KOFORIDUA TECHNICAL UNIVERSITY

FACULTY OF ENGINEERING
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DESIGN AND FABRICATION OF A BURNER FOR THE PROCESSING OF COW HIDE FOR 'WELE' PRODUCTION

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A PROJECT REPORT PRESENTED TO THE FACULTY OF ENGINEERING, DEPARTMENT OF MECHANICAL ENGINNERING, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING.

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CERTIFICATION

The underlisted students hereby declare that this project work is entirely original to us and that, to the best of our knowledge, it does not contain any work that has been published before by another person or that has been approved for the award of any other university diploma or degree, with the exception of instances where appropriate credit has been given in the text. As a result, we are accountable for any mistakes or other issues that may occur.

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ABSTRACT

The traditional means of processing 'wele' involves a very long and tiring procedure which ends up making the final produce unwholesome for human consumption due to the source of fuel used in singeing the cow hide. The purpose of this study was to design, build, and test a burner that would be used to remove fur from cow hides in order to produce "wele." The inadequacies of the existing techniques for singeing cow hides were examined, and design specifications that would address the issues identified were developed and applied in the creation of three unique burner concepts. Following the assessment of the concepts and selection of the optimal design, the machine was constructed and its functioning was assessed by subjecting it to three separate samples of tough cow skins at temperatures of 100°C, 200°C, and 350°C, at which point the stainless-steel press turned red-hot. It has been shown that, although it will affect the singeing time, singeing the hides at lower temperatures will provide the highest quality hide. Additionally, it was discovered that singeing at higher temperatures causes the hide to become less moist than at lower temperatures and, if improperly managed, can result in charring of the hide. It was determined that the device offered a quicker and safer way to singe cow skin for "wele" production without sacrificing the calibre of the meat being generated.

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

ABBREVIATIONS

US EPA	-	United States Environmental Protection Agency
USDA	-	United States Department of Agriculture
FEA	-	Finite Element Analysis
CAD	-	Computer Aided Design
pH	-	Potential of Hydrogen
L	-	Length
m_i	-	Initial mass
m_f	-	Final mass

SYMBOLS

kg	-	Kilogram
kgf	-	Kilogram force
N	-	Newton
m/s^2	-	Meter per second squared
mm	-	Millimetre
%	-	Percentage
s	-	Second
Ø	-	Diameter
V	-	Volts
A	-	Amps
µF	-	Micro Farad
Ω	-	Ohms

CHAPTER ONE

INTRODUCTION

1.1 Background

After the carcass is dressed, animal skins are primarily regarded as a byproduct of the meat processing business. Despite being viewed as byproducts in the meat processing sector, they are extremely important to the cosmetic, leather, and pharmaceutical industries (Mikkilineni, 2016). However, following additional processing, animal skins are regarded as edible in some regions of the world. Animal skins are used in soups and stews in West Africa, pig skins are used to make the popular snack known as pork rinds in the United States, and cow skin soup is used as a hangover remedy in Jamaica.

Processed cow hides, or "wele," are highly prized culinary ingredients that are frequently used to make a variety of meals in Ghana. It is especially well-liked when used to make soups and sauces since it gives the food preparations a distinctive flavor and texture. Health experts have expressed concerns about the way cow hide, or "wele," is prepared, but customers' acceptance of it hasn't really changed. Health experts claim that the preparation techniques for "wele" might not adhere to the highest standards of sanitation, posing possible health concerns (Friday A.C. et al, 2016). Spent engine oil, wood, abandoned electrical and electronic goods, vehicle tires, and various polystyrene polymers (plastic) are among the fuel sources used to burn the fur off of the hide.

Polyaromatic hydrocarbon dioxins and benzene may be present in hides that have been treated with firewood and discarded engine oil (Okiei et al., 2009). Some engine oil contains lead, a hazardous element that may poison the hides. Burning wood may leave behind dioxin residues that worsen skin conditions (US EPA, 1994). Styrene fumes are produced when plastics made of polystyrene are burned to smoke cow hides; these fumes can cause headaches and problems with the central nervous system.

1.2 Problem Statement

The traditional means of processing ‘wele’ requires the cow hide to undergo three (3) stages of burning under very high temperatures to completely remove the thick fur of the cow.

According to a report by Amfo-Otu et al. (2014), some abattoirs and butchers use worn-out lorry tires and discarded electronic devices as a source of fuel for burning the fur off of the cow hide. This practice contaminates the food with toxic chemicals, making it unwholesome for human consumption and also poses a health and environmental threat to the residents (Okiei et al., 2009).

An improved method of removing the fur from the cow hide involves the use wood as a source burning fuel in a clay molded furnace. Although this process minimizes the contamination involved in the process of making ‘wele’, it does not address the drudgery and risk of burns involved in the process. Hence the need for a system which requires less human effort in the process while maintaining the required quality of the end product.

1.3 Aim

To design and fabricate a burner for dehairing cow hide during the production of ‘wele’ for the meat processing industry.

1.4 Objectives

1) To design a burner for dehairing cow hide using Solidworks Software.
2) To simulate the effects of the forces applied during the operation of the machine.
3) To fabricate the burner for dehairing cow hides.

4) To test the burner and evaluate the quality of ‘wele’ produced after singeing.

1.5 Justification

The results of this study will serve as the basis on which a machine can be designed to automate the entire process of ‘wele’ production while maintaining minimum environmental pollution and drastically reducing the drudgery involved in the process.

1.6 Scope of Study

This study will focus on the design and fabrication of a machine that will only improve upon the singeing stage of ‘wele’ processing.

1.7 Outline of the Project Work

Chapter one discusses the background of the project, the problem statement, aim and objectives, justification and scope of the study. A review of papers and publications pertaining to the applications and singeing of animal skins can be found in Chapter 2. The methods that were used to accomplish the research's goals are described in Chapter 3. In the fourth chapter, the machine test findings are presented and thoroughly discussed. The fifth and final chapter closes things off by outlining the ramifications of the findings and offering helpful suggestions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Background

This chapter aims at providing insights into the key concept of this thesis. Firstly, it sheds light on some of the uses of various animal skins in the food processing and leather making industry. After that, the major methods used in dehairing animal hides will be described. Next, the hazards associated with the processing of cow hide into edible beef skin (wele) in terms of food safety, environmental safety and personal safety will be discussed. Finally, quality parameters of food such as the color, texture and moisture content will be reviewed.

2.2 Uses of Animal Skins

Animal skins have been adapted for use in many ways all over the world. In some countries, animal skins from pigs, cattle, goats, and chicken have been habituated for consumption as food products as it contains a significant quantity of vitamins and collagen. They are often used in the preparation of food to improve upon the taste, quality and nutritional value. Animal skins or hides can also be processed into leather which has a wide variety of uses in terms of human requirements. In the religious setting, animal hides are treated and used to make prayer mats especially among those in the Islamic religion. Some of these uses of animal skins are further elaborated below.

2.2.1 Making of Gelatin from Hides

Gelatin is a high molecular weight polypeptide or protein made from animal collagen, usually extracted from cow and pig skins and bones by alkaline or acidic extraction (Jamilah et al., 2002). It is commonly found in the production of capsules, cosmetics, ointments, and foods (**Figure 2.1**). Collagen is one of the major materials that cartilage, bone and skin are made of. Thus, taking gelatin might increase the production of collagen in the body (WebMD, n.d.).

In food production, gelatin is used as an ingredient to improve upon the consistency, uniformity and elasticity of food products (Benjakul et al., 2009). Large quantities of gelatin are accounted for in many food products like baked goods, desserts, ice cream, dairy products, and candies annually (Djagny et al., 2001). According to research by Haug et al. (2011), around 326,000 tons of gelatin were produced in the year 2007 only, of which 46% were from pig skin, 29.4% from raw hide, 23.1% from bones, and 1.5% from different parts. In spite of its nutritional value, the use of gelatin from warm blooded animals was banned in some countries due to the transmission of Mad Cow Disease (Bovine Spongiform Encephalopathy) and some religious reasons.

Figure 2.1: Applications of Gelatin [Source: (Alipal et al., 2021)]

2.2.2 Using Chicken Skin as an Alternate Source of Fat

One of the globally most popular meat products on the market is the chicken sausage (Barbut, 2016). It contains 20–35% fat, which goes a long way to improve the overall eating experience, i.e., texture, flavor and juiciness, of meat products (Cierach et al., 2009). Chicken skin contains 3% collagen (Cliche et al., 2003), where the smaller portions are integrated into meat emulsion or utilized as a wellspring of fat chiefly for soup preparation. Chicken skin is regularly utilized as a fat-reducing agent in meat items (Nath et al., 2016). It helps to improve the texture of hot dogs when used in its production as a source of fat (A. S. Babji et al., 1998).

2.2.3 Making Prayer Mat from Goat Skin

Members of the Islamic religion are well known for their consumption of goat and cow meat especially during their religious festivities. After these festivities, some tanners treat the hides and add modifications such as accessories and bleach in order to turn it into a prayer mat or rug as shown in **Figure 2.2**. They are sometimes also used as indoor decorations.

Figure 2.2: Prayer Mat Made from Goat Skin [Source: https://www.etsy.com/uk/listing/1204810058/nordic-goat-hide-fur-rug-scandinavian?ga_order=most_relevant&ga_search_type=all&ga_view_type=gallery&ga_search_query=southwest+reindeer&ref=sr_gallery-2-3&pro=1&frs=1&organic_search_click=1 (Accessed: 27/10/2023)]

2.2.4 Utilization of Pig Skin

Pig skin is popularly known for its use as a raw material for the production of gelatin and collagen which are used in food production, cosmetics and drugs (Nollet et al., 2011). In 2001, the Unites States Department of Agriculture (USDA) found that pork collagen can effectively reduce purge and increase the cooking yield of meat sausages. Pork rind, a popular snack in the United States, is produced from pig skins.

Hydrolyzed cow and pig skins have been observed to have a higher emulsification stability and binding capacity to fat and water than non-fat dry milk and are a preferred alternative (Satterlee et al., 1973). In a study by Osburn et al., (1997) to evaluate the pig skin connective tissue's water-binding capacity, the pig skin connective tissue is heated to 700°C, and the resulting gel was observed to have an increased water-binding power and hardness. In contrast, when the proportion of pig skin connective tissue gel used in bologna is 10% to 15%, the bologna's hardness decreased, and the juiciness increased.

2.2.5 The Leather Industry

The leather making industry is responsible for the conversion of animal skins and hides into physically and chemically stable materials to satisfy various human needs. In countries where animal hides and skins are not processed for consumption, they are tagged as by-products of the meat industry. These by-products of the meat industry are then treated and become raw materials for the leather making industry (Langmaier et al., 1999). Leather made from animal hides are used in crafting clothes and accessories like jackets, pants, bags, belts, wallets and shoes (**Figure 2.3**). The leather making industry has a bad reputation for the level of pollution that occurs during its manufacturing process because of high water consumption, organic waste and odour (Haile et al., 2018).

Figure 2.3: Items Crafted from Leather [Source: https://www.indiamart.com/proddetail/leather-products-16421689930.html (Accessed: 27/10/2023)]

2.3 Methods of Dehairing Hide

The process of separating fur from raw hides is known as dehairing. Dehairing is done by subjecting the animal skin to chemical and mechanical treatments. The various methods of dehairing cattle, i.e., Chemical Dehairing, Enzymatic Dehairing, Electrolysis Dehairing and Singeing are explained below.

2.3.1 Chemical Dehairing

Chemical dehairing is done by applying chemicals to the animal hide with varying time, temperature and pH levels. Examples of chemicals used in cattle dehairing are hydrogen sulphate (HSO_4^-), sodium sulphide (Na_2S), hydrogen peroxide (H_2O_2), organic sulphates and other depilatory substances. The process of dehairing cattle using Na_2S and H_2O_2 was proposed and patented by Bowling and Clayton (Bowling et al., 1992). This method of dehairing was developed with the intention of reducing the microflora of beef hide. As expected, large reduction rates were observed because of 10% sodium sulphide and the consequently high pH of the solution (Castillo et al., 1998).

A drumming procedure to get rid of hair off of animal skin by using sulphur compounds in the occupancy of alkali and alkaline metal hydroxides in the presence of air and alcohol was also explained and patented by (Eckert et al., 1979). The dehairing process undergoes the drumming of skins within the air in alcohol of 10 to 50 parts by weight with reference of 100 parts raw hide weight. The alcohol contains 1 to 2 parts by weight with reference of 100 parts weight of raw hide followed by 2 – 4 parts of α or β-Mercaptoalkanol (with 2 to 6 carbon atoms) by the reference of 100 parts of raw hide weight, of a soluble base or the basic earth metal hydroxide. The author attached an example procedure to dehair the salted beef hides. (See **Figure 2.4**).

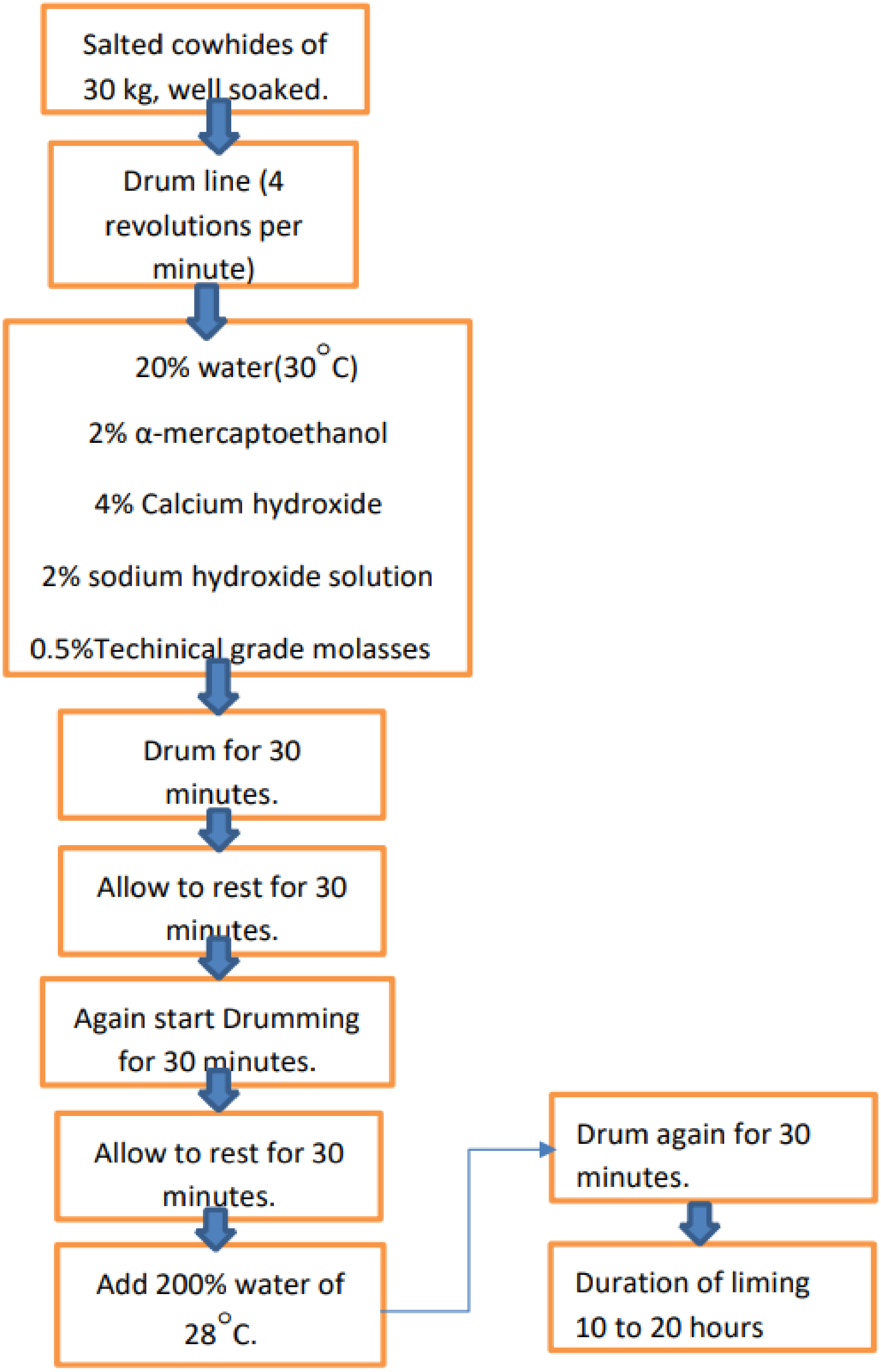


Figure 2.4: Flow Chart for Dehairing Salted Beef Hides Using Organic Sulphur Compounds.
[Source: (Mikkilineni, 2016)]

2.3.2 Enzymatic Dehairing

This is a method of dehairing hides using enzymes to break the bonds that hold the fur to the animal's skin without smashing it (Dutta et al., 1985). It is a preferred alternative to the chemical method of dehairing hides in the leather making industry since it produces far less environmental pollutants (Sundararajan et al., 2011). Some of the enzyme used to dehair hides are: the alkaline proteases produced from Bacillus Licheniformis RP1, grown on shrimp, the alkaline protease from Bacillus Cereus VITSN04, a serine alkaline protease from alkaliphilic Bacillus Altitudinis gvc11 and a mixture of proteolytic bacteria enzymes from Streptomyces Griseus.

2.3.3 Electrolysis Dehairing

In this process, wet hides which are untanned are introduced into an electrolytic solution (example: 1% NaOH, 30% Methanol), (3% LIOH, no alcohol) for about 10 minutes at a pH of 7 on the side with the fur, followed by allowing a direct current of (12V, 3A), (6V, 3 A) to pass through it by connecting the cathode (-ve) to the side with the hair and the anode (+ve) to the fleshy part of the hide. This loosens the hair follicles making it easy for the fur to be removed mechanically. (Whitmore et al., 1950).

2.3.4 Singeing

Singeing is a method of dehairing animal hides where the hide is placed directly on open flames to burn the fur off of the skin. It is the most popular method of dehairing favoured in most African countries as it prevents the cracking of the carcass hide and imbues the final meat product with flavours that are highly acceptable by the local populace (Obiri-Danso et al., 2008). Despite its popularity, singeing of hides have raised lots of discussions about the health implications on consumers because of the types of fuel used in burning the hide. Some local butchers use scrap lorry tires (**Figure 2.5** and **Figure 2.6**) and discarded electronic equipment found on refuse dumps as a source of fuel for singeing animal hides due to the scarcity of fire wood. Apart from the depreciation in muscle quality which could speed up post-mortem glycolysis (Carr, 1985), the source of fuel used evokes toxins into the animal hide and elevates the presence of heavy metal concentrations in the meat product, making it dangerous and unwholesome for human consumption (Obiri-Danso et al., 2008).

Figure 2.5: Singeing of Goat in Open Fire Fuelled with Scrap Tyres [Source: Friday A.C. et al, 2016]

Figure 2.6: Open Burning of Scrap Tyres for Singeing of Cattle Hides [Source: Woko et al., 2020]

2.4 Potential Hazards Associated with the Processing of Cow Hide into Edible Beef Skin (wele).

Hazards associated with the processing of cow hide into edible beef skin (wele) can be classified into three main groups: Food Safety, Personal Safety and Environmental Safety.

2.4.1 Food Safety

According to a study by Terrance M. Arthur et al. (2007), cow hide was found to be the main source of cross-contamination of the animal's carcass. Bacteria in hides migrate to underlying sterile tissues of the carcass during the removal process of the hide. The most prominent microorganisms which reside in the alimentary canal of cattle and are present in the feces are E. Coli O157, Salmonella spp., Listeria spp. and Campylobacter spp. (Chapman et al., 2001). In order to reduce the levels of contamination these microbes pose, slaughter houses have installed washing cabinets at vantage points in their slaughter lines and dressing lines (Delazari et al., 1998).

It is also worth noting that the outer surface of the hide has been exposed to dust, dirt and fecal material throughout the course of the animal's lifespan and would act as a primary source of contamination. This kind of contamination can be prevented by practicing proper washing, brushing, drying and application of preservatives. Poor sanitation practices and the failure of food preservatives increases the action of foodborne pathogens such as Salmonella spp. and E. Coli O157: H7 (Sofos et al., 1994).

Care should also be taken when selecting a method of dehairing the hide for the making of wele. Choice of chemicals and the source of fuel used in the dehairing process may end up making the hide toxic and unsafe for human consumption.

2.4.2 Environmental Safety

Because metals may be toxic in small concentrations, the potential risk of heavy metal contamination in meat is receiving more attention from the food safety and human health communities (Santhi et al., 2008). Cattle hides dehaired by means of the traditional singeing method are exposed to toxic organic compounds like dioxins and benzene (dada et al., 2018). There is also possibility of contamination by heavy metals and smoke depending on the source of fuel burnt for singeing (Ekenma K et al., 2015). When the singed co hides are washed and scrapped, the wastewater becomes genotoxic and harmful to the environment by means of water pollution. The smoke from singeing and the release of hydrogen sulphide gas into the atmosphere during the chemical treatment of hides leads to air pollution (Dima W. Nazar et al., 2005). This is a very toxic gas with an irritating odour, which causes respiratory and paralysis problems in humans (Mwinyihija M et al., 2010).

2.4.3 Personal Safety

Study has shown that miners, firefighters and construction workers are more susceptible to sleeping disorders, muscular and skeletal disorders, heart diseases, traumatic diseases and injuries that may lead to death (Chen et al., 2007). It has been reported that employees who are directly involved in the hide singeing process at the abattoir develop eye and oculo-visual symptoms. Workers in slaughterhouses who are close to open flames and other heat sources may develop corneal diseases and crystalline lens clouding, which impairs their vision (Mikkilineni, 2016). Workers who are directly exposed to allergens on the slaughterhouse floors experience watery, itchy, and burning eyes (Wilson et al., 2008). In a study, Shikdar et al., (2003) reported that, due to poorly designed machines and poor work area spacing design (such as inappropriate heights), normal standing and sitting positions were impossible. Direct Managers receive complaints from the affected workers regarding back pain, upper body and neck pain, hand soreness, and fatigue (Mikkilineni, 2016).

2.5 Quality Parameters of Food

Quality parameters are factors used to rate food commodities as good or bad. Quality parameters may be assessed using the senses of the body or by using measuring instruments. Some quality parameters of food include color, texture and moisture content.

2.5.1 Color of Food

Color is a very essential factor used in the assessment of the quality of food products in the agriculture sector. It is the first indication of food freshness, desirability, ripeness and safety and is the primary consideration for customers when grocery shopping (McCaig et al., 2002). In many research fields, the instruments used to measure color quality are the colorimeter and spectrophotometer.

2.5.2 Texture of Food

Food texture describes the mechanical characteristics of food such as the brittleness, chewiness and gumminess (Szczesniak et al., 2002). There are five primary characteristics that researchers look out for when measuring the texture of food. These characteristics are hardness, cohesiveness, viscosity, elasticity, and adhesiveness. There are many instruments used to measure the mechanical characteristics of food. Examples are the dendrometer, texturometer, gelometer and tenderometer.

2.5.3 Moisture Content of Food

The moisture content of food is the most frequently measured quality parameter in the food industry. It plays a very important role in defining the microbial stability, food processing operations, quality of the food, legal and label requirements (Mikkilineni, 2016). The various methods used to analyze the moisture content of food products are the microwave oven method, conventional or forced draft oven method and the evaporation method.

Many concerns have been raised by health experts on the quality of ‘wele’ produced from the traditional means of using discarded electronics, car tires or wood as a source of fuel. Despite the warnings on the possible implications of consuming ‘wele’ produced from these processes, it’s popularity and purchase by consumers have not changed. In order to improve upon the method of production of the popular food ingredient, a machine which provides a much more healthier means of removing the fur off of the hide while reducing the drudgery involved will be designed, fabricated and evaluated.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Background

The materials and methods describe the steps taken to accomplish the report's goals. It includes information about the design requirements used in generating the concepts, the design concepts, the evaluation criteria and the decision matrix used to rank the different concepts. Additionally, it contains the final design's schematics, comprehensive descriptions of each machine component, the design parameters taken into account, specifics of the structural analysis performed on the final design model and information on the fabrication procedures used to create the machine.

3.2 Design Requirements

Four (4) major design requirements were considered in designing concepts that will best serve the purpose of a burner for dehairing cow hide in the process of making ‘wele’. These are the Environment, Safety, Ease of Maintenance and Ease of Operation.

3.2.1 Environment

Under the environmental requirement of the design, the parameter considered was the level of pollution, that is, how much environmental pollutants would be produced while using the machine to dehair cow hides.

3.2.2 Safety

For the safety requirement, the parameter considered by the researchers was protection from harm. This implies how much protection one is open to while using the machine to dehair cow hide. It can also be defined as the amount of danger associated with the operation of the machine.

3.2.3 Ease of Maintenance

The parameter that was considered under the ease of maintenance criterion was parts interchangeability. The easier it is to take the machine apart and replace parts when they are faulty, the easier it is to maintain the machine.

3.2.4 Ease of Operation

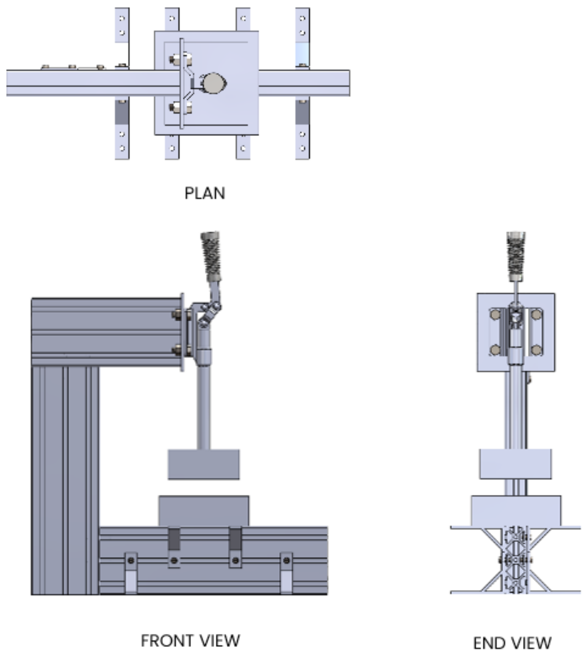
Ease of operation was associated with the operating time of the machine. It was a parameter considered to rate how fast it would be to use a model or concept to dehair one full cow hide.

3.3 Design Concepts

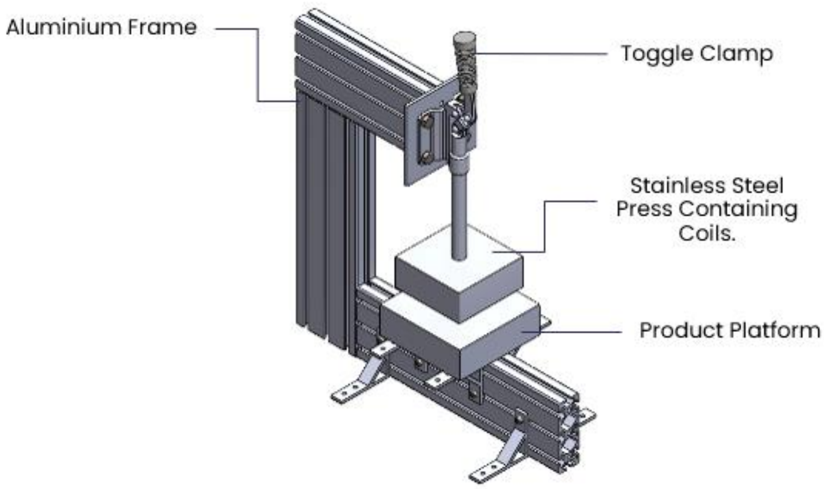
Three different burner designs were created and assessed in accordance with the design requirements specified by the researchers. The Hot Press was the name of Concept One, the Rotary Burner was Concept Two, and the Linear Burner was Concept Three.

3.3.1 Concept One – Hot Press

The first concept was called the Hot Press. It had a simpler design and mode of operation. **Figure 3.1** shows the orthographic projection of the Hot Press and its main parts.



(a) Orthographic Projection



(b) Parts of the Machine

Figure 3.1: Concept One - Hot Press

3.3.1.1 Working Principle

The turgid hide is cut into square pieces and placed on the product platform. When switched on, the stainless-steel press containing the coils become heated by means of induction heating. The toggle clamp is then pushed down to press the hot metal onto the cow hide on the product platform. After a few seconds, the clamp is released and the hide is removed and cleaned. The process is repeated until the required quality of singe is reached.

3.3.1.2 Advantages

a) The design contains very few parts making it simple and easy to fabricate.

b) It has a very easy mode of operation and can easily be disassembled by means of spanners and screwdrivers.

c) Very little smoke will be produced during the operation of the machine, hence, there is reduced environmental pollution.

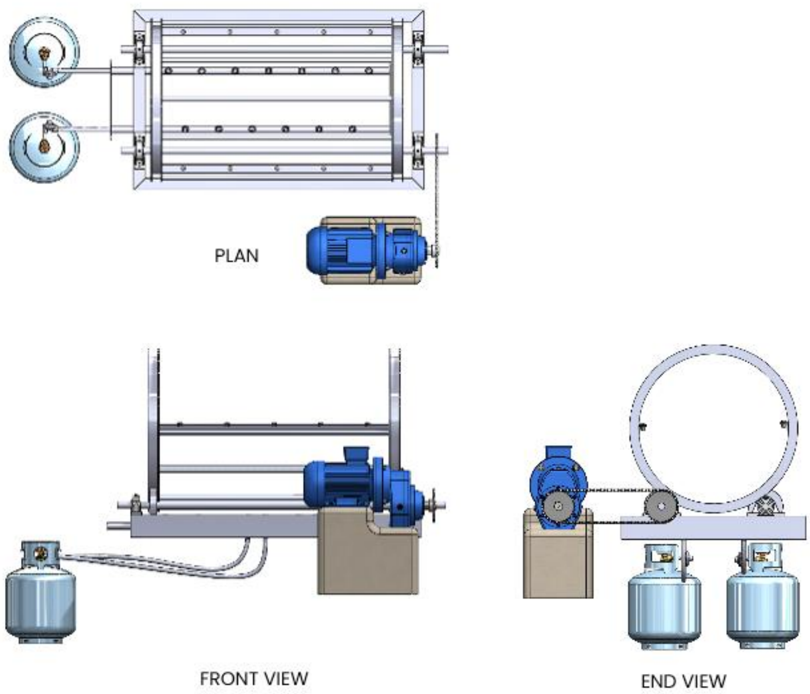
3.3.1.3 Disadvantages

a) The aluminium frame and toggle clamps are difficult to obtain.

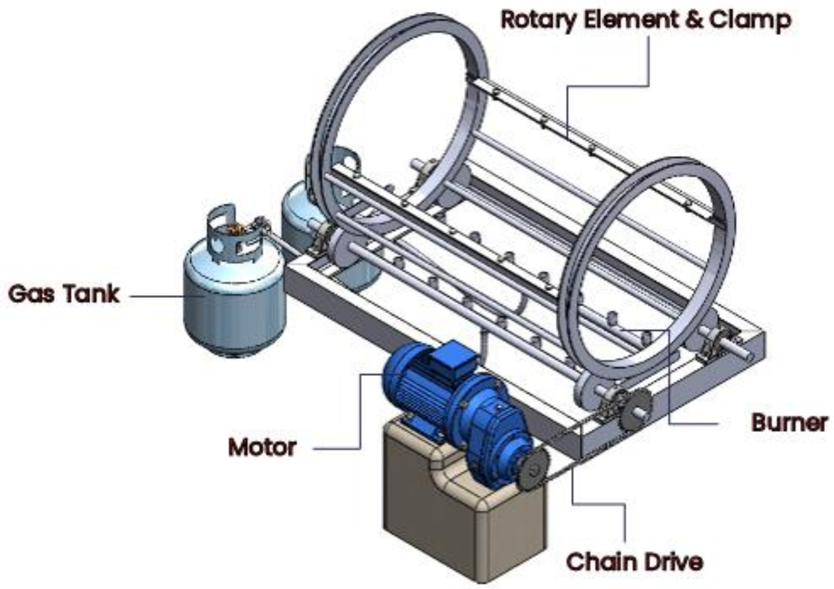
b) The machine can only accommodate and singe a small sample size of cow hide.

3.3.2 Concept Two – Rotary Burner

Concept two, dubbed the Rotary Burner had a more complex design and mode of operation as compared to the first concept as shown in **Figure 3.2**.



(a) Orthographic Projection



(b) Parts of the Machine

Figure 3.2: Concept Two – Rotary Burner

3.3.2.1 Working Principle

The turgid hide is passed through a roller to stretch it out and remove all the creases and folds that'll make removal of the fur difficult. The hide is folded around the rotary element, which is linked to a motor by means of a chain drive and clamped at both sides. The motor is switched on and the burner is lit fueled by propane gas. Singeing, which takes place as the hide swings above the open flames on the sensor controlled rotary element, is monitored. The hide is cleaned and inspected after a while. The process is repeated if the singeing is incomplete.

3.3.2.2 Advantages

a) The machine can be used to accommodate and singe a large sample size of cow hide.

b) All the parts required to produce the machine can easily be obtained on the market.

3.3.2.3 Disadvantages

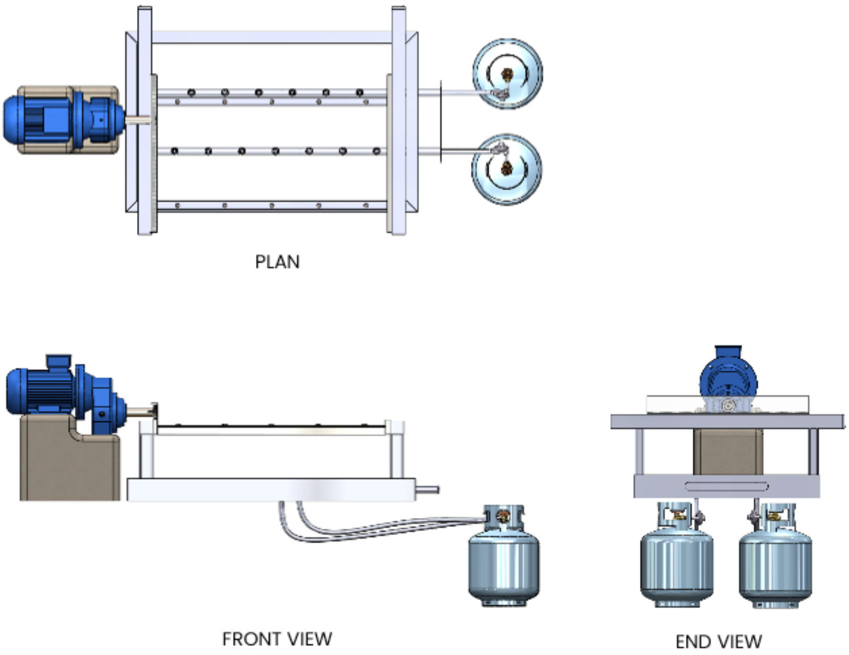
a) The design is expensive to produce owing to the number of parts required for production.

b) Using gas for singeing will produce dense smoke which will pollute the environment.

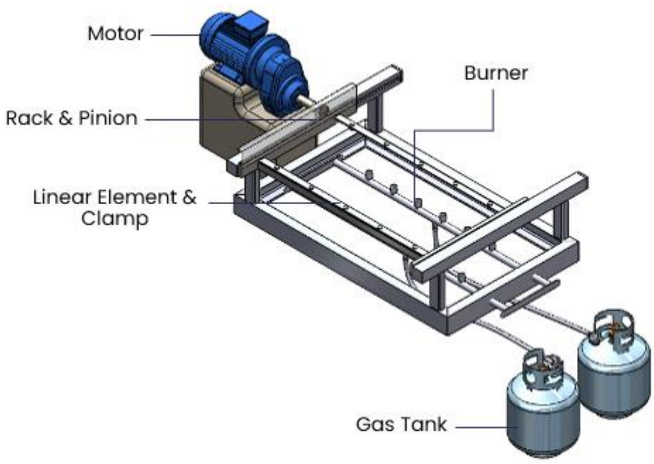
c) Fixing the hide on the machine will be a slow process, leading to an increase in the overall operation time.

3.3.3 Concept Three – Linear Burner

The third and final concept as shown in **Figure 3.3** was the linear burner. It had a slightly similar mode of operation to that of the second concept.



(a) Orthographic Projection



(b) Parts of the Machine

Figure 3.3: Concept Three – Linear Burner

3.3.3.1 Working Principle

The turgid hide is passed through the roller to stretch it out and remove all the creases and folds that will make removal of the fur difficult. The hide is stretched across the linear element, which is linked to a motor by means of a rack and pinion mechanism and held in place by the clamps. The motor is switched on and the burner is lit fueled by propane gas. Singeing, which takes place as the hide moves back and forth by the sensor controlled linear element above the open flames, is monitored. The hide is cleaned and inspected after a while. The process is repeated if the singeing is incomplete

3.3.3.2 Advantages

a) It is simple to find all the parts needed to make the machine on the market.

b) The machine is simple to use and does not require much expertise to operate.

3.3.3.3 Disadvantages

a) The machine will take longer to fix the hide, which will add time to the entire singeing operation.

b) It will be difficult to clean the hide during the singeing operation since one would have to offload the hide in order to reach the singed surface.

c) Gas singeing will produce dense smoke, which will contaminate the surrounding air.

3.4 Evaluation Criteria

Based on the design requirements, an evaluation criterion was developed for rating the concepts to determine which concept would best combine all the properties required of the burner. **Table 3.1** shows a summary of the evaluation criteria used to rate the three design concepts.

3.5 Decision Matrix

All the concepts were rated by means of the evaluation criteria and their corresponding values were recorded as shown in **Table 3.2**. Concept one scored the highest value of 4.2, followed by concept two which scored 2.7 and finally concept three with a score of

2.5. By unanimous decision, concept one, which scored the highest, was chosen as the final design. The design was run through the Solidworks FEA simulation to run stress and deformation tests and afterwards slated for fabrication.

Table 3.1: Evaluation Criteria Table

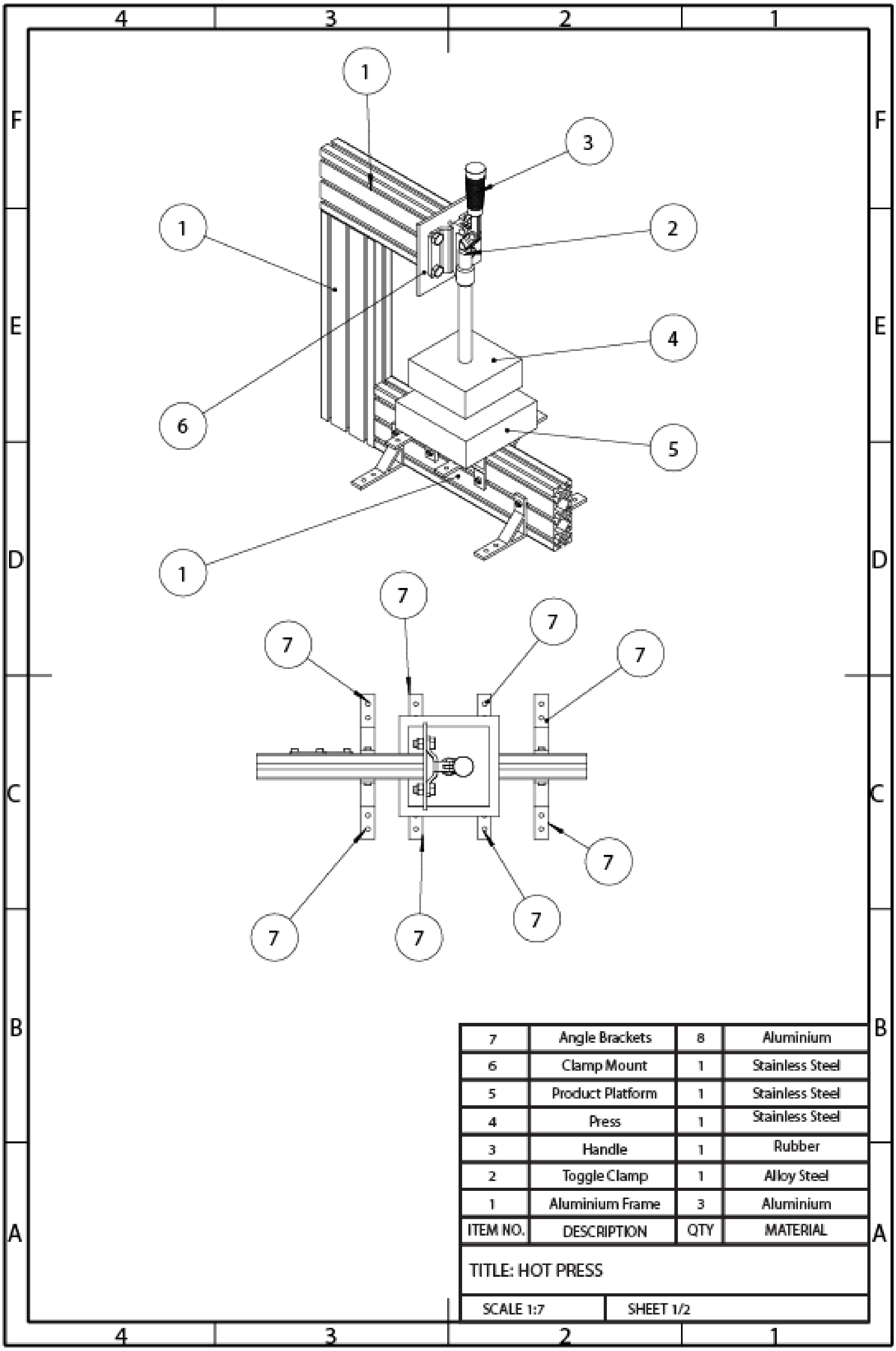
CRITERION	**ENVIRONMENT**		**SAFETY**		**EASE OF OPERATION**		**EASE OF MAINTENANCE**	
Weighted Value	0.50		0.20		0.20		0.10	
Parameters	Level of Pollution		Protection from Harm		Operating Time		Parts Interchangeability	
	Magnitude	**Score**	**Magnitude**	**Score**	**Magnitude**	**Score**	**Magnitude**	**Score**
	Very Low	5	Very High	5	Very Fast	5	Very Easy	5
	Low	4	High	4	Fast	4	Easy	4
	Average	3	Average	3	Average	3	Average	3
	High	2	Low	2	Slow	2	Difficult	2
	Very High	1	Very Low	1	Very Slow	1	Very Difficult	1

Table 3.2: Decision Matrix Table

CRITERION	WEIGHTED VALUE	PARAMETERS	CONCEPT ONE			CONCEPT TWO			CONVEPT THREE		
			MAG.	SCORE	VALUE	MAG.	SCORE	VALUE	MAG.	SCORE	VALUE
Environment	0.50	Level of Pollution	Low	4	2.00	Avg.	3	1.50	Avg.	3	1.50
Safety	0.20	Protection from Harm	High	4	0.80	Low	2	0.40	Low	2	0.40
Ease of Operation	0.20	Operating Time	Very Fast	5	1.00	Avg.	3	0.60	Slow	2	0.40
Ease of Maintenance	0.10	Parts Interchangeability	Easy	4	0.40	Difficult	2	0.20	Difficult	2	0.20
Total Score					**4.20**			**2.70**			**2.50**

3.6 Schematics of the Final Design

Figure 3.4 shows the parts list and materials of the design and assembly and **Figure 3.5** shows the detailed engineering drawings of the various parts of the design. These schematics guided the fabrication of the parts although some components were modified during the fabrication process. (All parts are in millimeters)



ITEM NO.	DESCRIPTION	QTY	MATERIAL
7	Angle Brackets	8	Aluminium
6	Clamp Mount	1	Stainless Steel
5	Product Platform	1	Stainless Steel
4	Press	1	Stainless Steel
3	Handle	1	Rubber
2	Toggle Clamp	1	Alloy Steel
1	Aluminium Frame	3	Aluminium

Figure 3.4: Engineering Drawing of the Final Design

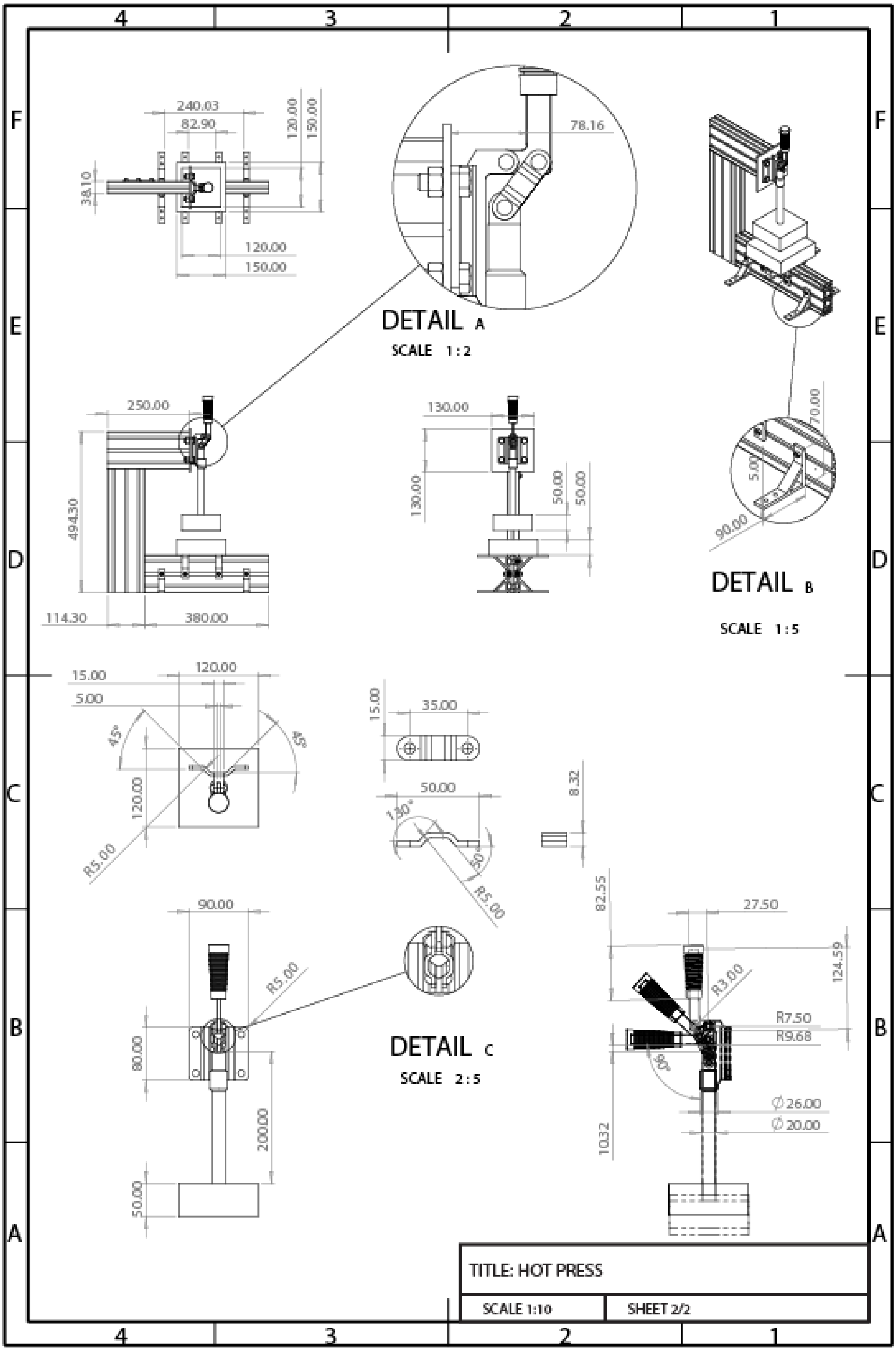


Figure 3.5: Engineering Drawing of the Individual Parts of the Final Design

3.7 Components of the Model and Materials Selection

The machine support, toggle clamp and the heating element constituted the three primary parts of the final design. Below is a list of each part's functions along with the materials that were used in its creation.

3.7.1 Machine Support

The machine support acts as the base of the design and holds the entire structure in place. It was designed with 114.3 x 38.1 mm aluminium frames, but due to the unavailability of the material as at the time of the fabrication, the aluminium frame was substituted with 80mm square pipes. The product platform was made by joining a 12mm thick stainless-steel plate with a 12mm thick mild steel plate. The toggle clamp mechanism was then mounted to the machine support via a 3mm mild steel plate.

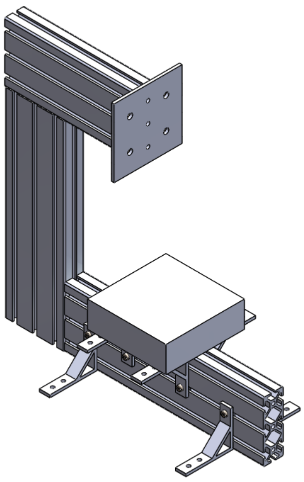


Figure 3.6: Machine Support

3.7.2 Toggle clamp

The toggle clamp houses the heating element and is used as the press for singing the hide when heated. Because the part was unavailable for purchase at the time of the fabrication, a piston mechanism with a lock was designed as a substitute for the press. The part was made using 30mm and 25mm diameter stainless steel pipes for the piston mechanism and 130mm square stainless-steel plates of 3mm thickness for the stamping base.

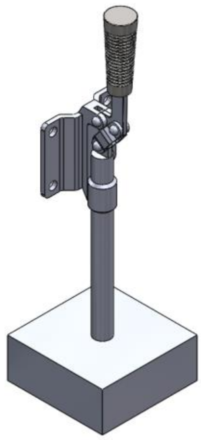


Figure 3.7: Toggle Clamp

3.7.3 Heating Element

The heating element is responsible for making the stamp hot enough for singeing the cow hide. It was made from a circuit containing 2 MOSFET Transistors, 2 diodes, 2 Zener diodes, 4 resistors, 2 toroidal coils of 55 turns each (1.5” swg 19), 4 non-polarized capacitors and a pancake induction coil of 11 turns made from 3mm copper wire. **Figure 3.8** shows the circuit diagram of the heating element with details on the specifications of all the various components used. The MOSFET Transistors were mounted on a heat sink to prevent them from getting damaged by the heat generated during their operation.

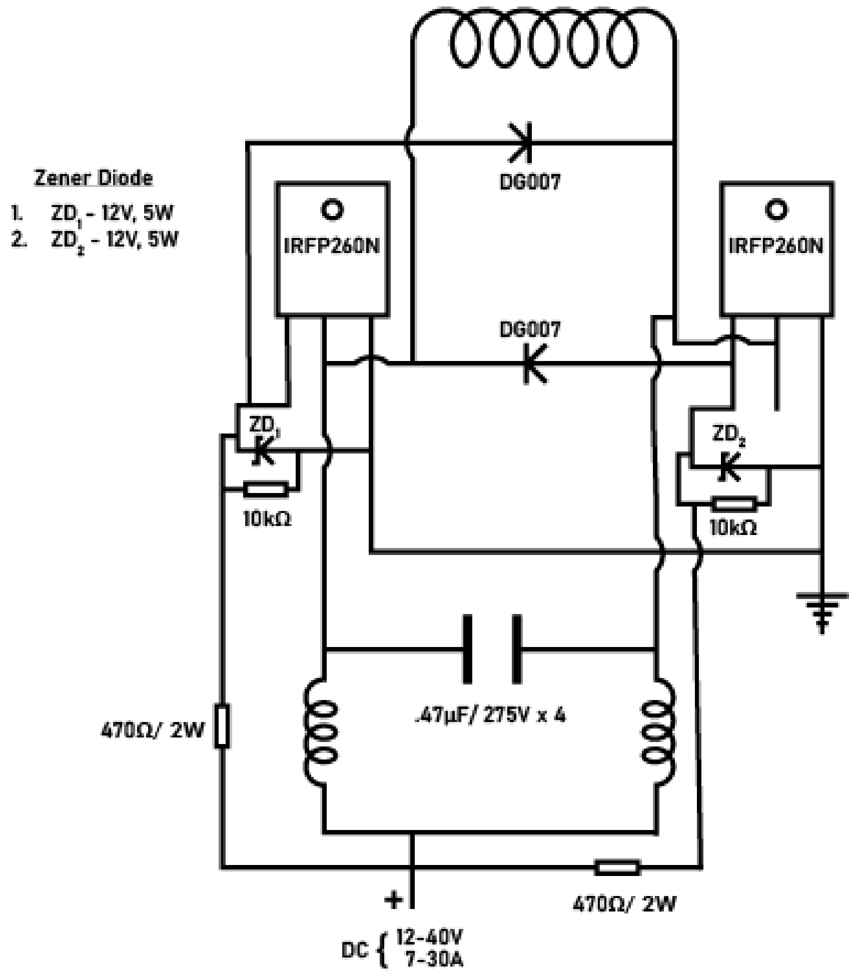


Figure 3.8: Circuit Diagram of Induction Heater

3.8 Structural Analysis of the Final Design

Finite Element Analysis (FEA) with SOLIDWORKS® SOFTWARE was used to perform structural analysis of the final design in order to evaluate the strength of the chosen materials for the various components subjected to loads during machine operation. These parts were the subject of a static analysis; the FEA simulation methods are described in more detail below.

3.8.1 Material Selection

Different materials were applied to different parts of the assembly for the simulation. The parts that made direct contact with the ingestible food commodity (the product platform and stamp) had stainless steel applied to them for food safety reasons. The aluminium frame and the brackets had aluminium applied to them and all other parts were specified as mild steel.

3.8.2 Connections (Interaction Between Parts)

In Solidworks Simulation, connections refer to how components that are in contact with each other through the use of a spring, bolt, pin, bearing, etc. interact. To avoid the simulation treating the product platform and the stamp on the toggle clamp as welded surfaces or elastic materials, a local interaction between them was described as surfaces in contact.

3.8.3 Fixtures

Fixtures explain the model's support system. A fixed geometry fixture was defined at the base of the Machine Support to hold the model in place for the loads that would be given to it in order to provide this effect to the simulation.

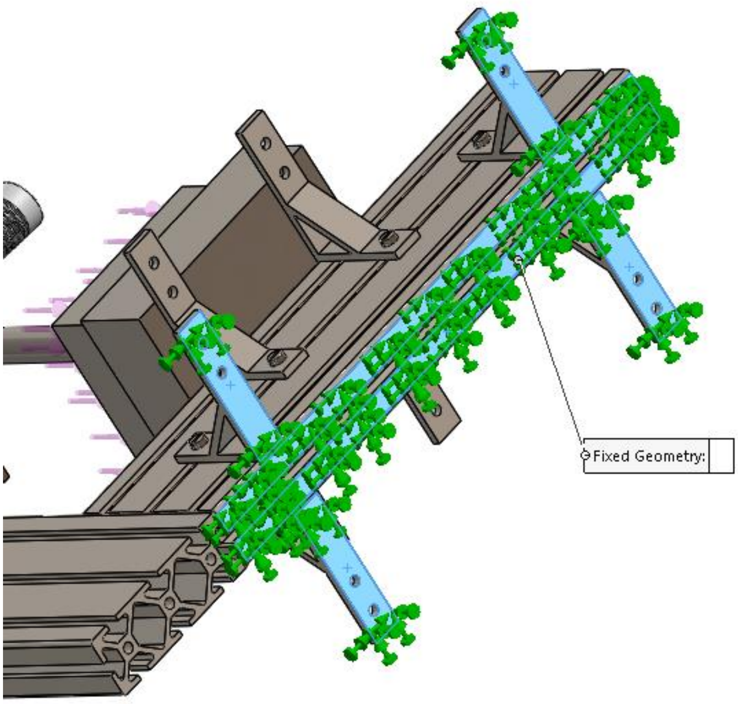


Figure 3.9: Fixtures Applied to the Model

3.8.4 External Loads

To mimic the interactions produced by outside entities or phenomena, loads are employed. In **Figure 3.10**, the loads applied to the assembly are denoted by purple arrows. When a mass force of 2kgf is applied to the stamp, the net force on the hot stamp will be 19.62 N (2 kg×9.81m/s^2). Using larger weights will cause the hide to burn more quickly, making it difficult to monitor.

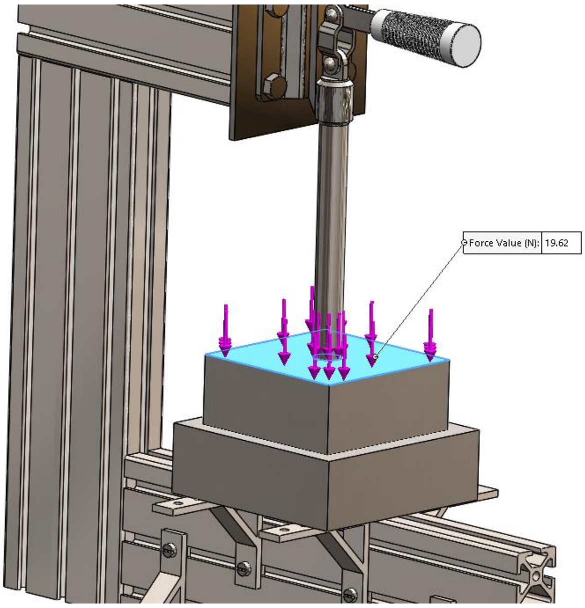


Figure 3.10: External Load Applied to the Model

3.8.5 Mesh

Meshing is the act of breaking down the CAD model into incredibly tiny components that are solved one at a time to assess the system's overall behavior. Another name for it is piecewise approximation. The specific mesh parameters utilized for the investigation are displayed in **Table 3.3**.

Table 3.3: Details of Mesh Applied to the Designed Model

Mesh Type	Solid Mesh
Mesher Used	Blended curvature-based mesh
Jacobian points for High quality mesh	16 points
Max Element Size	29.6397 mm
Min Element Size	1.48199 mm
Mesh quality	High
Total nodes	1605686
Total elements	964646

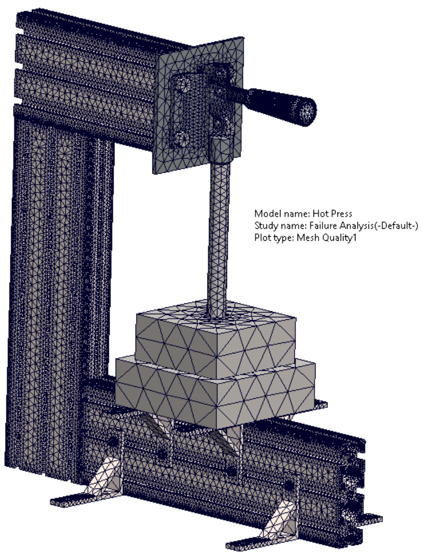


Figure 3.11: Mesh Applied to Model

3.9 Fabrication of the Mechanical Components

The machine was constructed and assembled at the Charay Engineering Company Limited in Tema. The following is a summary of the steps and processes that were involved in the process, which took one week to complete.

3.9.1 Machine Support

An 70mm square galvanized steel pipe was cut into 3 sizes of 250mm, 380mm and 495mm using a cutting machine and welded together to form the structure of the main support, by means of an arc welding machine, as shown in **Figure 3.12**. Three 70mm square mild steel plates of thickness 1.5mm were also cut and welded to seal the open ends of the square pipes with the exception of the point where the toggle clamp was mounted to the main support. A 150mm square piece of a mild steel plate having 3mm thickness was then cut and welded to seal the portion where the toggle clamp was to be attached to the main support. A stainless-steel plate of thickness 12mm was welded on top of a mild steel plate of thickness 12mm to form the product platform of dimensions 140mm square. Finally, 4 pieces of the 3mm mild steel plate were cut to dimensions 70mm ×60mm and welded to the base of the structure for support.

Table 3.4: Bill of Materials for Main Support

S.N.	Component	Material	Specification
1	Main Structure	Galvanized Steel Square Pipe (70mm × 70mm)	L = 1125mm
2	Pipe Covers	Mild Steel Plate (1.5mm)	250mm × 80mm
3	Toggle Clamp Mount & Base Support	Mild Steel Sheet Metal (3mm)	280mm × 150mm
4	Product Platform	Stainless-Steel Plate (12mm)	140mm × 140mm
5	Product Platform	Mild Steel Plate (12mm)	140mm × 140mm

Figure 3.12: Fabrication of the Machine Support

3.9.2 Toggle Clamp

The toggle clamp was made by cutting a stainless-steel pipe of diameters 30mm and 25mm into lengths of 220mm and 375mm respectively and welding them to form a T-shaped rod. Another stainless-steel pipe of diameter 30mm was cut to dimension 150mm, drilled at two points and the T-shaped rod was slotted into it. A 255mm × 45mm stainless-steel plate of thickness 5mm was bent to form a U channel and welded to the T-shaped rod. Two 130mm square stainless-steel plates of thickness 3mm were welded together with a space of 12mm, to form the stamp which houses the heating coils of the induction heater, and attached to the U channel protruding from the T-shaped rod.

Table 3.5: Bill of Materials for Toggle Clamp

S.N.	Component	Material	Specification
1	T-Shaped Rod	Stainless-Steel Pipe (Ø30)	L = 370mm
2	Slot mount	Stainless-Steel Pipe (Ø25)	L = 375mm
3	U Channel	Stainless steel plate (5mm)	255mm × 45mm
4	Stamp	Stainless-Steel Plate (3mm)	260mm × 130mm

Figure 3.13: Fabrication of the Stamping Base of the Toggle Clamp

3.9.3 Assembly of Parts

The toggle clamp was placed upright on the product platform and aligned. Afterwards, the larger diameter pipe around the toggle clamp was welded to the machine support at the allocated mounting point to form the piston mechanism. Two M12 nuts were welded to the holes drilled at the point of attachment to be used as locks for the toggle clamp after attaching M12 bolts to it.

3.10 Product Testing

After the final assembly, the machine was tested using three samples of raw hide measuring 80mm × 80mm. The samples were labelled A, B and C, soaked in water overnight to make them turgid and prevent burning during the test and weighed.

3.10.1 Instruments Used for Data Collection

The time taken to completely singe the hide was recorded using a stopwatch, the temperature used for the singeing was measured using an infrared thermometer and the mass of the hide was measured using a digital scale.

3.10.2 Types of Tests Performed

Two types of tests were carried out on the burner after the assembly of the machine: Induction Heating Test and Direct Heating Test.

3.10.2.1 Induction Heating Test

In the induction heating test, the induction heater was attached to the machine and used to heat the stamp for singeing the cow hide. As a result of the lack of the required power supply for the functioning of the machine, high temperatures required to singe the cow hide could not be reached. The stainless-steel press could only reach temperatures of about 50℃ which only lead to the drying of the wet hide instead of singeing. The results of this test were not used in the evaluation of the machine.

3.10.2.2 Direct Heating Test

This test involved the use of a blowtorch to manually heat the base of the stainless-steel press to a required temperature and using it to singe the cow hide. Sample A was singed at 100℃, Sample B was singed at 200℃ and Sample C was singed when the press was red hot at about 350℃. The time taken to singe each sample was recorded and the moisture content after the singeing was completed was calculated using the formular:

$$Percentage\ Moisture\ Content = \frac{m_i - m_f}{m_f} \times 100\%$$

$$Where\ m_i = Mass\ before\ singeing\ and\ m_f = mass\ after\ singeing.$$

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Background

This chapter discusses the results obtained from the tests carried out on the burner and also shows the relationship between the various test results.

4.2 Design of the Burner

Three concepts were generated for use as the burner for dehairing cow hides using Solidworks Software as shown in **Figure 3.1**, **Figure 3.2**, and **Figure 3.3** respectively. After evaluation of the concepts, concept one was chosen as the final designed and further developed for fabrication using detailed parts and schematic diagrams shown in **Figure 3.4** and **Figure 3.5**.

4.3 Simulation Results

Once all the parameters of the study are specified and the simulation is run, the software automatically calculates the effects of the applied load on the model based on the applied physics and study type. Graphical results of the stress, strain and deformation that the body undergoes is shown at the end of the simulation with records of their maximum and minimum values.

4.3.1 Static Nodal Stress

The maximum stress recorded within the assembly after the application of the loads during the simulation was 0.86Mpa. This indicates that the assembly will not fail under the operating force as the maximum stress recorded after the simulation was below the tensile yield strength of the aluminium applied to the model which was 276 MPa. **Figure 4.1** shows a contour plot of the stress in the assembly as its mode of deformation.

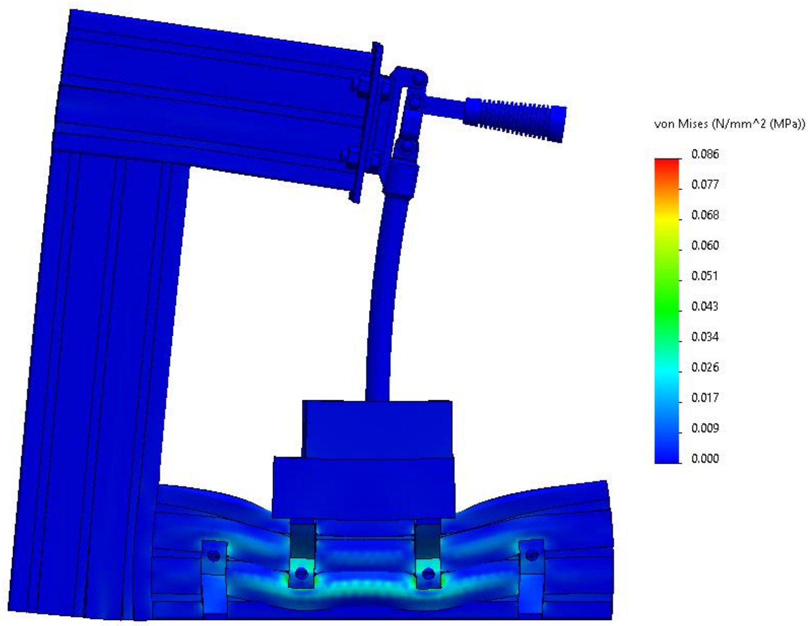


Figure 4.1: Contour Plot of Stresses in the Design Assembly

4.3.2 Static Strain

The maximum strain recorded as a result of the stress acting on the assembly during the simulation was $2.329{\times}10^{-19}$. The small size of the maximum is as a result of the load applied not being large enough to cause any form of deformation within the assembly

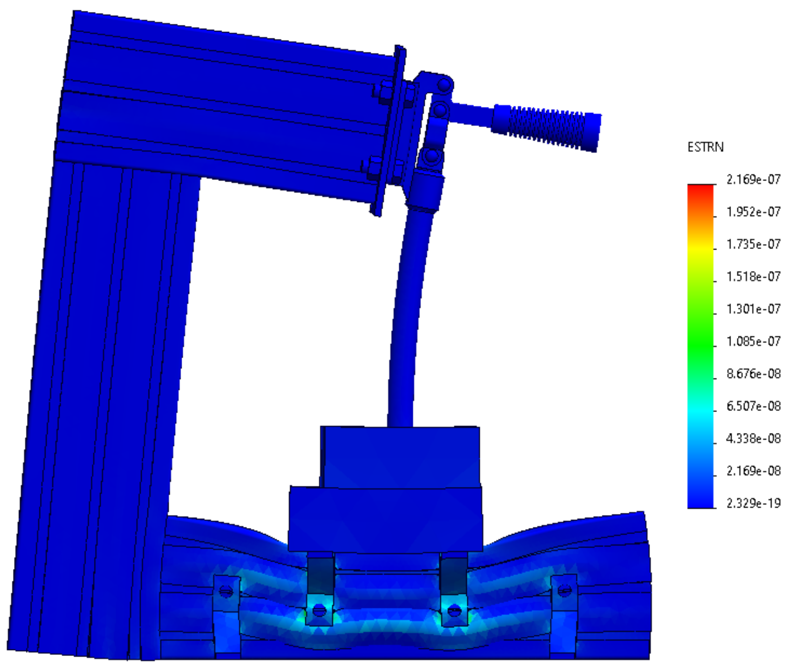


Figure 4.2: Contour Plot of Strain in the Design Assembly

4.3.3 Factor of Safety

The maximum factor of safety of the simulation had a maximum value of 2.705×10^3. The value of the factor of safety is as a result of the small nature of the applied force. As a result, the machine will be able to withstand the applied load over 2000 times.

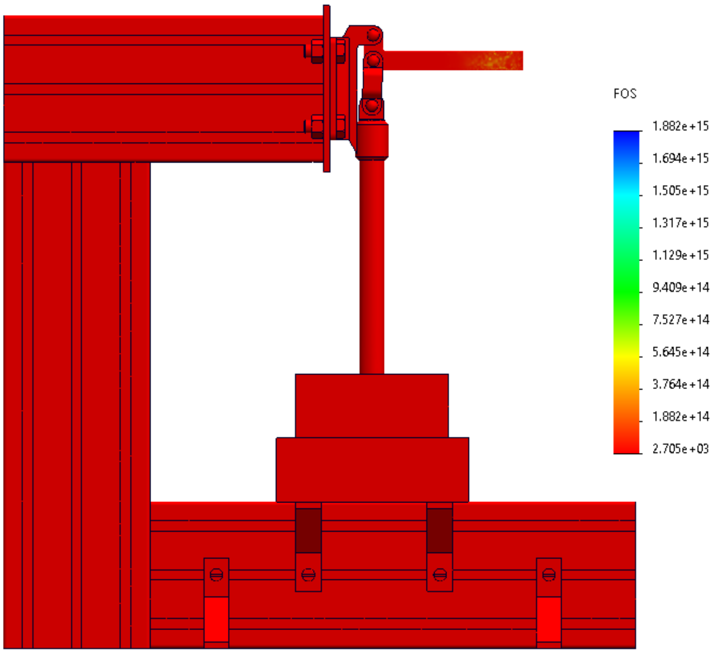


Figure 4.3: Contour Plot of The Factor of Safety of the Design Assembly

4.4 Final Assembly of Fabrication

Figure 4.4 shows the final assembly of the burner with the various parts labelled and **Figure 4.5** also shows the induction heating component designed for the machine. The burner was painted with black spray paint with the exception of the surfaces on the press and product platform which come in direct contact with the food commodity.

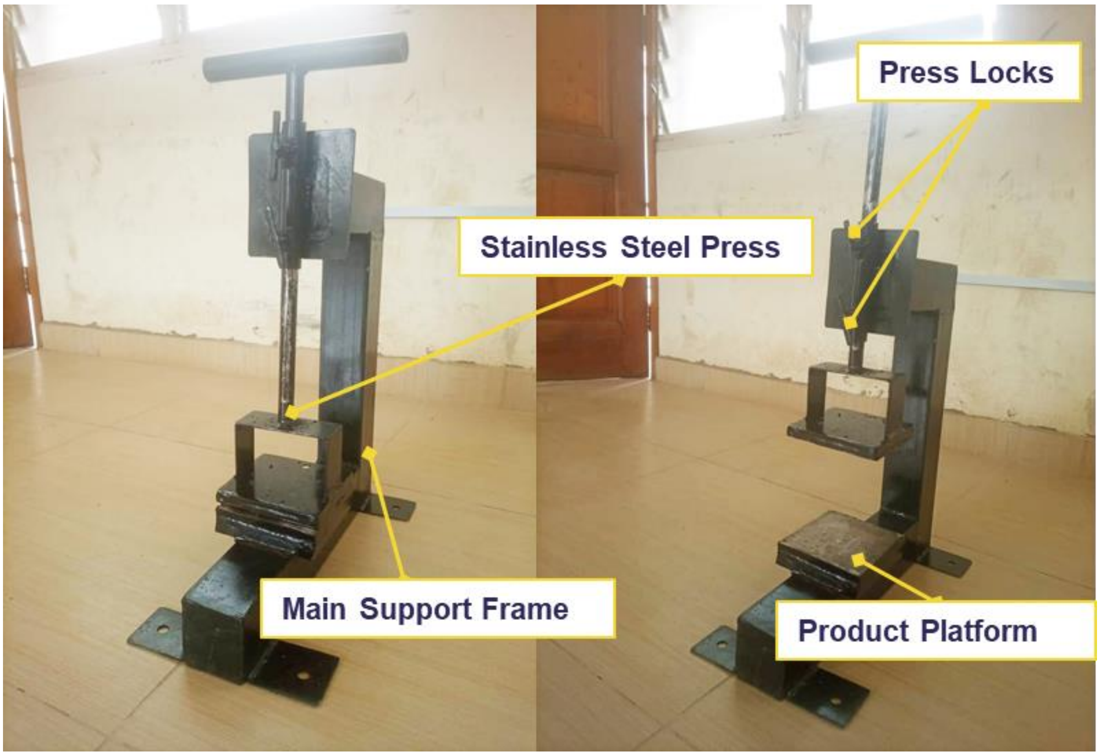


Figure 4.4: Final Assembly of All Components

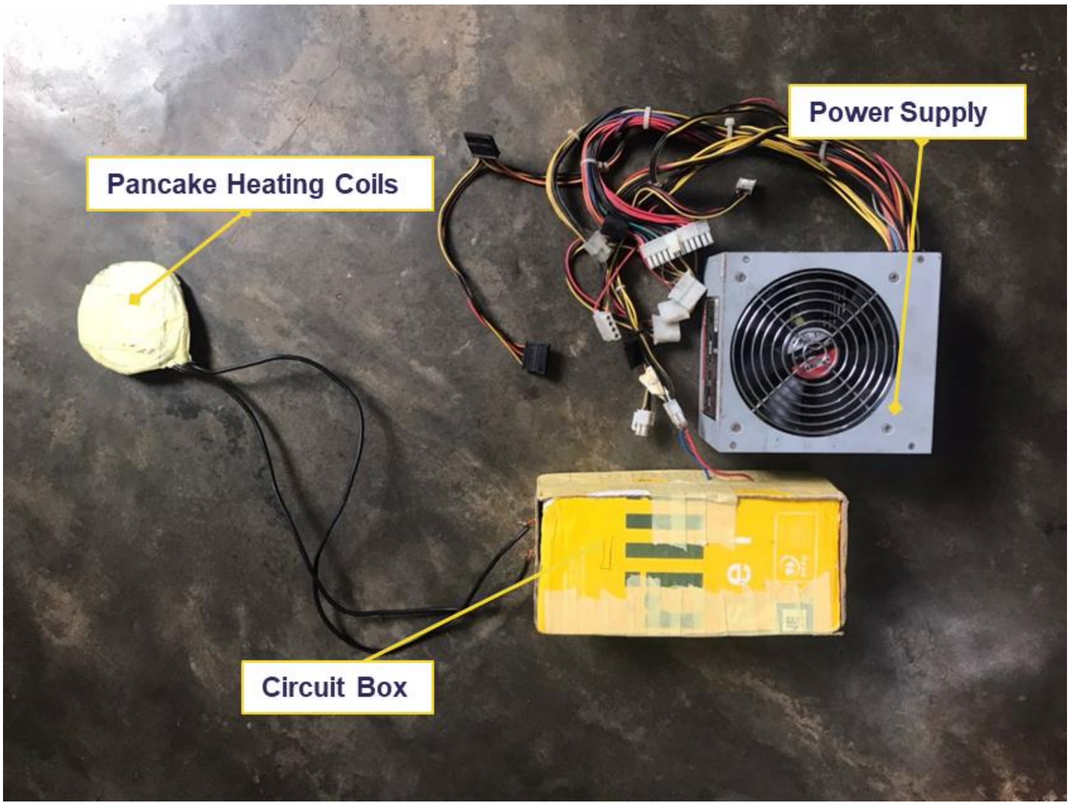


Figure 4.5: Induction Heating Component

4.5 Design Calculations

The magnitude of the compressive force required for the singeing operation given a mass of 2kgf is given by:

$$Compressive\ force = Mass \times Acceleration\ due\ to\ gravity$$

$$= m \times a$$

$$= 2kgf \times 9.81\, m/s^2$$

$$= 19.62N$$

The compressive stress induced in the machine resulting from the compressive force is given as:

$$Compressive\ Stresss = \frac{Compressive\ Force}{Cross\ Sectional\ Area(Product\ Platform)}$$

$$= \frac{19.62N}{(140 \times 10^{-3}m)^2}$$

$$= 1001.02Pa \approx 1kPa$$

4.6 Evaluation of the Machine

The results from the testing of the machine using three similar samples labelled A, B and C singed at different temperatures are shown below.

4.6.1 Sample A (Singeing at 100℃)

The initial weight of Sample A was 22 grams. The blow torch was used to directly heat the base of the stainless-steel press and when the temperature reached a 100℃, the press was used to stamp the cow hide for a few seconds and raised. A brush was used to clean the surface of the hide and the process was repeated until all the fur on the hide was removed. The total time elapsed between the singeing and cleaning of the hide with the brush was ninety seconds. The surface finish of the hide after singeing was golden brown as shown in **Figure 4.6** and the moisture content after singeing was 66%.

$$Percentage\ Moisture\ Content = \frac{22 - 13.25}{13.25} \times 100\%$$

$$= 66\%$$

Figure 4.6: Summary of Sample A Test Results

4.6.2 Sample B (Singeing at 200℃)

Sample B weighed 26 grams at the start of the test. The press was heated to 200℃ and used to singe the hide. After singeing, the hide was cleaned with a brush to remove ashes and pieces of burnt fur. The process was repeated until all the fur was off of the hide. The time taken to completely singe and clean Sample B was sixty-five seconds and the surface finish of the hide after the process was dark brown as shown in **Figure 4.7**. The moisture content in the hide after the test was approximately 60%.

$$Percentage\ Moisture\ Content = \frac{26 - 16.20}{16.20} \times 100\%$$

$$= 60\%$$

Figure 4.7: Summary of Sample B Test Results

4.6.3 Sample C (Singeing at 350℃)

The initial weight of Sample A was 25 grams. The blow torch was used to directly heat the base of the stainless-steel press until it was red hot at a temperature of about 350℃. The press was then used to stamp the hide for a few seconds and raised. A brush was used to clean the surface of the hide and the process was repeated until all the fur on the hide was removed. The total time taken to complete the singeing of Sample C was thirty seconds. The hide looked charred as shown in **Figure 4.8** and had a moisture content of 52%.

$$Percentage\ Moisture\ Content = \frac{25 - 16.40}{16.40} \times 100\%$$

$$= 52\%$$

Figure 4.8: Summary of Sample C Test Results

4.7 Relationship Between the Singeing Temperature and Time

The graph in **Figure 4.9** shows how the singeing temperature affects the time taken to completely singe the cow hide (including cleaning).

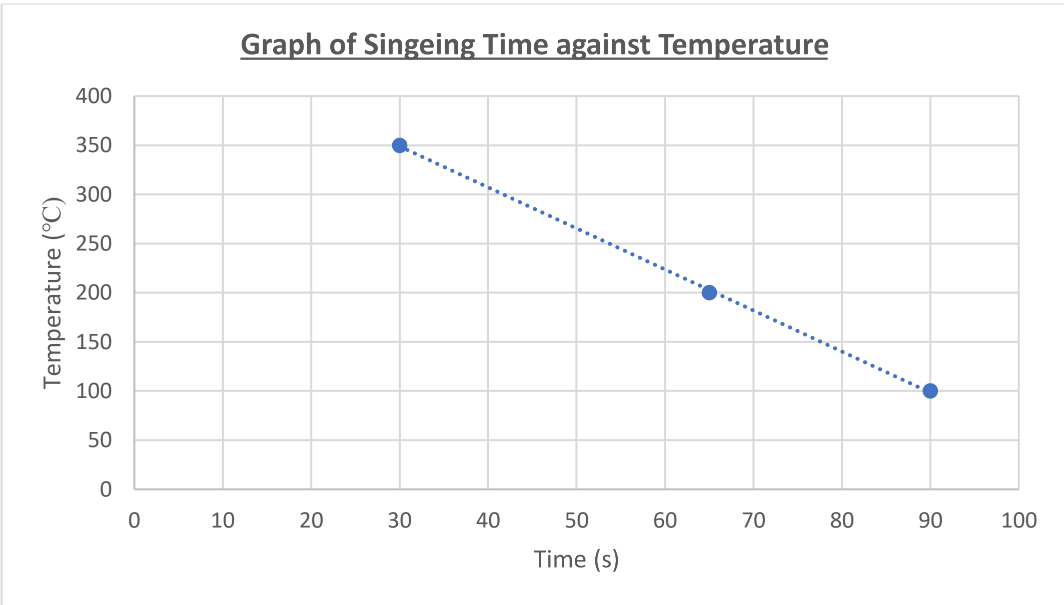


Figure 4.9: Relationship Between Temperature and Time

4.8 Discussion of Results

From the results of the testing, it can be deducted that, singeing the hide at lower temperatures yields the best quality of cow hide though the time taken to complete the operation is substantially increased as shown by the relationship between the temperature and time of singeing in **Figure 4.9**.

The moisture content remaining after the singeing operation is also lower at increased temperatures. When care is not taken, one might accidentally burn the hide and obtain an end product that is not wholesome for consumption.

The overall size of the hides we also observed to have shrunk and deformed after the application of heat to their surface. This however did not affect the integrity of the hide and could be rectified after soaking the singed hide in water before proceeding to the boiling stage of the 'wele' making process.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

- The burner for singeing cow hides for the production of 'wele' for use as a food commodity was designed using Solidworks Software as shown in **Figure 3.1**.
- Finite Element Analysis (FEA) simulations were carried out on the final assembly as shown in **Figure 4.1**, **Figure 4.2** and **Figure 4.3**. The maximum stress, strain and factor of safety obtained (0.86MPa, 2.329×10^{-19} and 2.705×10^{3} respectively) indicates that the model will be able to withstand the operating forces of the machine without failing.
- The burner was fabricated after undergoing some material and design changes due to the unavailability of some of the required materials as shown in **Figure 4.4**.
- Singeing the hide at higher temperatures reduces the time required to complete the operation but can lead to charring and reduced quality of the hide when not properly monitored.
- The moisture content of the hide after singeing is lowest at higher singeing temperatures where a temperature of 100℃ reduced it to 66%, 200℃ yielded 60% and the moisture content after singeing at 350℃ was 52%.

5.2 Recommendations

The following recommendations were proposed by the researchers to be considered for further look into the project:

1. A prototype which can accommodate a bigger sample size should de designed to compare its efficiency at singeing cow hides.
2. The induction heater should be supplied with the necessary power requirement and used to operate the machine to observe the overall time taken to heat the stainless-steel press and also singe the hide.

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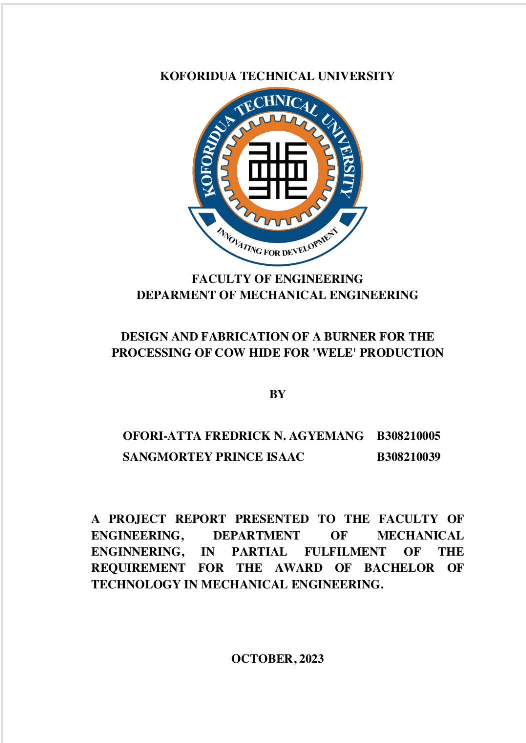

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DESIGN AND FABRICATION OF A BURNER FOR THE PROCESSING OF COW HIDE FOR 'WELE' PRODUCTION

BY

OFORI-ATTA FREDRICK N. AGYEMANG B308210005
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