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Design and Development of the Rotary Base of A CNC Milling Machine

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ABSTRACT

The CNC milling machine is a precision work positioning device used in metal working to enable the operator to drill or cut work at an exact fix. As a rotary base it is fitted with a dividing plate that enables regular work positioning at divisions and rotates freely under the control of a worm (hand wheel)

The milling process uses a rotary center to remove material by advancing the cutter into a workpiece.

The technique of machine in the study was to design an affordable, durable, and portable machine. Thus, the CNC with precision stepper or servo motors connected with pin or lead screw moments along the axis.

The study was taken for education purpose to have a hand on experience as a student and gain wider knowledge to overcome any would be challenges in the world of technology.

To that the machine was made by use of direct calibration method to depict machine error such as speed, noise, and temperature.

Following instructions in machine operation to avoid inaccuracy and down time of machine performance was recommended.

Keywords: *Rotary machine, CNC milling, Workpiece, G. Code*

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CHAPTER ONE

1.1INTRODUCTION

Technology signifies many innovations of new gadgets, different valuable equipment that enhances human civilization and development.

The CNC machine is one type that is programmable and automated with excellent precision.

The process of the CNC machine is controlled by numbers, letters, and syllables and all involves the use of Computer to control machine tools, like lather, mills, and grinders.

Digital control has become more and more useful to be used because of the coded software that aid in designing and developing desired works or products.

The rotating Base of a CNC machine in this case is that of a rotating plate on a table which is precise on work positioning devise and is used in metalworking to enable the operator to drill or to cut at exact interval around a fixed axis and is fitted with a dividing plate to enable regular work positioning at divisions.

The plate rotates freely under [=r the control of a worm (hand wheel)

The main aim of the study was to be successful in operating the rotating base of a CNC milling machining precision with high quality parts and also to have a hands on experience as a student and achieve the knowledge in order to overcome would be challenges in this world of technology and contribute positively to the ever developing social and economic sustainability.

The milling machine covers a variety of operations and machines ranging from small and large in size. The milling machine is one of the commonly used to machine custom parts to precise tolerance. Milling can be done with a wide range of machine tools with original class of it being for the milling machine called Milo.

The machine is able to work by the aid of its axis which has the role of providing motorized motion in each dimension as commanded by the control panel or G-Code programmed through the controller.

The rotary Base of a milling machine is fixed on a flame with a detachable column that supports the machine and provides rigidity to resist cutting forces.

The axis of the CNC machine is attached to the machine flame to allow motion using XY coordination program via G-Codes from the central panel, but to achieve a revolution it has to include the Z and the A, B, axis for a complete revolution. Each CNC axis has its own component in order to satisfy its function.

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The first step in the operation of the rotating base of a CNC milling machine is calibrating the tools to know whether the Stepper or Servo motors and any other systems are working according to the program being configured.

1.2 STATEMENT OF PROBLEM

Since purchasing and installing traditional CNC machine is not an option but a need thus calls for sufficient knowledge and skills in order to undertake the research and be able to come up with tangible results or solutions and so an alternative solution to provide a hands on experience with equipment like the CNC machine be so desirable.

In this case a proposed desktop CNC rotating base milling machine to fit on the standard table was to be designed and developed with interface commonly available, CAM software powered by AC outlet and easy to use, robust enough and used above all for education purpose. The machine was prohibitive and portable.

1.3 SPECIFIC OBJECTIVE

The study was undertaken in order to understand the working principles of the rotating machine to ascertain the validity, reliability and availability of localised materials and its usefulness to learning environment.

1.4 JUSTIFICATION OF THE STUDY

The need to bring out the creative mind of the leaner through innovation, by designing and development of the CNC milling machine, a major new development in computer technology with a lower- cost open source, easily operable, easy interface, and flexible and low power consumption. The machine with vital part of machining tool, that merges all machine components into a single complete system and efficient because of its total dynamic stiffness and damping response.

1.5 PROJECT OBJECTIVE

- To design and develop a machine that would produce more precise products for more technological advancement such as the CNC machine.
- Study different methods about the CNC machine with less errors
- Design a rotating base that would hold the workpiece with rigidity as it is being cut.
- Design a rotating base to stand a test of time and less expensive.

1.6 LIMITATION

- High cost starts up due to planning
- Difficult in machine geometric with complex parts
- Non availability of industrial equipment to use when making the machine.

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CHAPTER TWO

2. 1 LITERATURE REVIEW

The earliest machined object ever discovered was a bowl, found in Italy and made in 700 BC using a lather.

Attempts to automate machine started in the 18thcentury which where powered by steam.

The first programmable machine was developed in the late 40's in MIT. It was punched cards to encode each increment.

The proliferate of the computer in 50's and 60's added the "C" to the CNC and radically changed the manufacturing industry.

Today's CNC machines are advanced robotic systems with multi- axis and multi- tooling capabilities.

The development of metal cutting machines (once called machine tools) started from the inversion of the cylinder, which was changed to a roller guide by a journal bearing.

The ancient Egyptian used rollers to transport required stories from a quarry to a building site.

The first Deep Hole drilling machine was built by Leonardo De Vinchi (1450 – 1519)

In the 1840's the first Engine lathe was introduced by Maud Slay (1771 – 1831) which added the load screw back to the previous design.

Many more developments for conversional machine came via the introduction of the copying techniques, CAMs, attachment and automotive mechanism that reduced manual labour and consequently raised product accuracy.

Machine to tool of dynamiters are used to measure, maintain and control forces generated during machining. The method holds the tools and relate them to produce accuracy and surface integrity.

The introduction of numerical control (CN) technology opened doors to computer numerical control (CNC) machine centre leading to enhanced production accuracy and uniformity. CNC machines are electro mechanical and manipulate shop tools and inputs. It represents one of the two common methods (3D) in printing technology like the SLA, SLS/SLM and FDM being the other to generate prototypes from digital software file.

The earliest CNC relied on a common telecommunication data storage technology known as "punched tape" or perforated paper tape.

The punched tape technology is long obsolete, as date medium quickly transmitted to analogy and them digital computer processing in the 1950's and 60's

Machining generally is a way to transfer then in a stock piece of maternal such as block of

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plash and arrive at a finished product (typically a prototype part) by means of controlled maternal removal process.

The ability to program computer devices improve both speed and accuracy and machine requires the use of multiple tools to make desired cuts of different sizes

2.2 TYPES OF MACHINE INCLUDE.

- Conversional machining technology that involve, drills which work by spinning a drill bit and removing the bit about and onto contact with a stationary block of stock material.
- Lathe – spin the block of material against the drill bit and put contact with material by literally moving a cut tool until it progressively touches the spinning maternal. (Being one of the most common CNC milling machines used to day) that involves the use of rotary cutting tools to remove material from the stock unit.
- Novel technology is electrical and or chemical machining technologies that are specialised techniques to cut material e.g.
  - ✓ Electronic beams machining (Chomical machining).
  - ✓ Electronic discharge (EDM) machining
  - ✓ Photochemical machining
  - ✓ Ultrasonic machining for special massive production involving particular type of material.

The CNC rotary Base milling machines are used to precision metal working, they are typically made with a solid base that can clamp on another fixture. The table has a des that rotates. Freely and designed to reach a maximum table rotation set by many manufactures. The mini indexing incremental is the smallest angle on the rotary table.

From the history of technology view point, it is clears that naming the type of machine with the term “milling” was an extension from the words Eelier senses of “processing material by abstraction.

Paula Agosto do richer junior ET studied a design of CNC prototype machine with three axis 600mm long and 90% control motion.

Anita Pinero elal (6) designed and constructed a low cost three axis mini CNC plotter using stepper motor Arduino control software and a code to machine control.

Jacques de Vuacason, circa (2005) developed a rotary fill milling machine and was very well known used in the production of tall cased clocks and accomplished the first interchangeable parts in the clock history. Others in this clock history included James Harrison of water bury and Gideon Roberts of Bristol milling machine all to the advancement of new technology and precision making process for good and quality goods.

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In conclusion of literature review, it has proved that data collection as a research help enlighten means and ways of improving on the desired type of prototype and makes it easy and quick to design and operate both for education and production purpose.

The main characteristic of the machine centre in a CNC milling, machine include: -

✓ .

General milling operation depends to a greater extent upon judgment in setting up a job, workpiece, table, taper in spindle, and selecting of proper milling cutting holding under circumstances as follows,

- Proper positioning of table, workpiece, taper in spindle cutter before setting up the job.
- Selection of correct milling cutters with diameter as necessary as possible.
- Checking machine for good running order and proper lubrication and free movement in all direction of rotating milling cutter (whether clockwise or counter clockwise)
- Feeding workpiece in a direction opposite the rotating of the milling cutter (conversional milling).
- Fixing of the feed or speed before machine starts to operate.
- Use of recommended cutting oil liberally.
- Use of common sense and good judgement in planning and profit from previous mistakes.

Program function of the CNC machine has specific functions such as: -

- Absolute incremental motion that use G 90 for absolute position
- G 91 for default value and incremental motion
- G 28 and G 88 for programmed home command and entered feedback to return to O position.
- G04 – Dwell term
- G05 – Clamping workpiece
- G08 – Splint smoothing on
- G70 – Inch mode
- G86 – Turn CNC relay on/off and so on.

Qualify in a machining centre must be belt in front of the design though delivery and setup. Careful instructing to operate the machine is impotent to prevent a crash. Unintentional collision of the work with the tool.

Crushes can result in tool damage or mechanical failure. All CNCs are shipped with specified handing to avoid shocks and are trained mechanicals.

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CHAPTER THREE

Introduction

3.1 DESIGN CONCEPT

Controlling a machine by means of a prepare program is called numerical control (NC) as defined by the Electronic industrial Association (EIA). The presenter of CNC-technology Numerical control.

The first prototype of numerical control machine was built in 1952 at the Masshutts Institute of Technology (MIT) in the United States. With NC, the machine tool was controlled with the help of characters fitted with computer numerical system which has now become a reality.

3.2 ROTARY BASE CNC MACHINE

The concept of the Rotary Base CNC machine is based on an indexed table and is specifically designed to make the repetitive moves around the platform, essentially highly precise work positioning device that index parts to be worked or machined in multiple operations. It can impact any type and size of the indexer in a given application.

The modification concept of the rotary base in this case of the study was derived from the formation of the Whirl-Wind which is a column of Air moving rapidly around and round in a cylindrical or funnel shape taking in this case a tropical cyclone storm (Vortex, More) or Tornado.

The Whirl-Wind Concept can be used in many rotary tables such as the Chopper spiral, Rotor milling spiral, Chine worm milling machine etc.

In the study, the prototype rotary base was designed with some mechanism as the whirl-wind, but modified on the outer appearance and would be used either manually or powered. Thus, making it possible by means of adjustment.

The prototype rotary base included: -

- The base plate
- Spindle
- Working tool
- Motor washer left hand
- Washer base plate left and right-hand side
- Pins/ bolts
- Two Servo motors
- Rotating base
- Worm gear
- Bearings.

3.3 EXPLAINATION OF FEATURES AS STATEED ABOVE

1. A BASE PLATE is the plate by which an impression cylinder is held by rotation in contact with a table or a flat supporting plate at the base of a column, designed to distribute

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the column's weight over a greater area and provide increased stability. Equally it is a solid piece of material that has enough strength and sturdiness to hold the work-piece without folding in.

2**. A SPINDLE** is a slender rounded load with tapered ends used in hand spinning or a rod or pin serving as an axis that revolves or on which something revolves. A spindle as a tool is a rotating axis of the machine, which often has a shaft at its heart. The spindle system is one of most important key components in overall machine tool structure

A **CNC** spindle is the heart of any mill and consist of a rotating assembly with a taper where tool holders may be installed. A CNC spindle and motor with optional transmission of some kind rotates the CNC spindle. The transmission matches the highest power rmp range of the CNC spindle motor to the rmps that are ideal for the particular speeds and feeds of the material being cut. Self-contained spindles incorporate the rotating assembly and motor all-in-one. Where parts and the spindle bearings are fitted to a cast iron housing (this is the case with the modified prototype)

3. WORKING TOOL is a tool holder that are used for cutting operations. the arrangement depends on the construction of the machine tool bed and spindle orientation. For the proposed modification and required rotating operation, facing, external and internal rotating features are ideal. A suitable position of the turret was one with its axis along the direction of the existing 4axis.

The size of the tooling assembly was determined by the existing size of the table. To this modification the tool holder has a provision for carrying two horizontally located tools, for internal operations vertical location of tools was used with vertical slots.

4. **MOTOR WASHERS** are stainless steel flat washers that ensures tightness and strict military standards for performance and reliability 15795/NASM 15795 Compliant. The washer may vary from 0.051 degree to 0.08 degree in thickness.

5. **PIN** are commonly used as pivots, hinges, shafts, jigs and fixtures to locate or hold parts. They are precision ground (unless noted) for more accurate alignment, and slightly oversized for a tight fit. To aid insertion, ends are beveled or rounded (unless noted). Materials that have a breaking strength are measured as double shear, which is the for required to break a pin into three pieces

The types include, 360 stainless steel that is corrosion resistant dowel pins and magnetic with diameter tolerance of +0.0002.

6. BEARINGS are used with round supported shafts and have a fixed – alignment design for application where shaft misalignment is unlikely. They are made to

tight tolerance and combine speed and accuracy

7. **WORMS AND WORM GEARS,** are related according to the power from input parameters, and predicted by its life time. The gear case is analysed for oil temperatures as H-loss=33000+ (1-e) +p-in*0. 001341.Tight tolerance is used in machine tools to reduce backlash. The precision ground gears use special machinery to exact tolerances. Manual dialling worm drives are adjusted via a set of screws that brings the worm and gears into each other and allows the radial locational adjustment to counteract manufacturing errors.

8. **ROTATING BASE** is a standard internally mounted worm wired to directly on point and locking connector for homing position registration accurate to a single step it is connected with motorized rotary stage and can be installed electrically thus restricting rotor table travel in applications where the full rotational travel needs to be limited to a specific angle of travel less than 360 degrees. The integral rotary motor encoder would be specified where it provides 0.001-degree resolution encoder feedback when connected with a 180; 1 worm gear ratio, 200 step – per revolution servo motor and divided by ten micro – step drive. For increased rotary motion resolution, 400 count servo motor can be used.

9. MOTORS drives the rotor system and include, servo motors or step motors with encoders or step motors with feedback.

Servo motors are more expensive than stipple motors and are usually used at large scale manufacturing.

There are several important factors that differentiate the two motors such as their use. The servo motor is used in a closed loop system while the step motor is used in open loop system and generally step motors produce more torque at low speed than do servo motors. Closed loop allows the system to compensate for changes in the load characteristics, system dynamics or disturbance inputs. Feedback systems are divided into three categories that are different in their properties and these include, servo motors, encoders, linear feedback system and their properties also include contact and noncontact or linear or rotary motion, measurement type, accuracy and cost.

This would be seen in the bubble diagram and the orthographic settings as indicated below.

ISOMETRIC DRAWING (BUBBLE DIAGRAME)

Figure 1 isometric drawing of the machine (BUBBLE DIAGRAM) source: Author

ORTHOGRAPHIC DRAWINGS

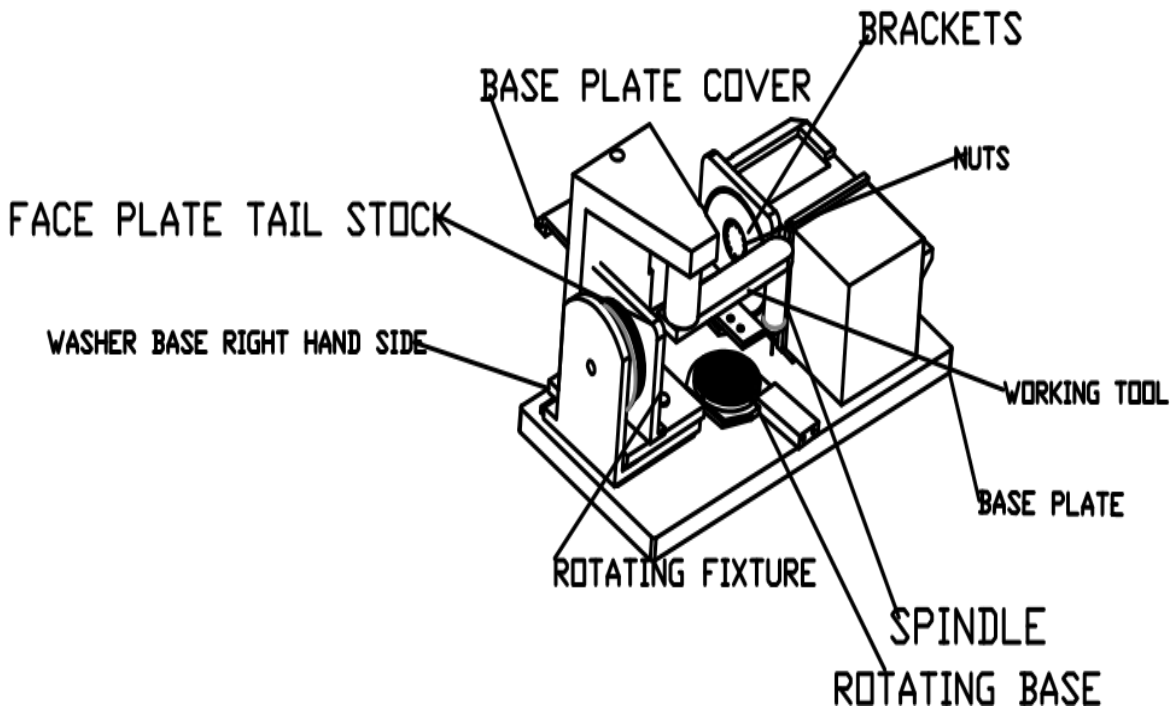
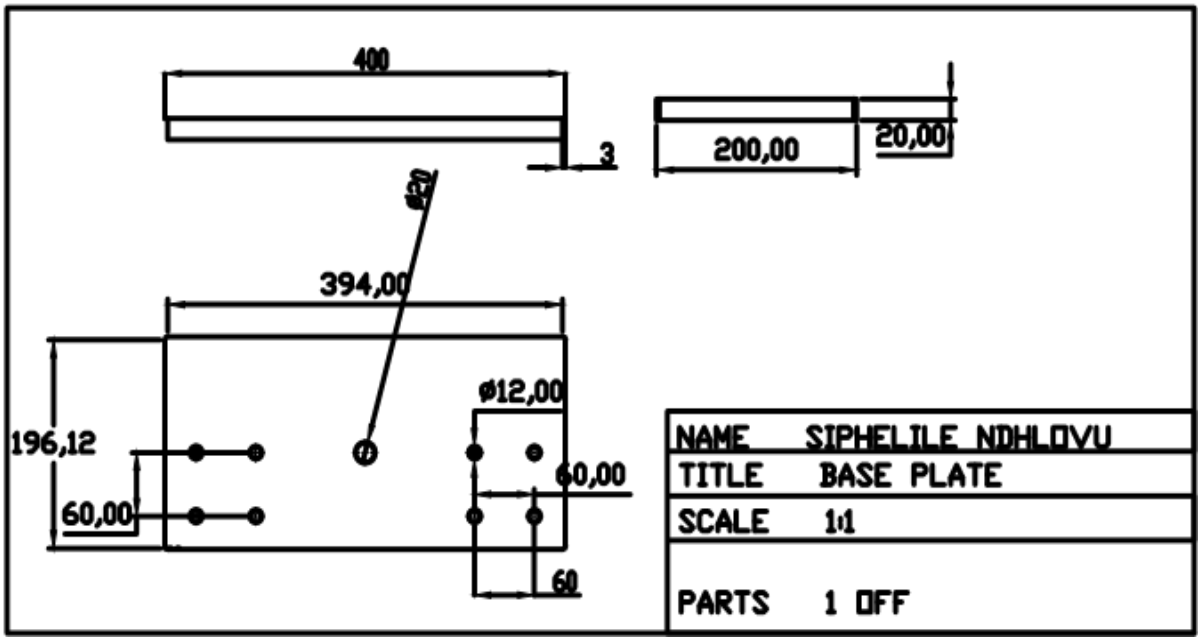


Figure 2 Base plate, source: Author



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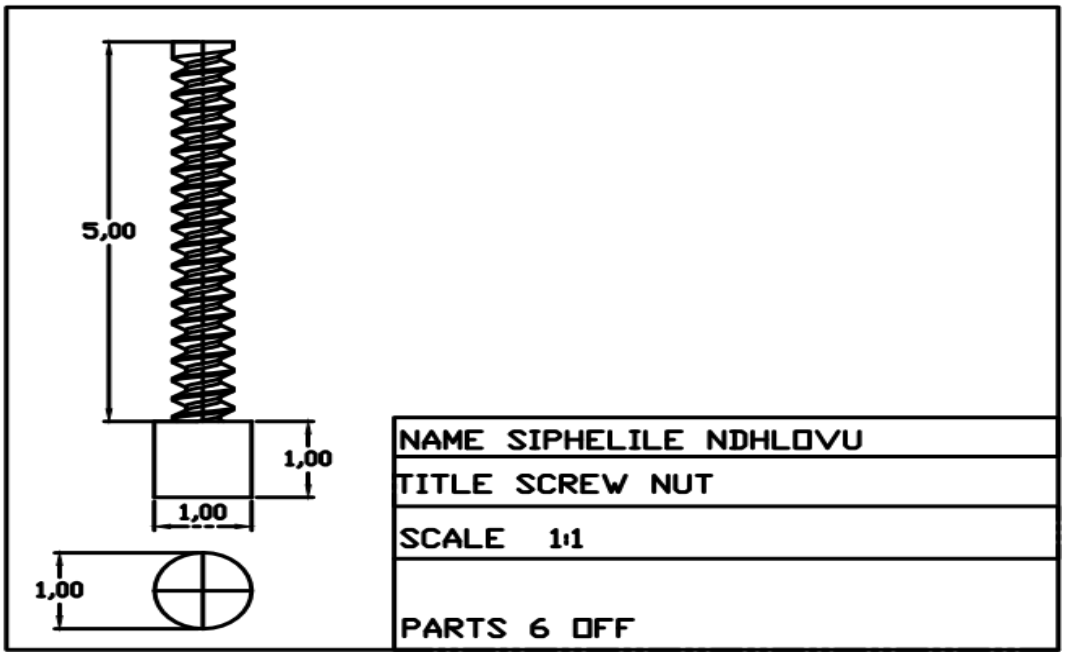

Figure 3 Screw nut, Source: Author.

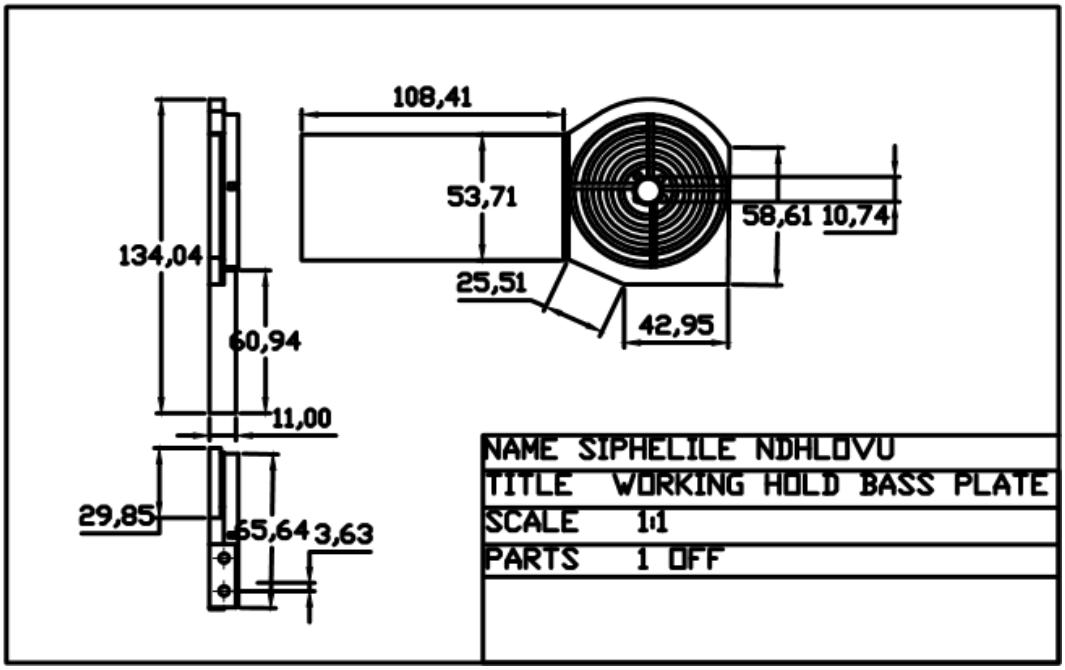

Figure 4 working hold base plate, source: Author

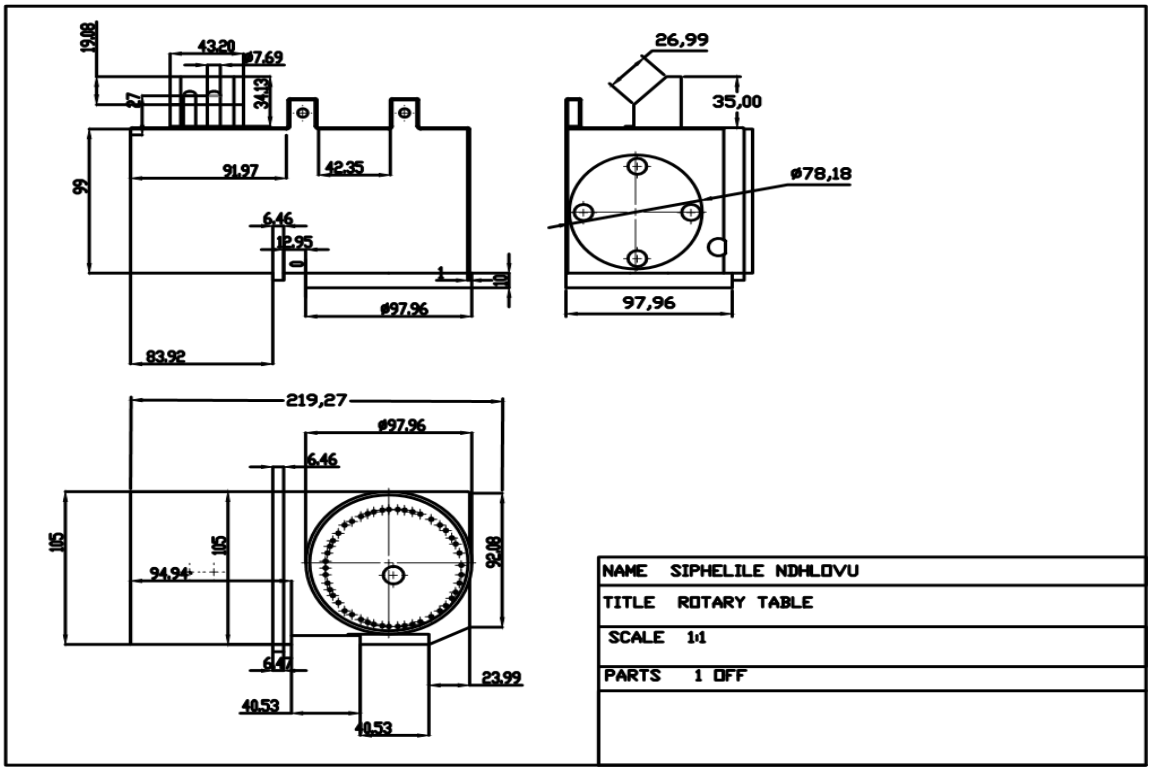

Figure 5 Rotatory Table, Source: Author

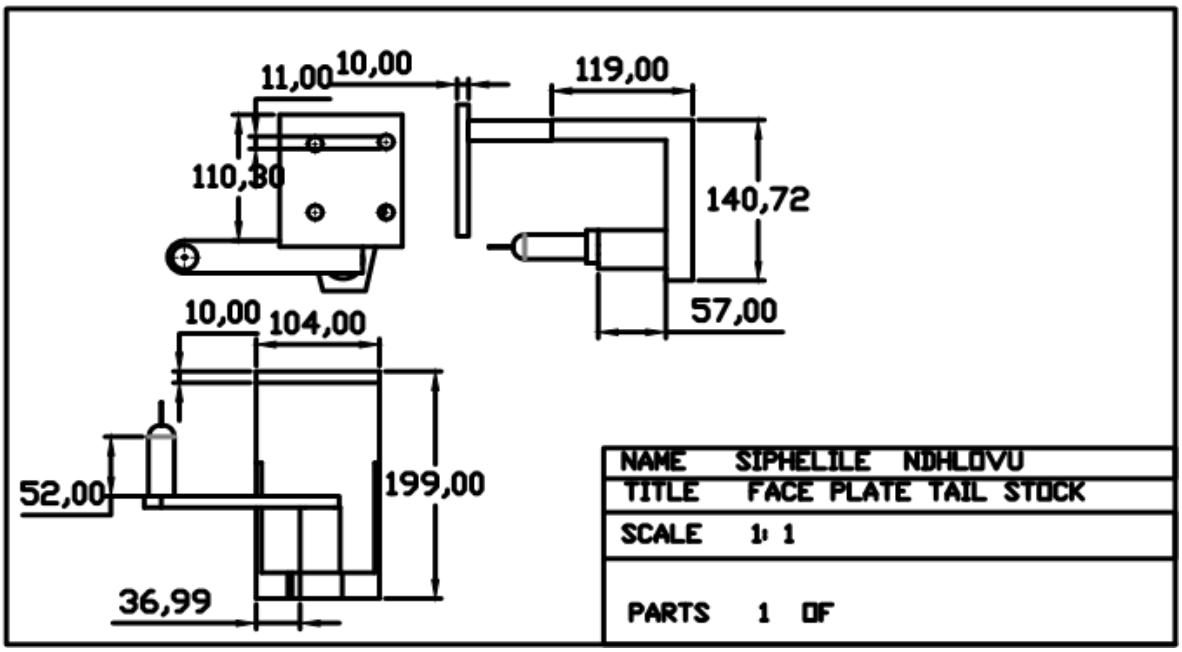

Figure 6 Face plate Tail Stock, source Author

Figure 7 Left Bracket, Source: Author

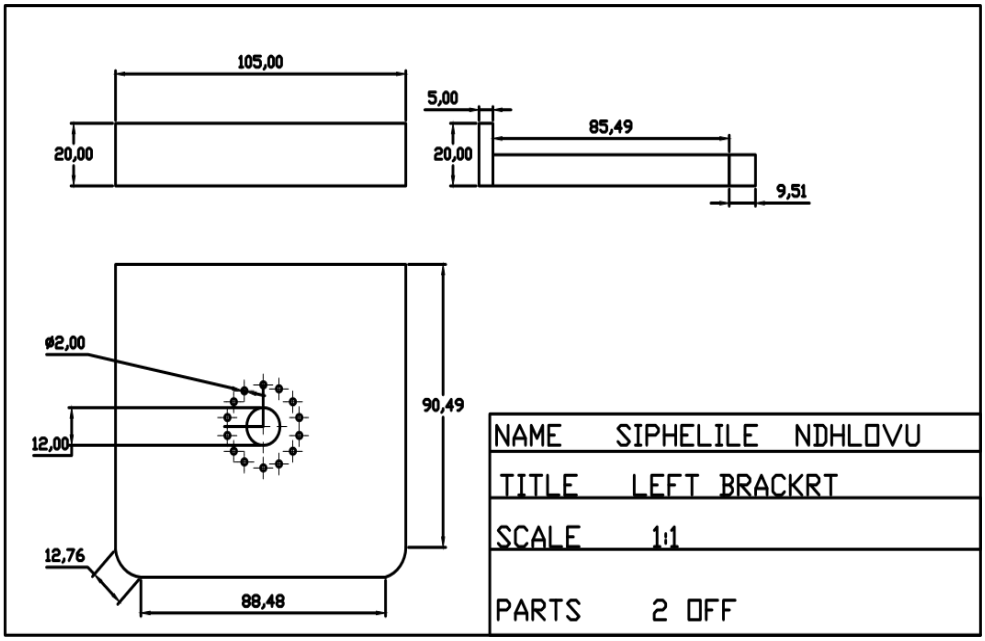

Figure 8 Pins, Source: Author

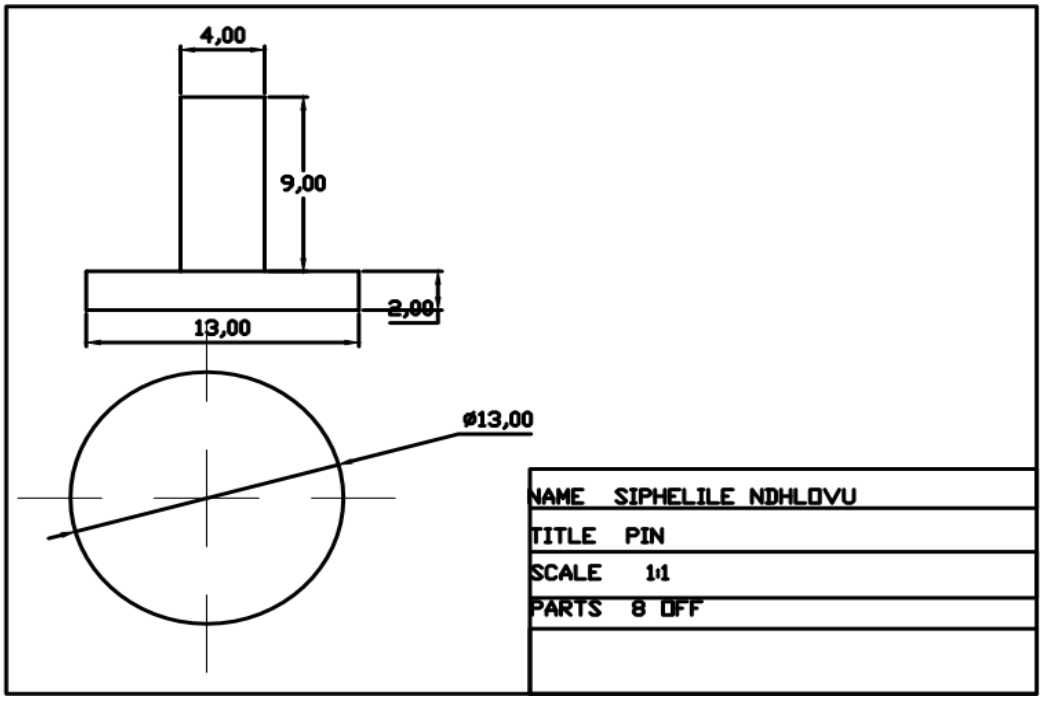

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Figure 9 Fixture Plate Cover, Source: Author

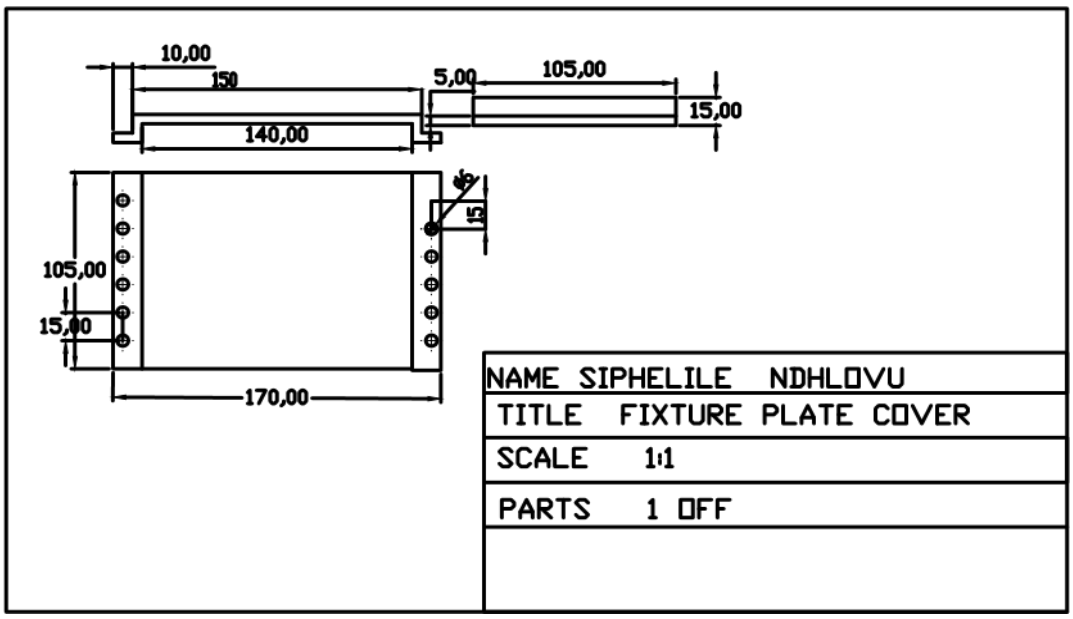


Figure 10 Rotating base, Source: Author

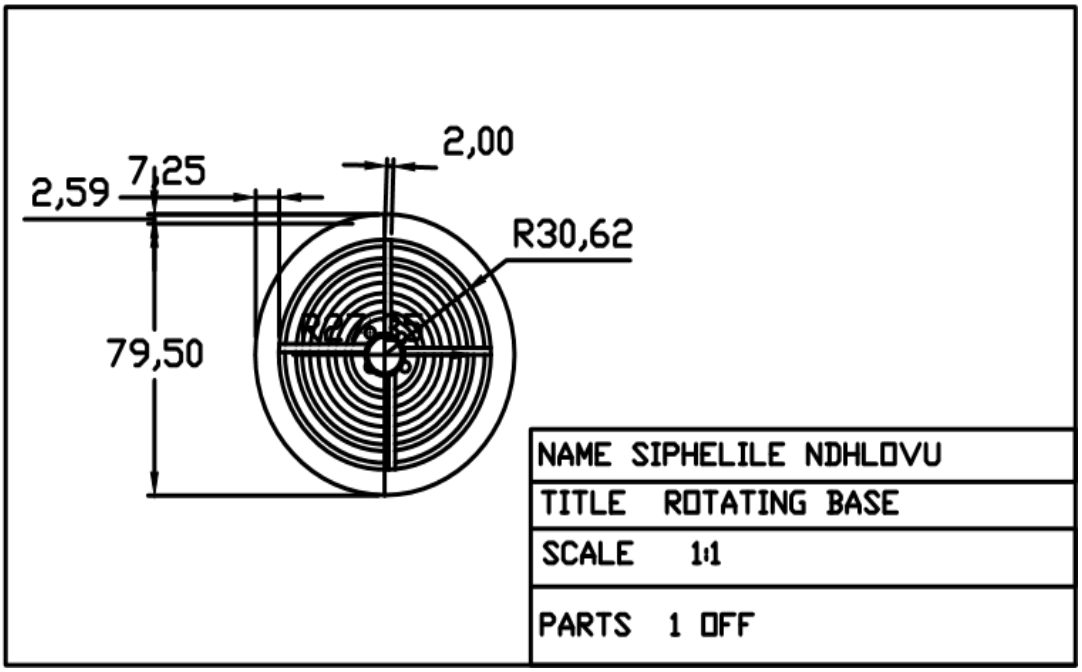
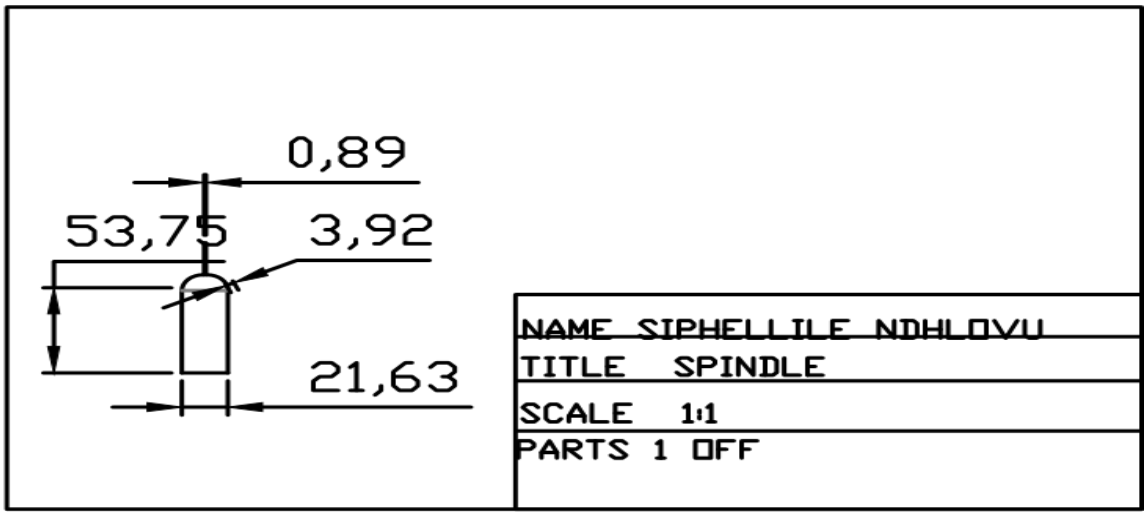
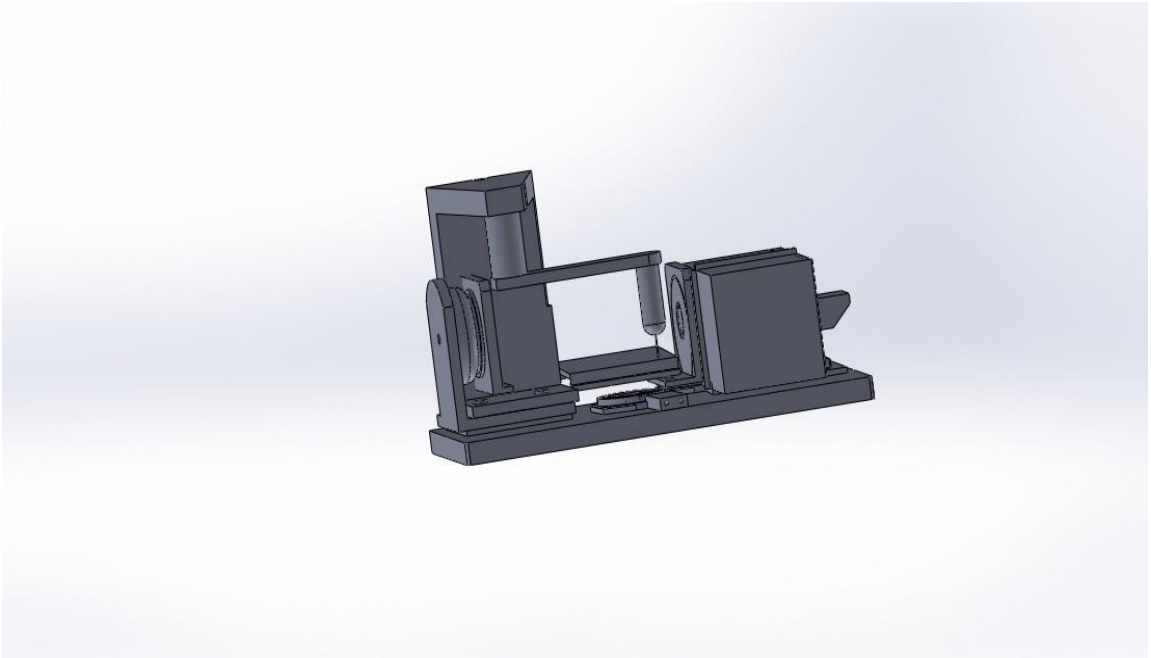


Figure 11 Spindle, Source: Author



PROTOTYPE STRUCTURE

Figure 12 prototype structure, source; Author



3.4 MATERIAL SELECTION

The selection of material for the Design of the rotating base of a CNC milling machine is very important as the table is not expected to yield but instead should have stiffness limited, with cutting forces causing deflection and making loss of accuracy being the major concern.it is therefore important to stay above the natural frequency of the applied loads by ensuring the structure of stiffness enough and counteract any harmonics with a damped design.

It is important to evaluate the material selection by noting the following properties: -

1. Physical properties of the material, such as metal, relating to its colour, density, weight and heat conductivity.

2. Chemical properties involves the behaviour of the metal when placed in contact with the atmosphere, salt water, or other substances.

3. Electrical properties encompasses the electrical conductivity, resistance and magnetic qualities of the metal.

4. Mechanical properties relate to the load carrying ability, wear resistance, hardness and elasticity.

When selecting a stock for a job, the main concern is the mechanical properties of the material (metal).

The mechanical properties used as measurements under load include: -

- Strength
- Hardness
- Toughness
- Elasticity
- Plasticity
- Brittleness
- Ductility and
- Malleability

The properties are described in terms of the types of forces or stresses that the metal withstands and how these are resisted.

-Strength is the property that enables the metal to resist deformation under load, this will include, the attained strength which is the maximum strength that a material can withstand and the tensile strength which is the measurement of resistance to being pulled apart when placed under the load.

-Hardness is the property of the material to resist permanent indentation and is always specified in terms of a particular test such as the Rockwell test.

-Toughness is the property that enables a material to withstand shock and to being deformed and may be considered as a combination of strength, plasticity and elasticity. Metal under which include, copper, nickel, and iron, magnesium, zinc, aluminium, lead, tin, cobalt and bismuth.

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- Ductility is the property of material to stretch, bend, or twist without cracking or breaking and this property makes out possible for the material to be drawn out onto a wire. E.g. gold. Silver. Nickel, aluminium, tungsten, platinum, copper, zinc, iron, lead and tin

- Malleability is the property that enables a material to deform by compressive forces without developing defects, the material can be stamped, hammered, forged, pressed, or rolled into thin sheets and materials in this category include, gold, silver, iron, copper, aluminium, zinc, tin and lead.

- Corrosion, although not a mechanical property, it is important in the discussion of metals as it gives the ability to metals to resist attacks from atmospheric, chemical, or electrochemical conditions and is at times called oxidation and is illustrated by rusting of iron.

-Brittleness is the property of a material that break and shatters before it deforms, e.g. cast iron, glass, bronze, aluminium, money, tin, zinc, structural steel, hardened steel, copper and brass.

Two material most suitable for the application are cast iron and epoxy – granite composite. Cast iron has a yearlong settling time after casting and as such is unacceptable in timeline. Epoxy granite is important as the composite material consist of granite and quartz particles in an epoxy matrix wherein carbon is added or glass chopped fibre to the mix to improve stiffness and strength.

This would be noted in the geometry of the designed housing with a double – cantilever that allows the designing of one rotary in both A and B axis

The major elements of the housing are to hold tapered roller bearings, preload mechanism, a worm drive and a circular bore for a platter. It is a unit-body design, with the entire structure to be machined out of aluminium.

Aluminium is used in the construction of the CNC machine because of its properties that it contains and these include: -

- Its silvery colour
- Its ductility
- Its malleability
- Conductivity
- Resistance to corrosion and is a good alloy with other metals such as zinc, copper, iron.

Other materials that can be selected in the machine setup include: -

1. Copper, that can be used in the electrical appliances and electroplates. Copper has good properties such as: -

* Best conductivity of heat and highly resistant to corrosion

* It is a non –ferrous metal and can with-stand severe bending and forging without failing

* Can easily be alloyed with other metals for high strength.

2. Zinc is the fourth most used metal from iron, aluminium and copper. It is commonly used in coating on iron. Its specific gravity is 6.2 low melting point and its tensile strength is 19 to 25 MPs.

3. Cast iron is primarily an alloy of copper and carbon and it is used in making beds of machines such as, lathe machines, drilling machines, bolts, nuts, motors and engines and other machine parts. Its properties include,

- Brittle weak in tension
- Low cost
- Good casting characteristics
- High compressive strength
- High wear resistance and good corrosion resistance

4.ceramics; are corrosion-resistant and made from aluminium oxide and silicon nitride, their heat and wear resistance mean they can function in high heat cutting environments where tools would not. These tools are typically ideal for cast iron, hard steel and super alloys.

5. solid carbide, is more resistant to wear, although prone to chipping instead of wearing out evenly over time, but are used mainly in finishing applications and usually made by sintering them with another metal such as, tungsten, titanium,

6. Carbon steel, are found to be very expensive, contain 0, 6- 1.5 % carbon with small amount of manganese and silicon. The material is used typically for low –speed operations in twist drills, forming tools, milling cutting and turning.

.7 -high – speed steel (HSS), is a material with a combination of chromium, tungsten, and molybdenum to give it improved hardness, toughness and wear resistance over carbon-steel, they are built to last and provide a high material removal rate for both ferrous and non –ferrous materials.

CHAPTER FOUR

4.1 Results and Discussions

4.2 Results

The testing study of a CNC machine was undertaken by looking at the effects of speed rate, noise (sound) and temperature on the machine accordingly.

The objective of the test was to optimise the milling parameters to achieve minimum deviation on the effects of depth of pockets in order to minimise inaccuracy during machining.

The operation was conducted on the vertical CNC milling machine (CMM) specifications

and interpreted on environmental data (ANOVA) for necessary discussions.

4.3 Discussions

It was discovered that machine operation system required accuracy in testing and performance of the entire system at large and as such was the case.

Testing is the only comprehensive inductor which depicts, detached pictures regarding accuracy of machine tools.

Machine tools are tools which are used to carry out or cut out the desired workpiece to perfection and to the standard requirement.

Generally, they are different methods that can be used to test the performance of the machine for quality production and this include direct calibration. Another is the Taguchi method of calibration that defines the quality of products in form of the losses impacted by the product to the society from the time of production to use. The losses are due to deviation of the product's functional characteristics from its desired target value.

The losses due to functional variation are uncontrolled factors, such as noise factor (external factor) temperature factor and human factor etc.

CHAPTER FIVE

5.1 Conclusion and Recommendations

5.2 Conclusion

In conclusion the CNC rotary base milling machine was made looking at its formulation and calibration.

The direct method of calibration was under taken to depict machine error such as speed, noise and temperature.

After testing the errors, it was discovered that errors in machine are caused due to geometric errors, imperfection of structural elements and compensations used in assembly or sub-assembly levels and kinematic errors introduction by motion of rigid bodies to reach the exact desired position.

To the reason, for the machine to perform accurately and run a test of time, it was recommended that proper instructions be followed when operating the machine to avoid short comings such as en-accuracy and down time.

5.3 RECOMMENDATIONS

The following where some of the recommendations made.

- Good selection of the location for sensing the temperature to establish correct thermal model

- Application of compensation system to obtain the surface accuracy with desired positions
- Introduction of thermals by use of correct or proposed methods
- The emission sound precision levels of different machine tools not to exceed the limit value
- Accuracy of the CNC machine be at per for machining tolerance of tools to avoid manual counting
- Spindle be surface ground before assemble.

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