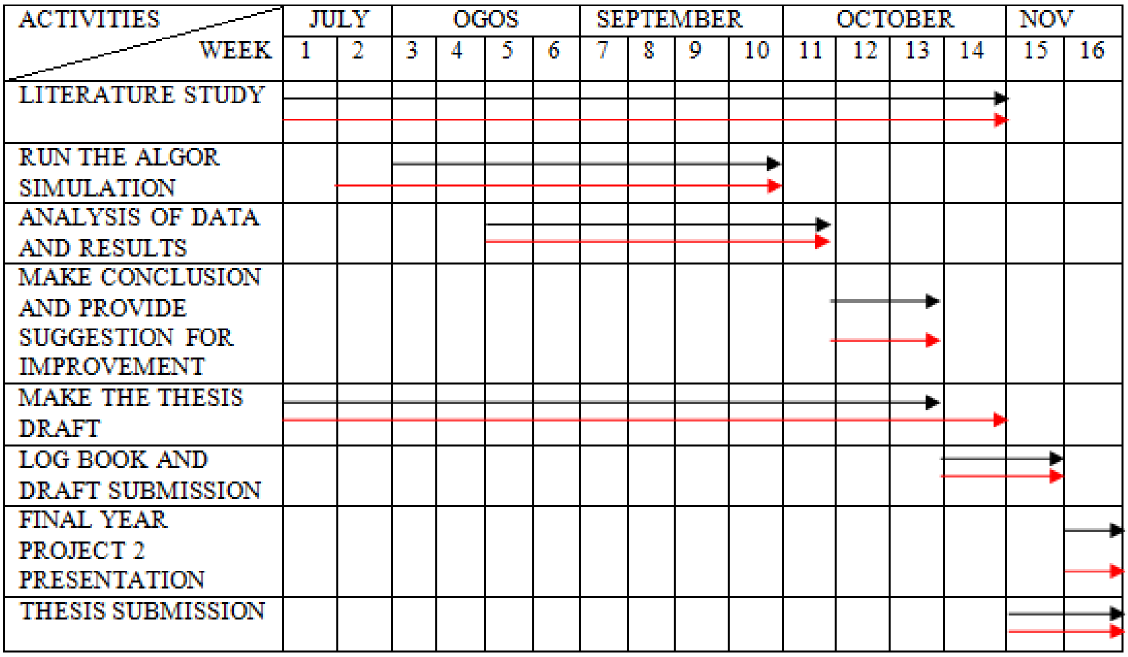
APPENDIX A1

GANTT CHART FOR FINAL YEAR PROJECT 1



APPENDIX A2

GANTT CHART FOR FINAL YEAR PROJECT 2



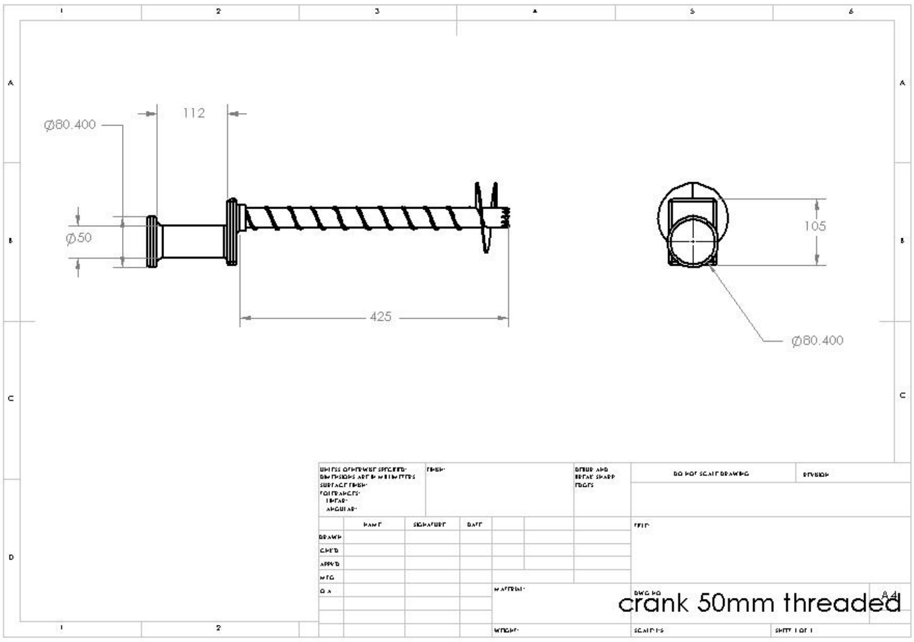
ACTIVITIES	JULY		OGOS				SEPTEMBER				OCTOBER				NOV	
WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
LITERATURE STUDY																
RUN THE ALGOR SIMULATION																
ANALYSIS OF DATA AND RESULTS																
MAKE CONCLUSION AND PROVIDE SUGGESTION FOR IMPROVEMENT																
MAKE THE THESIS DRAFT																
LOG BOOK AND DRAFT SUBMISSION																
FINAL YEAR PROJECT 2 PRESENTATION																
THESIS SUBMISSION																

Planning progress →

Actual progress →

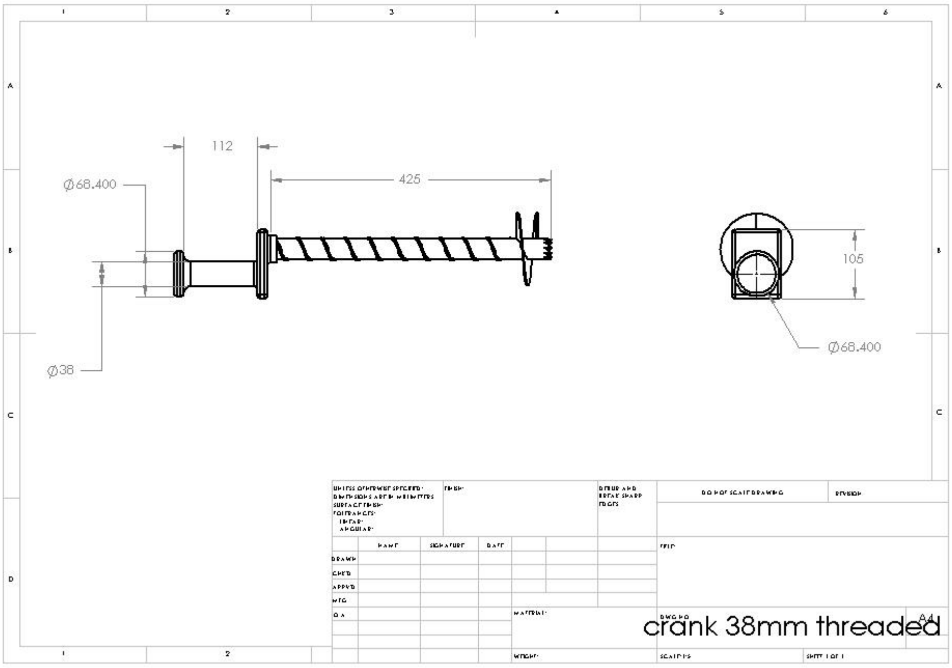
APPENDIX B1

TECHNICAL DRAWING OF CRANK HANDLE (DESIGN A)



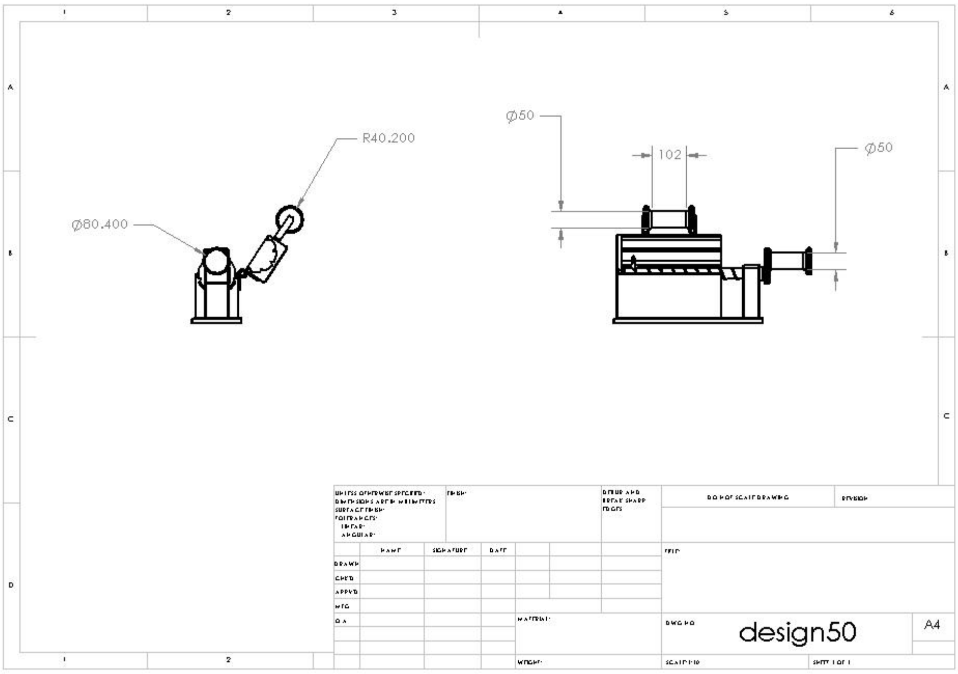
APPENDIX B2

TECHNICAL DRAWING OF CRANK HANDLE (DESIGN B)



APPENDIX B3

TECHNICAL DRAWING OF BASE (DESIGN A)



APPENDIX B4

TECHNICAL DRAWING OF BASE (DESIGN B)