DESIGN OF AN APPROPRIATE COMBINED SHEET METAL ROLL FORMING AND BENDING MACHINE FOR SMALL SCALE FABRICATION ENTERPRISES

BY

KAGGWA WILLIAM NAMUTALE

SUPERVISOR: KAKEBE SEKAJJA ROBERT

AN INDIVIDUAL PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING, TECHNOLOGY, APPLIED DESIGN, AND FINE ART OF KA BALE UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF MECHANICAL ENGINEERING OF KABALE UNIVERSITY.

JANUARY, 2021

b)

DECLARATION

I hereby declare that the work presented in this document is an account of my individual project carried out personally and has thus never been presented to any institution of higher learning for any academic award

Name and Signature **Date:** 05/02/2021

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KAGGWA WILLIAM NAMUTALE 16/

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APPROVAL

This individual project report has been submitted for examination with the approval of the following supervisor.

Name and Signature **Date**

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KAKEBE SEKAJJA ROBERT

(Kabale university)

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DEDICATION

This report is dedicated to God Almighty and my lovely parents, *Mr. Namutale Nakabale Dan* and *Mrs. amutale anyanzi Catherine* for all their efforts on me. May God reward them abundantly.

e)

ACKNOWLEDGMENT

I acknowledge the efforts of all my lecturers and supervisors especially ***Mr. Kakebe Sekajja Robert,*** for all the help that they provided in the pursuit and completion of this course.

More honors to my parents and friends for the motivation and encouragement they offer to me to ensure that am successful in my endeavors.

Furthermore, glory and honor to the almighty God for all he provides; the Grace, the gift of **life,** and putting in place the provisions that have helped push through this course.

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ABSTRACT

Sheet metal fabrication is an important element in the manufacturing and production in Uganda and worldwide today. Several processes such as bending and rollforming are used to change the shape or appearance, mechanical properties, and any other property of the sheet metal as required **for** use. To accomplish this, various machines such as bending machines, metal cutters, roller benders, and many others are used. These machines are huge, expensive, have a high-power requirement, can handle thicknesses of up to 6mm. For these reasons and more, small-scale fabrication workshops cannot buy and use them. This project intends to provide an appropriate option to these workshops instead of being charged expensively or rather send off the work to bigger workshops. To make the appropriate design, the required specifications were established, components were selected and then sized, and then a layout of the machine was generated using 3D modeling software (OS SOLJDWORKS). The design specifications were obtained from the flaws in the available designs and the market demands. With these, components that could serve ro fulfill these requirements were chosen and thereafter were sized using various formulas and mathematical constants as provided in this document. With these, all the components were then modeled in DS SOLIDWORKS and an assembly was also made. To conclude, implementing this project will give the target market an economized system, fitting within their very limited resources, that can be used to better their lives. The various sources of the data (references) given in this report are also provided at the end of the document.

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CHAPTER ONE

INTRODUCTION

_I Background

e Fabrication enterprise is a large and growing enterprise. There are many special purposes **machines** used in this enterprise today. The proper selection of the machines depends upon the type of work undertaken by the particular enterprise. Most of these enterprises use sheet metal for e fabrication of several parts and components therefore they purchase a lot of sheet metal processing machines.

Sheet metal is any metal whose thickness lies between 0.45mm (approx. 0.5mm) to 6.07mm approx. 6mm). Sheet metal is usually measured in mm, mils, gauges; where mm is the most commonly used and straightforward dimension for the thickness of the sheet metal. One mil equates to a thousand of an inch and a gauge refers to thickness in terms of weight per square foot[I]. There are many examples of Sheet Metalwork, which can be seen in our everyday lives. **In** manufacturing, success depends on efficiency. With costs rising, material utilization has become **an** important factor, that is, "scrap-reduction" in a way that most of the sheet material is used. Therefore, engineers optimize the design to ensure that the made parts can be accommodated within the standard sizes of sheet metals [2]

The metals generally used for Sheet Metalwork include black iron sheet, copper sheet, tin plate, aluminum plate, stainless sheet, and brass sheet [3]

Sheet metal forming processes are those in which force is applied to a piece of sheet metal to modify its geometry rather than remove any material. This applied force stresses the metal beyond its yield strength causing the material to plastically deform but not to fail. Bending is a metal forming process in which a force is applied to a piece of sheet metal, causing it to bend or fold at an angle and form the desired shape. This process causes deformation along one axis [2], [4]

Heavy-duty sheet metal rolling machines today cost about 14000USD (Over 52Million UShs) and the heavy-duty bending machines cost 22000USD (over 81Million UShs)[5] since they are so sophisticated, automatic and most of them are computerized. In addition to their expensiveness, they consume too much power, bulky therefore they consume a lot of floor space, and heavy maintenance and repair costs. Small scale fabrication workshops can't afford these and face a big

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Tinge in their endeavors to earn a living through fabrication, to a point where they push works

- xe they have no machines to perform tasks required by their customers.

t Problem Statement

heer metal bending in production is a top process in several small-scale fabrication workshops ts and requires bulky and expensive machines which can be afforded by the large-scale -~aon enterprise. A combined sheet metal rollforming and bending machine, designed articularly for the mentioned processes, would be of great help in increasing the jobs, work output, q!!aliry of products to the small-scale fabrication workshops owners with fewer funds to buy e heavy-duty" machines.

12 Objectives

1.2.1 General Objective

Te design an appropriate combined sheet metal roll forming and bending machine.

1.2.2 Speeifie Objectives

n) To determine the design specifications for the combined sheet metal roll forming and bending machine.

To select and size the components of the machine

e) To generate a layout of the machine.

1.3 Justification

Small-scale enterprises will keep losing out on some jobs especially those that require the bending processes and the power wastage will reoccur on even small jobs that wouldn't require operating me heavy machines.

1.4 Significance of the Research

Provision of an alternative for achieving the bending and rolling processes at a cheaper but reliable cost using this novel, increase in production especially in small and "just starting" workshops and o)

imsnes **since** there are quicker means of performing the production processes, and a reduction floor space occupied by several machines in the workshops (portability of the machine).

I

LITERATURE REVIEW

-- ... chapter gives information 011 the details about all the concepts and parameters related to the project. .... :::icepts about sheet metal, the sheet metal forming processes, the existing machines, the power sources r several sheet metal roll forming and bending machines, and forms of power transmission among ers.

LI. Sheet Metal

-..5 briefly discussed in the background, sheet metal is metal formed by running hot slabs of metal ..::ough a series of rough rolling stands that make them thinner and longer. To make the metal _ en thinner, these sheets go through finishing rolling stands and are then cooled and rolled into **oils.**

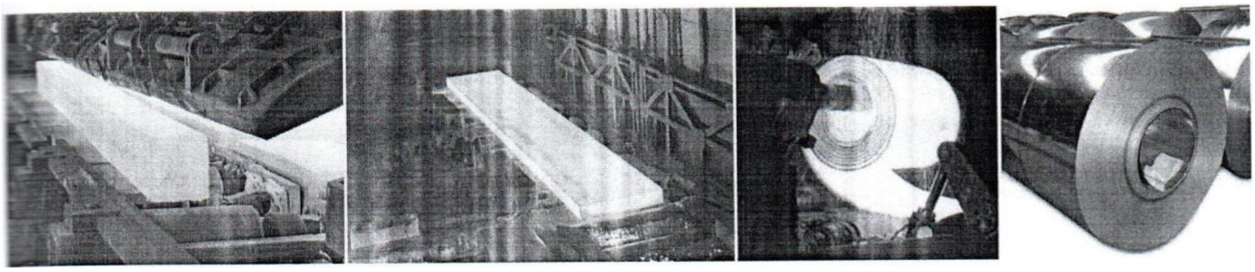

Figure 2.1. The rolling process for the sheet metal

Sheet metal is usually made from two materials, i.e. galvanized steel and stainless steel.[4] Sheet metal usually made through rolling has thicknesses ranging between 0.5mm to 6mm. Sheet metal usually has similm mechanical properties as the base metal from which it is made, that is to say, a sheet made from steel has the properties of that steel such as the durability and tensile strength. The figure below illustrates several sheet metal sizes. [6]

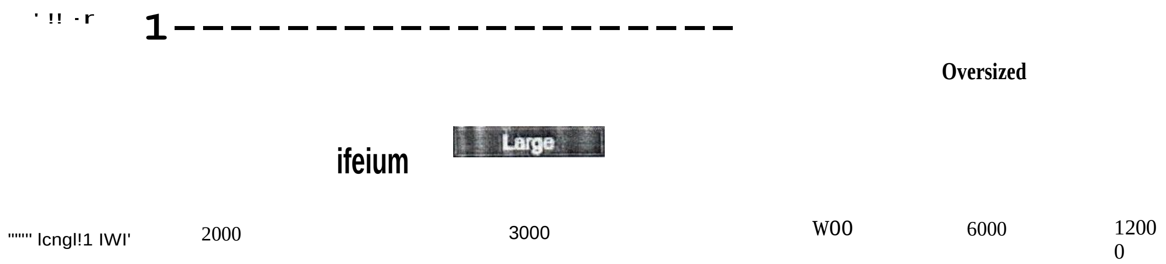

Figure 2.2 Sheet metal sizes

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~"'£":·"\metal is formed using two methods that is cold rolling and hot rolling. Cold rolling is used to i:C...!1 sheets up to 3mm, beyond this (from 3mm to 6mm), hot rolling is applied since it is cost-efficient.

:..:: Sheet Metal Forming

Sheet metal forming is a process where pieces of sheet metal are modified to their geometry rather **cm** removing any materials. The applied process generates a force that stresses the material "">.:yond the yield strength causing the material to plastically deform but not to fail.[8] This in turn **gives** the possibility to bend or stretch the sheet to a variety of complex shapes. Some of the processes include sheet metal bending. peen forming, drawing, extrusion, and many more. [4]

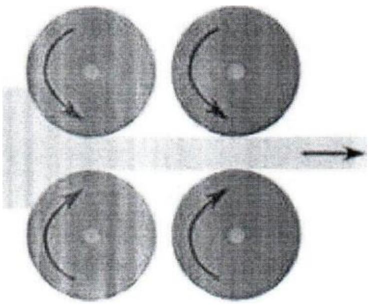

Figure 2.3 Rolling process for sheet meta/forming

2.3 Sheet Metal Bending:

Bending is a metal forming process in which a force is applied to a piece of sheet metal, causing it to bend at an angle and form the desired shape. A bending operation causes deformation along one axis, but a sequence of several different operations can be performed to create a complex part. Bent parts can be quite small, such as a bracket, or up to 20 feet in length, such as a large enclosure or chassis. [3]A bend can be characterized by several different parameters, shown in the image below.

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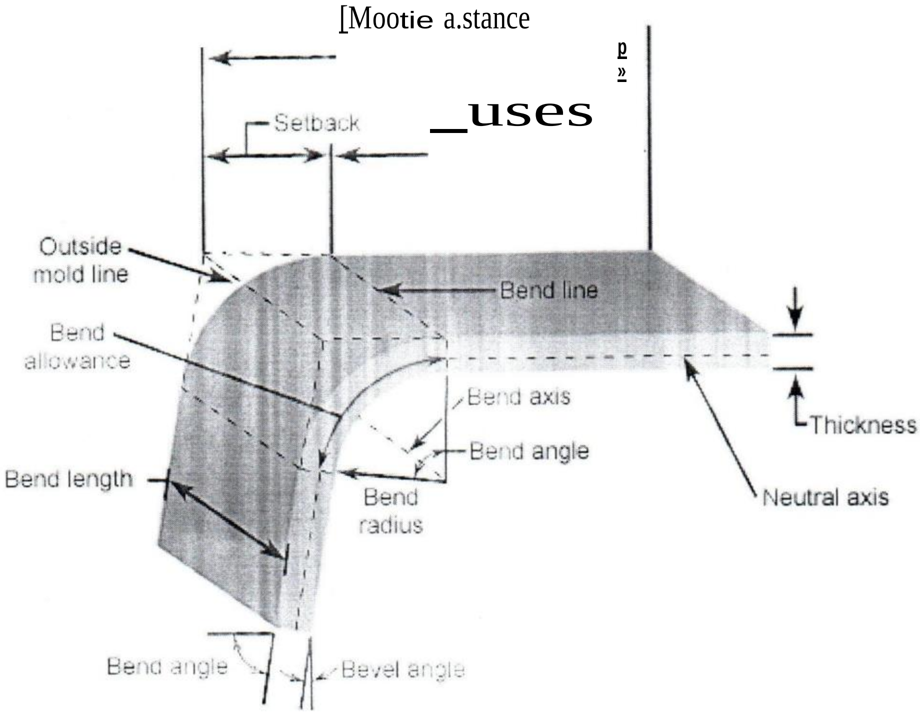

Figure 2.4 The bending diagram

The terms related to the above diagram are discussed below;

- *Bend line* - The straight line on the surface of the sheet, on either side of the bend, that defines the end of the level flange and the start of the bend.
- *Outside mold line* - The straight line where the outside surfaces of the two flanges would meet, were they to continue. This line defines the edge of a mold that would bound the bent sheet metal.
- *Flange length* - The length of either of the two flanges, extending from the edge of the sheet to the bend line.
- *Mold fine distance* - The distance from either end of the sheet to the outside mold line.
- *Setback* - The distance from either bend line to the outside mold line. Also equal to the difference bet ween the mold line distance and the flange length.
- *Bend axis* - The straight line that defines the center around which the sheet metal is bent.
- *Bend length* - The length of the bend, measured along the bend axis.

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ₑd radius - The distance from the bend axis to the inside surface of the material, between e bend lines. Sometimes specified as the inside bend radius. The outside bend radius is equal **me** inside bend radius plus the sheet thickness.

.. **Eknd** angle - The angle of the bend, measured between the bent flange and its original position, **or** as the included angle between perpendicular lines drawn from the bend lines.

.. *3r?> el angle* - The complementary angle to the bend angle.

__ ,:t of bending results in both tension and compression in the sheet metal. The outside portion -::::e sheet will undergo tension and stretch to a greater length, while the inside portion **a.p,eriences** compression and shortens. The neutral axis is the boundary line inside the sheet metal, **ziong** which no tension or compression forces are present. As a result, the length of this axis **emains** constant. The changes in length to the outside and inside surfaces can be related to the ;mal !lat length by two parameters, the bend allowance and bend deduction, which are defined **elow.**

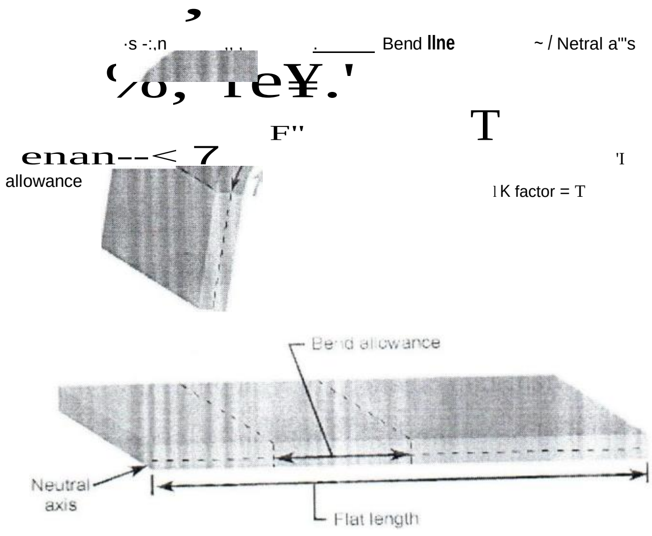

Figure 2.5The bending parameters

Below are the definitions for the above parameters.

- *Neutral axis:* The location in the sheet that is neither stretched nor compressed, and therefore remains at a constant length.

- *K-factor:* The location of the neutral axis in the material, calculated as the ratio of the distance of the neutral axis (measured from the inside bend surface) to the material thickness. The K-factor is dependent upon several factors (material, bending operation, bend angle, etc.) and is typically greater than 0.25, but cannot exceed 0.50.
- *Bend allowance:* The length of the neutral axis between the bend lines, or in other words, the arc length of the bend. The bend allowance added to the flange lengths is equal to the rota! flat length.
- *Bend deduction:* Also called the bend compensation, the amount a piece of material has been stretched by bending. The value equals the difference between the mold line lengths and the total flat length.

hen bending a piece of sheet metal, the residual stresses in the material will cause the sheet to ring-back slightly after the bending operation. Due to this elastic recovery, it is necessary to er-bend the sheet a precise amount to achieve the desired bend radius and bend angle. The final

end radius will be greater than initially formed and the final bend angle will be smaller. The ratio **fthe** final bend angle to the initial bend angle is defined as the spring-back factor, Ks. The amount f spring-back depends upon several factors. including the material, bending operation, and the **tial** bend angle and bend rc1dius.

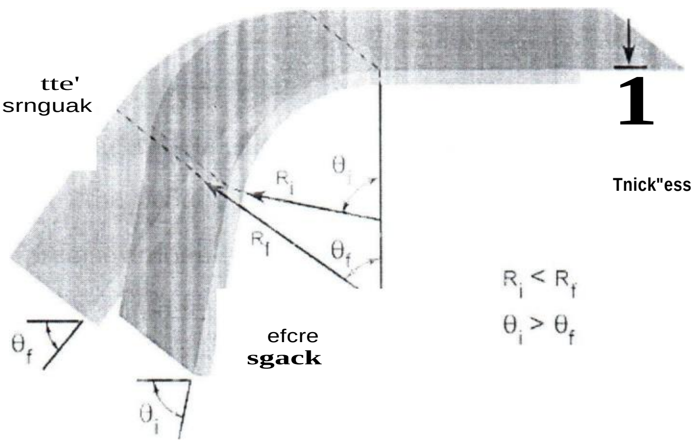

Figure 2• Spring-back

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-~ plastic deformation of the work over an axis, creating a change in the part's geometry.

Similar t o other metal forming processes, bending changes the shape of the workpiece, while the ne of material will remain the same. Sheet metal brakes are used to bend the material into a S desired geometry. Bends in the same plane should be designed in the same direction to avoid reorientation. which will save both money and time. Keeping a consistent bend radius will make parts more cost-effective.

metal roller bending is a process for making circular arc pieces or geometries.[9]

te: Small bends to large, thick parts tend to become inaccurate, so they should be avoided if ssible.

__ Sheet Metal Roll Forming

ol forming. sometimes spelled "rollforming", is a metal forming process in which sheet metal is ogressively shaped through a series of bending operations. The process is performed on a roll rming line in which the sheet metal stock is fed through a series of roll stations. Each station has _ rdler, referred to as a roller die, positioned on both sides of the sheet. The shape and size of the roller die may be unique to that station, or several identical roller dies may be used in different positions. The roller dies may be above and below the sheet, along the sides, at an angle, etc. As the sheet is forced through the roller dies in each roll station, it plastically deforms and bends. Each rt ll station performs one stage in the complete bending of the sheet to form the desired part. The roller dies are lubricated to reduce friction between the die and the sheet, thus reducing the tool ·• ~ar. Also, lubricant can allow for a higher production rate, which will also depend on the material thickness, number of roll stations, and radius of each bend. The roll forming line can also include other sheet metal fabrication operations before or after the roll forming, such as punching or shearing.[IO]

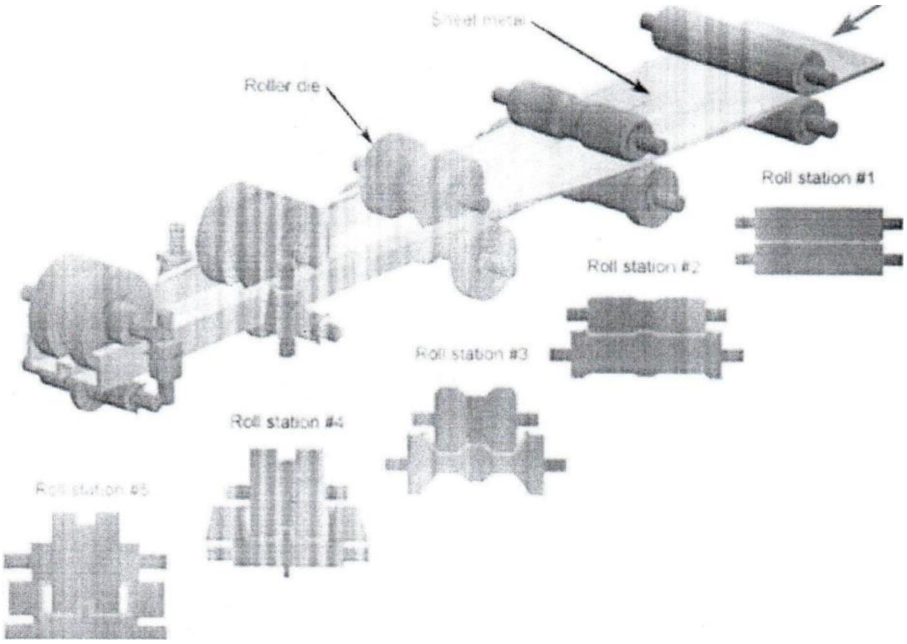

Figure 2.7 Roll forming line

The roll forming process can be used to form a sheet into a wide variety of cross-section profiles. **An** open profile is most common, but a closed tube-like shape can be created as well. Because the **final** form is achieved through a series of bends, the part does not require a uniform or symmetric cross-section along its length. Roll forming is used to create very long sheet metal parts with pical widths of 1-20 inches and thicknesses of 0.004-0.125 inches. However wider and thicker sheets can be formed, some up to 5 ft wide and 0.25 inches thick. The roll forming process is capable of producing parts with tolerances as light as ±0.005 inches. Typical roll-formed parts include panels, tracks, she! ving, etc. These parts are commonly used in industrial and commercial buildings for roofing, lighting, storage units, and other applications.

Since demand for several shapes such as round pipes of all sizes, is greatly increasing especially in the energy industry such as the chemical industry, wind power, thermal power plants, etc., many equipment has been designed to handle such requirements.

Machines for roll bending work with three or four rollers. The bending principle is usually the same with the three or four rollers machine.[II] v)

~- :. **Roll Bending Machines with 3 Rolls**

e machine with 3 rollers usually has two fixed rollers, while the upper vertical roller is sitioned accordingly to complete the desired bending. By changing the relative position and rating movement of the working roller, continuous plastic deformation is achieved for the rkpiece to receive a predetermined sh:1pe.

hile bending. the workpiece is positioned between the lower rollers and upper roller. After placing the sheet between the rollers, the upper roller is lowered to secure the workpiece, and at e same time. it has achieved sufficient pressure on the sheet, generating plastic bending. When - raring the roller there is friction between the sheet metal and the roller, so the sheet moves along ts longitudinal direction. At the same time, the upper roller adds pressure to the workpiece.

When the roller crosses the lower limit of the upper roller (the roller deformation zone) in one turn **and** the pressure exceeds the bending limit, plastic deformation occurs and the sheet is folded to **its** desired dimensions by its entire length. By adjusting the relative position between the lower and upper rolls, the sheet can be folded to ⊲ di,1rncter that is not less than the diameter of the upper roller. Here you can see the principle of the sy111111etrical circular bending machine with 3 rollers:

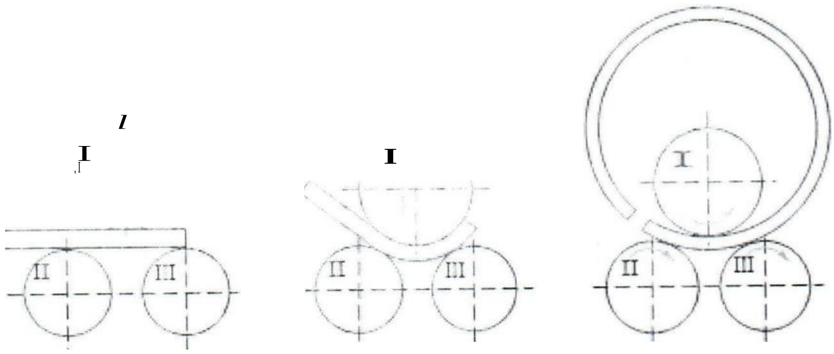

Figure 2.roller bending schematic

As shown in the figure above, rollers 2 and 3 move in the same direction and at the same speed. Because of the friction between the sheet metal and the rollers, the workpiece moves in advance. By adjusting the position of the upper roller, the desired bending angle can be achieved. If the workpiece does not achieve the proper curvature after the first bending, it can be adjusted and started the process in the opposite direction until the desired shape is achieved.

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bending due to the position of the rollers on the workpiece inevitably remains a flat part at ends of the sheet. This flat part is approximately half the length of the gap between the centers

ıOı e **lower** rollers.

.1ntages of 3 roller benders

A simple construction strnctme,

comfortable use

lower price than those with more rollers

Note: With these advantages, still make them the most wanted model of roll sheet metal bending **machines.**

2+.2. Roll Bending Machines with 4 Rolls

With 4 rolls, the operation principle is similar to the machine with 3 rollers, with the main ufference being that the additional roller is used for better input of the material and execution of

ue process of pre-bending.

During bending, the upper and lower rollers are static, the material is firmly positioned between **them,** and the side rollers move and bend the material. To eliminate the flat edges of the material, **he** lower roller moves upward to hold the material firmly, and the side roller moves and occupies **ne** position for pre-bending. Unlike a roll bending machine with 3 rollers, where during the prebending it is assumed that the material is lowered when entering the machine, in the rolling machine with 4 rollers, the material is positioned horizontally, allowing the use of motorized horizontal material holders when inserting materials in certain models. Besides, the input of materials can be carried out on both sides, so the machine can be placed next to the wall and save space.

The advantage of a roll machine with 4 rollers has a unique complete bending process, they also offer quicker and easier management, but they also have a higher price.

The machine accepts the material in one stroke, performs the pre-bending, and continues to bend the sheet. This system does not require an operator to remove, turn, and then straighten the material after pre-bending, as is the c:,se with 3-rollers bending machines. The material remaining in the machine makes the machine with 4 rollers up to 50% more efficient compared to 3-roller models and allows the material to bend at the desired diameter immediately after pre-bending. The bending of the flat edge starts after bending the material in one direction.

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-~ side rollers are positioned to the left and the right of the bottom roller and have their axes. The mdependent axis of each roller allows perfect bending. The "rear" side roller (located on the other ₒ of the material insertion) also has a rear end stop function and aligns the material. This feature ows the operator to work without the assistance of other people. Bending in the shape of the _ **... ape** is also possible on the machine with 4 rollers. The side rollers can be positioned in the corner r making the coupling and the bottom roller can be lifted to hold and position the material.[l]

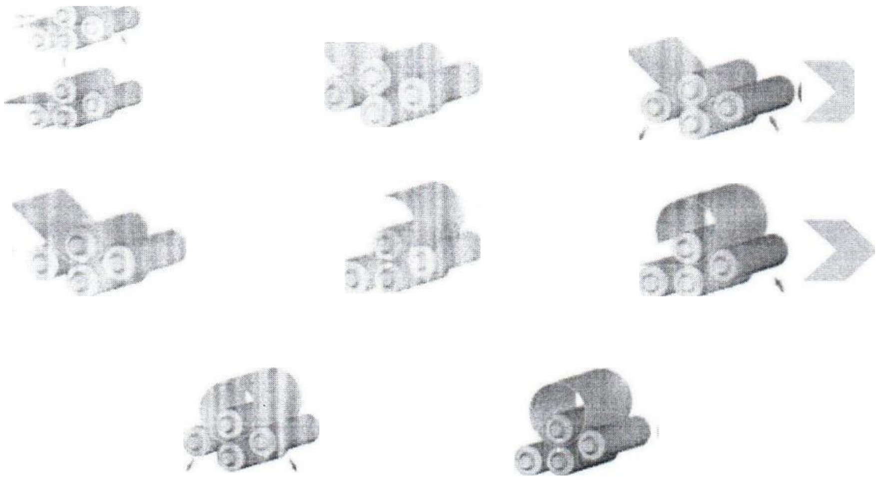

Figure 2.9 The 4-ruller bending process.

Note: Roll bending machines with 3 or *4* rollers are the necessary machinery in many industries, and working with them is very simple.

2.5. Rollers

For industrial milers, the most commonly used materials include plain steel, galvanized steel, stainless steel, zinc-plated steel, or even an alloy of steel and aluminum steel, aluminum, PVC, rubber, polyurethane. The Surface of the rollers is usually provided with a coating to lengthen their resistance to corrosion.

The most common types of rollers on market today are straight, concave, flanged, or tapered with diameters ranging between 0.625" and 8"

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bending processes, steel rollers are mostly used because of their strength against wear and

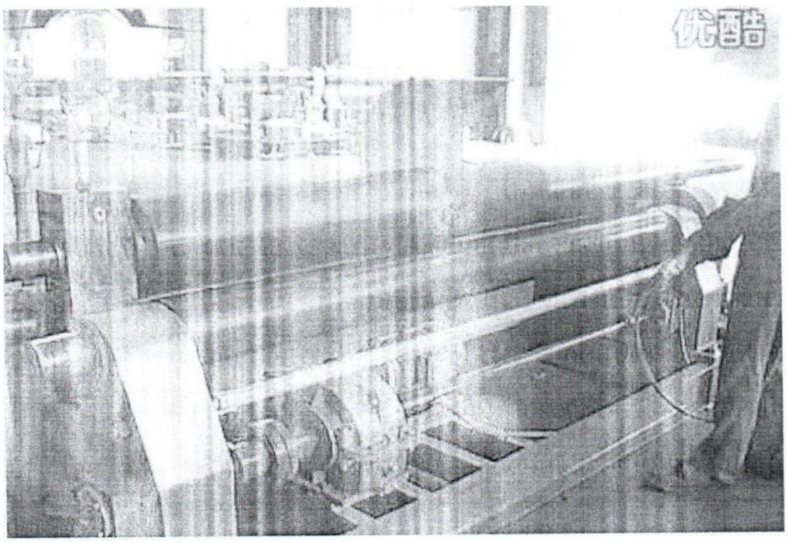
-t.1ness (1-lirn bet ween 65 and l 00), dur,tbi li ty. Furthermore, steel can withstand higher eeratures (up to 350°F) and holds up to deforming forces longer than any other material hence ___.:~ replacement and maintenance costs.

Existing Machines

- .**Sheet Metal Roll Bender**

s **Is** a mechanical jig having three or four rollers used to bend a metal bar into a circular arc. Te rollers freely rotate about three parallel axes, which are arranged with uniform horizontal **acing.** Two outer rollers, usually immobile, cradle the bottom of the material while the inner er. whose position is adjustable, presses on the top side of the material.

c .. bending may be clone to both sheet metal and bars of metal. ff a bar is used, it is assumed to ea uniform cross-section, but not necessarily rectangular, as long as there are no overhanging ~ncours, i.e. positive draft. Such bars are often formed by extrusion. The material to be shaped is suspended between the rollers. The encl rollers support the bottom-side of the bar and have a atching contour (inverse shape) to it to maintain the cross-sectional shape. Likewise, the middle roller is forced against the topside of the bar and has a matching contour to it. [5] The figure below **shows** a roller bender. [12]



ligure 2.I0 An industrial roll bending machine for heavy-duty activities

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242. sheet Metal Bending Machine

ding machines are machines that plastically deform work over an axis, creating a change in part's geometry. The available machine use hydraulics majorly to change the part's geometry.

e machines weigh over 20 tons and cost over USHS250 million. During installation, these machines have to be firmly fixed to the ground to avoid any accidents during operations and also duce vibrations ol the machine.

he figure below shows a sheet metal bending machine.

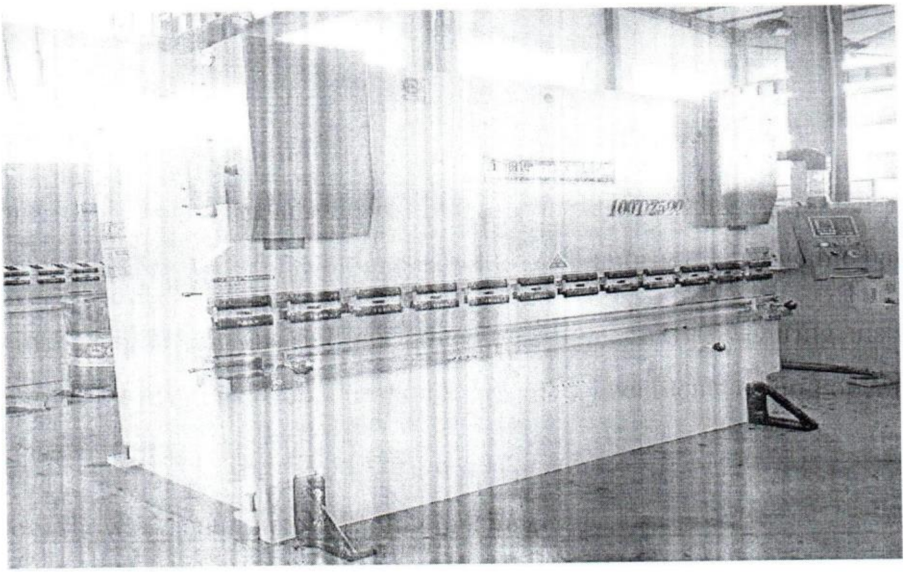


Figure J.11 A heavy-duty bending nwchine used in industries or big production plants for bending sheet metal

2.7 Power Transmissions for the Existing Machines.

Mechanical power transmissions, with the assistance of rotary motion, transfer power from the prime mover to the c1ctuator (operational machine or operational member). These systems consist of units that are very different from electricaL pneumatic, and hydraulic ones. These units are known as mechanical drives. The drives have couplings or clutches which are located between the actuator and the prime mover. This forms a full system whose function is defined by the function

of the actuator.

ln choosing the mode for the drive, the following factors are considered;

bb)

lhe required sped of the aacin; operating member very often differs from the speeds of the standard prime movers.

The driven side speed has to be frequently changed (regulated), whereas the prime mover cannot be used to full advantage for this purpose.

3 **Asa rule standard motors are designed for uniform rotary motion, while operating** members lrnve sumeti111es to n,o,e with varying speed or periodic halts.

ere are various mechanical drives in existence which include chain drive, gear drive, belt drive mention but a few. Some general considerations, mainly the available experience of design, manufacture, and operation o I' various drives enable us to outline generally the limits of priority cation of these dris.

2.7.1 Transmission by Gears

<u>Ex</u>cept for the noise they give off and their high price, gear drives have an advantage over all other , rives in all features, especially in operational safety and endurance, efficiency, and smaller c.1mensions. Ckars include spm gears, bevel gears. helical gears, miter gears, etc.

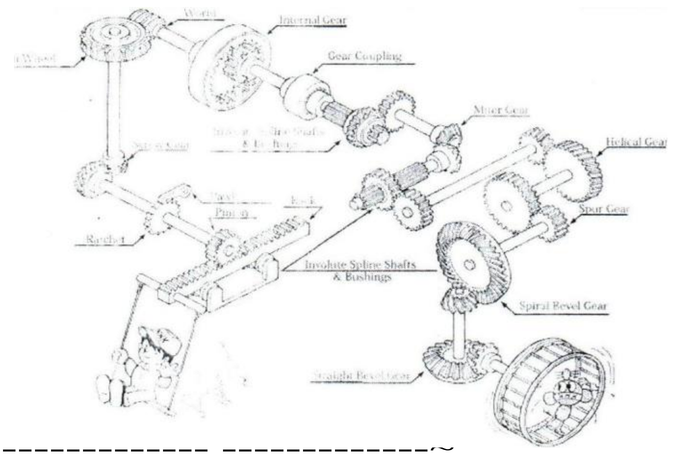


Figure 2.12 A gear drive

Gear transmission has been widely usecl in mechanical equipment as one of the most important lransmis-,ion modes. *The* gear transmission chain involves the processes of installing parts on

~ls and connecting or the meshing gear pairs. The meshing of the gear pair is defined by the gnment of the gear profile.I 13]

elow are some of the advantages of gear drives;

I. Cear drives have high transmission efficiency

·›They can transmit motion over a small center distance of shafts 3. These drives are ideal for low, medium, high power transmission

-l. A large and constc1nt velocity ratio of 60:1 can be obtained by using gear trains with mm1mum space

5. Ge<11 drives are rnech;1:1ically strong. ,!!lowing scopes for lifting higher loads
6. Longer service life compared to both belt and chain drives
7. They can transmit large power

2.7.2 Transmission Through Chain Drives.

Chain Drives arc the most important drives for the transmission of power. It is a positive drive system, unlike sel !"-drives. The velocity ratio of chain drives, i.e., the ratio of angular velocity of ::he driving sprocket wheel remains constant with no-slip and no creep. The velocity ratio, in this case, is as high as 8 which is quire high.

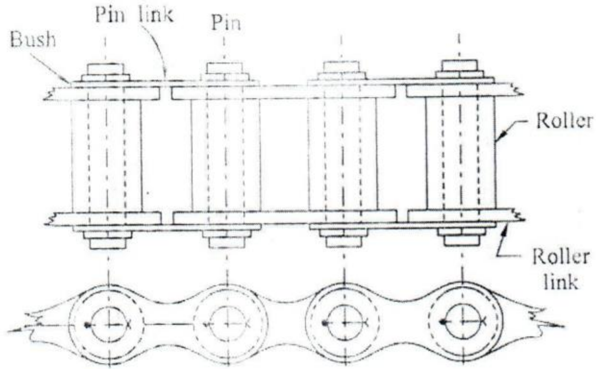
Chain drives me wry mt1ch st1itable for the power transmission for small center-to-center distance and can be suitably used up to *2.S* 111 but he distance can be increased in most special application.

The following chain types are commonly used;

1. Roller Chain

Roller chains are simple chains which arc used in bicycle, motorcycle, scooter, machine tools, etc. The figure below shows a portion of a roller chain with pin links. A roller link consists of two rollers that roll on two bushings which are press-fitted into two link plates. A pin link consists of two pins which are press-fitted into tao link plates.

•aaas..s 4at. a.ta.ad.a..act



cc)

Figure 2. J3 A roller chain

silent Chain:

The figure below shows several laminations of the links pinned together. The bush is fitted into **each** hole of'Lhe lamination of links. The chain is made by joining these links through pins. These **are** silent chains Each link plate has two teeth with a space in between them to accommodate the

mating tooth of sprockets.

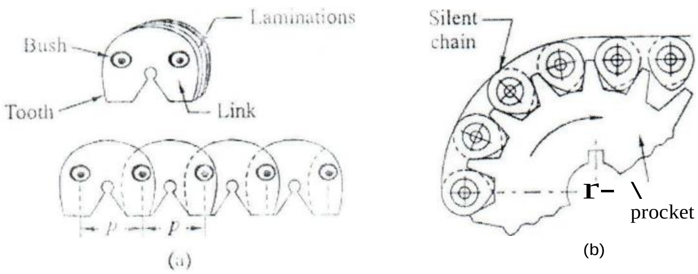


Figure 2. J4 A silent chain

Though the chain type needs a lot c)f lubrication, very expensive, hard to align, it has various advantages such as an effective power transmission, a high-velocity ratid, a positive drive without slip, can be used for very short center-to-center distances (up to 2.Sm).[14]

2.8 Power Sources for Existing Machines

The major power source for the industrial-based machinery is a 3-phase supply.

-M Ihree-Phase Electric Powe.

s IS a common method of alternating current electric power generation, transmission, and stribution. It is a type of polyphase system and is the most common method used by electrical gds worldwide to transfer power. It is also used to power large motors and other heavy loads.

an asymmetric three-phase power supply system, three conductors each carry an alternating urrent of the sate frequency and voltage amplitude relative to a common reference but with a hase difference of one-third of a cycle between each. The common reference is usually connected the ground and often to a current-carrying conductor called the neutral. Due to the phase difference, the voltage on any conductor reaches its peak at one-third of a cycle after one of the ther conductors and one-third fa cycle before the remaining conductor. This phase delay gives constant power transfer to a ba1:mced line.tr loild. It also makes it possible to produce a rotating magnetic field in an electric motor and generate other phase arrangements using transformers (for instance, a 2-phase system using a Scott-T transformer)

The advantages of a 3-phase power supply inelade

1. They ,',tn supply with no neutral and the same phase-to-ground voltage and current capacity per phase can transmit three times as much power.
2. When provided with the neutral wire, it allows three separate single-phase supplies to be provided at a constant voltage and is commonly used for supplying groups of domestic properties which are each singe-phase load.

2.8.2 Split-Phase Electric Powt·r

This is used when three-phase power is not available and allows double the normal utilization voltage to be supplied for high-power loads.

2.8.3 Two-Phase Electric Po,,'er

This power source uses two AC volages. with a 0O-electrical-degree phase shift between them. Two-phase: circuits may be wired with two pairs of conductors, or two wires may be combined, requiring only three wires for the circuit. Currents in the common conductor add to 1.4 times the current in the individual phases, so the common conductor must be larger.[15]

::_ **.3D Modelling Software.**

_ include solid works, CA TIA, DS SOLIDWORKS, AutoCAD, SolidEdge, ANSYS, etc. For st applications in Mechanical Engineering DS SOLIDWORKS, ANSYS, and CATIA are **stly** used.

_9.1DS SOLIDWORIS

'5_:.dWorks Corporation was founded in December 1993 by Massachusetts Institute of echnology graduate Jon Hirschtick. SolidWorks is a solid modeler and utilizes a parametric ~rure-based approach which was initially developed by PTC (Creo/Pro-Engineer) to create odels and assemblies. The so lhvare is written on Parasolid-kernel. It rnns primarily on Microsoft indows. While it is possible to run Solidorks on an Intel-based Mac with Windows installed, he application's developer recommends against this. SolidWorks does not support macOS.

Solid Works is published by Dassault Systemcs (DS).[l 6]

Is major advantage is that it's easy t learn and use. 3D modeling has changed the way designing is done. Not only does 3D modeling hdp the designer but they help the end-user to visualize space requirements, but also improves drawing efficiency ant accuracy.

Note: CA TIA and SolidEdge work in the same manner as SOLIDWORK.S but lack most features added to DS SOLID WORKS.

The software allows the designer to see what they would not see when designing in 2D. It gives the designer the ability to physically see how much real estate an object takes from all perspectives. When designing in 2D, the designer needs to create a separate plan and elevation view to see the space requirements of an object, which rakes longer to do.

The software helps to crec1te a wcJrking ~imubtion Atl1e designed component as it would perform in real-time.

dd)

1' lodelling Software.

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:-he software helps to cre8te a working ~imuhtiun *A* tl1e designed component as it would perform in real-time.

• .a.a.au.a.as.aai.

ee)

METHODOLOGY

he methodology discussed below describes how all the objectives of the project were to be ined and the results expeered tom each method that will be stated.

3l: Determination of the Design Specifications.

ra obtain data about the existing machines. the components, attachments, power sources, mechanisms, .zes. and costs, concerning the conceptmtl design. desk research was done. This involved study various text books, _journals, pt1blicc1tions. websites. The obtained data was presented as the review of literature related to the machines that peform the rollforming and bending operations.

:llrough this research. setbacks in the available machines were to be obtained.

Furthermore, interviews were carried out in the available small-scale workshops around Kabale town to understand the desired requirements of the appropriate machine for their kind of works. In doing this. various specifications rL·garding the design of the machine were to be obtained.

3.2 Selection and Sizing of the Components for the Machine

The selection was done reviewing vmious product catalogues (for those available on market), standard formulae and equations, several theories were to be used to appropriately size the components of the machine.

3.3 Generation of the layout of the Machine 3.3.1

3D Components

Modeling of these components was clone using the features of DS SOLID WORKS for its added advantages over the other modeling software from its simplicity to learn to its added features such as analysis and animation.

3.3.2 Sized Assembly

The modeled components were then assembled using DS SOLIDWORKS to obtain a visual description of the layout of the machine ff)

CHAPTER FOUR
PRESENTATION AND DISCUSSION OF FINDINGS

This chapter describes the findings and results from the research that was carried out using the ~ds described above.

- The Design Specifications

-~i.lgh the review of literature, interviews, and research, various machine components were **ted** that could fulfill these req\1irernents for th-: potential users of the machine. Discussed _ m,- are the various c1scertaim:cl curnponents.

- I.I The Machine Components

rom the selection process in the previous chapter. the following components of the machine **ere** chosen for use:

I. The machine base
'ı -. The rollers
3. The roller plates
4. The sprockets ,mct chain
::>. The adjustment assembly
6. The bernling mechanism
7. Motor and pulley system.

4.2. Sizing of the Components

The details to the sizing of the various chosen components are discussed as follows below.

-t2. I. Tht i\lachine Bas(;'.

The function of the base is to hold all the machine components including the rollers, the motor, and the bending mechanism. Stainless steel was picked for its superiority in strength, durability, hardness, stability. Thi.'. unit weight of steel hollow sections was calculated from

$$\text{Unit Weght (in kg/m)} = \frac{\text{Seuional Area (in mm}^2\text{) x Density (in g/cm}^3\text{)}}{1000}$$

The *yield strength, wear and tear resistance* and other properties were picked from tables provided in the appendix of this repor..

gg)

The total weight of the base was calculated using:

$$Weight = Vulume \times Density$$

$$W = (\pi r^2 h) \times \left({}^{mass}/_{Vol} \right)$$

For steel, the density= ~050kg/m^3.

Sheet metal *gauges* and weights are provided in *ta/Jle 1* found in the appendix of this document. This is made up of rectangular hollow sections of· 3 .7 lkg/m and size of 60x40x2.5. several pieces of differently sized cross-sections were to be cut to form a rectangular base of l000xl400xl200. Then a sheet metal platform of I 400x I 200x6 on which side plates are to be welded was put.

The chosen holl,)w sections h;-1ve a rigid it> of *7CJ.3CrPa,* Elasticity 0f *207GPa,* and a unit weight 0f *76.5\n.*

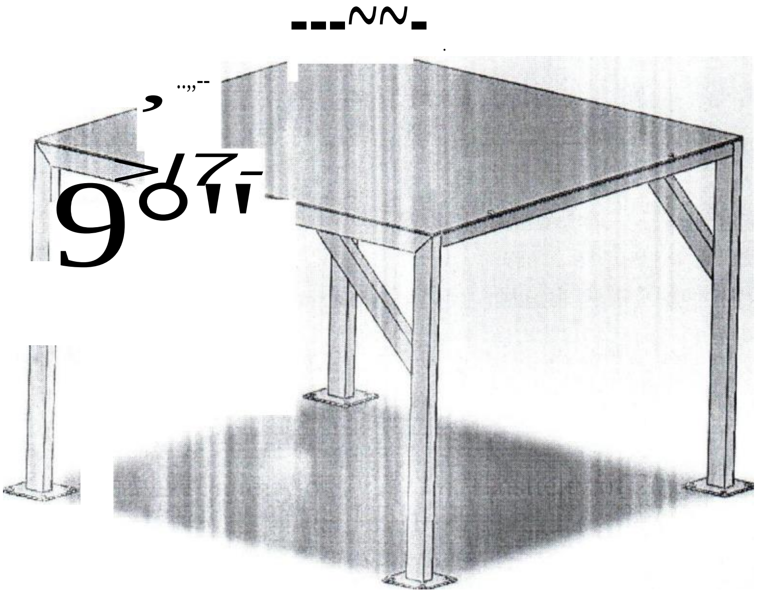


Figure 4.1 l1 SOJJDWORXS model for the base

This is nrndc' from 60x40 HS that h;1\'C b1..Tt1 welded c1t 45° and 90". A top sheet is then welded to the fabricated legs. The sizes of the different parts are listed in the table below

MEMBER	DESCRIPTION	DIMENSION (LxwxHIT)

jj)

Top sheet	This is used as the base for the machine c0mponcnts.	1400xl320x6
Hollow Sections	These ;ire cut to the required sizes (at 45 and or 90) and then welded as shown in the drawing.	40x60xl200 40x60xl000 40x60xl400 40x60xl280
Footings	These are cut fo, flat bars and then holes arc ,u; lkd into them for the bolts.	90x90x8
Bolts	These are used to secure the frame to the ground for more stbilit of the m chine	M20xl.2

Table 4.1 Si:!es(or the puh ojthe machine base

4.2.2 The Rollers.

Rollers chosen for this machine were stepped cylindrical components that are made from steel. Steel rollers come with various advantages such its their strength and stability during deformation, higher toughness. rigidity, and hardness as cornp,1rc·d to metals such as aluminum.

A sample roller shown below was used, with the shown dimensions, to ascertain Torques, length, deflections.

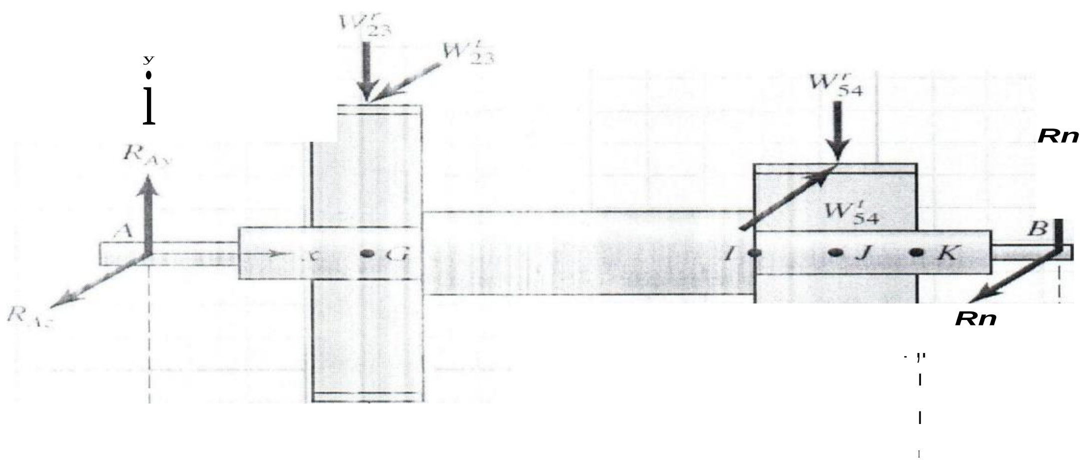


Figure 3.1 The sc1111p/e roller that was analyzed

e angular deflection was obtained fron1 lhe formula below;

$$f) = \frac{T\text{-}l}{Gh} \ldots\ldots (1)$$

nere

_ n the angular deflection of the roller

- is the modulus or rigidity of the roller

1:, the polar moment of inertia

T **is** the applied torque

s the kngtl! of the roller

From the obtained dimensions, the weight of the roller was obtained from;

Weight = Volume x Density (in Kg)

*where the **Volume= nr^{2}h and***

Density = 8050/{g /m^3 (For steel)

The Hardness Kock we'll (Him) or thl~ roller w.1s c:dculme,1 from

$$Haw = N - d/s$$

Where *N and s* are scale factors for a given steel 1ype

dis the depth of' the load point ,1fl,'1· impact

The figure below shows the calculated dimensions of the bottom roller

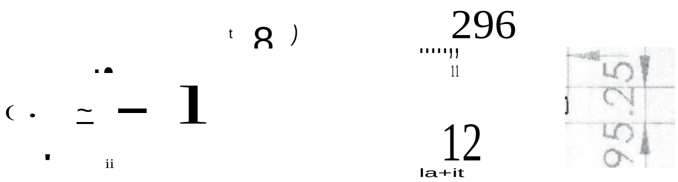


Figure I] dirnensionsji1r the bottom roller

The two bottom rollers are equal in size. These have an extended step to which a key was added or engaging the sprockets with the rollers as shown above. Each bottom roller is 1300mm (total

ength).

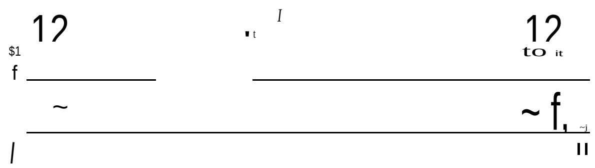
From *Equation (!),* the results of angular ,kflec.;tio11 0ľ the roller obtained were:

$9_0 = 5.47(10^{-4})$rad $9, =$

7.09107)ad

$3_8 = 1.10(1\ u^{-3}$ *)racl;* where *B* is the extr..:me right end.

The top roller has a total length of l 000mm and its dimensions are shown in the figure below



Figun, 4.3 di111ensio111· ofthe top roller

With these rcslllts, the miler was considered satisfactory to carry out the desired job.

The rollers were drawn in DS SOUDWORKS witlJ the stepped ends for the bearings.

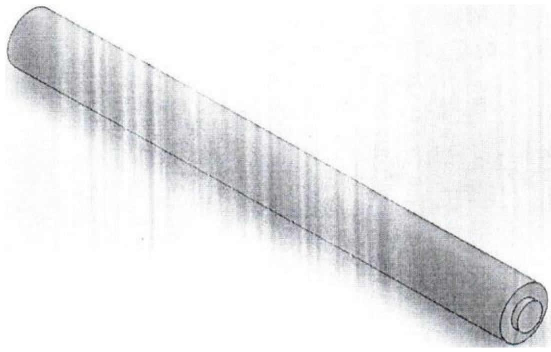
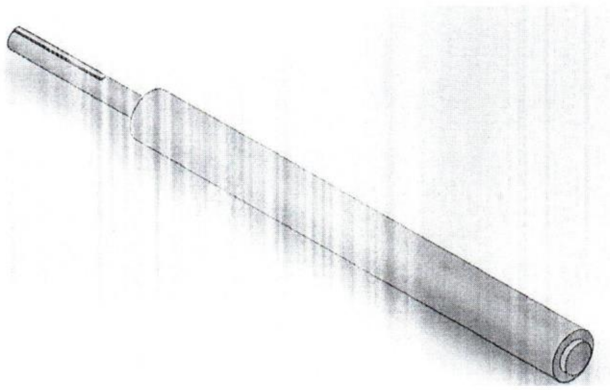


Figure 4.L,' The isometric 1/ew of the top roller



kk)

Figwe 4.5 111'1e11' *of one of the bottom rollers*

The drawing below shows the roller assembly drawn using SolidWorks.

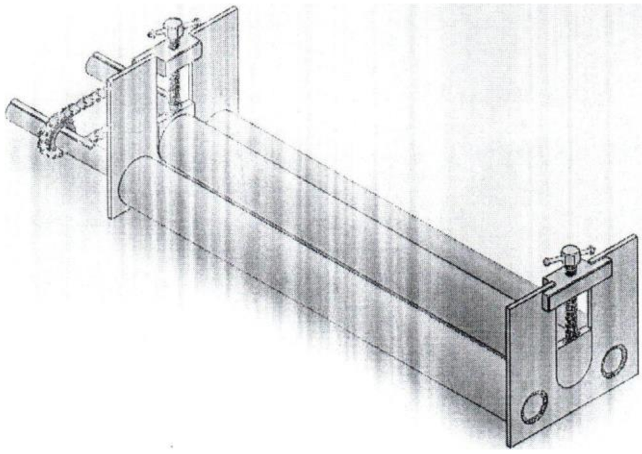
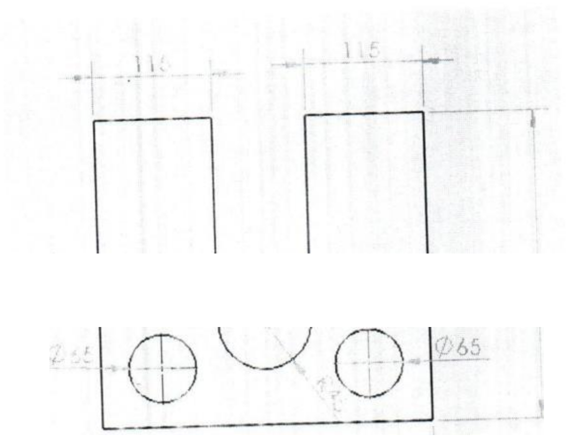


Figure 4.6 Model for the roller assembly

4.2.3 The Side Plates

These arc rhil·k pLllc:, cut frorn . 0mm thick slll·er. !1d:d They have drill holes for the bottom roller bearings. a cut 'U' shape for adjusiment a::,se111bly for the top roller. Shown below are the dimensions for the side plates.



Figu,·e 4. 7 The side plute dimensions

4.2.4 The Sprockets and Chain.

THE SPROCKETS

These were to be made from cast iron and each sprocket has **14** teeth. The drawing below shows three 2D \ iews of one of the sprockets.

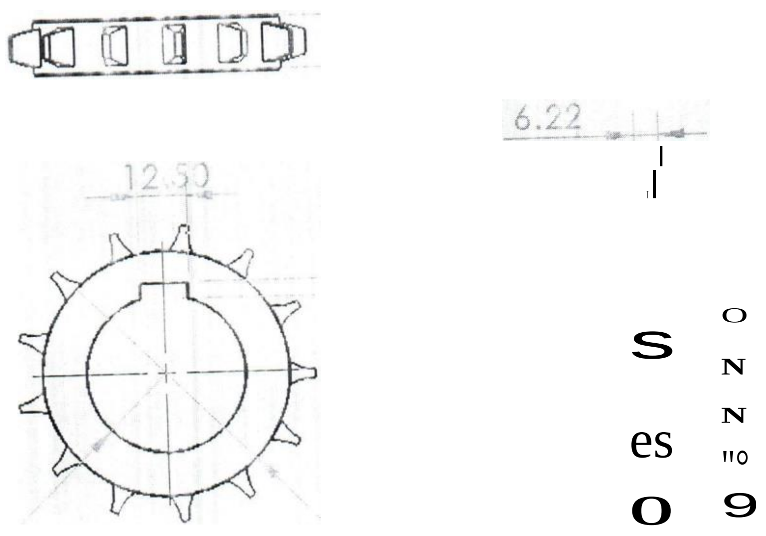


Figure 4.8 Line dra1Fingjor the spJ"Oc:ket showing dimensions

ll)

-.:ese were then used to develop 13D sl1own below.

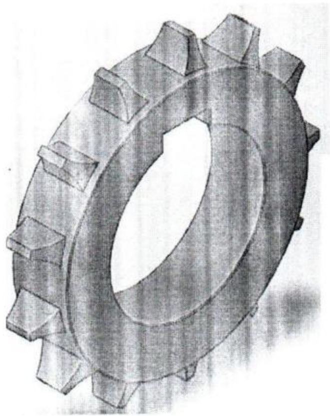


Figure 4.9 Sprucket

THE CHAIN

The chain links have the following dimen ions

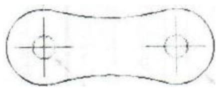


Figure 4.10amesions _tor the inner link

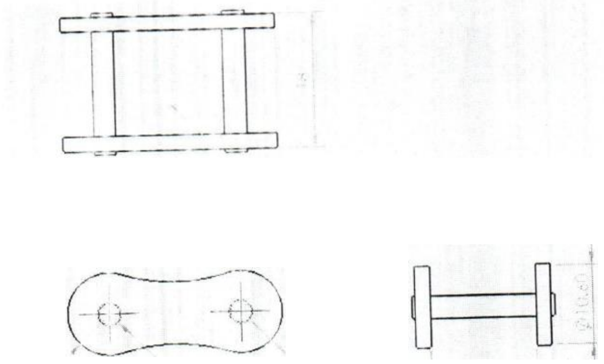


Figure 4. I I dimensiunsfor the outer link for the chain

Below is the assembly of the sprckets and chain that were developed in DS SOLIDWORKS

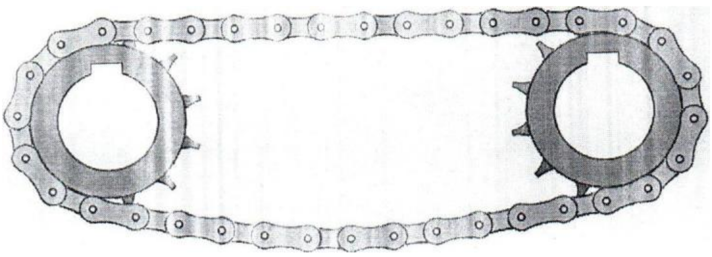


Figure I J2 [11e c/1ain and sprockets assembly

4.2.5 The Adjustment Assembly

The bearings for the top roller a ·e enclo~ed and c11Ltched to the adjustment assembly (bolt and nut assembly / as shown in fig. 4.1' below

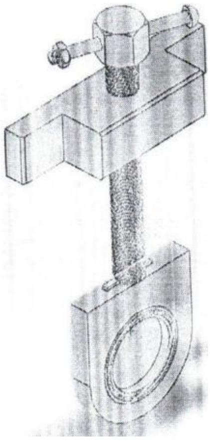


Figure 4. 13 The udj11st111...:nt mechanism assembly

4.2.6 The Bending Mechanism

The bending allowance, Ab from the eqLution was:

$$- \% \left(+ \frac{a}{Io«} \right)$$

Where a is the bend angle R is

the bend radius

t is the thickness of the sheet meLI

$J<ba$ is the factur used to e..;timate stretching

If $R-2, Ka = 033$ mnd i! $R>2, 1 == 0.50$

$$== 2rr(^{90} h60)(-os-n + 0.33(2)) = 0.14mm$$

The maximum bending force that tl"-e opcr:ttor wi 11 need to bend the sheet metal obtained was;

$$F_{,\dot{n},,,} - \frac{Kb_1 (7'S)wt^2}{D}$$

Where $J(bf == 0.33$ (!'or edge lx·nding)

TS is the tensile strength of sheet metal tis the thickness of the sheet metal

is the width in the direction of he bend axis

0.3'.:> x l.'53 x 35 0.85 x4 5,7=7.89k9f

The figure below shows the mechanism that was to be analyzed.

i"igure 0/. / 4 t1 sl,c'tt·h ful' !lie bending mechanism

Material selection for the bending mxhanism was based on maximum bending force, tensile strength, deflections, that were obtained from standard material's tables.

Then the weight uf the lx·nding 1c1echanism w;1s calculated from

$$\text{\11.'eight}, W = \frac{\text{Mass}, M}{\text{Volume}, V}$$

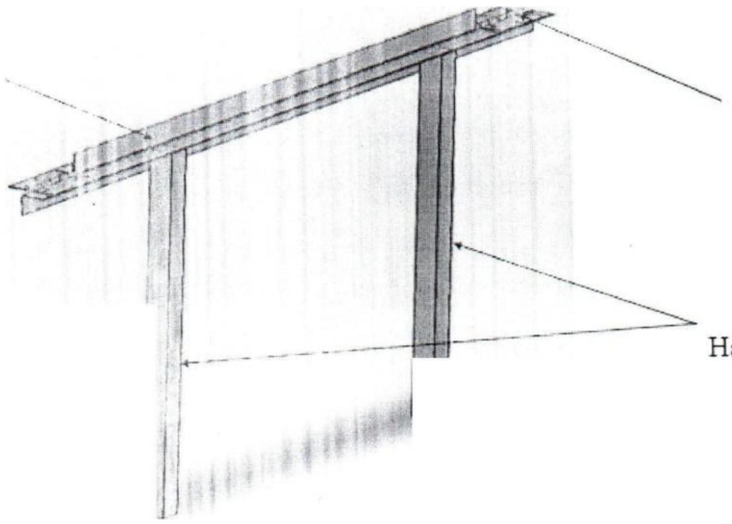
$$\frac{0O}{78.95} = \mathbf{5.066N}$$

The 111ecllanism wm, then mode.Gd i11 DS 30LIDWORKS using steel angle bars of tensile strength 0r *5:!0MPu,* this can bend a maximum thickness of not more than 2mm *(ta = 2mm),* 850mm wide using an Skgf. With tLcse properties, the deformation was very low.

mm)

The handles are 700mm long, 40011,111 frnrn one ltanclle to another, and the angle bars used are 900mm ,the angk b,1 · used for holdi!lc\ th, work piece) and 1400mm (the angle bar to which the handles are welded).

Figure 4.15 below shows the bendinµ; mechanism.



Fi:J.we 4. I 5 Tne 02ndit,:. assen1n!y l!lvde!ed in SOLID WORKS

The mechanism was made of an angle bar that can be adjusted when loading the sheet metal and then locked tightly to the length that needs bendi11g. The handles, which were made from square hollow sections (si1...: 40x402.5) welm·d to ‹111 angk bar, are then moved upwards away from the machine base to bend the sheet metal to the required angle. This rotation is enabled by the provided "'equal flanged binges."

4.2.7 Motor and Pulley System

Tht' synd,rnnotLS sp:,;cl 01·:,n ir1,.lucti.J11 r.1t)[CJC

The equation below was applied to c01lculate the synchronous speed for the motor.

$$\frac{120 \times f}{}$$

, • r-s;.a me:rrr:ae

Where *rpm*- synchronous pee (in rpn)

f= supply frequency in (cycles/sec); taking f = SOHz

Np= number of motor pole:

12x50

== --- = **1500rpm** 4

For rollforming processes, the sheet metal is formed at speeds between *0.07rps* and *O.lrps.* Taking a rotor peed, *n,* = *0.0Brp.:* = 4.t1rpm, the slip. *s* of the motor was obtained from:

$$s - \frac{1500 - \cdot l\text{-}.B)}{(4} \quad 0.99 = 99\%$$

Taking the resistance. R=0.350. reactance.X = 3.5D, the impedance, Z is;

$$= \sqrt{(R^2 + X^2)}$$

$$= \sqrt{(0.35^2 + 3.5^2)} = 3.52\Omega$$

Using a phase voltagl·, V==220v, tht [1].orqu: for the motor was obtained using the equation below

$$T = \left[\frac{\left(\frac{N_2}{N_1}\right)^2}{2\pi n_s}\right]\left[\frac{sE_1{}^2R_2}{R_2{}^2 + (sX_1)^2}\right]$$

$$= (0.(l1380) \frac{0.99 \text{ x Bl } 1.83)}{0.1421} = \mathbf{18.}\ 56\text{Nm}$$

The required power input was then obtained from;

P,-- IVcos6

\I 2 '.'. () E . c*A*) *1~* *Ii* lU 5 0 () 9

P ut = - = - = *JL* ..) · *cosU* = *1* , = - = - = .

I. 3.'>2 · 3.52

• *aat.*

oo)

$$= (625)(220)(0.099) = \mathbf{1361.25W}$$

The Tomi losses P, associated tu ndling -:heel m1:tal uf size 2mm is $245W$. Therefore, the power output of the mu tor was obtaine as.

$$P == /Ji - Pr, = 1361.25 - 245 = \mathbf{1116.25W}$$

The horsepower of a motor:

Electrical power sated in horsepower or watts. *A* horsepower is a unit of power equal to 746 watts or 33.0000 Ib-f per minute (5.50 lb-ft pei- scl·ond). A watt is a unit of measure equal to the power produced by a current or ı amp across the potential difference of I volt. It is 1/746 of l horsepower. The watt is the base unit of electrical power. Motor power is rated in horsepower and watts. I lorsepower is used to measure the energy produced by an electric motor while doing

work.

$$J\text{-}/P = \frac{1116.25}{746} = \mathbf{1.50}$$

Where HP horsepower

The efficiency or the motor:

This was obtained from the equation belo •

$$f = \frac{P}{Ji} \times 100\%$$

$$= \frac{1116.25}{1361.25} \times 100 = 0.820 = \mathbf{82\%}$$

With this efficiency. RPS, and horseower, research was made for the available motors on market and one of*0.rps* =*6rpm* with th.s specification, the chosen motor can run the imposed loads appropriately.

The pulleys:

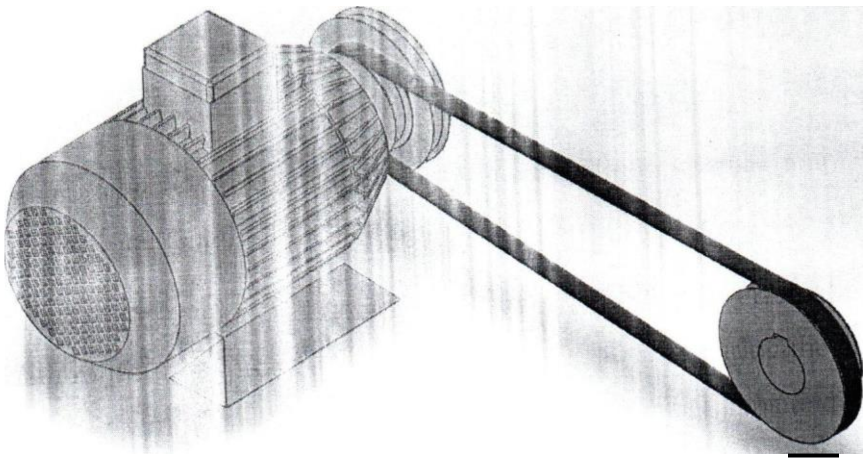
iWWiTi aaa.a.

The chosen type is the *stepped* with dumcters or I 10mm and 80mm, with a nominal shaft diameter of l 4mrn.

The total length of the belt is I l G7mm.

The mot\11· is designed to rotate i11 2 d: ect:ons !hilt i,,; l·lockwise and counter-clockwise directions to facilit:1le a srnootb roll form in!:- p1ov ~ss that is rulling tbe workpiece during the clockwise rotation 01· the mutor ,rnd withdr:.wing it while the motor rotates in the opposite direction

lCOtmter-clockwise direction).



Fi_!,ure !. le TIie dc1 *eloped assembly*

4.3 The layout and assembly of the nine

After moddling the components in D SOLID WORKS, these were all appropriately assembled as presented below.

4.3.l Thl' :\sstn,t>led Systtm

The maeline wa assembled in. OLLI WHkKSa shown in the figure below.

pp)

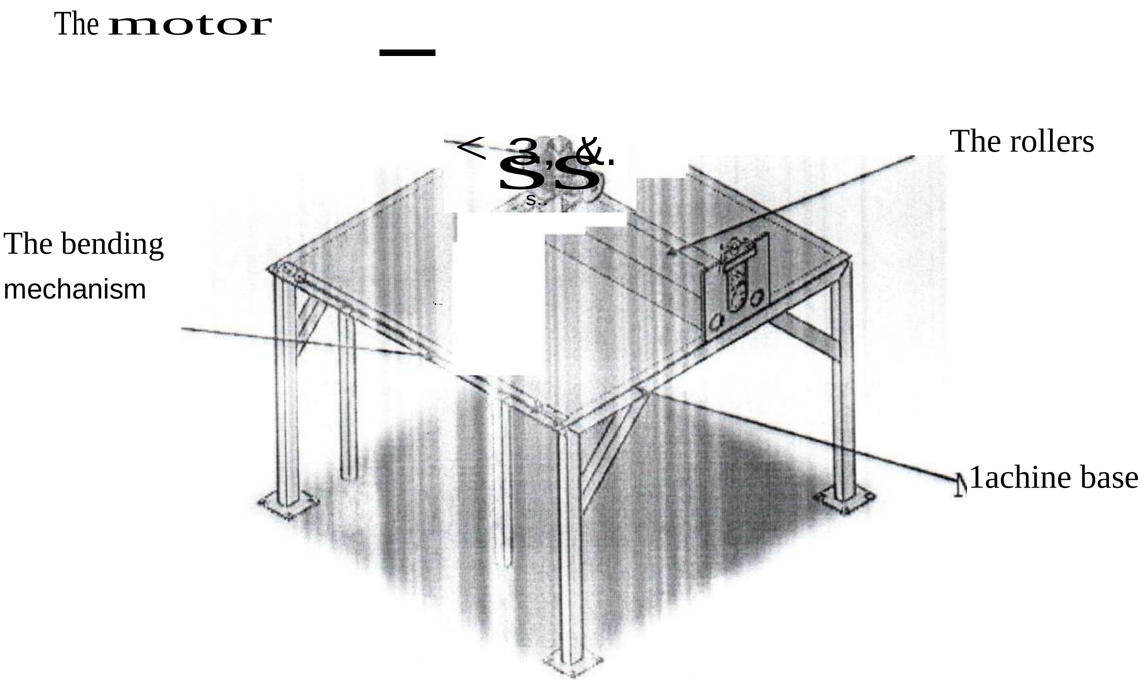


Figure 4. I 7 Lube/Lee! system

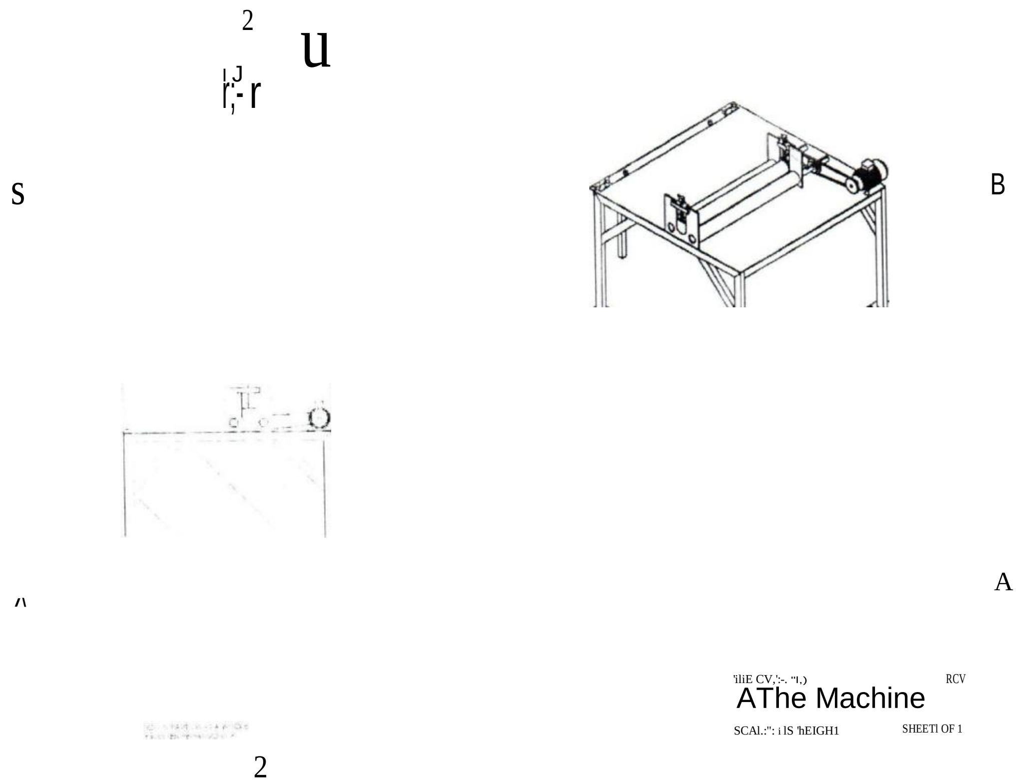


Figure 4. 18 Thf 1•ario11, views uf the machine.

qq)

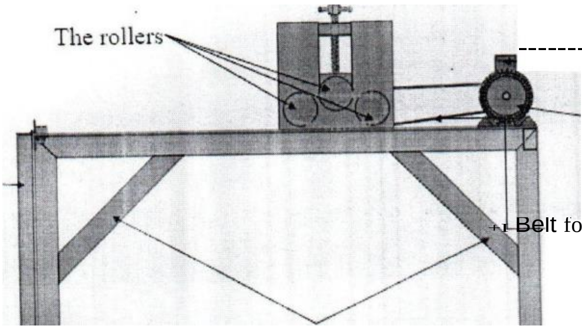


Figure 4. 19 A cross-section view of the assembly

Chapter Five
CONCLUSIONS AND RECOMMENDATIONS

This chapter gives a conclusion about the project and recommendations about further improvements on this project.

5.1 Conclusion

Jobs related to the rollforming and bending processes are usually "thrown-out" by the small-scale fabrication workshops operators since they require bulky and expensive machines that they lack room for and can not afford them. By combining the processes and ensuring that they can be performed by a more portable machine as compared to the available ones, this gives these operators an option to perform most domestic jobs, improve their income and therefore their lives. The combined sheet metal rollforming machine was achieved through following the set objectives. The design specifications of the machine were analyzed to conform to most mechanical and scientific standards. The selection and sizing of the components was done using formula relating to the required characteristics and properties. The components were modelled and then assembled using DS SOLIDWORKS.

5.2 Recommendation.

Since the available machines lack the concept covered in this design and the portability of the machine as compared to the available machines, this project, if completely analyzed and tested can be of great importance to the fabrication enterprise as a whole but also serve the needs of the smallscale enterprise (the target market). For future researchers, students, and instructors, the following ideas can be considered.

- With more research, this project can be prototyped, tested, and then fabricated for the enterprises it is designed for.
- More design specifications can be added depending on the requirements of the users of the machine.
- The sized components require further material analysis before any prototyping can be done.
- With these or more modifications made, the designed layout can be appropriately modified too.
- Adding safety and operation attachments such as process indicators, safety sensors, for better use as a commercial machine.

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Appendix

Appendix A: Sheet Metal Gauges and Weights

Gauge	Standard Steel			Galvanized Steel			Stainless Steel			Aluminum, Brass, Copper				
	Thickness		Weight	Thickness		Weight	Thickness		Weight	Thickness		Aluminum Weight	Brass Weight	Copper Weight
(ga)	inch	mm	(u/re)	inch	mm	(IB/#?)	inch	mm	(tut?')	inch	mm	(u/r?)	(/r?)	(l/r?)
3	02391	6 073	10							0.2294	5 827		9.819	10 392
4	02242	5095	9375				0 2344	5 954		0 2043	5 189		8 745	9 2550
5	0.2092	5.314	8.750				0.2187	5.555		0.1819	4.620		7.788	8.2420
6	01943	4 935	€ 125				0.2031	5159		0 1620	4115	2 286	6.935	7 340
7	0.1793	4.554	7 500				0.1875	4.763	7.871	0.1443	3.665	2.036	6.175	6.536
8	0164.4	4176	6.875			7 031	0165	4191	6.930	01265	3 264	1.813	5499	5821
9	0·45	3.797	250	0.1532	3.891	6.406	0.1562	3.967		01144	2 906	1.614	4 898	5.183
10	01345	341£€	5625	0 1382	3510	5781	0 1406	3571	5 670	01019	2 588	1 438	4 361	4616
11	0116	3.038	5 000	01233	3132	5156	0.125	3.175	5.040	0.0907	2 304	1.280	3.884	4110
12	0'04&	2 657	1375	0 1084	2 753	4531	0 1094	2 779	4 410	0 0808	2 052	1 140	3457	3.650
13	0 0897	2.278	3750	0.0934	2.372	3.906	0.0937	2.380		0.0720	1 829	1.016	3.080	3.250
14	0 0747	1 897	3 125	0 0785	1.994	3 281	0.0781	1 984	3150	0 06-11	1 628	0.905	2743	2.900
15	0.0673	1.709	2813	0.071	1.803	2.969	0.0703	1.786		0.0571	1 450	0.806	2.442	2.585
16	0 0598	1519	2.500	0.0635	1613	2.656	0.0625	1.588	2.520	0 0508	1 290	0.717	2 175	2.302
17	0.0538	1.367	2250	0.0575	1.461	2.406	0.0562	1.427		0.0453	1151	0.639	1.937	2.050
18	0 0476	1 214	2.000	0 0516	1311	2156	0.05	1.270	2 016	0.0403	1 024	0.569	1 725	1.825
19	0 0418	1.062	1 750	0 0456	1.158	1 906	0.0437	1110		0.0359	0 912	0.507	1.536	1.626
20	0..359	0912	500	0 0'396	1 006	1 656	0 0375	0 953	1512	0 0320	0813	0 452	1 367	1 448
21	0 0329	0.836	1375	0 0366	0 930-	1531	0.0344	0.874		0.0285	0.724	0.402	1.218	1.289
22	00299	0 759	1 250	0 0336	0 853	1 406	0.0312	0 792	1 260	0 0253	0 643	0.357	1 05	1.148
23	0029	0683	1125	0 0306	0.777	1281	0.0281	0714		0.0226	0.574	0.319	0.965	1.023
24	0 0239	0 607	1.000	0 0276	0 701	1.156	0.025	0.635	1.008	0 0211	0 536	0.284	0 860	0.910
25	0.0209	0.531	0 875	0.0247	0.627	1.031	0.0219	0556		0.0179	0.455	0.253	0.766	0.811
26	0 0179	0 455	0 750	0 0217	0 551	0 906	0.0187	0 475	0.756	00159	0.404	0.224	0.682	0 722
27	001€4	0.417	0.688	0.0202	0.513	0.844	0.0172	0.437		0.0142	0 361	0.200	0.608	0 643
28	00149	0 378	0 625	0 0187	0475	0.781	0.0156	0 396		0.0126	0 320	0.178	0 541	0.573
29	0.0135	0.343	0.563	0.0172	0.437	0.719	0.0141	0.358		0.0113	0.287	0.160	0.482	0.510
30	00120	0 305	0500	00157	0 399	0 656	0.0125	0318		0 0100	0 254	0 141	0429	0 454
31	0.0105	0.267		0.0142	0.361		0.0109	0.277		0.0089	0 226		0.382	0.404
32	007	0 24€		00134	0 340		0.0102	0 259		0 008	0 203		0340	0 350
33	000	0.229					0.0094	0.239		0.0071	0 180		0.303	0.321
34	0 2062	0 20					0 0086	0218		0 0063	0160		0.269	0 286
35	0 0075	0191					0.0078	0 198		0 0056	0 142		0.240	0.234
36	000€7	0170					0 007	0 178		0 0050	0 127		0214	0 225
37	0064	0.163					0066	0.168		0 00445	0 113		0191	0.202
38	0 0067	0170					0062	0157		0 00396	0 101		0 170	0 180

rr)

Appendix D: Bolts and Nut Sizes

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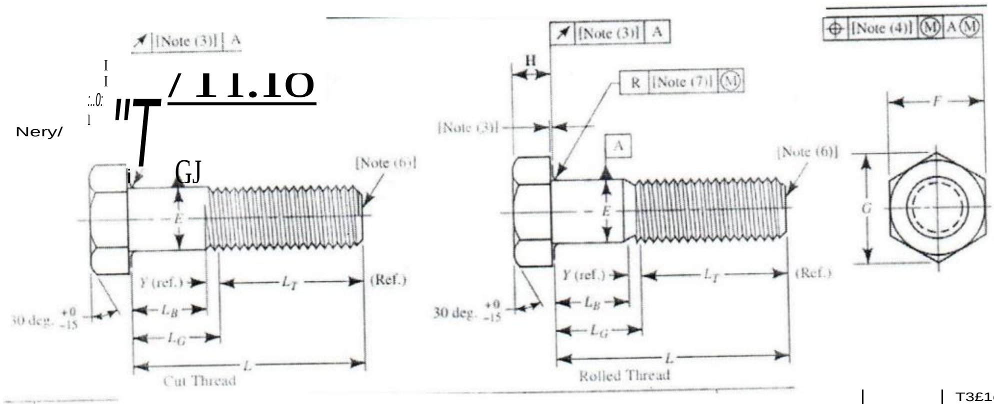
Nery/

GJ



:\onunJ! Su:t ::-: B,F>.: Ptc<l.uct 0:;,mP.<:."1 :-;'o:e (lS [No a (15)]		Body [) .. Ultlt\ Note (5) Max.	Min.	B34¢	Width A1o Fa! } Note (2) Max.	Min.	WtdiliAtro•i.. Comet: G Max.	Mi BI¢	Head Height H Mar	Mm.	Ramu of Fllet H Max	:-Ohn.	Tread Leneth I~ Note(IO) Ref	T3£1on Thread Length l N-ott{!O) Ma....;;.,Rtf.	Toal Ruout of Beanng Suufaee FLM Note(3) Max
½	0.5000	0515	04£2		0.875		1010	0969 %,	0323	0302	003!	0 009	L00	019	0016
k	0620	0642	0605	11/.e	10(1^ O.S50	l 031	l 227	Jl7S	0 .W3	OJ7$	0 06.2	0021	1.2:5	022	0019
%,	07500	076$	O729	1:;.	1250	1.21:!	l -143	l.3S}	OAS~	0.455	0062	0021	us	O25	0.022
f:	0.S-S0	O 695	0 652	lfi.:.	lHS	l.39.J	1660	l5S9	0.50:>	0531	0 00.2	0031	1.50	0.18	0.02S
I	.000	1022	O9	l}i	1625	l.575	lS76	! 796	oor	0591	0093	0062	l.75	0 JI	002$
I	.I!5	1I49	i09	1,	1$l2	.756	2093	2002 ,	071£	065$	0.09)	0062	!.00	O34	0.032
1¼	1.2500	1.277	1.223		'.000	l 9lS	2.J09	:.~ 't,,	0.Sll	0.7'9	009)	OO62	!.00	0)6	0.035
1⅜	1.3750	1.404	1.345	2.21s$		2II9	252	2416 •	0s7s	0510	093	0002	225	044	0.0JS
1½	1.5000	1.531	1.470	2%	2575	2300	2742	2622 ,	O974	O902	0090	000.2	225	O4	O0-ll

Appendix C: Hollow Sections Properties

·ct ion Cross-se	Material grade	h (mm)	b (mm)	t (rnrn) Al	A2	S	r,(mm) Cl	C2
05	1.4.'WI	99.99	99.85	4.65	4.67	4.62	2.38	1.78
S H S I O I I ·· I 0 0·5	l.4301/1.4307	149.82	149.80	4.99	5 02	4.99	5.94	7.42
SHS15U·l5 06	1.4301/1.4307	150.57	100.03	5.89	5.86	5.87	7.42	6.68
RHS 150· 10 ()'<5	1.4571	100.09	99.73	4.69	4.68	4.71	5.05	5.94
SHS IOU 10 ()x5	1.4571	120.30	120.14	4.63	4.67	4.62	5.64	5.94
SHIS 120/12 08	1.-140-l	l 50.0 I	150.5 l	7.77	7.76	7.76	9.65	I I. 13
SHS l 50 ·- l 5 R +() <S	I .4-lU4	l 50.0 l	100.20	7.78	7. 7 3	7 .73	8.9 l	10.39
ll S 150 · l ($HIS ,	l A5ll9	50.14	50.26	l.89	I .91	1.89	2.50	2.50
5050 SHS ı	1.4509	40.07	40.02	2 .02	2.03	2.00	1.75	1.7 5
4040 $HS –	1.4 509	29.98	29.97	1.90	1.95	1.95	1.50	l.50
30-30 RHS	1.4003	119.84	79.67	2.81	2.83	2.81	3.86	4.16
120·8l SHS 3	l .4003	79.75	79.74	2.81	2.80	2.79	3.56	4.16
8O·SO SllS :	1.4162	150.42	150.02	8.01	8.05	8.05	11. l 7	11.16
150'l5 ()x8	SJ55J2H	l50.31	150.7-l-	5.73	5.73	5.71	8.91	8.16
SflSl5015 RHS 06	S355J2H	200.01	100.19	4.62	4.60	4.65	3.56	3.56
200, I (RllS l)()x5	S355J2H	149.96	100.15	5.74	5.71	5.69	4.16	4.45
5II, 11 SHIS 200 106	S355J2H	202.25	200.48	5.85	5.87	5.85	7.42	6.68
20 06								

Appendix D: Standard Sizes for Angle Bars

Stainless Steel Equal Angle Bars

Sizes i Width in MM	Thickness in MM
20 x 20	3mm
25 x25	3mm to 6mm
30 30	3mm to 6mm
32 x 32	3mm to 6mm
38 x 38	3mm to 6mm
40 x 40	3mm to 6mm
50 x 50	3mm to 6mm
60 x 60	5mm to 6mm
65 x65	5mm to 6mm
75x75	5mm to 6mm

Sizes/ Width in Inch	Thickness in Inch
3/4" x 3/4"	1/8"
1"x1"	1/8" to 1/4"
	1/8" to 1/4"
1.1/4" x 1.1/4"	118" to 1/4"
1.1/2"x1.1/2"	1/8" to 1/4"
	1/8" to 1/4"
2"x2	1/8" to 1/4"
	3/16" to 1/4"
2 1/2" x 2 1/2"	3116" to 1/4"
3"x 3"	3/16" to 1/4"