DESIGN AND ANALYSIS OF SOIL LIFTING HAND TOOL

मिट्टी उठाने वाले हाथ उपकरण का डिजाइन और विश्लेषण

Utkarsh Sharma

Thesis

Master of Technology in CAD/CAM

(Mechanical Engineering)

2024

Department of Mechanical Engineering

College of Technology and Engineering

Maharana Pratap University of Agriculture & Technology

UDAIPUR (RAJASTHAN)

DESIGN AND ANALYSIS OF SOIL LIFTING HAND TOOL

मिट्टी उठाने वाले हाथ उपकरण का डिजाइन और विश्लेषण

Thesis

Submitted to the

Maharana Pratap University of Agriculture & Technology
Udaipur

In Partial Fulfilment of the Requirement for

the Degree of

Thesis

Master of Technology in CAD/CAM

(Mechanical Engineering)

2024

Department of Mechanical Engineering

College of Technology and Engineering Maharana Pratap

University of Agriculture & Technology

UDAIPUR (RAJASTHAN)

COLLEGE OF TECHNOLOGY AND ENGINEERING
MAHARANAPRATAPUNIVERSITY OF AGRICULTURE &TECHNOLOGY, UDAIPUR

CERTIFICATE-I

Dated: / /2024

The research work embodied in this thesis titled **"DESIGN AND ANALYSIS OF SOIL LIFTING HAND TOOL"** submitted for the award of degree of Master of Technology, Udaipur, (Raj.), is original and bonafide record of research work carried out by me under the supervision of **Dr. Mahendra Singh Khidiya**, Associate Professor, Department of Mechanical Engineering , College of Technology and Engineering, Udaipur. The contents of thesis, either partially or fully, have not been submitted or will not be submitted to any other Institute or university for the award of any degree or diploma.

The work embodied in the thesis represents my idea in my own words and where other ideas or words have been included, I have adequately cited and referenced the original sources. I also declared that I have adhered to all principle of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact source in my submission. I understand that any violation of the above will cause for disciplinary action by the University and can also evoke penal action from the sources, which have thus not been properly cited or from whom proper permission has not been taken when needed.

The manuscript has been subjected to plagiarism check by software DrillBit.

It is certified that as per the check, the similarity index of content is 8% and within permissible limit as per the MPUAT guidelines on checking Plagiarism.

Dated : / /2024 (Utkarsh Sharma)

COLLEGE OF TECHNOLOGY AND ENGINEERING
MAHARANAPRATAPUNIVERSITY OF AGRICULTURE & TECHNOLOGY, UDAIPUR

CERTIFICATE-II

Dated: / /2024

This is to certify that this thesis entitled **"DESIGN AND ANALYSIS OF SOIL LIFTING HAND TOOL"** submitted for the degree of **Master of Technology** in Mechanical Engineering in the subject of **CAD/CAM** embodies bonafide research work carried out by **Mr**. **Utkarsh Sharma** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on **/ /2024**.

The manuscript has been subjected to plagiarism check by software DrillBit. It is certified that as per the check, the similarity index of the content is 8% and is within limit as per the MPUAT guidelines on checking Plagiarism.

(Dr. B.L. Salvi)
Head
Department of Mechanical Engineering
College of Technology and Engineering,
MPUAT , Udaipur

(Dr. Mahendra Singh Khidiya)
Major Advisor
Department of Mechanical Engineering
College of Technology and Engineering,
MPUAT, Udaipur

(Dr.Anupam Bhatnagar)
DEAN
College of Technology and Engineering, Udaipur
Maharana Pratap University of Agriculture and Technology
Udaipur, Rajasthan

COLLEGE OF TECHNOLOGY AND ENGINEERING

MAHARANAPRATAPUNIVERSITY OF AGRICULTURE &TECHNOLOGY,

UDAIPUR

CERTIFICATE-III

Dated: / /2024

This is to certify that this thesis entitled **"DESIGN AND ANALYSIS OF SOIL LIFTING HAND TOOL"** submitted by **Utkarsh Sharma** to Maharana Pratap University of Agriculture & Technology, Udaipur, in partial fulfillment of the requirements for the degree of **Master of Technology** in Mechanical Engineering (CAD/CAM) after recommendation by the examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination held on / /2024 was found satisfactory; we therefore, recommended thesis to be approved.

(Dr. Mahendra Singh Khidiya)
Major Advisor

(Dr. M.A. Saloda)
Advisor

(Dr. B.L Salvi)
Advisor

(Dr. Trilok Gupta)
DRI Nominee

(Dr. Anupam Bhatnagar)
DEAN
CTAE, Udaipur

(Dr. B.L Salvi)
Head
Department of Mechanical Engineering

Approved / Not approved

DIRECTOR RESIDENT INSTRUCTION

M.P.U.A.T, UDAIPUR

COLLEGE OF TECHNOLOGY AND ENGINEERING

MAHARANAPRATAPUNIVERSITY OF AGRICULTURE & TECHNOLOGY, UDAIPUR

CERTIFICATE-IV

Dated: / /2024

This is to certify that **Utkarsh Sharma** student of Master of Technology in the Mechanical Engineering (CAD/ CAM) has made all correction/modifications in this thesis entitled **"DESIGN AND ANALYSIS OF SOIL LIFTING HAND TOOL"** which were suggested by the external examiner and the advisory committee in the oral examination held on //2024. Thefinal copies of the thesis duly bound and corrected were submitted on / /2024.

(Dr. B.L Salvi)
Head
Department of ME
CTAE, Udaipur

(Dr. Mahendra Singh Khidiya)
Major Advisor
Department of Mechanical Engineering
CTAE, Udaipur

ACKNOWLEDGEMENT

It gives me immense pleasure to express my deep sense of gratitude to my major advisor, **Dr. Mahendra Singh Khidiya,** Associate Professor of Department of Mechanical Engineering, College of Technology and Engineering, Udaipur, for his invaluable guidance, critical suggestion, motivation, constant inspiration and above all his supportive attitude right from the beginning that enabled me in bringing up this thesis in the present form.

I express my sincere gratitude to the members of my advisory committee, **Dr. B.L. Salvi**, Head, Department of Mechanical Engineering, **Dr. M.A Saloda**, Retd. Professor, Department of Mechanical Engineering, and DRI Nominee **Dr. Trilok Gupta**, Associate Professor and Head of Department of Civil Engineering.

I am highly thankful to **Dr. Mahendra Singh Khidiya** and **Dr. B. L. Salvi** for their motivation throughout my research work. I would also like to thank **Dr. Sanwal Singh Meena,** Associate Professor and Head of department, Farm Machinery and Power Engineering.

I am indebted to **Dr. Anupam Bhatnagar**, Dean, College of Technology and Engineering, Udaipur for his due attention and encouragement during the study period and also for providing me the necessary facilities during the study period and also for providing me the necessary facilities during the course of research.

Words can hardly resister the sincere and heartfelt feeling which I have for my M.tech and other staff members for their help, support and encouragement for their kind cooperation and help as and when needed.

I feel short of words to express my gratitude to my family members for their utmost co-operation, sacrifice and encouragement during the course of this work.

Place: Udaipur, Rajasthan

Date: / /2024 **(Utkarsh Sharma)**

CONTENTS

LIST OF TABLES

LIST OF FIGURES AND GRAPHS

LIST OF ABBREVIATIONS

i.e.	:	That is
viz	:	Namely
CAE	:	Computer-Aided Engineering
MSD	:	Musculoskeletal Disorders
3D	:	Three dimensional
et.al.	:	and other
CAD	:	Computer-Aided Design
GPa	:	Gega Pasal
MPa	:	Mega pascal
mm	:	Millimetre
cm	:	Centimetre
S.No.	:	Serial number
Fig	:	Figure
sec	:	Seconds
CTAE	:	College of Technology and Engineering
DME	:	Department of Mechanical Engineering
Bpm	:	Beats per minute
FOS	:	Factor of safety
etc	:	et cetera (and the other things)

LIST OF SYMBOLS

σ	:	stress
I	:	moment of inertia
&	:	and
g	:	grams
H	:	Height
D	:	Diameter
W	:	Width
L	:	length
ºF	:	degree Fahrenheit
N	:	Newton

CHAPTER - I

INTRODUCTION

The Industrial Revolution occurred around 200 years ago and had a profound impact on how people lived and how development occurred. It is possible that the industrial systems created during the Industrial Revolution are to be responsible for the rise of capitalism and the creation of modern cities. Development of various factories, constructions sites took place which resulted in requirements of labours. Even just 50 years ago, workers were just beginning to incorporate technology.

Workers should look for creative methods that utilise technology to cut down on personnel costs and hours. One reason why workers should look at new technologies in different industries is because of autonomous variables.

For centuries, the construction sector has been the slowest to accept new technology because of things like pricing, accessibility of new technology, and the inflexibility of employees conditioned to doing things a certain way. Farmers are looking to cut their cost and time, for which better tools can be one of the methods. Excavation, filling, ploughing landfills etc these can be very complex based on hours of work, altitude, soil profile etc. Shovels and buckets have unloading methods of various lengths and dimensions. So far very less experiments have been done on ergonomic designs of shovel and hoe.

The soil lifting hand tool "shovel" is used by workers and farmers in various applications. Few studies have done on improved shovel but more work is required on ergonomic improved and incorporation of more features in the shovel. Different versions of integrated tools with different blade size have been constructed and improved based on immediate observation. A number of criteria, including productivity and perceived effort, were used to evaluate the new tool. The mining business, where research is being done on hardware, software, etc., has been greatly impacted by this. With time, the safety, productivity, and maintenance workload will all be enhanced by these new designs. In occupations involving Manual Material Handling (MMH), common tools used are the shovel, spade, and hoe. We are aware of very few studies that have been done to create a particular ergonomic tool that would serve as a shovel.

Based on several trials and ergonomic studies examining the real-world use of traditional shovel and hoe in various MMH jobs, various prototypes of the combination tool with different shovel handles and shovel blades were developed. The shovel's design, physiological responses, efficiency, subjective assessments of perceived effort, and worker reactions to its adoption will all be examined, and the new, ergonomically constructed model will be able to meet the goals.

1.1 Musculoskeletal Disorders

The majority of injuries sustained by workers using various hand lifting tools are muscular sprains and strains. Joint, bone, and nerve damage can also result from labor. The body's ongoing deterioration is frequently the cause of these injuries. When combined, these wounds are referred to as musculoskeletal diseases. Musculoskeletal diseases typically impact the hand and wrist, shoulders, neck, upper back, low back, hips, and knees in workers.

Numerous well-known musculoskeletal illnesses can be diagnosed. Among them are: Carpal tunnel syndrome is a condition affecting the nerves in the hand and wrist that is brought on by bending the wrist repeatedly, gripping objects firmly, and repeatedly forcing the wrist up against hard surfaces.

Different kinds of injuries are frequently linked to different kinds of building activity. For instance, employees who perform overhead labor, like sheet metal workers and painters, frequently experience shoulder and neck issues. The following trades have the highest chance of shoulder issues: painters, scaffold builders, and insulators Many more knee problems affect people who perform floor-level labor while kneeling, such as roofers, floor layers, sheet metal workers, and insulators.

The following are possible risk factors for musculoskeletal problems of the hands, wrist, neck, and shoulder:

- Exertion of force or muscles.

- Uneasy body alignment.
- Labor that is repetitive.
- Manual tool vibration.
- Strong items and tools can cause external contact stress.

1.2 Shovel

A shovel is a hand tool, as shown in Fig. 1.1. The shovel has different usages in different fields; in construction, it is used for lifting and transferring concrete, cement, or sand from one point to another, whereas in farming, it is used for digging soil and lifting soil from one place to another. The most important features for selecting a proper shovel include weight, length, handle type, blade size, and shape. Usually, the shovel weighs between 1.5 and 3 kg (3.3 lb to 6.6 lb), The type and weight of the material (such as steel, aluminium, or plastic) that is appropriate for the intended application determines the weight in part. For instance, a light shovel (e.g., 1.5 kg, 3 lb) would work for light snow, while a larger, more durable shovel (e.g., 3 kg, 6.5 lb), might be required for stones or coal.

In agricultural operations, the shovel is a vital equipment that helps with many jobs that are necessary for farming. Its wide blade digs dirt well, making it easier to transfer seedlings and sow crops. Shovels are also used by farmers to mix soil additives and fertilizers, which guarantees the best possible distribution of nutrients. Shovels are also essential for cleaning weeds and rocks from fields, which encourages the establishment of healthy crops. Because of their tough design, they can handle bulky materials like mulch and compost, which are necessary for improving soil quality and retaining moisture. All things considered, the shovel's durability and adaptability make it an essential tool for agricultural pursuits, increasing farming operations' production and efficiency.

Fig 1.1: Normal shovel

1.2.1 Parts of Shovels

A. Grip

The top portion of a shovel that is joined to the shaft is called the grip. If there is no handle at all, we can use the shovel by grasping the top of the shaft. The handle can be made of wood, plastic, or metal. A grip handle will be provided if the shovel shaft is made of fibreglass to assist prevent splinters. Shorter shovels and digging shovels frequently have D-shaped handles, which improve grip.

B. Shaft

The long, "pole-like" portion of all shovels is known as the shaft, which is employed as leverage when working a shovel. Typically, they are made of metal, fibreglass, or wood. The material you wish to use may depend on your own preferences or your budget because each of these materials has advantages and disadvantages in terms of shovel use and durability. The strongest and longest-lasting shafts are often made of metal, although traditionalists prefer wooden shafts because they are more aesthetically beautiful and ergonomic. A shovel shaft's length might vary, thus it's important to match the shovel's height to your own height to make it comfortable to use.

C. Collar

Where the blade and shaft of a shovel connect is called the collar. The collar must be strong and reliable; otherwise, it could collapse or break when doing demanding duties. If one of the ends has to be replaced, the collar can be detached from the shaft and handle portion of the shovel, which is often attached using a rivet or screw. The shaft and handle often last considerably less time than the blade, so if either one breaks, you may buy replacements and fasten them to your old blade at the collar.

D. Kickplate

A step is another name for the kickplate of a shovel. Though not all shovels will have one, a kickplate allows you to apply pressure by placing your foot on the topmost edge of the blade. Typically, kickplates are attached to digging shovels so that the user's excess weight can be used to dig down farther into the earth. Since the user can use their weight to help dig rather than only their arm and back muscles, using a kickplate will produce better results and make the job much easier for them.

E. Blade

A shovel's lowermost component that makes contact with the ground is called the blade. It is often made of metal or aluminium, though fibreglass or plastic can also be used in some cases. The design of the blade, which comes in a variety of sizes and shapes, probably distinguishes the various types of shovels the most.

F. Tip

The lowest edge of a shovel's blade that is furthest away from the shaft is known as the tip. Depending on the shovel's intended usage, it can take several different forms, For moving or scooping, flat tips work well, but cutting and digging require pointy or rounded tip

1.3 Types of Shovel

a. Edging Shovel

This shovel has been particularly created to make clean, distinct margins around lawns or borders. It features a long shaft with a little metal semi-circle connected at the bottom, a straight footplate where you may push down with your feet, and all of this is coupled to a long base. The blade is often flat and sharp since it has to press firmly into the soil or grass. Since it doesn't need to create deep cuts to be successful, the blade is relatively shallow. Although their primary usage is for establishing and maintaining garden edging, they may also be helpful for other chores, such as breaking up superficial plant roots. These shovels are perfect for use in confined spaces where precision is required to prevent damaging neighbouring plants because of their relatively modest blade size.

Fig.1.2: Edging shovel (Source : Oshanwers)

b. Trench Shovel

The trenching shovel, often called a ditch shovel, has two main applications. It may first dig shallow trenches and then clean out and tidy up bigger ditches that a stronger instrument has already dug. The blade of a trench shovel is long, thin, and has a pointed tip. It is also angled. Because there is practically any room on the footplate for the shovel to be driven into the ground with your weight, you will have to utilise arm force instead. This is because the blade of the shovel is so thin. This implies that digging anything deeper than a shallow trench would be extremely challenging and time-consuming. Landscape gardeners are the main users of trench shovels.

Fig.1.3: Trench shovel, (Source: Oshanwers)

c. Flat Shovel

Flat shovels have a flat blade, as implied by their name. Any flat-bladed shovel is primarily intended for scooping, and they frequently have a slightly concave blade, like a spoon that has been squared off, which improves its carrying capacity. They are perfect for filling wheelbarrows or other garden containers and are handy for transferring garden supplies like soil, mulch, or gravel. Despite having a flat blade that makes them poor diggers, they feature a big footplate that will assist you apply pressure to drive the blade into the ground. This is helpful for shallow digging projects like edging or trench cleaning. A flat shovel is mostly used for scooping, spreading, and transporting, but it can also be used for other tasks, making it a highly practical garden tool to have on hand.

d. Tree-Planting Shovel

With these shovels, a task that would take considerably longer with other shovel kinds may be completed much more quickly. They are made particularly for planting trees. A spade used for planting trees has a short, thin blade that tapers to a point or curve. Because of the thin blade, it can dig holes of different sizes by circling the shovel in the earth. The length of the shaft can vary depending on the task at hand; longer shafts function better on flat, level terrain, while shorter shafts perform better on slopes or inclined terrain. These shovels can be used to prepare a hole for planting a tree or to dig up a tree for transplantation. The shovels may also be used to dig shallow trenches where a long trench for a flower bed makes more sense than making several little plant holes since they resemble trenching shovels. Additionally, it may be used to clear larger excavations of rubble or stones.

e. Power Shovel

The term "power shovel" refers to two distinct instruments. The first is simply a gas- or electricity-powered snow shovel. These contain rotating blades that take up and scatter snow, making it simple to clean a snow-covered path or driveway. These are far more effective than a typical snow shovel, but as you might anticipate, they cost a lot more money. They are a more compact and lightweight substitute for the standard snow blower. A jackhammer-style tool with a shovel attachment is the second kind of power shovel. In very compacted soil, they are used to dig holes and trenches or to excavate the earth. They are especially helpful since they can operate in spaces where larger gear cannot because of their tiny size.

f. Post Hole Shovel

A post hole shovel, commonly referred to as a post hole digger, is a kind of double shovel. It is made up of two shovels that are connected and typically feature long, thin, inwardly bending blades with curled points. The shovel can easily cut through any roots or other obstructions due to the design of its blades. The blades take on a cylindrical form when they are closed together. A post hole shovel is generally used to create deep holes for the installation of fence posts. They remove a cylinder of earth from the ground in a single quick action by employing a dig, squeeze, and raise motion. A post hole shovel is a good purchase if you need to dig several post holes. Compared to attempting to dig the holes with a digging shovel, it makes the holes considerably more quickly and with much neater results for a finished product that is tidy and professional-looking.

Fig.1.4: Post hole shovel (Source:Tree.com)

g. Handheld Shovel

There are many other names for these shovels, including garden shovel, garden trowel, hand shovel, hand trowel, and garden spade (though calling this a spade would be inaccurate). These are essentially little shovels that may be used for a number of gardening activities, such as pulling weeds, removing plants, and creating holes for new plants. Their short shafts, which are typically approximately six inches long, are what distinguish them from larger shovels. These tools can be made in a variety of ways, but they all generally feature a narrow, rounded or pointed blade that is about four inches broad. A portable shovel often has a convex blade for improved scooping.

h. Root Shovel

Although root shovel designs might vary, they all usually feature extended triangular blades. These blades may have a flattened tip or may occasionally have a point at the tip. The blade's side edges are frequently serrated, which makes it easier to cut through the roots of mature plants. These shovels are made especially to assist in removing plants or trees, either for trash or transplantation. With the help of their blades, aged trees' thick, well-established roots may be cut through and destroyed, creating more room for new roots to form and spread. These shovels may also be used to dig holes for newly planted trees or plants.

i. Scoop Shovel

A scoop shovel is different from other shovels in that it has a significantly bigger blade and a shaft and handle that are somewhat shorter so that the total height is the same. The tip of the blade is typically flat, however it can occasionally be rounded. Scoop shovels feature stiff side edges and a scooped form that helps hold in whatever material you are moving. They may be used to transport bulk materials including dirt, gravel, wood chips, and rubbish. Aluminium scoop shovels last less time than more durable metal scoop shovels, while they can be made of a variety of materials. Before purchasing a scoop shovel, think about the material you will be moving and how much of it you will need to move. Even while they won't last as long, the aluminium shovels are lighter, which may make transporting a lot of stuff considerably less difficult.

j. Snow Shovel

A snow shovel is a need to keep in your garage if you are in an area that frequently receives snowfall. These shovels feature lengthy shafts made of a variety of building materials, including plastic, metal, and wood. Large, rectangular, and vertically curved describe the blade. With this form, you can easily scoop snow off the sidewalk or front steps and dump it anywhere you choose. Some snow shovels contain metal ridges or grooves along the blade tip that may be used to chip away at ice in addition to helping with snow removal.

Snow shovels are available in a wide range of materials, with metal or plastic blades that come in a wide range of sizes. The most effective and efficient way to shovel snow is using a big blade with a sharp edge and a deep curve. You might want to spend money on an ergonomic snow shovel if you have a big area to clear of snow or if you need to do it frequently. These have curved shafts that lessen back strain while shovelling snow, and they may also have additional grips along the shaft so you may reposition your grip for more comfort. Additionally, ergonomic grip handles on snow shovels will make it easy for your hands.

k. Pointed Digger Shovel

You will want a pointed digger shovel if you wish to dig through difficult, compacted soils or even rocky soils. The blade of this kind of shovel will have a sharp tip and slightly upward curving edges. A tool with these two characteristics is the best for both digging and holding onto the material that has been dug out. These shovels have a long, broad footplate and a long, metal or wooden shaft. Your weight may be used to dig through deeper or denser dirt with the footplate than it can with conventional shovels.

l. Round Digger Shovel

For digging holes in softer soil types, a circular digger shovel works best. It features a pointed digger shovel-like blade with curved edges, but the tip is curved. It is perfect for transplanting bedding plants as well as for drilling holes for new trees or plants. A pointed digger shovel would be more suitable if you have thick clay, rocky soil, or rough soil, while a round digger shovel could struggle to deliver the results you need.

m. Folding Shovel

These smaller spades may be folded in half for simple portability. They are practical for taking on camping excursions and other outdoor activities when space is at a premium, and it makes sense to carry one of these in your car's trunk in case of emergencies.

Cheap folding shovels often have a very limited lifespan and will shatter or break with little effort. Invest in an all-steel design for durability; these are also better suited for heavy-duty use.

1.4 Motivation

The current work aims to design a shovel that increases overall yield while also immediately lowering time consumption. Shovels are frequently used for clearing weeds, irrigating with water, building bunds, moving straw, etc. Workers are having problems while working with the shovel as its height is fixed, and workers with less height require more strength to work. The shovel blade is also fixed, so it requires more effort to lift soil. Not every worker and field condition will gain advantages from the same shovel size because to considerations such as uneven height and soil loading. As a result, the typical shovel was inflexible and inappropriate for meeting all of the labourers' demands for efficient work. Therefore, in order to do the operation efficiently, a multipurpose shovel that can swiftly adjust its metal head or blade angle should be introduced, and the wooden handle should be swapped out for a suitable replacement.

1.5. Problem statement

Have to focus on work-related treatments to help minimise risk factors by developing an ergonomic approach that reduces risk factors that can lead to musculoskeletal diseases or other forms of injury/disease.

- The researcher has worked in production shovelling, and while the dredging effectiveness of various materials has been thoroughly documented, there has been very little study done on grasping and no work done on tool height adjustment.
- The research effort shows application in several outworks on the handle design. One research indicated that a curved shank design reduced trunk flexion during dredging, but that it was effective for less hard surface dredging. Looking into the research gap suitable objectives are selected to overcome the research.

1.6. Objectives

(1) To study soil lifting tool(shovel), design improvements and stress analysis of its CAD model.

(2) To develop and testing of improved Shovel.

(3) Performance analysis and optimisation.

1.7. Thesis overview

The present work was aimed to re-design and develop improved shovel, which's blade can revolves in many angles, which also has height adjustable handle, All element of this work is described in the following manner.

CHAPTER I present, a brief introduction of shovel and their types and motivation behind the work, also discusses the problem statement

CHAPTER II presents, a literature review of Shovel that how their parameter affects the finishing and a research gap is discussed.

In CHAPTER III, the materials and methodology used for the present work is discussed. In this chapter the procedure of design, development, and testing of the shovel is shown.

In CHAPTER IV, evaluation of the developed tool by testing and examine performance when operating with a different condition is presented. Discussion on the effect of varying parameters like heart rate, body temperature, equivalent stress, etc. and the comparison of the results is also presented here.

CHAPTER V present, the conclusion and the suggestions that can be used for future work. In the end, the references to be listed that are used in the study, and abstract of the thesis in both the language Hindi and English are presented.

CHAPTER - II

LITERATURE REVIEW

In this chapter, it was discussed in brief, about various research work done on shovel, various survey and researches has been done and analysed. Various researchers did their work for optimization of shovel, using help of experiments and different types of simulation softwares. Brief literature review work done was presented in this chapter. Finally, with the help of the literature study, the methodology, parameters, and material have been determined and will be detailed in the next chapter.

2.1 Shovel

Copley et al. (1923). Under the bromine flow of the time, Taylor found bucket loads of iron ore weighing 17.3 kg to 1.6 kg of rice cabbage. It was discovered that maximum efficiency could be reached with a 9.7 kg load by altering the bucket size to meet the density of the material to be crushed. This required only 140 people to complete a task that previously required 400–600 men. A more thorough investigation of mine dredging was conducted by Humphreys et al. 1960s. Ten guys in total lifted the coal from the ground on a conveyor line that was 0.91 meters apart and between 0.23-030 meters above the ground. Three distinct elevator shafts and three independent modes were presented.

Freivalds, A. (1986) Studied, A two-phase experimental analysis which was conducted to examine the effects of lift angle, blades size and shape, hollow- and closed-back design, handle length, and energy expenditure on shovelling performance, expected low-back compressive stresses, and subjective evaluations of perceived exertion. These recommendations for shovel design were derived from the research. the wide square-point shovelling blade, the round-point digging blade, the hollow-back design to reduce weight, the strong socket for strength in heavy-duty applications, the step for excavating in difficult terrain, the long tapered handle, and the 32-degree lift angle

Degani et. al. (1993) Compared two shovel designs and reported that workers using a modified shovel design with two perpendicular shafts experienced less fatigue and were able to work longer hours than those using a standard shovel when excavating trenches up to 90 cm deep. Compare this improved two-axle excavator to a standard one. The modified bucket was evaluated and tested in a controlled laboratory environment using surface recorded electromyography of the spinal muscles. Stress levels that were obtained during a field research were also used to test the new bill design. Electromyographic measurements of the muscles between the lumbar vertebrae show a significant loss and a progressive deterioration in range of motion when the modified bucket is used to clear debris in trench excavation down to a depth of ninety centimetres.

Chang et.al. (1999) A standard wooden handle, two fiberglass handles, and three different types of gardening tools (shovel, rake, and shovel) were utilized to measure dozer performance, strength growth, EMG, workload, and mental ratings of perceived exertion. The most successful criterion for pedaling was the relative efficiency of pedaling power, which can be calculated by dividing impact power by effort. The hollow fiberglass handle performed 12% better than the fiberglass and wood handles.

Harivanam et al. (2010) Has studied that , There was little difference in the quantity of scoops removed in the ten-minute sessions; however, the perforated shovel users removed 9.5% more clay than the standard shovel users (404 kg vs. 369 kg, respectively). Stable oxygen uptake normalized to participant weight and clay weight also shown that people consumed 11.7% less relative energy per kilos of clay scooped with the perforated shovel.

Burgess-Limerick et al. (2012) created Using Operations and Maintenance Analysis Technology (OMAT), mining equipment manufacturers can collaborate to expedite advancements in mining equipment safety design while also assessing the hazards associated with O&M jobs. Requesting manufacturers to adhere to this process serves two purposes: firstly, it gives equipment buyers a standard method of evaluating how well the concerns raised in the EMESRT Design Philosophies are taken into account in the equipment design; secondly, it gives manufacturers more data to work with while designing the equipment.

Hezekiah et al. (2020) has studied assessed the incidence of work-related injuries among employees who manually shovel sand in Nigerian sand mines. Determining the kind, frequency, and risk factors of injuries was the aim. To choose 215 workers, a non-probabilistic sampling procedure was applied. A variety of metrics were measured and compared to the literature criteria, including the following: break time, throw height, throw distance, shovel weight, scooping rate, and length. The Nordic Questionnaire was updated and used to gauge pain connected to the job. The Numeric Pain Rating Scale (NPRS) was used to gauge the severity of injuries sustained when shovelling. Data analysis was done statistically using SPSS. Over 72% of all task variables did not follow the suggested values.

The average height of the shovel handle measured (0.98 ± 0.18 m) was less than the average chest height of the users (1.21 ± 0.14 m).

The long scoping phase without a break, the fast throwing action, the difficult lifting, and the usage of the wrong shovels were the characteristics of the sand shovelling work. Low back pain (LBP) and shoulder pain are the most prevalent ailments, accounting for 43% of all reported pain. As age climbed, the prevalence of pain reduced. The study found that there was a lack of knowledge on the need of using a shovel correctly and appropriate shovelling procedures. However, in order to lessen the amount of physical labor involved in shovelling sand in underdeveloped nations, the authors suggested redesigning shovels for this purpose, introducing new technology, and providing appropriate ergonomics training.

2.2 CAE Simulation of shovel

Chu et.al. (2013) The finite element model was made using ANSYS Workbench. Constrained processing was followed by modal analysis of an arrow-shaped shovel to create the first six model forms of the rack. The modal analysis shows that as the order grows, the first six natural frequencies become larger. The regular orders of the main modes are up and down perpendicular to the horizontal direction, and the odd order of major modes is horizontal hunting along both sides of the shovel handle of the tool. Most of the distortion at the shovel head occurs in the first six models on the rack. The results offer a conceptual structure for improving and developing the shovel.

Lim et.al. (2016) The goal of this research is to create an agricultural shovel that will help farmers prevent musculoskeletal disorders by minimizing effort. Context and Goals: The majority of farming jobs, including using shovels, require repetitive labour and improper alignment of body parts, both of which increase the risk of musculoskeletal disorders. It is necessary to create and market agricultural machinery and equipment in order to decrease the load. The improved shovel was designed and produced as a test sample to assess both new and current shovels in an effort to reduce the discomfort that ten farmers had expressed with shovels. Twenty male participants were selected during the study, and physical complaints during shovelling with a shovel were evaluated mentally in addition to measuring muscular activity (percent MVC) for six different body locations.

Mohan et. al. (2021) designed multipurpose shovel that is adaptable and capable of operating on the following angles: He employed the Von Mises Stress technique to analyze the stress at 180 degrees, 90 degrees, and 35 degrees, and ANSYS was used to assess how it performed.

Mitrev et al. (2011) has conducted research utilizing CAD/CAE on the mechanical system of a large mining excavator that features a tripower system. Autodesk Inventor's Dynamic Simulator was used to conduct the test. A 3D model of the excavator's working equipment was created in order to determine (analyse) the force, geometrical, dynamical, and dynamical properties of the mechanical system. Furthermore, these factors are analysed during every cycle of excavator operation.

2.3 Musculoskeletal Disorders due to Shovel

Walker et al. (2002) has studied that due to their physically demanding activity, farmers are susceptible to musculoskeletal conditions such hand-arm vibration syndrome (HAVS), neck and upper limb signs and symptoms, low back pain (LBP), and osteoarthritis (OA) of the knees and hips. The epidemiological data regarding to such dangers is examined in this review. The most compelling evidence concerns osteoarthritis (OA) of the hip, which is expected to have a significant influence on public health. Additionally, there is less strong but possibly significant evidence that farmers have knee OA and LBP more frequently than individuals in jobs with lower physical demands. Particularly tractor drivers appear to have higher levels of LBP. The dangers of soft tissue rheumatism in the neck and limbs are not well understood.

Rahul Jain et al. (2018) used a bulky, complicated hand instrument that caused health problems relating to their employment. Using hand tools that are designed with ergonomics in mind can significantly reduce health issues related to work. Supplies and methods. After 614 articles were subjected to the selection criteria, 58 papers that dealt with the physical design of hand tools were selected. This issue has seventeen articles that discuss improving hand tools used in the industrial sector. It seems that musculoskeletal disorders are the most common health issue associated with the workplace. While some studies concentrated on human and key elements, the majority of papers concentrated on product and quality variables to improve hand tools.

Saxena et. al. (2021) An first assessment was conducted at a brick building site in Rampur (UP), India, regarding personal and situational discomfort. A sample of sixteen employees (mean age = 35.8 years; standard deviation = 3.1 years) yielded a REBA score of

17. Using computer-aided ergonomics, the shovel handles can be oriented toward the tank bottom in four distinct ways: H75, H80, H85, and H90 (partially measured). The bucket handle's orientation has an impact on the C0-C1 cervical joint, left shoulder, right shoulder, and left wrist. The least amount of torque at the bucket joint was produced using the H80 handle.

Khan et al. (2021) The purpose of this work is to design and create an automated hand shovel (AHS), a gardening tool that minimizes hand fatigue, boosts labour efficiency, and removes muck. This is accomplished by designing a four-bar linkage with a sliding clutch that is driven by a high-torque DC motor. Six healthy participants' actual hand movements were tracked using 3D motion tracking cameras while they were scratching in the trials. The purpose of this equipment is to replicate the movement path used in the actual dredging procedure. In order to minimize resistance to the mechanism during drilling, the tooltip is modified. The AHS structure controls hand, wrist, and arm position during surgery and gives the human arm the proper support.

Kuvshinkin et al. (2021), The topic covered in this paper discusses the fundamentals of building a system to compare dredge performance under particular operating situations. Indicators are utilized to assess the effectiveness of mineral shovels. The most important components of the developed approach are discussed. An algorithm for comparison is suggested to be utilized.

Hasheminejad et. al. (2021), The present study was carried out in two phases. The initial phase involved 138 personnel in all. The Scandinavian Skeletal Muscle Questionnaire was employed to ascertain occupational risk variables and ascertain the prevalence of MSA. In the second phase, pleasant treatments with PE were used to reduce MSA, and the impact of the intervention was examined. In all, 64 participants—32 in the case group and 32 in the control group—participated in the second stage. The most common locations for neuromuscular disease were the shoulders (63.7%), waist (63%), and wrist (63%). 52.1%.The prevalence of MSA in the intervention group did not significantly differ from the control group following the completion of the PE intervention program. Nevertheless, once the five tasks that were previously categorized as high-risk were reevaluated, the final scores of all five tasks were lower.

2.4 Work done on Ratchet Mechanism

Judkins et al. (2004) has tested group consisted of twenty-two individuals who were divided into three hand size categories: small, medium, and big. Every participant chose where on a handle to best place a trackball and a trigger. The ideal diameter or size of the handle that each participant desired was stated. The pivot range that each subject wanted to open and close the handle was also chosen by them. Finally, for the trackball and trigger controls at the chosen places, each participant applied their own desired force. The suggested handle diameter falls between 4.3 and 5.7 cm, according on the data gathered during this experiment. With the handle in the open and closed positions, the suggested range of rotation is 8.1 to 17.3 degrees. On average, 3.0 lbs is the acceptable actuation force for a trackball, while 0.6 lbs is the required actuation force for a ratchet.

Chen et al. (2010) In this research paper, a new linear matching method (LMM) methodology that can be broken down into cyclical and constant elements is described for the direct determination of the ratchet limit of a structure under a typical cyclic load situation. This study examines the cyclic load history, which includes multiload extremes that encompass the most intricate practical applications. The numerical values procedure calculates the maximum a constant load, or the ratchet limit, which indicates the load carrying capacity of the structure subjected to a cyclic load condition to withstand an extra constant load. First, an LMM shakedown analysis is performed to obtain a stable cyclic state of component.

Popa et al. (2017) Has used a multi-material additive manufacturing method, they proposed the design of a novel compliant ratchet mechanism. The design makes it possible to do away with springs and the pawl or gear's usual global movement found in conventional ratchets. It is also utilising current developments in 3D printing technology to swap out conventional mechanisms with multi-material ones. Finite element (FE) computational simulations are used to assess this design, and motion tests in two opposing directions are used to confirm it. Additionally, we demonstrate a parametric analysis of the geometric and material characteristics of our current design and go through how this fundamental idea may be modified for certain uses.In this work, we put forth a new compliant ratchet mechanism that combines the compliant and traditional ratchet mechanisms' guiding principles. The system permits pieces to move in one direction while preventing motion in the other. While employing the ratchet tooth shape to limit the motion of the parts in the opposite direction, the behaviour is achieved by converting the displacement of parts to elastic deformation in the flexible area during the insertion phase.

Amir Hosein et. al. (2018) demonstrated the design of a novel multi-material additively manufactured compliant ratchet mechanism. The pawl or gear may move globally and springs, which are commonly seen in traditional ratchets, can be eliminated thanks to this design. It is also utilizing the latest developments in 3D printing technology to swap out conventional systems with multi-material ones. Computational finite element (FE) simulations are used to assess this design, and physical testing of motion in two opposing directions are used to confirm it. A parametric assessment of the geometric and material qualities of our current design is also shown, and also talked about how this fundamental design idea may be tailored to certain needs.

Tran et al. (2020) For precise rotation in either the clockwise or counterclockwise direction, a ratchet mechanism has been employed. In contrast to the conventional mechanism, this one is built using fixed-guided beam flexures, which lower friction and increase precision. This work uses the pseudo-rigid-body model and the fmincon method to give a static analysis and parameter optimization for fixed-guided beam flexures. The highest stress level and the x-direction displacement have also been confirmed using the fixed-guided beam's Finite Element Method (FEM). The application of the modified pseudorigid-body model (M-PRBM) also greatly improves the maximum stress value's accuracy. According to the findings, the average discrepancies in maximum stress between MPRBM and FEM for aluminum are 3.48%, whereas for titanium they are less than 10.8%. alloy steel and carbon steel

Oleg V. et al. (2021) finds out The production of fine-module ratchet teeth requires the use of cutting instruments with unique cutting edge geometry due to their geometric features. In order to cut fine-module ratchet teeth on cylindrical surfaces, the article explains how to shape the cutting edges of two different types of tools: rack-type cutters and cutters. Rectilinear surfaces are proven to be able to approach the predicted theoretical profile of the cutting teeth's front and rear edges. Furthermore, there are negligible differences between the actual and predicted profiles—0.2–0.4% for the cutter and 0.3–0.4% for the rack-type cutter, respectively. Here are some examples of how to calculate the rack-type cutter's and cutter's geometric parameters for cutting ratchet teeth using a 0.5 mm module.

2.5 Pulse oximeter

James et al. (1999) An essential instrument in today's emergency care practice is the pulse oximeter. nevertheless medical professionals have a limited understanding of the fundamental concepts and related restrictions of pulse oximetry, despite the dependence on the data provided by this monitor. The objective of this essay is to cover the basic concepts of pulse oximetry while acknowledging its limitations. Performance restrictions in the context of anemia, motion artifact, hypotension, vasoconstriction, and carboxyhemoglobinemia are a few of these. In light of these considerations, the accuracy of pulse oximetry is examined, and its uses in emergency medicine—including both oximetric and plethysmographic procedures-are further explored.

Kim et al. (2013) Found that, The medical needs of the elderly are predicted to rise as populations in affluent nations continue to age. This study presents a 24-hour continuous heart rate monitoring system for the elderly and a finger sensor pulse oximeter of the ring type. We also show that it is achievable to recover precise measures of heart rate variability from photoelectric plethysmography data obtained with a finger-attached ring-type pulse oximeter sensor. For efficiency and low power consumption, we used a CPU with an integrated ZigBee stack while designing the heart rate sensor. Additionally, we employed a Fourier transform to examine the different distorted signals resulting from motion artifacts and developed an algorithm that used a least squares estimate to calibrate the signals for improved accuracy.

Sutar et al. (2016) Has studied an efficient biomedical application/device for heart rate monitoring and oxygen saturation determination using PCB designed .An approach for determining the blood's oxygen saturation level is pulse oximetry. This is a quick and easy way to find out how well your heart is supplying oxygen to the various organs in your body. The subject of biomedical engineering and its product development has seen a significant shift as a result of recent advances in the tiny and wearable device idea. It uses an extremely small Microcontroller ATmega328 based low cost Arduino Mini kit along with Texas Instruments OPT101 photodiode.

2.6 Digital thermometer

Lanchester (1989) found out that a economically accessible silicon diode thermometers now nearly match a stated, but non-linear, characteristic. A low-cost circuit has been created that measures temperatures with a precision that is often constrained by the calibration accuracy of the diode being used. The resolution of the circuit is 0.01 K between 1.5 and 25 K, and 0.1 K between 25 and 375 K. A conventional integrated analog to digital converter serves as the foundation for the design. A look-up table recorded on an EPROM allows for exact linearization without the need for a microprocessor.

Wang et al. (2014) Has conducted that, some of the crucial indicators that might reveal a person's physical condition is their body temperature. In the past few years, digital thermometers have been progressively used in therapeutic settings. However, due to measurement time or accuracy issues, very few thermometers are actually utilized in clinical settings. In the paper, we present the design of an enhanced digital thermometer with high precision and rapid reaction time. The following steps are taken for optimal performance: 1) the human body is measured using a thermocouple and resistance temperature detector (RTD); 2) results are digitalized using the AD7793 high resolution and low noise analog-to-digital converter (ADC); 3) specific assembly and heat isolation methods are taken into consideration for better performance; and 4) final calibration is carried out to further improve the thermometer's precision.

Abbasi (2017) has studied about a brief trial of patients with leukemia admitted to University Hospitals (UH) Seidman and Cancer Center in Cleveland for chemotherapy with a high dose or stem cell transplantation, a wearable digital thermometer detected increases in body temperature up to 180 minutes earlier than standard monitoring. The Bluetooth-enabled patch transmits temperature readings to mobile devices that are compatible with Apple or Android every 10 minutes as opposed to the current recommended 4 hours.

Onubogu et al. (2021) has studied that,depending on the ambient temperature, the average difference that infrared noncontact thermometry uses to estimate temperature at the core may change. In Nigerian locations where the mean ambient temperature is 28.3±1.8°C, an infrared non-contact forehead thermometer reading of 37.1°C may be regarded as the fever cut off for non-contact forehead temperature measurement.

2.7 Summary of literature review

The literature review on shovels reveals a significant evolution in their design, encompassing changes in shape, size, blade configuration, and handle materials. Historically, shovels have undergone modifications to enhance functionality and ergonomics. Researchers have explored the optimization of shovel shapes and sizes to accommodate diverse tasks and user preferences. Perforated shovel blades have been introduced to reduce weight while maintaining durability, facilitating easier handling and manoeuvrability. Innovations such as shovels with two axels have emerged to improve efficiency in specific applications, enabling users to transport heavier loads with greater ease. Additionally, studies have investigated various materials for shovel handles, aiming to enhance durability, comfort, and grip. These material changes range from traditional wood to modern composites, each offering distinct advantages in terms of strength, weight, and resistance to environmental factors. Overall, the literature underscores a dynamic landscape of innovation driving continuous improvement in shovel design and performance.

The literature on Computer-Aided Engineering (CAE) in shovel analysis highlights its pivotal role in enhancing shovel design and performance. CAE tools enable engineers to simulate various operating conditions and stress factors, aiding in the optimization of shovel geometry, material selection, and structural integrity. Through finite element analysis (FEA) and computational fluid dynamics (CFD), CAE helps identify potential weaknesses, improve efficiency, and mitigate failure risks. It enables designers to assess factors like load distribution, wear patterns, and ergonomics, leading to the development of more robust and user-friendly shovel designs. Overall, CAE serves as a valuable tool in the continual evolution and advancement of shovel technology.

This literature review also highlights on Pulse oximeter and ratchet mechanism, pulse oximeters essential for monitoring blood oxygen levels, have evolved with innovations like miniaturization, wireless connectivity, and improved accuracy, enhancing portability and usability in diverse settings. Similarly, ratchet mechanisms have seen innovations such as ergonomic designs, material advancements, and digital integration, optimizing performance and user experience across industries.

CHAPTER - III

MATERIALS AND METHODS

In this chapter, the materials and research techniques were briefly discussed. Method used to create an advanced Shovel is discussed here. The tools and equipment which are used to make this hand tool is explained in this chapter. Experimental and CAE simulation approach is used here which is also been explained in this chapter. SolidWorks 2020 version is used for 3D designing whereas ANYSYS is used for analysis. Design and Analysis was done at Department of Mechanical Engineering, CTAE, Udaipur.

The whole process of fabrication was done in workshop which is located at mechanical engineering department at CTAE, Udaipur

3.1 Conventional soil lifting hand tool

There are so many soil lifting hand tool available in the market but mostly shovel is used for soil lifting activity. The conventional soil lifting tool is shown in figure 3.1. In the present work the existing shovel was studied and designing parameters were identified. Further the shovel was used for soil lifting and the limitations were identified.

Fig 3.1: Shovel with all dimensions

3.1.1 Limitations and deficiency of existing shovel

The typical shape of the common shovel, which is used extensively in agriculture and construction, presents several difficulties. When used for extended periods of time, it causes tiredness and strain in laborers since it is not adjustable. Its inflexible design is devoid of ergonomic elements, which can cause pain and even injuries, especially to the shoulders and back. Furthermore, the lack of versatility of classic shovels limits their effectiveness in a variety of activities. Additional challenges arise when people with small heights are not able to use it easily, shovel blades blade are fixed so its design does not allow for effective lifting or scooping. These problems highlight the necessity for innovative shovel design in order to improve worker productivity and welfare.

In order to overcome the limitation, the modification were done in the existing shovel. The proposed modified shovel have height adjustment and blade angle variation features. Ratchet mechanism was used and height adjustment was done by co-axial pipe.

3.2 Design improvements

In order to improve existing soil tool 'shovel', some design improvements are required. The proposed design improvement and schematic diagram of shovel to be improved is shown in Fig. 3.2.

3.2.1 Design of pin for ratchet

The factor of safety in a shaft and pin of a ratchet mechanism ensures reliability under load, preventing failure. Material strength is taken into consideration, torque stresses, and operational conditions. Proper design and material selection maintain safety margins, crucial for longevity and performance. Factor of safety = Ultimate Stress/Allowable Stress, Here the diameter of shaft is crucial as it will experience bending moment, when the shaft is subjected to a bending moment only then the maximum stress(tensile or compressive) is given by the bending equation,

$$\frac{M}{I} = \frac{\sigma_b}{y} \quad \text{....(1)}$$

In this M= Bending moment, I= Moment of inertia σ_b =Bending stress and y=dia/2

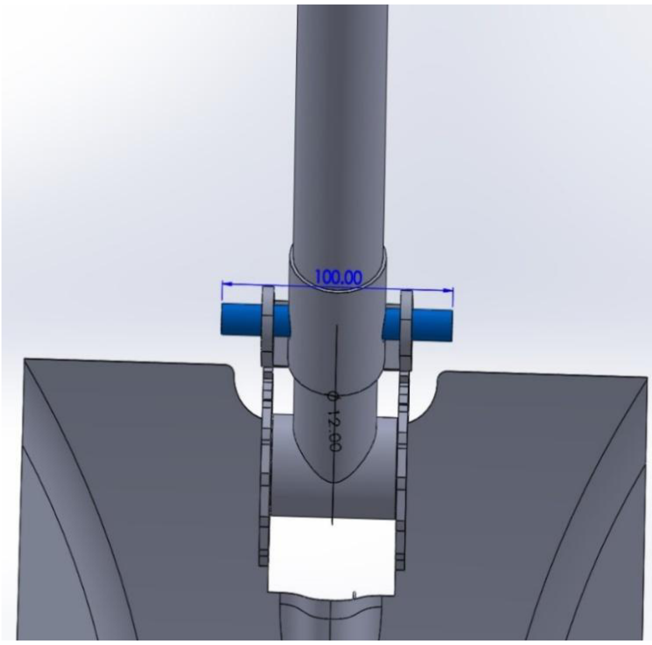


Fig 3.2: Ratchet pin

- In this ultimate strength of MS pin is considered 60MPa or 60N/mm²
- Taking Factor of safety (FOS) 2.5
- Working stress = 60/2.5 = 24 N/mm²
- Moment of inertia = I= $\frac{\pi}{64} x d^4$
- Force acting on pin= F (100 N force is applied and it will equally distribute on pin ends, so it will 50 N)
- Bending moment = Force applied x Perpendicular distance
  M = 50 N x 0.012m = 0.6 x 10^3 N-mm

(For 100N force) By putting value in equation 1 we get that for FOS 2.5 diameter d=7.45mm or 8mm is enough, we have taken 12mm diameter pin with is stronger and safer. Similarly, for 200N force, diameter of shaft 8.44 mm or 9 mm is enough for factor of safety 2.5.

Now, the pin is tested for shear failure:

Now for shear stress on pin we have this relation: F = $\sigma_s \, x \, A_s$ ......(2)

$$F = \sigma_s \, x \;\; 2x \, \frac{\pi}{4} d^2 \, \text{........} (A_s = 2x \, \frac{\pi}{4} d^2)$$

By using the above equation, shear stress of pin is 2.68 Mpa.

Where d is diameter of shaft, A_s is area ,F is force acting on it,Fs is shear force and σ_s is shear stress.

$$\text{Here } \sigma_s = \frac{\sigma \, shear \, strength}{Fs} \quad ..... (3)$$

By using the above equation, shear stress of pin is 2.68 Mpa and shear strength is 60 Mpa which shows that actual shear stress is less then max shear strength of the pin, therefore the design of pin is safe

σ_s actual < σ_s strength

3.3 Initial conceptual sketch

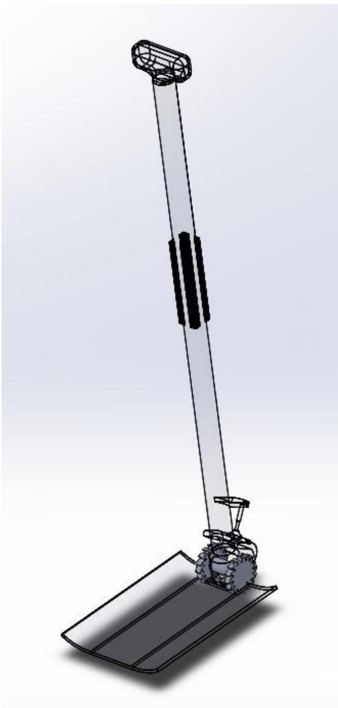


Fig 3.3: Initial shovel sketch

3.4 CAD model development

- CAD model of modified shovel is an adjustable shovel that allows the workers to simply change the angle of the shovel blades based on type of work or the soil condition and his or her height. The adjustable shovel is made up of a metal head, a shovel handle, and a moveable section with adjustable length, which moves to obtain the desired angle at the time of operation. These elements are used to create a versatile shovel that can travel to various angles due to the Ratchet locking mechanism. The goal of the this modified shovel is to provide a simple design shovel with rotating characteristics for multipurpose use. The optimised shovel will introduce a standard shovel for all types of soil conditions, as well as a shovel that can withstand vibration and, lastly, a compact Height and hand-adjustable shovel for all workers.

- CAD model of shovel is designed using Solid Works and developed shovel is been analysed using Ansys Workbench
- Firstly, The specifications are set up to create the shovel's conventional structural layout.
- Secondly, which material shall be used is specified,
- Thirdly, the shovel adjustable moving support part is designed to with varying height.
- fourthly according to CAD design, the modified shovel has been fabricated.

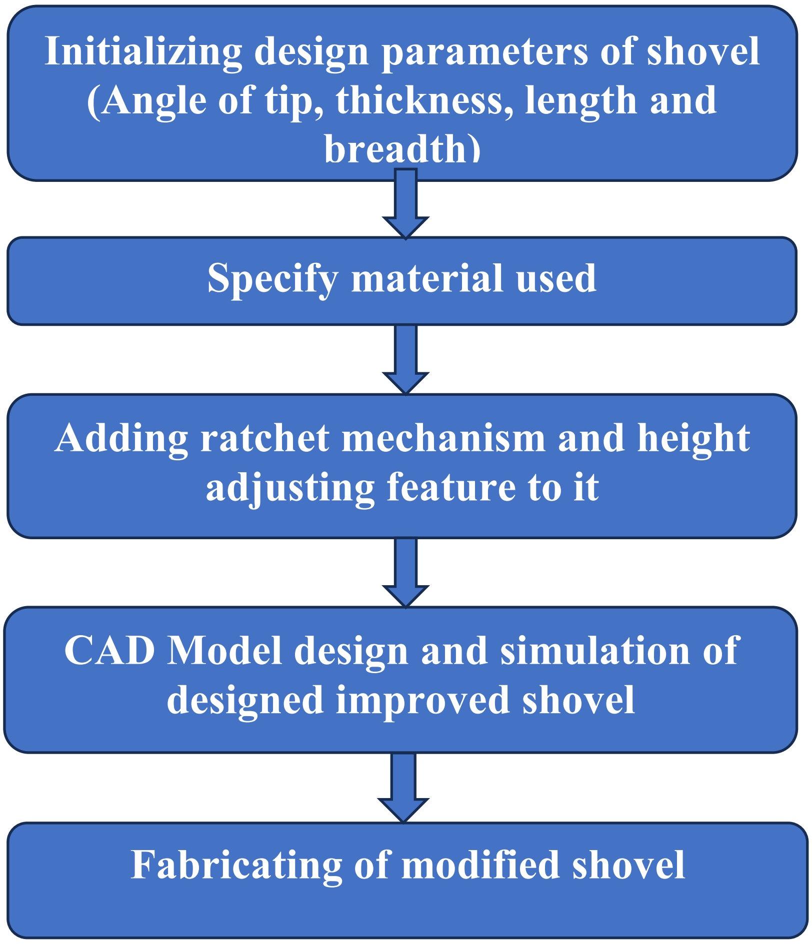


Fig. 3.4: Work flow chart

3.5 Selection of Material

When selecting a shovel, the construction material is an important factor to take into account. The material you choose will depend on your needs. You will need a heavy-duty shovel for your heavy-duty projects, thus the finest material is solid steel. The shovel won't break at the collar point if the entire thing is constructed of one solid piece (as this is the weakest point of most shovels and the cause for most breakages).

Titanium is currently a popular material for high-end shovels because it is lightweight and incredibly durable—even more so than steel. Titanium is also rust- and corrosion-resistant, making for a long-lasting shovel. Although titanium shovels do have a high price tag that deters some people, if you're seeking for a durable shovel that will last for many years, then a titanium shovel is a great option. A shovel's collar material and the manner in which the handle and blade are linked to the shaft should also be taken into consideration. Bolts are the most durable, whereas screw joints and nuts often only last for about a year.

In our study we have used mild steel, which properties are shown below :-

Table 3.1: Material Properties

Mass Density	7850kg/m ^{3}
Tensile Strength	425 MPa
Yield Strength	360 MPa
Shear Modulus	80 GPa
Modulus of Elasticity (E)	190-210-GPa
Poisson Ratio	0.27-0.30
Specific Heat Capacity	0.46
Thermal Conductivity	58.6 W/mk

3.6 Material specified

Properties of Outline Row 3: Mild Steel

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7850	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
6	Isotropic Elasticity				
12	Strain-Life Parameters				
20	S-N Curve	Tabular			
24	Tensile Yield Strength	2.5E+08	Pa		
25	Compressive Yield Strength	2.5E+08	Pa		
26	Tensile Ultimate Strength	4.6E+08	Pa		
27	Compressive Ultimate Strength	0	Pa		

Fig 3.5 : Properties of material used

3.7 Modified shovel: CAD Modelling and Simulation

Computer-Aided Engineering, often known as CAE, is a word used to represent the complete process of product engineering, from design and virtual testing using advanced analytical algorithms through the planning of manufacture. Its essential in every sector of business where product development is done using design tools, computer-aided engineering is considered standard practice. As technology enables testing and simulations of the product's physical attributes without the requirement for a physical prototype, CAE is the next step in not just developing a product but also aiding the engineering process. Finite Element Analysis, Computational Fluid Dynamics, Multibody Dynamics, Thermal Analysis and Optimizations are the most frequently utilized simulation analysis types in CAE.

The way most things are designed has entirely altered thanks to computer-aided engineering (CAE) software. Engineers may now examine a variety of design options right on the computer screen by modelling how parts will react in typical and a typical situation.

Steps to be followed for CAE simulation:

- Material specified
- Preparation of CAD model
- Setup according to geometrical

- Setup process and solution
- Results and Reports

3.8 Preparation of CAD model

For this research study, 3D CAD model was developed using SolidWorks software (academic-version) at Department of mechanical engineering in computation lab, CTAE college Udaipur, in this the improved (modified) shovel was created, which contains four major parts that is shovel handle, shovel rod, shovel blade and ratchet gear.

Preparing a CAD model for a modified shovel on SolidWorks involves meticulous attention to detail and a structured approach. Firstly, each component—shovel handle, rod, blade, and ratchet gear—needs individual design considerations. Begin with rough sketches or concept drawings to visualize each part's dimensions and functionality. In SolidWorks, start by creating separate part files for each component. Utilize sketch tools to define profiles, extrude or revolve features to add depth, and apply appropriate dimensions and constraints to ensure accuracy. For the shovel handle, consider ergonomics and grip comfort; for the rod, focus on strength and stability; for the blade, emphasize cutting efficiency and durability; and for the ratchet gear, prioritize precise teeth profiles and smooth operation, it helps the shovel blade to rotates and make some angles.

Once the individual parts are designed, assemble them in SolidWorks to ensure proper fit and functionality. Utilize assembly features to mate and align components, and simulate movements to verify the mechanism's operation. Finally, conduct thorough reviews and iterations to refine the design before proceeding to manufacturing.

3.9 Height adjusting

Since the worker was facing problems Workers encounter difficulties with non-adjustable shovel heights, leading to discomfort and strain. Fixed heights may not accommodate varying user heights or tasks, causing ergonomic issues and inefficiencies. Adjustable designs could alleviate these challenges, promoting safer and more comfortable working conditions, So to make it adjustable a coaxial pipe has been used and height can be adjusted and fixed by using nut and bolt. In figure 3. All avaible heights is shown.

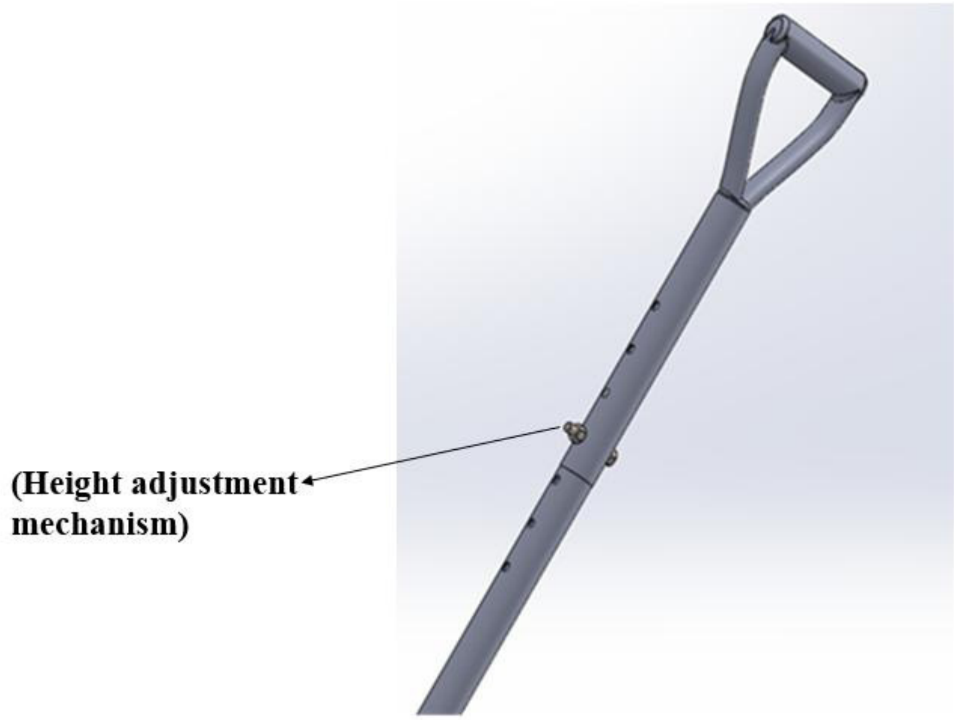


Fig 3.6 : Shovel handle **(Source: CAD Lab, DME, CTAE)**

(1) 708 mm **(2) 758 mm** **(3) 808 mm** **(4) 858 mm**

Fig 3.7 : Modifed shovel all heights

3.10 CAD Model of Ratchet mechanism

Ratchet gears provide unidirectional motion control, preventing backward movement. They are vital in mechanisms like hand tools, allowing for efficient power transmission, safety, and precise operation in various applications, Here in figure 3.7 length and diameter of shaft is mentioned i.e 100mm and 12mm respectively.

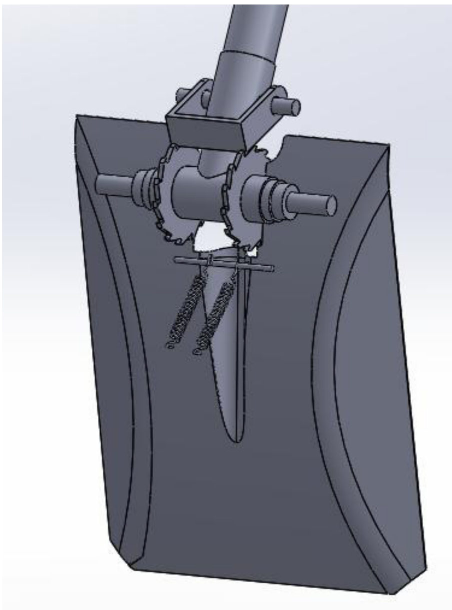


Fig 3.8: 3-D ratchet mechanism (Source: CAD Lab, DME, CTAE)

a. Ratchet gear in CAD :

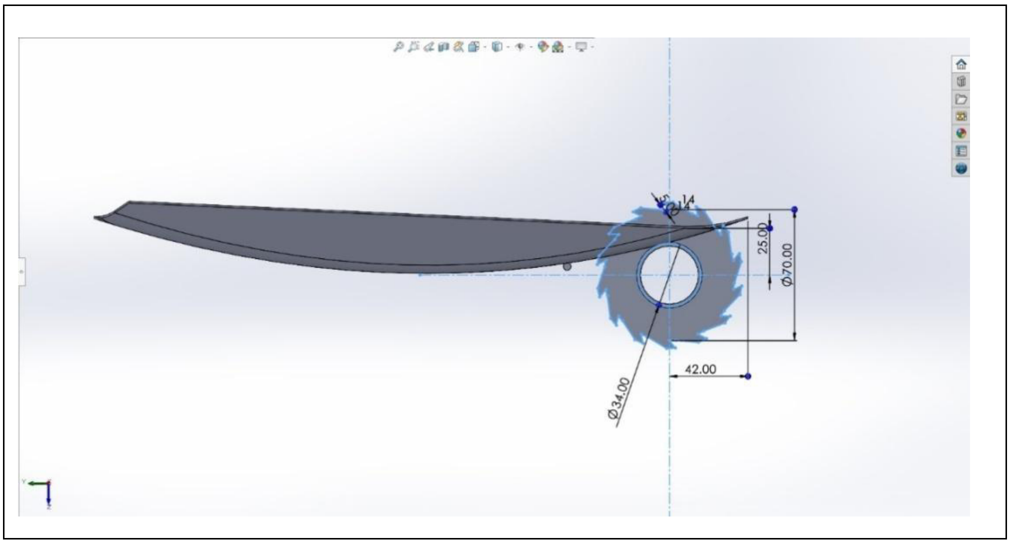


Fig 3.9 : Ratcheted gear details

The above figure shows the 3D design of new devloped Shovel with all the demension mentioned. The shovel has the height adjustable feature and rotating blade feature which is done by ratched machanism.

b.) Angles formed by ratchet teeth

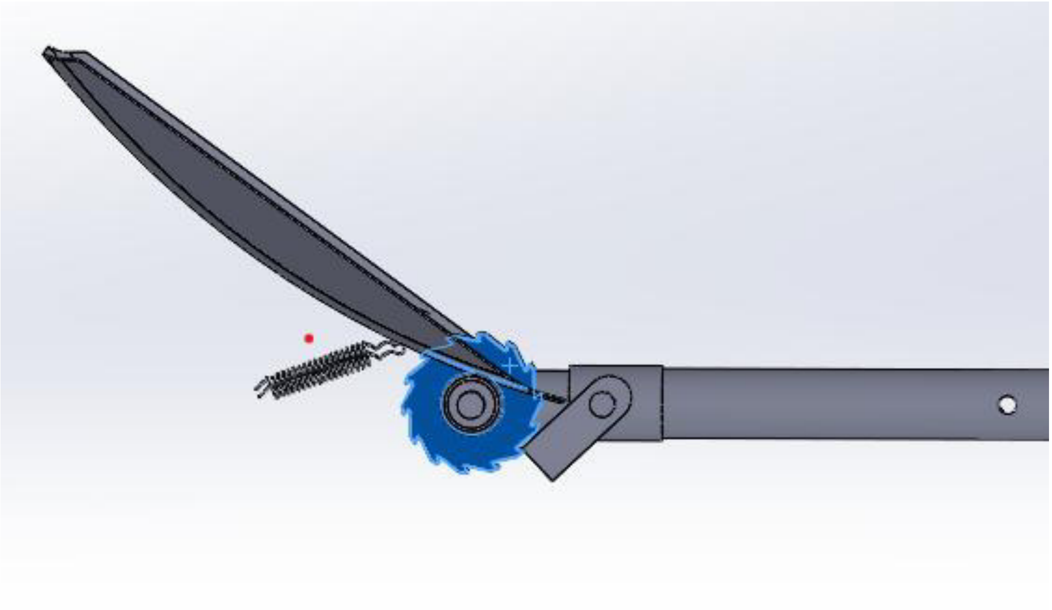


Fig3.10: Modified shovel gear(ratchet gear)

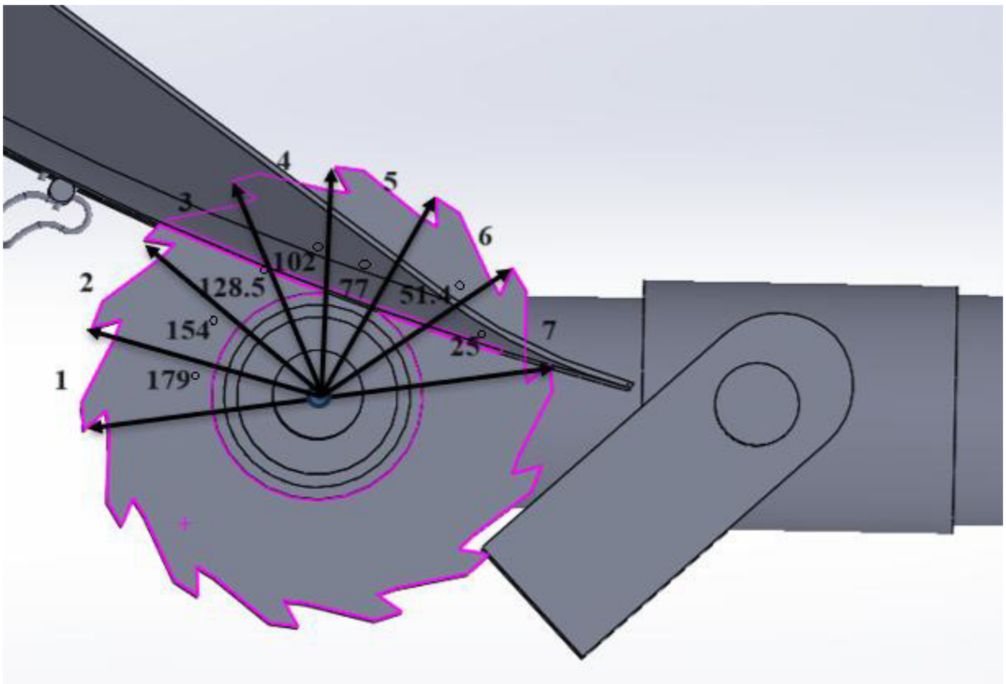


Fig 3.11: Ratchet gear angles

Ratchet gear helps for the movement of the blade with is been attracted on the shaft end and angles formed ratchet gear are 179º ,154º 128.5º ,102º ,77.1º ,51.4º and 25.7º. In above fig. the blade can be moved to seven different angles out of those four angles are been studied here which is shown here the angles are 25.7º, 77.1º, 102.8º and 128º. Each angle represents a specific position or movement within the gear system, facilitating efficient operation. In a ratchet mechanism, these angles determine the degree of rotation or engagement, contributing to precise motion control. Understanding and optimizing these angles are essential for enhancing the performance and reliability of the gear system

Shovel Blade details in CAD:

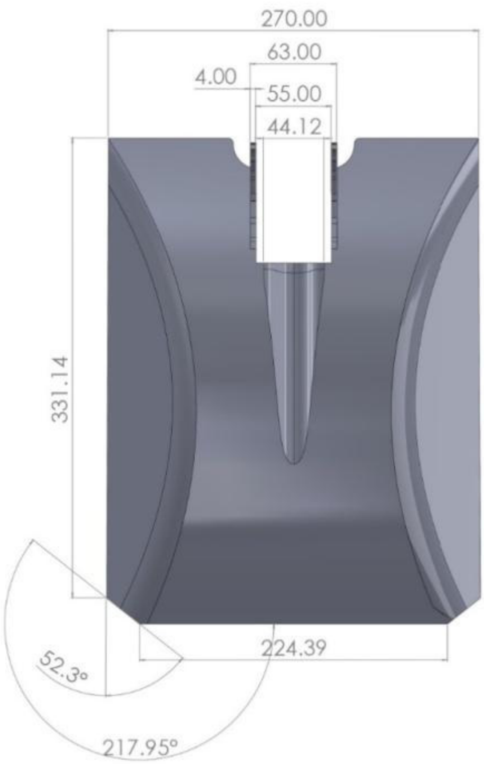
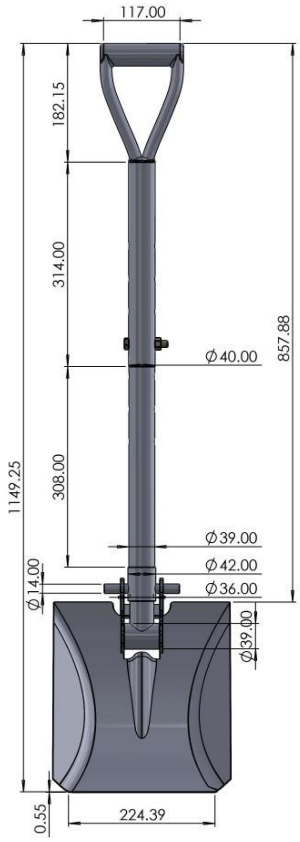


Fig 3.12 : Shovel blade details

a. Modified Shovel 3D-Shovel design



All dimensions are in mm

Fig 3.13: 3D-Shovel design in Solidworks with all specification

The length, breadth, and height of a modified shovel design were precisely calculated in SolidWorks with exact measurements. SolidWorks facilitates the visualization of the design, enabling engineers to analyze its performance virtually before physical prototyping. Such precision in design not only enhances usability but also contributes to safety and efficiency.

b. Side profile of shovel

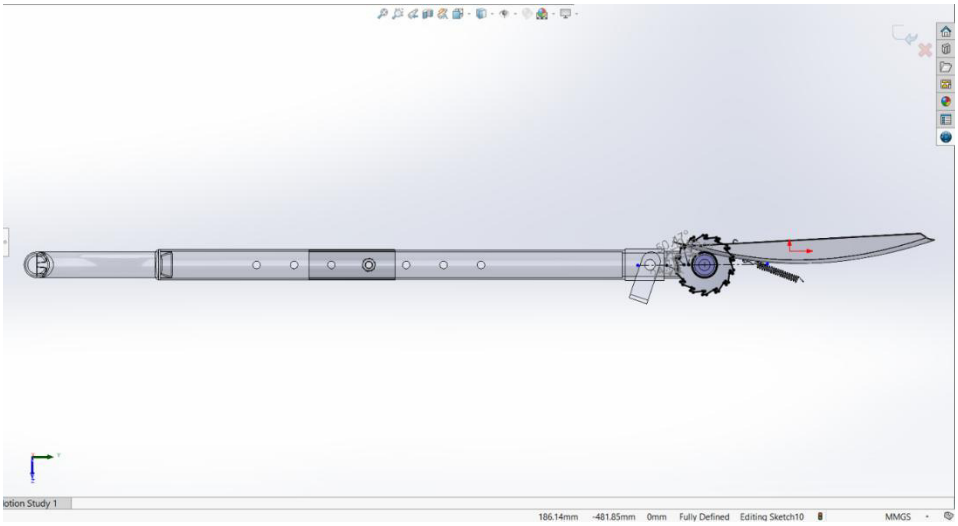


Fig 3.14: Shovel side profile

c. All view images of modified shovel

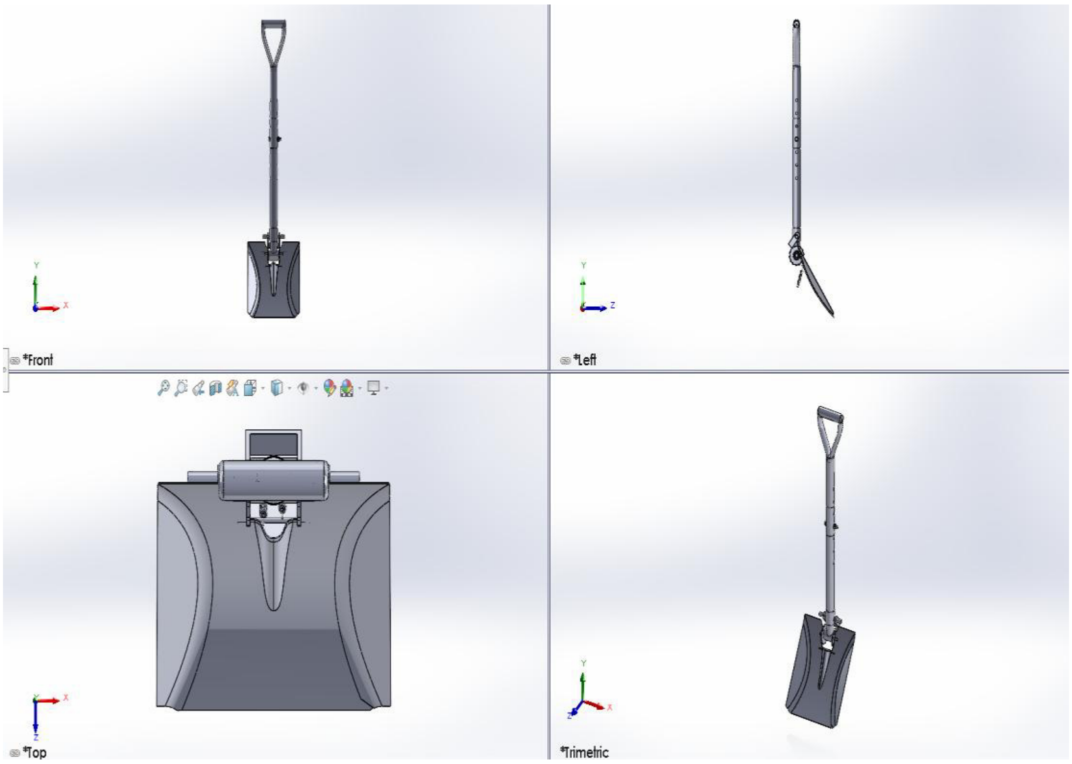


Fig 3.15: All view images of shovel

- The above figure shows the various views of shovel, i.e. Front view, left view, Right view and trimetric view

3.11 Development of modified Shovel

Welding By using heat at high temperatures, the manufacturing technique of welding enables you to combine materials such as metals. In this below image the welding machine was used it is available in DME,CTAE,

While looking for a method to form iron into usable shapes, the welding process was chosen. In the early years of welding, the first product was welded blades because hard steel that was too brittle for use was generated when iron was carbonised. Later, hammer forging and interlacing the stiff and soft iron with high-carbon material produced a robust and resilient blade. Filler material is used during the welding process.

Fig 3.16: Welding machine

Fig 3.17 : Welding process

Modified shovel is made by connecting the blade to the handle socket using welding processes, This makes the attachment sturdy and flexible enough to tolerate frequent use. For alignment and strength, precision welding is essential, which enhances the shovel's overall performance and durability.

A milling machine is a piece of machinery that uses a multi-point tool for cutting to remove a layer of material from the surface. The milling cutter quickly removes metal while rotating at an intense speed because to its many cutting edges. It is among the most adaptable and frequently used machine tools in the entire globe. Various process are being caried out with help of this milling machine, ratchet gear teeth is this modified shovel.

3.12 Final fabricated ratchet mechanism

Fig 3.18 : Ratchet mechanism

3.13 Final fabricated Modified Shovel

Fig 3.19: Modified shovel

The core innovation of this modified shovel lies in its ratchet mechanism, which allows the blade to rotate to four different angles. This feature enables users to adapt the shovel to different tasks and working conditions efficiently. Whether digging, scooping, levelling, or shoveling, the adjustable blade angles offer optimal positioning, reducing strain on the user's wrists, arms, and back.

The new modified shovel comes with a handy height-adjusting feature. In which a worker can easily customize the shovel's length according to his needs, making digging tasks more comfortable and efficient for everyone, regardless of height.

3.14 Measuring tools and instruments

3.14.1 Pulse oximeter

A Person's heart rate is the number of times his heart beats in a minute. Our body automatically controls your heartbeat to match whatever you're doing or what's happening around you. That's why your heartbeat gets faster when you're active, excited or scared, and drops when you're resting, calm or comfortable. Heart rate can be measured using pulse oximeter. Heart rate is an important indicator of your overall health too. When a person's heart rate is too fast or too slow, that can be a sign of person is doing some physical activity or may be other health problems. The ability to feel your heart rate throughout your body is also a potential way for doctors to diagnose medical conditions. Heart rate can we measured using oximeter, Oximeter is an instrument used to count our heart rate, A technique called pulse oximetry is performed to determine the blood's oxygen saturation level. It is a simple, painless test to determine how well oxygen is being delivered to the body parts that are farthest from the heart, such the arms and legs. The error percentage of instrument is 0.3.

In this work the heart rate is measured using pulse oximeter, here work has been defined to ten workers, All worker has given a normal shovel and data (heart rate) has been recorded, after certain duration modified shovel has been given to them and their heart beat is been measured using oximeter Adults typically have a resting heart rate between 60 and 100 beats per minute. If heart rate increases it indicates fatigueness. Pulse rate measurement range is 35-220 Bpm and oxygen saturation range is 25-100 percent.

Fig 3.20 : Pulse oximeter

3.14.2 Digital thermometer

A digital thermometer is a technological wonder of temperature measurement, providing accuracy and practicality for a wide range of uses. Unlike traditional mercury or dial thermometers, digital thermometers utilize electronic sensors to detect temperature changes accurately.

The least count of a digital thermometer refers to the smallest temperature difference that the thermometer can detect and display. It essentially represents the precision of the thermometer's measurements. The least count varies depending on the design and specifications of the thermometer. For many digital thermometers used in everyday applications, the least count is typically around 0.1°C or 0.2°F. This means that the thermometer can detect temperature changes as small as 0.1°C or 0.2°F and display them on its screen. Normal body temperature, typically measured orally, is considered to be around 98.6°F (37°C) for adults, although slight variations can occur depending on factors such as age, time of day, and individual differences. Generally, temperatures between 97°F (36.1°C) nd 99°F (37.2°C) are considered within the normal range. Body temperature tends to be lower in the morning and slightly higher in the late afternoon and evening.

In this study, the body temperature of ten workers was recorded using a digital thermometer while doing a task with a normal shovel and later with a modified shovel. Working with a standard shovel can significantly elevate body temperature due to the exertion involved.

A high body temperature can vary depending on the cause and severity but is typically considered to be above 100.4°F (38°C) when measured orally. The other factor of increase in body temperature may be due to work out or doing some physical work, According to National Institute of Health (NIH) temperature can suddenly climb to as high as 40 C (104 F) during intense exertion.

3.15 Testing and performance

3.15.1 Overall discomfort test :

A discomfort test is a useful tool for identifying, prioritizing, and documenting workers ergonomic concerns. It is considerably simpler to do evaluation, Its widely used and recognised scale, it could be simple to take it for granted. The Overall Discomfort Test benefits employees by recognizing certain ergonomic problems, allowing for focused interventions that reduce strain, increase overall health and productivity, and improve workplace comfort. Levels of discomfort, assessed on a scale or in another way, would serve as the measuring. The total of all the individual feelings experienced by the operator through the various sense channels would represent the overall amount of discomfort. By using the Participative Ergonomics for Manual Tasks (PErforM) Handbook Worksafe QLD, the worker discomfort survey result has been completed it follows, Work Health and Safety Act 2011 (WHS Act) Work Health and Safety Regulation 2017 (WHS Regulation)

For testing and performance purpose, workers was asked to work with normal shovel and modified shovel, various parameter was observed, whole human body parts comfort was observed, that includes neck head, upper back left shoulder, right shoulder both elbows, both forearms etc. discomfort score has been given by range 0 to 5 where, 0 means – No Discomfort, 1- Minor Discomfort, 2- Mild Discomfort, 3- Moderate Discomfort, 4- Major Discomfort and 5- Severe Discomfort.

3.15.2 Performance analysis using soil lifting:

To see how well normal and modified shovels work and analyse how much soil they can lift in what amount of time. It compares comfort. By testing them in real conditions, figure out which one is better for different kinds of soil lifting jobs. soil displacement per scoop, lift time for a given volume

Key physical indicators were examined in the performance analysis of a modified shovel to see how effective it was in comparison to a standard shovel, modified shovel maximum height can extend up to 858 mm whereas standard shovel maximum height is 780 mm and diameter of both shovel blade is 224 mm. Survey focus areas were heart rate, body temperature, and oxygen saturation. The modified shovel's advantage over its conventional equivalent was demonstrated by the results. However, those using the modified shovel showed lower heart rates, which suggests less effort. Body temperature stayed more constant, indicating improved comfort and endurance over an extended period of time. Consistently greater oxygen saturation values highlighted increased respiratory efficiency. These results highlight the practical advantages of the modified shovel, indicating improved functionality and user comfort in hard activities.

For performance purposes, workers were asked to lift soil weighing 100 kg at a fixed distance of 3 feet. Various parameters were observed while working with a normal shovel, similar observations were taken with a modified shovel. Ten workers were used for taking observations from normal shovel and modified shovel. Workers oxygen level, body temperature, and heart rate was observed. The observation table formed is shown below and its average result is shown in chapter 4th result and discussion.

Table 3.2 : Performance analysis of modified shovel

S.no	Worker	Soil lifting time(sec)	Pulse oximeter reading (Bpm)		Oxygen saturation level (%)		Body Temperature(°F)	
			Before work	After work	Before work	After work	Before work	After work
Normal shovel								
1	1st worker	109	69	90	98	94	98.2	98.9
2	2nd worker	97	77	89	99	93	96.6	97.5
3	3rd worker	100	68	79	97	94	97.5	98.3
4	4th worker	105	79	92	98	94	98.1	98.9
5	5th worker	103	63	89	96	93	96.9	98.4
6	6th worker	99	73	94	97	95	97.1	97.9
7	7th worker	115	81	92	99	95	98.3	98.7
8	8th worker	110	65	88	97	93	97.9	98.6
9	9th worker	101	62	79	98	94	98	98.7
10	10th worker	107	77	90	96	93	97.5	98.9
Average		**105**	**71**	**88**	**97.5**	**93.8**	**97.6**	**98.5**
Modified shovel								
1	1st worker	78	69	77	98	97	98.2	98.5
2	2nd worker	90	77	81	99	97	96.6	97.1
3	3rd worker	93	68	80	97	95	97.5	98
4	4th worker	75	79	80	98	96	98.1	98.5
5	5th worker	90	63	70	96	95	96.9	97.2
6	6th worker	86	73	81	97	94	97.1	97.7
7	7th worker	76	81	88	99	97	98.3	98.7
8	8th worker	70	65	75	97	95	97.9	98.2
9	9th worker	70	62	76	98	94	98	98.3
10	10th worker	95	77	84	96	94	97.5	98
Average		**82.3**	**71**	**79**	**97.5**	**95.4**	**97.6**	**98**

3.16 Results for performance analysis obtained from Measuring tools

A.) Effects on heart beats

In this heart rate is measured using pulse oximeter, here work has been defined to ten workers, all worker has given a normal shovel and data (heart rate) has been recorded, after certain duration modified shovel has been given to them and their heart beat is been measured using oximeter adults typically have a resting heart rate between 60 and 100 beats per minute.

Table 3.3: Heart rate form normal shovel and modified shovel

(S. no	Time (duration of work), min.	Heart rate(bpm)										Average Heart Rate, bpm
		Workers										
		1	2	3	4	5	6	7	8	9	10	
(A)	**Normal shovel**											
1.	0	68	65	67	66	69	67	70	67	72	64	**68**
2.	5	83	77	79	78	82	78	78	79	83	75	**79**
3.	10	90	85	89	87	96	92	85	90	94	93	**90**
4.	15	110	103	99	95	104	107	106	105	109	108	**105**
5.	20	118	115	110	110	114	117	118	115	112	116	**115**
(B)	**Modified shovel at 51.4^o angle**											
1.	0	69	63	67	66	69	60	70	67	71	64	**69**
2.	5	76	69	72	74	80	68	78	81	78	70	**74**
3.	10	78	73	79	80	87	78	85	88	85	78	**81**
4.	15	89	85	91	89	95	88	94	99	97	89	**92**
5.	20	97	99	103	107	115	99	104	109	110	97	**102**
(C)	**Modified shovel at 154^o angle**											
1	0	67	65	65	70	66	62	72	64	72	61	**66**
2	5	80	72	70	76	75	72	75	69	78	68	**75**
3	10	87	82	77	86	85	83	88	76	89	75	**83**
4	15	94	96	91	98	96	97	93	89	99	94	**95**
5	20	107	105	99	110	101	106	100	97	108	109	**104**

Out of seven angles formed by ratchet gear angle 54.1 degrees and 154 degrees of the modified shovel are most suitable angles. It enhances the effectiveness of digging by allowing easier soil penetration and requiring less work from the worker. In order to maximize user comfort and performance, these angles are the most ideal.

B) Effects on body temperature while working with normal shovel and modified shovel

- **Worker using normal shovel**

Fig 3.21: Using normal shovel

- **Worker using modified shovel**

Fig 3.22: Using modified shovel

Table 3.4: Observation table for body temperature

S. no	Time (duration of work), min.	Body temperature (ºF)										Average body temperature
		Workers										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
(A)	**Normal Shovel**											
1.	0	97.8	97.5	96.6	97	97.4	97.2	98	97.3	96.9	98.5	**97.2**
2.	5	98.1	98.5	97.2	97.6	98	98.1	98.9	98.3	97.4	98.6	**98.1**
3.	10	98.3	98.9	97.4	97.8	98.8	98.9	99	98.5	97.9	99.2	**98.5**
4.	15	98.9	99.2	98.2	98.1	99.4	99.3	99.7	98.8	98.1	99.4	**99.1**
5.	20	99.8	100	99.8	98.9	100.3	100.7	100.4	99.3	98.9	100.2	**99.9**
(B)	**Modified Shovel at 51.4 º Angle**											
1.	0	97.5	98.4	96.3	97.2	97.4	98.1	98.2	97.3	96.5	98.3	**97.4**
2.	5	97.9	98.6	97.4	97.4	97.8	98.4	98.8	97.7	96.7	98.5	**97.9**
3.	10	98.2	98.3	97.6	97.6	98	98.2	99.4	98.5	97.2	98.7	**98.1**
4.	15	98.4	98.7	98.3	98.2	98.5	99.4	99.6	98.8	98.2	99.7	**98.5**
5.	20	98.7	99.2	98.9	98.6	99.2	99.8	99.9	99.2	99	100.1	**99.1**
(C)	**Modified Shovel at Angle 154º Angle**											
1	0	97.5	98.2	96.1	96.9	97.4	98.4	98.2	97.3	96.5	97.2	**97.3**
2	5	98	98.6	97.4	97.2	97.8	98.4	98.8	97.7	97.2	98.7	**97.7**
3	10	98.2	98.3	97.4	97.6	98.4	98.8	99.4	98.5	98	99.4	**98.3**
4	15	98.4	98.5	98.3	98.2	98.7	99.2	99.6	98.8	98.5	99.7	**98.7**
5	20	98.7	99.2	98.9	98.6	99.2	99.8	99.9	99.2	99	100.1	**99.2**

In this the body temperature of ten workers has been recorded by using digital thermometer while doing a task from normal shovel, and later by modified shovel. Working with a standard shovel can significantly elevate body temperature due to the exertion involved. The repetitive movements, combined with the resistance of soil, generate heat within the body. As muscles contract and energy is expended, metabolic processes accelerate, further raising internal temperatures.

This increase in body heat can lead to sweating, a natural cooling mechanism, but may also result in fatigue and discomfort if not managed properly. Adequate hydration and breaks to rest and cool down are essential to mitigate the effects of heightened body temperature during manual labor with a standard shovel.

CHAPTER - IV

RESULTS AND DISCUSSION

This chapter presents results derived from comprehensive experiments and analytical work, showcasing project outcomes through insightful graphs. Experimental and CAE simulation approach results are shown in this chapter, ANYSYS 2021 R1 version is used for analysis. Design and Analysis work is done at CAD lab, Department of Mechanical Engineering, CTAE, Udaipur.

4.1 Stress analysis of modified shovel using ANSYS Workbench

Results were generated by using ANSYS Workbench, where the Engineering data and geometry data were entered and model was made which we see in below fig. ANSYS is been used to get maximum deformation and equivalent stress on modified shovel blade. As ratchet gear was added on shovel blade the objective was to ensure the blade remains strong and reliable despite the added complexity of the ratchet mechanism. Its analysis helped determine how the blade would handle different loads and pressures. ANSYS will help to analysis the maximum stress and maximum deformation it can bear it will confirm that the blade could withstand compromising the tool's functionality.

Meshing was done and various load were added there, Meshing the shovel blade in Ansys software involves discretizing its geometry into finite elements for accurate simulation. By defining element types, sizes, and refinement, meshing ensures numerical stability and solution accuracy. The process aims to balance computational efficiency with fidelity to capture complex geometrical features and stress concentrations. Proper meshing facilitates accurate analysis of structural integrity, stress distribution, and performance under various conditions.

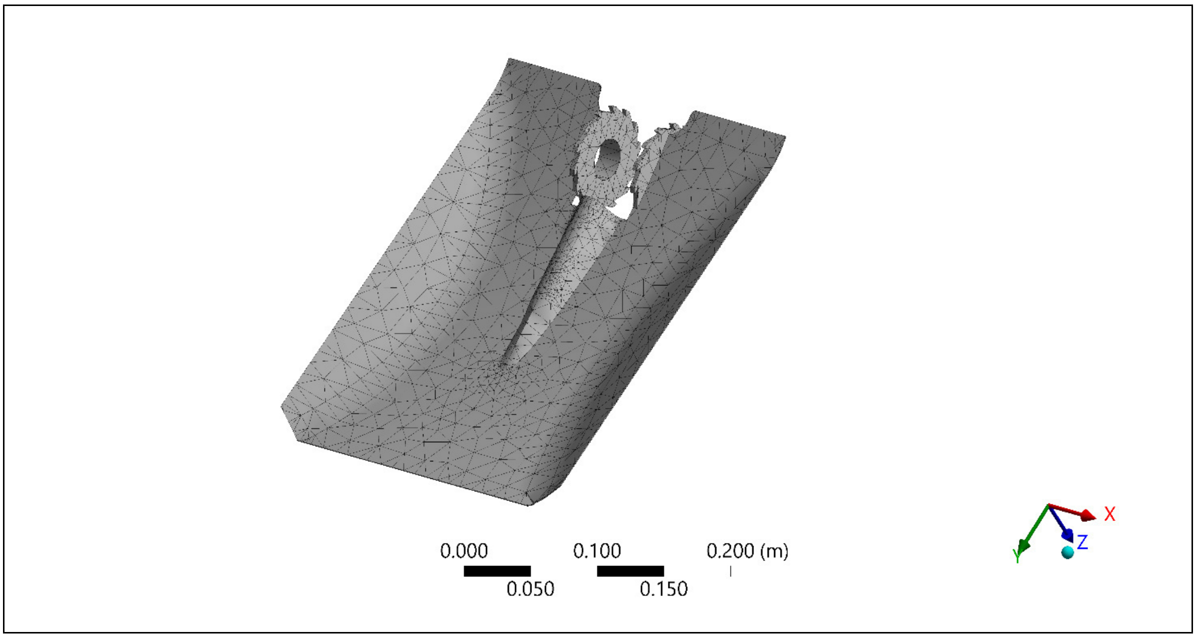


Fig 4.1: Meshing of shovel blade

- In below image the Total deformation is shown when load is applied on the shovel blade, the image shows the minimum to maximum deformation.

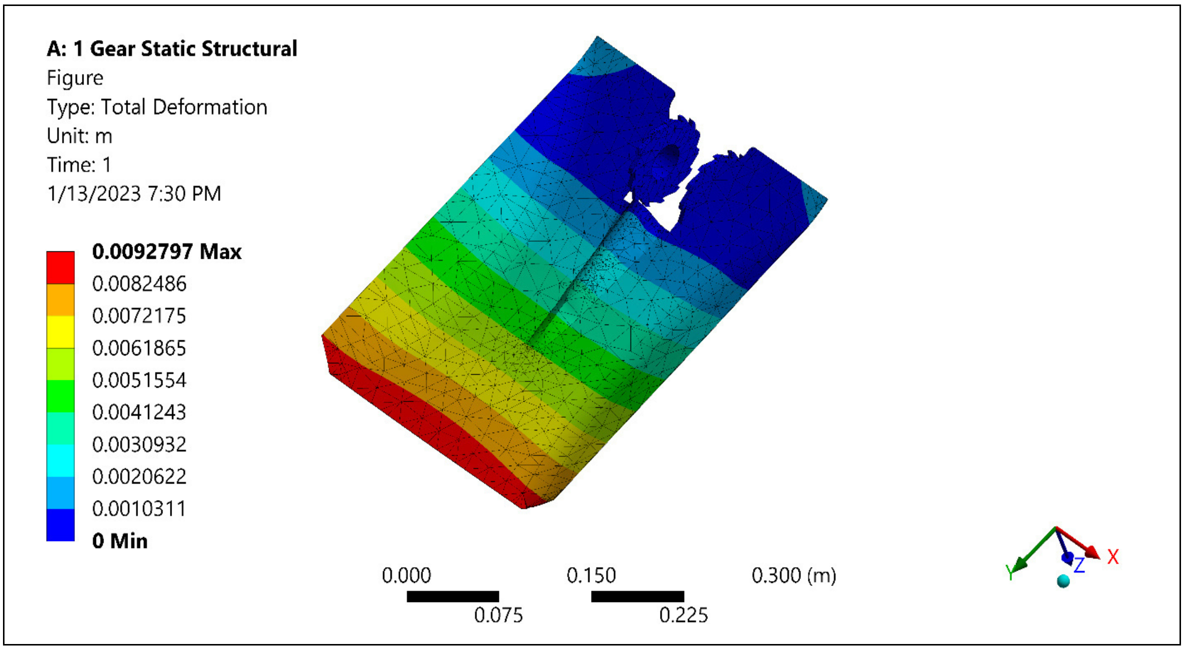


Fig 4.2: Total deformation of shovel blade

In this above figure 4.2 its shows the total deformation range over the shovel blade, The ANSYS image displays the total deformation range across the shovel blade, providing crucial insights into structural behaviour under load. This visualization helps to assessing potential weak points, optimizing material distribution, and ensuring the shovel's durability and performance in real-world conditions.

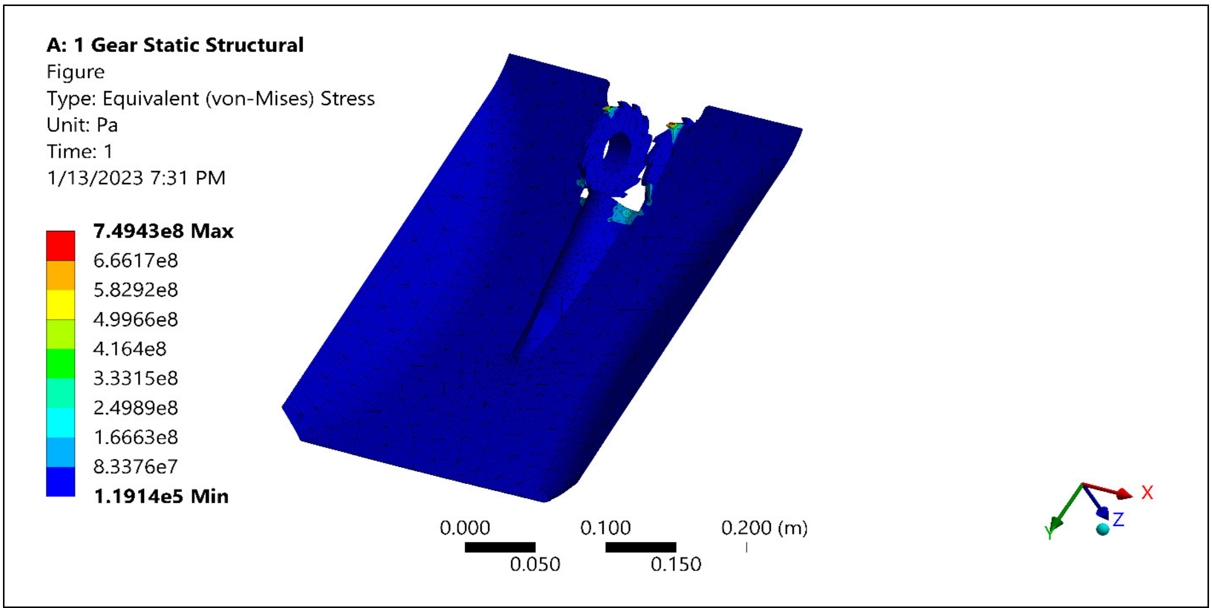


Fig 4.3: Minimum to maximum equivalent stress

Since the ratchet mechanism was attached to the shovel blade, to examine its strength after modification, the ANSYS Workbench was used, and with the help of this equivalent stress and total deformation of modified shovel was calculated.

Considering standard factor of safety of shovel, it was found that maximum equivalent stress was order its limits, so the modified shovel can consider safe while operating.

4.2 Modified shovel features:

Here below figure all features of developed shovel is shown, like height adjusting and blending of shovel blade. The ratchet mechanism ensures smooth rotation and secure locking at each angle, enhancing usability and safety. it will help it to rotate to seven angles i.e **25.7 degree, 51.4 degree, 77.1 degree ,102.8 degree, 128.5 degree, 154 degree and 179 degree.** Here most useable angles are 154 degree, 77.1 degree and 51.4 degree which is shown in below figure 4.4, 4.5 and 4.6 respectively.

Fig 4.4 : Shovel at 154º

Fig 4.5: Shovel at 77.1º

Fig 4.6: Shovel at angle 51.4º

4.3 Height Adjustment Feature:

In addition to the ratchet mechanism, the shovel is equipped with a height adjustment feature, allowing users to customize the handle length according to their height and preferences. Proper ergonomic positioning is crucial in reducing the risk of musculoskeletal disorders and fatigue. With the ability to adjust the handle height, users can maintain a neutral posture, minimizing strain on their muscles and joints during prolonged use. This feature accommodates workers of different heights, promoting inclusivity and comfort in the agricultural workforce. It has four height levels which can we adjusted according to requirements.

Fig 4.7: Shovel Minimum height (708 mm)

Fig 4.8: Shovel maximum height (857 mm)

4.4 Performance analysis and optimization of improved shovel

A.) Effects on heart rate with normal shovel and improved shovel.

For performance analysis and optimization purpose observation table was made comparing heart rates using a normal shovel and modified shovel (at 51.4º and 154º angles), distinct patterns emerge. Initially, the heart rate curve for both tools rises sharply as physical exertion increases. It was also observed that while working with normal shovel heart rate increases above 110 bpm in time interval of 16 mins. Whereas while working with modified shovel at 51.4º and 154º angles heart rate was under 104 bpm till 20 mins of work, which shows that with modified shovel workers can work more.

Table 4.1: Average heart rate for normal and modified shovel

S. no.	Time (min)	Average heart rate (bpm)		
		Normal shovel	Modified shovel at (51.4º) Angle	Modified shovel at (154º) Angle
1	0	68	69	66
2	5	79	74	75
3	10	90	81	83
4	15	105	92	95
5	20	115	102	104

The above table reference are taken from Chapter 3 of this thesis Table 3.3, here in this table average results are mentioned.

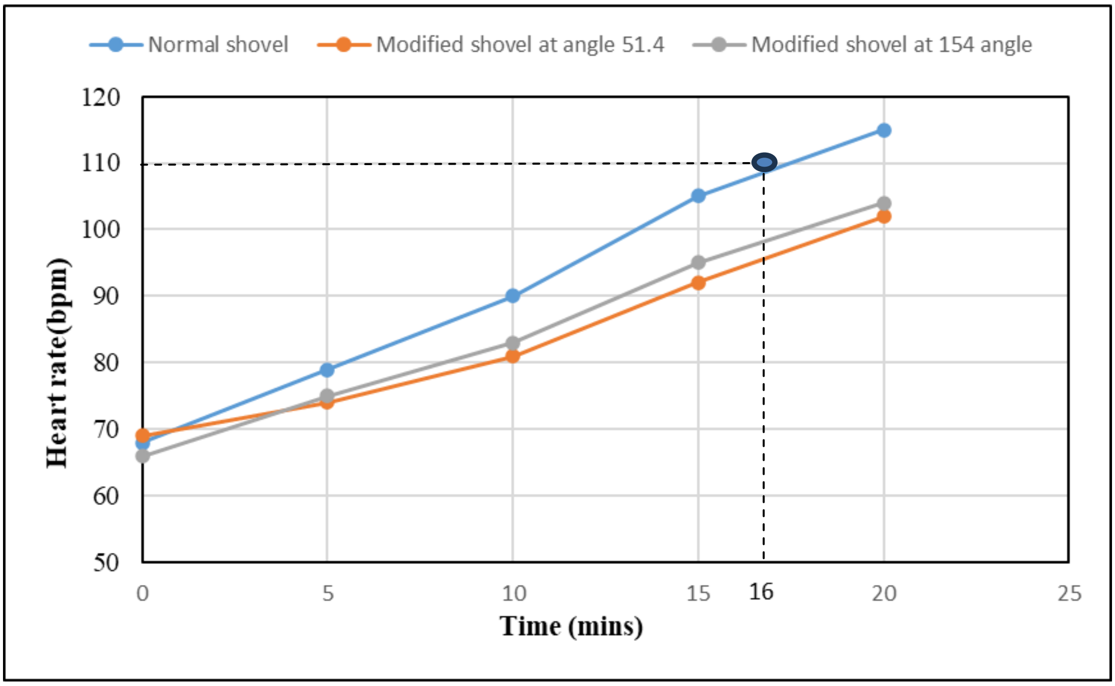


Fig 4.9 : Graph plotted against time and heart rate

- In above fig 4. The results shown, in the plotted graph comparing heart rates while using a normal shovel a modified one, distinct patterns emerge. Initially, the heart rate curve for both tools rises sharply as physical exertion increases.
- In this the worker heart rate is measured for 20 mins and both shovels results has been noted. An average for ten workers heart rate is been taken and graph is been plotted according
- However, it was observed that in normal shovel after certain time of work heart rate increases gradually it goes till 115 bpm, whereas in modified shovel it remains under 104 bpm its shows that normal shovel gives exertions it requires more amount of energy.

(B) Effects on body temperature with normal shovel and improved shovel

For performance analysis and optimization purpose observation table was made comparing body temperature using a normal shovel and modified shovel (at 51.4^o and 154^o angles), distinct patterns emerge. Initially, body temperature curve for both tools rises sharply as physical exertion increases, it was observed that till 16 mins of working with normal shovel body temperature increase above 99.2 degree Fahrenheit, whereas with modified shovel body temperature remains under 99.2 till 20mins, so worker can work more.

Table 4.2: Average body temperature while working with normal and modified shovel

S.no.	Time (min)	Average body temperature(ºF)		
		Normal shovel	Modified shovel at (51.4º) angle	Modified shovel at (154º) angle
1	0	97.2	97.4	97.3
2	5	98.1	97.9	97.7
3	10	98.5	98.1	98.3
4	15	99.1	98.5	98.7
5	20	99.9	99.1	99.2

The above table reference are taken from Chapter 3 of this thesis Table 3.4, here in this table average results are mentioned.

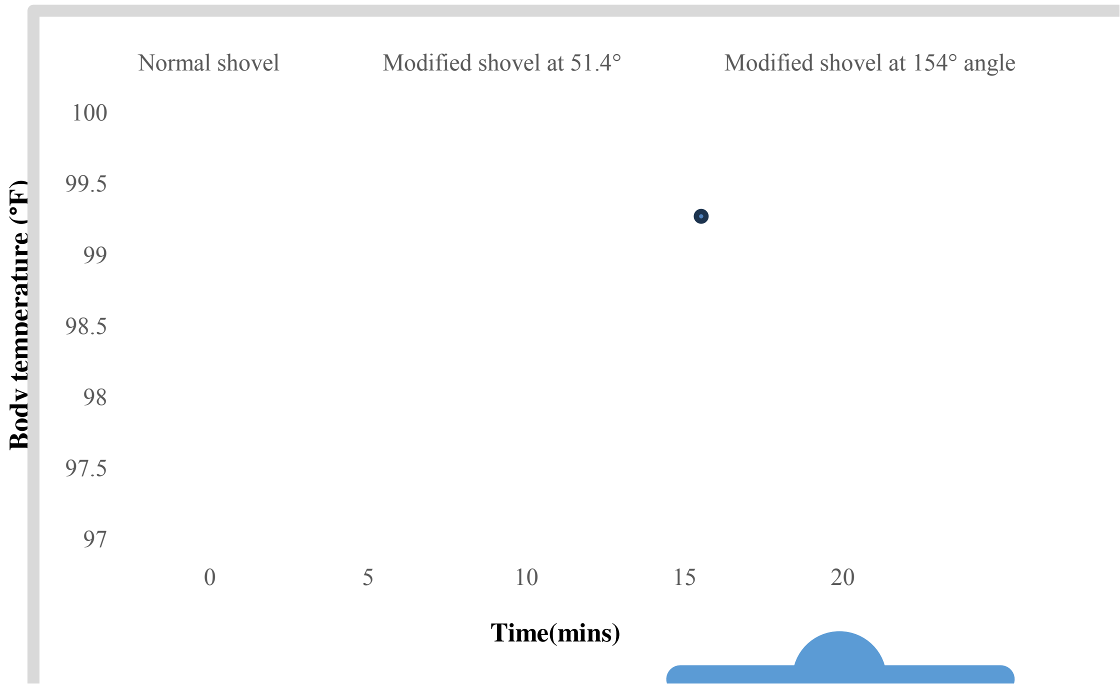


Fig 4.10: Graph plotted against time and body temperature

In Figure 4.16 It can be determined that the increase in body temperature is 97.2 to 99.9 degrees Fahrenheit for a normal shovel and 98.9 to 99.9 degrees Fahrenheit for a modified shovel in time duration from 15 minutes to 20 minutes. It can be determined that a modified shovel requires less effort to work, whereas a normal shovel requires more effort.

4.5 Overall- Discomfort test :

An overall discomfort was conducted and in which certain task was given to workers, firstly normal shovel was used and discomfort score was recorded, similarly same task is done my modified shovel and score is been recorded in same way, trials has been done ten times with each sample and took average, in this all the discomfort or pain has given a certain score as mentioned below. Average score while working with normal shovel was 3 whereas with modified shovel was 2.

Table 4.3: Observation table obtained from survey of Overall discomfort

S. No.	Body parts	Discomfort Score (Normal Shovel)	Discomfort Score (Modified Shovel)
1.	Neck	3	2
2.	Head/eye	0	0
3.	Upper back	4	2
4.	Left shoulder	2	2
5.	Right shoulder	2	2
6.	Left elbow	3	1
7.	Right elbow	2	1
8.	Left forearm	2	2
9.	Right forearm	2	2
10.	Left wrist	2	1
11.	Right wrist	2	1
12.	Left hand/finger	0	0
13.	Right hand/finger	0	0
14.	Low back	4	2
15.	Left hip/thigh	2	2
16.	Right hip/thigh	2	2
17.	Left knee	3	1
18.	Right knee	3	1
19.	Left ankle/foot	0	0
20.	Right ankle/foot	0	0

This test result has been carried out after working for 20mins and break was taken after 20mins interval. Here the discomfort score has been given by range 0 to 5 where, 0 means – No Discomfort, 1- Minor Discomfort, 2- Mild Discomfort, 3- Moderate Discomfort, 4- Major Discomfort and 5- Severe Discomfort. By using the Participative Ergonomics for Manual Tasks (PErforM) Handbook Worksafe QLD, the worker discomfort survey result has been generated.

4.6 Comparative performance evaluation of normal shovel and modified shovel

Analysing the performance of normal and modified shovels in soil lifting involves comprehensive assessment. Parameters include soil displacement per scoop, lift time for a given volume, and ergonomic factors affecting user fatigue, assess the effectiveness and potential improvements of shovel designs for various applications. For this observation ten workers was assigned and 100 kg of soil was lifted by normal and modified shovel from a fix distance 3 feet, various parameters like soil lifting time, heart rate, oxygen saturation and body temperature was observed.

Table 4.4: Comparing Performance evaluation of normal shovel and modified shovel

S. no	**Tool used**	**Soil lifting time (sec)**	**Pulse oximeter reading (Bpm)**		**Oxygen saturation level (%)**		**Body Temperature (ºF)**	
			Before work	**After work**	**Before work**	**After work**	**Before work**	**After work**
1.	**Normal shovel**	105	71	88	98	94	97.6	98.5
2.	**Modified shovel**	82	72	79	98.1	95	97.6	98

The above table reference are taken from Chapter 3 of this thesis Table 3.2, here in this table average results are mentioned, below bar graph shows

(A) Normal and modified shovel soil handling time (Mass lifted 100 kg)

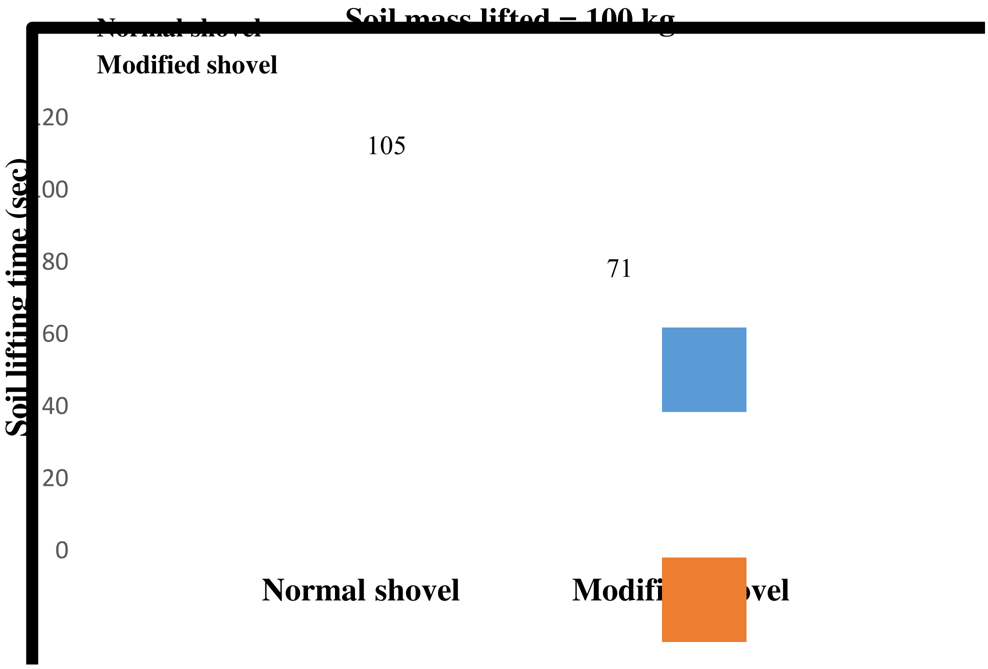


Fig 4.11: Soil lifting time for normal and modified shovel

(B) Effects on heart rate while lifting 100 kg soil from normal and modified shovel

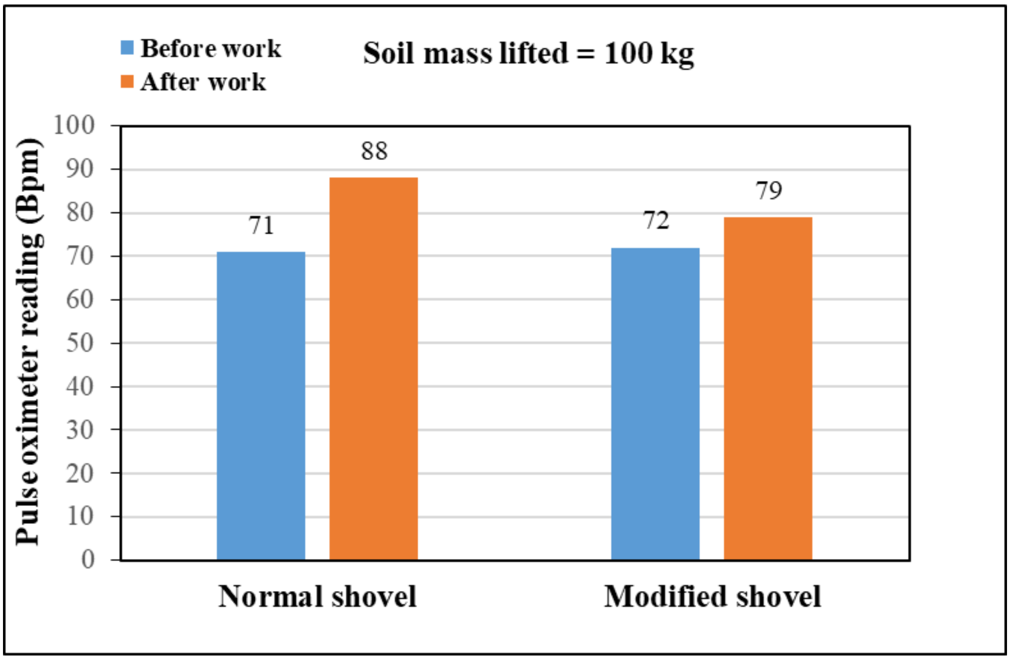


Fig 4.12: Heart rate by pulse oximeter of normal and modified shovel

(c.) Oxygen saturation level while lifting 100 kg soil form normal and modified shovel

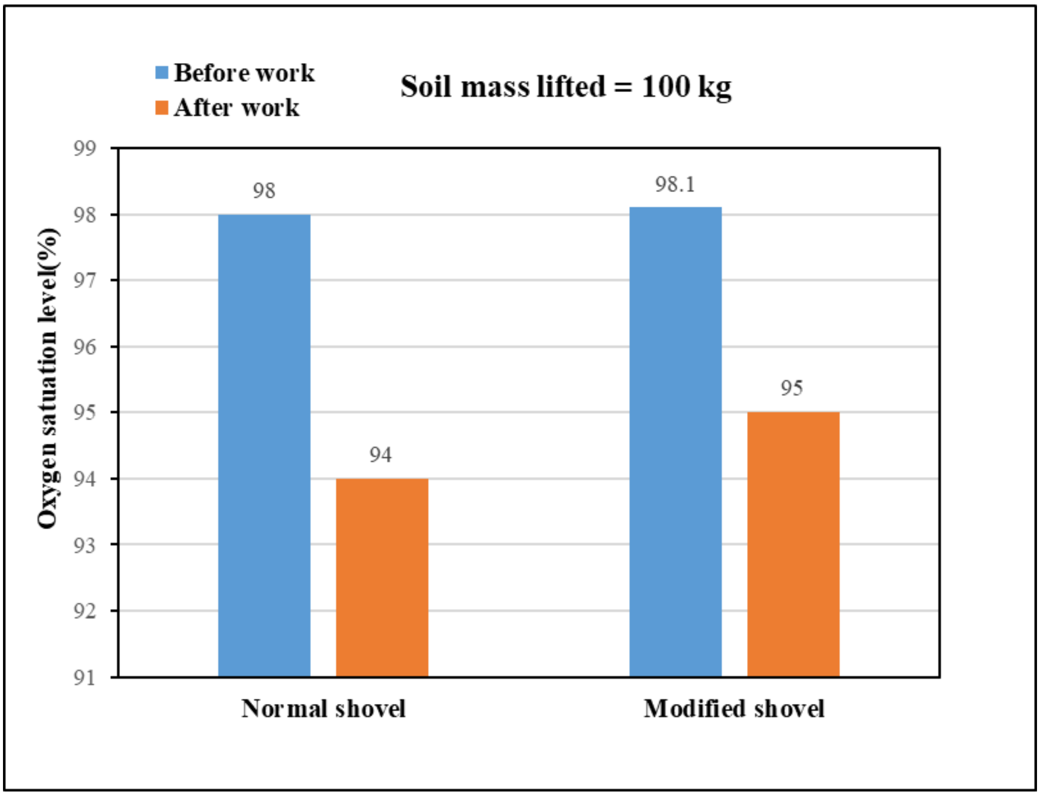


Fig 4.13: Oxygen saturation level for normal and modified shovel

(D) Effects on body temperature while lifitng 100 kg soil

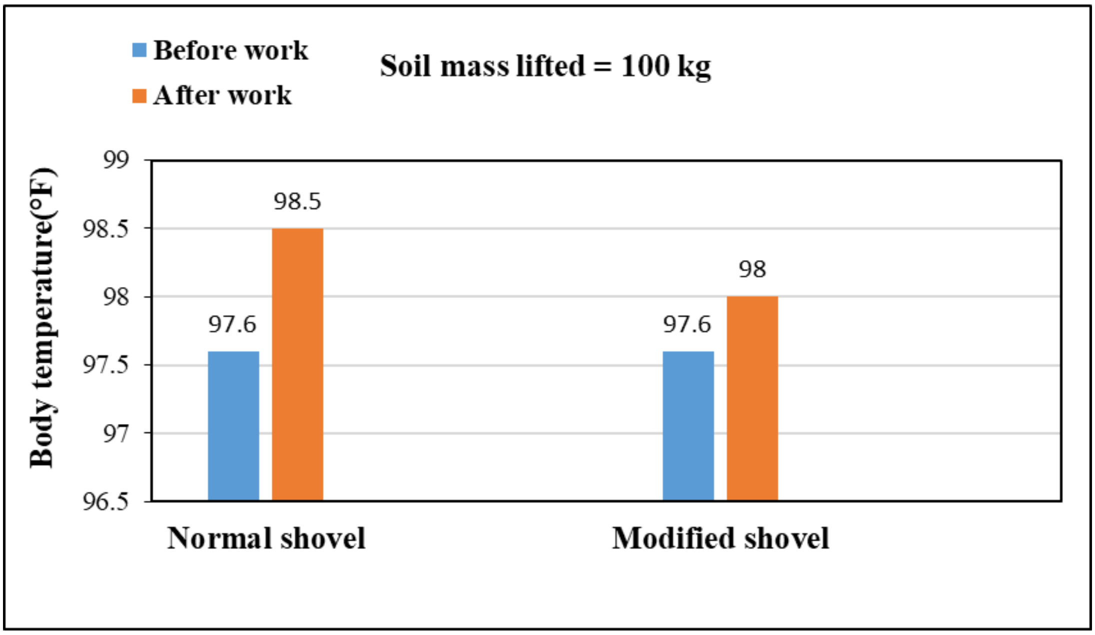


Fig 4.14: Body temperature before and after working with normal and modified shovel

Soil handling concluded that modified shovel is better in performance, the bar graph comparing the normal and modified shovel demonstrates a clear advantage of the modified shovel, Body temperature, oxygen saturation, pulse rate, and soil lifting time are all evaluated, and the modified shovel performs better than the normal shovel. The graph also indicates that workers can work more without much exertion Workers who used the modified shovel reported feeling less physically stressed, as indicated by their lower body temperatures and pulse rates. Collectively, these results show how the modified shovel is a better option than the standard shovel for enhancing worker efficiency and health.

CHAPTER - V

CONCLUSIONS

The below mentioned conclusion were taken out from research work carried out, the integration of modified shovel designs has significantly reduced worker exertion, A modified shovel aids in reducing musculoskeletal disorders by incorporating ergonomic features that minimize strain on the body. Its design promotes proper posture and distributes the workload more evenly, decreasing the risk of injuries such as strains, sprains, and a MSD repetitive motion disorders, resulting in a safer and healthier work environment as evidenced by decreased heart rates during labour-intensive tasks, and by this advancement underscores the importance of ergonomic innovations in enhancing productivity efficiency and worker well-being in various industries reliant on manual labour.

The key findings and results are:-

- It was concluded from the analysis of that in normal shovel after certain time of work heart rate increases gradually it goes till 115 bpm, whereas in modified shovel it remains under 104 bpm its shows that normal shovel gives exertions it requires more amount of energy.
- Overall-discomfort test was conducted for normal shovel and modified shovel, were average score as 3 for normal shovel and 2 for modified shovel, which shows that its better than old one.
- The body temperature of ten workers has been recorded by using digital thermometer while doing a task from normal shovel, and later by modified shovel it was concluded that body temperature while working with normal shovel goes 99.9 degree Fahrenheit(average) whereas by modified shovel is goes 99.2 degree Fahrenheit, which shows less exertion in modified shovel
- Firstly, the ergonomic design of the modified shovel significantly reduces strain and fatigue on the user, making it a more comfortable and sustainable tool for extended use. By minimizing the risk of repetitive strain injuries and muscle fatigue, it not only enhances productivity but also prioritizes the well-being of the user.
- Furthermore, the specialized features of the modified shovel, such as adjustable height, interchangeable blades, and multifunctional capabilities, make it a versatile tool suitable

for a wide range of tasks and environments. Whether used in gardening, construction, or outdoor exploration, its adaptability ensures optimal performance in diverse scenarios.

- Performance analysis for the modified shovel and the normal shovel was done. 100 kg of soil was lifted and moved to a 3-foot fixed distance; the modified shovel took 82 seconds, whereas the normal took 105 seconds; and the oxygen saturation level also dropped while working with the normal shovel, which shows the fatigue while working with the normal shovel.

SUGGESTIONS FOR FUTURE WORK

Through the results obtained for Analysis of soil lifting hand tool from CAE simulation using Ansys workbench, and from experimental performance using heart rate analysis and by overall-discomfort test are provided here, some suggestions can be recommended which will be useful for future work. The below-mentioned future scope of the work can be taken for consideration for modified shovel:

Future work on shovel design should focus on integrating advanced materials and technologies to further enhance performance and ergonomics. This could involve the utilization of lightweight yet durable composite materials for handles and blades, reducing strain on users while maintaining strength and durability. Additionally, the incorporation of sensor technology could enable real-time feedback on shovel usage, helping users optimize their technique and reduce the risk of injury.

Furthermore, there is potential for the development of smart shovels equipped with IoT (Internet of Things) capabilities, allowing for remote monitoring of shovel usage, maintenance alerts, and even predictive analytics to anticipate wear and tear. Collaboration with ergonomics experts and industrial designers could lead to the creation of customizable shovel designs tailored to individual user preferences and ergonomic requirements.

Moreover, research into automated or semi-automated shovel technologies could revolutionize labour-intensive tasks, increasing efficiency and reducing the physical strain on workers. Overall, future work should aim to continue improving shovel design to promote both productivity and worker well-being in various industries.

REFERENCES

Abbasi J. Wearable Digital Thermometer Improves Fever Detection. *JAMA*. 2017;318(6):510. doi:10.1001/jama.2017.10248

Amir Hosein Sakhaei, Sawako Kaijima, Tat Lin Lee, Ying Yi Tan, Martin L. Dunn, Design and investigation of a multi-material compliant ratchet-like mechanism, Mechanism and Machine Theory,Volume 121,2018,Pages 184-197,ISSN 0094-114X,

Burgess-Limerick, Robin, Joy, J., Cooke, T., & Horberry, T. (2012). EDEEP—An Innovative Process for Improving the Safety of Mining Equipment. Minerals, 2(4), 272–282.

Chang, S. R., Park, S., & Freivalds, A. (1999). Ergonomic evaluation of the effects of handle types on garden tools. International journal of industrial ergonomics, 24(1), 99-105.

Chen, H., and Ponter, A. R. S. (July 23, 2010). "A Direct Method on the Evaluation of Ratchet Limit." ASME. *J. Pressure Vessel Technol*. August 2010; 132(4): 041202.

Chu, X. H., Wang, J. F., Jiao, R. B., Wu, H. Y., & Zhou, L. F. (2013). Modal Analysis of Arrow Shaped Shovel Based on ANSYS Workbench. In Applied Mechanics and Materials (Vol. 385, pp. 296-299). Trans Tech Publications Ltd.

Degani, A., Asfour, S. S., Waly, S. M., & Koshy, J. G. (1993). A comparative study of two shovel designs. Applied Ergonomics, 24(5), 306-312.Rodahl, K. (1989). Physiology of Work. CRC Press.

DiMartino, A., Doné, K., Judkins, T., Morse, J., Melander, J., Oleynikov, D., & Hallbeck, M. S. (2004). Ergonomic Laparoscopic Tool Handle Design. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 48(12), 1354-1358.

Freivalds, A. (1986). The ergonomics of shovelling and shovel design—an experimental study. *Ergonomics*, *29*(1), 19–30. https://doi.org/10.1080/00140138608968237

Harivanam, S., Marklin, R. W., Papanek, P. E., &Cariapa, V. (2010). A Shovel With a Perforated Blade Reduces Energy Expenditure Required for Digging Wet Clay. Human factors, 52(4), 492-502.

Hasheminejad, N., Choobineh, A., Mostafavi, R., Tahernejad, S., & Rostami, M. (2021) Prevalence of musculoskeletal disorders, ergonomics risk assessment, and implementation hand tool improvement research for prevention of work-related problems: a review. International journal of occupational safety and ergonomics, 24(3), 347-357.

Hezekiah Oluwole ADEYEMI, Adekunle Olorunlowo DAVID, Olasunkanmi Oriola AKINYEMI, Omobolaji Taofeek OPAFOLA, Ayoola Abiola BABALOLA, Sand shovelling and related injuries among sand mine workers in Nigeria, Scientific African, Volume 8, 2020, e00313,ISSN 2468-2276, https://doi.org/10.1016/j.sciaf.2020.e00313.

Jain, R., Sain, M. K., Meena, M. L., Dangayach, G. S., & Bhardwaj, A. K. (2018). Non-powered hand tool improvement research for prevention of work-related problems: a review. International journal of occupational safety and ergonomics, 24(3), 347-357.

James E Sinex, Pulse oximetry: Principles and limitations, The American Journal of Emergency Medicine, Volume 17, Issue 1,1999,Pages 59-66,ISSN 0735-6757

Khan, M. R., & Gupta, A. R. (2021). Design and Development of an Automated Hand Shovel. In Ergonomics for Improved Productivity (pp. 525-532). Springer, Singapore.

La Medicina del lavoro (2021) Prevalence of musculoskeletal disorders, ergonomics risk assessment and implementation of participatory ergonomics program for pistachio farm workers. La Medicina del lavoro, 112(4), 292.

Lanchester, C, Digital thermometer circuit for silicon diode sensors, Cryogenics, Volume 29, Issue 12,1989,Pages 1156-1159, ISSN 0011-2275,https://doi.org/10.1016/0011-2275(89)90294-4.ter.

Lim, C., Lee, K., Kim, K., Kim, H., Seo, M., Kim, S., & Chae, H. (2016). Development and assessment of shovel applying foothold. Journal of the Ergonomics Society of Korea, 35(2), 67-74.

Mohan T, Gajendran P, Barkath SS, Gopalakrishnan S. Design Analysis and Fabrication of Multi-Purpose Shovel. Annals of the Romanian Society for Cell Biology. 2021 May 25;25(6):4494-500.

Oleg V. Sharkov, Sergey I. Koryagin, Nikolay L. Velikanov, Forming the profile of cutting tools for manufacture of fine-module ratchet teeth, Materials Today: Proceedings,Volume 38, Part 4,2021,Pages 1437-1440,ISSN 2214-7853,

Onubogu UC, Wonodi W, West BA. Comparison of Temperature Readings, Infrared, Non-Contact Thermometer with Contact Digital Thermometer Readings in Children. West Afr J Med. 2021 Sep;38(9) 851-858. PMID: 34676741.

Oshanwers, 2024 (accessed on 12 march 2024) https://www.ccohs.ca/oshanswers /ergonomics /shovel.html

Park, S.-M., Kim, J.-Y., Ko, K.-E., Jang, I.-H., & Sim, K.-B. (2013, March 1). Real-Time Heart Rate Monitoring System based on Ring-Type Pulse Oximeter Sensor. *Journal of Electrical Engineering and Technology*. The Korean Institute of Electrical Engineers. Reference to physiological responses. J. Human Ergonomics 8: 11-21.

Rennie, A. R. (1977). Labour-intensive civil construction. Applied Ergonomics, 8(4), 229-233.

Safework, 2024(accessed on 23 march 2024) https://www.safework.nsw.gov.au/

Saxena, A., Bhardwaj, S., & Saxena, V. (2021). Ergonomics Study on the Handle Orientation of Shovel. In Ergonomics for Improved Productivity (pp. 705-711). Springer, Singapore.

Sutar N, M. Parihar, R. Ijare and K. Gowari, "Design and development of SMD based wearable pulse oximeter," *2016 International Conference on Communication and Signal Processing (ICCSP)*, Melmaruvathur, India, 2016, pp. 1812-1816, doi: 10.1109/ICCSP.2016.7754480

Tran, N., & Dao, T. (2020). Statics Analysis and Optimization Design for a Fixed-Guided Beam Flexure. *Journal of Advanced Engineering and Computation, 4*(2), 125-139.

Walker, Bone.k, K. T. Palmer, Musculoskeletal disorders in farmers and farm workers, *Occupational Medicine*, Volume 52, Issue 8, December 2002, Pages 441–450

Wang, Guojing & Wang, Weidong & Li, Kaiyuan & Liu, Hongyun. (2014). A digital thermometer with fast response and high precision. 504-510. 10.1109/BMEI.2014.7002827.

ABSTRACT

Shovels are fundamental tools utilized across various industries and domestic settings for excavation, lifting, and moving materials such as soil, sand, gravel, and snow. Their design has evolved over centuries to meet specific needs and challenges encountered in different applications. There are multiple challenges relating to a conventional shovel's shape, which is frequently used in construction and agriculture. Because it cannot be adjusted, laborers experience fatigue and strain while using it for long periods of time. Its rigid form lacks ergonomic components, which can lead to discomfort and even injuries—particularly to the back and shoulders.

In this thesis computer-aided design (CAD) model of the modified shovel including innovative features like ratchet mechanisms and height adjustment is been created. ANSYS Workbench is also been used for performing stress analysis in order to ensure its structural reliability and efficacy under diverse situations. This allowed possible for us to generate actual situations and spot any weak points, which made it easier to optimize the design for optimal longevity and dependability. In addition, pulse oximeters and digital thermometers are used to determine how well the shovel performed in real-life situations. During use, we were able to observe changes in temperature and physical responses, which provided us with important information on the ergonomics and comfort of the tool.

In this thesis modified shovel is made that reduces time consumption instantly and improves total yield. The current model is an adjustable shovel that allows the workers to simply change the angle of the shovel blades based on type of work or the soil condition and his or her height. The adjustable shovel is made up of a metal head, a shovel handle, and a moveable section with adjustable length, which moves to obtain the desired angle at the time of operation. These elements are used to create a versatile shovel that can travel to various angles due to the Ratchet locking mechanism. The goal of the this modified shovel is to provide a simple design shovel with rotating characteristics for multipurpose use.

ABSTRACT (HINDI)

खुदाई, उठाना, और सामग्री जैसे मिट्टी, रेत, बालू, और बर्फ को हटाने के लिए अलग-अलग उद्योगों और घरेलू सेटिंग्स में उपयोग किए जाने वाले शोवेल मौलिक उपकरण हैं। उनका डिज़ाइन युगों के लिए बदला है ताकि वे विभिन्न अनुप्रयोगों में पाए जाने वाले विशेष आवश्यकताओं और चुनौतियों को पूरा कर सकें। एक पारंपरिक शोवेल के आकार से संबंधित कई चुनौतियाँ हैं, जो निर्माण और कृषि में अक्सर प्रयोग किया जाता है। क्योंकि यह समायोजित नहीं किया जा सकता, श्रमिकों को इसका उपयोग लंबे समय तक करने के लिए थकान और तनाव का सामना करना पड़ता है। इसका कठोर रूप इर्गोनोमिक घटकों की कमी के कारण असहजता और यहां तक कि चोटों का कारण बन सकता है–विशेष रूप से पीठ और कंधों में।

इस थीसिस में संशोधित शोवेल का कंप्यूटर सहायित डिज़ाइन (CAD) मॉडल बनाया गया है, जिसमें रैचेट मेकेनिज़्म और ऊंचाई समायोजन जैसी नवाचारी विशेषताएँ शामिल हैं। इसके अलावा, स्ट्रेस विश्लेषण के लिए ANSYS वर्कबेंच का उपयोग किया गया है ताकि विभिन्न स्थितियों में इसकी संरचनात्मक विश्वसनीयता और प्रभावकारिता की सुनिश्चित की जा सके। यह हमें वास्तविक स्थितियों में वास्तविक स्थितियों को उत्पन्न करने और कमजोर बिंदुओं को पहचानने की संभावना दी, जिससे डिज़ाइन को आदर्श लंबाई और विश्वसनीयता के लिए संशोधित करना आसान हो गया। इसके अतिरिक्त, पल्स ऑक्सीमीटर और डिजिटल थर्मामीटर का उपयोग करके यह निर्धारित किया गया कि शोवेल वास्तविक जीवन की स्थितियों में कितना अच्छा काम करता है। उपयोग के दौरान, हमें तापमान और शारीरिक प्रतिक्रियाओं में परिवर्तन देखने की संभावना थी, जो हमें उपकरण की इर्गोनॉमिक्स और सुविधा के बारे में महत्वपूर्ण जानकारी प्रदान करते हैं।

इस थीसिस में संशोधित शोवेल बनाई गई है जो समय की खपत को तुरंत कम करती है और कुल उत्पाद को बेहतर बनाती है। वर्तमान मॉडल एक समायोज्य शोवेल है जो कर्मचारियों को सीधे शोवेल की ब्लेड का कोण परिवर्तित करने की सुविधा प्रदान करता है, जो काम के प्रकार या मिट्टी की स्थिति और उनकी ऊंचाई के आधार पर होता है। समायोज्य शोवेल एक धातु हेड, एक शोवेल हैंडल, और एक समायोजनीय लंबाई के साथ एक चलती भाग से बना है, जो संचालन के समय आवश्यक कोण प्राप्त करने के लिए चलता है। ये तत्व एक विविध शोवेल बनाने के लिए प्रयुक्त होते हैं जो रैचेट लॉकिंग मेकेनिज़्म के कारण विभिन्न कोणों में चल सकता है। इस संशोधित शोवेल का उद्देश्य मल्टीपर्पज उपयोग के लिए घुमावदार विशेषताओं वाले एक सरल डिज़ाइन शोवेल प्रदान करना है।

LIST OF PUBLICATION

1. Utkarsh Sharma, M. S. Khidiya, B. L. Salvi (2023). State-of-the-Art Developments in Soil Lifting Hand Tool : A Review, International Journal of Scientific Research in Science, Engineering and Technology, Volume me 10, Issue 3, ISSN : 2394-4099 doi https://doi.org/10.32628/IJSRSET23103111