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Mechanical School Production

Design and modeling study of roll forming machine for a U-Shape channel products

دراسة تصميم ونمذجة لماكينة تشكيل بالدرفلة لإنتاج مجارى علي شكل حرف (U)

Thesis submitted to the Postgraduate College Sudan University of Science and Technology in fulfillment of the Requirements for the Degree of M.Sc. in mechanical engineering

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بسم الله الرحمن الرحيم

وَإِذْ قَالَ رَبُّكَ لِلْمَلَائِكَةِ

إِنِّي جَاعِلٌ فِي الْأَرْضِ خَلِيفَةً ۖ قَالُوا أَتَجْعَلُ فِيهَا مَنْ

يُفْسِدُ فِيهَا وَيَسْفِكُ الدِّمَاءَ وَنَحْنُ نُسَبِّحُ بِحَمْدِكَ وَنُقَدِّسُ

لَكَ ۖ قَالَ إِنِّي أَعْلَمُ مَالَاتَعْلَمُونَ (30) وَعَلَّمَ آدَمَ

الْأَسْمَاءَ كُلَّهَا ثُمَّ عَرَضَهُمْ عَلَى الْمَلَائِكَةِ فَقَالَ أَنْبِئُونِي

بِأَسْمَاءِ هَٰؤُلَاءِ إِنْ كُنْتُمْ صَادِقِينَ (31) قَالُوا سُبْحَانَكَ

لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا ۖ إِنَّكَ أَنْتَ الْعَلِيمُ

الْحَكِيمُ (32) قَالَ يَا آدَمُ أَنْبِئْهُمْ بِأَسْمَائِهِمْ ۖ فَلَمَّا أَنْبَأَهُمْ

بِأَسْمَائِهِمْ قَالَ أَلَمْ أَقُلْ لَكُمْ إِنِّي أَعْلَمُ غَيْبَ السَّمَاوَاتِ

وَالْأَرْضِ وَأَعْلَمُ مَا تُبْدُونَ وَمَا كُنْتُمْ تَكْتُمُونَ (33)

سورة البقرة الاية 30

Dedication

صدق الله العظيم

The presence of some people in our lives means it's continuance because they are the reason of our existing in the life and because they are the source of the light for us .

These people can’t be described by words because words less than their ranks and without their presence we couldn’t arrive to what we are now.

To our fathers who stayed beside us every single life moment.

To our mothers who lookout nights and shed tears for us

To our teachers ……………………………..

To our friends ……………………………….

To all who stood beside us ………………….

You where the candles that lit the way for us when the life darkened.

For all those we say we will never forget what you have done.

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First of all we want to dedicate our special thanks for our supervise Dr.Abdalfatah Belal, for his undaunted patience, guidance, and his constant advise through our study in Sudan university for science and technology, he provide numerous constrictive criticism and detailed comments .to say the least without his encouragement and enthusiasm, we would probably would not have gone on this far ,his effort are greatly appreciated ………thanks Dr.Abdalfatah

We would like to take this opportunity to thanks our dear parents for the support and for being patient all along

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Finally, we would like to stress here that the work reported here would not have been possible without the grant of Sudan university of science and technology specially the school of mechanical engineering our head masters and teachers thanks very much

Abstract

Manufacturing technology of roll forming is one of the important methods and technologies of metal shaping. The need for mass production, devoting and optimization of old and conventional methods is playing important role these days in market need. This research provided a design of Roll Forming machine that form sheet metal into U-shape channel which used in variety of applications, the machine design has been accomplished through manual calculation and computer simulation the results shows that the design is reliable, functional and withstand the loads acting on it, the machine design have a lot of benefits such as; continuous production rate, produces symmetric products, high quality products, doesn’t need skilled operator, less weight, small size, adjustable to a variety of products by design a new sets of rollers, less cost and more safety,

الملخص

اصبحت تقنيات التشكيل عن طريق الدرفلة من اهم طرق وتقنيات تشكيل المعادن. الحاجة الي الإنتاج الكمي و تطوير و تحسين طرق الإنتاج تلعب دورا مهما في احتياجات السوق الحالي. هذا البحث قدم تصميما لماكينة التشكيل عن

طريق الدرفلة لإنتاج منتج علي شكل حرف U والذي يدخل في كثير من التطبيقات الصناعية المختلفة, تم اكمال التصميم عن طريق الحسسابات الإعتيادية وعن طريق استخدام النمذجة بمساعدة الحاسوب حيث تم التاكد من النتائج, وتؤكد النتائج بأن التصميم معتمد و فاعل , وان تصميم هذه الماكينة يتحمل كافة الاحمال المسلطة عليه, وتمتاز الماكينة بعدة مميزات منها : الإنتاج المستمر و تماثل المنتجات و جودة المنتجات العالية و لاتحتاج لعمالة ماهرة و قلة الوزن والحجم, قابلة تغير المنتجات عن طريق تصميم مجموعة الدرافيل و قلة التكلفة و عالية الأمان.

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List of symbols

Symbol	Description
R	radios
N	Number of revolution
Σall	Over all stress
St	allowable bending stress
Sf, SH	the AGMA factor of safety
Yn	stress cycle factor for bending stress
Y^{θ}	temperature factors
Yz	the reliability factors
Wt	the tangential transmitted load
K_o	is the overload factor
K_v	the dynamic factor
K_s	the size factor
b	the face width of the narrower member
mt	the transverse metric module
KH	Load distribution factor
KB	the rim-thickness factor
Yj	geometry factor for bending strength
ZR	the surface condition factor
ZE	elastic coefficient
ZI	is the geometry factor for pitting resistance
Sc	the allowable contact stress

ZN	the stress cycle life factor
ZW	the hardness ratio factors for pitting resistance
Wt	The tangential load
m	Gears module
V	Line velocity
H	Power transmitted in watts
N	Number of teeth.
d	Pitch diameter of the *pinion,* in (mm)

CHAPTER ONE

INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1 Preface

Manufacturing technology is a way or method of manufacturing a certain product and each company has its own development of manufacturing technology and those developed methods is a company patent. It’s very conventional methods used in Sudanese companies and all of the modern machines are imported from other industrial countries which is very expensive, our country is full of resources, but need more researches and designs to develop a new technology of manufacturing for new and custom product.

This research will provide a design of Roll Forming machine that form sheet metal into U-shape channel which used in variety of applications, through computer simulation, instead of using manual method of producing this product.

1.2 Research problem

How to replace Manual sheet metal forming method with a mechanical machine?

How to design machine element?

How to test and analysis designed elements of the machine?

1.3. Motivation of the research

This research provide a solution by designing of roll forming machine that give low cost, high quality, high production rate, symmetric products and independent of lapper skills, and the cost of the machine will be decreased by manufacturing it locally rather than buying it from international market and allow custom products with different dimensions and shapes to be produced through different shapes of the pressing pair of rollers which will be designed according to variety of products company may need.

1.4 Research Objectives

The objectives of this research are:

1- Design of Roll forming machine elements for U-Shape channel product.

2- Analysis and simulation of the machine elements using CAE software.

3- Modeling of the designed machine using CAD software.

1.5 Research area

Developments of manufacturing technology of sheet metal cold roll forming.

1.6 Research lay out

After this introduction chapter two will be a theoretical background about methods of sheet metal forming processes and about mechanical elements used in roll forming, then chapter three will be full representation of the mechanical design and calculation and drafts for the u-shape machine elements, chapter four will be a simulations and analyzing through computer software for important elements of the machine elements, and show the experiments obtained to get design parameters, then chapter five will be a show of results and recommendations for development of this machine.

CHAPTER TWO

PREVIOUS STUDIES AND LITERATURE REVIEW

CHAPTER TWO

LITERATURE REVIEW AND PREVIOUS STUDIES

Type equation here.

2.1 Preface

Metal forming is a kind of manufacturing process that the part attains a specified shape by permanent deformations through applied forces and impellent boundaries such as tool and dies. The external forces can be in the form of compression, tension, torsion, shearing, bending, drawing or a combination of the various forces. Usually ingots from simple shapes are formed using tools and dies. Shaping of the metal stock means plastic deformation throughout or some parts of the material stock. Plastic deformation is strain values due to stresses above elastic limit. Reason for this aforementioned plastic deformation is slips occurring between crystallographic planes of the metallic structure.

Metal forming processes are being widely used since early ages. Starting with hammering iron to make tools, war equipments such as swords or blades, metal forming has an immense history. Many advantages of metal forming processes are listed:

1. Utilization of metal is very high in some cases 100% material is used directly as final product.

2. Fatigue life of the formed products compares very much to the conventional production methods such as casting or cutting.

3. It is not affected with cutting tools’ shorter life and risk of changing dimensions because of abrasion or breakage used in machining processes.

4. It is a robust process that can give same final shape and dimensions for high amounts of production.

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4. It is a robust process that can give same final shape and dimensions for high amounts of production.

5. Production cycle time is very low compared with chip consisting and many casting processes, since casting requires higher temperatures compared to hot forming in case heating is much significant in casting.

Metal forming technology is used in following areas; Aerospace, Appliance, White goods, Construction, Medical equipment manufacturing, Military, Rail car and rail car component manufacturing and Automotive.

2.2 Classification of Metal Forming Processes

In general terms, metal forming processes can be classified in terms of type and shape of formed parts and deformation zone. Classification is bulk-forming and sheet forming at first sight. Afterwards these also have minor branches Figure (2.1) shows Classification of Metal Forming Processes.

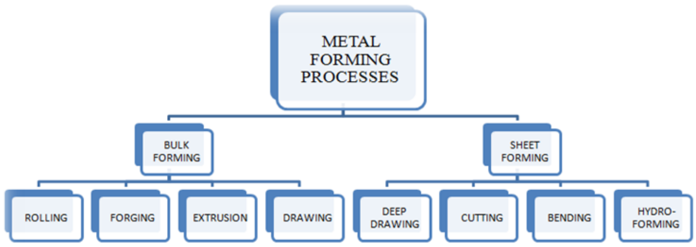


Figure 2.1: Classification of Metal Forming Processes

Bulk Forming Processes involve large amount of plastic deformation. The cross- sectional area of work piece changes without volume change, Shape of the deformation zone that covers the cross-section changes during forming of the material. The ratio cross-section area/volume is small. For most operations, hot or warm working conditions are preferred although some operations are carried out at room temperature. Subheadings are briefly defined as following; Rolling: Compressive deformation process in which the thickness of a plate is reduced by squeezing it through two rotating cylindrical rolls [1].

2.2.1 Forging

The work-piece is compressed between two opposing dies so that the die shapes are imparted to the work.

2.2.2 Extrusion

The work material is forced to flow through a die opening taking its shape.

2.2.3 Drawing

The diameter of a wire or bar is reduced by pulling it through a die opening (bar drawing) or a series of die openings (wire drawing).

In Sheet-Forming Processes, the cross-section of work-piece does not change; the material is only subjected to geometry changes. The ratio cross-section area/volume is very high. Sheet metalworking operations are performed on thin (less than 6 mm) sheets, strips or coils of metal by means of a set of tools called punch and die on machine tools called stamping presses. They are always performed as cold working operations. However, there are new trends to warm the sheet before forming

Forming operations are classified According to working temperature into;

1- Cold Forming, is a metal deformation process performed at room temperature namely below the melting and recrystallization temperature. Advantages are dimensional accuracy, better surface finish, high strength and hardness of the finished part. Whereas; there is need for higher forces and power in addition sometimes annealing before process.

2- Warm Forming, is metal deformation performed at temperatures above the room temperature but below the recrystallization one. Advantages are lower forces and power, more complex geometries and no annealing process. However; another heating process is required before forming.

3- Hot Forming process involves deformation of preheated material at temperatures above the re-crystallization temperature. Advantages of the process are forming of the large geometries being possible, requirement of lower forces and power due to low flow stresses and occurrence of no work hardening. However, process gives lower dimensional accuracy and surface finish, higher production cost and shorter tool life.Figure {2.2) shows the classifications of forming operations according to working temperature

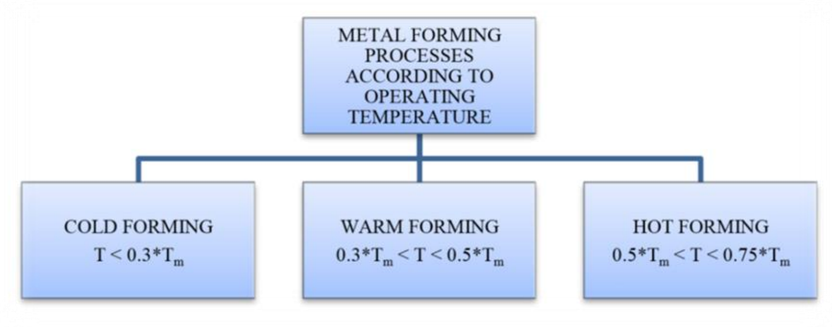


Figure 2.2: classifications of forming operations according to working temperature

2.3 Definition of Roll Forming Process

In Rolling Process, thickness of the work is reduced by compressive forces exerted by two or more opposing rolls. Process produces continuous strip of metal through a series of contoured rolls. Accordingly, cross-section of the metal part is formed into a pre-determined shape.

Cross-section area of the rolled material is decreased in single direction or both directions while passing through the rollers. Aforementioned change leads to elongation in the rolling direction.

The nature of roll forming when cold rolling is applied; allows the finished part to be within very tight tolerances. Roll formed sections have an advantage over extrusions of similar shapes due to being generally much lighter and stronger, when having been work hardened in a cold state. Exclusions are observed when hot rolling is applied.

Roll forming has extended usage in areas such as the aircraft industry, architectural industry, electronics, and the automotive industry.

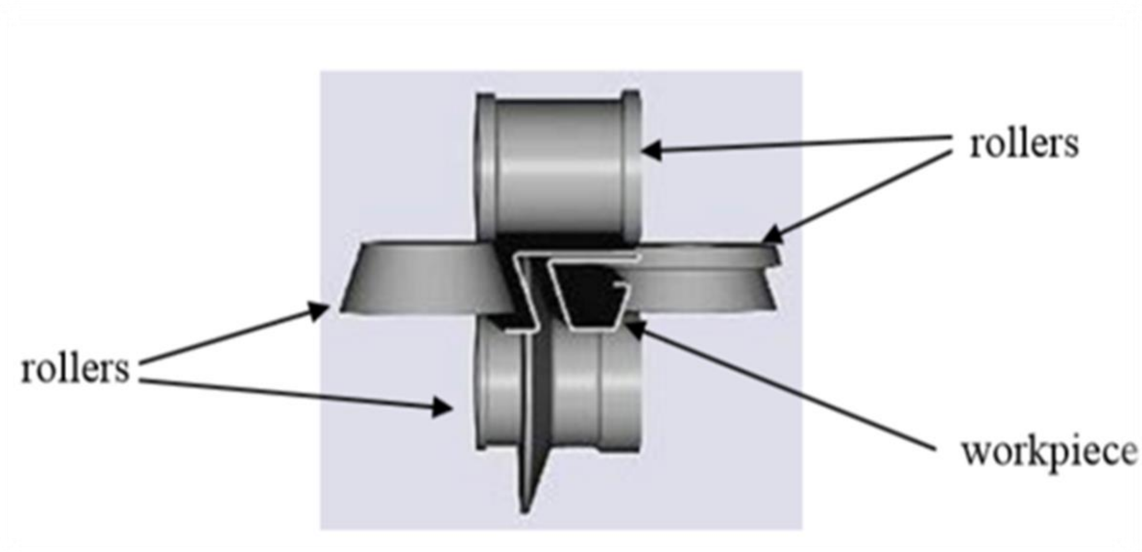


Figure 2.3: Roll Forming Stand

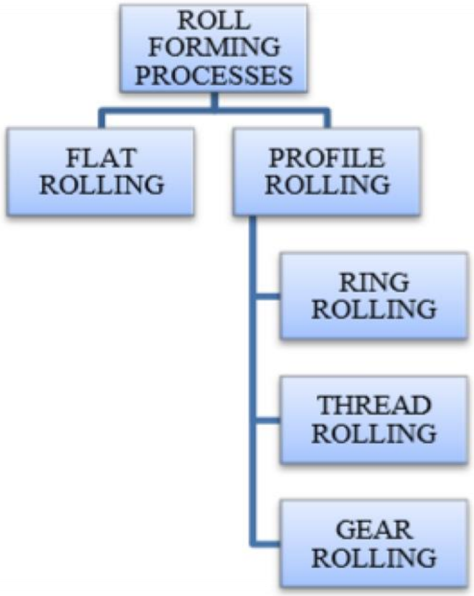


Figure 2.4: Classification of Roll Forming Processes

Flat Rolling is used while rolling sheet metals or any cross-section without boundaries at perpendicular direction to both rolling and rollers axis. At the same time; the rollers have no contours along their movement axis.

In Shape Rolling; the work-piece is deformed by a gradual reduction into a contoured cross section (I-beams, L-beams, U-channels, rails, round, squire bars and rods, etc.).

Ring rolling means, thick-walled ring of small diameter is rolled into a thin-walled ring of larger diameter. Thread rolling is used to form threads on cylindrical parts by rolling them between two thread dies. Gear rolling is similar to thread rolling with three gears (tools) that form the gear profile on the work.

In addition to the former classification, there is cold and hot rolling cases applicable to roll forming processes. Same benefits and unfavorable properties exist for each rolling case as told while classifying general metal forming.

2.4 Roll forming technology

Roll forming is a type of rolling involving the continuous bending of a long strip of sheet metal into a desired cross-section. The strip passed through sets of rolls mounted on consecutive stands, each set performing only an incremental part of the bend, until the desired cross-section (profile) is obtained (see figure 2.5) shows bending along rolls. Roll forming is ideal for producing constant-profile parts with long lengths and in large quantities [2]

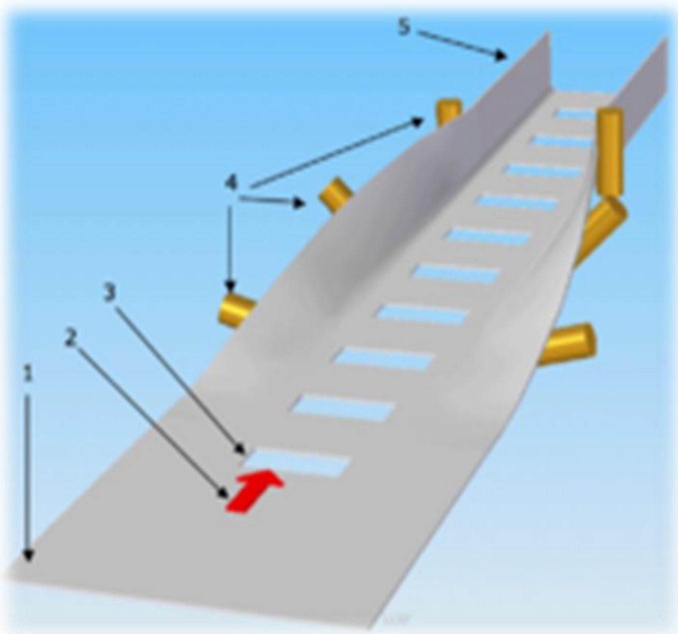


Figure 2.5: Roll forming process

2.4.1 Process

The process of roll forming is one of the simpler manufacturing processes. It typically begins with a large coil of sheet metal, between 1 inch (2.5 cm) and 20 inches (51 cm). In width, and 0.004 inches (0.10 mm) and 0.125 inches (3.2 mm) thick, supported on an un-coiler. The strip is fed through an entry guide to properly align the material as it passes through the rolls of the mill, each set of rolls forming a bend until the material reaches its desired shape. Roll sets are typically mounted one over the other on a pair of horizontal parallel shafts supported by a stand(s). Side rolls and cluster rolls may also be used to provide greater precision and flexibility and to limit stresses on the material. The shaped strips can be cut to length ahead of a roll forming mill, between mills, or at the end of the roll forming line [3].

2.4.2 Geometric Possibilities

The geometric possibilities can be very broad and even include enclosed shapes so long as it is the same cross-section throughout. Typical sheeting thicknesses range from 0.004 inches (0.10 mm) to 0.125 inches (3.2 mm), but they can exceed that. Length is almost unaffected by the rolling process. The part widths typically are not smaller than 1 inch (2.5 cm) however they can exceed 20 inches (51 cm). The primary limitation is profile depth, which is generally limited to less than 4 inches (10 cm) and rarely larger than 6 inches (15 cm) due to roll-imparted stresses and surface speed differentials that increase with depth.

Tolerances can typically be held within ±0.015 inches (0.38 mm) for the width of the cross-sectional form, and ±0.060 inches (1.5 mm) for its depth [4].

2.4.3 Production Rates

The production rate depends greatly on the material thickness and the bend radius; it is also affected by the number of stations or steps required. For bend radii of 50 times the material thickness of a low carbon steel 0.7 inches (18 mm) thick can range from 85 feet per minute (26 m/min) through eight stations to 55 feet per minute (17 m/min) through 12 stations or 50 feet per minute (15 m/min) through 22 station [13].

The time taken for one product to take shape can be represented by a simple function. The function is as follows: $t = (L + n \cdot d) / V$, where L is the length of the piece being formed, n is the number of forming stands, d is the distance between stands, and V is the velocity of the strip through the rolls [5].

In general roll forming lines can run from 5 to 500 feet per minute (1.5 to 152.4 m/min) or higher, depending on the application. In some cases the limiting factor is the punching or cutoff applications [9].

2.5 Machine basic components

The mechanism composes of; shafts, gears and other components but there is some important component theoretical background;

2.5.1 Gears

Gears are a means of changing the rate of rotation of a machinery shaft. They can also change the direction of the axis of rotation and can change rotary motion to linear motion.

Unfortunately, mechanical engineers sometimes shy away from the use of gears and rely on the advent of electronic controls and the availability of toothed belts, since robust gears for high-speed and/or high-power machinery are often very complex to design. However, for dedicated, high-speed machinery such as an automobile transmission, gears are the optimal medium for low energy loss, high accuracy and low play.

Gears are of several categories, and can be combined in a multitude of ways, some of which are illustrated in the following figures [10].

2.5.1.1 Gearbox design

This gearbox used to decrees the speed of the motor to meet the speed of roll forming.

The gear box design will be good if less variation at gears dimensions for this reason we will calculate the square root of the transmission ratio.

- Reliability of gears =90%
- Gears quality: commercial
- Gears type: spur gears
- The method use for gears design is AGMA method
- Material used in gears is through hardened steel grade one

$$\sigma\text{all} = \frac{\text{St}}{\text{Sf}} \times \frac{\text{Yn}}{\text{Y}^{\theta} Yz}$$

$$\text{Wt} = \frac{H}{V}$$

2.5.1.2 AGMA stress equation

$$\sigma = Wt \times K_o \times K_v \times K_s \frac{1}{bmt} \times \frac{KH \times KB}{Yj}$$

From the diagrams and equation of K_H We can determine the K_H

$$K_v = \left(\frac{A + \sqrt{200V}}{A}\right)^B$$

A=50+56(1-B)

$$B = 0.25(12 - Qv)^{\frac{2}{3}}$$

Y_j=0.33 all this values from AGMA standers [11]

2.5.1.3 Designing for pitching resistance:

The fundamental equation for pitting resistance (contact stress) is:-

$$\sigma_c = \sqrt{(W_t \times K_o \times K_v \times K_s \frac{KH}{dw1} \frac{ZR}{ZI})}$$

$$Z_I = 0.16 \, \frac{R}{R+1}$$

The equation for the allowable contact stress σ*c*, all is:

$$\sigma c,\ \text{all} = \frac{Sc}{SH}\frac{ZNZW}{Y\theta YZ}$$

2.6 N.X modeling software

Siemens NX software is an integrated product design, engineering and manufacturing solution that helps you deliver better products faster and more efficiently [11].

NX, formerly known as NX Unigraphics or usually just UG, is an advanced high-end CAD/CAM/CAE software package originally developed by Unigraphics, but since 2007 by (Siemens PLM Software) [12]. It is used, among other tasks, for:

1. Design (parametric and direct solid/surface modelling)
2. Engineering analysis (static, dynamic, electro-magnetic, thermal, using the finite element method, and fluid using the finite volume method).
3. Manufacturing finished design by using included machining modules.
4. NX is a direct competitor to TopSolid, CATIA, Creo, Autodesk Inventor, and SolidWorks.

2.6.1 NX advantages

NX is the industry’s most integrated, flexible and efficient solution for product design, engineering and manufacturing [13].

1. No other solution employs synchronous technology for flexible design in an open environment
2. No other solution integrates multi-discipline simulation so tightly into the development process

3. No other solution offers such a full range of advanced part manufacturing applications
4. No other solution is integrated as tightly with team center, the world's leading Product Lifecycle Management (PLM) platform [14].

2.6 Finite Element Analysis (FEA)

FEA becomes the best mean to show how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. Finite element analysis shows whether a product will break, wear out, or work the way it was designed. It is called analysis, but in the product development process, it is used to predict what is going to happen when the product is used [15].

FEA works by breaking down a real object into a large number (thousands to hundreds of thousands) of finite elements, such as little cubes. Mathematical equations help predict the behavior of each element. A computer then adds up all the individual behaviors to predict the behavior of the actual object [16].

Heislitz et al. [17] used the code PAM-STAMP to simulate the roll forming process. The strip was pulled through the rolls with a constant speed, without friction and without rotating tools. The explicit FEM code was used. They tried both eight node brick element and shell element and they also concluded that re-meshing reduced the simulation time when they used shell elements. They concluded that ''at the current status of development, the simulation of roll forming by using PAM- STAMP is not very efficient due to the required CPU''.

CHAPTER THREE

METHODOLOGY

CHAPTER THREE

METHEDOLOGY

3.1 Preface

This research is mainly based on design and modeling of a roll forming machine for sheet metal to produce a u-shape channel with specified dimensions as shown in Figure (3.1). The material of the product is mild steel EN ISO S 235 and the machine produces continuous product thus the length of the product doesn't affect the design.

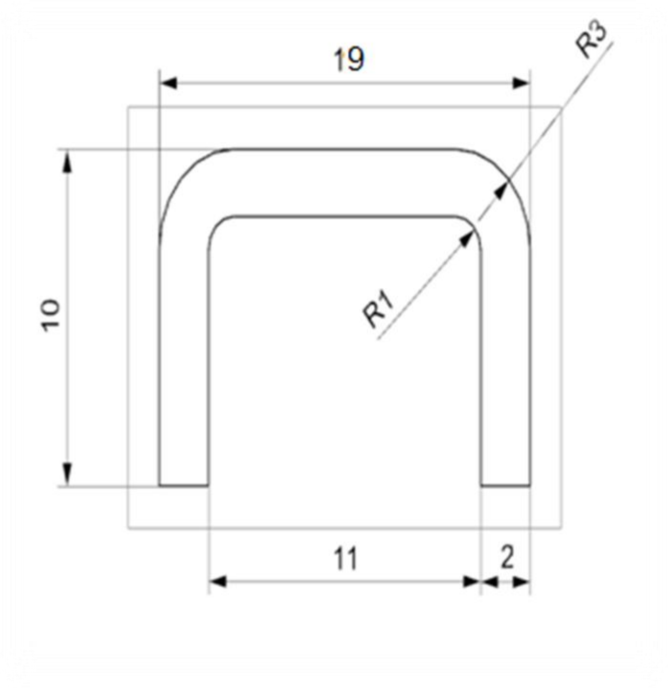


Figure 3.1: U-shape product dimensions

3.2 Design concept

The machine have same working concept of the pipe forming, it have several pairs of rollers in each step the sheet metal take a partially the shape of the U-shape channel, Figure (3.2) shows the conceptual design of the machine. These rollers are driven through a shaft which is connected with other shafts using sprocket and chain to allow adjusting the gap between each pair of the rollers, and the power source is electrical motor. Figure (3.2) shows the Steps of forming pipes, in each step the sheet metal take the profile partially till it become pipe profile, and Figure (3.3) shows the Steps of forming for the U-shape machine in each step the sheet metal take the profile partially till it become U-shape profile.

Figure (3.2) conceptual design of pipes

Figure (3.3) Steps of forming for the U-shape machine

3.3 Design calculations

Design will start with Calculation of the strip width, Number of forming steps, Speed reduction, shafts and rollers designs.

3.3.1 Strip width calculation

From the shape of the product the width will be: calculated as the following

Width = circumferential of the U-shape profile as shown in (figure 3.4)

Width = 38.28 = 38.3 mm

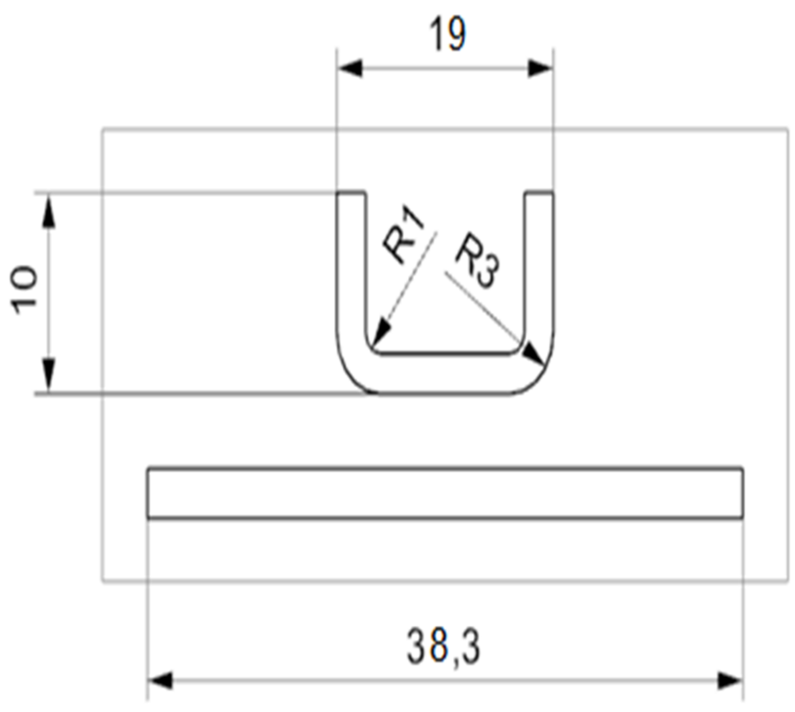


Figure 3.4: Strip width calculation

3.3.2 Number of forming steps

Dividing the total lengths with the horizontal spacing between passes will give the required number of forming stations (see equation below). Figure (3.5) shows distances from the edge of the strip to the edge of the product.

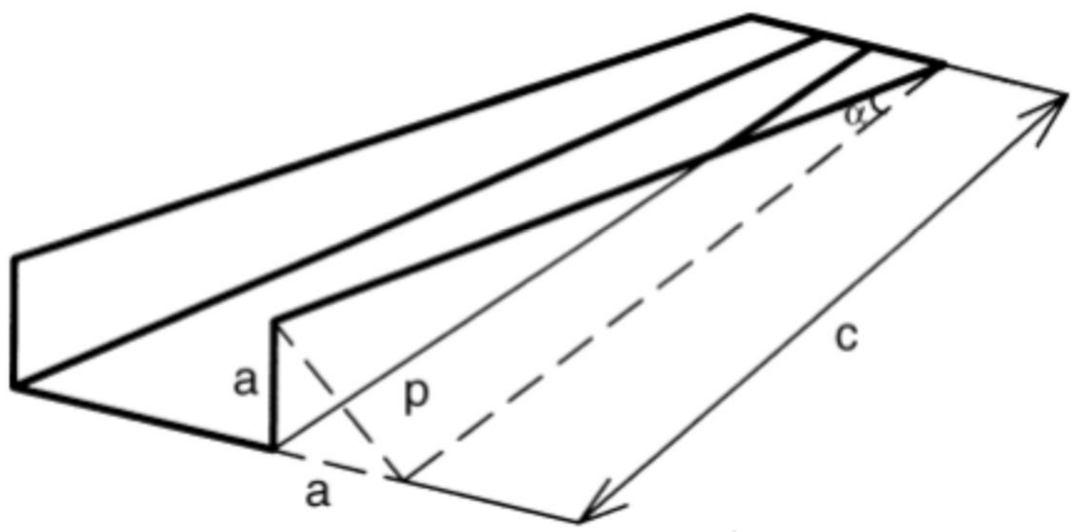


Figure 3.5: Product distances

we would like to calculate the value of (c) which is distance from the edge of the strip to the edge of the product.

$c = \frac{p}{\tan(\alpha)}$

$p^2=2\times a^2$

a = 10 mm

$p^2 = 2\times100= 200$ mm

p= 14.14 mm

Assuming α =1.5 (small value)

$c = \frac{14.14}{0.0262}$ = 539 = 600 mm (for better results)

This is the distance from first to the last pass .

Roller diameter = 100 mm

$N = \frac{C}{D}$+1 (Roll forming hand book)

$N = \frac{600}{100}$ = 6+1=7

Then the number of passes = 7 passes.

3.3.3 Speed reduction calculations

The roll forming needs very low velocity to press and give a good specifications product. And common production rate as practiced in Giad pipes manufacturing company doesn't exceeds 7.5 to 15 meters per minute.

Required speed = $\frac{8\,m}{60\,sec}$ = 0. 13 m/sec

Number of revelations = $\frac{60\times0.13}{3.14\times0.1}$ = 25.47

For better results we took it 25 RPM, rolling requires lower speeds.

The motor speed is 1450 RPM and must be decreased to 25 RPM, in two stages; first stage is gearbox and second stage using pulleys.

3.3.3.1 Design of gearbox

In this stage speed must be reduced from 1450 to 250 RPM.

Transmission ratio = $\frac{1450}{250}$ = 5.8

It is hard to reach the final speed in one step. The gear box design will be good if less variation at gears dimensions for this reason we will calculate the square root of the transmission ratio;

$\sqrt{(5.8)} = 2.408$

R=2.408

Figure 3.6 shows the gearbox diagram.

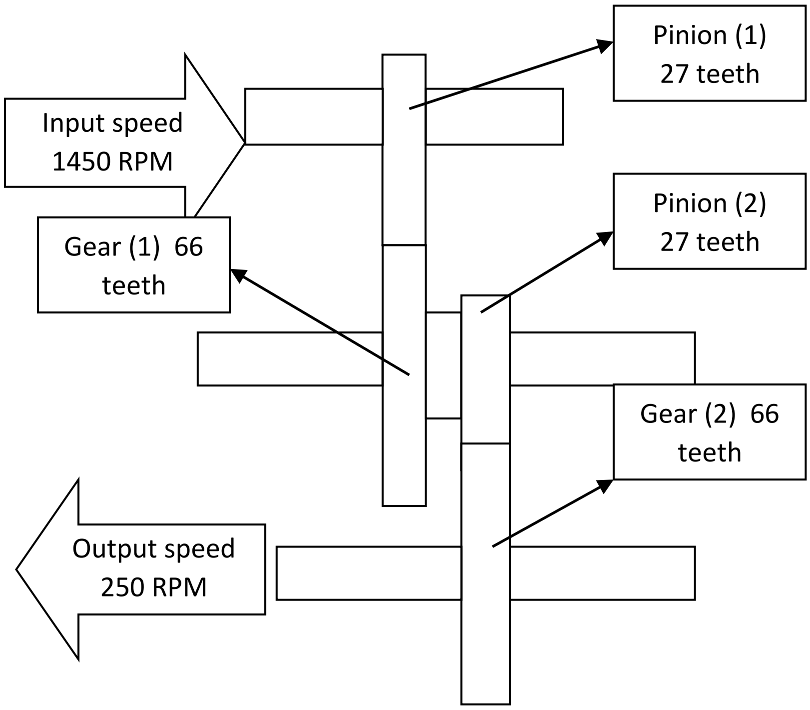


Figure 3.6: Gear box diagram

- Reliability of gears =90%
- Gears quality: commercial
- Gears type: spur gears
- The method use for gears design is AGMA method
- Material used in gears is through hardened steel grade one and it can be hardened from 200 to 400 HB take hardness number = 250.
- Life time of gearbox is 5 years,

The machine works for 16 hours per day

0.4×16=6.4 hours\day

Number of revolutions in the whole gear box life =

$N= 6.5\times250\times290\times60\times5 =14\times10^{6} \approx 10^{8}$

Standard surface conditions Z_R for gear teeth have not yet been established. When a detrimental surface finish effect is known to exist, AGMA specifies a value of Z_R greater than unity. Take Z_R=1.5

We used Excel software for the calculation of the gearbox Table (3.1) (3.2), (3.3) and (3.4) shows the calculation of spur gear design using AGMA standard.

Table 3.1 Calculation of pinion (1) design using AGMA standard

m	H	N	n	St	Qv	YN	Yz	Ko	KH	KB	Ks	Yθ	Yj	fs
4.50	18750	27	1450	221	7	0.93	0.832	1	1.6	1	1	1	0.3	2.5
d	v	B	A	Kv	Wt	Sall	b	bmx	bmn					
121.50	9.2257	0.731	65.04	1.4	2032.4	98.5	32.21471	70.7	42.4					
Sc	ZN	ZW	ZI	ZE	ZR	σc	Strength	FS						
866.00	0.79	1	0.203	195	1.5	582	822.2837	1.413						

Table 3.2 Calculation of Gear (1) design using AGMA standard

4.50	18750	66	606	221	7	0.93	0.832	1	1.6	1	1	1	0.3	2.5
d	v	B	A	Kv	Wt	Sall	b	bmx	bmn					
297.00	9.4251	0.731	65.04	1.5	1989.4	98.5	31.63182	70.7	42.4					
Sc	ZN	ZW	ZI	ZE	ZR	σc	Strength	FS						
866.00	0.79	1	0.203	195	1.5	372	822.2837	2.209						

Table 3.3 Calculation of pinion (2) design using AGMA standard

m	H	N	n	St	Qv	YN	Yz	Ko	KH	KB	Ks	Yθ	Yj	fs
4.50	18750	27	606	221	7	0.93	0.832	1	1.6	1	1	1	0.3	2.5
d	v	B	A	Kv	Wt	Sall	b	bmx	bmn					
121.50	3.8557	0.731	65.04	1.3	4862.9	98.5	68.99471	70.7	42.4					
Sc	ZN	ZW	ZI	ZE	ZR	σc	Strength	FS						
866.00	0.79	1	0.203	195	1.5	582	822.2837	1.413						

Table 3.4 Calculation of Gear (2) design using AGMA standard

m	H	N	n	St	Qv	YN	Yz	Ko	KH	KB	Ks	Yθ	Yj	fs
4.50	18750	66	250	221	7	0.93	0.832	1	1.6	1	1	1	0.3	2.5
d	v	B	A	Kv	Wt	Sall	b	bmx	bmn					
297.00	3.8882	0.731	65.04	1.3	4822.3	98.5	68.48066	70.7	42.4					
Sc	ZN	ZW	ZI	ZE	ZR	σc	Strength	FS						
866.00	0.79	1	0.203	195	1.5	372	822.2837	2.209						

3-3-2-1 AGMA stress equation

$$3\pi m \leq b \leq 5\pi m$$

Hence the face width value is acceptable**.**

3.3.3.2 Design of pulleys

The output speed of the gearbox is 250 RPM to reduce the 250 a pulley with 550 mm is used connected to the machine and other one connected to gearbox with diameter of 55 mm and the speed reduction equation will be 250× (55/550) = 25 RPM

3.3.4 Shaft design

Shaft length depends on the width of the rollers, bearings, sprockets and gears and adding clearances between those components.

3.3.4.1 Calculation of the applied force

From the material propagates for ISO S235 steel used for the product is 235 MPa

$F = s_y \times A$

$F = 370 \times A$

F = force required to deform a sheet metal

A= the area which force act on it

From the Nx software area which the force act on has been calculated as shown in Figure (3.6).

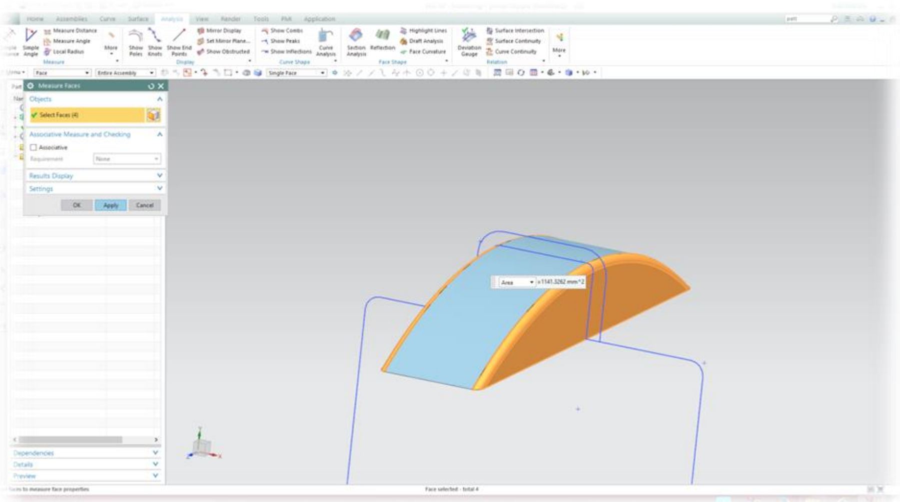


Figure 3.7: The area of applied force

A =570.66 =571 mm^2

F = 235000000×0.000571 =143..2 KN

F =144 KN

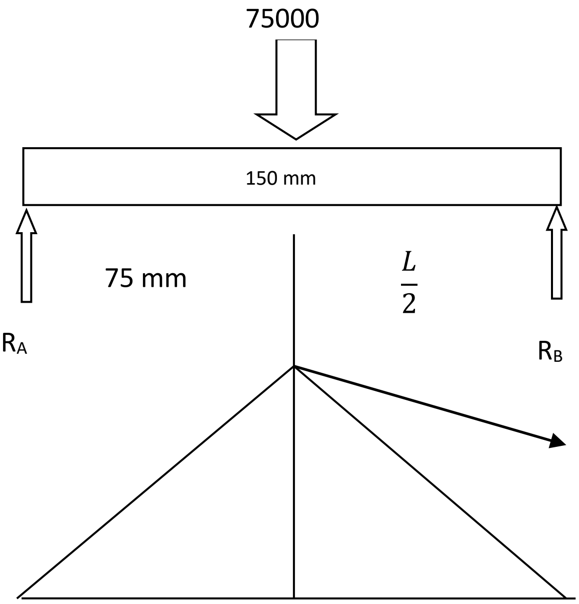
This is the required force to bend the sheet metal 90 deg

The same force affecting the driving shafts. Thus the force acting on the different steps will be;

144/6 = 24.33 KN

For more safety calculation we take 3 as safety factor then force will be 75 KN.

1050 HR steel has a mean ultimate tensile strength of Sut = 725 MPa and mean yield strength of 415MPa.The endurance limit is 362 MPa. This material is used to manufacture the shaft



$M_{max}=\frac{F\times L}{4}$

$$\frac{75000\times 150}{4}=2812\;KN.mm$$

Figure 3.8: Bending moment diagram for the shaft

$d_{shaft}=\left(\frac{32\;Ma}{\pi Sy}M\right)^{\frac{1}{3}}$

M_a is a midrange and alternating bending moments

$d=\left(\frac{32\times 1.5}{\pi\times 415}\;2812000\right)^{\frac{1}{3}}=48.79\approx 50mm$

The shaft standard diameter = 50 mm

$T = F\;\times d$

$T = 24330\times 50$

T = 1216500 Nmm

Design for static loading

$d_{\,shaft}=\frac{32\times 3}{\pi\times 415}\left((1216500^2+2812000^2)^{0.5}\right)^{\frac{1}{3}}=10.69\approx 11mm$

Design for dynamic loading

d_{shaft}=$\{\frac{16\times Sf}{\pi}\{\frac{1}{Se}[4(Kf \times Ma)^2+3(Kfs \times Ta)^2]^{0.5}+\frac{1}{Su}[4(Kf \times M)^2+3(Kfs \times Tm)^2]^{0.5}\}\}^{0.3}$

Kf=1.66, Kfs=1.63, Ma=1.5, Ta=0

d_{shaft}= $\{\frac{16\times 3}{\pi}$ $(\frac{1}{364}$ $[4(1.66 \times 1.5)^2+3(1.63 \times 0)^2]^{0.5}+\frac{1}{750}$ $[4(1.66 \times 2812000)^2+3(1.63 \times 1216500)^2]^{0.5}\}\}^{0.3}$ = 54.009 = 55mm

-Then we choose the biggest value, the shaft diameter is 55 mm.

3.3.5 Rollers design

The dimensions of the roller depends on the product shape and number of passes and mating shaft design to give the internal diameter. Froffm the shape of the product in each step the shape of the rollers can be designed as the following

3.3.5.1 First pair of rollers

The first one is the entry of the product (see figutr)

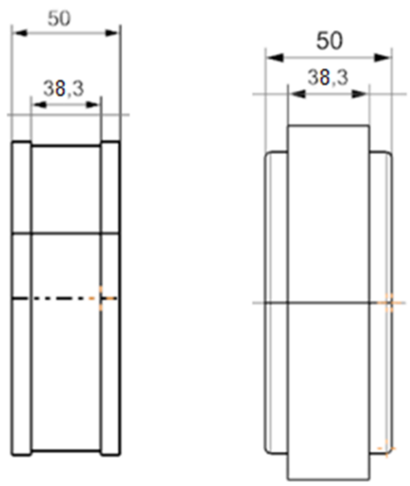


Figure 3.9: Female and male roller for the first step

3.3.5.2 Second pair of rollers

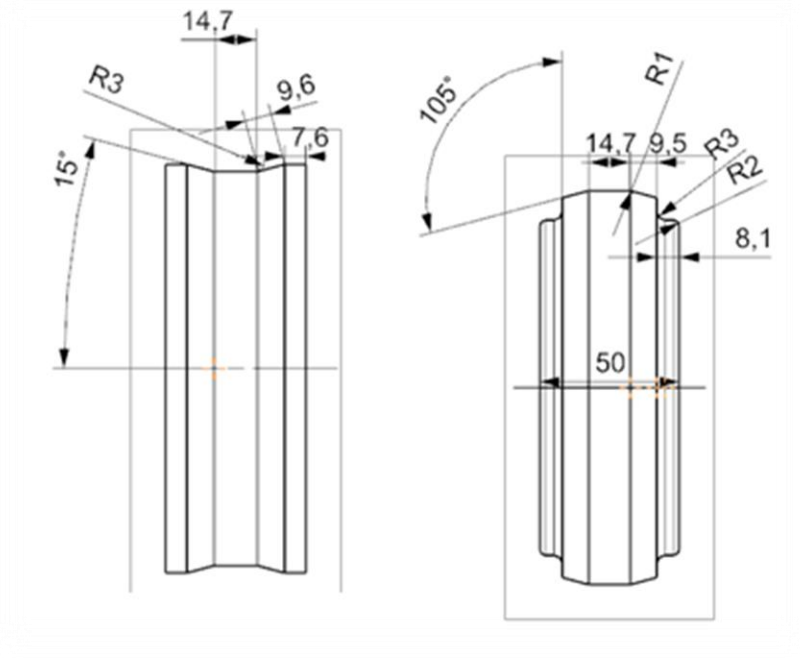
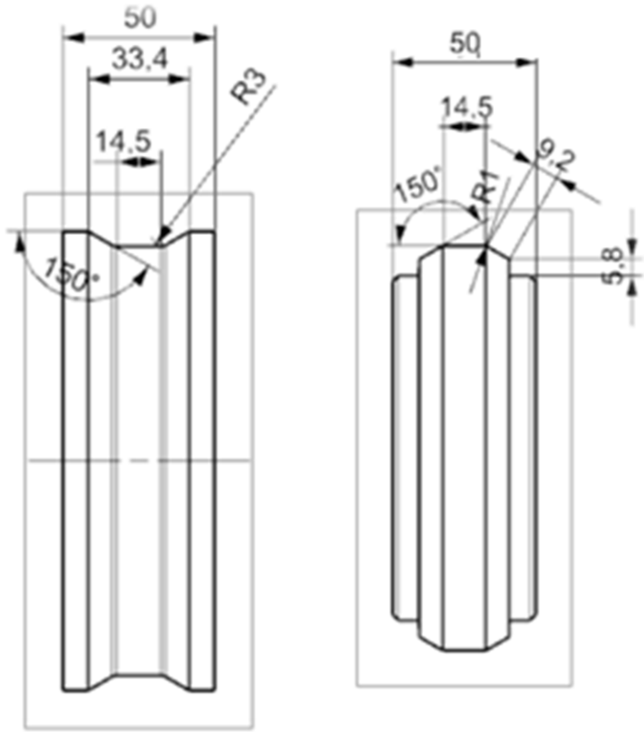


Figure 3.10: Female and male roller for the second step

3.3.5.3 Third pair of rollers



3.3.5.4 Fourth pair of rollers

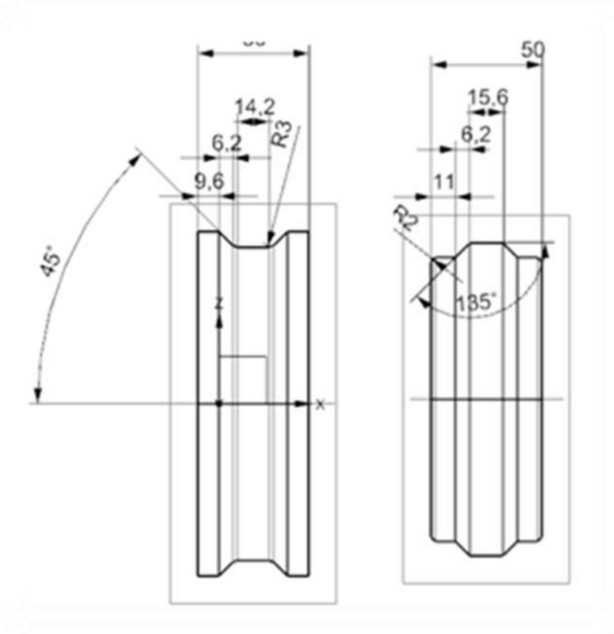


Figure 3.12: Female and male roller for the fourth step

3.3.5.5 Fifth pair of rollers

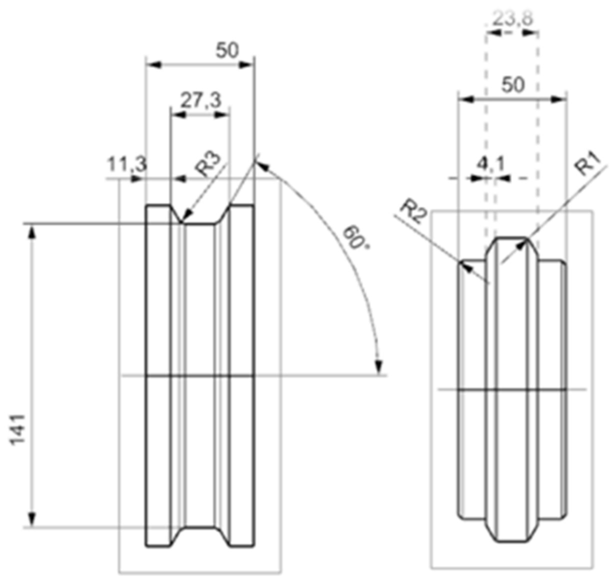


Figure 3.13: Female and male roller for the fifth step

3.3.5.6 Sixth pair of rollers

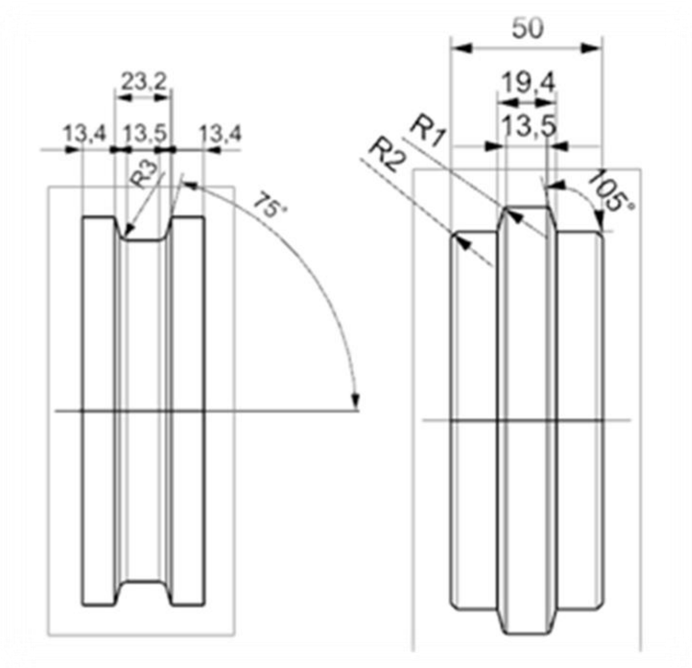


Figure 3.14: Female and male roller for the step

3.3.5.7 Seventh pair of rollers

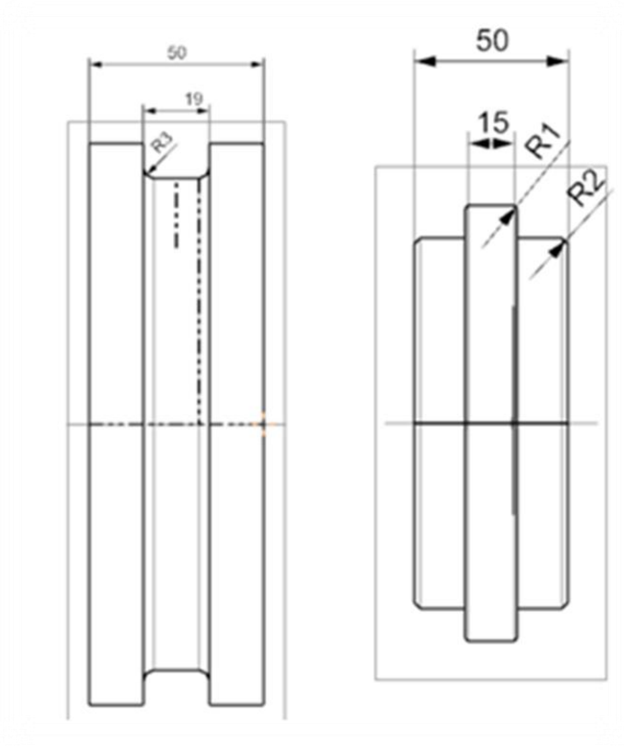


Figure 3.15: Female and male roller for the Seventh step

3.3.6 Transmitted power calculation

The required power depends on the total load applied, and the speed of the machine, and thus;

$p = F.V$

$v = 0.13$ m/sec

$F = 144$ kN

$p = 144 \times 0.13$

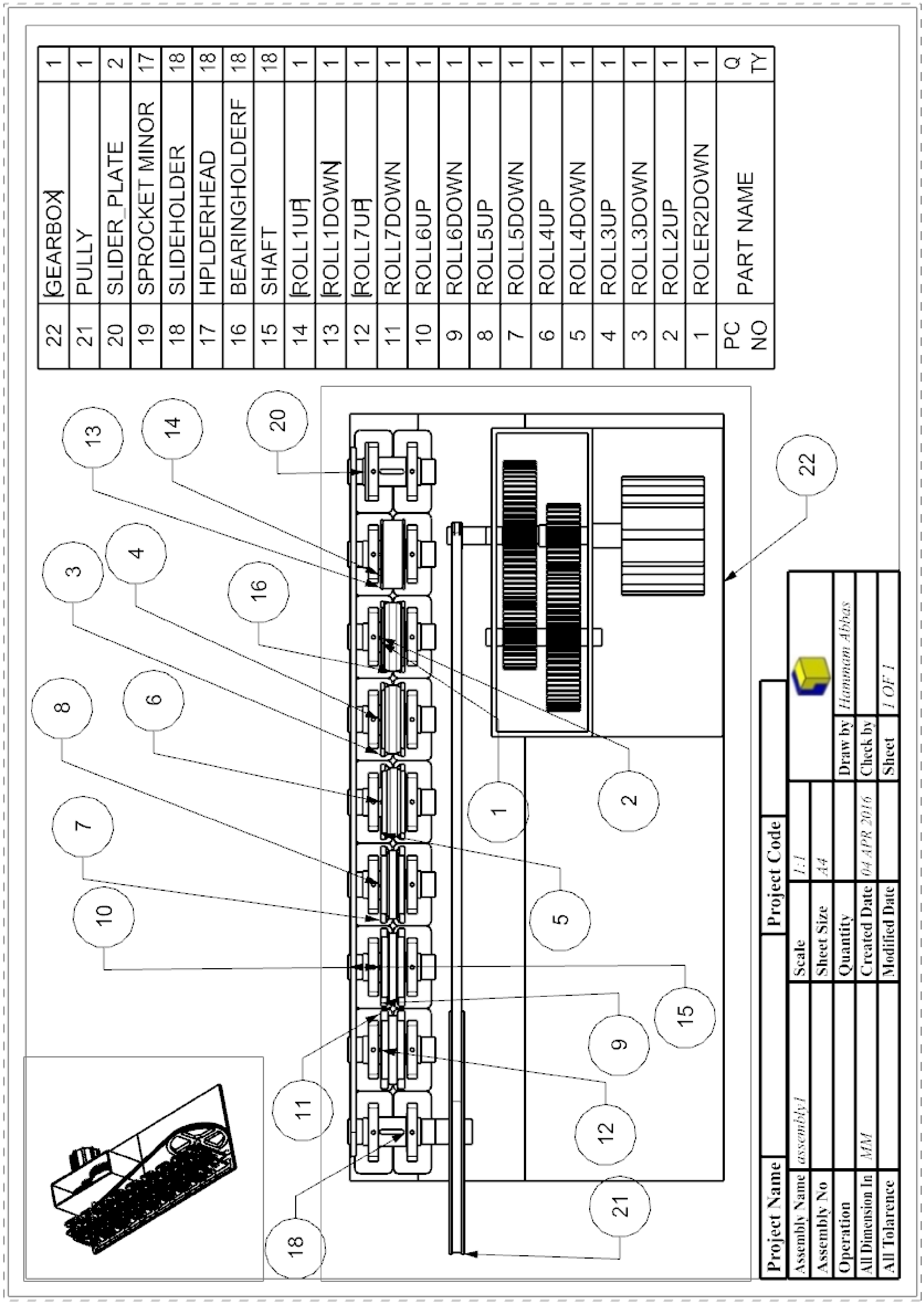
$p = 18.72$ kW

$p = 18720/750$

$p = 24.96 = 25$ hp

3.4 Machine sketch

The final drawing of machine elements is show in Figure (3.16), and (3.17) shows the part list of U-shape machine.



PC NO	PART NAME	QTY
22	GEARBOX	1
21	PULLY	1
20	SLIDER_PLATE	2
19	SPROCKET MINOR	17
18	SLIDEHOLDER	18
17	HPLDERHEAD	18
16	BEARINGHOLDERF	18
15	SHAFT	18
14	ROLL1UP	1
13	ROLL1DOWN	1
12	ROLL7UP	1
11	ROLL7DOWN	1
10	ROLL6UP	1
9	ROLL6DOWN	1
8	ROLL5UP	1
7	ROLL5DOWN	1
6	ROLL4UP	1
5	ROLL4DOWN	1
4	ROLL3UP	1
3	ROLL3DOWN	1
2	ROLL2UP	1
1	ROLER2DOWN	1

Figure 3.16: Part list of U-shape machine

PC NO	PART NAME	QTY
7	CYL ROLLER BRG, 2 ROW, CAGE, INCR ACCY, NNK, DIN,NN_3009_K	4
6	HEX CAP NUT, THIN, BIG, DIN,M12	4
5	HEX HEAD BOLT, DIN,M10X90	2
4	SLIDER_PLATE	5
3	SPROCKET MINOR	17
2	SLIDEHOLDER	19
1	BEARINGHOLDERF	18

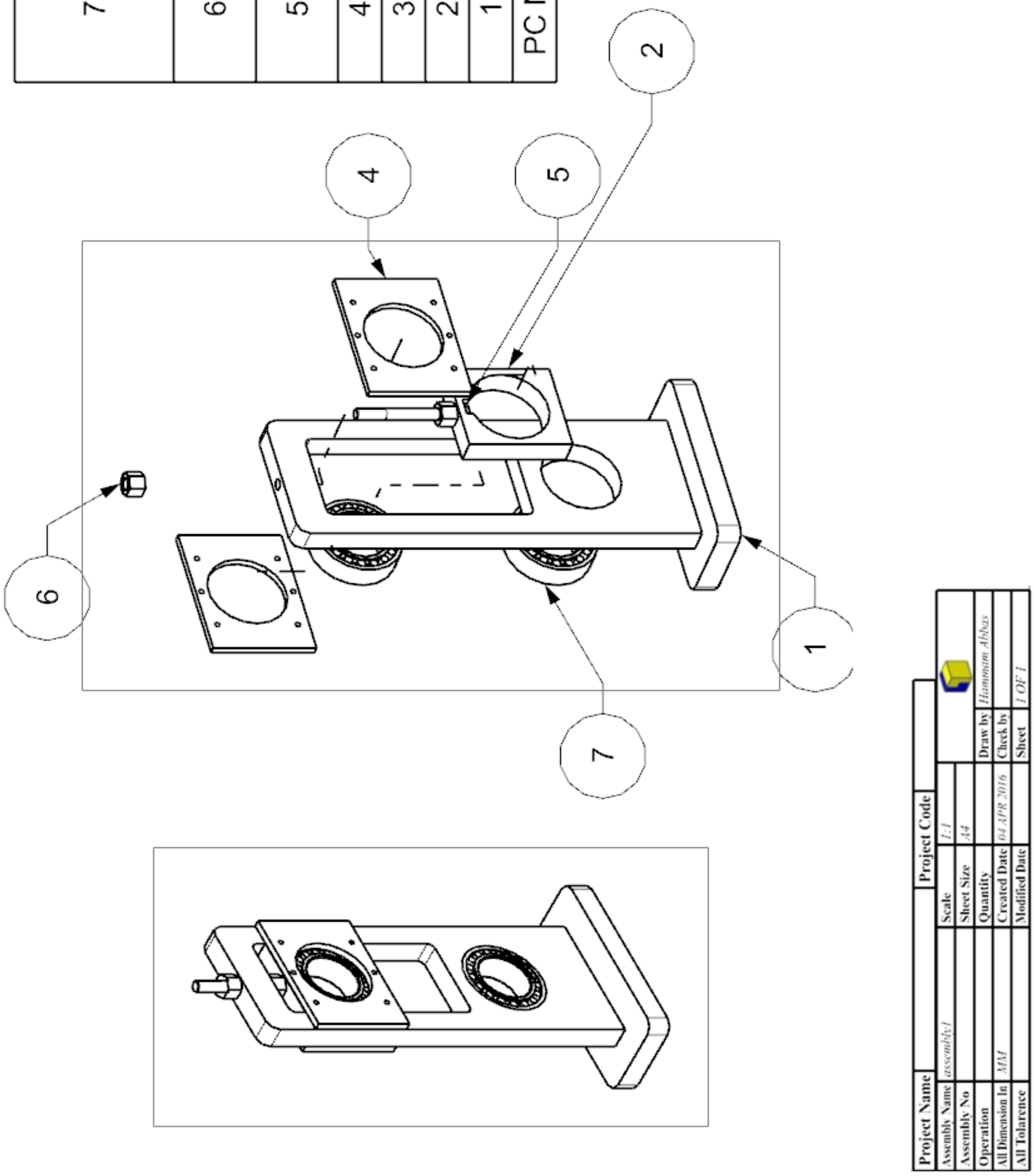


Figure 3.17: Part list of rollers holder

CHAPTER FOUR

RESULTS AND RESULTS DISCUSSION

CHAPTER FOUR

RESULTS AND RESULTS DISCUSSION

4.1 Preface

In this chapter we will show the model simulation Using Nastran structure analysis software built in NX software that we made and will show the results we got.

4.2 Structural analysis

With the aid of the Nx software Structural analysis will be applied to the sheet metal of the product and the rollers to and the results will be used in the optimization of the machine design.

4.2.1 Preprocesses

First step of the analysis is model preparing and then boundary conditions and parameters of the analysis will be specified and parts will be meshed and then solving and get the results.

4.2.2 Model preparing

Preparing the sheet-model model and applying the parameters on the sheet metal (see Figure 4.1).

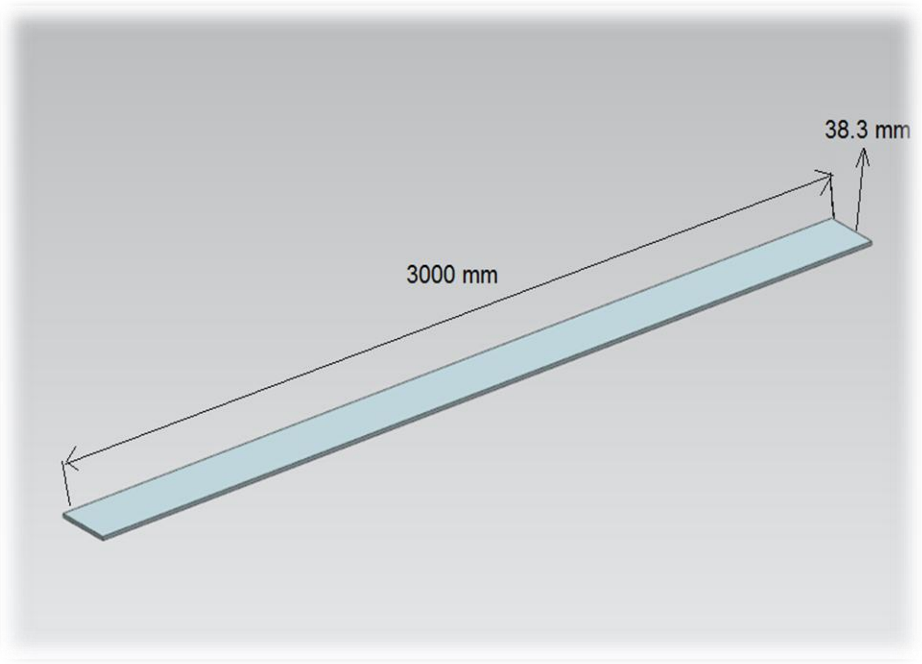


Figure 4.1: Sheet metal model

4.2.3 Analysis parameter

The middle edge is fixed (see figure 4.2) the force acting on the both edges of the sheet metal 144 KN.

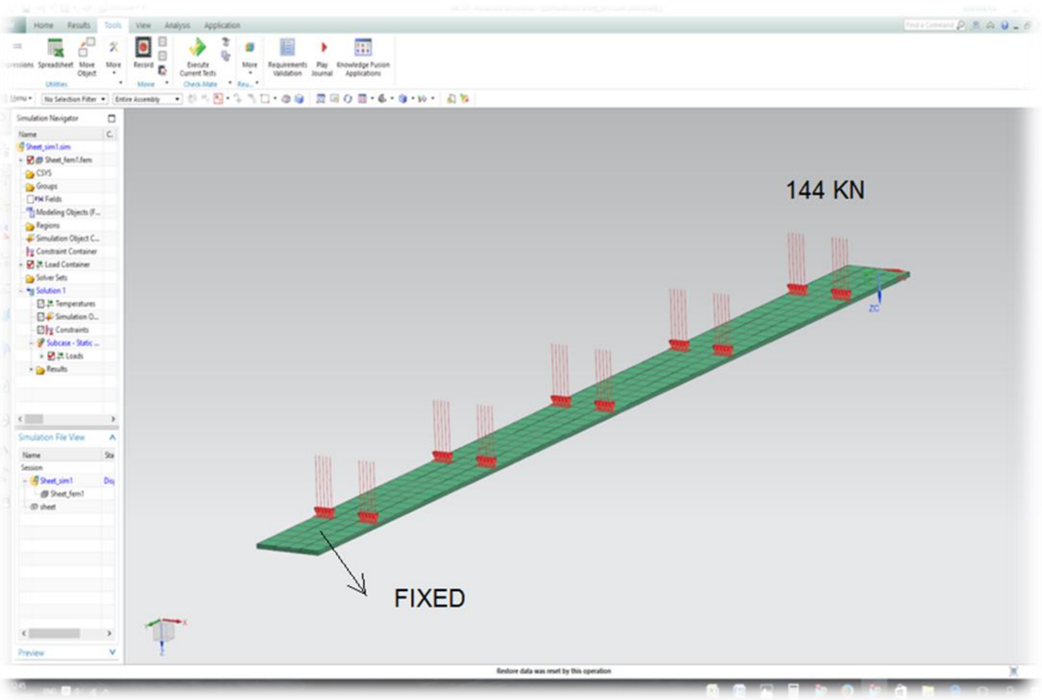


Figure 4.2: Analysis parameters

4.3 Post processes

The results of the analysis results for ;

1- Displacement of the sheet metal.
2- Stress element nodal.

4.3.1 Displacement of the sheet metal

The result of analysis shows that the sheet metal of the product bends when force of 144 KN Figure (4.3) shows the Displacement of the sheet metal. The displacement increases when we move from the middle to the edges of the sheet metal.

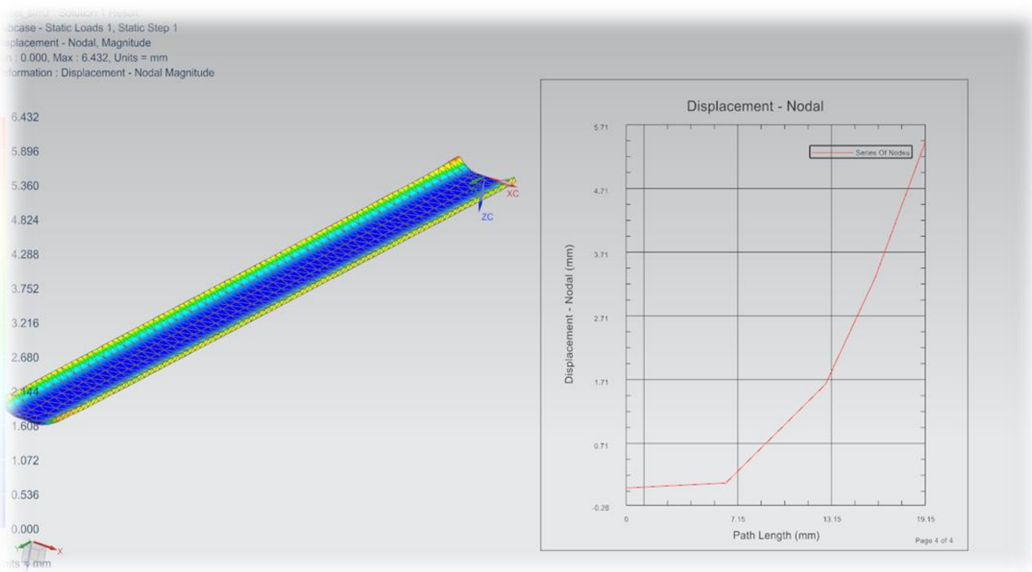


Figure 4.3: Displacement of the sheet metal.

4.3.2 Stress element nodal

The results shows the streets applied on the sheet metal, Figure (4.5) shows the stress element nodal result, from the figure it was notice that the maximum stress is in the middle edges of the product.

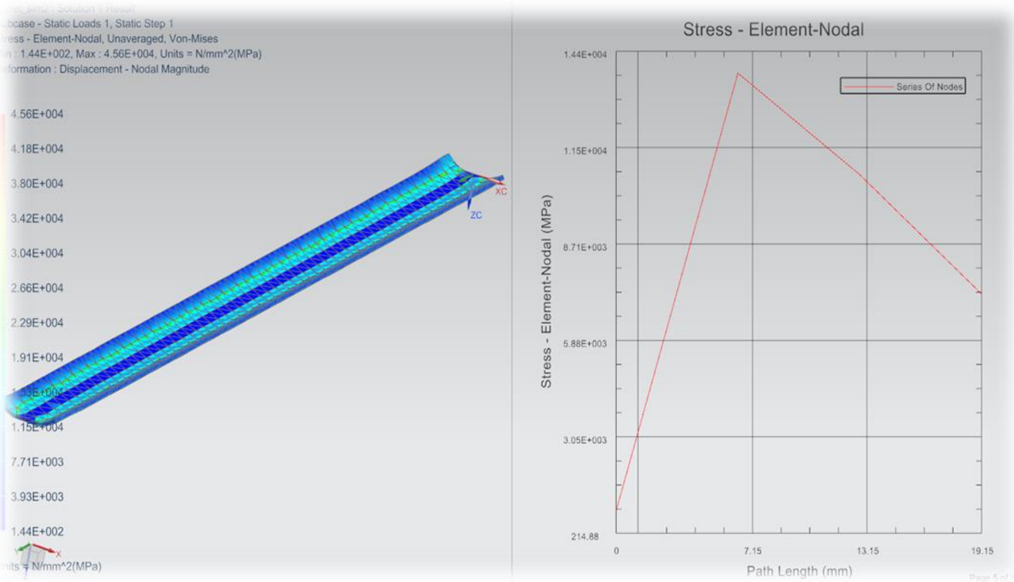


Figure 4.4: Stress element nodal result

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Machine elements has been designed, simulated ,analyzed and modeled

5.2Machine benefits and specifications

The design was made to develop the machine with the following benefits: Continuous production rate, Produces symmetric products, High quality products, Doesn’t need skilled operator, Less weight, Small size, Adjustable to a variety of products by design a new sets of rollers, Less cost and more safety.

Machine horse power is 25 hp, and the production rate is 0.13 m/s.

5.3 Recommendations

As we mentioned any single small piece of machine exposed to forces and moments and here is some recommendations needed to reconsider;

1- Design of the pulleys.
2- Design of keys.
3- Design of chain.
4- Selection of sprockets
5- Selection of bearings.
6- Calculate the tolerances
7- Design lubricating system.

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APPENDIX

Useful figures:

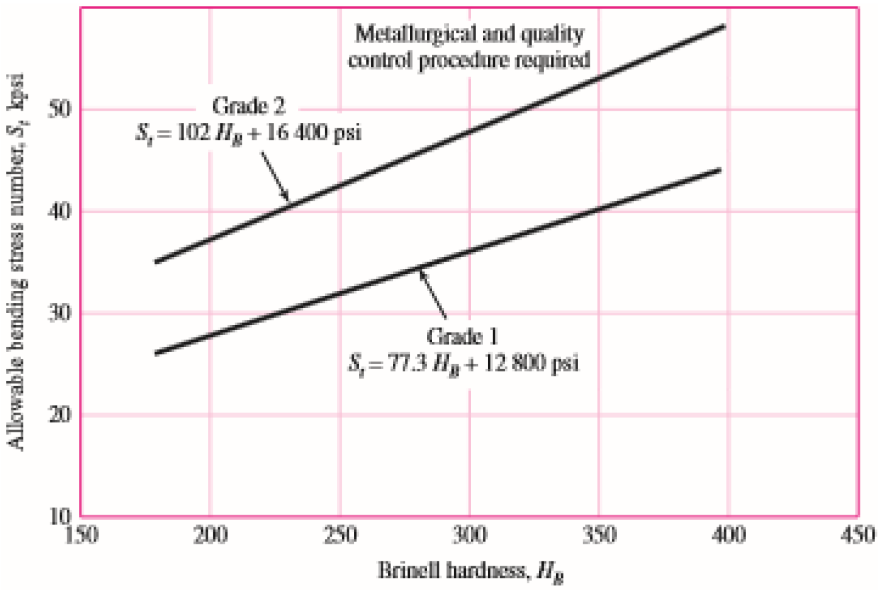

Figure 1: Allowable bending stress number for through-hardened steels. The SI equations are St =0.533HB+ 88.3 MPa, grade 1, and St =0.703HB +113 MPa, grade 2. (Source: ANSI/AGMA 2001-D04 and 2101-D04.)

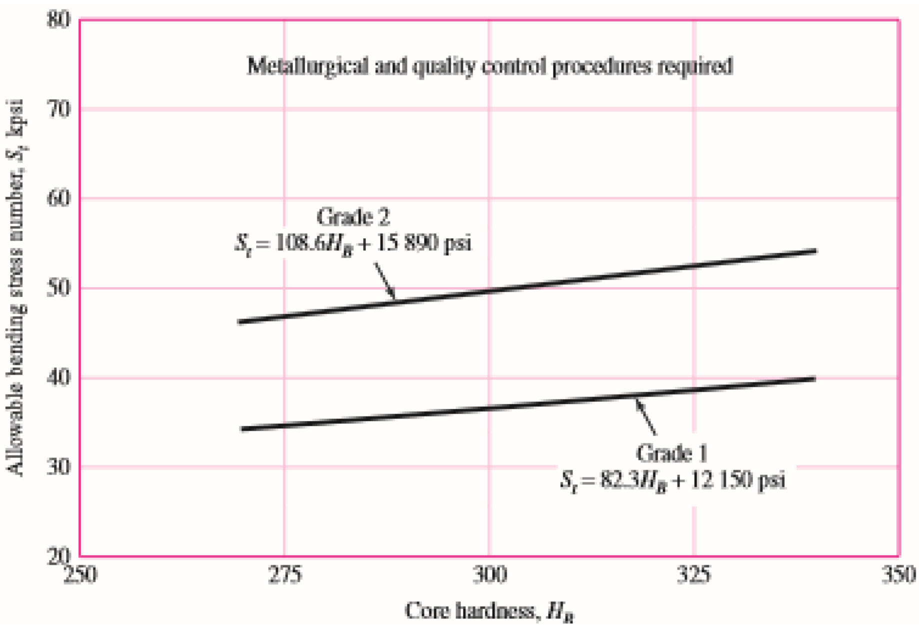

Figure 2: Allowable bending stress number for nitrided through- hardened steel gears (i.e., AISI 4140, 4340), St. The SI equations are St = 0.568HB +83.8 MPa, grade 1, and St = 0.749HB +110 MPa, grade 2. (Source: ANSI/AGMA 2001-D04 and 2101-D04.

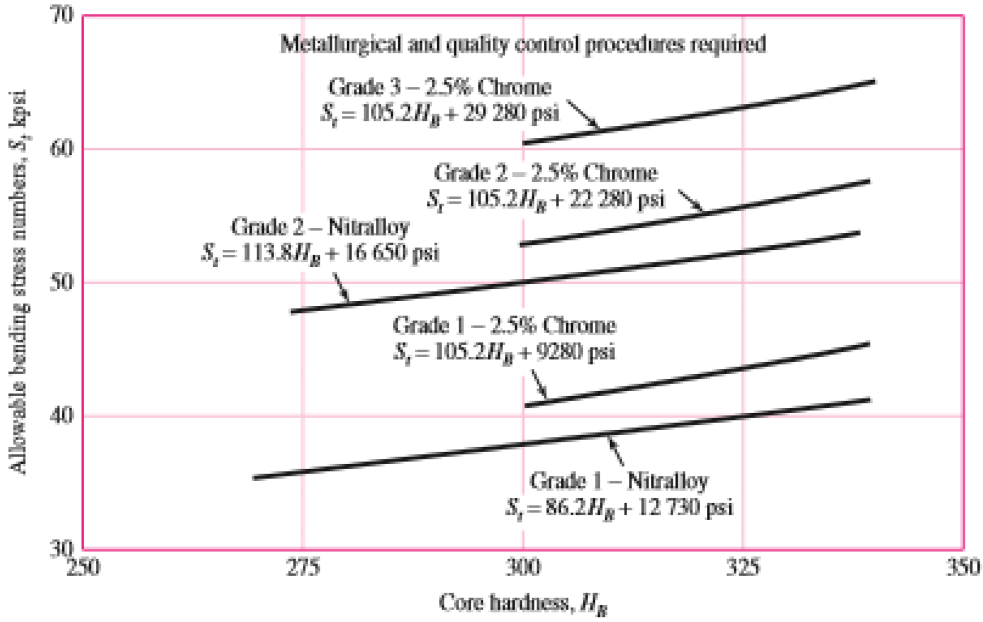

Figure 3: Allowable bending stress numbers for nitriding steel gears St. The SI equations are St = 0.594HB +87.76 MPa Nitralloy grade 1 St =0.784HB +114.81 MPa Nitralloy grade 2 St =0.7255HB +63.89 MPa 2.5% chrome, grade 1 St =0.7255HB +153.63 MPa 2.5% chrome, grade 2 St =0.7255HB +201.91 MPa 2.5% chrome, grade 3 (Source: ANSI/AGMA 2001- D04,2101-D04.)

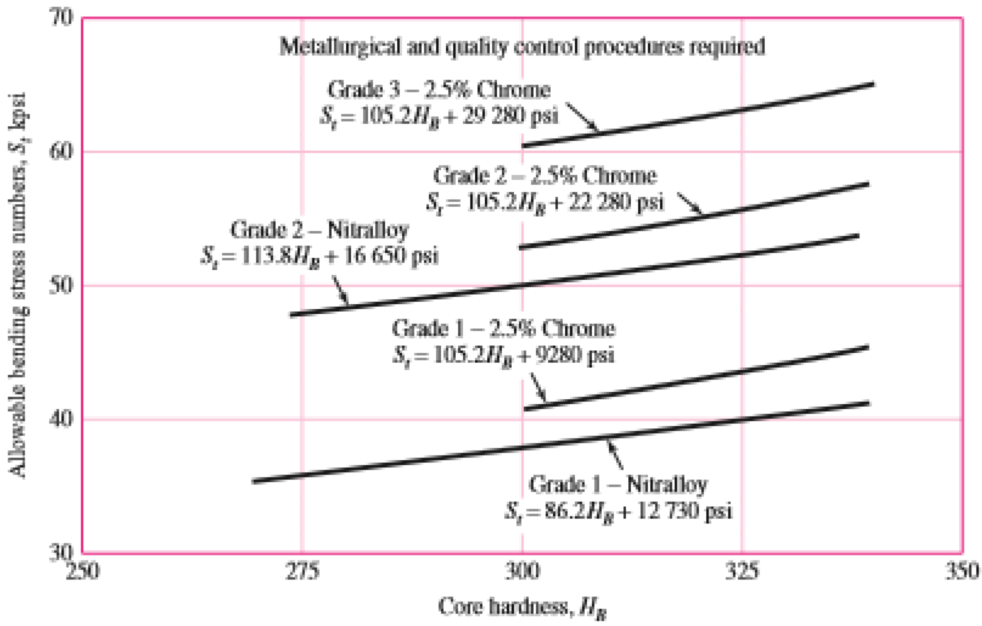

Figure 4: Allowable bending stress numbers for nitriding steel gears St. The SI equations are St = 0.594HB +87.76 MPa Nitralloy grade 1 St =0.784HB +114.81 MPa Nitralloy grade 2 St =0.7255HB +63.89 MPa 2.5% chrome, grade 1 St =0.7255HB +153.63 MPa 2.5% chrome, grade 2 St =0.7255HB +201.91 MPa 2.5% chrome, grade 3 (Source: ANSI/AGMA 2001- D04,2101-D04.

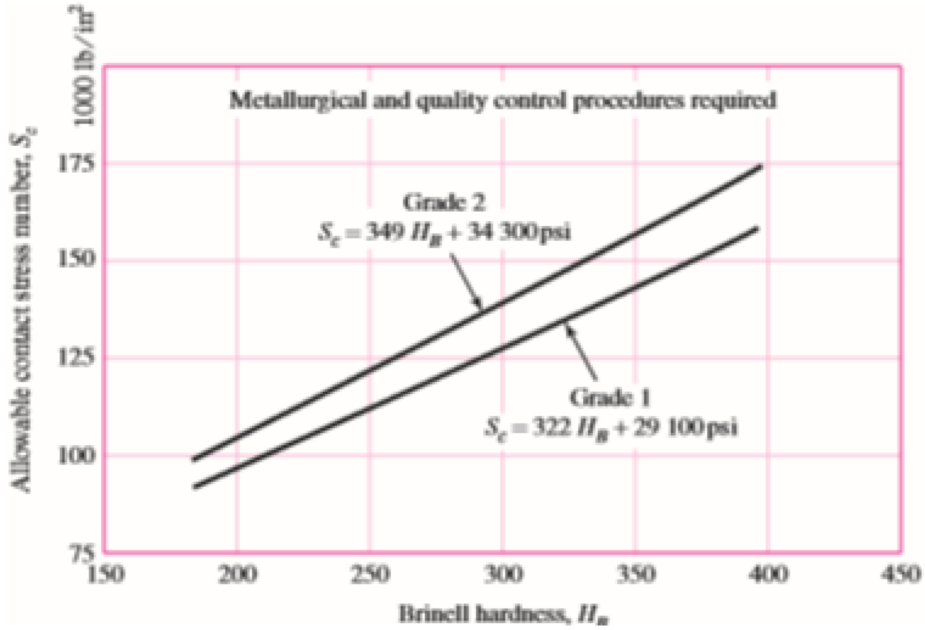

Figure 5: Allowable bending stress numbers for nitriding steel gears St. The SI equations are St = 0.594HB +87.76 MPa Nitralloy grade 1 St =0.784HB +114.81 MPa Nitralloy grade 2 St =0.7255HB +63.89 MPa 2.5% chrome, grade 1 St =0.7255HB +153.63 MPa 2.5% chrome, grade 2 St =0.7255HB +201.91 MPa 2.5% chrome, grade 3 (Source: ANSI/AGMA 2001-D04,2101-D04.)

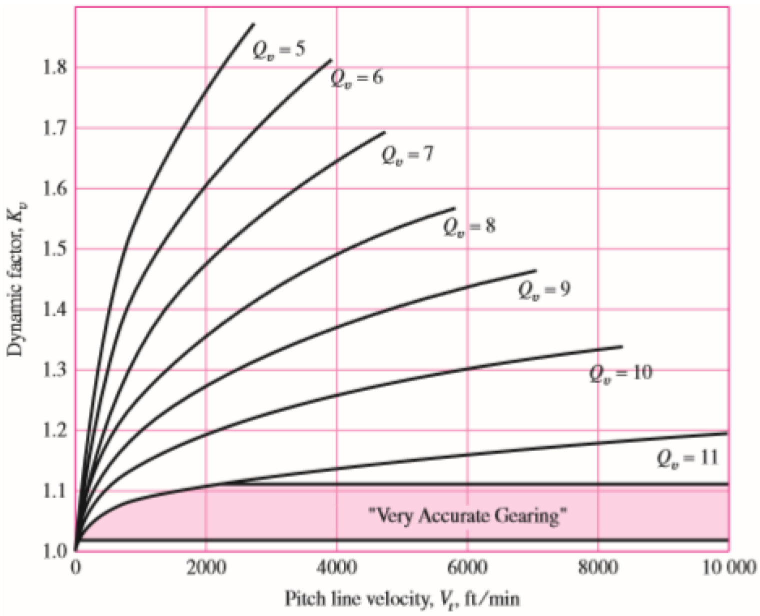

Figure 6: Dynamic factor Kv. The equations to these curves are given by Eq. (14–27) and the end points by Eq. (14–29). (ANSI/AGMA 2001-D04, Annex A)