Republic of Yemen
Ministry of Higher Education and Scientific Research
University of Emirates
Faculty of engineering
Mechatronics

DESIGN AND DEVELOPMENT OF HIGH ACCURACY FIVE-AXES CNC MACHINE

تصميم وتطوير ماكينة سي ان سي خمسة محاور عالية الدقة

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A graduation project document submitted to the department of Engineering as partial fulfillment of the requirements for bachelor degree in Mechatronics.

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Supervisor Certification

I certify that the preparation of this project entitled

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Abstract

In the machining of complicated surfaces, the cutters with large length/diameter ratios are used widely and the deformation of the machining system is one of the principal error sources. During the process planning stage, the cutting direction angle, the cutter lead and tilt angles are usually optimized to minimize the force induced error

Multi-axis milling (especially five-axis) is in the ascendant for high precision manufacturing of a product with a sculptured surface such as ship propeller, owing to its multi-axis linkage and resulting outstanding superiorities. Needs of a faster-improving manufacturing level of sculptured surface milling are derived by higher performance requirement of complicated equipment, which makes the planning of tool orientations more significant and challenging.

This paper builds a tool orientation optimization model with inclusion of the influence of deflection error caused by cutting force to achieve better machining precision controlling in five-axis sculptured surface milling. The basic idea of the optimization method is described firstly, followed by the prediction of cutter deflection error. Then determining processes of the related subset to restrain the tool orientations are developed. Lastly, comparative experiments are designed and performed through milling a propeller rotor possessing numerous blades in a five-axis machining center. By comparison with several other tool orientation methods, the average values and volatility of deflection error are both suppressed better utilizing the optimization modeling. The experiment results reflect that it is insufficient to consider single geometric constraint or kinematic constraint, and greater attention should be paid to the role of cutter deflection caused by cutting force in planning the tool orientations.

Although 5-axis free form surface machining is commonly proposed in CAD/CAM software, several issues still need to be addressed and especially collision avoidance between the tool and the part. Indeed, advanced user skills are often required to define smooth tool axis orientations along the tool path in high speed machining. In the literature, the problem of collision avoidance is mainly treated as an iterative process based on local and global collision tests with a geometrical method. In this paper, an innovative method based on physical modeling is used to generate 5-axis collision-free smooth tool paths.

In the proposed approach, the ball-end tool is considered as a rigid body moving in the 3D space on which repulsive forces, deriving from a scalar potential field attached to the check surfaces, and attractive forces are acting. A study of the check surface

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

With the on-going development of technology and economy, new industrial requirements such as high precision, good quality, high production rates and low Production costs are increasingly demanded. Most of such requirements, including dimensional accuracy, conformance to tolerances of finished products and production rate can be met with better machine tools. With the help of CNC technology, machine tools today are not limited to human capabilities and are able to make ultra-precision products down to Nano scales in a much faster manner. The traditional design philosophy of machine tools is multifunctional and highest precision possible. For example, a shank with spindle together with tailstock can be added onto a standard three axis vertical milling machine to become a multifunctional drilling-milling-turning machine, meaning the machine tool is designed to be used for multiple instead of single purposes. However, with the dramatic increase of industry varieties and the growing demand of miniature products, these general-purpose machine tools are not efficient, either in terms of machine time or cost, in manufacturing products with special sizes and precision requirements.

1.2 PROBLEM STATEMENT:

Many things are becoming smaller, thinner, and more complicated in shape as technology advances. The goal of this project is to solve the issue of machining different types of work. For batch runs and one-off prototypes, 5-axis desktop CNC machines offer high-quality, precisely controlled milling and 3D printing. They are a fantastic option for people or any organization because of their desktop size and affordable price. By avoiding multiple-turn setups, 5-axis capabilities shorten operation times, streamlines production, and enables the milling of highly functional parts on a variety of materials

1.3 PROJECT OBJECTIVES:

The following list might be used to outline the project's primary goals:

1. Making use of the knowledge we acquired during our four years of study in the department of Mechatronics Engineering.
2. To make an optimal design that satisfy the requirement
3. Automating one of the most crucial industrial systems.
4. Creating an adaptable system to handle numerous product changes.
5. The reduction of ergonomic injury.
6. Lowering manufacturing costs by doing away with the need for labor.
7. Acquiring the bare minimum working space needs.
8. Getting the practical Knowledge of wiring a scientific documentation according to the international guidelines.

1.4 MOTIVATION.

The motive behind this project comes from the needs of the labor market for this project and also for the products we work, which affects a large percentage of customers from engineers and technicians who want complex parts that meet their needs faster instead of ordering them from abroad, because this project is not available in Yemen and that is why we decided to make it And to become the first in the local industry we intend to complete this CNC 5-AXIS project.

Applying principles and knowledge from mechatronics engineering to a full project is another motivation. Developing cooperation abilities can also help you create integrated engineering machines, which are extremely tough to create on your alone.

1.5 METHODOLOGY

- Literature review and related work.
- Implementation of the project with Arduino because it is cheap, in order to understand the working mechanism of “CNC 5 axis" machines.
- design the machine "as CAD" in the "Solid Work" program.
- simulate for kinematic in the "PowerMill" program.
- simulate for dynamic in MATLAB.
- deducing the mathematical equations of movement.
- correcting the parameters to reach the required values.
- making a CAM for all CAD pieces and then manufacturing them.
- assembling the pieces.

- preparing the "fusion360 and cimatron15" program to generate a toolpath 5 axis

1.6 RESEARCH ORGANIZATION

In addition to this chapter, this research is organized as follows:

- Chapter 1 Introductions
- Chapter 2 Literature Review
- Chapter 3 Project Methodology
- Chapter 4 mathematical and simulation
- Chapter5 implementation
- Chapter 6 Conclusion and Future Work

CHAPTER 2
BACKGROUND AND LITERATURE REVIEW

2.1 BACKGROUND

In 1949, the first CNC machine was invented. Since then, CNCs have evolved rapidly changing industries and manufacturing forever. Depending on your budget, time, work material, shape, and size of the product, you can choose from several types of CNC machines to make almost anything you want. A precision CNC machine tool called a 5-axis CNC machine, commonly referred to as a 5-axis Machining Center, removes materials from a workpiece using a variety of cutting tools. It does this by placing the item or simultaneously cutting it along five separate directional axes until the required shape is obtained. A radial drilling machine, which moves up and down, would be an illustration of a 1-axis machine in more detail (Z axis). In accordance with the same reasoning, a 3-axis CNC machine may move forward and backward (X axis), up and down (Z axis), and right to left (Y axis). Two more rotary axes on a 5-axis CNC machine provide access to an endless array of milling options. Rotating axes A, B, and C, which revolve around the X, Y, and Z axes, respectively, are examples of rotary axes. Even if there are only three additional axes and not two, the overall number of axes is still five. Machine-dependent, the additional axes can be combined in any way, including AB, AC, or BC. The additional axes allow for undercutting, which is previously only possible on machines with fewer axes if the item was repositioned using extensive fixtures. A 5-axis CNC machine avoids circumstances that are not only time-consuming but also potentially error-prone in machines with fewer axes.

2.1.1 **HOW CNC MACHINE WORKS**

1. First, the part program is inserted into the MCU of the CNC.
2. In MCU all the data process takes place and according to the program prepared, it prepares all the motion commands and sends it to the driving system.
3. The drive system works as the motion commands are sent by MCU. The drive system controls the motion and velocity of the machine tool.
4. The feedback system records the position and velocity measurement of the machine tool and sends a feedback signal to the MCU.
5. In MCU, the feedback signals are compared with the reference signals and if there are errors, it corrects it and sends new signals to the machine tool for the right operation to happen.
6. A display unit is used to see all the commands, programs and other important data. It acts as the eye of the machine.

2.2 APPLICATION:

Almost every manufacturing industry uses CNC machines. With an increase in the competitive environment and demands, the demand for CNC usage has increased to a greater extent. The machine tools that come with the CNC are lathe, mills, shaper, welding, etc. The industries that are using CNC machines are the automotive industry, metal removing industries, industries of fabricating metals, electrical discharge machining industries, wood industries, etc

2.3 TYPES OF CNC MACHINE

There are types of CNC machines:

1. CNC Lathes
2. CNC Mills,
3. CNC drilling,
4. CNC Grinding,
5. CNC Plasma Cutting Machines,
6. CNC Laser Cutters,
7. 3-Axis high speed CNC,
8. ATC CNC Router.

Types of 5-axis

- Table/Table 5-axis Machines
- Head/Head 5-axis Machines (5-AXIS CNC MILL).

2.3.1 CNC LATHE MACHINE

Lathe CNC machines are defined by their capability to turn materials during operation. They have a smaller number of axes than CNC milling machines, making them shorter and more compact. CNC lathe machines consist of a lathe at the center that manages and transfers material programmatically to the computer. At the present time, it is widely used as a lathe due to its fast and accurate function. Once the initial setup is done, a semi-skilled worker can operate it easily. This type of lathe is also used for mass production such as capstan and turret. But there is no programmed fed system.

Figure 2.1: CNC Lathe Machine

2.3.2 CNC MILLING MACHINE

It is one of the most common types of CNC machine, that have built-in tools for drilling and cutting. The materials are located inside a milling CNC machine, after which the computer will lead the tools to drill or cut them. Most of the CNC milling machines are available in 3 to 6-axis configurations. This machine is used to produce gears like spur gear and is also used to drill the workpiece bore and make slots by inserting part program into the system. A semi-skilled worker can operate it easily. It is also used for mass production such as a capstan and turret. But there is no programmed fed system. The parts made by this machine are very precise in dimensional tolerance.

Figure 2.2: CNC Milling Machine

2.3.3 **CNC DRILLING MACHINE**

The CNC drilling machine is typically applied for mass production. Drilling machines, however, often have a multi-function machining center that is occasionally mingled and sometimes twisted. The greatest sink time for CNC drilling is with tool changes, so for speed, the variation of hole diameter must be reduced. The fastest machine size for drilling holes consists of several spindles in the turret with drills of different diameters pre-mounted for drilling. This type of CNC machine can perform reaming, counterboring, and tapping holes.

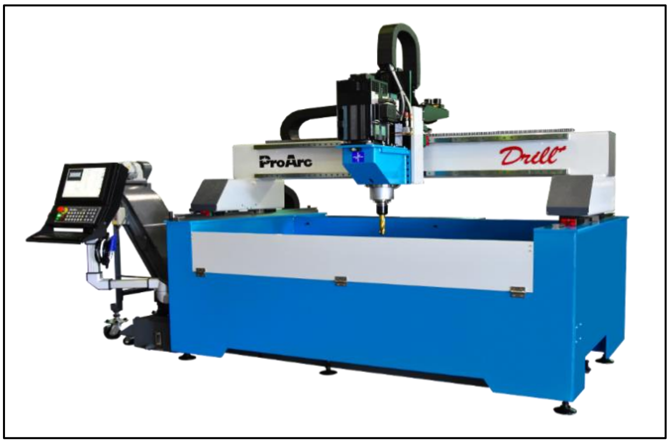

Figure 2.3: CNC Drilling Machine

2.3.4 **CNC GRINDING MACHINE**

It is a precision performance tool that uses a rotating wheel to cut metal away from the metal. Typically, CNC grinding machines are used for camshafts, ball bearings, transmission shafts, and other working pieces, which require an accurate and correct finish. Numerous pieces made using a CNC grinding machine are cylindrical. A grinding machine also use to make other types of workpieces. In CNC grinding machines “CNC” holds for computerized numerical control.

Figure 2.4: CNC Grinding Machine

2.3.5 CNC CUTTING MACHINE

The Laser-cutting CNC machines are designed to cut through hard materials, although they use a laser to perform this task instead of a plasma torch. Lasers offer a high degree of accuracy, but they are not as effective as plasma torches. Laser-cutting CNC machines commonly use one of these three types of lasers that is CO2, neodymium (Nd), or yttrium-aluminum-garnet (Nd: YAG).

Figure 2.5: CNC Cutting Machine

2.3.6 CNC PLASMA CUTTING MACHINE

This machine similar to milling CNC machines, plasma-cutting CNC machines are also used to cut materials. But they differ from their milling counterparts by doing this operation applying a plasma torch. A plasma cutting machine is defined as it is a method that cuts by electrically conductive materials using an accelerated stream of hot plasma. These types of CNC machine feature a high-powered torch that’s capable to cut through rough materials like metal.

Figure 2.6: CNC Plasma Cutting Machine

2.3.7 5-AXIS HIGH SPEED CNC MACHINING CENTER WITH MONOBLOC STRUCTURE ANTARES

Its compact design easily fits into any production environment, while still benefitting from the large working envelope. The monobloc structure ensures stiffness and accuracy throughout its lifetime, maximum accessibility to the working area for piece loading / unloading by manual or automated systems. Full acoustically-lined enclosure to contain dust and to reduce the noise generated by the machining operation, the advanced design of the structure, a result of CMS’ research center, and the technical solutions adopted guarantee rigidity and precision over time so that the high finish and accuracy of the workpieces remains a constant feature of your production over the years. The accuracy of ANTARES CMS boasts the industry's best-in-class performance in its category: +23% machining precision and accuracy.

Figure 2.7: 5-Axis high speed CNC machining center with monobloc structure Antares

2.3.8 ATC CNC ROUTER

Small 3D CNC Router is a 4 axis CNC machine with automatic tool changer spindle, good at 2D/3D wood carving and engraving, it has a smart table size of 1200*1200mm / 4'x4'. The 4 axis ATC CNC router here refers to the ATC CNC router with a rotating spindle, which can swing 180° from left to right. The working path of the 4 axis ATC CNC router includes X, Y, Z and A axis. So it is also suitable for cutting and engraving 3D workpieces, such as foam molds, wood and stone sculpture and statues except for the basic applications. In addition, it can also drill side holes or make side grooves or slots on the side of wood panels. The 4 axis ATC CNC router has an extensive use in sculpture and statue making, mold, furniture, decoration, craft, advertising and other fields.

Figure 2.8: ATC CNC Router

2.4 MAIN COMPONENTS OF CNC SYSTEM

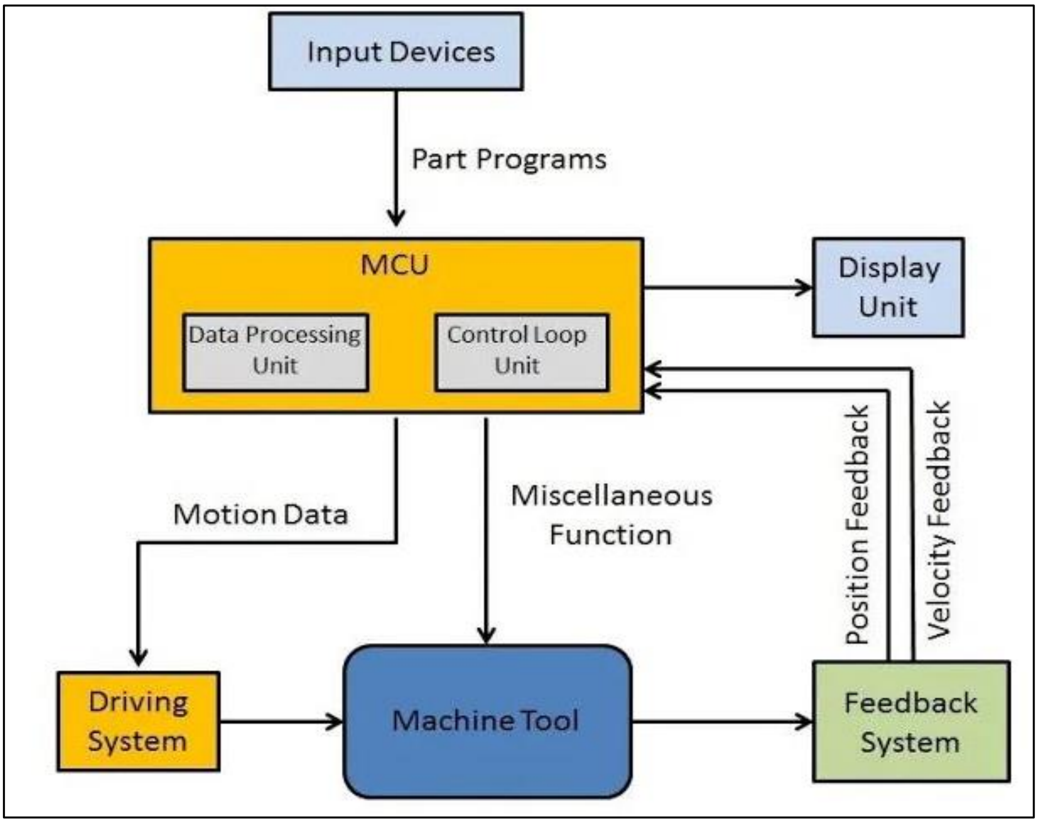

Figure 2.9: Components of CNC system

There are five main components of the numerical control or NC system. These are:

2.4.1 PROGRAM OF INSTRUCTIONS

A typical desktop program instructs computers to perform specific tasks. The NC machine's program of instructions is a step-by-step set of instructions that tells the machine what it needs to do. These instructions can tell the machine to turn the piece of metal to a specific diameter, drill a hole to a specific length, form a specific shape, and so on. The set of instructions is coded in numerical or symbolic form and written on a specific medium that can be interpreted by the NC machine's controller unit.

Previously, punched cards, magnetic tapes, and 35mm motion picture film were commonly used for writing instructions, but now 1-inch-wide punched tape is more commonly used. The program instructions are written by an expert with both programming and machining knowledge. The individual should be familiar with the various steps of machining required to manufacture a specific product and be able to write these steps in the form of a program that can be understood by the NC machine's control unit, which will eventually direct the machine tool to perform the required machining operations.

Manual data input (MDI) is another method for manually entering instructions into the controller unit. This method is used for very simple jobs. Then there's direct numerical control (DNC), which uses a direct link to control machines without using a tape reader. [2]

2.4.2 CONTROLLER UNIT OR MACHINE CONTROLLER UNIT (MCU)

The controller unit is the most important component of NC and CNC machines. The electronics components make up the controller unit. It reads and interprets the instruction program and converts it into mechanical actions of the machine tool. As a result, the controller unit serves as a vital link between the program and the machine tool. The control unit operates the machines in accordance with the instructions provided to it.

A typical control unit includes a tape reader, a date buffer, signal output channels to machine tools, machine tool feedback channels, and sequence control to coordinate the overall machining operation.

Initially, the tape reader, which is an electromechanical device, reads the set of instructions from the punched tape. The data from the tape is stored in the data buffer as logical blocks of instructions, each of which results in a specific sequence of operations. The controller sends instructions to the machine tool via signal output channels connected to the servomotors and other machine controls.

The feedback channels ensure that the machine correctly executed the instructions. The controller unit's sequence control component ensures that all operations are carried out in the correct order.

One thing to keep in mind about the controller unit is that all modern NC machines are equipped with a microcomputer that serves as the controller unit. The program is directly fed into the computer, and the computer controls the operation of the machine tool. These machines are known as Computer Controller Machines (CNC).

2.4.3 MACH MACHINE TOOL

The machine tool is responsible for the actual machining operations. The machine tool can be any machine, such as a lathe, drilling machine, milling machine, and so on. The machine tool is the part of the NC system that is controlled. In the case of CNC machines, the microcomputer controls the machine based on a set of instructions or a program.

The control panel or control console on the NC machine contains the dials and switches that the operator uses to operate the NC machine. There are also displays to show the user information. The majority of modern NC machines are now referred to as CNC machines.

2.4.4 **DRIVING SYSTEM:**

The driving system of a CNC machine consists of amplifier circuits, drive motors and ball lead screw. The MCU feeds the signals (i.e. of position and speed) of each axis to the amplifier circuits. The control signals are than augmented (increased) to actuate the drive motors. And the actuated drive motors rotate the ball lead screw to position the machine table. [3]

2.4.5 **FEEDBACK SYSTEM:**

This system consists of transducers that act as sensors. It is also called a measuring system. It contains position and speed transducers that continuously monitor the position and speed of the cutting tool located at any instant. The MCU receives the signals from these transducers and it uses the difference between the reference signals and feedback signals to generate the control signals for correcting the position and speed errors. [3]

2.4.6 **DISPLAY UNIT:**

A monitor is used to display the programs, commands and other useful data of CNC machine.

CHAPTER 3
PROJECT METHODOLOGY

3.1 INTRODUCTION:

The machine design includes the mechanical system and the electrical system. In the mechanical part, the component assemblies need to be structured to ensure stability and transmission in limitation. The machine frame connects the machine parts and the shaft to ensure precise, flexible and coherent movement between the drives to form the most complete system. Based on the kinematics as described in Figure 1. The spindle and movement of axes are positioned in the appropriate directions. For mechanical system, Inventor software is used to build, simulate and analyze the components. The 3D CAD model of the CNC machine is depicted in Figure 2. In this design, X, Y, Z axes are driven by stepper motors through the ball screws. A and B axes are driven from the stepper motors through timing belts. The original design was based on commercially available parts, other components were redesigned to meet the using functions.

In which, A and B axes are calculated to ensure strong linkages and bring efficiency when the machine is in operation. First, it is necessary to select the hard machining materials, the timing belt transmission is used to reduce the torque of the motor, and then calculate dimension, the transmission ratio between the dynamics. Full CNC machine structure is assembled through the 3D CAD simulation sketching stage as shown in Simulations of axis motion are carried out, re-size the parts and then machining.

3.2 MACHINE SPECIFICATIONS

Table 3.1: Machine Specifications

Machine Type	5-Axise CNC Multi-Tasking Machine
Function	Milling, Drilling, Lathe,
Liner axis	900x 650 x 450 mm X, Y, Z
Rotary Axis	20 to -110, 360-degree A, C
Structure Dimension	2000 x 1500 x 2000 mm X, Y, Z
Motor Type	Steeper Motor
Spindle Speed	18000 rpm
Communication	LPT

3.3 CNC DESIGN SOFTWARE

3.3.1 DESIGN THE BASE

We frist designed the base in order to obtain durability and non-vibration,based on what we studied in the course Designing Elements of Machines and Thory of Machines ,using the Solidwork program as show (Fig3-1).

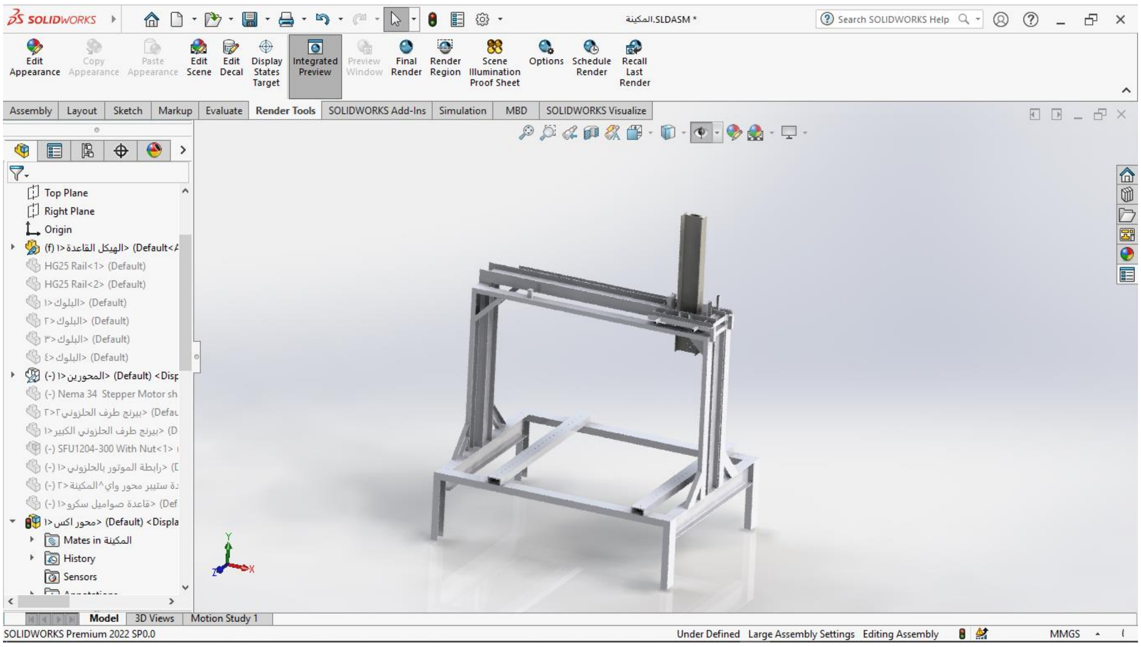

Figure 3.1: Designed the base

3.3.2 DESIGN THE ROTATION AXIS

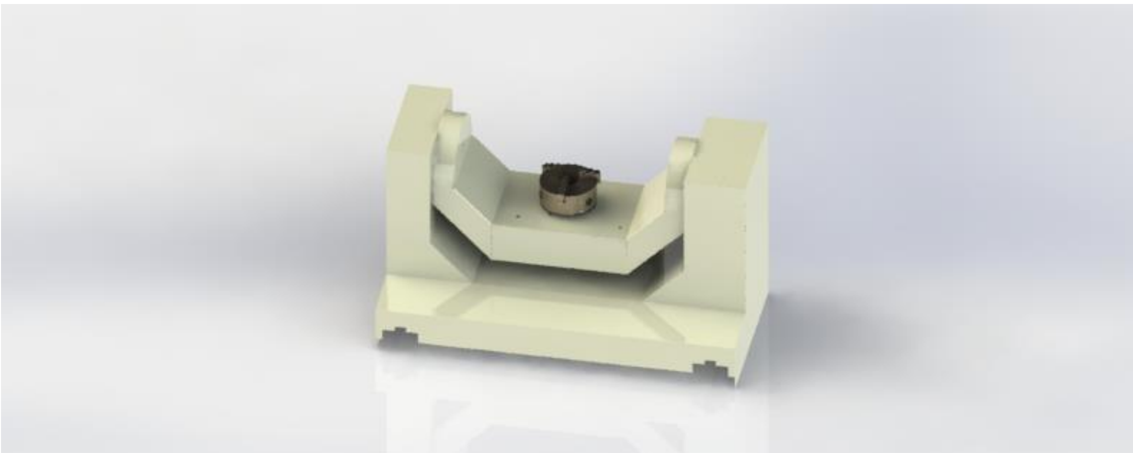

Figure 3.2: The rotation axis

3.3.3 DESIGN THE LINER AXIS

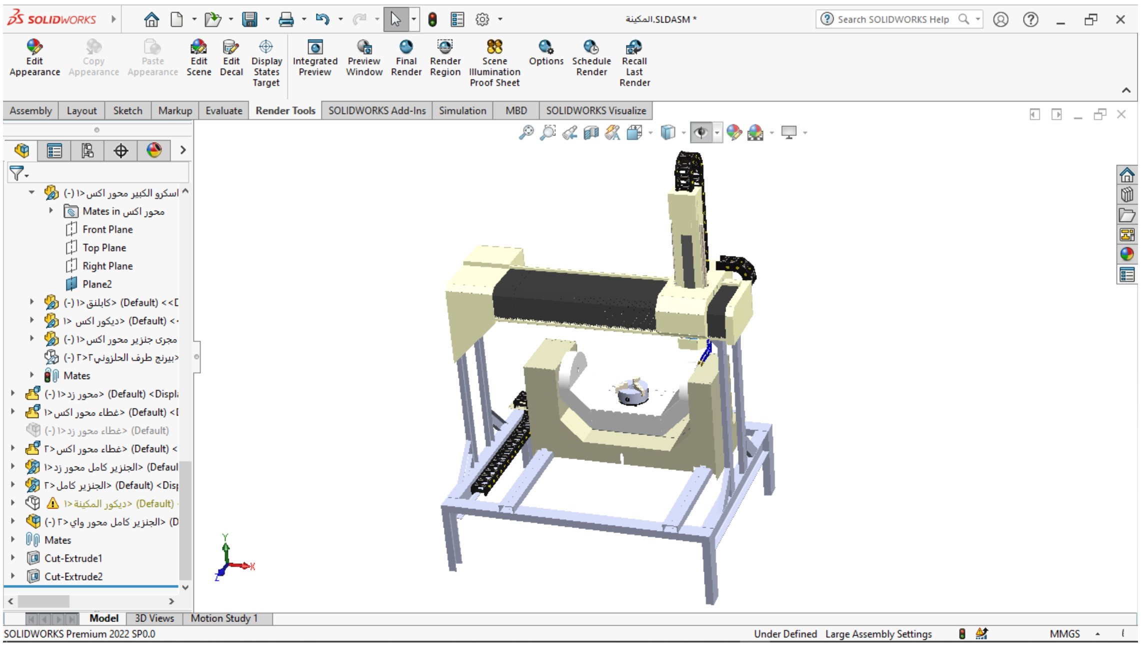

Figure 3.3: the liner axis

3.3.4 FINAL DESIGN

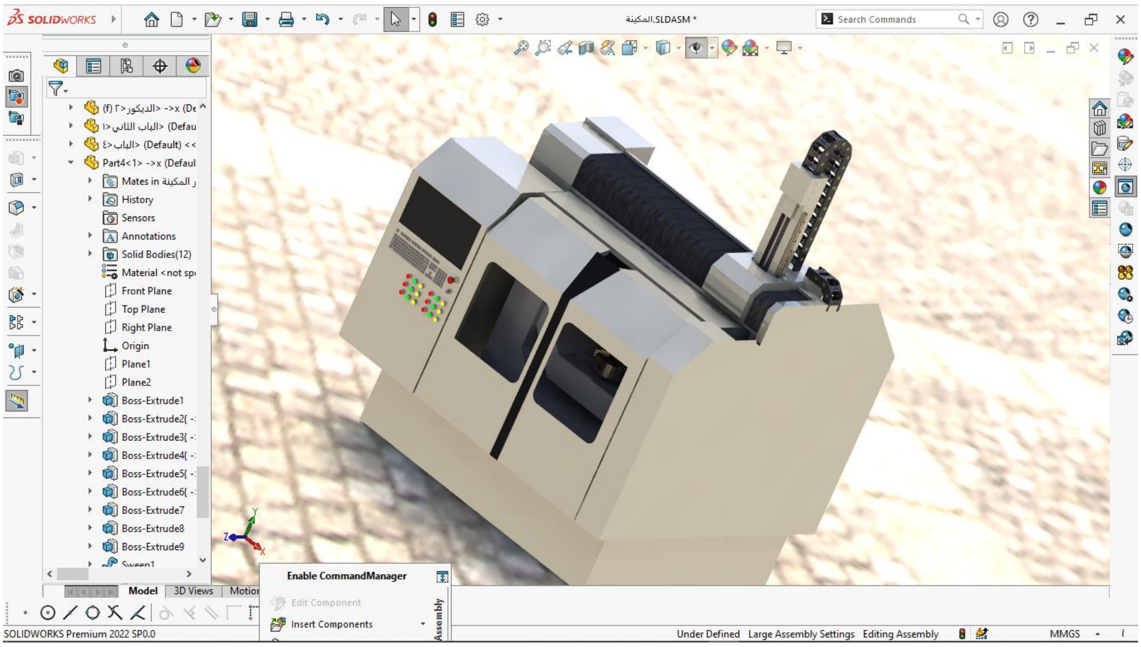

Figure 3.4: Final design

3.4 COMPONENTS:

3.4.1 **ELECTRONIC COMPONENTS**

Table 3.2: List of electronic components

NO.	COMPONENT	Quantity
1	5-Axis Breakout Board	1
2	Spindle 3.5KW (3Ph Synchronous Motor)	1
	Inverter 3.5kw	1
3	DMA860H Stepper Motor Driver	5
5	Stepper Motor Nema 34 G450B	5
7	16mm Panel Mount Signal Power Led Indicator Light Green/Red Pilot Lamp DC 12V/24V	12
8	Push button switch	6
9	Emergency stop switch button	1
	Selector switch	1
12	Connection Wires	

3.4.1.1 5-AXIS BREAKOUT BOARD

Figure 3.5: 5-Axis Breakout Board

The latest upgraded 5 axis breakout board is specially designed for the CNC single axis 2-phase stepper driver controller, such as M542, M542H, MA860H, 2M542, 2M982, DM542(A), DM860(A) etc. single axis stepper driver controller series. With this 5-axis breakout board, any 1-5 single axis stepper driver controllers can be directly controlled by the PC via the MACH3, EMC2, KCAM4, etc.

- **FEATURES:**

  - Maximum support 5-axis stepper motor driver controllers
  - Compatible with MACH3, Linux CNC (EMC2) etc. parallel-control CNC software.
  - USB power supply and peripherals powered phase are separated to protect computer security.
  - All the signals are opto-isolated which can protect your computer security.
  - 5-input interface to define the Limit, Emergence-Stop, Cutter alignment, etc.
  - Wide input voltage range: 12-24V, and with anti-reverse function.
  - One relay output control interface, accessed by the spindle motor or the air pump, water pump, etc.

- Output 0-10V analog voltage for inverter to control the spindle speed.

- **SPECIFICATIONS**

Table 3.3: Specifications Breakout Board

Electrical proportional (ambient temperature Tj =25)	
Input power	USB port to directly get power from PC and 12-24 power supply
Compatible stepper motor Driver	Max 5 2-phase Microstep controllers
Driver type	Pulse and Direction Signal controller
Net/Total Weight	Approx 27g
Dimension	90*70*20 mm

3.4.1.2 SPINDLE

It is a device that operates by electricity and generates torque through an internal motor, where the torque moves to the cutting tool that connects to the work piece to cut it.

Figure 3.6: CNC Spindle

SPINDLE PARAMETERS

Table 3.4: Spindle parameters

Power	3500 W
Voltage	380 V AC
Idling	0-18000r / min.
Spindle diameter	100mm
HP	5.71 hp
Current	14.6 A

3.4.1.3 INVERTER 3.5KW

Figure 3.7: Inverter 3.5kw

3.4.1.4 DMA860H STEPPER MOTOR DRIVER:

Figure 3.8: DMA860H Stepper Motor Driver

3.4.1.5 STEPPER MOTOR

NEMA 34 is a stepper motor with a (86×86×115 mm) faceplate and 1.8° step angle (200 steps/revolution). Each phase draws 5.6 A , allowing for torque of 8.5 N.M NEMA 34 Stepper motor is generally used in Printers, CNC machine, Linear actuators and hard drives.

Stepper motors are a very practical technique of moving things to a desired position since they operate in steps and you can precisely control how many steps you travel in each direction. They are therefore excellent for most CNC applications.

Figure 3.9: Stepper Motor

NEMA 34 STEPPER MOTOR SPECIFICATIONS VOLTAGE:

Table 3.5: Stepper Motor Specifications

NEMA 34 Stepper Motor Specifications	
Rating	60V
Current Rating	5A
Holding Torque	8.5 N.m
Step Angle	1.8 deg
Steps Per Revolution	200
No. of Phases	2
Motor Length	115mm
No. of Leads	4
Inductance Per Phase	11mH

3.4.1.6 PANEL MOUNT SIGNAL POWER LED INDICATOR:

Figure 3.10: Led Indicator

16mm Panel Mount Signal Power Led Indicator Light Green/Red Pilot Lamp DC 12V/24V

3.4.1.7 EMERGENCY STOP PUSH BUTTON:

Figure 3.11: E.Stop

3.5 MECHANICAL COMPONENTS

3.5.1 RAIL GUIDE 25MM &BLOCK 25MM:

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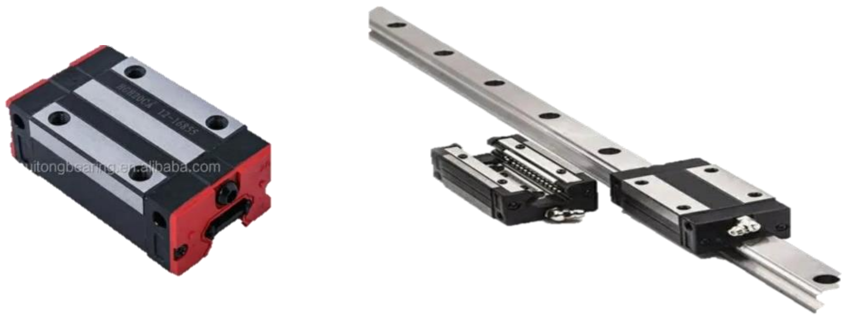


Figure 3.12: Rail guide 25mm &block 25mm

3.5.1.1 LEAD SCREW 16MM AND BEARING BRACKET AND COUPLING

Figure 3.13: lead screw and bearing Bracket and coupling

3.5.1.2 CHACK 200MM

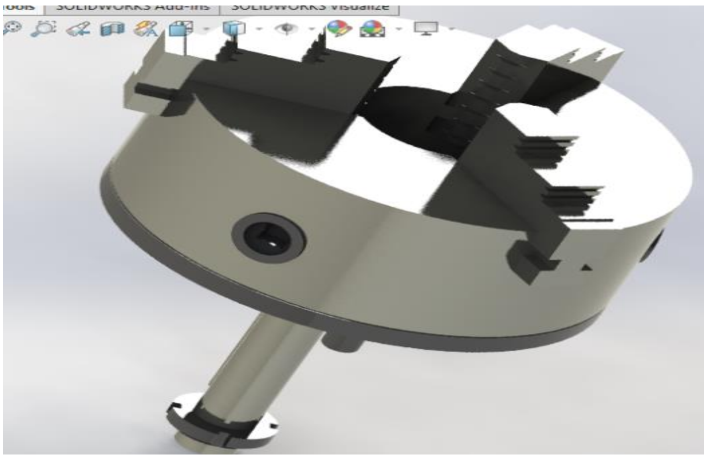


Figure 3.14: Chack

3.5.1.3 R55 35MM X 100MM PLASTIC CABLE WIRE HOLDER

Figure 3.15: Wire holder

3.5.1.4 OIL DISPENSER

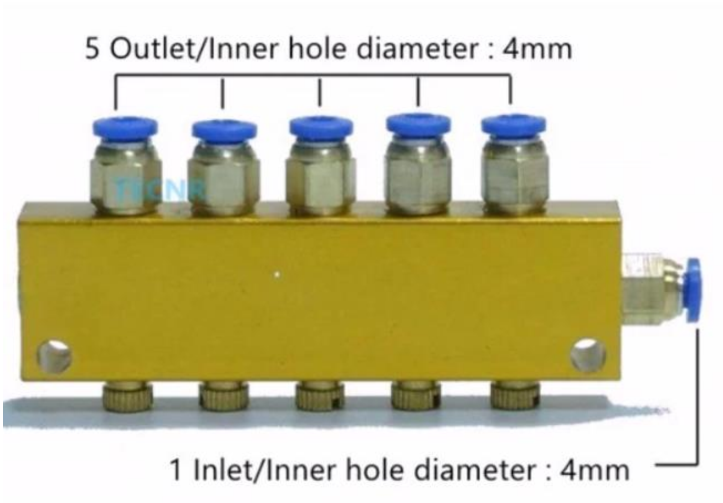


Figure 3.16: Oil dispenser

3.5.1.5 AUTOMATED DISTRIBUTOR

Figure 3.17: Automated distributor

3.5.1.6 NMRV63 GEAR BOX 1:20:

‘ 

Figure 3.18: Bearing Gear box

3.5.1.7 GALVANIZED RECTANGULAR IRON TUBE THICKNESS 1.5:

Galvanized rectangular iron tube, size 40 x 20 mm, thickness 1.50 mm, hollow stainless-steel tube, used in a variety of applications, including industrial maintenance, transportation tools and equipment. It was used to install the screen mesh show in (Fig. 3-19) [

.

Figure 3.19: Galvanized rectangular iron tube thickness 1.5

3.5.1.8 GALVANIZED ANGLE IRON 60MM:

Galvanized angle iron tube, size60x 60 mm, thickness 6 mm, hollow stainless-steel tube, used in a variety of applications, including industrial maintenance, transportation tools and equipment. It was used to install the screen mesh show in (Fig. 3-20)

.

Figure 3.20: Galvanized angle iron 0.5

3.5.1.9 GALVANIZED H 16:

Galvanized (H) iron tube, size 160x 85mm, thickness 6 mm, hollow stainless-steel tube, used in a variety of applications, including industrial maintenance, transportation tools and equipment. It was used to install the screen mesh show in (Fig. 3-21)

Figure 3.21: Galvanized H 12

3.5.1.10 GALVANIZED C:

Galvanized (U) iron tube, size102x 51 mm, thickness 6.1mm, hollow stainless iron tube, used in a variety of applications, including industrial maintenance, transportation tools and equipment. It was used to install the screen mesh show in (Fig. 3-22)

.

Figure 3.22: Galvanized U 14

3.5.1.11 COUPLING

This shift screw is mainly used in stepper motor, machine tool, Screw without processing, direct connected to bearing. Lead screw was PVC tube packaging.

Figure 3.23: coupling

3.5.1.12 SCREW

Socket cap screws are threaded fasteners that have a cap head with an internal socket drive for installing in areas with limited side clearance

In this project used various types of screws with different sizes as follow:

Table 3.6: Types of Screw

B18.3.1M - 5 x 0.8 x 12 Hex SHCS -- 12NHX	
B18.3.1M - 5 x 0.8 x 20 Hex SHCS -- 20NHX	
B18.3.1M - 8 x 1.25 x 40 Hex SHCS -- 28NHX	
B18.3.5M - 3 x 0.5 x 8 Socket FCHS -- 8N	

B18.3.1M - 3 x 0.5 x 20 Hex SHCS -- 20NHX	

3.5.1.13 GEAR BOX

Figure 3.24: Gear box

CHAPTER 4
MATHEMATICAL & SIMULATION

4.1 MASS PROPERTIES OF: A & C AXIS WITH FULL LOAD

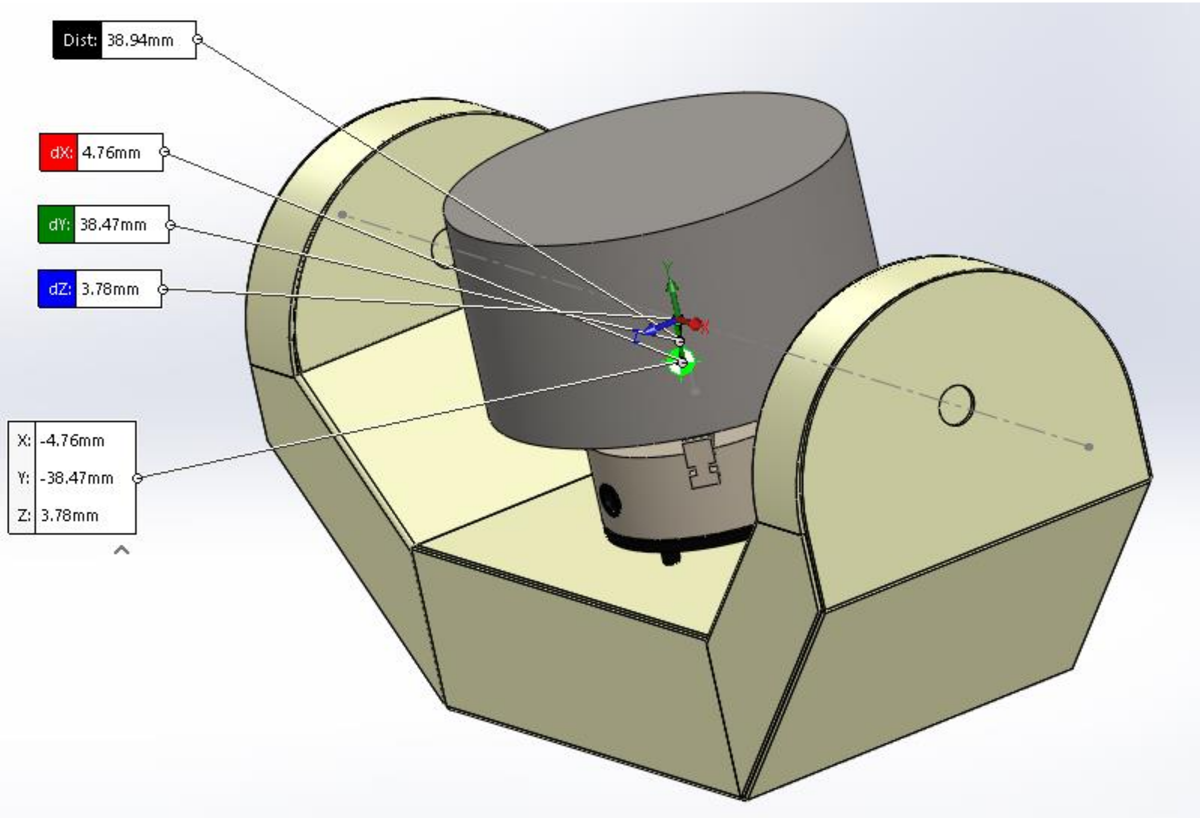


Figure 4.1: A & C Axis with full load

the center of mass and the moments of inertia are output in the coordinate system of : A & C axis origin

Mass = 215.4 kilograms

Volume = 0.0297 cubic meters

Surface area = 5.159 square meters

Center of mass: (meters)

X = -0.0048

Y= -0.0385

Z = 0.0038

Principal axes of inertia and principal moments of inertia: (kilograms * square meters)

taken at the center of mass.

Ix = (0.9951, 0.0973, -0.0196) Px = 5.137

Iy = (-0.0986, 0.9919, -0.08) Py = 7.21

Iz = (0.016, 0.0816, 0.9966) Pz = 9

Moments of inertia: (kilograms * square meters)

taken at the center of mass and aligned with the output coordinate system. (Using positive tensor notation.)

Lxx = 5.158 Lxy = 0.1992 Lxz = -0.0612

Lyx = 0.1992 Lyy = 7.203 Lyz = -0.1494

Lzx = -0.0612 Lzy = -0.1494 Lzz = 8.987

Moments of inertia: (kilograms * square meters)

taken at the output coordinate system. (Using positive tensor notation.)

Ixx = 5.48 Ixy = 0.2386 Ixz = -0.065

Iyx = 0.2386 Iyy = 7.21 Iyz = -0.1808

Izx = -0.065 Izy = -0.1808 Izz = 9.3

4.2 TORQUE A & C AXIS WITH FULL LOAD ABOUT NMVR40 BEAM

4.2.1 COMMENTS:

d =center of mass in Y axis = 0.0385 meter

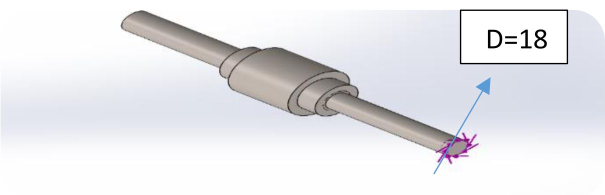
Torque about X axis at an angle 90 = m x g x d = 215.4kg x 9.81 m/s2 x 0.0385 meter = 81.2 N.m

$\tau_{torsion} = \frac{T*c}{J}$

NOTE this torque is effect about cylindrical beam its diameter is 18mm

T = torque = 81.2 N.m

c =radius = 9mm



J = first moment of inertia $= \frac{\pi * (0.018)^4}{32} = 0.0103 \times 10^{-6}\ m^4$

$\tau_{torsion} = \frac{81.2 * 0.009}{0.0103 \times 10^{-6}} = 70.195$ MPa NMVR40 beam

4.3 MASS PROPERTIES OF: A & C AXIS WITHOUT LOAD

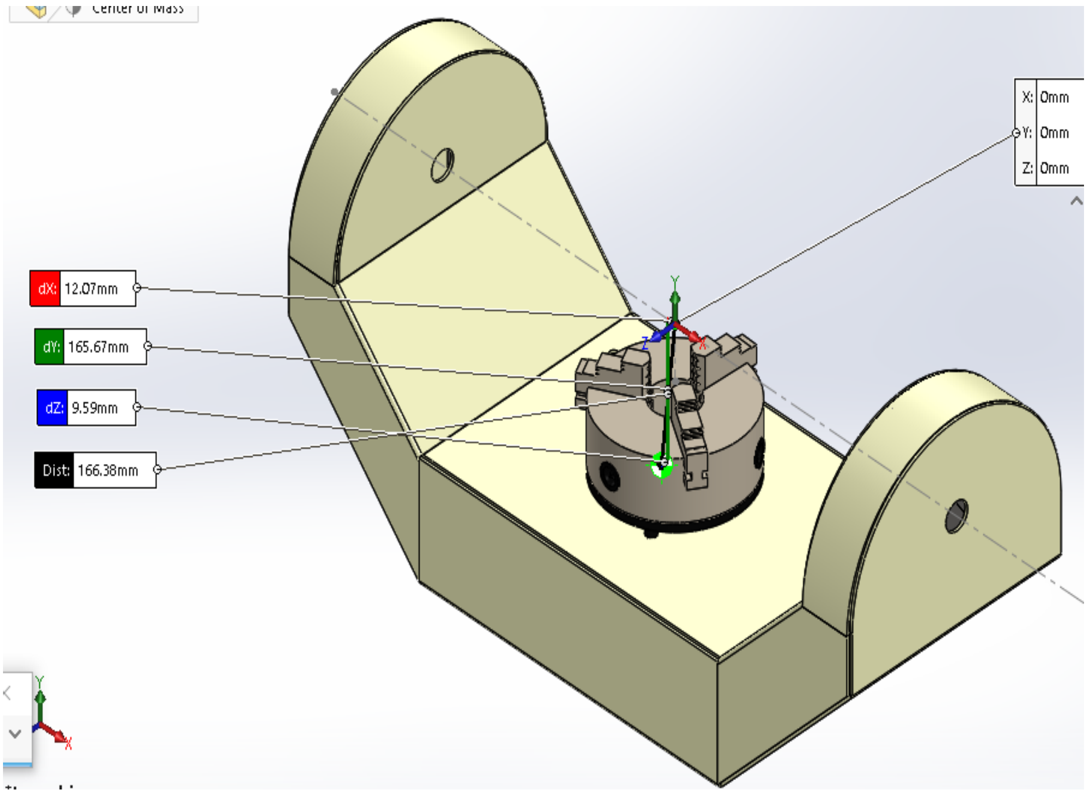


Figure 4.2: A & C Axis without load

the center of mass and the moments of inertia are output in the coordinate system of : A & C axis origin

Mass = 84.93 kilograms

Volume = 0.019 cubic meters

Surface area = 4.762

Center of mass: (meters)

X = -0.0121

Y= -0.1657

Z = 0.0096

Principal axes of inertia and principal moments of inertia: (kilograms * square meters)

taken at the center of mass.

Ix = (0.9997, 0.0189, -0.0146) Px = 1.509

Iy = (-0.0222, 0.961, -0.2758) Py = 5.182

Iz = (0.0089, 0.276, 0.961) Pz = 5.351

Moments of inertia: (kilograms * square meters)

taken at the center of mass and aligned with the output coordinate system. (Using positive tensor notation.)

Lxx = 1.51 Lxy = 0.0688 Lxz = -0.0552

Lyx = 0.0688 Lyy = 5.194 Lyz = -0.0458

Lzx = -0.0552 Lzy = -0.0458 Lzz = 5.337

Moments of inertia: (kilograms * square meters)

taken at the output coordinate system. (Using positive tensor notation.)

Ixx = 3.849 Ixy = 0.2386 Ixz = -0.065

Iyx = 0.2386 Iyy = 5.214 Iyz = -0.1808

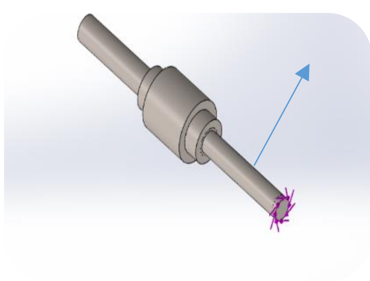
Izx = -0.065 Izy = -0.1808 Izz =7.681

4.4 TORQUE A & C AXIS ABOUT NMVR40 BEAM

d =center of mass in Y axis = 0.1657 meter

Torque about X axis at an angle 90 = m x g x d = 84.93kg x 9.81 x 0.1657meter = 138 N.m

D=18



NOTE this torque is effect about cylindrical beam its diameter is 18mm

$$\tau_{torsion} = \frac{T * c}{J}$$ T=torque

c =radius = 9mm

J = polar moment of inertia = $\frac{\pi * (0.018)^4}{32}$ =0.0103 x10^{-6} m^4

$\tau_{torsion}$ = $\frac{138 * 0.009}{0.0103 \times 10^{-6}}$ =120.512 MPa

4.5 SIMULATION FOR A TORQUE WITHOUT LOAD

Date: 2023\1 \4

Study name: Torsion

Analysis type: Static

Since the torque is greater when no load, then the stresses will be calculated according to this torque. This case will be simulated

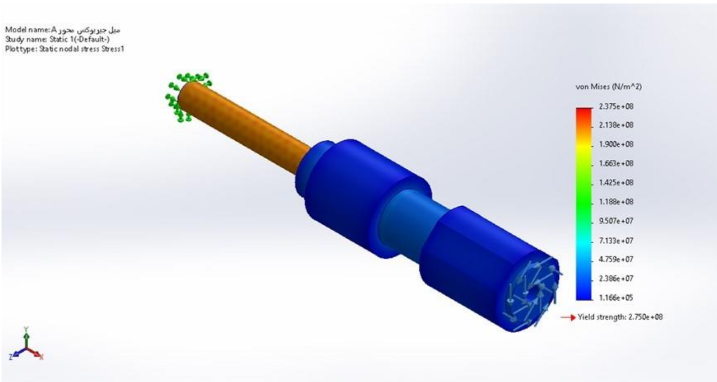
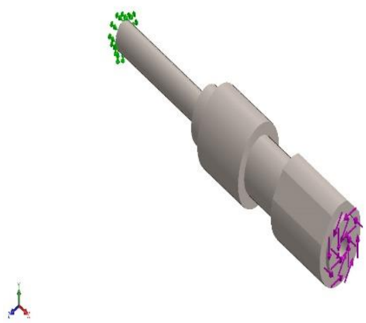


Figure 4.3: Simulation for NMVR40 beam

4.5.1 MODULE INFORMATION



Model name: ميل جيربوكس محور A

Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
ميل الجيربوكس 	Solid Body	Mass:2.17319 kg Volume:0.000271644 m^3 Density:8000.12 kg/m^3 Weight:21.2972 N	C:\Users\Owner\Desktop\المشروع\ميل جيربوكس محور A .SLDPRT

4.5.2 STUDY PROPERTIES

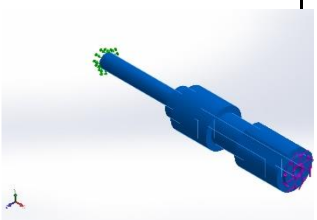
Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic

Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\Owner\Desktop\المشروع)

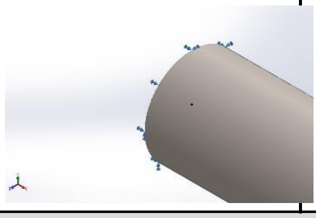
4.5.3 UNITS

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

4.5.4 MATERIAL PROPERTIES

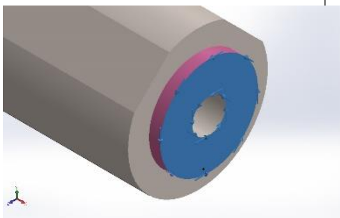
Model Reference	Properties	Components
	Name: **AISI 347 Annealed Stainless Steel (SS)** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **2.75e+08 N/m^2** Tensile strength: **6.55e+08 N/m^2** Elastic modulus: **1.95e+11 N/m^2** Poisson's ratio: **0.27** Mass density: **8.000 kg/m^3** Shear modulus: **7.7e+10 N/m^2** Thermal expansion coefficient: **1.7e-05 /Kelvin**	**SolidBody 1(beam)(ميل جيربوكس محور A)**
Curve Data:N/A		

4.5.5 LOADS AND FIXTURES

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed Geometry

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	1.00136e-05	-1.5878	2.89557	3.30234
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Torque-1		**Entities:** 1 face(s) **Reference:** Face< 1 > **Type:** Apply torque **Value:** 138 N.m

4.5.6 MESH INFORMATION

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	6.47817 mm
Minimum element size	2.15937 mm
Mesh Quality	High

4.5.6.1 MESH INFORMATION - DETAILS

Total Nodes	17520
Total Elements	11193
Maximum Aspect Ratio	9.4248
% of elements with Aspect Ratio < 3	99.5
Percentage of elements with Aspect Ratio > 10	0
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:03
Computer name:	SXXXN

4.5.7 RESULTANT FORCES

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	1.00136e-05	-1.5878	2.89557	3.30234

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

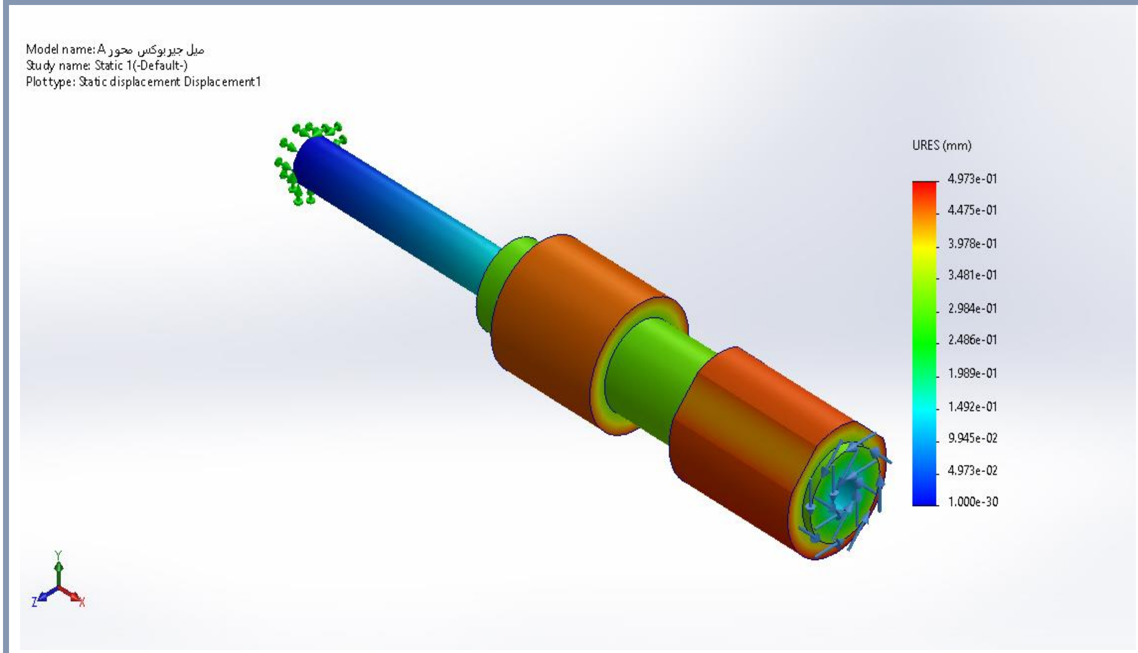
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-0.00015372	0.000397135	-0.000273216	0.000505958

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

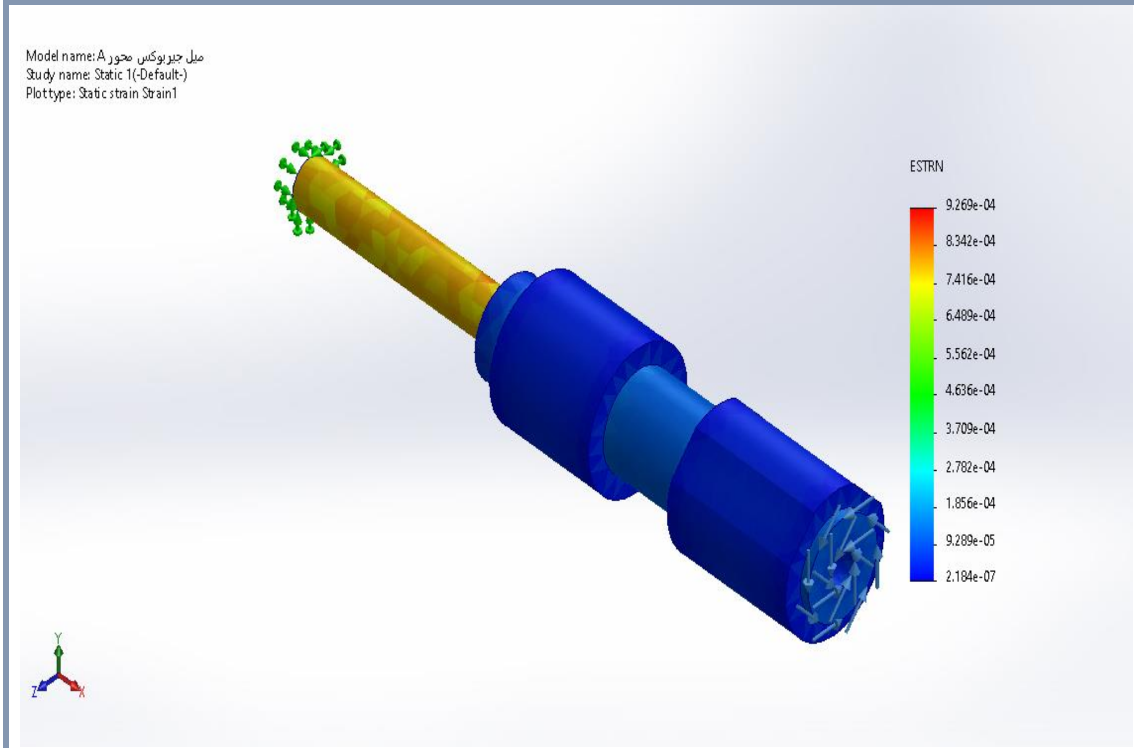
STUDY RESULTS

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 39	4.973e-01mm Node: 17035



A ميل جيربوكس محور-Static 1-Displacement-Displacement1

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	2.184e-07 Element: 7136	9.269e-04 Element: 3710



A ميل جيربوكس محور-Static 1-Strain-Strain1

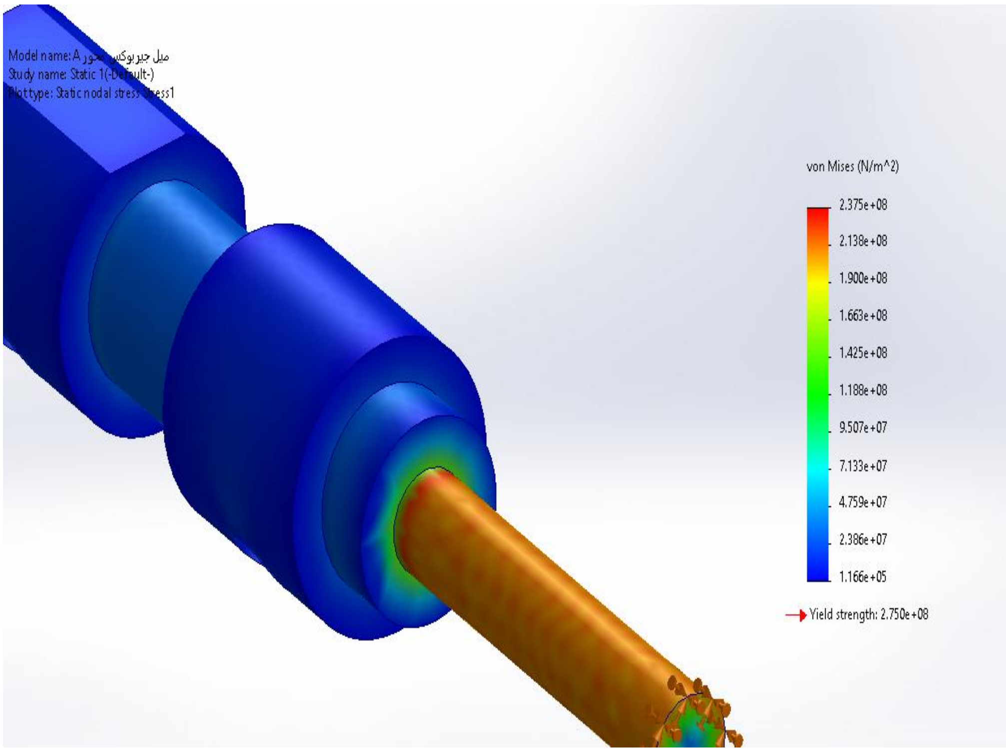
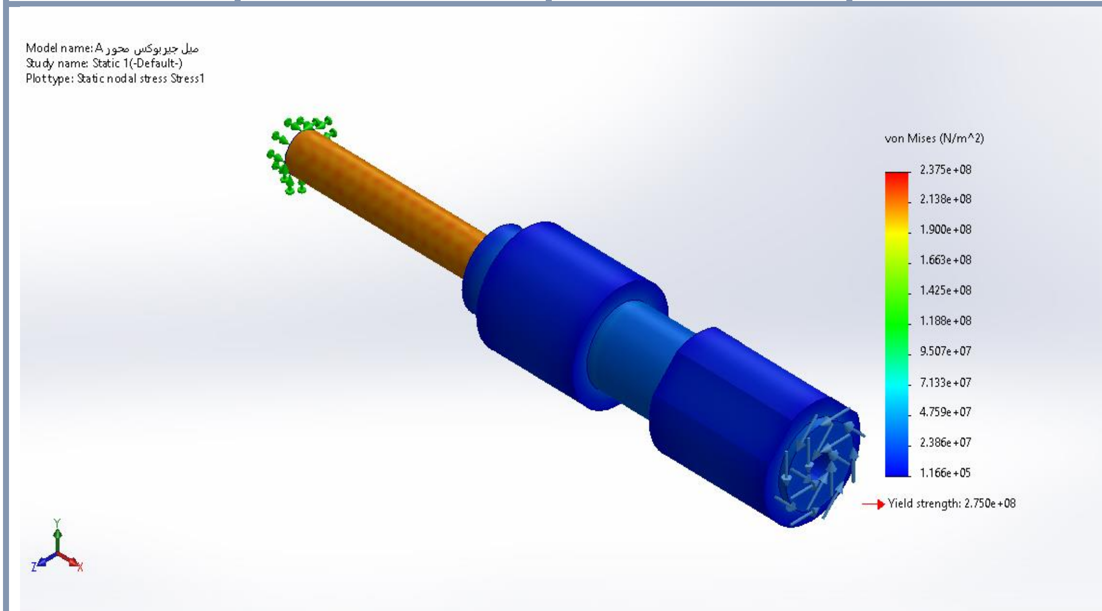


Image Comments:
maxmuim stresses

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.166e+05N/m^2 Node: 1167	2.375e+08N/m^2 Node: 13286



A ميل جيربوكس محور-Static 1-Stress-Stress1

4.6 COUNTERWEIGHT

Counterweights are added at one end of the two axles to reduce the torque on the motor

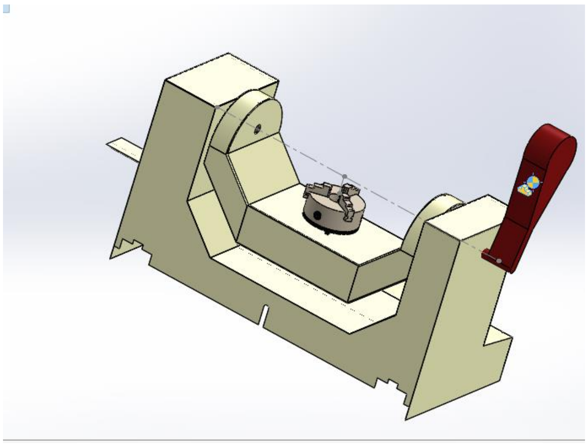


Figure 4.4: Counterweight

T1 = A&C axis torque

T2 = Counterweight torque

A =The angle of inclination of the center of mass of the counterweight with the vertical axis

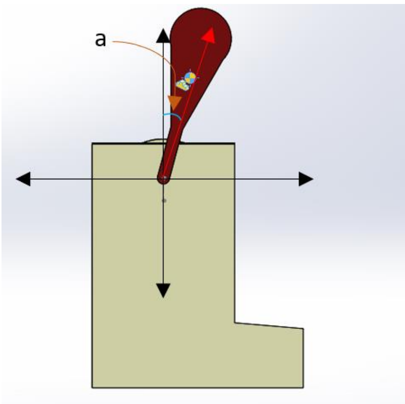


Figure 4.5: The angle of inclination of the center of mass

The torque is negative when his direction is with the counterclockwise.

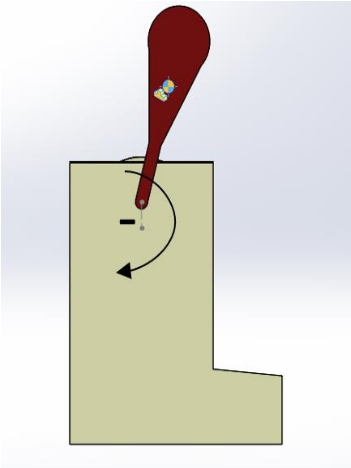


Figure 4.6: torque direction

$T_a = -T*\cos(x)$

$T_b = -T*\cos(x - 180 - a) = T*\cos(x - a)$

$T_{total} = T*\cos(x-a) - T*\cos(x)$

Suppose that

T1 =Counterweight torque for the two axes

T2 = The effect of the mass of the load on the torque of the two axles

$T_{total} = T1*\cos(x-a) - T2*\cos(x)$

Then, using the MATLAB program, we conducted several experiments until we reached the exact values of a&T1

4.6.1 GRAPH OF TORQUE EQUATIONS IN MATLAB

without load suppose T2 =1

```
close all
T1=0.923;
T2=1;
syms x ;
a=pi/36;
ezplot(T1*cos(x-a)-T2*cos(x),[25*pi/18 38*pi/18])
```

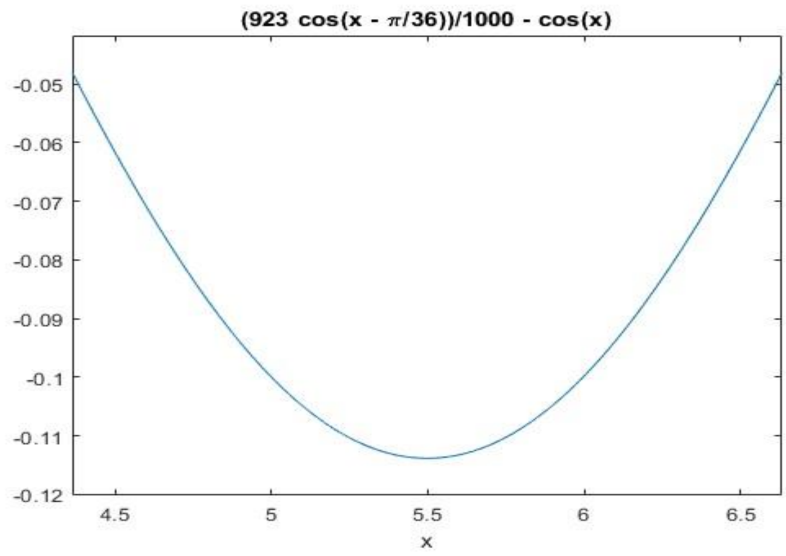


Figure 4.7: The relationship between torque and A-axis angle

When loaded, only half the load becomes T2 = 0.8 and then we ran the tests inside the MATLAB program until we reached the exact T1 value. The value of a fixed discrepancy according to the previous conclusion

```
close all
T1=0.738;
T2=0.8;
syms x;
a=pi/36;
ezplot(T1*cos(x-a)-T2*cos(x),[25*pi/18 38*pi/18])
```

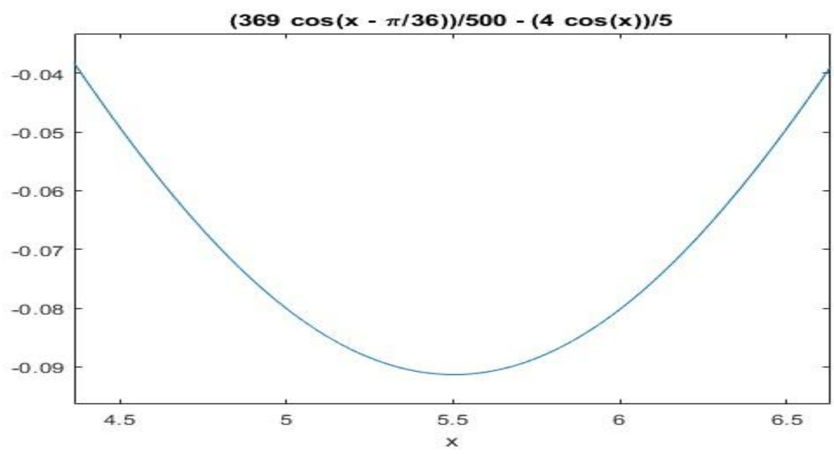


Figure 4.8: relationship between torque and A-axis angle with load effect

We note that the torque required for mass balance is between 0.923 and 0.738 of the torque of the two axes. In order to calculate the mass of the counterweight, the length of the torque arm must be assumed. Let's assume that the length of the torque arm is 20 cm

$$\text{T1,2}= F * l$$

$$T = 132N \cdot m$$

$$T_1 = 0 \cdot 923 * 132$$

$$T_2 = 0 \cdot 738 * 132$$

$$m_1 = \frac{T_1}{l * g} = \frac{121.84}{0.2 \times 9 \cdot 81} \approx 62kg$$

$$m_2 = \frac{T_2}{l * g} = \frac{97.42}{0.2 \times 9 \cdot 81} \approx 50kg$$

We're going to create a weight of 50 kg, an increase of 12 kg, and this increase is added whenever the load is less loaded.

4.7 SIMULATION OF BASE

The weight of the A&C axis is 85 kg.

The weight of the Y-axis is 75 kg.

The maximum weight of the load is 130 kg.

The Z-axis pushes the cutting tool down with a force roughly equivalent to the weight of 10 kg.

The mass of the A&C & Full Load axes is equal to 300 kg.

Gross Weight (W)= m X g = 300 X 9.81 = 2.943 kN

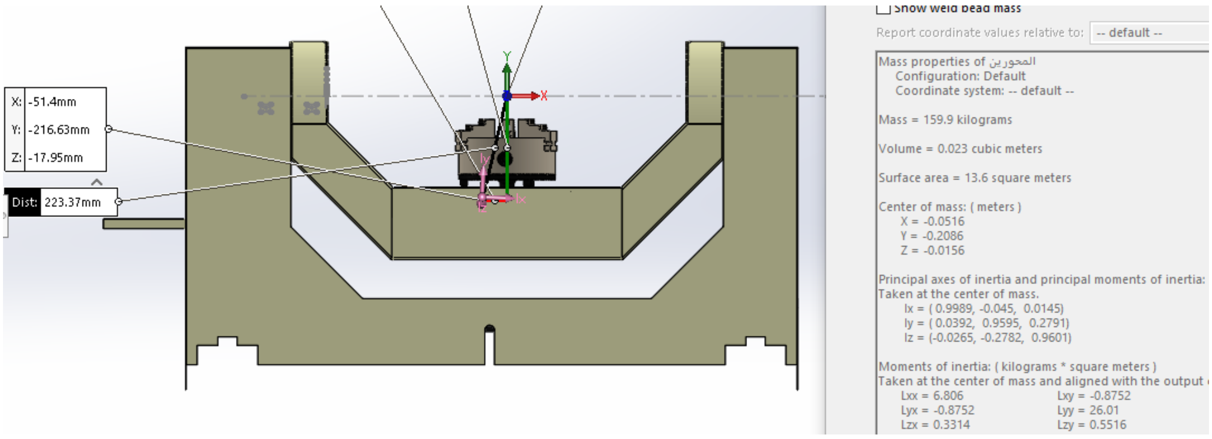


Figure 4.9: The weight of the A&C&Y

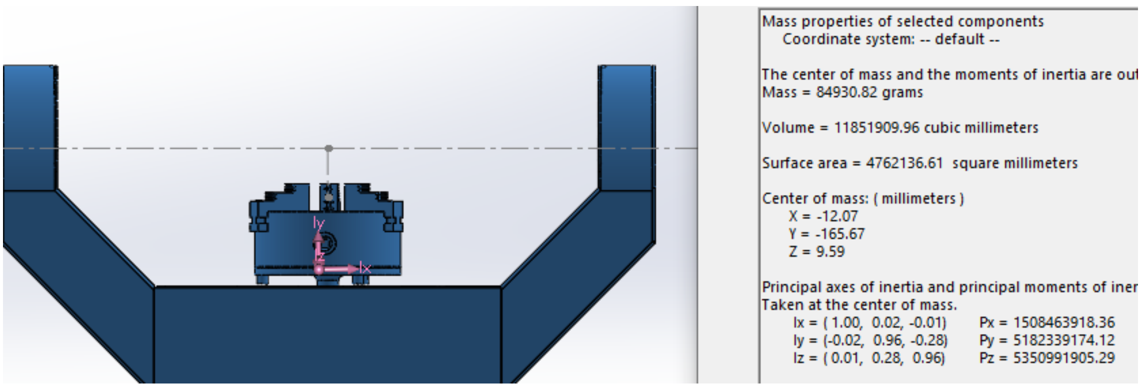


Figure 4.10: The weight of the A&C

The weight affects 2 C channel beam as shown in the following picture:

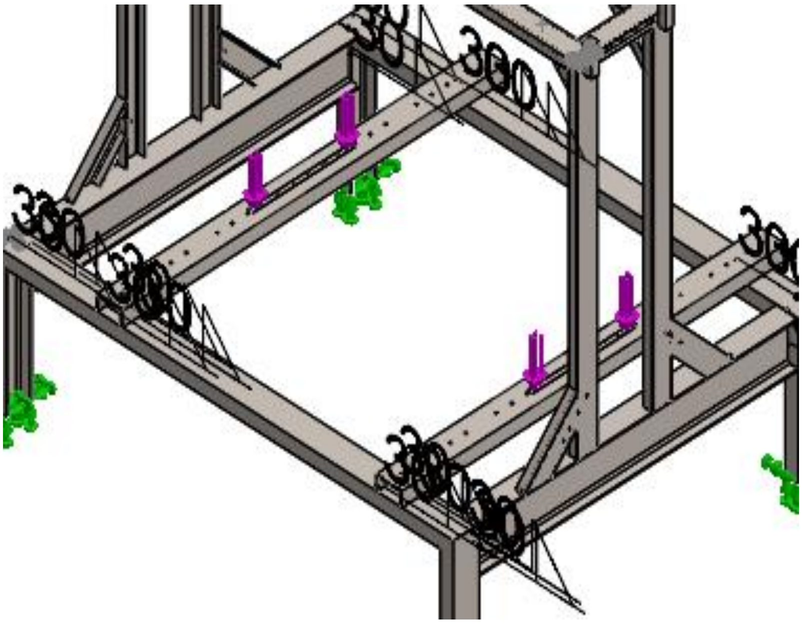
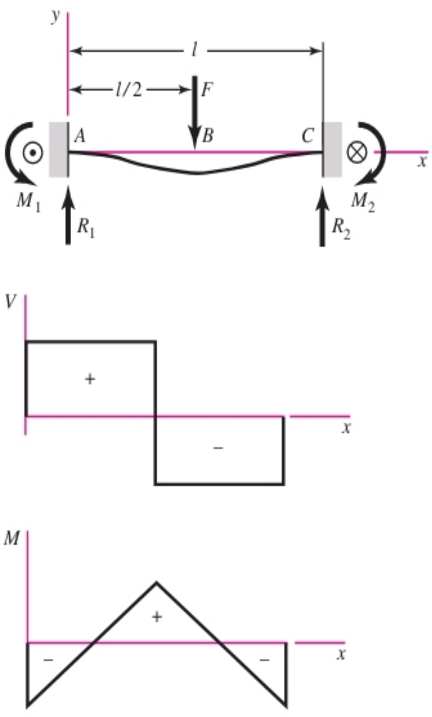


Figure 4.11: The weight affects

Since each beam is welded from both sides, we will calculate the moments of the couple according to the following equations:

14 Fixed supports—center load



$$R_1 = R_2 = \frac{F}{2} \qquad M_1 = M_2 = \frac{Fl}{8}$$

$$V_{AB} = -V_{BC} = \frac{F}{2}$$

$$M_{AB} = \frac{F}{8}(4x - l) \qquad M_{BC} = \frac{F}{8}(3l - 4x)$$

$$y_{AB} = \frac{Fx^2}{48EI}(4x - 3l)$$

$$y_{max} = -\frac{Fl^3}{192EI}$$

(continued)

$R_1 = R_2 = \frac{1472}{2} = 736$ N

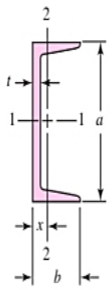
$V_{AB} = -V_{BC} = 736$ N

$M_{AB} = M_{BC} = \frac{1472}{8}(4 * 0.625 - 1.250) = 230$N.m

Table A-7

Properties of Structural-Steel Channels*

a, b = size, in (mm)
w = weight per foot, lbf/ft
m = mass per meter, kg/m
t = web thickness, in (mm)
A = area, in^2 (cm^2)
I = second moment of area, in^4 (cm^4)
k = radius of gyration, in (cm)
x = centroidal distance, in (cm)
Z = section modulus, in^3 (cm^3)



a × b, mm	m	t	A	I_{1-1}	k_{1-1}	Z_{1-1}	I_{2-2}	k_{2-2}	Z_{2-2}	x
76 × 38	6.70	5.1	8.53	74.14	2.95	19.46	10.66	1.12	4.07	1.19
102 × 51	10.42	6.1	13.28	207.7	3.95	40.89	29.10	1.48	8.16	1.51
127 × 64	14.90	6.4	18.98	482.5	5.04	75.99	67.23	1.88	15.25	1.94
152 × 76	17.88	6.4	22.77	851.5	6.12	111.8	113.8	2.24	21.05	2.21
152 × 89	23.84	7.1	30.36	1166	6.20	153.0	215.1	2.66	35.70	2.86
178 × 76	20.84	6.6	26.54	1337	7.10	150.4	134.0	2.25	24.72	2.20
178 × 89	26.81	7.6	34.15	1753	7.16	197.2	241.0	2.66	39.29	2.76
203 × 76	23.82	7.1	30.34	1950	8.02	192.0	151.3	2.23	27.59	2.13
203 × 89	29.78	8.1	37.94	2491	8.10	245.2	264.4	2.64	42.34	2.65
229 × 76	26.06	7.6	33.20	2610	8.87	228.3	158.7	2.19	28.22	2.00
229 × 89	32.76	8.6	41.73	3387	9.01	296.4	285.0	2.61	44.82	2.53
254 × 76	28.29	8.1	36.03	3367	9.67	265.1	162.6	2.12	28.21	1.86
254 × 89	35.74	9.1	45.42	4448	9.88	350.2	302.4	2.58	46.70	2.42
305 × 89	41.69	10.2	53.11	7061	11.5	463.3	325.4	2.48	48.49	2.18
305 × 102	46.18	10.2	58.83	8214	11.8	539.0	499.5	2.91	66.59	2.66

*These sizes are also available in aluminum alloy.

We will study the stresses on one beam only. Therefore, it will be taken into account that the effective weight is half the weight of the axes and is equal to 1.472 kN.

For the case we will study will be the moment of the couple about the axis 2. And at dimensions 102x51 t= 6.1mm

A=13.28cm^2

I_{2-2} =29.1 cm^4

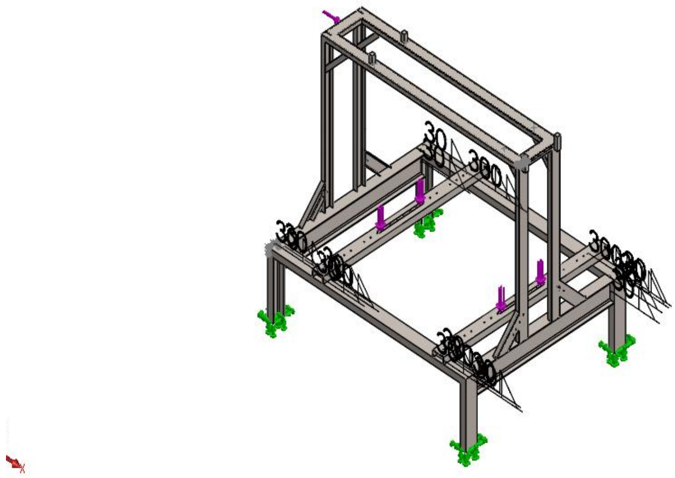
x= 1.51cm

$$\sigma_b = \frac{Mx}{I} = \frac{230 * 0.015}{29.1 * 10^{-8}} = 11.856\ Mpa$$

$$\sigma_b = \frac{M(0.051 - x)}{I} = \frac{230 * 0.0359}{29.1 * 10^{-8}} = 28.375\ Mpa$$

$$\tau = \frac{F/2}{A} = \frac{736}{13.8 * 10^{-4}} = 533 \cdot 34kpa$$

MODEL INFORMATION



الهيكلModel name:
Current Configuration: Default<As Machined>

Solid Bodies			
Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Boss-Extrude8 	Solid Body	Mass:166.595 kg Volume:0.0211953 m^3 Density:7.860 kg/m^3 Weight:1.632.63 N	C:\Users\Owner\Desktop\المشروع\محور سي\الهيكل\الهيكل.SLDPRT Aug 6 20:44:14 2023

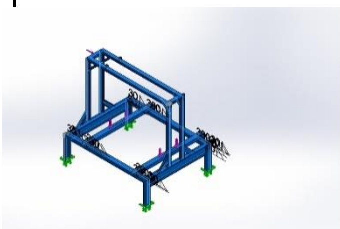
STUDY PROPERTIES

Study name	Static 1
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SOLIDWORKS Flow Simulation	Off
Solver type	Automatic
Inplane Effect:	Off
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method:	Off
Result folder	SOLIDWORKS document (C:\Users\Owner\Desktop\المشروع\محور سي\الهيكل)

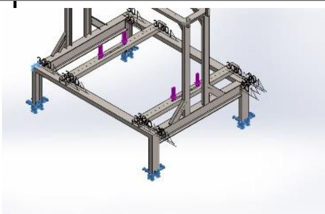
UNITS

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

MATERIAL PROPERTIES

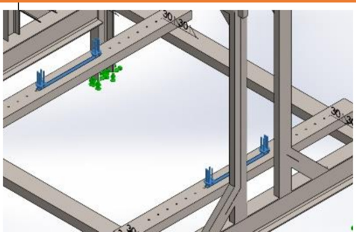
Model Reference	Properties	Components
	Name: **201 Annealed Stainless Steel (SS)** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **2.92e+08 N/m^2** Tensile strength: **6.85e+08 N/m^2** Elastic modulus: **2.07e+11 N/m^2** Poisson's ratio: **0.27** Mass density: **7.860 kg/m^3** Thermal expansion coefficient: **1.7e-05 /Kelvin**	**SolidBody 1(Boss-Extrude8)(الهيكل)**
		Curve Data:N/A

LOADS AND FIXTURES

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** **4 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	-39.3539	2.943.58	-0.0395042	2.943.84
Reaction Moment(N.m)	0	0	0	0

Load name	Load Image	Load Details
Force-1		**Entities:** **2 face(s)** **Type:** **Apply normal force** **Value:** **1.471.5 N**
Force-2		**Entities:** **1 face(s)** **Type:** **Apply normal force** **Value:** **40 N**

MESH INFORMATION

Mesh type	Solid Mesh
Mesher Used:	Blended curvature-based mesh
Jacobian points for High quality mesh	16 Points
Maximum element size	111.945 mm
Minimum element size	5.59726 mm
Mesh Quality	High

MESH INFORMATION - DETAILS

Total Nodes	538605
Total Elements	257414
Maximum Aspect Ratio	1.457.8
% of elements with Aspect Ratio < 3	55.6
Percentage of elements with Aspect Ratio > 10	1.16
Percentage of distorted elements	0
Time to complete mesh(hh;mm;ss):	00:00:56
Computer name:	SXXXN

RESULTANT FORCES

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-39.3539	2.943.58	-0.0395042	2.943.84

Reaction Moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	0

Free body forces

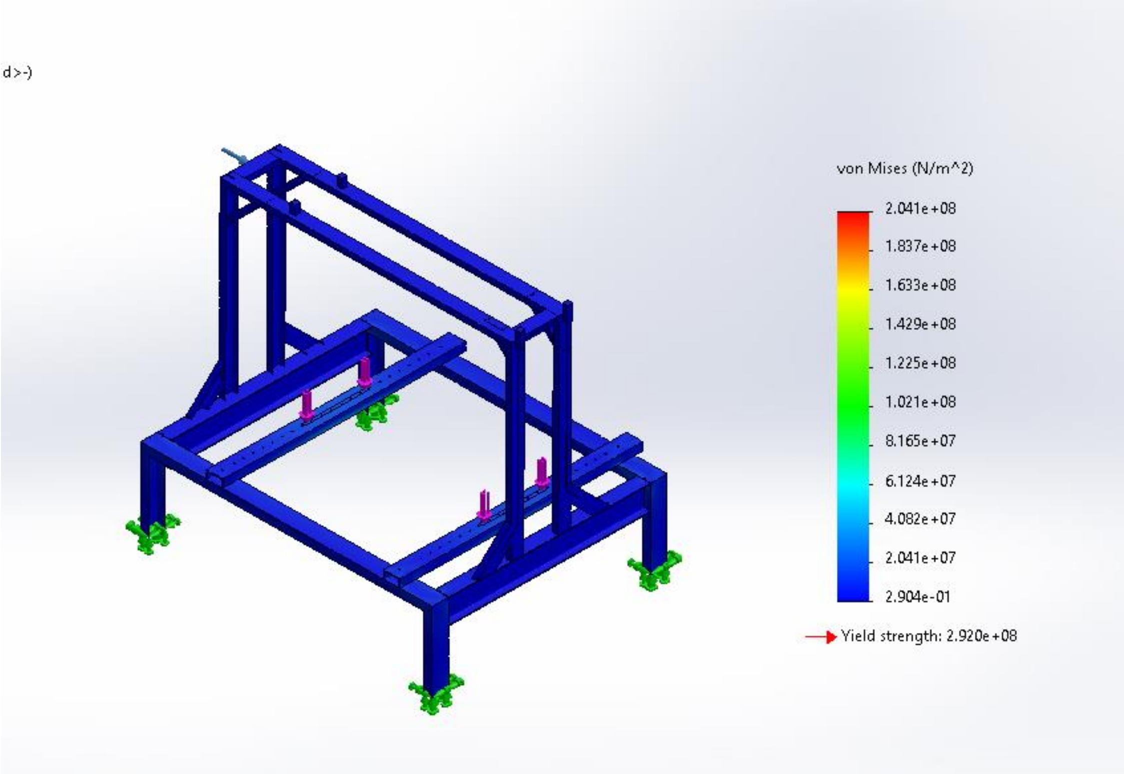
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	-110.007	-364.875	-8.57616	381.194

Free body moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N.m	0	0	0	1e-33

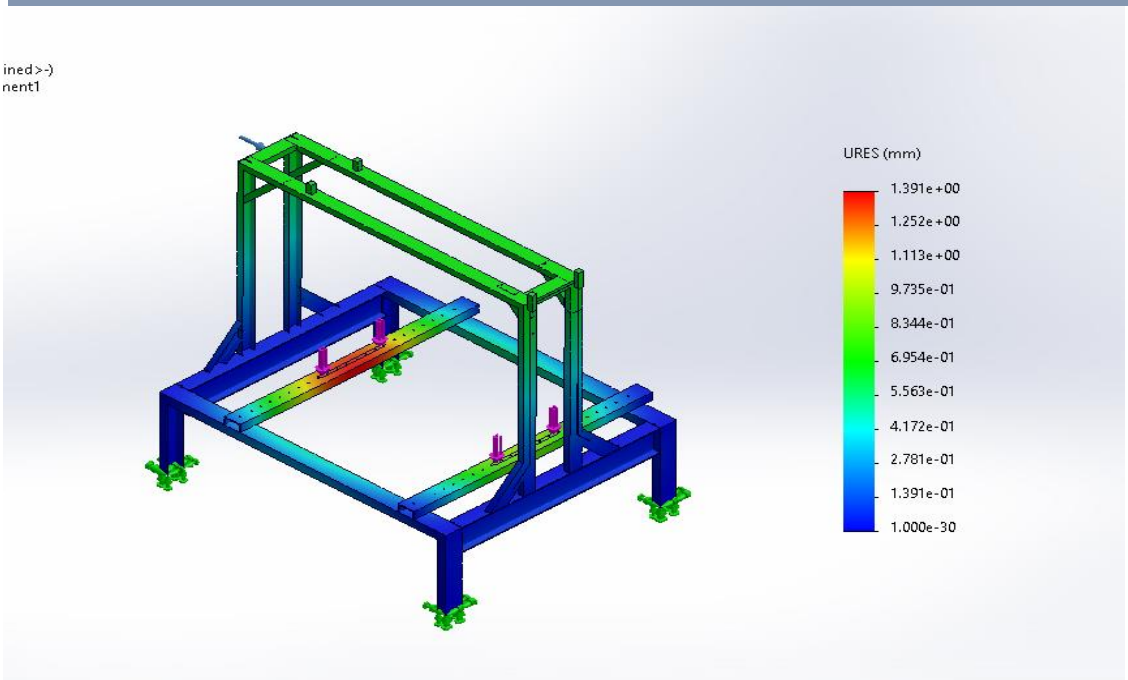
STUDY RESULTS

Name	Type	Min	Max
Stress1	VON: von Mises Stress	2.904e-01N/m^2 Node: 317290	2.641e+08N/m^2 Node: 137724



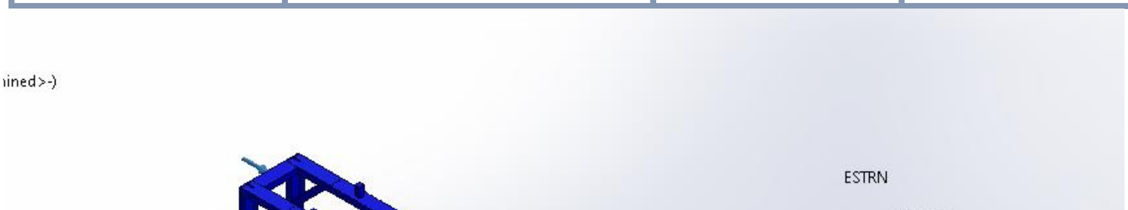
-Static 1-Stress-Stress1الهيكل

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 567	1.391e+00mm Node: 425623



-Static 1-Displacement-Displacement1الهيكل

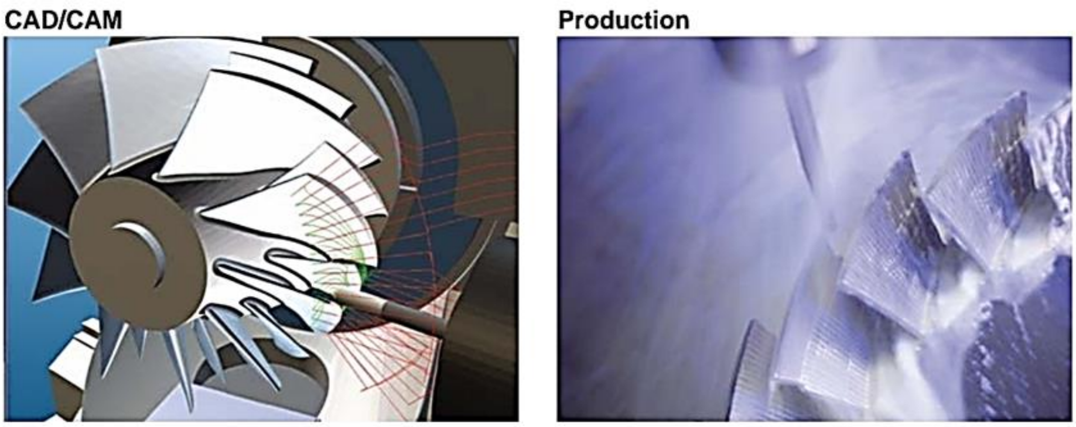
Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	6.132e-13 Element: 2694	3.560e-04 Element: 131892

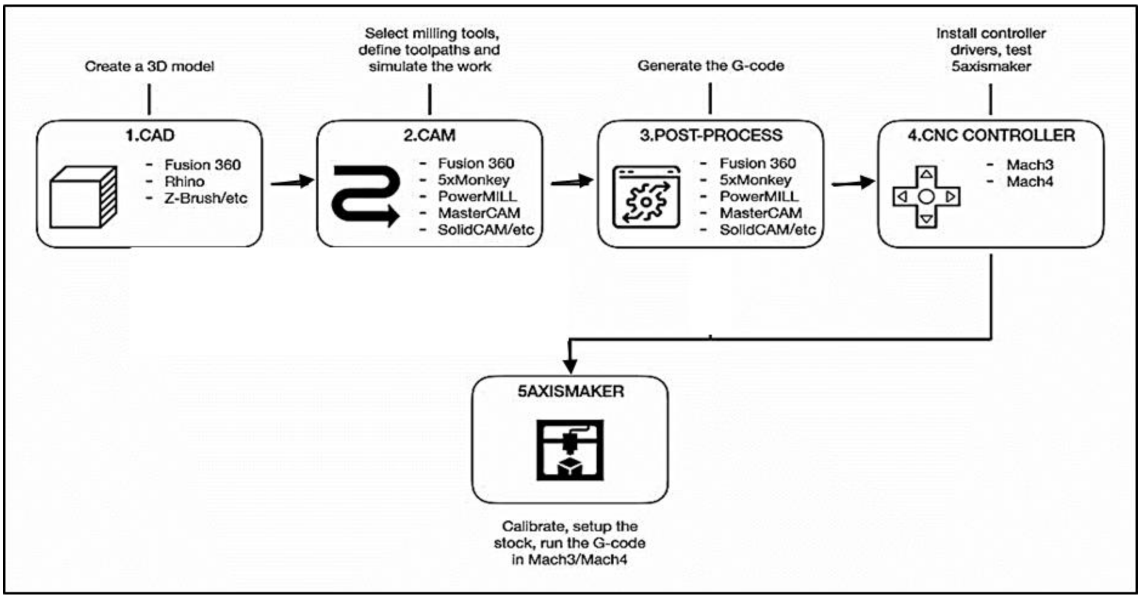


CHAPTER 5
IMPLEMENTATION

5.1 5-AXIS CNC STRUCTURING PRODUCTION

The production process chain generally starts with workpiece design. The data generated at this stage provides the basis for further processing and, ultimately, for production





5.2 SEARCH FOR SYSTEMS AND SOFTWARE

First, the search for the programs necessary to operate the five-axis system, as well as the programs necessary to generate the G-cod five axes, commensurate with the programs operating the system, then the Mach3 program was the operating program for the system

Miniature model of the machine

Making a miniature model of the machine and controlling it by Arduino, in order to understand the working mechanism of a five-axis machine. Then, after making sure that the systems and software can be operated and understanding the kinematics of 5 axis, we worked on importing the necessary parts for the project.

5.3 DESIGN (CAD) STAGE

Designing the elements of the machine using the Solidwork program, then we assembled all the pieces

5.4 COMPUTER AIDED MANUFACTURING STAGES (CAM)

The Artcam program and the sheet program were used in order to create a tool path for the designed pieces that need to be manufactured by CNC machines, such as cutting iron sheets with plasma

5.5 STRESS AND VIBRATION ANALYSIS AND SIMULATION

Studying the stresses affecting the machine, choosing the appropriate shape for it, choosing the type of material, studying the vibrations that can affect the work of the machine, and finding solutions for it, where some parts of the base of reinforced concrete were chosen to dampen vibrations.

5.6 INSTALLATION, ASSEMBLY, POWER SUPPLYBASE WELDING, ASSEMBLY AND POWER SUPPLY OF PARTS AND MOTORS

Welding the base of the machine in order to ensure non-vibration, and reinforced concrete was poured in some parts of the base for the importance of its stability

The axles were installed after welding their basic parts and then installing the motors and supplying them with power

Connecting data wires that connect the computer with the "Mach3 Breakout Board " and the Drivers and Inverter

5.7 CREATE POST PROCESS FOR OUR MACHINE

Definition of the post process : It is a computer program that links between the CAM programs and the machine where the G-cod is generated by. Its job is to generate the G-code in proportion to a specific machine according to the number of axes, kinematics and dimensions of the machine.

We created the post process according to the specifications of our machine

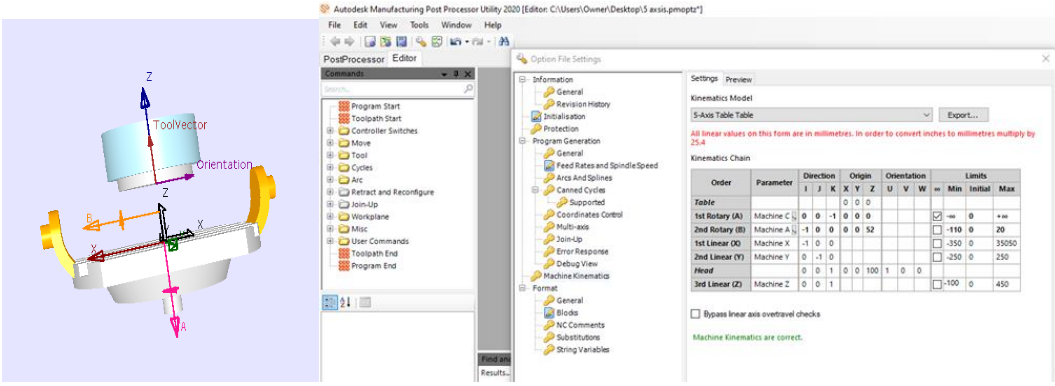


Figure 5.1: postprocessor for Machine kinematics

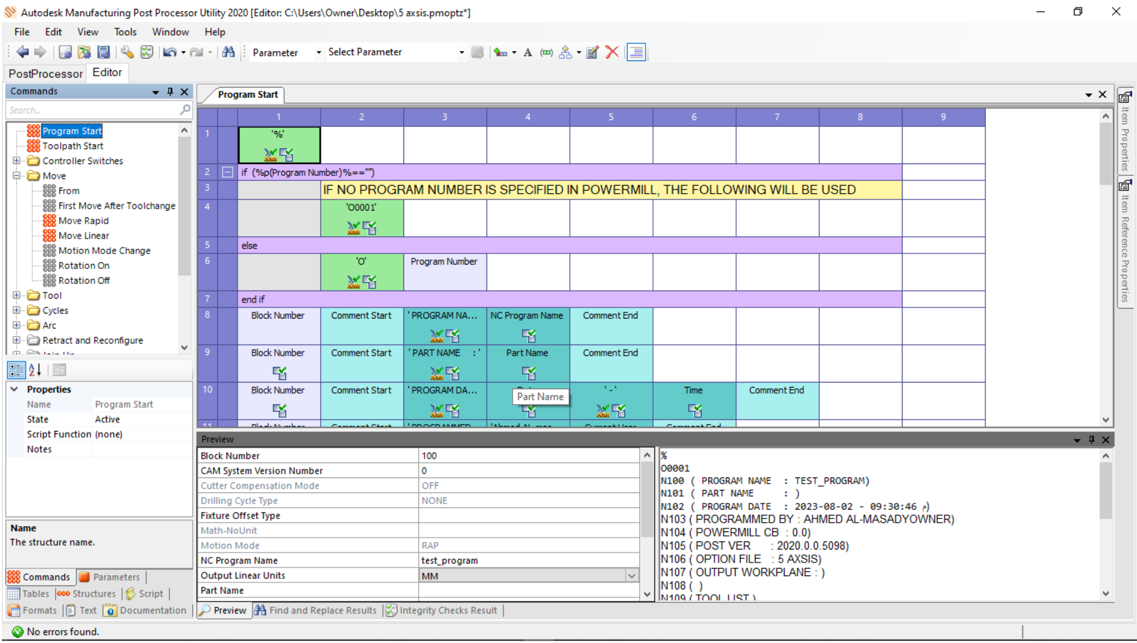


Figure 5.2: postprocessor For the machine motion start

Artificial intelligence algorithms were also created, and their function is to choose the best path for the tool and prevent collision so that we get a more accurate product and a smoother surface

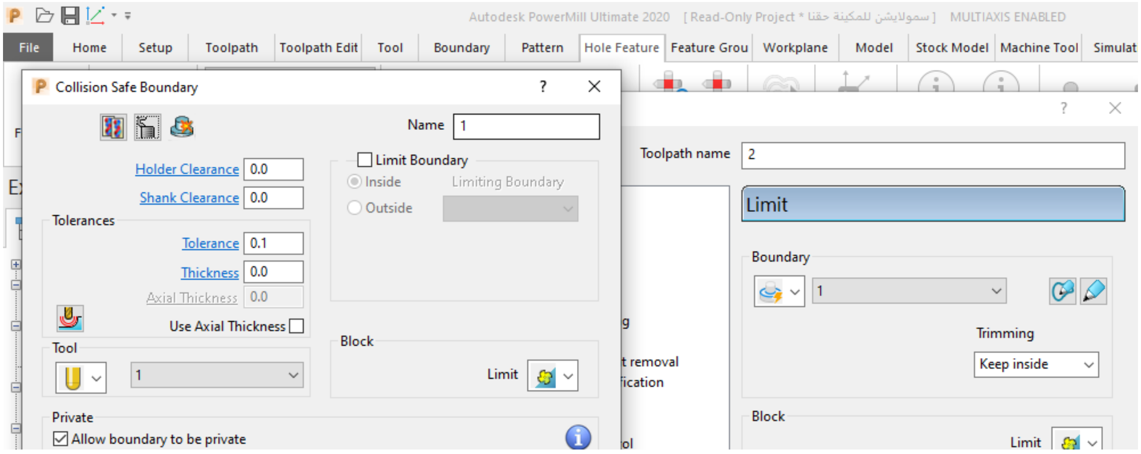


Figure 5.3: Collision avoidance technology

The deviation of the cutting tool resulting from the accidental force during cutting was also compensated, and this is what makes the products More accurate

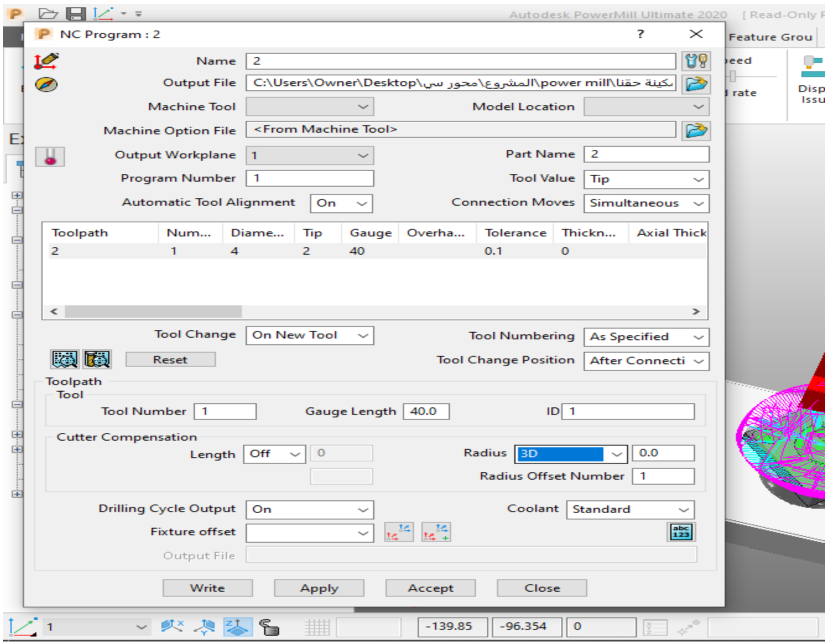


Figure 5.4: Cutting tool deviation compensation

5.8 KINEMATIC SIMULATION

The CAD of 5 axis has been included within the power mill program in order to simulate the machine and the piece for which the mill is made at the same time, which makes the manufacturing process and the creation of the Tool path easy as it can perform experiments when manufacturing a product on the computer and then Running it in reality

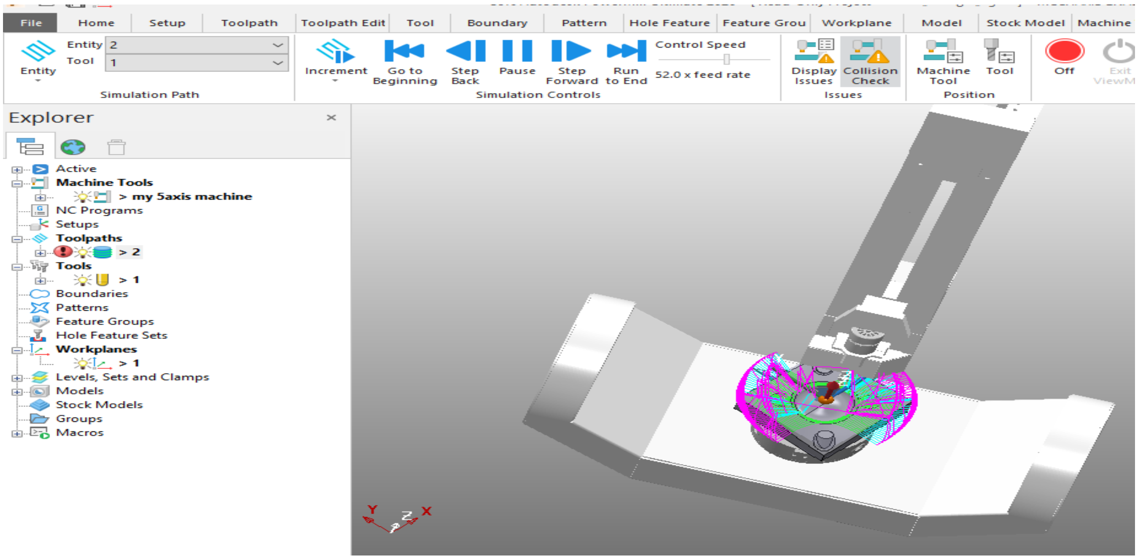


Figure 5.5: Create Toolpath for our machine

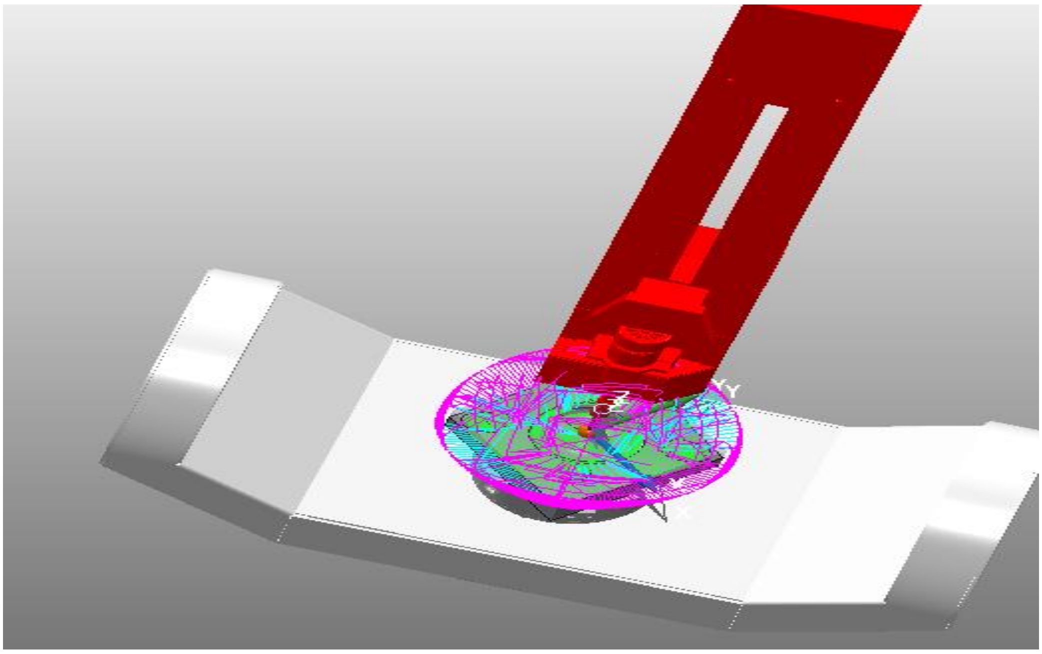


Figure 5.6: Machine parts collide during simulation

We notice that the Z axis appears in red and the machine stops working, and this happens when there is a collision between the parts of the machine or between the cutting tool and the parts of the machine

* Note / This happens when the system of collision avoiding the collision that works with artificial intelligence is disabled

.

5.9 CNC CONTROL SOFTWARE

5.9.1 MACH 3

Itures and provides a great value to those needing a CNC control is very rich in feat software package. Mach3 works on most Windows PC's to control the motion of Code. While comprising many advanced -motors (stepper & servo) by processing G control software available. Mach3 is customizable features, it is the most intuitive CNC and has been used for many applications with numerous types of hardware.

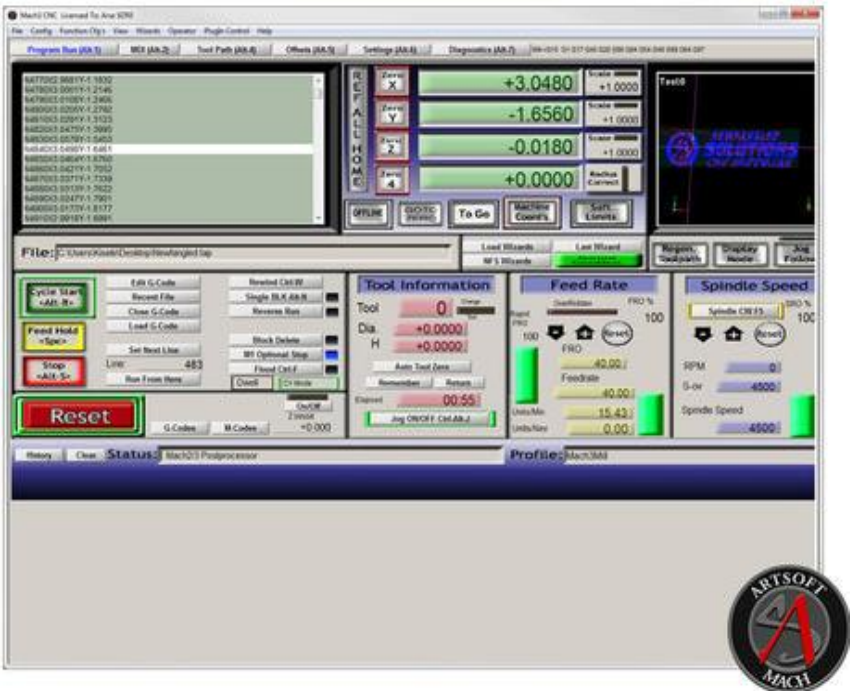


Figure 5.7: Mach3 Interface

Note: The settings on MACH3 below is in condition that breakout board and stepper drivers are connected in common anode.

5.9.1.1 MACH3 SETTING

Check whether the MACH3 driver is installed correctly.

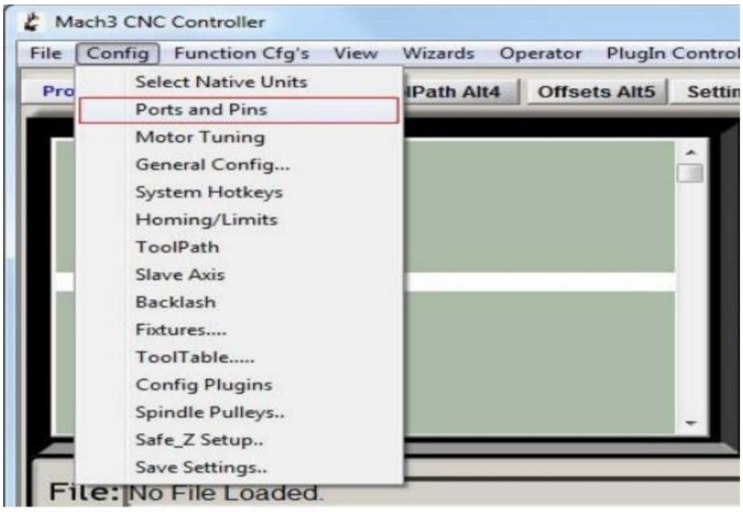


Figure 5.8: MACH3 Configuration

Setup Units: Choose “MM’s” in Config->Set Default Units for Setup.

Figure 5.9: Setup Units

Click “Config”->”Ports and Pins” on Main Interface.

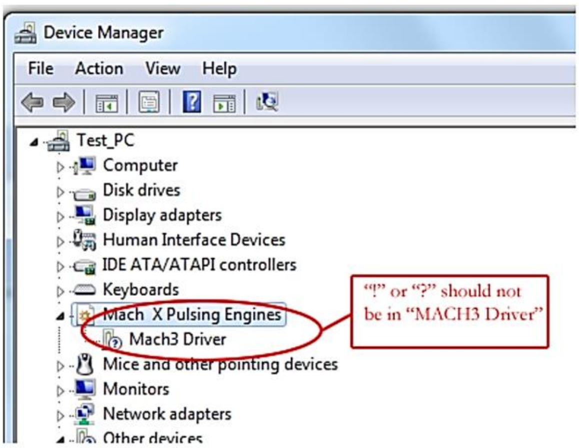


Figure 5.10: Main Interface

Enter in “Port Setup and Axis Selection” to set “Port#1” and “Kernel Speed” shown as below.

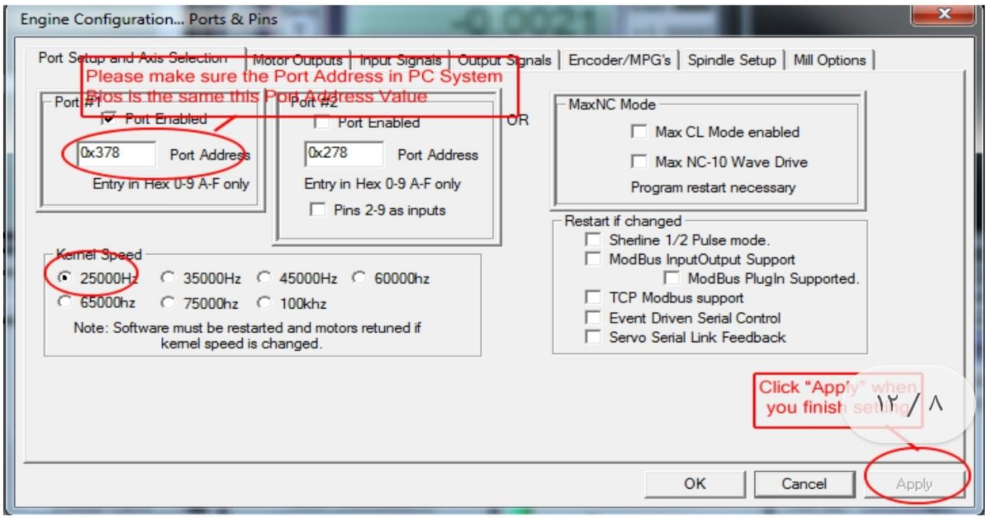


Figure 5.11: Port Setup and Axis Selection

Click “Motor Outputs” to set it shown as below.

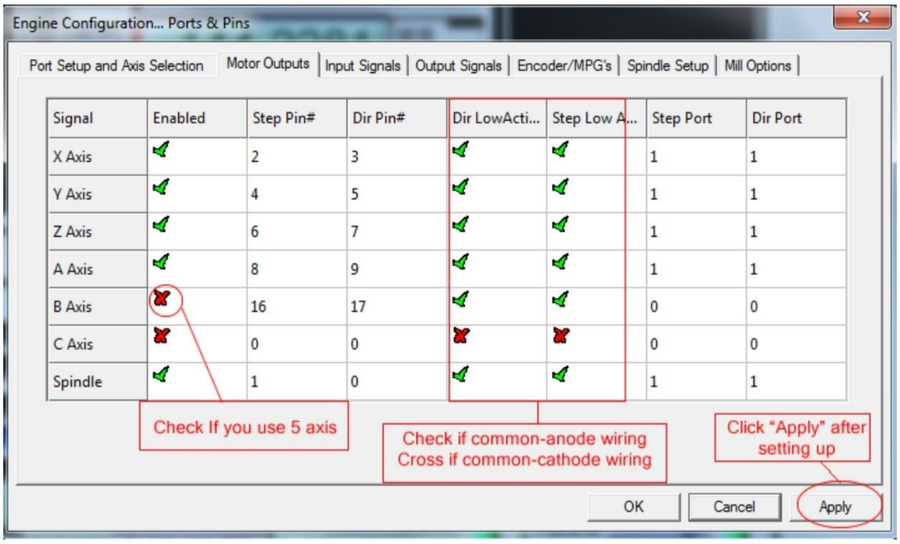
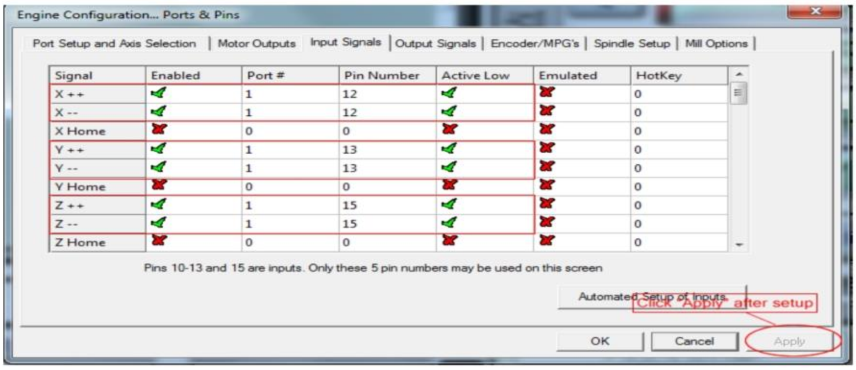


Figure 5.12: Motor Outputs

Click “Input Signals” to set it shown as below.



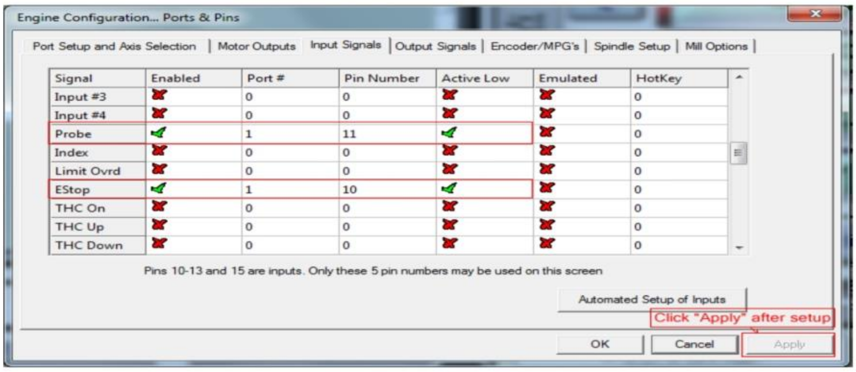


Figure 5.13: Input Signals

Click “Output Signals” to set it shown as below.

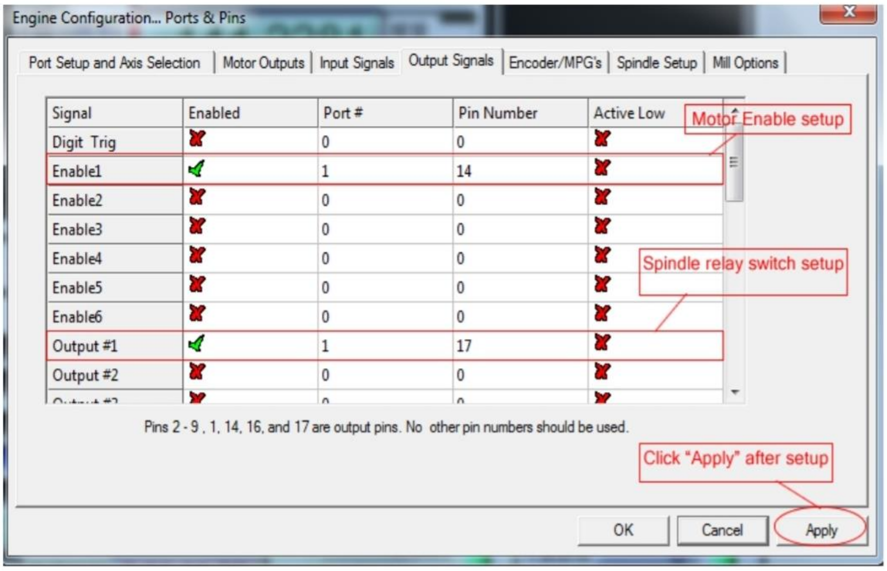


Figure 5.14: Output Signals

Click “Spindle Setup” to set it shown as below.

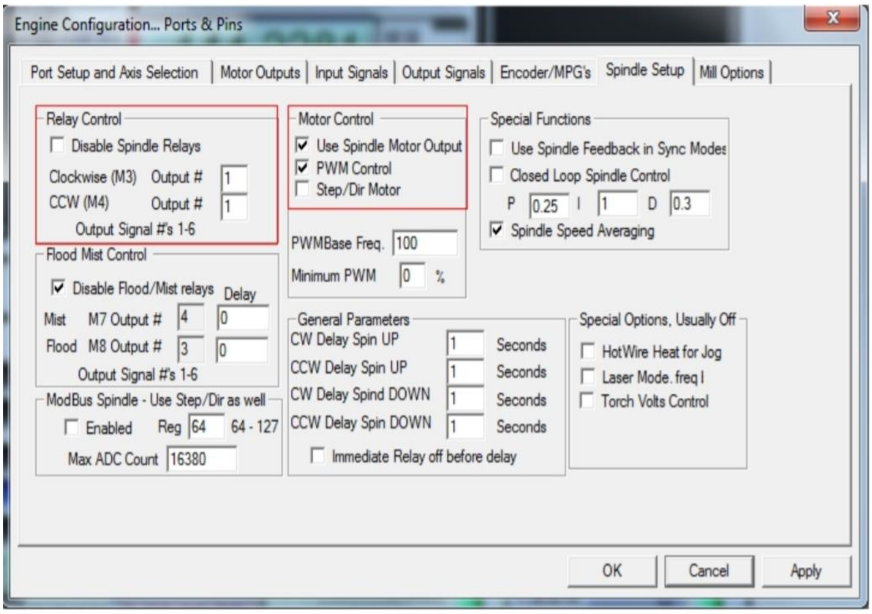


Figure 5.15: Spindle Setup

Motor debugging. Click Config->Motor Turning and Setup.

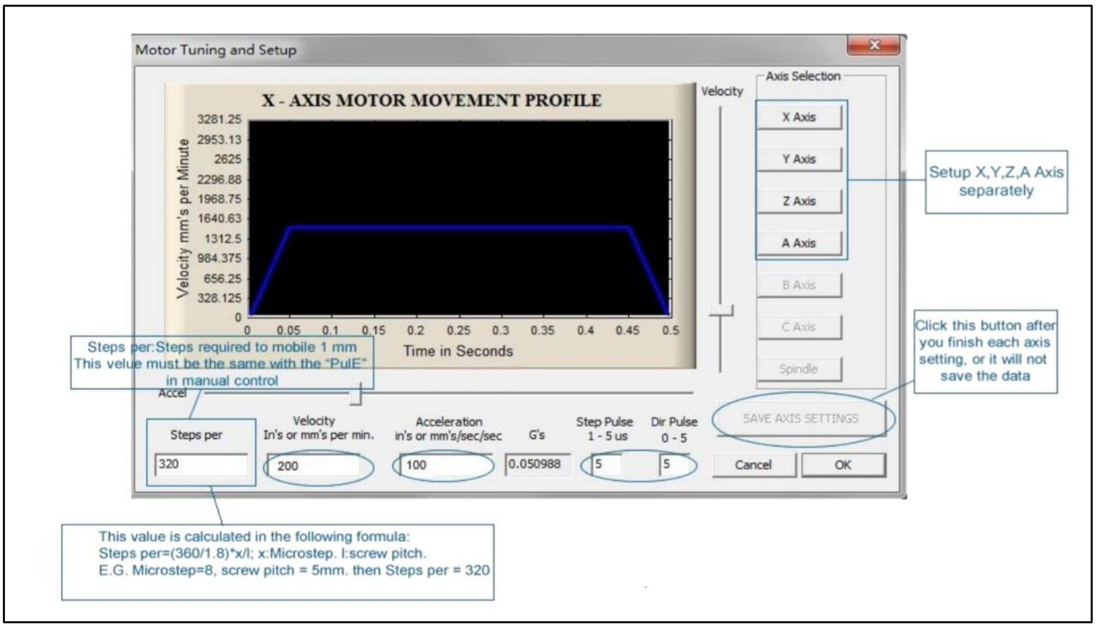


Figure 5.16: Motor debugging

Click “System Hot Keys Setup”. Set X, Y, Z axis hotkey shown as below. Then you can manual control the corresponding axis motor turning via hotkeys.

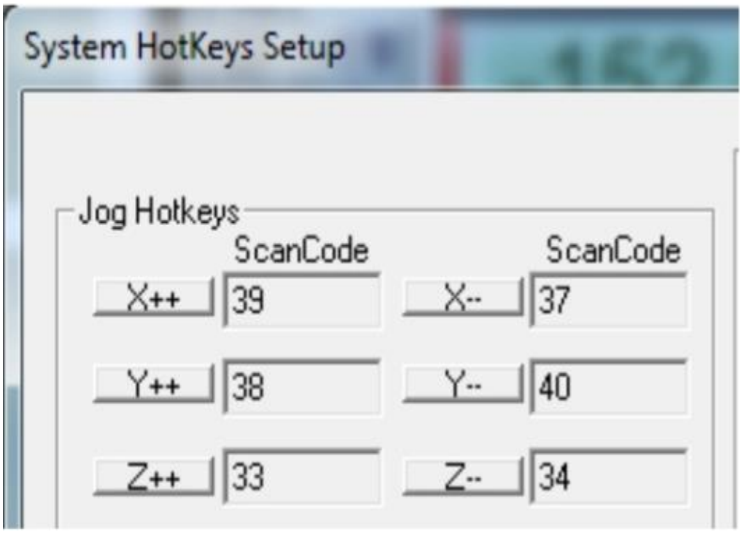


Figure 5.17: Set X, Y, Z axis hotkey

CHAPTER 6
CONCLUSION AND FUTURE WORK

6.1 CONCLUSION

The work presented in this thesis is a part of a larger effort to make machining a rapid prototyping process. In summary, we present a new technology for generating toolpaths directly from the CAD model of the part. The key idea here is the use of accessibility considerations as the driving constraint in path generation .

This is fundamentally different from the feature-based approach, and especially targets the realm of 5-axis machining, for example, of aerospace parts. This approach is an extension of concepts developed by numerous other researchers in the areas of CAM, surface machining and robotics.

6.2 FUTURE WORK

This thesis is a seed work in developing a fully automated access-based tool path generation system. As a proof of concept, we have shown the functioning of our system and demonstrated the capabilities of it to generate toolpaths for real world parts.

We have implemented the modules to generate the toolpaths from the CAD model of a part, however to develop a system useful to the industry, couple of important modules should be researched upon and implemented.

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APPENDIX A
THE CODE OF THE CENTER FINDING MODIFICATION

```
Rem VBScript To center probe inside a pipe
If GetOemLed (825) <> 0 Then 'Check to see if the probe is already grounded or faulty
Code "(Probe plate is grounded, check connection and try again)"
Else
FeedCurrent = GetOemDRO(818) 'Get the current settings
XCurrent = GetDro(0)
YCurrent = GetDro(1)
Code "G4 P1" 'Pause 1 second to give time to position probe plate
Code "F4" 'slow feed rate to 4 ipm
Rem Probe Left

XNew = Xcurrent - 3 'probe 3 inches to left
Code "G31 X" &XNew
While IsMoving() 'wait for the move to finish
Wend
XPos1 = GetVar(2000) 'get the probe touch location
Code "G0 X" &XCurrent 'rapid move back to start point
Rem Probe Right

XNew = XCurrent + 3 'probe 3 inches to right
Code "G31 X" &XNew
While IsMoving()
Wend
XPos2 = GetVar(2000)
XCenter = (XPos1 + XPos2) / 2 'center is midway between XPos1 and XPos2
Code "G0 X" &XCenter 'rapid move to the x center location

Rem Probe up
YNew = YCurrent + 3
Code "G31 Y" &YNew
While IsMoving()
Wend
YPos1 = GetVar(2001)
Code "G0 Y" &YCurrent

Rem Probe down
YNew = YCurrent - 3
Code "G31 Y" &YNew
While IsMoving()
Wend
YPos2 = GetVar(2001)
YCenter = (YPos1 + YPos2) / 2
Rem move To the center

Code "G0 Y" &YCenter
While IsMoving ()
Wend
Code "F" &FeedCurrent 'restore starting feed rate
```

APPENDIX B

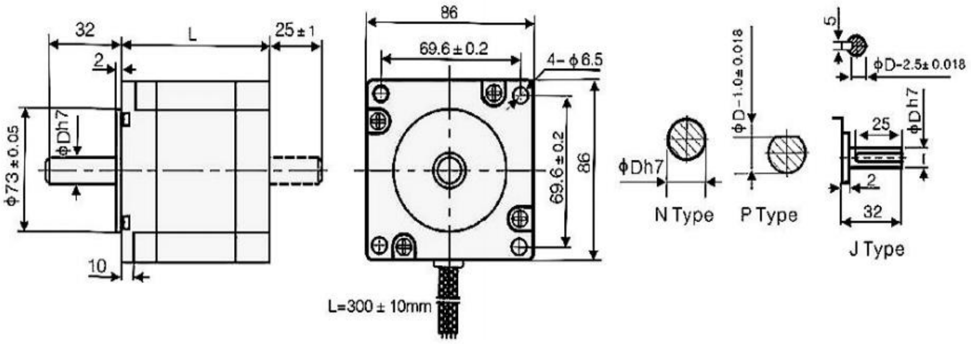
NEMA34STEPPERMOTOR

Nema 34 Stepper Motor

Nema 34 hybrid bipolar stepper motor is a permanent magnet stepper motor with an end face size of 86mm x 86mm. Nema 34 stepper motor with high torque is used for CNC machine, 3D printer and robot arm, etc. It is simple structure, small size and easy assembly. ATO high torque stepper motor at low cost, including 2 phase open loop, 3 phase open loop and 2 phase closed loop, can be controlled by AC or DC digital stepper controllers for precise position control.

2 Phase Open Loop Stepper Motor

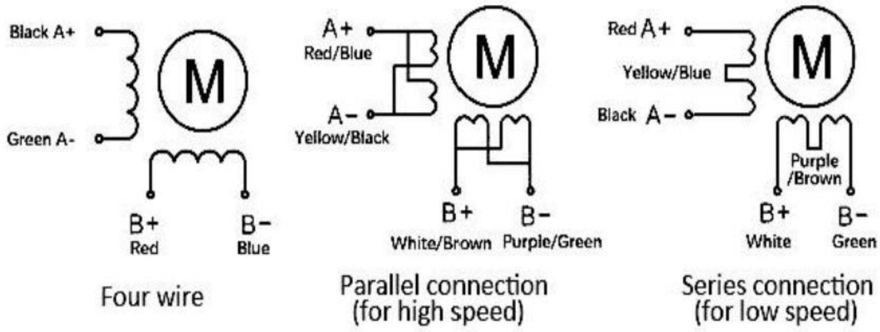
Specification



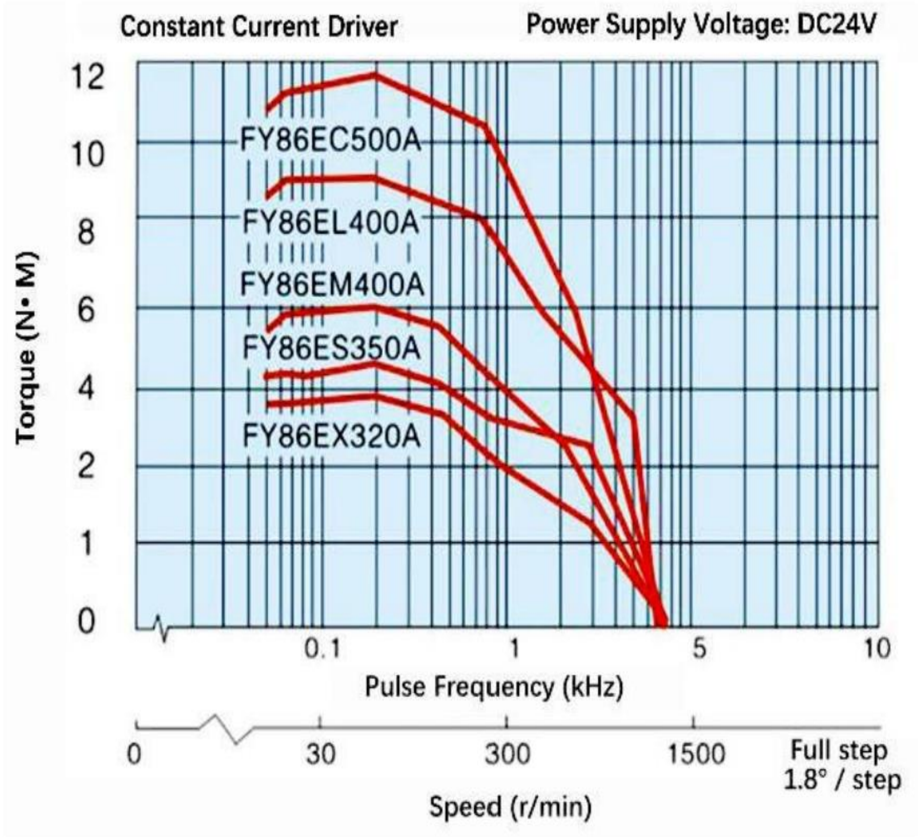
Model	Step Angle (°)	Motor Length (mm)	Rated Current (A)	Holding Torque (N.m)	Phase Resistance (Ω)	Phase Inductance (mH)	Rotor Inertia (g.cm²)	Lead Wires (NO.)	Motor Weight (Kg)
FY86ES350A	1.8	80	3.5	4.50	1.0	4.4	1500	4	2.00
FY86EM400A		94	4.0	6.00	0.8	3.5	2700	4	2.80
FY86EL400A		118	4.0	8.50	0.97	5.5	4100	4	3.80
FY86EC500A		150	5.0	12.0	1.20	6.0	6200	4	5.20

Technical Specification	
Shaft Diameter	14mm/ 12.7mm
Step Angle Accuracy	±5% (Full Step, No Load)
Resistance Accuracy	±10% (20℃)
Inductance Accuracy	±20% (1KHz)
Temperature Rise	80℃ Max. (rated current, 2 phase on)
Ambient Temperature	-20℃~+50℃
Insulation Resistance	100MΩ Min. 500VDC
Dielectric Strength	1Min. 500VAC
Shaft Radial Play	0.02Max. 450g Load
Shaft Axial Play	0.08Max. 450g Load
Radial Max. Load	75N
Axial Max. Load	15N
Warranty Period	12 months
Certificate	CE, ROHs, FCC

Wiring Diagram

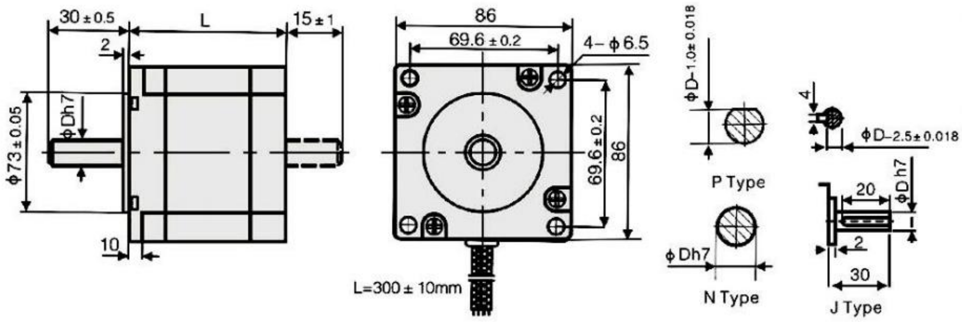


Speed-Torque Curve Diagram



3 Phase Open Loop Stepper Motor

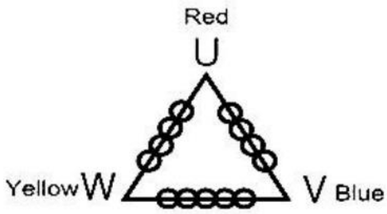
Specification



Model	Step Angle (°)	Motor Length (mm)	Rated Current (A)	Holding Torque (N.m)	Phase Resistance (Ω)	Phase Inductance (mH)	Rotor Inertia (g.cm²)	Lead Wires (NO.)	Motor Weight (Kg)
FY86TM200A	1.8	97	2.0	4.00	4.65	14.6	2400	3	2.80
FY86TC320A		145	3.2	8.50	2.60	9.57	4560	3	4.70
FY86TL300A		125	3.0	6.00	2.00	8.00	3480	3	3.80

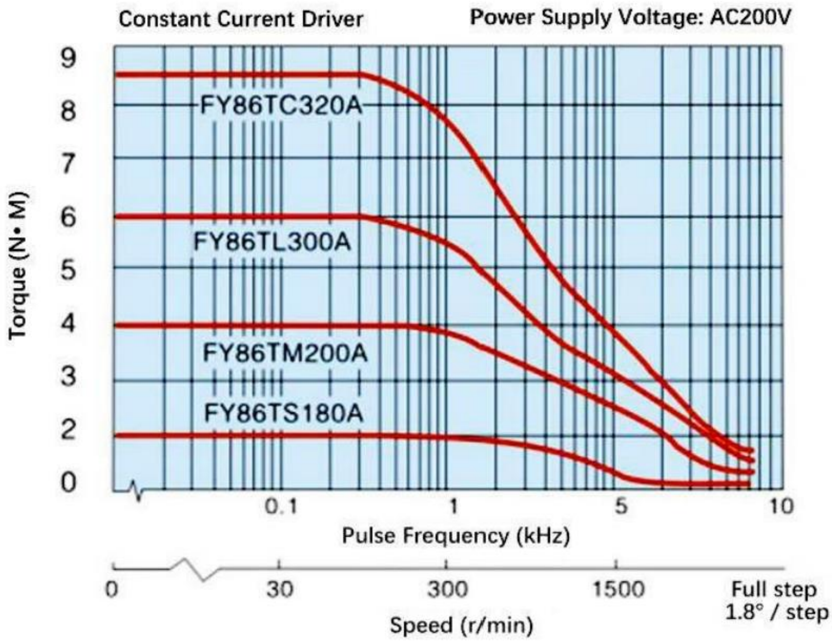
Technical Specification	
Shaft Diameter	14mm
Step Angle Accuracy	±5% (Full Step, No Load)
Resistance Accuracy	±10% (20℃)
Inductance Accuracy	±20% (1KHz)
Temperature Rise	80℃ Max. (rated current, 2 phase on)
Ambient Temperature	-20℃~+50℃
Insulation Resistance	100MΩ Min. 500VDC
Dielectric Strength	1Min. 500VAC
Shaft Radial Play	0.02Max. 450g Load
Shaft Axial Play	0.08Max. 450g Load
Radial Max. Load	75N
Axial Max. Load	15N
Warranty Period	12 months
Certificate	CE, ROHs, FCC

Wiring Diagram



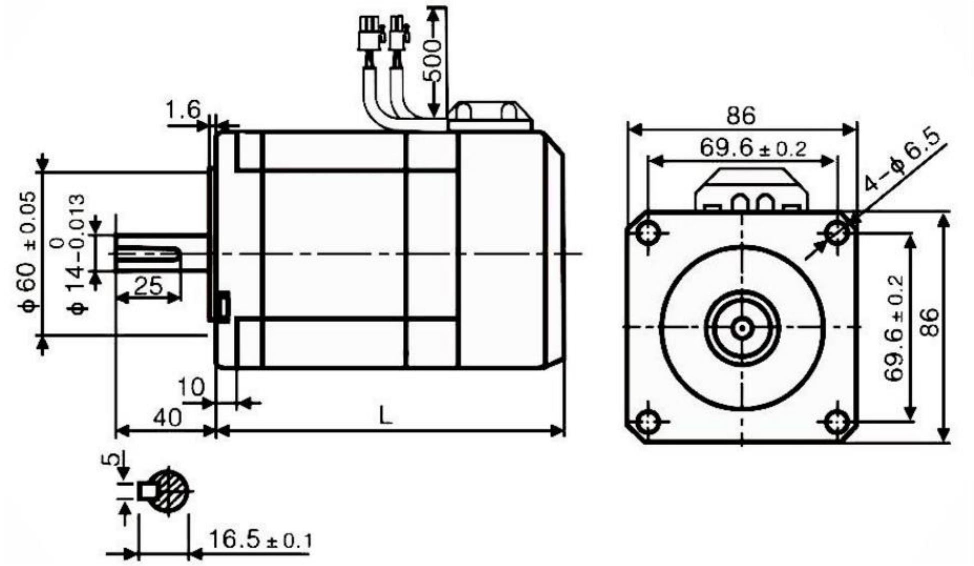
3 wire

Speed-Torque Curve Diagram



2 Phase Closed Loop Stepper Motor

Specification

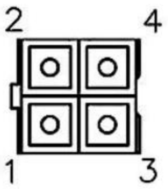


Model	Step Angle (°)	Motor Length (mm)	Rated Current (A)	Holding Torque (N.m)	Phase Resistance (Ω)	Phase Inductance (mH)	Rotor Inertia ($g.cm^2$)	Lead Wires (NO.)	Motor Weight (Kg)
FY86EC620BC1	1.8	172	6.2	12.00	0.65	5.6	5600	4	5.00
FY86EM620BC1		102	6.2	4.50	0.34	2.5	1800	4	2.10
FY86EL620BC1		134	6.2	8.20	0.45	4.7	3600	4	3.60

Technical Specification	
Shaft Diameter	12mm
Step Angle Accuracy	±5% (Full Step, No Load)
Resistance Accuracy	±10% (20℃)
Inductance Accuracy	±20% (1KHz)
Temperature Rise	80℃ Max. (rated current, 2 phase on)
Ambient Temperature	-20℃~+50℃
Insulation Resistance	100MΩ Min. 500VDC
Dielectric Strength	1Min. 500VAC
Shaft Radial Play	0.02Max. 450g Load
Shaft Axial Play	0.08Max. 450g Load
Radial Max. Load	220N
Axial Max. Load	60N
Warranty Period	12 months
Certificate	CE, ROHs, FCC

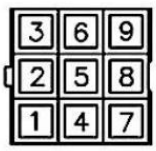
Motor & Encoder Wiring Diagram

Motor Wiring



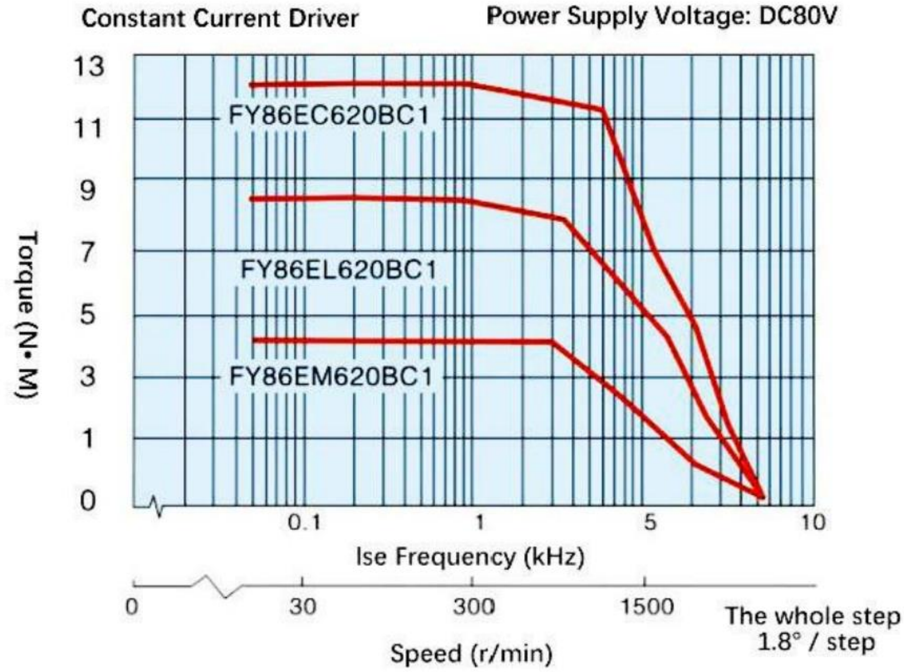
Motor End	Color	Function
1	Blue	B-
2	Red	B+
3	Green	A-
4	Black	A+

Encoder Wiring



Encoder	Color	Function
1	Blue	EA+
2	—	—
3	Blue/White	EA+
4	Orange	EB+
5	—	—
6	Orange/ White	EB-
7	Red	VCC
8	Black	GND
Encoder	Shield	

Speed-Torque Curve Diagram



APPENDIX C

USER MANUAL FOR DMA860H

User’s Manual

For

DMA860H

Fully Digital Stepper Drive

Version 1.0

Attention: Please read this manual carefully before using the drive!

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Table of Contents

1. Introduction, Features and Applications

Introduction

The DMA860H is a fully digital stepper drive developed with advanced DSP control algorithm based on the latest motion control technology. It has achieved a unique level of system smoothness, providing optimal torque and nulls mid-range instability. Its motor auto-identification and parameter auto-configuration feature offers quick setup to optimal modes with different motors. Compared with traditional analog drives, DMA860H can drive a stepper motor at much lower noise, lower heating, and smoother movement. Its unique features make DMA860H an ideal choice for high requirement applications.

Features

- Anti-Resonance provides optimal torque and nulls mid-range instability
- Motor auto-identification and parameter auto-configuration technology, offers optimal responses with different motors
- Multi-Stepping allows a low resolution step input to produce a higher microstep output, thus offers smoother motor movement
- 16 selectable microstep resolutions including 400, 800, 1600, 3200, 6400, 12800, 25600, 51200, 1000, 2000, 4000, 5000, 8000, 10000, 20000, 40000
- Soft-start with no "jump" when powered on
- Input voltage 18-80VAC or 26-113VDC
- 8 selectable peak current including 2.40A, 3.08A, 3.77A, 4.45A, 5.14A, 5.83A, 6.52A, 7.20A
- Pulse input frequency up to 200 KHz, TTL compatible and optically isolated input
- Automatic idle-current reduction
- Suitable for 2-phase and 4-phase motors
- Support PUL/DIR and CW/CCW modes
- Over-voltage, over-current protections

Applications

Suitable for a wide range of stepping motors, from NEMA size 23 to 42. It can be used in various kinds of machines, such as X-Y tables, engraving machines, labeling machines, laser cutters, pick-place devices, and so on. Particularly adapt to the applications desired with low noise, low heating, high speed and high precision.

2. Specifications

Electrical Specifications (T_j = 25℃/77℉)

Parameters	DMA860H			
	Min	Typical	Max	Unit
Output Current	1.0	-	7.2 (Peak)	A
Input Voltage	18	48	80	VAC
	26	68	113	VDC
Logic Signal Current	7	10	16	mA
Pulse input frequency	0	-	200	kHz
Pulse Width	2.5	-	-	uS

Pulse Voltage	-	5	-	VDC
Isolation resistance	500			MΩ

Operating Environment and other Specifications

Cooling	Natural Cooling or Forced cooling	
Operating Environment	Environment	Avoid dust, oil fog and corrosive gases
	Ambient Temperature	0℃ — 50℃
	Humidity	40%RH — 90%RH
	Operating Temperature	70℃ Max
	Vibration	5.9m/s^2 Max
Storage Temperature	-20℃ — 65℃	
Weight	Approx. 620g (21.9oz)	

Mechanical Specifications

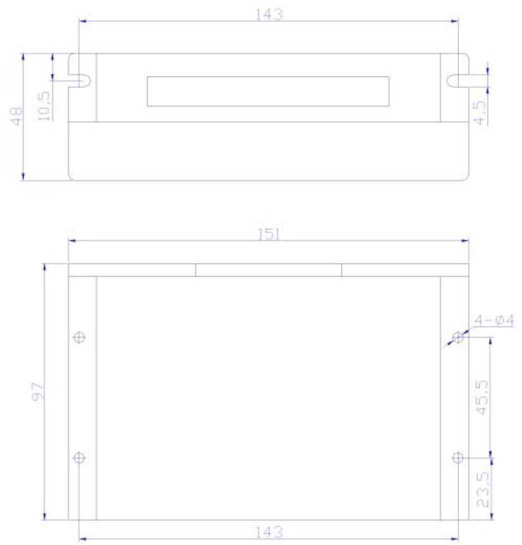


Figure 1: Mechanical specifications

***Recommend use side mounting for better heat dissipation**

Elimination of Heat

- Driver's reliable working temperature should be <70℃(158℉), and motor working temperature should be <80℃(176℉);
- It is recommended to use automatic idle-current mode, namely current automatically reduce to 50% when motor stops, so as to reduce driver heating and motor heating;
- It is recommended to mount the driver vertically to maximize heat sink area. Use forced cooling method to cool

the system if necessary.

3. Pin Assignment and Description

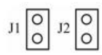
The DMA860H has two connectors, connector P1 for control signals connections, and connector P2 for power and motor connections. The following tables are brief descriptions of the two connectors. More detailed descriptions of the pins and related issues are presented in section 4, 5, 9.

Connector P1 Configurations

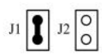
Pin Function	Details
PUL+	Pulse signal: In single pulse (pulse/direction) mode, this input represents pulse signal, each rising or falling edge active (set by inside jumper J1); 4.5-5V when PUL-HIGH, 0-0.5V when PUL-LOW. In CW/CCW mode (set by inside jumper J2), this input represents clockwise (CW) pulse. For reliable response, pulse width should be longer than 2.5μs.
PUL-	
DIR+	DIR signal: In single-pulse mode, this signal has low/high voltage levels, representing two directions of motor rotation; in CW/CCW mode (set by inside jumper J2), this signal is counter-clock (CCW) pulse. For reliable motion response, DIR signal should be ahead of PUL signal by 5μs at least. 4.5-5V when DIR-HIGH, 0-0.5V when DIR-LOW. Please note that rotation direction is also related to motor-driver wiring match. Exchanging the connection of two wires for a coil to the driver will reverse motion direction.
DIR-	
ENA+	Enable signal: This signal is used for enabling/disabling the driver. High level (NPN control signal, PNP and differential control signals are on the contrary, namely low level for enabling.) for enabling the driver and low level for disabling the driver. Usually left **UNCONNECTED (ENABLED)**.
ENA-	

Selecting Active Pulse Edge or Active Level and Control Signal Mode

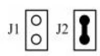
There are two jumpers J1 and J2 inside the DMA860H specifically for selecting active pulse edge and control signal mode, as shown in figure 2. Default setting is PUL/DIR mode and upward-rising edge active. (Note: J3 inside the driver is used to reverse the default rotation direction.)



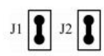
(a) J1, J2 open circuit
PUL/DIR mode and Active at rising edge (NPN)



(b) J1 open circuit, J3 shirt circuit
PUL/DIR mode and active at falling edge (NPN)



(c) J1 short circuit, J3 open circuit
CW/CCW mode and Active at rising edge (NPN)



(d) J1, J3 short circuit
CW/CCW mode and active at falling edge (NPN)

Figure 2: J1 and J2 jumper Settings

Connector P2 Configurations

Pin Function	Details
AC	Power supply, 18~80 VAC or 26-113VDC, Including voltage fluctuation and EMF voltage.
AC	
A+, A-	Motor Phase A
B+, B-	Motor Phase B

4. Control Signal Connector (P1) Interface

The DMA860H can accept differential and single-ended inputs (including open-collector and PNP output). The DMA860H has 3 optically isolated logic inputs which are located on connector P1 to accept line driver control signals. These inputs are isolated to minimize or eliminate electrical noises coupled onto the drive control signals. Recommend use line driver control signals to increase noise immunity of the driver in interference environments. In the following figures, connections to open-collector and PNP signals are illustrated.

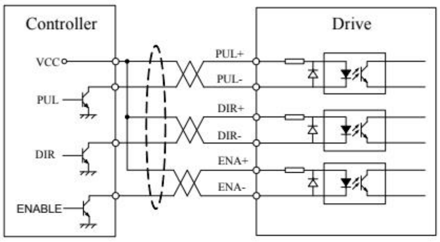


Figure 3: Connections to open-collector signal (common-anode)

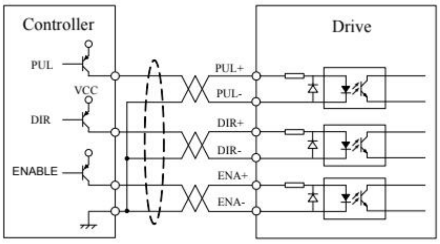


Figure 4: Connection to PNP signal (common-cathode)

5. Connecting the Motor

The DMA860H can drive any 2-pahse and 4-pahse hybrid stepping motors.

Connections to 4-lead Motors

4 lead motors are the least flexible but easiest to wire. Speed and torque will depend on winding inductance. In setting the driver output current, multiply the specified phase current by 1.4 to determine the peak output current.

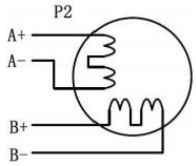


Figure 5: 4-lead Motor Connections

Connections to 6-lead Motors

Like 8 lead stepping motors, 6 lead motors have two configurations available for high speed or high torque operation. The higher speed configuration, or half coil, is so described because it uses one half of the motor's inductor windings. The higher torque configuration, or full coil, uses the full windings of the phases.

Half Coil Configurations

As previously stated, the half coil configuration uses 50% of the motor phase windings. This gives lower inductance, hence, lower torque output. Like the parallel connection of 8 lead motor, the torque output will be more stable at higher speeds. This configuration is also referred to as half chopper. In setting the driver output current multiply the specified per phase (or unipolar) current rating by 1.4 to determine the peak output current.

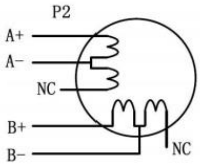


Figure 6: 6-lead motor half coil (higher speed) connections

Full Coil Configurations

The full coil configuration on a six lead motor should be used in applications where higher torque at lower speeds is desired. This configuration is also referred to as full copper. In full coil mode, the motors should be run at only 70% of their rated current to prevent over heating.

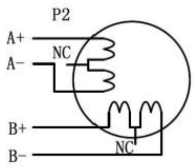


Figure 7: 6-lead motor full coil (higher torque) connections

Connections to 8-lead Motors

8 lead motors offer a high degree of flexibility to the system designer in that they may be connected in series or parallel, thus satisfying a wide range of applications.

Series Connections

A series motor configuration would typically be used in applications where a higher torque at lower speeds is required. Because this configuration has the most inductance, the performance will start to degrade at higher speeds. In series mode, the motors should also be run at only 70% of their rated current to prevent over heating.

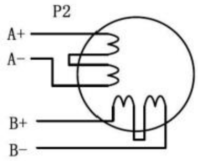


Figure 8: 8-lead motor series connections

Parallel Connections

An 8 lead motor in a parallel configuration offers a more stable, but lower torque at lower speeds. But because of the lower inductance, there will be higher torque at higher speeds. Multiply the per phase (or unipolar) current rating by 1.96, or the bipolar current rating by 1.4, to determine the peak output current.

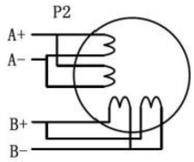


Figure 9: 8-lead motor parallel connections

6. Power Supply Selection

The DMA860H can match medium and small size stepping motors (from NEMA frame size 17 to 34) made by Leadshine or other motor manufactures around the world. To achieve good driving performances, it is important to select supply voltage and output current properly. Generally speaking, supply voltage determines the high speed performance of the motor, while output current determines the output torque of the driven motor (particularly at lower speed). Higher supply voltage will allow higher motor speed to be achieved, at the price of more noise and heating. If the motion speed requirement is low, it's better to use lower supply voltage to decrease noise, heating and improve reliability.

Regulated or Unregulated Power Supply

Both regulated and unregulated power supplies can be used to supply the driver. However, unregulated power supplies are preferred due to their ability to withstand current surge. If regulated power supplies (such as most switching supplies.) are indeed used, it is important to have large current output rating to avoid problems like current clamp, for example using 4A supply for 3A motor-driver operation. On the other hand, if unregulated supply is used, one may use a power supply of lower current rating than that of motor (typically 50%～70% of motor current). The reason is that the driver draws current from the power supply capacitor of the unregulated supply only during the ON duration of the PWM cycle, but not during the OFF duration. Therefore, the average current withdrawn from power supply is considerably less than motor current. For example, two 3A motors can be well supplied by one power supply of 4A rating.

Multiple Drivers

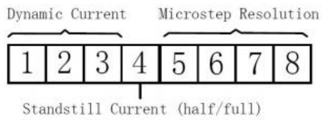
It is recommended to have multiple drivers to share one power supply to reduce cost, if the supply has enough capacity. To avoid cross interference, DO NOT daisy-chain the power supply input pins of the drivers. (Instead, please connect them to power supply separately.)

Selecting Supply Voltage

The power MOSFETS inside the DMA860H can actually operate within +24 ~ +80VDC, including power input fluctuation and back EMF voltage generated by motor coils during motor shaft deceleration. Higher supply voltage can increase motor torque at higher speeds, thus helpful for avoiding losing steps. However, higher voltage may cause bigger motor vibration at lower speed, and it may also cause over-voltage protection or even driver damage. Therefore, it is suggested to choose only sufficiently high supply voltage for intended applications, and it is suggested to use power supplies with theoretical output voltage of +20 ~ +68VDC, leaving room for power fluctuation and back-EMF.

7. Selecting Microstep Resolution and Driver Output Current

This driver uses an 8-bit DIP switch to set microstep resolution, and motor operating current, as shown below:



Microstep Resolution Selection

Microstep resolution is set by SW5, 6, 7, 8 of the DIP switch as shown in the following table:

Microstep	Steps/rev.(for 1.8°motor)	SW5	SW6	SW7	SW8
2	400	ON	ON	ON	ON
4	800	OFF	ON	ON	ON
8	1600	ON	OFF	ON	ON
16	3200	OFF	OFF	ON	ON
32	6400	ON	ON	OFF	ON
64	12800	OFF	ON	OFF	ON
128	25600	ON	OFF	OFF	ON
256	51200	OFF	OFF	OFF	ON
5	1000	ON	ON	ON	OFF
10	2000	OFF	ON	ON	OFF
20	4000	ON	OFF	ON	OFF
25	5000	OFF	OFF	ON	OFF
40	8000	ON	ON	OFF	OFF
50	10000	OFF	ON	OFF	OFF
100	20000	ON	OFF	OFF	OFF
200	40000	OFF	OFF	OFF	OFF

Current Settings

For a given motor, higher driver current will make the motor to output more torque, but at the same time causes more heating in the motor and driver. Therefore, output current is generally set to be such that the motor will not overheat for long time operation.

Since parallel and serial connections of motor coils will significantly change resulting inductance and resistance, it is therefore important to set driver output current depending on motor phase current, motor leads and connection methods. Phase current rating supplied by motor manufacturer is important in selecting driver current, however the selection also depends on leads and connections.

The first three bits (SW1, 2, 3) of the DIP switch are used to set the dynamic current. Select a setting closest to your motor's required current.

Dynamic Current Setting

REF Current	Peak Current	SW1	SW2	SW3
2.00A	2.40A	ON	ON	ON
2.57A	3.08A	OFF	ON	ON
3.14A	3.77A	ON	OFF	ON
3.71A	4.45A	OFF	OFF	ON
4.28A	5.14A	ON	ON	OFF
4.86A	5.83A	OFF	ON	OFF
5.43A	6.52A	ON	OFF	OFF
6.00A	7.20A	OFF	OFF	OFF

Notes: Due to motor inductance, the actual current in the coil may be smaller than the dynamic current setting, particularly under high speed condition.

Standstill Current Setting

SW4 is used for this purpose. OFF meaning that the standstill current is set to be half of the selected dynamic current, and ON meaning that standstill current is set to be the same as the selected dynamic current.

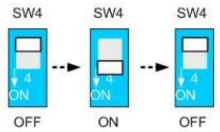
The current automatically reduced to 50% of the selected dynamic current one second after the last pulse. Theoretically, this will reduce motor heating to 36% (due to $P=I^2*R$) of the original value. If the application needs a different standstill current, please contact Leadshine.

Auto Tuning by SW4

To get the optimized performance, switch SW4 two times in one second to identify the motor parameter after power-up if it is the first time installation. The motor parameter is identified and the drive's current loop parameters are calculated automatically when SW4 is activated. The motor shaft will have a little vibration during auto-configuration. If the user changes the motor or the power supply, don't forget to toggle SW4 once again.

Auto Tuning Requirement and Procedure:

1. Motor is connected to drive.
2. Power is connected to drive.
3. Turn on the power.
4. Make sure there is no pulse applied to drive.
5. Switch SW4 two times in one second. That is OFF-ON-OFF or ON-OFF-ON.



8. Wiring Notes

- In order to improve anti-interference performance of the driver, it is recommended to use twisted pair shield cable.
- To prevent noise incurred in PUL/DIR signal, pulse/direction signal wires and motor wires should not be tied up together. It is better to separate them by at least 10 cm, otherwise the disturbing signals generated by motor will easily disturb pulse direction signals, causing motor position error, system instability and other failures.
- If a power supply serves several drivers, separately connecting the drivers is recommended instead of daisy-chaining.
- It is prohibited to pull and plug connector P2 while the driver is powered ON, because there is high current flowing through motor coils (even when motor is at standstill). Pulling or plugging connector P2 with power on will cause extremely high back-EMF voltage surge, which may damage the driver.

9. Typical Connection

A complete stepping system should include stepping motor, stepping driver, power supply and controller (pulse generator). A typical connection is shown as figure 10.

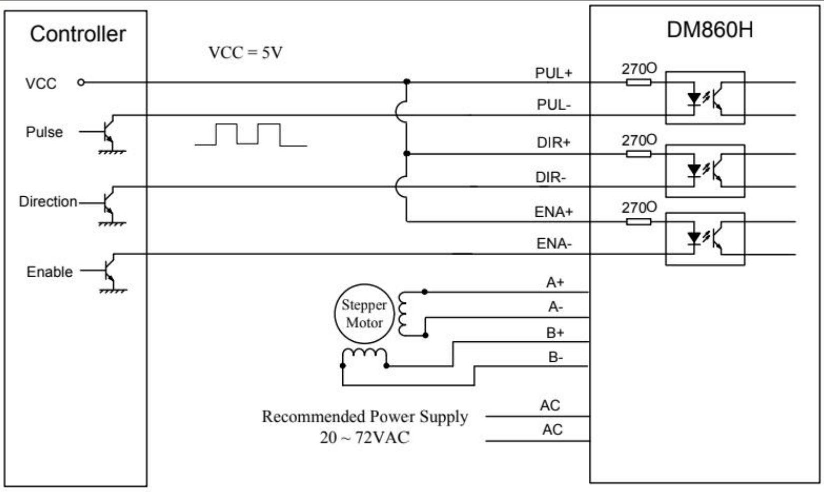


Figure 10: Typical connection

10. Sequence Chart of Control Signals

In order to avoid some fault operations and deviations, PUL, DIR and ENA should abide by some rules, shown as following diagram:

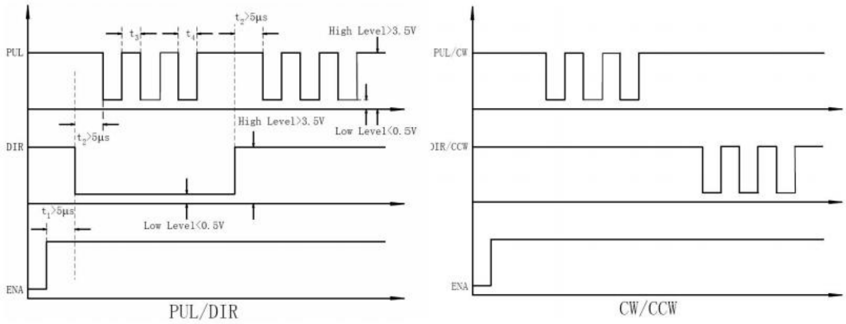


Figure 11: Sequence chart of control signals

Remark:

a) t1: ENA must be ahead of DIR by at least 5μs. Usually, ENA+ and ENA- are NC (not connected). See "Connector P1 Configurations" for more information.
b) t2: DIR must be ahead of PUL effective edge by 5μs to ensure correct direction;
c) t3: Pulse width not less than 2.5μs;
d) t4: Low level width not less than 2.5μs.

11. Protection Functions

To improve reliability, the driver incorporates some built-in protections features.

Priority	Time(s) of Blink	Sequence wave of red LED	Description
1st	1		Over-current protection activated when peak current exceeds the current limit.
2nd	2		Over-voltage protection activated when drive working voltage exceeds the voltage limit.

When above protections are active, the motor shaft will be free or the red LED blinks. Reset the driver by repowering it to make it function properly after removing above problems.

12. Frequently Asked Questions

In the event that your driver doesn't operate properly, the first step is to identify whether the problem is electrical or mechanical in nature. The next step is to isolate the system component that is causing the problem. As part of this process you may have to disconnect the individual components that make up your system and verify that they operate independently. It is important to document each step in the troubleshooting process. You may need this documentation to refer back to at a later date, and these details will greatly assist our Technical Support staff in determining the problem should you need assistance.

Many of the problems that affect motion control systems can be traced to electrical noise, controller software errors, or mistake in wiring.

Problem Symptoms and Possible Causes

Symptoms	Possible Problems
Motor is not rotating	No power
	Microstep resolution setting is wrong
	DIP switch current setting is wrong
	Fault condition exists

	The driver is disabled
Motor rotates in the wrong direction	Motor phases may be connected in reverse
The driver in fault	DIP switch current setting is wrong
	Something wrong with motor coil
Erratic motor motion	Control signal is too weak
	Control signal is interfered
	Wrong motor connection
	Something wrong with motor coil
	Current setting is too small, losing steps
Motor stalls during acceleration	Current setting is too small
	Motor is undersized for the application
	Acceleration is set too high
	Power supply voltage too low
Excessive motor and driver heating	Inadequate heat sinking / cooling
	Automatic current reduction function not being utilized
	Current is set too high

APPENDIX

Twelve Month Limited Warranty

Leadshine Technology Co., Ltd. warrants its products against defects in materials and workmanship for a period of 12 months from shipment out of factory. During the warranty period, Leadshine will either, at its option, repair or replace products which proved to be defective.

Exclusions

The above warranty does not extend to any product damaged by reasons of improper or inadequate handlings by customer, improper or inadequate customer wirings, unauthorized modification or misuse, or operation beyond the electrical specifications of the product and/or operation beyond environmental specifications for the product.

Obtaining Warranty Service

To obtain warranty service, a returned material authorization number (RMA) must be obtained from customer service at e-mail: tech@leadshine.com before returning product for service. Customer shall prepay shipping charges for products returned to Leadshine for warranty service, and Leadshine shall pay for return of products to customer.

Warranty Limitations

Leadshine makes no other warranty, either expressed or implied, with respect to the product. Leadshine specifically disclaims the implied warranties of merchantability and fitness for a particular purpose. Some jurisdictions do not allow limitations on how long and implied warranty lasts, so the above limitation or exclusion may not apply to you. However, any implied warranty of merchantability or fitness is limited to the 12-month duration of this written warranty.

Shipping Failed Product

If your product fail during the warranty period, e-mail customer service at tech@leadshine.com to obtain a returned material authorization number (RMA) before returning product for service. Please include a written description of the problem along with contact name and address. Send failed product to distributor in your area or: Leadshine Technology Co., Ltd. 3/F, Block 2, Nanyou Tianan Industrial Park, Nanshan Dist, Shenzhen, China. Also enclose information regarding the circumstances prior to product failure.

Contact Us

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Web: http://www.leadshine.com

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86-755-2641-7674 (for Asia, Australia, Africa areas)
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