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Signature : ....

Name of supervisor I : SHAFIZAL B. MAT

Date : 18-5-2009

Signature : ....

Name of supervisor II : ....

Date : ....

ERGONOMICS EVALUATION AND DESIGN OF THE HAND TOOLS USED IN MANUFACTURING INDUSTRIES

AHMAD AIZAT BIN AHMAD RAMLY

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Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

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“Hereby, I declared that this project report has written by me and is my own effort and that no part has been plagiarized without citation”

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Name of writer	**: …………………………………………**
Date	**: …………………………………………**

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ABSTRACT

In manufacturing industries the percentage of injuries that occur is higher than other sector. Most of the injuries linked to the used of hand tools. The injuries may cause from the poor design of the hand tools itself. This report presents the findings the redesign an existing hand tools and making analysis on the ergonomics design of the hand tools. By having fully understanding the ergonomics design of the hand tools and CATIA software can be applied together to carry out the new designed which are more safe and ergonomic hand tools. The existing and new design will be compare using 'RULA Analysis' module in CATIA. The particular strength of this research is to reduce injuries in using hand tools by designing an ergonomically well-designed hand tools.

ABSTRAK

Di dalam industri pembuatan, peratusan kecederaan yang berlaku adalah tinggi berbanding dengan sektor yang lain. Kebanyakan kecederaan berpunca daripada pengunaan peralatan tangan. Kemalangan tersebut berpunca daripada reka bentuk peralatan tangan yang naif. Laporan ini membentangkan keperluan untuk mereka bentuk kemabali peralatan tangan dan membuat analisa pada reka bentuk peralatan tangan yang ergonomik. Dengan memahami reka bentuk yang ergonomik dan juga perisian CATIA boleh diaplikasikan bersama untuk meraka bentuk peralatan tangan yang tidak merbahaya dan ergonomik. Reka bentuk yang sedia ada dan yang baru dibandingkan dengan meggunakan modul yang terdapat di dalam CATIA. Teras kekuatan kajian ini adalah untuk mengurangkan kecederaan dengan mereka peralatan tangan yang ergonomik.

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CHAPTER 1

INTRODUCTION

1.1 Background

In a large number of industrial occupations, hand tools are primary tools. A major concern of these industries is the higher percentage of injuries that occur annually. In many occupations, some of the major causes of work-related disorder and disease are linked to the use of hand tools. It has shown that tool design may play an important role in development of work related problems in the upper limbs. Poor design of a hand tools may result in cumulative trauma disorders. Occupational accidents can be linked directly to the use of specific hand tools as well.

Ergonomically well design hand tools may reduce the risk of occupational injuries. It is also provide comfortable work for the users and give high product quality to the consumers. As the use of hand tools may play an important role in the developments of disorders and accidents, it is obvious that improvements in the design of hand tools are essential for promoting professional users health, particularly where there is intensive exposure.

1.2 Objective

The main objective of this project is to design and perform ergonomics analysis of hand tools that are used in manufacturing industries.

1.3 Scope

The scopes of this project are;

i. Study on the literature review of the ergonomics design for hand tools that are used in manufacturing industries.
ii. Carry out conceptual design of the hand tools.
iii. Apply the concept of ergonomics in designing the hand tools.
iv. Study on the drawing tool and analysis tool (RULA analysis) using CATIA.
v. Carry out an analysis of ergonomics design by using RULA analysis in CATIA.
vi. Comparison between the existing design and new designs.

1.4 Problem Statement

A major concern of industries is the high percentages of injuries that occur annually. The relationship between occupational musculoskeletal disorders and the use of hand tools is well known. Poor design of hand tools may result in cumulative trauma disorders. Occupational accidents can be linked directly to the use of specific tools. As the use of hand tools plays such an important role in the development of disorders and accidents, this project will try to overcome the problem by designing an ergonomics hand tools. Ergonomically well-designed hand tools used in work situations with balanced work content reduce the risk of occupational injuries of the hand, wrist and forearm. It"s also provided comfortable work for the users and gives high product quality to the customers.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Injuries to the human body resulting from the use of hand tools can be classified as cumulative effect trauma or single-incident trauma. Cumulative effect trauma involves progressive damage to the tendons, tendon sheaths and related bones, and nerves of the hand, wrist, elbow and arms, resulting from long-term or improper use of a hand tool (Mital and Sanghavi, 1986).

Although it is impossible to eliminate all injury potential, maybe simple design modifications to the tools can change an unsafe tool into a relatively safe one. Take an example, the innovation of guards on hand tools have proved useful in the prevention of slipping of the hand over the blade and it can reduce the percentage of an injuries.

Mostly cheap tools that widely sold in market nowadays, made from unsuitable materials and poor workmanship. This will contribute to an injury to the users. Some examples include wrenches and spanners which open under normal working pressure, and hammer which chip or shatter when a blow is struk. Also, chisels and punches made of soft material often 'mushroom' with repeated blows, and knives of poor quality will lose their edge.

The texture of the tool handle is another important design consideration. Some grips can be improved by increasing the friction between the hand and the handle. The texture of the handle is not merely aesthetic but also functional (Fraser, 1983). A non-slip texture may also abrade the skin of the hands and inhibit adjustment of hand position (Drury, 1980). Design of hand grip should be based on the type of gripping action used (Drury and Pizatella, 1983), and the contact should be maximized as this will minimize shear stress on the skin (Pheasant and O'Neill, 1975).

Handle design for hand tools has been addressed by many authors (Van Cott and Kinkade, 1977; Greenberg and Chaffin, 1979; Woodson, 1981; Konz, 1983; Chaffin and Andersson, 1984; Chaffin, 1991). However, the problem of size and shape in the context of minimizing stress on the user or maximizing tool efficiency has not been well covered. Although considerable work has been done on grip strength, there is limited information about handle size, handle shape, and force capability (Cochran and Riley, 1986).

A few research studies have examined some aspects of handle design. Pheasant and O'Neill (1975) examined various screwdriver handle designs available in the UK and compared them with smooth and rough cylinders. Ayoub and LoPresti (1971) used electromyography in a study to find the optimum size of cylindrical handles for rotational tasks. The result of these two studies compared well. Mital and Channaveeraiah (1988) examined the effect of shape, wrist orientation and duration of repeated exertions on the maximum torque that could be exerted in different postures.

Riley and Cochran (1980) conducted a study on improved knife handle designs. On examining the cross-sectional perimeter of knife handles being used in a meat packing company, they determined that handles were too small. Bobjer (1989) examined the design of knives for the meat packing and processing industry that would reduce cumulative trauma disorders, and yet be comfortable to work with. The result of the work was to design two types of knife, a general-purpose knife and a dagger-grip knife, each of which is fitted with two handle sizes.

Cochran and Riley (1986) evaluated two variables affecting the performance of tang guards in preventing injury due to the hand slipping forward on a knife handle. They concluded that the height of the guard has a significant effect for both males and females.

Konz (1986) examined bent hammer handles, suggesting that when a tool gripped with a power grip has its working part extended above the hand, then a curve in the handle may be beneficial.

The classic work by Napier (1965) has distinguished between two discrete patterns of prehensile movement in which an object is held partly or wholly within the compass of the hand. These patterns were defined from both the anatomical and functional point of view. They were termed 'precision grip' and 'power grip'. With the precision grip, the edge is pinched between the flexor aspects of the fingers and the opposing thumb. The power grip occurs when the hand makes a 'fist' with four fingers on one side of the tool grip and the thumb reaching around the other side to 'lock' on the first finger. More recent work has been done to improve the description of the coupling of the hand (Kroemer, 1986). This improved notation gives a better understanding and definition of how the hand interacts with the control. To this end, the precision and power grips are insufficient. As an example of the system proposed by Kroemer, the precision grip is described as the 'thumb-two-finger grip'. Imrhan (1991) looks at the influence of wrist position on different types of pinch strength.

Electromyography has been used for two decades to evaluate industrial designs by quantifying muscle activities (Khalil, 1973), muscular effort, fatigue and the effectiveness of training (Lavender and Marras, 1990).

Tthe problem of obtaining ergonomically designed handles which are sized properly in the context of comfort and safety for the user needs to be addressed with more urgency.

2.2 Ergonomics

The word ergonomics comes from two Greek words:

- ERGO: meaning work
- NOMOS: meaning laws

Ergonomics is a science focused on the study of human fit, and decreased fatigue and discomfort through product design. Ergonomics can be an integral part of design, manufacturing, and use. Ergonomics is the scientific discipline concerned with designing according to the human needs, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance. The field is also called human engineering, and human factors engineering.

Ergonomic research is performed those who study human capabilities in relationship to their work demands. Information derived from these studies contributes to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people.

Ergonomics draws on many disciplines in its study of humans and their environments, including anthropometry, biomechanics, mechanical engineering, industrial engineering, industrial design, kinesiology, physiology and psychology.

When define ergonomics in term of science, it is the science of designing products that work in accordance with the way humans think, see, and behave. Products that are compatible with people will dramatically reduce human error, fatigue, discomfort, and stress, and have a profound positive impact on overall end-user performance.

The combined effect of good cognitive and physical ergonomics leads directly to consumer pleasure, fulfillment, and immediate acceptance of the product. Ergonomics reduces learning curves and limits the amount of customer education required for product sell-through.

In total, good ergonomics directly contributes to the success of the product and can be measured quantitatively in terms of customer satisfaction, market share, and profitability. Knowing how the study of anthropometry, posture, repetitive motion, and workspace design affects the user is critical to a better understanding of ergonomics as they relate to end-user needs.

2.2.1 History of Ergonomics

Ergonomics develop into a recognized field during the World War II, when for the first time, technology and the human sciences were systematically applied in a coordinated manner. Physiologists, psychologist, anthropologists, medical doctors, work scientists and engineers together addressed the problems arising from the operation of complex military equipment. The results of this inter disciplinary approach appeared so promising that the cooperation was pursued after the war, in industry. Interest in the new approach grew rapidly, especially in Europe and the United States, 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 at present represents ergonomics societies which are active in 40 countries or regions, with a total membership of some 15 000 people.

2.2.2 Characteristic of Ergonomics

The basis of ergonomics understands the physical and cognitive/perceptual limitations of human performance relative to interaction with products. Such interface analysis is crucial to establishing a safe and effective system of operation for the user.

2.2.3 Cognitive Ergonomics

Proper fit of a product to a user does not end with physical interfaces. The perceptual and cognitive demands that a product places on the user must also be examined. Note that a great misconception regarding these areas of human functioning is that they relate to emotive - and therefore qualitative - responses of users.

But rather, both perceptual and cognitive behaviors offer fact-based, quantitative data that can be used in product development.

2.2.4 Physical Ergonomics

Through understanding of the physical characteristics of a wide range of people is essential in product development. When analyzing design relative to human performance, ergonomists study anthropometric data, which includes size percentiles of a wide range of populations defined along such lines as gender and age.

Ranges of joint motions, strengths, and grips for various populations are also reviewed. These data serve as valuable information to designers and help ensure that the final product will physically fit the targeted end-users.

2.2.5 Ergonomics Needs

2.2.5.1 Important in Ease of Use

Ease of use may be extremely important both for frequently used products, such as an office photocopier, and for infrequently used products, such as a fire extinguisher. Ease of use is more challenging if the product has multiple features and/or modes of operation which may confuse or frustrate the user. When ease of use is an important criterion, industrial designers will need to ensure that the features of the product effectively communicate their function.

2.2.5.2 Important in Ease of Maintenance

If the product needs to be serviced or repaired frequently, then ease of maintenance is crucial. For example, a user should be able to clear a paper jam in a printer or photocopier easily. Again, it is critical that the features of the product communicate maintenance/repair procedures to the user. However, in many case, a more desirable solution is to eliminate the need for maintenance entirely.

2.2.5.3 User Interactions for the Products Function

In general, the more interactions users have with the product, the more the product will depend on ID. For example, a doorknob typically requires only one interaction, whereas a portable computer may require a dozen or more, all of which the industrial designer must understand in depth. Furthermore, each interaction may require a different design approach or additional research.

2.2.5.4 The Novel of the User Interaction Needs

A user interface requiring incremental improvements to an existing design will be relatively straightforward to design, such as the buttons on the next-generation desktop computer mouse. A more novel user interface may require substantial research and feasibility studies, such as the built-in trackball in the first Macintosh PowerBook notebook computer.

2.2.5.5 Safety Issues

All the products have safety considerations. For some products, these can present significant challenges to be design team. For example, the safety concerns in the design of a child"s toy are much more prominent than those for a new computer.

2.3 Common Workplace Motions

The workplace should be comfortable for users and adapt to their needs as much as possible. Workplace products designed with this in mind can lead to higher worker productivity and lower risk of injury and illnesses.

The human body has a natural range of motion (ROM). Despite the need to promote motion, users should try to avoid repetitive movements and certain extremes in their ROM over long periods of time. By considering both ROM and repetitive motion, products can be designed to operate within the optimal ranges to help reduce the occurrence of fatigue and muscle disorders.

2.3.1 Good and Bad Zones

There are 4 different zones that a user might encounter while sitting or standing:

- Zone 0 (Green Zone) Preferred zone for most movements. Puts minimal stress on muscles and joints.
- Zone 1 (Yellow Zone) Preferred zone for most movements. Puts minimal stress on muscles and joints.
- Zone 2 (Red Zone) More extreme position for limbs, puts greater strain on muscles and joints.
- Zone 3 (Beyond Red Zone) Most extreme positions for limbs, should be avoided if possible, especially with heavy lifting or repetitive tasks.

These zones are ranges where body limbs can move freely. Zones 0 and 1 include smaller joint movements, while Zones 2 and 3 represent more extreme positions. Zone 0 and Zone 1 are preferred for most movements to occur. Zones 2 and 3 should be avoided when possible, especially for repetitive and heavy tasks. Motion in these ranges puts more strain on muscles and tendons and could lead to the development of musculoskeletal disorders.

Figure 1 shows the ROM for common joint movements. Zone 0 is in green, Zone 1 is in yellow, and Zone 2 is in red. Zone 3 is anywhere beyond the red. Table 1 the numerical values for each Zone. (www.allsteeloffice.com/ergo)

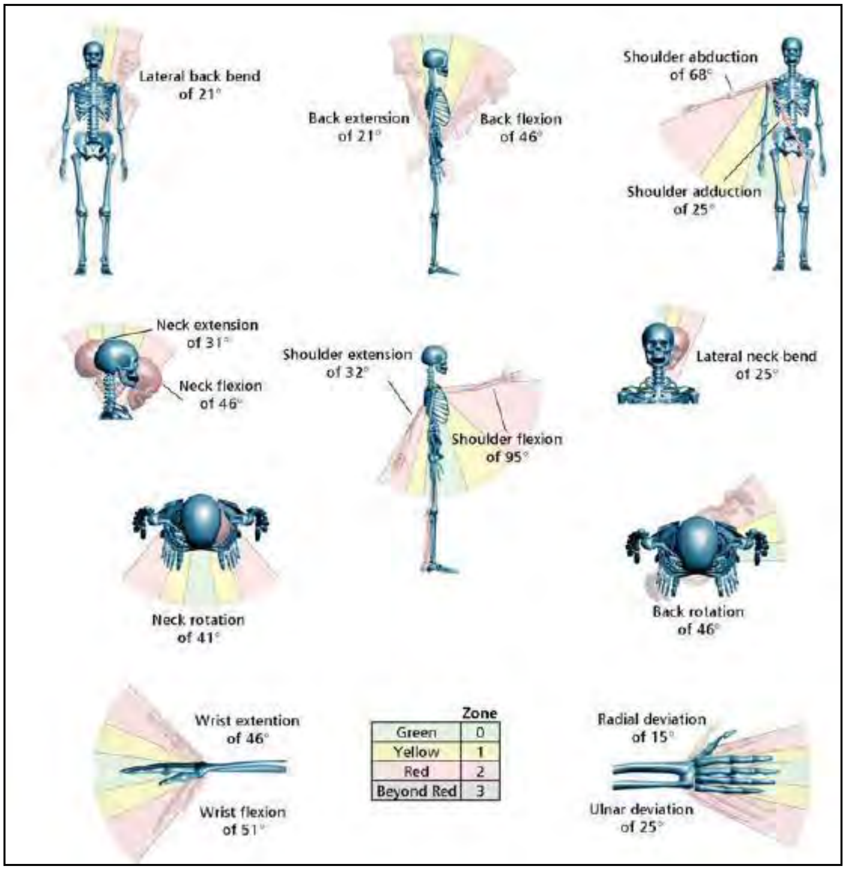


Figure 1: Range of motion

(Source: www.allsteeloffice.com/ergo)

Table 1: Numerical values for range of motion

		Range of Motion Zones			
	Movement	0	1	2	3
Wrist	Flexion	0 – 10	11 – 25	26 – 50	51+
	Extension	0 – 9	10 – 23	24 – 45	46+
	Radial Deviation	0 – 3	4 – 7	8 – 14	15+
	Ulnar Deviation	0 – 5	6 – 12	13 – 24	25+
Shoulder	Flexion	0 – 19	20 – 47	48 – 94	95+
	Extension	0 – 6	7 – 15	16 – 31	32+
	Adduction	0 – 5	6 – 12	13 – 24	25+
	Abduction	0 – 13	14 – 34	35 – 67	68+
Back	Flexion	0 – 10	11 – 25	26 – 45	46+
	Extension	0 – 5	6 – 10	11 – 20	21+
	Rotational	0 – 10	11 – 25	26 – 45	46+
	Lateral Bend	0 – 5	6 – 10	11 – 20	21+
Neck	Flexion	0 – 9	10 – 22	23 – 45	46+
	Extension	0 – 6	7 – 15	16 – 30	31+
	Rotational	0 – 8	9 – 20	21 – 40	41+
	Lateral Bend	0 – 5	6 – 12	13 – 24	25+

(Source: www.allsteeloffice.com/ergo)

2.4 Hand Tools

2.4.1 History of the Hand Tools

A tool is defined as an "an implement used to modify raw material for use". One of man‟s most distinctive characteristics is the ability to shape and mold the physical world around him. The use of tools has transformed a man from a relatively harmless, subtropical vegetarian to a predatory omnivore.

A main basis of tool design was specialization, using right tool for a specific job. The use of specified tools has lead humans to overcome their natural limitations. The appearance of a tool is influenced by the human body, the materials available, and the tasks to be formed. All tools are extensions of the human body and help increase the speed, power and accuracy nature has given us.

There are several processes used in the evolution of tool making. Reduction is the process by which a tool is made by reducing the size of a larger object. Conjunction is the process by which two or more parts are combined. Two or more parts that perform the same task is a process known as replication. This process helps improve effectiveness of tool, while decreasing the chance that the tool will fail or break.

2.4.2 Human Factors and Ergonomics

The rationale for existence of hand tools within various human cultures is provided by the discipline known as human factors and ergonomics. This discipline studies the interface and the relationship of the human being and the various practical artifacts human has created for purposes of survival or purposes of leisurely enjoyment.

These artifacts are physical and psychological extensions of the human being and compensate for many physical and psychological inadequacies which are attributed to the human being. It is important to attempt to provide a distinction between the terms ergonomics and human factors. Although there is a substantial overlap between the disciplines of human factors and ergonomics and although practicing professionals in these fields deplore any attempts at distinguishing between these disciplines. Human factors deal, though not exclusively, with psychological issues such as behavior, sensation, perception, information storage and retrieval and decision making. Ergonomics deals, though not exclusively, with anatomical and physiological issues.

2.4.3 Reasons that Hand Tools been created

Hand tools would not exist except for various human needs and requirements.. In essence, the human possesses several critical limitations, which must be compensated for by the machine. In general, the machine is superior to the human in such areas as strength, speed, vigilance and endurance. Hand tools, which may also consider machines, which to overcome human limitations while performing manual tasks. These insufficiencies are especially unique and are discussed in the following section.

2.4.3.1 Strength

Limitations in strength of the hand, have led to the design of hand tools which magnify human grip force, shown in Figure 2. Figure 2 shows bolt cutter which is a tool magnifies human strength. Pressure at handles A is greatly increased at B. A 50th percentile male grip of approximately 100 pounds may be multiplied as much three times by the handles of pair of pliers or a pair of wire cutters. Two handed tools such as pruning shears are capable of magnifying forces as much as ten times. The working ends of these tools provide a compressive force for purposes of crushing, holding, piercing, or cutting.

Figure 2: Bolt cutter.
(Source: Charles A. Cacha, 1999)

2.4.3.2 Penetrability

Human skin and underlying tissue are relatively soft and penetrable. Efforts in abrading most materials external to the human are generally unsuccessful without hand tools composed of some hard impenetrable material shown in Figure 3; The tool is harder and more impenetrable than human tissue.

These impenetrable materials are most traditionally iron and steel but may also be, or have been wood, plastic or bone. Saws and files are the best examples of tools composed of hard materials which are capable of abrading softer materials (Charles A. Cacha, 1999).

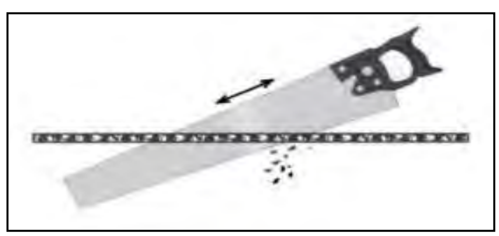


Figure 3: Wood saw.
(Source: Charles A. Cacha, 1999)

2.4.3.3 Bluntness

Human appendages end in digits which have relatively blunt, broad ends. This bluntness has two advantages;

i. Materials external to the human being cannot be pierced cut or penetrated by fingers.
ii. Small object s cannot be readily grasped and manipulated by blunt fingers.

Tools which compensate for this inadequacy are knives, scissors, chisels, awls and drills which punch, drill and cut various object; and tweezers which grasp small objects shown in Figure 4: The tool may be sharper and more pointed than human appendages (Charles A. Cacha, 1999).

Figure 4: Carving knives. (Source: Charles A. Cacha, 1999)

2.4.3.4 Shortness

In some situations the human may wish to extend his/her reach towards a remote object or an object located in an inhospitable environment. Tools such as tongs and pruning poles extend human reach beyond the limits of arm hand length is shown in Figure 5: Extension of human appendages. Tool reaching into inhospitable environment (Charles A. Cacha, 1999).

Figure 5: Tongs
(Source: Charles A. Cacha, 1999)

2.4.3.5 Flexibility

Hands and fingers may not retain rigidity due to fatigue and loss of strength over short periods of time. Tools, particularly tool handles such as those of a hammer, provide a needed rigidity which facilitates control and manipulation (Charles A. Cacha, 1999).

2.5 Design Principles

This section will present physical factors which are in term of ergonomic and safety importance.

2.5.1 Product Shape

For greatest comfort of use and least stress, the tool handle should be oriented so that, while working, the hand and the forearm are aligned. Since the shape of the tool handle will affect the posture used to hold it, the shape of the handle is a primary factor which can be used to reduce or eliminate fatigue in the human user.

The major muscles which flex the fingers and generate grip force are located in the forearm. These muscles have long tendons which span the wrist joint. Thus the gripping capability of the fingers is affected by the position of the wrist. Tichauer has presented evidence which indicates that continued use of hand tools with the wrist in a bent position can cause inflammation, chronic pain, and possible permanent injury both to the synovial sheaths protecting the tendons of the wrist and to the median nerve passing through the wrist (Tichauer, 1966).

The cross-sectional configuration of the tool handle also directly affects the operator's performance and health. For the chisel handle, the forces generated during use should be distributed on as large a pressure-bearing area of the palm as possible, while still being small enough to allow the fingers to wrap around the handle. A handle which is tapered from the back to the front has been found to be the most efficient in achieving this.

Recesses such as finger grooves should not be provided because of the wide variations in finger anthropometry in the population. In particular, a person with large fingers may create compressive forces on the lateral surfaces of the fingers, which are areas abundant in superficial nerves and veins.

If a tool has a short handle which does not span the breadth of the palm, high forces are created at the centre of the palm. Thus the tool handle should be designed to extend beyond the hand when gripped.

Sharp edges and corners may cause cuts, bruises, or abrasions. Hence one should seek to eliminate such hazards by rounding edges and corners with as large a radius as possible.

Excessive stress imposed on hand tissues will result in compression of the arteries, veins, or nerves supplying the intrinsic muscles of the hand (Tichauer, 1966). Three areas of the hand are considered pressure sensitive: palmar arch and ulnar nerve in the heel of the hand and the mid-palmar area (Tichauer and Gage, 997). Thus the handle was designed to be broader in the region where it pressed against the heel of the hand to minimize stresses in this region.

2.6 Hand Tools Involved

Below there are several hand tools that will be used in this project; power hand drill, saber saw and breaker.

2.6.1 Power Hand Drill

Figure 6: Power hand drill
(Source: http://home.howstuffworks.com/)

A power hand drill is an electrical motor that rotates a replaceable drill bit to make a hole in wood, plastic, or metal. Alternately, a screwdriver tip can be installed to turn screws. The parts of a power drill include the handle, an on/off trigger with safety latch, a reversing switch for changing the rotation direction of the drill bit, a torque adjustment, and the chuck that holds the drill bit in place. Corded drills are powered by a 110-volt electrical cord inserted into an electrical receptacle; cordless drills are powered by a battery in the drill's handle.

2.6.2 Saber Saw

Figure 7: Saber saw
(Source: http://home.howstuffworks.com/)

The powered saber saw uses a reciprocating motor to move a small saw blade up and down across the object to be cut. Blades available include those for wood (coarse or fine cut), metal, drywall/plaster, or plastic. Many saber saws come with an assortment of specialized blades, or they can be purchased individually for specific tasks. The handle includes a safety button and trigger switch. The shoe is a plate that keeps the blade at a specified distance from the work. A guide fence also is available for cutting straight lines.

2.6.3 Breaker

Figure 8: Breaker
(Source: www.hilti.com)

The breaker is commonly use in the construction field. The application of this breaker is to moderately heavy chiseling work on concrete and masonry, mainly on walls. It also can be used to channeling on concrete and masonry, concrete repair work, removing plaster and tiles. More over it can be used to chiseling breaches and penetrations for pipes in walls and floors

2.7 CATIA as a CAD Approach

In this project CATIA will be used as the computer aided design (CAD) approach. The design of the existing hand tools will be drawn first and then the new design of hand tools will be proposed. Lastly, both of the designs will through an ergonomics analysis using RULA analysis in CATIA. RULA analysis is one of the features in the Human Activity Analysis (AAA).

CATIA is used by the automotive and aerospace industries for automobile and aircraft product and tooling design. There are thousands of companies over the world using CATIA.

CATIA is found in a variety of industries throughout the world. Some of these industries include; Aerospace, Appliances, Architecture, Automotive, Construction, Consumer Goods, Electronics, Medical, Furniture, Machinery, Mold and Die, and Shipbuilding.

2.8 Human Activity Analysis

Human Activity Analysis (HAA) is an add-on to Human Builder (HBR) that allows maximizing human comfort, safety, and performance through a wide range of advanced ergonomics analysis tools that comprehensively evaluate all elements of a human‟s interactions with a product and specifically analyze how a mannequin will interact with objects in its virtual environment. Human Activity Analysis 2 (HAA) addresses the needs of human factors engineers, assembly and decommissioning planners, maintainability engineers, packaging engineers, and manufacturing engineers from industries as diverse as aerospace, automotive, plant design, ship building and electrical goods. It is effectively used in conjunction with Human Measurements Editor (HME) and Human Posture Analysis (HPA). These products are combined to create a fully integrated Human Engineering Design solution. The features of human activity analysis that will be used for this project;

2.8.1 Human Builder

This section can be define and create the probable user of the product or system that is, in fact, the human operator represented by a manikin. It can be manipulated as is needed in the design process for defining the human interface and it can be settled in a determine position.

2.8.2 Human Measurements Editor

Human measurements editor allowed the designer to personalize the manikin dimension and to select its work position.

2.8.3 Human Posture Analysis

Human posture analysis allows analyzing all quantitative and qualitative aspects of manikin posture. Whole body and localized postures can examine, scored and iterated to determine operator comfort and performance when interacting with the product in accordance with published comfort database.

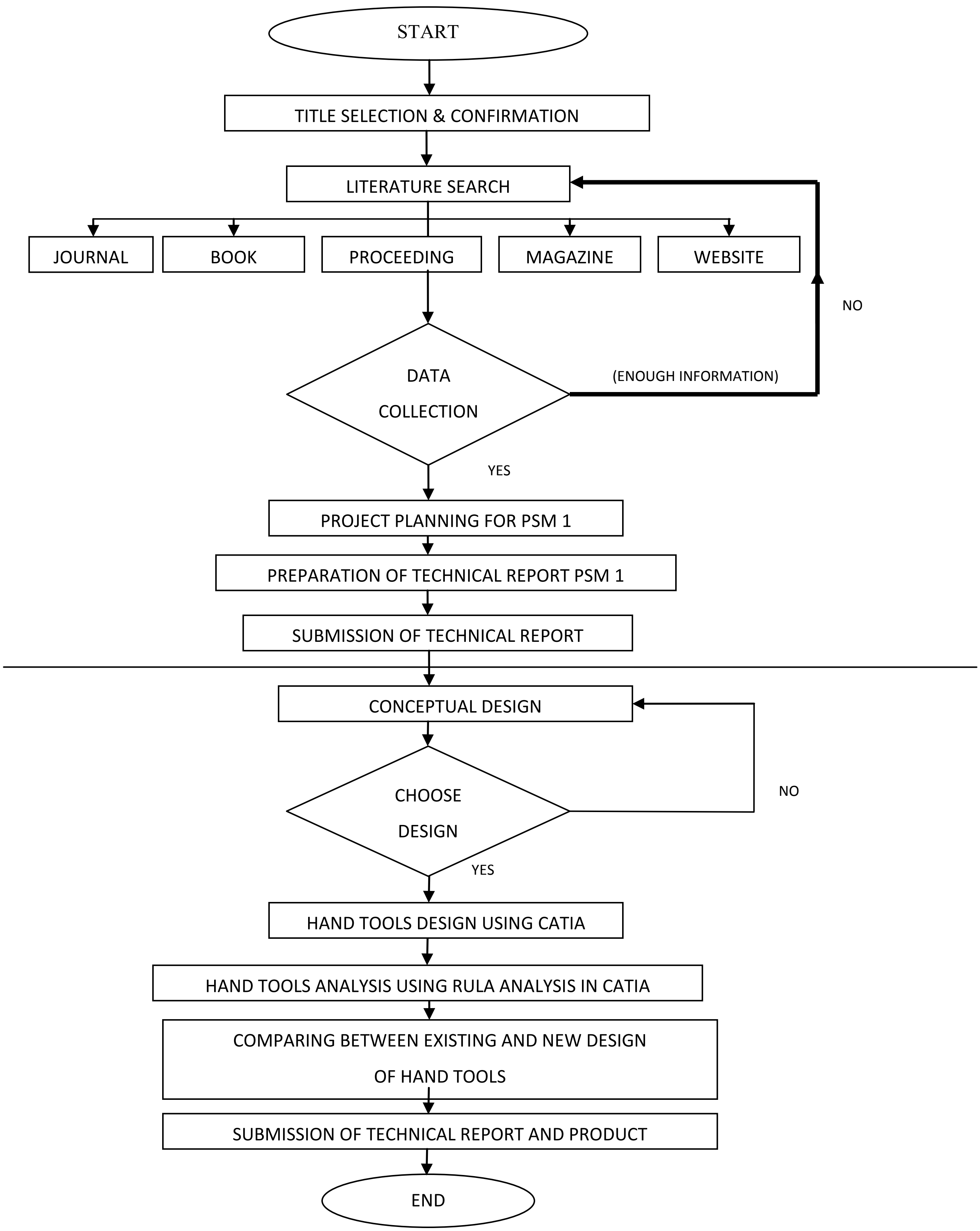
CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will cover methodology of this project flow that has been used along this project research. This chapter is related to the scopes and the flow chart of this project which is containing in chapter 1. Thus all the content that contain in this chapter is based on the scopes and flow chart.

3.2 Flow Chart



3.3 Literature Research

Literature research or commonly known as literature review is the core of this project research. In order to get the correct and accurate source, all the information has been search from internet, journals, books and also magazine. Literature is important part of this project in order to study previous research and its give lot of information that help in finishing this project research. Therefore the literature review will act as guidelines for this project in order to achieve the objectives of this project.

All the information that relates to this project has been compile into the second chapter which is contain the information about previous research, definition of ergonomics and relate to the ergonomics, hand tools and design principles.

3.4 Conceptual Design

There are 4 steps in conceptual design. The method breaks a complex problem into simpler subproblems. Solution concepts are then identified for the subproblems by external and internal search procedures. The four steps are;

1. Clarify the problem.
2. Search externally.
3. Search internally
4. Reflect on the results and the process.

3.4.1 Step 1: Clarify the Problem

Clarifying the problem consists of developing a general understanding and then breaking the problem down into subproblems if necessary. The mission statement for the project and the preliminary product specification are the ideal inputs to the concept generation process

Many design challenges are too complex to solve as a single problem and can be usefully divided into several simpler subproblems. The goal is to divide a complex problem into simpler problems such that these simpler problems can be tackled in a focused way.

3.4.2 Step 2: Search Externally

External search is aimed at finding existing solutions to both the overall problem and the subproblems. There at least three good ways to gather information from external sources which is patent searches and literature searches.

3.4.2.1 Search Patents

Patents are a rich and readily available source of technical information containing detailed drawings and explanations of how many products work. Thus to redesign an existing hand tools can take patents as a guidelines in designing the new hand tools. Whereby, through studying patents can generate a lot of ideas in designing hand tools.

3.4.2.2 Search Literature

As stated before literature review is the core of this project. All the literature review that relates to this project has been stated in the chapter 2.

3.4.3 Step 3: Search Internally

Internal search is the use of personal knowledge and creativity to generate solution concepts. Below several guidelines for internal research;

1. *Generate a lot of ideas*. The more ideas the person generates, the more likely the person is to explore fully solution space.
2. *Welcomes ideas that may seem infeasible*. Ideas which initially appear infeasible can often be improve. The more infeasible an idea, the more it scratches the boundaries of the solution space to think of the limits of possibility.
3. *Graphical and physical media*. Reasoning about physical and geometric information with words is difficult. Text and verbal language are inherently inefficient vehicles for describing physical entities.

3.4.4 Step 4: Results

After all of those step finally it comes to the outcome and the results. Whereby following the entire step to generate the concept design of the hand tools. But all the conceptual design must be relates to the ergonomics design. Finally the design which is consider the best followed the design principles and ergonomics design will be taken as the conceptual design.

3.5 Computational Modeling and Analysis Using CATIA

This project used CATIA V5 as the CAD software in computational modeling. The advantages of CATIA V5 are it could address the complete product development process, from product concept specifications through product-in-service, in a fully integrated and associative manner. Other than that, it also facilitates true collaborative engineering across the multidisciplinary extended enterprise, including style and form design, mechanical design, equipment and systems engineering, digital mock-up, machining, analysis, and simulation.

CATIA is used to design an existing and new design of hand tools. All the hand tools will design using CATIA. First of all design an existing of hand tools and then analysis the existing hand tools also using CATIA (this will discuss more in the analysis using CATIA). After determine all aspect of an existing design come out with new design which more ergonomic design than existing. Below is the sequence from design until analysis.

Figure 9: Draw an existing product

First of all draw an existing product. The product will be drawn after taken the entire dimension using all the properties that involves as shown in Figure 9.

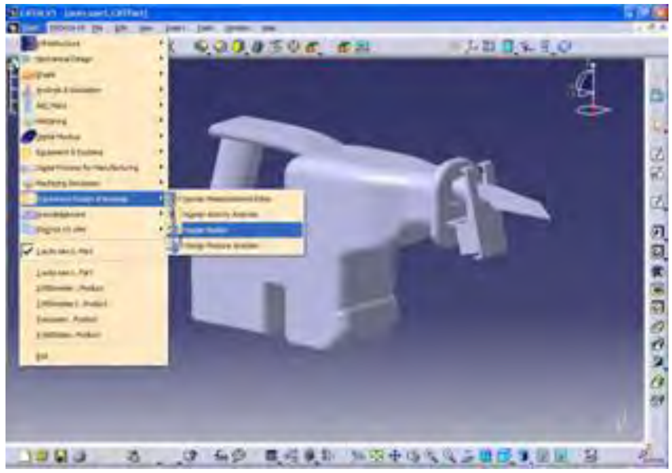


Figure 10: Human builder

Then click start at the top menu choose “Ergonomic Design and Analysis” and click at “Human Builder”. It will pop up another CATIA tab.

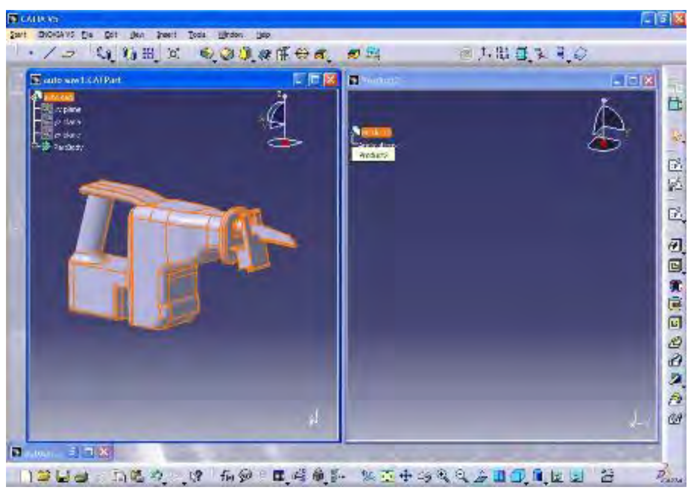


Figure 11: Drag the product

Then drag the product to the new tab and just drag it to the “product1” in the new tab. The product will appear in the new tab.

Figure 12: Inserts new manikin

Next click "Inserts a new manikin" set all the option of the manikin that desire. Manikin of Japanese has been selected for this project because Japanese posture is quit the same with Malaysian posture.

Figure 13: Adjust the manikin

Then a new manikin will appear on the screen. Thus adjust all the posture to posture desire as in the Figure 13.

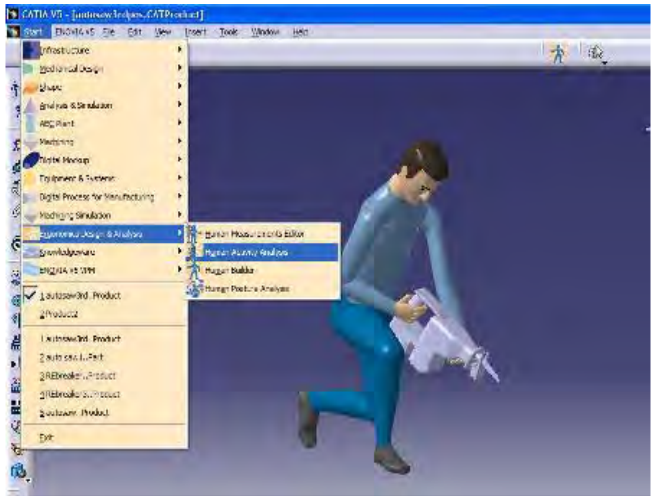


Figure 14: Human activity analysis

Next step is click start at the top menu choose “Ergonomic Design and Analysis” and click at “Human activity analysis”. Then the properties of human activity analysis will appear on the right side.

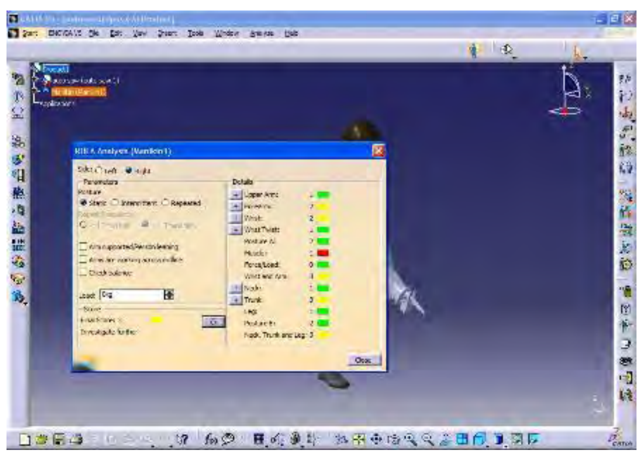


Figure 15: RULA analysis

Then click “RULA analysis” on the right side of the screen. Next click the body of the manikin and the analysis will appear on the screen. After that, set the parameter for the RULA analysis; which this will explain more on the next chapter. Then the result of the analysis will appear and it will show the scoring of the posture.

All of these steps will be repeated in redesign and analysis the new hand tools. After that, the results will be compared to the existing result so that, it will determine which design has the better RULA scoring.

3.6 Comparison between the Existing Design and New Design

Results from analysis using CATIA will be used in order to determine which at the existing and new designs of hand tools is more ergonomic. The comparison featuring; power hand drill, saber saw and breaker. In this part also will feature the differences between existing and the new design of the hand tools.

CHAPTER 4

RESULTS AND DISSCUSSION

4.1 Introduction

This chapter will discuss about the results and the analysis of this project. CATIA V5 R16 has been used in this project to do both CAD drawing and ergonomics analysis. Moreover, RULA analysis will be used during this project.

Based on the previous study, a well-design hand tools can prevent the user from any injuries. Thus this chapter will discuss an analysis of human posture while holding the hand tools. The score for the analysis is range from 1 to 4 and below is the description for the analysis using Human Activity Analysis;

Table 2: RULA scoring

Score	Description
Action 1	Score 1-2 means that the person is working in the best posture with no risk of injury from their work posture
Action 2	Score 3-4 means that the person is working in a posture that could present some risk of injury from their work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position, so this should be investigated and corrected.
Action 3	Score 5-6 means that the person is working in a poor posture with a risk of injury from their work posture, and the reasons for this need to be investigated and changed in the near future to prevent an injury
Action 4	Score 7-8 means that the person is working in the worst posture with an immediate risk of injury from their work posture, and the reasons for this need to be investigated and changed immediately to prevent an injury

(Source http://ergo.human.cornell.edu/)

The parameter will be set for each product and each posture there is two parameters for this analysis which is posture and load. There are three options to set the posture;

- Static : to analyze the posture while it‟s in static posture.
- Intermittent : to analyze the posture that tends to move while doing something.
- Repeated : to analyze the posture that will repeat the posture over and over again

Only parameter for posture will be fixed to the intermittent posture mean while for the load will depend on the product itself.

4.2 Analysis of the Existing Hand Tools

In this project focus on three hand tools commonly used in industries which is power hand drill, saber saw and breaker. Every product has been analyzed with 3 different postures. Thus in order to perform a comparison between existing and redesign product is based on the score of the human posture.

4.2.1 Existing Power Hand Drill

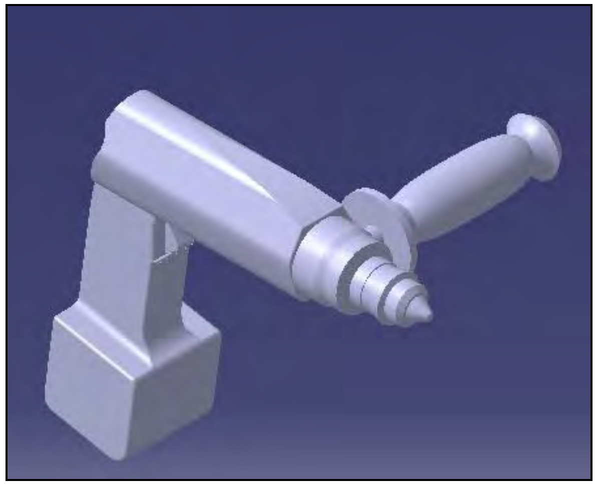


Figure 16: Power hand drill

Power hand drill is used to drilling onto an object in order to make a hole. This is one of the existing power hand drill that have in the market nowadays. There is an extra handle that attached on the side of the product. Below is the parameters that been set for the power hand drill while doing RULA analysis:

- Loads : 2.1kg
- Posture : Intermittent

4.2.1.1 First Posture Using Existing Power Hand Drill

Figure 17: First posture using existing power hand drill

Table 3: RULA scoring for first posture using existing power hand drill

Part of body	Score	
	Right	**Left**
Upper arm	2	3
Forearm	1	3
Wrist	3	3
Wrist twist	1	2
Muscle	1	1
Wrist and arm	4	6
Neck	1	1
Trunk	1	1
Leg	1	1
Neck, trunk and leg	2	2
Final score	**3**	**4**

Figure 17, shows that the first human posture while holding the power hand drills. This is one of the basic postures while using the power hand drill. First posture commonly used while doing drilling on the wall. The posture is standing still meanwhile both hand hold the power hand drill. Right hand is holding the trigger of the power hand drill and the other side of hand which is the left side is holding the handle that attach to the main body of the power hand drill. The purpose of the left hand holding the other handle that attach to the main body of the power hand drill is to hold and stabilize the power hand drill to prevent it from slipping.

More over the Table 3 above shows the scoring of this posture. Thus, based on the Table 3, wrist and arm is the highest score which is 4 on the right side and the left side is 6. Meanwhile others part of body score in range of 1 to 3.

The final score for this product is divided into two parts which is right side and left side. Final score for right side is 3 while on the left side is 4. Refer to the Table 2, score 3-4 means that the person is working in a posture that could present some risk of injury from their work posture and need to be corrected. While for score 5-6 means that the person is working in a poor posture with a risk of injury from their work posture. Therefore, as indicate on the analysis for the final score both side of human posture are acceptable but still need to be improved.

4.2.1.2 Second Posture Using Existing Power Hand Drill

Figure 18: Second posture using existing power hand drill

Table 4: RULA scoring for second posture using existing power hand drill

Part of body	Score	
	Right	**Left**
Upper arm	2	3
Forearm	1	3
Wrist	3	3
Wrist twist	1	2
Muscle	1	1
Wrist and arm	4	6
Neck	1	1
Trunk	1	1
Leg	1	1
Neck, trunk and leg	2	2
Final score	**3**	**4**

Figure 18, shows the second human posture while holding the power hand drill. The second posture also commonly used in using the power hand drill. This posture usually uses to do a drilling process for the lower height. Meanwhile both hands are similar in the posture before. The difference from the first posture is this posture is in squat position.

Table 4 shows the scoring for second posture which is still the wrist and arm part has the highest score for both sides. On the right side score is 4 and the left side is 6. Mean while the other part of body score is in the range is 1-3 which is acceptable.

The final score for second posture is 3 for the right side while on the left side score is 4. This indicates that the second posture is included in Action Level 2. Whereas this posture could present some risk of injury from this work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position. This means that the second posture is acceptable.

4.2.1.3 Third Posture Using Existing Power Hand Drill

Figure 19: Third posture using existing power hand drill

Table 5: RULA scoring for third posture using existing power hand drill

Part of body	**Score**	
	Right	**Left**
Upper arm	2	3
Forearm	2	3
Wrist	3	4
Wrist twist	1	2
Muscle	1	1
Wrist and arm	4	6
Neck	1	1
Trunk	3	3
Leg	1	1
Neck, trunk and leg	3	2
Final score	**3**	**5**

Figure 19, shows the third human posture while holding the power hand drill in doing work. This posture commonly used when doing the drill whereas the object need to be drill is on the floor. This posture need human to bend the body forward in order to reach the lower object which is needed to be drill. Mean while the posture of both hand are the same in holding the power hand drill, but in this posture both hand is lower than in the posture before.

Table 5 shows the scoring for the third posture. Same as in the second posture, wrist and arm has the highest score which is for both side score 4. Mean while the other part of body score is in the range is 1-3.

The final score is 3 for the right side and 5 for the left side, which is the scoring indicated that this posture is categorized in Action Level 2 and 3. Hence, the person is working in a poor posture with a risk of injury.

4.2.2 Existing Saber Saw

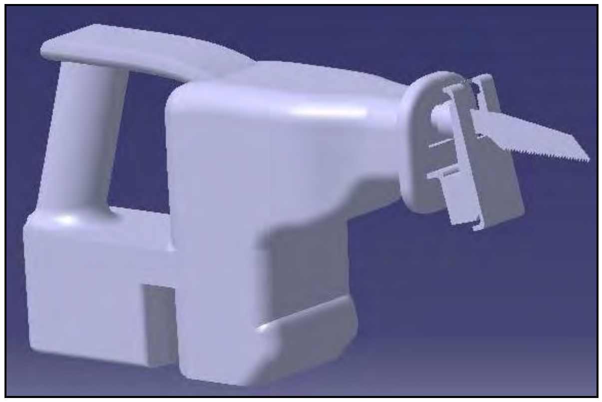


Figure 20: Saber saw

Function of the saber saw is to cut material as hard as steel pipe. This saber saw is one of the examples of its kind in the market that commonly used nowadays. The parameters for saber saw while doing the analysis are:

- Loads : 4kg
- Posture : Intermittent

4.2.2.1 First Posture Using Existing Saber Saw

Figure 21: First posture using existing saber saw

Table 6: RULA scoring for first posture using existing saber saw

Part of body	Score	
	Right	**Left**
Upper arm	1	3
Forearm	2	3
Wrist	2	4
Wrist twist	1	1
Muscle	1	1
Wrist and arm	3	6
Neck	1	1
Trunk	1	1
Leg	1	1
Neck, trunk and leg	2	2
Final score	**3**	**4**

Based on the Figure 21, shows the first human posture while holding the saber saw. This is common posture while using saber saw. The Figure 21 shows that the posture is standing straight mean while both hand are holding the saber saw. The right hand hold the handle of the saber saw while the left hand is hold the main body of the saber saw. The reason that right hand holds the main body is stabilize the usage of saber saw and because of the weight of the saber saw.

As shown in Table 6 is the scoring for the first posture which indicates that the highest scoring is wrist and arm part for left hand. The score for left side is 6 mean while for the right side is only 3. This indicates that the person is working in the in a poor posture with a risk of injury from their work posture. While the other part for both sides are acceptable in the range of scoring 1 to 4.

The final score for this posture is acceptable. The final score for the right side is 3 while for the left side is 4 and this posture is categorize in Action Level 2. These mean that this posture could present some risk of injury but still acceptable.

4.2.2.2 Second Posture Using Existing Saber Saw

Figure 22: Second posture using existing saber saw

Table 7: RULA scoring for second posture using existing saber saw

Part of body	Score	
	Right	Left
Upper arm	1	3
Forearm	2	3
Wrist	2	4
Wrist twist	1	1
Muscle	1	1
Wrist and arm	3	6
Neck	1	1
Trunk	1	1
Leg	1	1
Neck, trunk and leg	2	2
Final score	**3**	**4**

Figure 22 shows the second human posture while holding the saber saw. In this posture both hand posture are similar to the first posture. The differences are this posture doing work in squat position. This posture usually use while to cut the lower object. Thus the user must be in Figure 22 position in order to cut the lower object.

Table 7 shows the scoring for the second posture in holding saber saw. Still, wrist and arm for the left hand is high which is the score is 6 while the score for right hand wrist and arm is only 3. Mean while the other part of body score is in the range is 1 to 3.

The final score for second posture is 3 on the right side score while on the left side score is 4. The scoring indicated that this posture is categorized in Action Level 2. This posture is acceptable but still could present some risk of injury.

4.2.2.3Third Posture Using Existing Saber Saw

Figure 23: Second posture using existing saber saw

Table 8: RULA scoring for third posture using existing saber saw

Part of body	Right	Left
Upper arm	1	3
Forearm	2	3
Wrist	2	4
Wrist twist	1	1
Muscle	1	1
Wrist and arm	3	6
Neck	1	1
Trunk	3	3
Leg	1	1
Neck, trunk and leg	3	3
Final score	**3**	**5**

Figure 23shows the third human posture while using the saber saw. This posture commonly used when the object need cut is below than the users knee. This posture need human to bend the body forward in order to reach the lower object. While the posture of both hand are the same as before, but in this posture both hand is lower than in the posture before.

Table 8 indicates the scoring for third posture while using the saber saw. The highest score is wrist and arm for left hand side which is 6 while on the right side score is 3. While the other part of body score is in the range 1 to 3 except for the wrist score left hand side is 4.

The final score for third posture is 3 for the right side and on the left side are 5. Thus this posture is not stable because on right side is categorize in Action Level 2 while on the left side is categorize in Action Level 3.

4.2.3 Existing Breaker

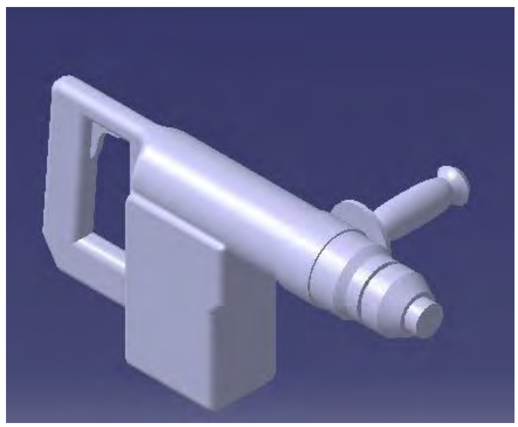


Figure 24: Breaker

Function of the breaker is to demolish the wall. This product commonly used in construction field. The parameters for breaker while doing the analysis are:

- Loads : 5.5kg
- Posture : Intermittent

4.2.3.1 First Posture Using Existing Breaker

Figure 25: First posture using existing breaker

Table 9: RULA scoring for first posture using existing breaker

Part of body	Score	
	Right	**Left**
Upper arm	1	3
Forearm	3	3
Wrist	3	3
Wrist twist	1	1
Muscle	1	1
Wrist and arm	4	5
Neck	1	1
Trunk	3	3
Leg	1	1
Neck, trunk and leg	3	3
Final score	**3**	**4**

Figure 25 shows the first human posture while holding the breaker. The first posture commonly used while using the breaker. This posture usually uses to do a demolition process for the same height to the body. The body of this posture is standing straight while both hand holding the breaker. The left hand is holding the handle in front of the breaker body and the right hand is holding the handle at the back of the breaker body.

Table 9 shows the scoring for first posture while using breaker. It is indicates that wrist and arm is the highest score which the right hand side is 4 while on the left side is 5. While the other part of the body scoring is around 1 until 3 and this is acceptable.

The final score for first posture is 3 on right sides while on the left side is 4. Thus, this posture is categorize in Action Level 2 which indicates that this posture could present some risk of injury from users work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position.

4.2.3.2 Second Posture Using Existing Breaker

Figure 26: Second posture using existing breaker

Table 10: RULA scoring for second posture using existing breaker

Part of body	Score	
	Right	**Left**
Upper arm	1	3
Forearm	3	3
Wrist	3	3
Wrist twist	1	1
Muscle	1	1
Wrist and arm	4	5
Neck	1	1
Trunk	3	3
Leg	1	1
Neck, trunk and leg	3	3
Final score	**3**	**4**

Figure 26 shows the second human posture while using the breaker. In this posture both hand posture are similar to the first posture. The differences is in this posture is the users bend the body in front but yet the leg still remain the same posture as in the first posture. This posture usually used by the user if the wall that want to be demolish is in area between user‟s knee and the user‟s hip.

Table 10 shows the scoring for second posture while using breaker. It is indicates that wrist and arm is the highest score which the right hand side is 4 while on the left side is 5. Mean while the other part of the body scoring is around 1 until 3.

The final score for first posture is 3 on right sides while on the left side is 4. Thus, this posture is categorize in Action Level 2 which indicates that this posture could present some risk of injury from users work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position. The final score is same to the previous posture.

4.2.3.3 Third Posture Using Existing Breaker

Figure 27: Third posture using existing breaker

Table 11: RULA scoring for third posture using existing breaker

Part of body	**Score**	
	Right	**Left**
Upper arm	1	3
Forearm	3	3
Wrist	3	3
Wrist twist	1	1
Muscle	1	1
Wrist and arm	4	5
Neck	1	1
Trunk	3	3
Leg	1	1
Neck, trunk and leg	3	3
Final score	**3**	**4**

Figure 27 shows the third human posture while using the breaker. These postures commonly use to demolish the wall which is at the lower area near to the floor. This posture need human to bend the body forward in order to reach the lower area. While the posture of both hand are the same as before, but in this posture both hand is lower than in the posture before.

In Table 11 indicates the scoring for third posture while using the breaker. The highest score is wrist and arm for left hand side which is 5 while on the right side score is 4. While the other part of body score is in the range 1 to 3.

The final score for third posture is 3 for the right side and on the left side are 4. Thus this posture is categorized in Action Level 2 means that the person works in a posture that could present some risk of injury from their work posture.

4.3 Analysis of the Redesign Hand Tools

4.3.1 Redesign Power Hand Drill

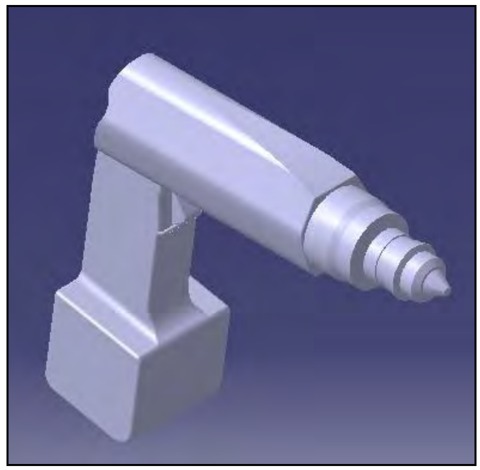


Figure 28: Power hand drill redesign

This is the redesign of the power hand drill. The handle on the side of the power hand drill has been eliminated. The handle is eliminated therefore for this analysis will get a better scoring than existing power hand drill. Below is the parameters that been set for the redesign power hand drill while doing RULA analysis:

- Loads : 2kg
- Posture : Intermittent

4.3.1.1 First Posture Using Redesign Power Hand Drill

Figure 29: First posture using redesign power hand drill

Table 12: RULA scoring for first posture using redesign power hand drill

Part of body	**Score**	
	Right	**Left**
Upper arm	2	3
Forearm	1	3
Wrist	3	3
Wrist twist	1	1
Muscle	1	1
Wrist and arm	4	5
Neck	1	1
Trunk	1	1
Leg	1	1
Neck, trunk and leg	2	2
Final score	**3**	**4**

Figure 29 shows that the first human posture while holding the redesign of power hand drill. The differences between and existing design and redesign power hand drill is the left hand is not holding onto the handle as the previous design. In this redesign power hand drill, users use the left hand to hold the main body.

Table 12 shows the wrist and arm is the highest score which is not good for human posture which is the score on the right side is 4 and the left side is 5. Meanwhile others part of body score in range of 1 to 3.

The final score for this product is divided into two parts which is right side and left side. Final score for right side is 3 while on the left side is 4. Score 3 to 4 means that the person is working in a posture that could present some risk of injury from their work posture and need to be corrected.

4.3.1.2 Second Posture Using Redesign Power Hand Drill

Figure 30: Second posture using redesign power hand drill

Table 13: RULA scoring for second posture using redesign power hand drill

Part of body	Score	
	Right	**Left**
Upper arm	2	3
Forearm	1	3
Wrist	3	3
Wrist twist	1	1
Muscle	1	1
Wrist and arm	4	5
Neck	1	1
Trunk	1	1
Leg	1	1
Neck, trunk and leg	2	2
Final score	**3**	**4**

Figure 30 shows the second human posture while holding the power hand drill. The second posture also commonly used in using the power hand drill. This posture usually uses to do a drilling process for the lower height. Meanwhile both hands are similar in the posture before. The difference from the first posture is this posture is in squat position.

Table 13 shows the scoring for second posture which is still the wrist and arm part has the highest score for both sides. On the right side score is 4 and the left side is 5. Mean while the other part of body score is in the range is 1-3 which is acceptable.

The final score for second posture is 3 for the right side while on the left side score is 4 and it"s indicate that the second posture is included in Action Level 2. Whereas this posture could present some risk of injury from this work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position. This means that the second posture is acceptable.

4.3.1.3 Third Posture Using Redesign Power Hand Drill

Figure 31: Third posture using redesign power hand drill

Table 14: RULA scoring for third posture using redesign power hand drill

Part of body	Score	
	Right	**Left**
Upper arm	2	2
Forearm	2	2
Wrist	3	3
Wrist twist	1	1
Muscle	1	1
Wrist and arm	4	4
Neck	1	1
Trunk	3	3
Leg	1	1
Neck, trunk and leg	3	3
Final score	**3**	**3**

Figure 31 shows the third human posture while holding the power hand drill in doing work. This posture commonly used when doing the drill whereas the object need to be drill is on the floor. This posture need human to bend the body forward in order to reach the lower object which is needed to be drill. Mean while the posture of both hand are the same in holding the power hand drill, but in this posture both hand is lower than in the posture before.

Table 14 shows the shows the scoring for the third posture. Same as in the second posture, wrist and arm has the highest score which is for both side score 4. Mean while the other part of body score is in the range is 1 to 3.

The final score for third posture is both scoring 3 which is the scoring indicated that this posture is categorized in Action Level 2. This posture is acceptable but still could present some risk of injury.

4.3.2 Redesign Saber Saw

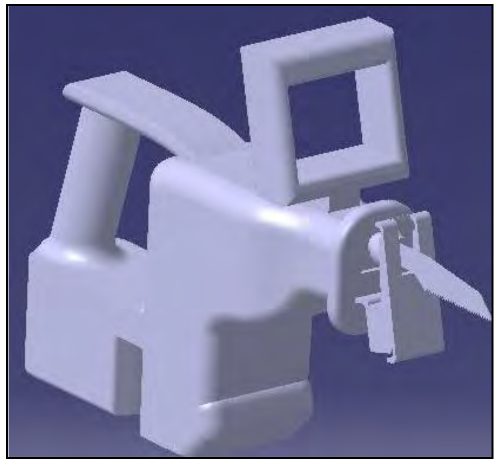


Figure 32: Saber saw redesign

This is the redesign of the saber saw. As in the Figure 32 the saber saw has been added with an extra handle in front of the saber saw body. This addition is to provide more comfortable for the user posture and to overcome the scoring for existing saber saw. The red parameters for saber saw while doing the analysis are:

- Loads : 4kg
- Posture : Intermittent

4.3.2.1 First Posture Using Redesign Saber Saw

Figure 33: First posture using redesign saber saw

Table 15: RULA scoring for first posture using redesign saber saw

Part of body	Score	
	Right	**Left**
Upper arm	1	3
Forearm	2	3
Wrist	2	3
Wrist twist	1	2
Muscle	1	1
Wrist and arm	3	4
Neck	1	1
Trunk	1	1
Leg	1	1
Neck, trunk and leg	2	2
Final score	**3**	**4**

Figure 33, showsthe first human posture while holding the redesign saber saw. In this redesign saber saw, all the posture is the same except for the left hand. Left hand is grasping the handle attach in the front of the body.

As shown in Table 15, the scoring for the first posture which indicates that the highest scoring is wrist and arm part for left hand. The score for left side is 4 mean while for the right side is only 3. While the other parts for both sides is acceptable where the scoring is in the range of scoring 1 to 4.

The final score for this posture is acceptable. The final score for the right side is 3 while for the left side is 4 and this posture is categorize in Action Level 2. These mean that this posture could present some risk of injury but still acceptable.

4.3.2.2 Second Posture Using Redesign Saber Saw

Figure 34: Second posture using redesign saber saw

Table 16: RULA scoring for second posture using redesign saber saw

Part of body	Score	
	Right	**Left**
Upper arm	1	3
Forearm	2	3
Wrist	2	4
Wrist twist	1	1
Muscle	1	1
Wrist and arm	3	4
Neck	1	1
Trunk	1	1
Leg	1	1
Neck, trunk and leg	2	2
Final score	**3**	**4**

Figure 34 shows the second human posture while holding the saber saw. In this posture both hand posture are similar to the first posture. The differences are this posture doing work in squat position.

Table 16 shows the scoring for the second posture in holding saber saw. Still, wrist and arm for the left hand is high which is the score is 4 while the score for right hand wrist and arm is only 3. Mean while the other part of body score is in the range is 1 to 3 except for the wrist on the left hand which is 4.

The final score for second posture is 3 on the right side score while on the left side score is 4. The scoring indicated that this posture is categorized in Action Level 2. This posture is acceptable but still could present some risk of injury.

4.3.2.3 Third Posture Using Redesign Saber Saw

Figure 35: Second posture using redesign saber saw

Table 17: RULA scoring for third posture using redesign saber saw

Part of body	Score	
	Right	**Left**
Upper arm	1	3
Forearm	2	2
Wrist	2	3
Wrist twist	1	1
Muscle	1	1
Wrist and arm	3	4
Neck	1	1
Trunk	3	3
Leg	1	1
Neck, trunk and leg	3	3
Final score	**3**	**4**

Figure 35shows the third human posture while using the saber saw. The posture in holding the saber saw is the same as the first posture. In this posture both hand is lower than in the posture before and the bodies of the users also bend forward.

Table 17 indicates the scoring for third posture while using the saber saw. The highest score is wrist and arm for left hand side which is 4 while on the right side score is 3. While the other part of body score is in the range 1 to 3.

The final score for third posture is 3 for the right side and on the left side are 4. Thus this posture is categorized in Action Level 2. Hence this posture is acceptable while using the saber saw.

4.3.3 Redesign Breaker

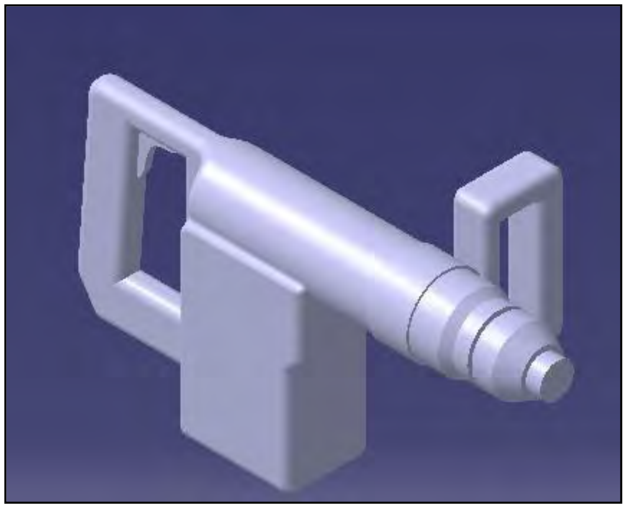


Figure 36: Breaker redesign

Figure 36 shows the redesign of the breaker. The handle of the breaker which is on side of the breaker has been changed its shape. The changing of the shape of the handle is to make the users feel comfortable while grasp it and to produce better posture. The parameters for breaker while doing the analysis are:

- Loads : 7.5kg
- Posture : Intermittent

4.3.3.1 First Posture Using Redesign Breaker

Figure 37: First posture using redesign breaker

Table 18: RULA scoring for first posture using redesign breaker

Part of body	Score	
	Right	Left
Upper arm	1	3
Forearm	3	3
Wrist	3	3
Wrist twist	1	1
Muscle	1	1
Wrist and arm	4	4
Neck	1	1
Trunk	3	3
Leg	1	1
Neck, trunk and leg	2	3
Final score	**3**	**4**

Figure 37 shows the first human posture while holding the redesign breaker. The difference from the previous posture with existing breaker is that the users need to grasp the handle bar at the side of the body.

Table 18 shows the scoring for first posture while using breaker. It is indicates that wrist and arm is the highest score which both right and left score 4. While the other part of the body scoring is around 1 until 3 and this is acceptable.

The final score for first posture is 3 on right sides while on the left side is 4. Thus, this posture is categorize in Action Level 2 which indicates that this posture could present some risk of injury from users work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position.

4.3.3.2 Second Posture Using Redesign Breaker

Figure 38: Second posture using redesign breaker

Table 19: RULA scoring for second posture using redesign breaker

Part of body	**Score**	
	Right	**Left**
Upper arm	1	3
Forearm	3	3
Wrist	3	2
Wrist twist	1	1
Muscle	1	1
Wrist and arm	4	4
Neck	1	1
Trunk	2	2
Leg	1	1
Neck, trunk and leg	2	2
Final score	**3**	**4**

Figure 38 shows the second human posture while using the breaker. In this posture both hand posture are similar to the first posture. In this posture, the users bend the body in front but yet the leg still remains the same posture as in the first posture.

Table 19 shows the scoring for second posture while using breaker. It is indicates that wrist and arm is the highest score which is both side score 4.

The final score for first posture is 3 on right sides while on the left side is 4. This posture is categorize in Action Level 2 which indicates that this posture could present some risk of injury from users work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position. The final score is same to the previous posture.

4.3.3.2 Third Posture Using Redesign Breaker

Figure 39: Third posture using redesign breaker

Table 20: RULA scoring for second posture using redesign breaker

Part of body	**Score**	
	Right	**Left**
Upper arm	1	3
Forearm	3	3
Wrist	3	2
Wrist twist	1	1
Muscle	1	1
Wrist and arm	4	4
Neck	1	1
Trunk	3	3
Leg	1	1
Neck, trunk and leg	3	3
Final score	**3**	**4**

Figure 39 shows the third human posture while using the breaker. The posture of both hand are the same as before, but in this posture both hand is lower than in the posture before.

Table 20 indicates the scoring for third posture while using the breaker. The highest score is 4 for wrist and arm for both sides. While the other part of body score is in the range 1 to 3.

The final score for third posture is 3 for the right side and on the left side are 4. That means this posture is categorized in Action Level 2 means that the person work in a posture that could present some risk of injury from their work posture.

4.4 Comparison between Existing and Redesign

In this part will discuss the comparison between existing and redesign for each product. The analysis is based on the score of human posture while using the product. Hence the best score for human analysis using RULA analysis will be the best ergonomic design.

Only one posture is to be taken to do the comparison. Third posture for each product will be used to perform the comparison because that is the critical posture compared to others. In that third posture, most of the users will bend body forward while using each product. Furthermore, most of the users will be in squat position. This comparison will be discussed by each product.

4.4.1 Comparison for Power Hand Drill

Table 21: Comparison RULA scoring for Power Hand Drill

Part of body	**Score**			
	Existing hand drill		**Redesign hand drill**	
	Right	**Left**	**Right**	**Left**
Upper arm	2	3	2	2
Forearm	2	3	2	2
Wrist	3	4	3	3
Wrist twist	1	2	1	1
Muscle	1	1	1	1
Wrist and arm	4	6	4	4
Neck	1	1	1	1
Trunk	3	3	3	3
Leg	1	1	1	1
Neck, trunk and leg	3	3	3	3
Final score	**3**	**5**	**3**	**3**

Table 21 shows the comparison in human posture between existing and redesign power hand drill. The main different between those design is on the left side for both existing and redesigns power hand drill. As shown in the table the redesign has managed to reduce score for several part of the body which is for upper arm, forearm, wrist, wrist and arm, then lastly the final score. But then the reducing only occurred on the left side but there is not a single difference for the right side for both postures.

The score for upper arm and forearm for left side has been reduced from 3 to 2. Thus, it reduced from Action Level 2 to Action Level 1by means that the person is working in the best posture with no risk of injury from their work posture. The score for wrist has been reduced from 4 to 3 while the score for wrist and arm is from 6 to 4. Even though the score for wrist manage to reduce but it still maintain in Action Level 2. While for wrist and arm, the score manage to reduce from Action Level 3 to Action Level 2.

Lastly, for the final score, on the right side till maintain the score which is 3 while for the right side, the redesign of power hand drill manage to reduce the score. The score that has been reduced is from 5 to 3. Hence, this indicates the redesign of power hand drill has also reduced the left side from Action Level 3 to Action Level 2.

Thus, as for the power hand drill, the redesign of the product itself success because the redesign of the power hand drill manages to reduce the score. Moreover, it does also reduce the Action Level. Reducing of the scoring its caused by eliminating the handle in front of the power hand drill. The handle may cause the users hand being in a deviated and awkward position. Actually it"s acceptable but the users cannot hold on that posture for a long period because it may cause an injury to the users but with eliminating the handle it"s managed to reduce the probability of the injury.

4.4.2 Comparison for Saber Saw

Table 22: Comparison RULA scoring for Saber Saw

Part of body	**Score**			
	Existing hand drill		**Redesign hand drill**	
	Right	**Left**	**Right**	**Left**
Upper arm	1	3	1	3
Forearm	2	3	2	2
Wrist	2	4	2	3
Wrist twist	1	1	1	1
Muscle	1	1	1	1
Wrist and arm	3	6	3	4
Neck	1	1	1	1
Trunk	3	3	3	3
Leg	1	1	1	1
Neck, trunk and leg	3	3	3	3
Final score	**3**	**5**	**3**	**4**

Table 22 shows the comparison in human posture between existing and redesign of saber saw. The main different between the existing and redesign in term of scoring is on the left side. As for the right side for both existing and redesign posture is remain the same. This may cause of the posture of the right side is remain the same. Which this can be seen by comparing Figure 23 and Figure 35 that both figures show the right hand is grasp the handle of the saber saw. As shown in the table, the redesign has managed to reduce score for several part of the body which is for forearm, wrist, wrist and arm then lastly the final score.

The score for forearm for left side has been reduced from 3 to 2. Thus it reduced from Action Level 2 to Action Level 1by means that the person is working in the best posture with no risk of injury from their work posture. The score for wrist has been reduced from 4 to 3 while the score for wrist and arm is from 6 to 4. Even though the score for wrist manage to reduce but it still maintain in Action Level 2. While for wrist and arm, the score manage to reduce from Action Level 3 to Action Level 2. The final score, on the right side still maintain which is 3 while for the right side, the redesign of power hand drill manage to reduce the score from 5 to 4. Hence this indicates the redesign of power hand drill has also reduced the left side from Action Level 3 to Action Level 2. That means the redesign posture is acceptable even though the posture could present some risk of injury.

Thus the redesign of the saber saw success; it can be proved by comparing the score for existing and redesign of the posture. Furthermore the redesign posture also manages to reduce the Action Level. This may cause of the adding a handle in front of the saber saw. The adding of the handle does help the users to handle the saber saw more stable and comfortable if compare than existing design. Which is the pervious design may cause the left hand of the users in a deviated and awkward position. Hence by adding an extra handle managed to reduce the probability of the injury while using the saber saw.

4.4.3 Comparison for Breaker

Table 23: Comparison RULA scoring for Breaker

Part of body	Score			
	Existing hand drill		Redesign hand drill	
	Right	Left	Right	Left
Upper arm	1	3	1	3
Forearm	3	3	3	3
Wrist	3	3	3	2
Wrist twist	1	1	1	1
Muscle	1	1	1	1
Wrist and arm	4	5	4	4
Neck	1	1	1	1
Trunk	3	3	3	3
Leg	1	1	1	1
Neck, trunk and leg	3	3	3	3
Final score	**3**	**4**	**3**	**4**

Table 23 shows the comparison in human posture between existing and redesign of breaker. The main different between the existing and redesign in term of scoring is on the left side. As for the right side for both existing and redesign posture is remain the same. This is because of the posture of the right side is remain the same. As shown in the table the redesign has managed to reduce score for two part of the body which is for wrist, wrist and arm then lastly the final score.

The score for wrist has been reduced from 3 to 2 while the score for wrist and arm is from 5 to 4. The score manage to reduce from Action Level 2 to Action Level 1, which means the person is working in the best posture for wrist with no risk of injury from work posture. Mean while for wrist and arm, the score manage to reduce from Action Level 3 to Action Level 2. The final score, on the right side still maintain which is 3 so does on the left side which is maintain with the score 4. Hence this indicates the redesign of power hand drill has no effect on the scoring posture of the users.

Thus the redesign of the breaker did not make any different on the final score but did a little improvement on two part of the body; wrist, wrist and arm. So the change the design of the handle on the side of the breaker body manages to reduce minor scoring part but this redesign is acceptable because at least it did not make it even worst. The redesign of the posture still maintain the previous scoring; Action Level 2.

4.5 Discussion

The posture of the human body can be analyze by using RULA analysis. Hence, this will determine the best product which is the existing or the redesign product is more ergonomic. This is because of the posture of human body does reflect to the design of the product. If the product is more ergonomic, thus the person is working in the best posture with no risk of injury from their work posture.

First product that has been analyzed is power hand drill. The redesigned of power hand drill is better than existing product. Result of the elimination of the handle on the front of the power hand drill machine. The redesign of the product manages to improve the human posture by reducing the Action Level 3 for existing product to the Action Level 2 for redesign product.

Result for saber saw analysis; proved that the redesign of the saber saw is better than an existing product. This is because of the addition of an extra handle in the front of the saber saw body. Which is with an extra handle could provide more comfortable posture to the users. The redesign of the product manages to improve the human posture by reducing the Action Level 3 for existing product to the Action Level 2 for redesign product.

Mean while for the last product is breaker. Based on the result of the analysis, the redesign of the product fail to give a major change in the scoring but then only managed to give the minor change on several part of body. Thus, changing of the handle design on side of the breaker body did not manage to change the final score of the analysis but this analysis is not a failure and it is acceptable. This because; the redesign of the posture still maintaining the previous posture which is at the Action Level 2.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This project indicates that an ergonomic design of a hand tool is important. This is because the design of a product (hand tool) does reflect the human posture that handling the product. Through the analysis by using RULA analysis that is in CATIA will indicate the scoring for human posture. Description about the scoring has been explained in Table 2. More over through this analysis can be conclude that human cannot stay in one posture for long period because this might present some risk of injury from their work posture.

The ergonomics study is very important for present and future. Through the ergonomic study; to improve the performance, the potential accidents and potential ill health can be reduced. Thus based on the analysis that has been done, it can be concluded that it is impossible to prevent any injury while using the hand tool but it can only be minimize. An ergonomic well design hand tools can minimize the risk or the potential of the injury cause by the posture while using the hand tool. The design of a hand tool reflects the posture of the users. Hence an ergonomic well design hand tool will improve the user postures.

5.2 Recommendations

During this project there are several problems that has been faced which;

- Analysis using CATIA (RULA analysis) is very hard especially in moving the human posture. There is only several analysis for ergonomics that included in CATIA.
- The result should be categorized as an Action Level 1; means that the person is working in the best posture with no risk of injury from their work posture.

Below is the recommendation to encounter the problem;

- Use the SAFEWORK as the platform to analysis the human posture. SAFEWORK focused more to human posture than CATIA. Thus it has more application in analysis the human posture.
- Should redesign lot of concept in order to get better results in analysis.

This study can be continued because there is large scope about ergonomics. For the next study, it is recommend that not just focus in studying the human posture while using the hand tools. The next study can be recommended to study an ergonomic in work place which is in manufacturing and study other regular activity of the human posture such as human posture while using the computer; the position of the table, monitor and mouse that suits best to the human posture.

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APPENDICES

GANTT CHART FOR PSM 1

Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
Title Selection & Confirmation							MIDTERM BREAK								
Product Selection															
Literature Search															
Literature Review															
Project planning															
Preparation of Technical Report															
Submission of Technical Report															

GANTT CHART FOR PSM 2

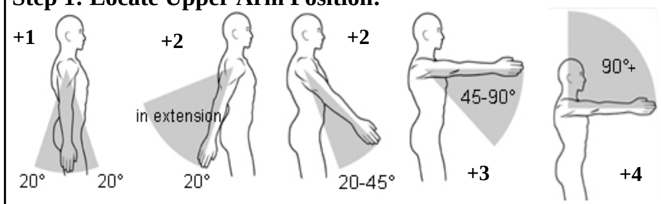
Task	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
CAD Drawing							MIDTERM BREAK								
Existing Hand Tool Design															
Existing Hand Tool Analysis															
Redesign Hand Tool															
Redesign Hand Tool Analysis															
Comparison Between Existing And Redesign															
Preparation and Submission of Technical Report															

RULA Employee Assessment Worksheet

*based on **RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99***

A. Arm and Wrist Analysis

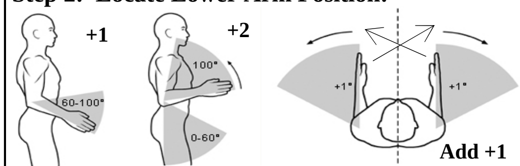
Step 1: Locate Upper Arm Position:



Step 1a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

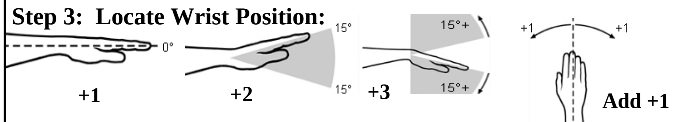
Step 2: Locate Lower Arm Position:



Lower Arm Score

Step 2a: Adjust…
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:



Step 3a: Adjust…
If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 7: Add Force/Load Score
If load < .4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain Wrist and Arm Score. Find row in **Table C**.

Wrist & Arm Score

SCORES

Table A: Wrist Posture Score

Upper Arm	Lower Arm	1		2		3		4	
		Wrist Twist		Wrist Twist		Wrist Twist		Wrist Twist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C: Neck, trunk and leg score

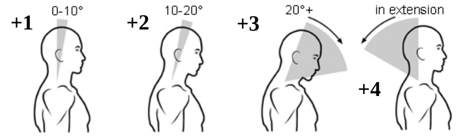
Wrist and Arm Score	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1 or 2 = acceptable posture
3 or 4 = further investigation, change may be needed
5 or 6 = further investigation, change soon
7 = investigate and implement change

Final Score

B. Neck, Trunk and Leg Analysis

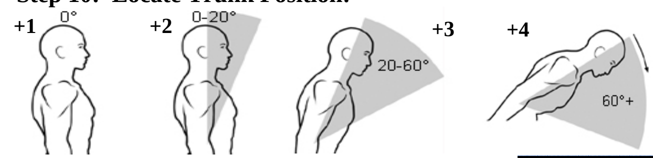
Step 9: Locate Neck Position:



Neck Score

Step 9a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:



Step 10a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Table B: Trunk Posture Score

Neck Posture Score	1		2		3		4		5		6	
	Legs		Legs		Legs		Legs		Legs		Legs	
	1	2	1	2	1	2	1	2	1	2	1	2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture Score B

+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 14: Add Force/Load Score
If load < .4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score

=

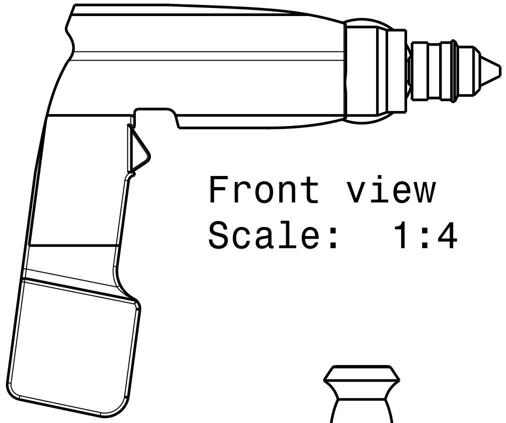
Step 15: Find Column in Table C
Add values from steps 12-14 to obtain Neck, Trunk and Leg Score. Find Column in **Table C**.

Neck, Trunk & Leg Score

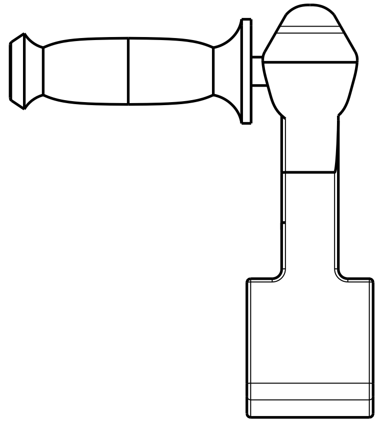
Task name: ______________________ Reviewer: ______________________ Date: ____/____/____

provided by Practical Ergonomics

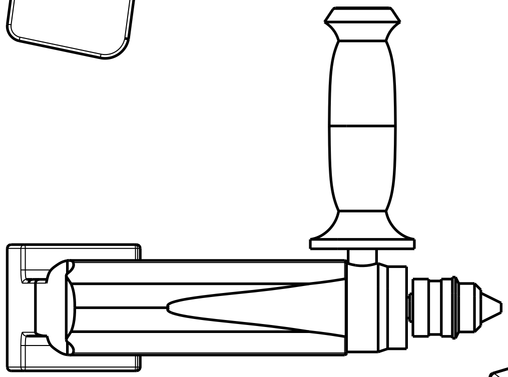
rbarker@ergosmart.com (816) 444-1667



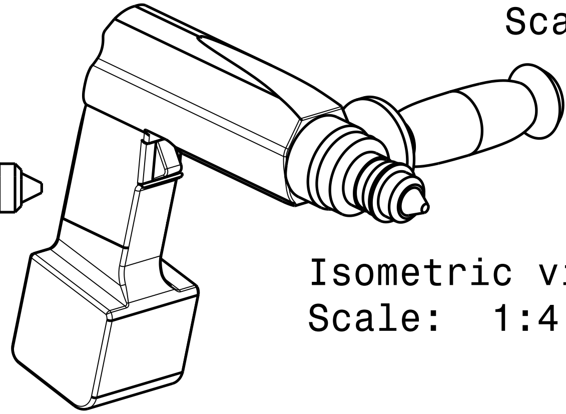
Front view
Scale: 1:4



Left view
Scale: 1:4



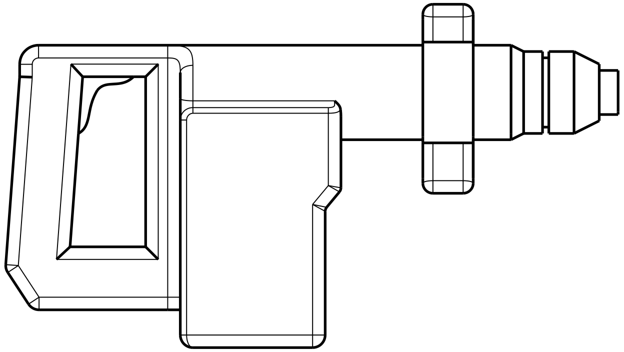
Top view
Scale: 1:4



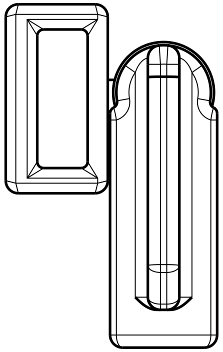
Isometric view
Scale: 1:4

DESIGNED BY: AIZAT DATE: 4/4/2009	EXISTING HAND DRILL		
CHECKED BY: XXX DATE: XXX			
SIZE A4		UTeM	
SCALE 1:1	WEIGHT (kg) 0.95	DRAWING NUMBER	SHEET 1/1

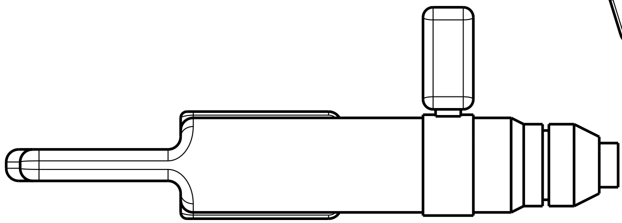
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



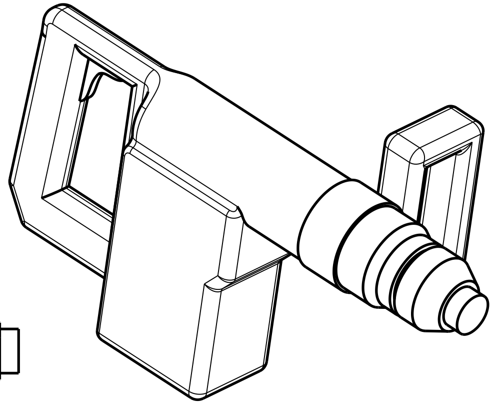
Front view
Scale: 1:6



Left view
Scale: 1:6



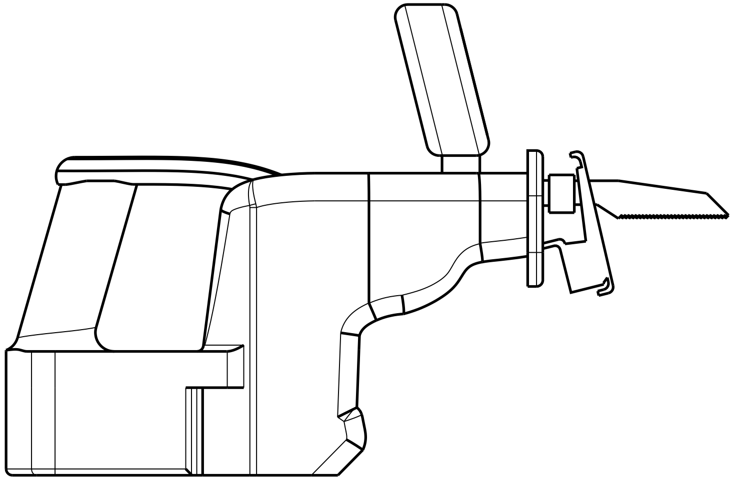
Top view
Scale: 1:6



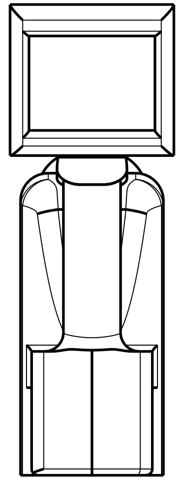
Isometric view
Scale: 1:6

DESIGNED BY: AIZAT DATE: 4/4/2009	REDESIGN OF BREAKER			
CHECKED BY: XXX DATE: XXX				
SIZE A4		UTeM		
SCALE 1:1	WEIGHT (kg) 3.93	DRAWING NUMBER		SHEET 1/1

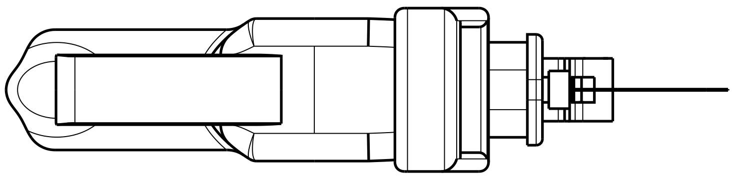
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



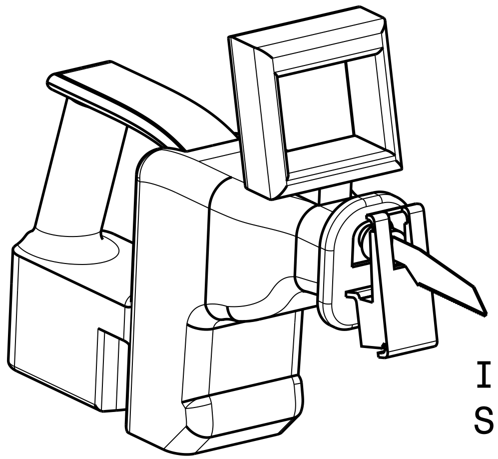
Front view
Scale: 1:6



Left view
Scale: 1:6



Top view
Scale: 1:6



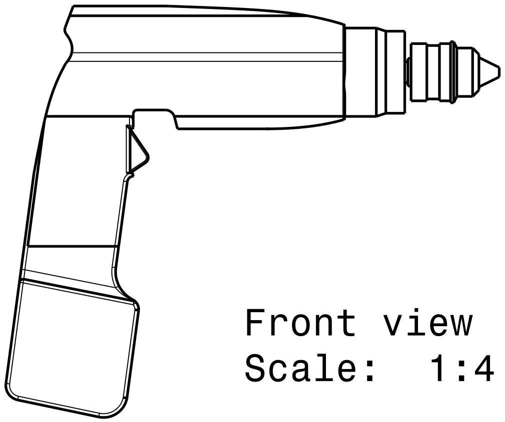
Isometric view
Scale: 1:6

DESIGNED BY: AIZAT DATE: 4/4/2009	REDESIGN OF SABER SAW	
CHECKED BY: XXX DATE: XXX		
SIZE A4	UTeM	
SCALE 1:1	WEIGHT (kg) 6.50	DRAWING NUMBER
SHEET 1/1		

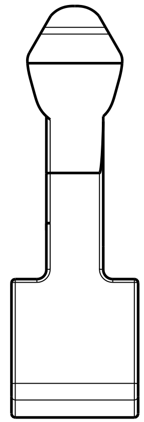
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_

D C B A

4

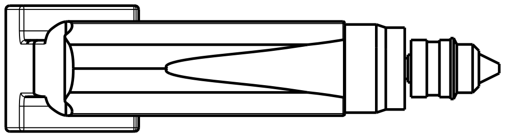


Front view
Scale: 1:4

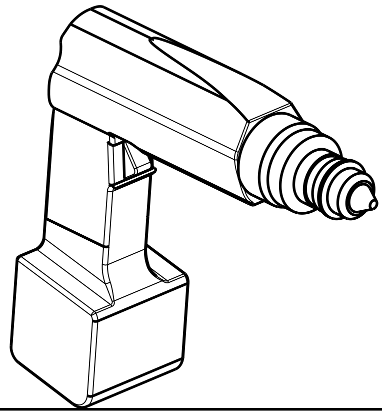


Left view
Scale: 1:4

3



Top view
Scale: 1:4



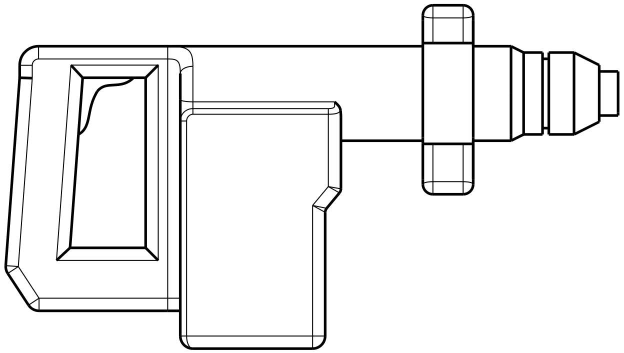
Isometric view
Scale: 1:4

2

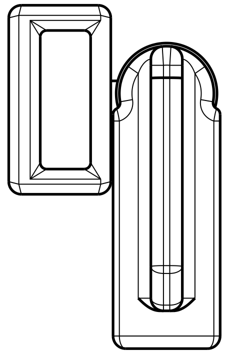
DESIGNED BY: AIZAT DATE: 4/4/2009	REDESIGN OF POWER HAND DRILL		I _ H _ G _
CHECKED BY: XXX DATE: XXX			F _ E _
SIZE A4	UTeM		D _
SCALE 1:1 / WEIGHT (kg) 0.83	DRAWING NUMBER	SHEET 1/1	C _ B _
This drawing is our property; it can't be reproduced or communicated without our written agreement.			A _

1

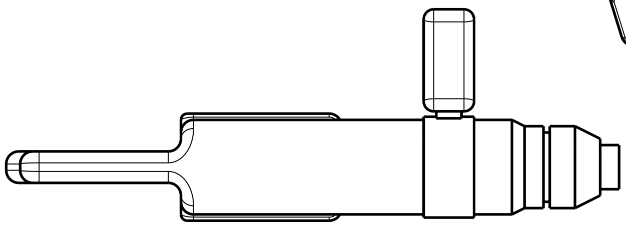
D A



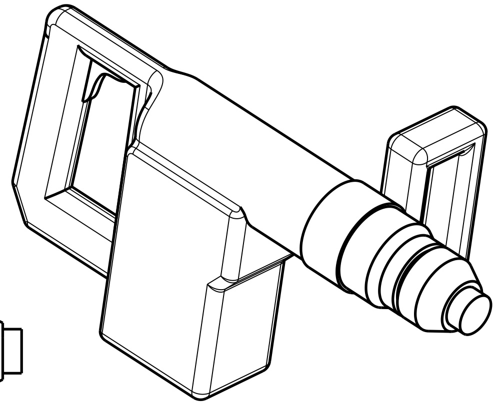
Front view
Scale: 1:6



Left view
Scale: 1:6



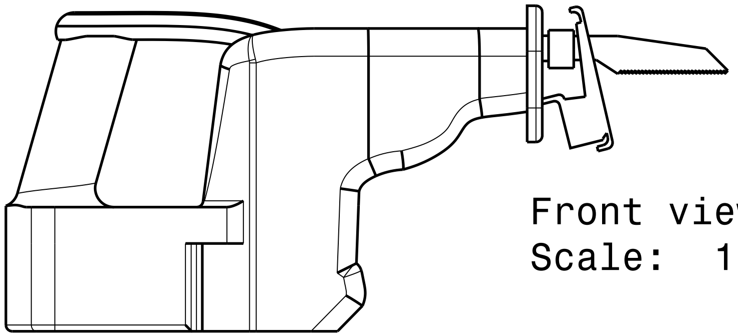
Top view
Scale: 1:6



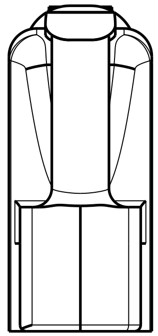
Isometric view
Scale: 1:6

DESIGNED BY: AIZAT DATE: 4/4/2009	REDESIGN OF BREAKER		
CHECKED BY: XXX DATE: XXX			
SIZE A4		UTeM	
SCALE 1:1	WEIGHT (kg) 3.93	DRAWING NUMBER	SHEET 1/1

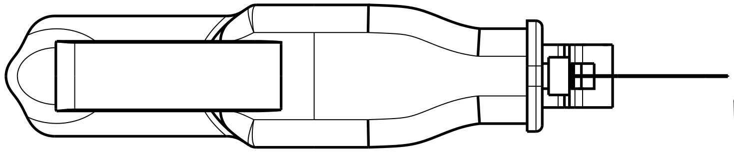
I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_



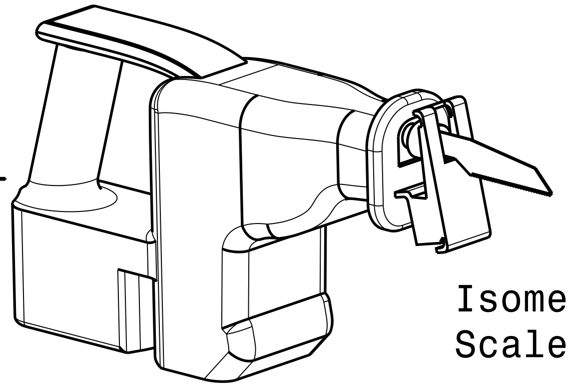
Front view
Scale: 1:6



Left view
Scale: 1:6



Top view
Scale: 1:6



Isometric view
Scale: 1:6

DESIGNED BY: AIZAT DATE: 4/4/2009		EXISTING SABER SAW		I _
CHECKED BY: XXX DATE: XXX				H _ G _ F _
SIZE A4	(projection symbol)	UTeM		E _ D _
SCALE 1:1	WEIGHT (kg) 6.11	DRAWING NUMBER	SHEET 1/1	C _ B _
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