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DESIGN AND DEVELOPMENT OF MECHANICAL SYSTEM FOR LOW COST 3-AXIS CNC ROUTER

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Abstract*— The idea behind this research work is to design and fabricate a low cost, compatible, desktop, easily operable and flexible 3 axis CNC router. The selection of the components used for CNC router based on the latest technology and optimum cost. We chosen design of CNC router worked on moving gantry compared to moving bed. Moving gantry design increase workable space, increase movement in z axis. The CNC router machine is fabricated and tested by engraving different design on MDF board of thickness 6mm and area 300x300mm. On the basis of different tests like depth test, speed test and accuracy test of CNC router, it can be concluded that the proposed CNC router is cost effective, flexible and accurate. The achieved accuracy of engraving accuracy is 99% and of depth is 97%. Popularity of CNC router increases rapidly in all areas Popularity of this increase due to impressive capabilities of these machines. By using this we can create the complex shapes which can take long time when the skilled craftsman make the product. In the last few year business is increasing in router system. But many do not know about this machine how they work and what is he do. This is where we want to help. We will discuss and explain the basics of CNC router Systems. In today world the use CNC system technology along with their storage capacity and high computational is increase use in production of products. Now days the most challenging factor how the CNC technology make simple, cheaper and affordable. Objective of this thesis is to design of 3 axis CNC router and fabrication. The structure of CNC router have big part in total cost of the CNC router system thinking of design the structure which is systematic study of drive motors and spindle motors. Maximum travel of CNC router system on x axis, y axis and z axis also which defined approach of machining work volume of the machine material removal also study. We make design and structure which have precision in making the product.CNC router give more flexibility to manufacturing the product. There is also waste produce and error in manufacturing the product.CNC router is used for manufacturing door carving, sign boards, wood panels, interior decoration and exterior by making the product from CNC router repeatability is increase and reduce time. In this thesis we discussed about the design of the CNC on AUTOCAD and proe.cnc router made less in cost and having the good accuracy. Fabrication of CNC router by assemble of different parts of router to make final assemble CNC router we test and analyze the speed of router and cutting accuracy with depth measurement test. We cut the different alphabets on the MDF board of thickness of 6mm and cutting from 3mm to 6mm.we make the CNC router in which the gantry is moving with help steppers motor which are controlled by the computer and microcontroller to give motion to the system. The frame of CNC router is made with the aluminum extrusion and MDF board.

***Index Terms*— CNC, Autocad, Modeling & Drafting, Design and Simulation.**

I. INTRODUCTION TO CNC

CAD computer aided design to make design and computer aided manufacturing by Command given to machine which highly automated. We make program from design file that is uploaded to CNC machine via software which give every commands to the operate CNC machine. When we make the component there many tools are required to like drilling, cutting etc. Normally machines can make all the process at one place and to installation different machines require different machine operator. Series of steps to make the product is highly automated and give product which similar to CAD design uploaded through software with increase in new innovation and technology give the new economy requirement for product new requirement to make highly precision product machine also give high production industry good quality product time consume in the process decrease and low cost for product. There are other requirements for product dimension accurate and tolerances limit should match with final products. By using the CNC technology we can make ultra precision products same as product in much faster manner production rate also high not possible by help of human. Most of the machines are multifunctional can do different function and produce high precision products. There is increase in the industry varieties and demand growing for miniature products so these big size machines are not efficient to make special size product manufacturing requirements for these products vary so there machine are not efficient either in terms of cost or time consume. There are many advantages to make small size product by the help of smaller size machine. By using small size machine we can save space installation for machine. There is less requirement of energy which decrease cost of machine. So requirements of minimum components bring down the cost of machine and during machining process vibration and noise

is decrease because of small size weight moving components of machines also decrease. Small size machine decrease pollution to environment. When the machine less weight and small in size so we can move machine from one place to other. The layout of industry plant or manufacturing center more flexible we can change the layout when required. They also increase the production rate by faster operation.

OBJECTIVE OF WORKS:

1. To drafting of design of CNC router
2. Design the mechanical system of cnc router.
3. Selection of movement of machine
4. Fabrication of all components to assemble.
5. Test and analysis the result
6. Make low cost CNC router

II. LITERATURE REVIEW

In paper [1] **Venkata Krishna pabolu** et al (2010) paper discussed design the three dimensional computerised numerical control (CNC) and put into practice for Industrial utilisation. In this paper fix cnc machine was created. He also give details about different modules such as electronic, electrical development along with technical details of their implementation.

In paper [2] **Dr.J.B. Jayachandraiah** et al (2014) give proposal about to Developing the low cost CNC router which is having the ability. The prototyping of low cost three axis CNC router is achieved by computers interface with microcontroller base CNC system in installed arduino system with small budget for making router the author conclude that small machine tools which is use to fabricate small parts can provide flexibility and efficiency in manufacturing the system and reduce the capital which is give the benefit for small business holder.

In paper [3] **Ahmed A.D.Sarhan** et al. (2015) in this paper he make CNC gantry milling structure which have potential to produce the high surface finish has been designed and analyzed. the motive of author of this paper to achieve lowest natural frequency of 202 hz corresponding to 12000 rpm at all motion amplitudes with a full range of suitable frequency responses. Improvement in dynamic behaviour of gantry frame which can sustain the frequency above the 200 Hz the modification process is carry to increase the stiffness of structure of gantry. The author studied the dynamic behaviour of structure with change in spindle position. The result shown by the author that according to critical Condition the minimum frequency of the structure will be acceptable. Designed of CNC gantry machine is capable of functioning at speed of 12000rpm.

In paper [4**] kulkarni bharat** P (2016) he develop CNC machine controlled by computer for drilling he make machine working on arduino uno to control program for drilling the hole in objects. This machine highly accurate and high flexibility. This machine is reduce the cost of product which is increase the demand for this machine in industry. He first created the design upload the design in the command into the software which control motion of the gantry of drilling machines.

In paper [5**] Sundar Pandian** et al. (2014) develop low cost 3 axis CNC machine using of- the- shelf component, stepper motors with drivers, arduino open source microcontroller and open source motor control software. he used body with high density PVC. In this machine has fix gantry and movable bed so there is less working area. This was developed for only for educational purpose.

In paper [6] **B.Malleswara Swami** et al. (2012) according to this paper author describe two methods for one is static analysis and other is dynamic analysis. Author used standard type bed for analysis. This is carried out to reduce the weight without changing structural rigidity and the accuracy by adding the ribs at the suitable location. Static analysis is done for 1g gravtitational force Consider as external load with the load 5g which is five times of external load applied on structure. In model analysis he find the natural frequency of body is to make for dynamic and vibration characteristics. then optimized Design is created by tool after optimization result which he get reduce the weight by 1.55% with original value and average frequencies shifted by approx. 8.8% with 1st natural frequency.

In paper [7] **Druv Patel** et al. (2014) in this paper he studied influences of various parameter like tool speed, tool feed and depth of cut on CNC router and Concluded from ANOVA that percentage contribution of feed rate is maximum and its means feed rate is most important value which is affect Modelling for the surface finish.

In paper [8] **Monika Nowak** et al. (2012 he give brief about the choice of selection of geometric and physical structure mobile machine by specifying the design requirements and development of elimination conditions based on these requirements. The selection procedure was based on an analysis of functional Description of the required shaping movements and developing appropriate condition for elimination of alternatives using the information concerning. The needs of future portable machine operators.

In paper [9] **Grzegorz Szwengier** et al. (2012) he gave in this paper by research on selection on geometric kinematic structure of newly designed milling machine. There is lot of design available for milling machine author suggested best procedure and help to select useful combination of machine parts with desired output provided with constraints of machine.

In paper [10] **Desai** et al.(2015)This paper is research about development of algorithms of CNC machine control by computer in the paper it develop the algorithms for interpreters and interpolators it tested on CNC router machine for linear as well as circular interpolation.

III. METHODOLOGY

This system can be divided in to three parts:

1. Mechanical system
2. Electronics system
3. CAM and CAD software

The mechanical system get signal from the electronics system the signal transfer into the stepper which give the motion to gantry. The commands which are from the software system like GRBL controller universal g code sender.

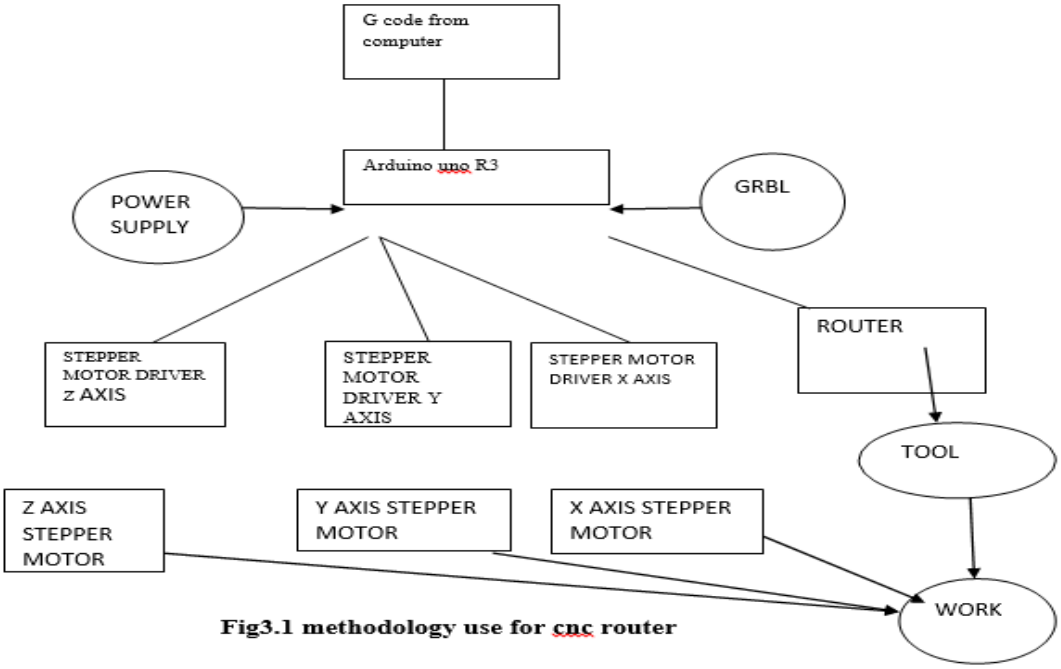

Fig3.1 methodology use for cnc router

A. MECHANICAL SYSTEM

The mechanical system which has made 3 axes movement the power transmission to machine system by help of the gt2 pulley and solid v wheel. Stepper motor is attached to the each axis of the CNC router where it moved x-axis y-axis and z-axis. It moved according to the signal received electronics system. Each stepper motor attached to pulley to x and y axis. The steeper motor is attached pulley and belt system which move with the wheel in x axis and in y axis. In z- axis the stepper motor is coupled to acme screw by help of coupler to motion in z axis. In the z axis we attached the spindle motor which is join with the plate mount on aluminium extrusion. Spindle motor is moves up and down with the help of acme screw. In the system we use stepper motor this is give controlled linear motion for each axis carry the load so it can move by nema17. The tool path of spindle motor is control these motion in x-axis, y-axis and z-axis which carving the design on the work piece.

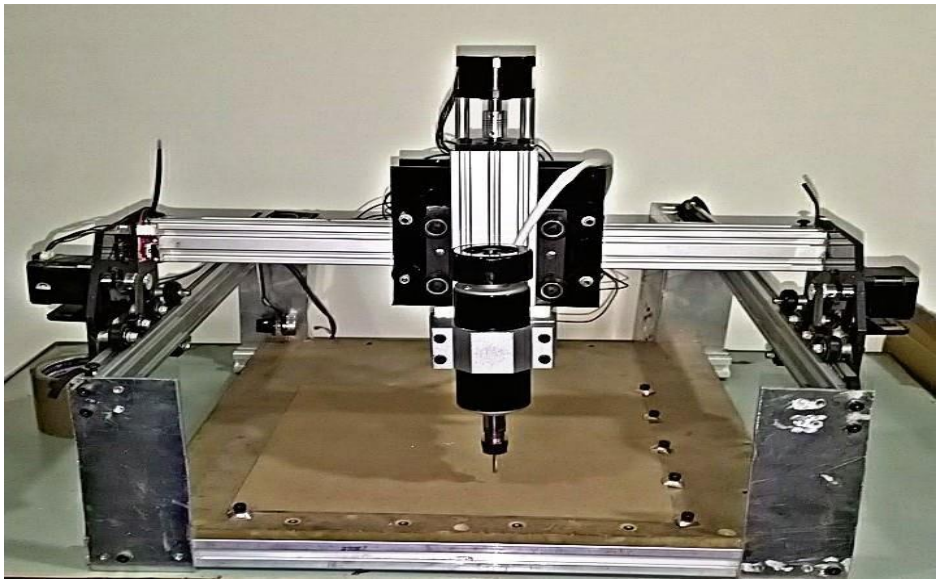

Fig 3.2 Cnc router mechanical system

IV. DRAFTING & DESIGNING

A. Drafting

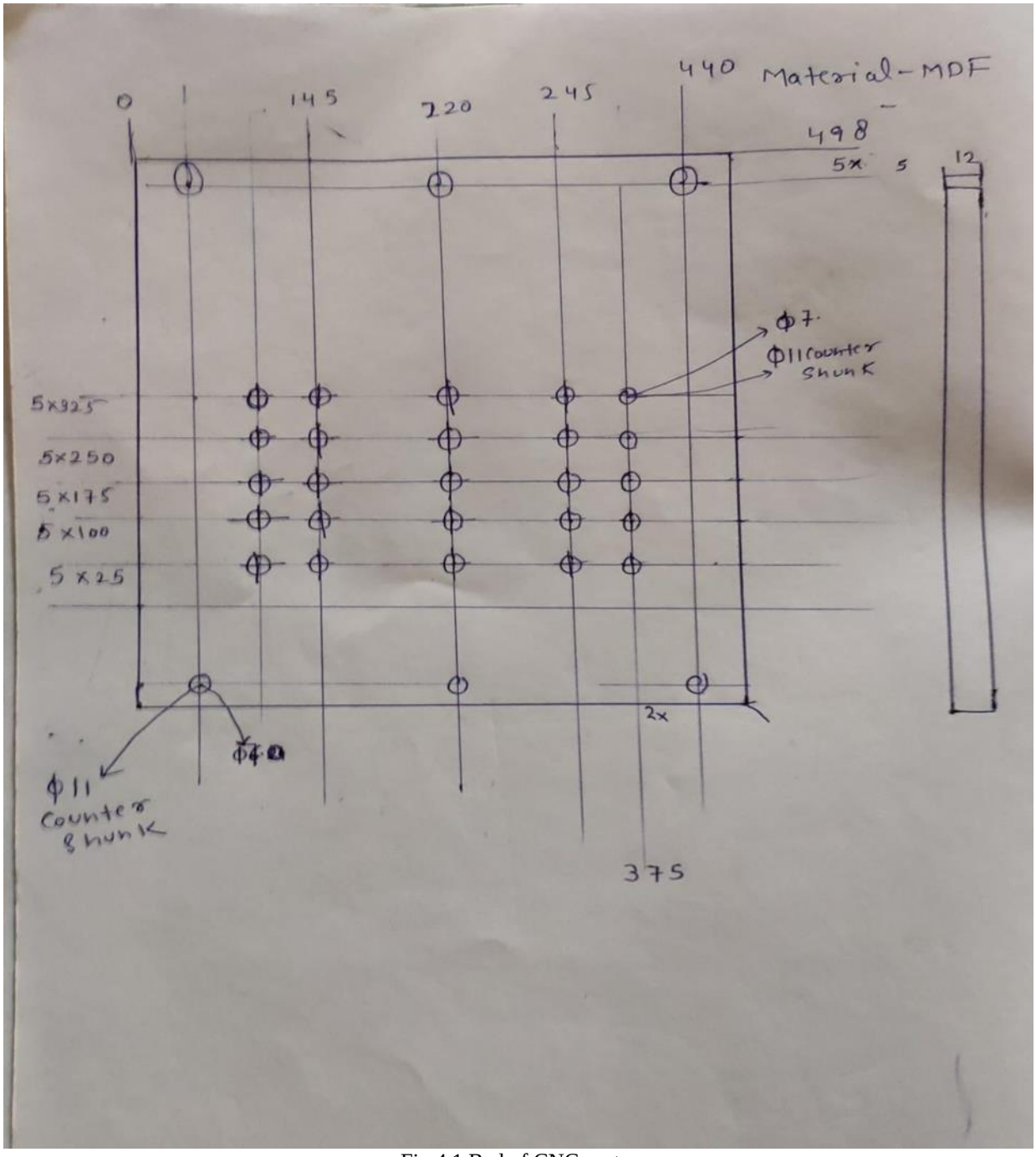

Fig 4.1 Bed of CNC router

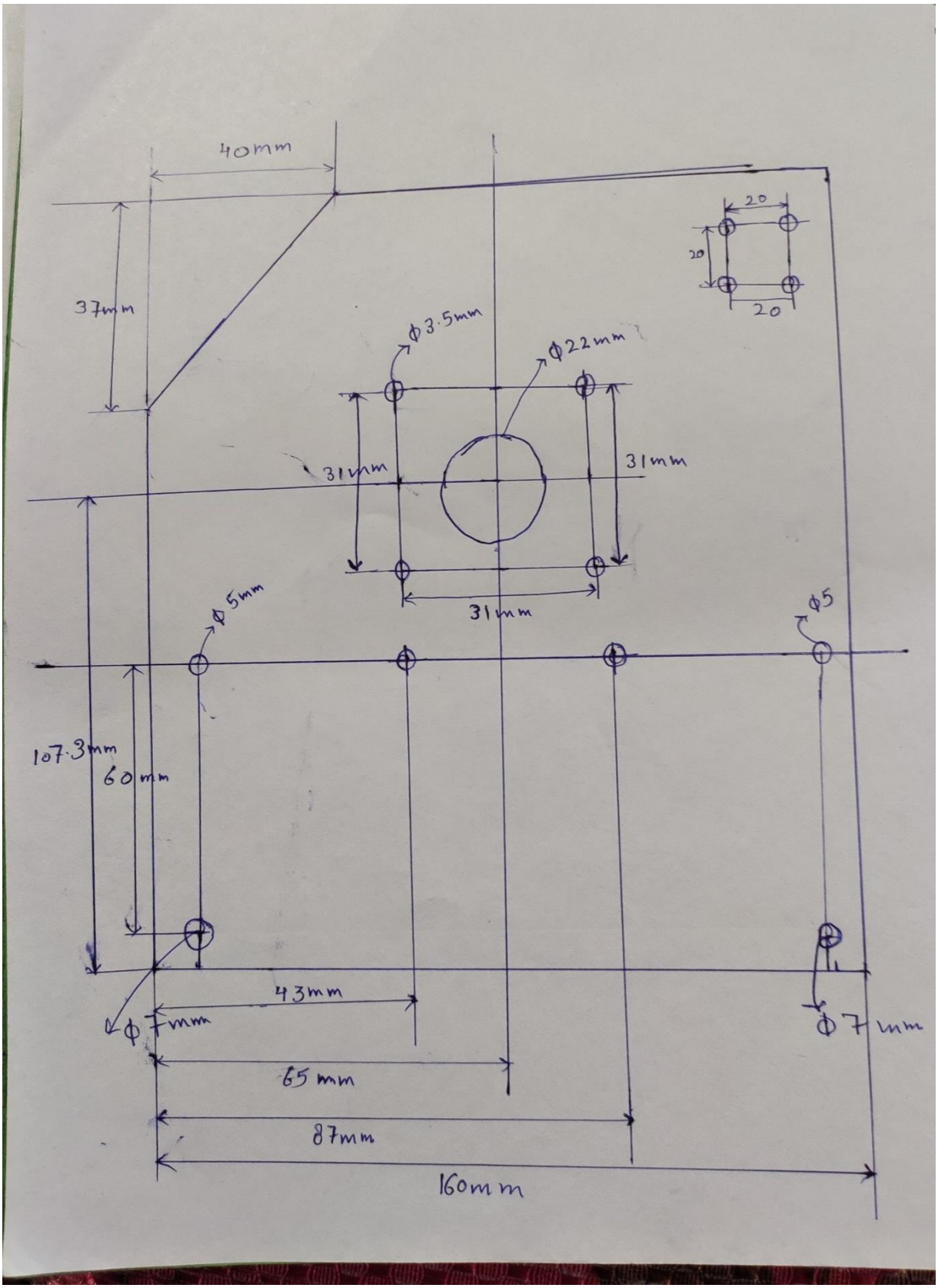

Fig 4.2 Gantry plate

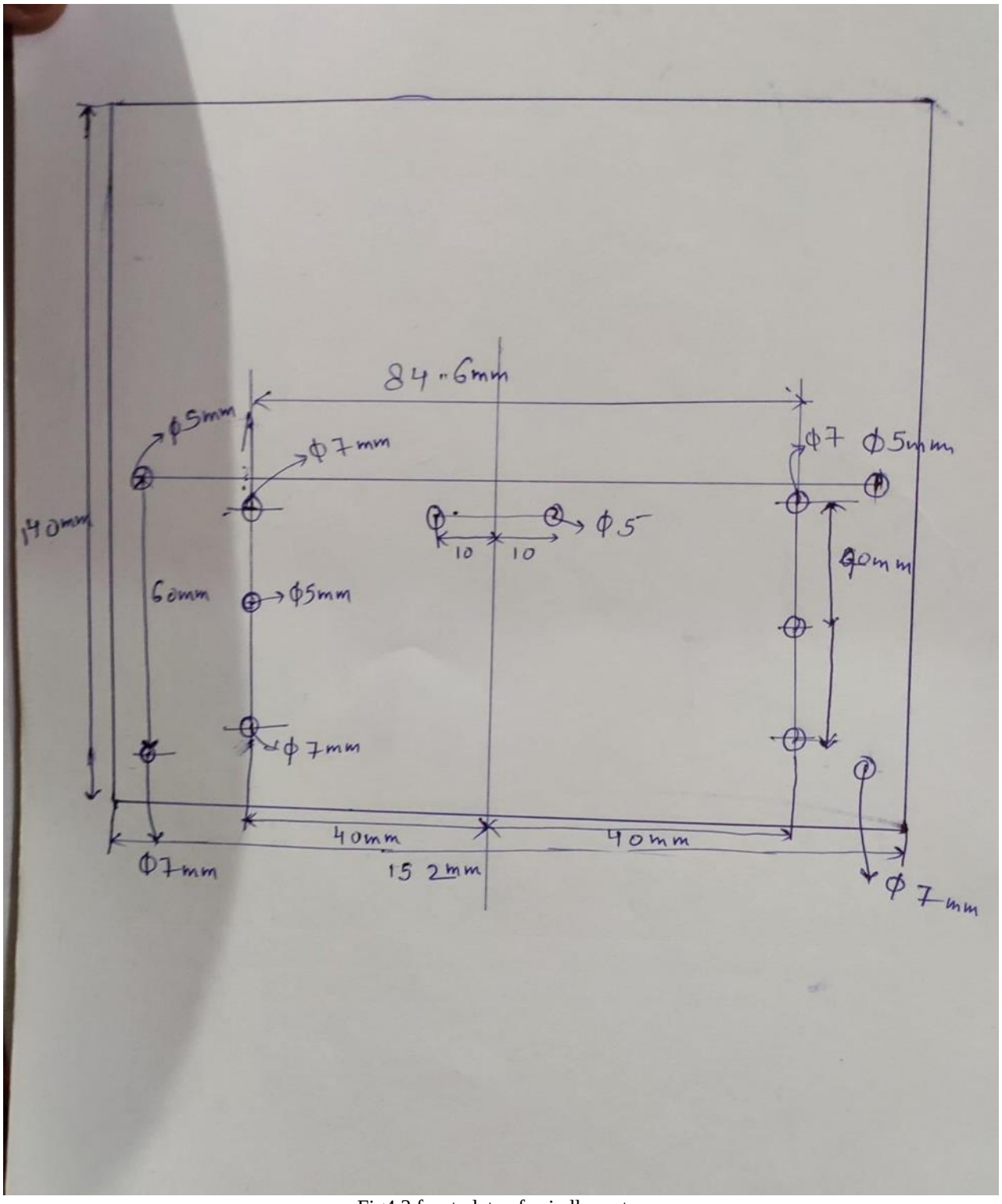

Fig4.3 front plate of spindle motor

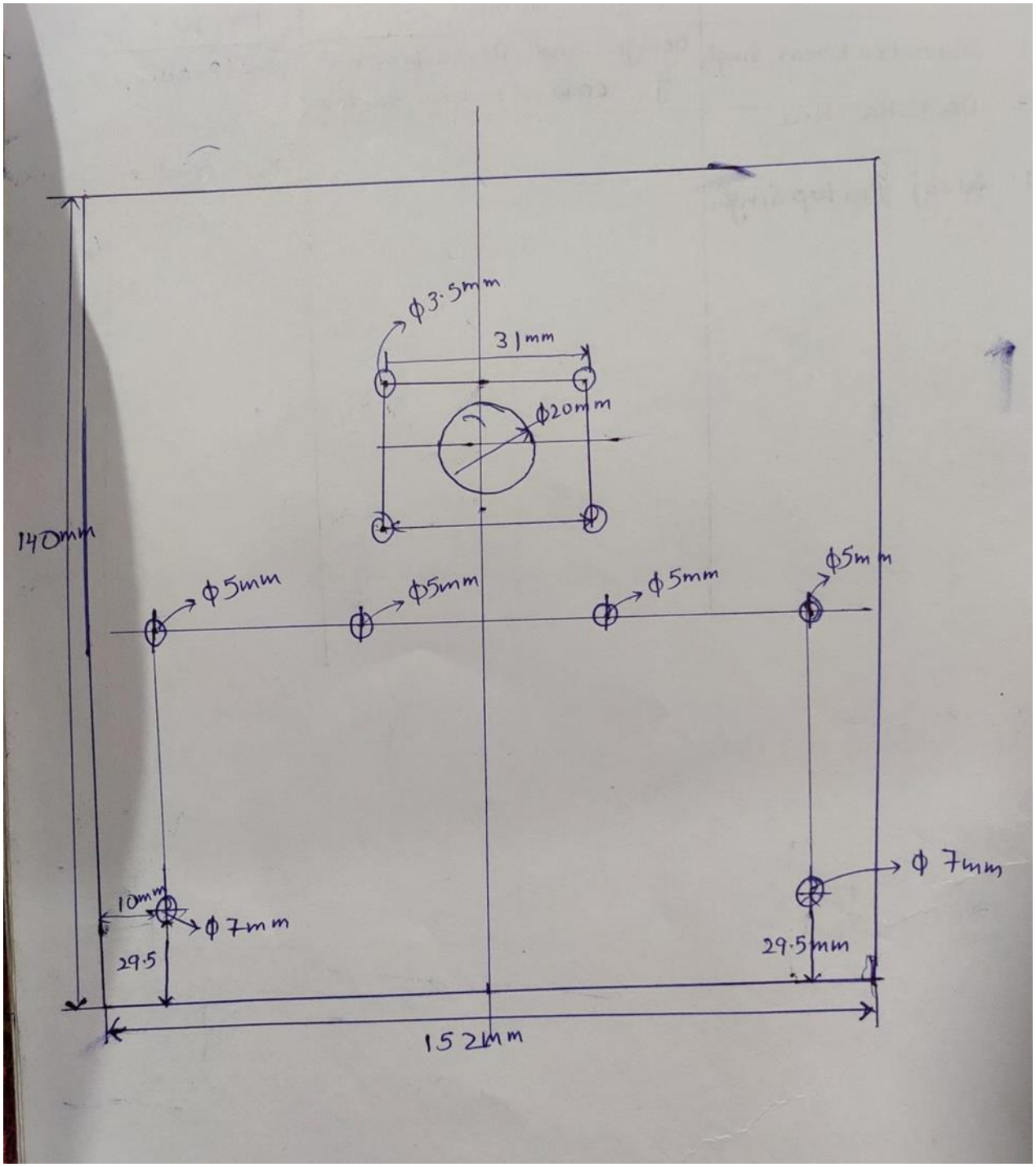

Fig 4.4 back plate of CNC router

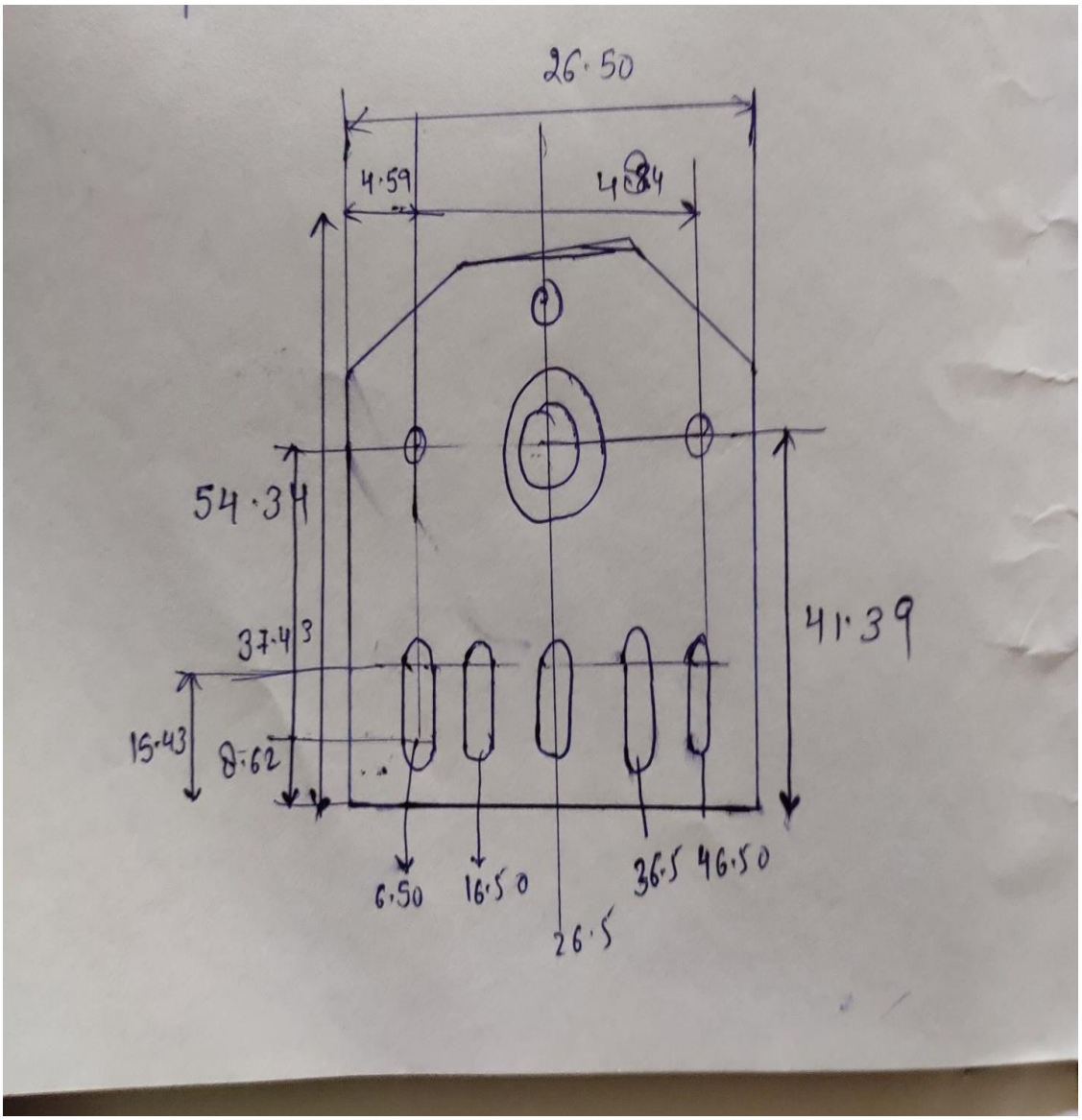

Fig 4.5 motor mounting plate

This is drafting of motor mount plate used in the system where we mount the stepper motor nema 17 and attached with 6mm aluminium spacer to join on plate of motor and aluminium profile. In this case we design and motor mounting plate from acrylic board according to the dimension given in this draft design. We are also attach the coupler and acme srew to stepper motor.

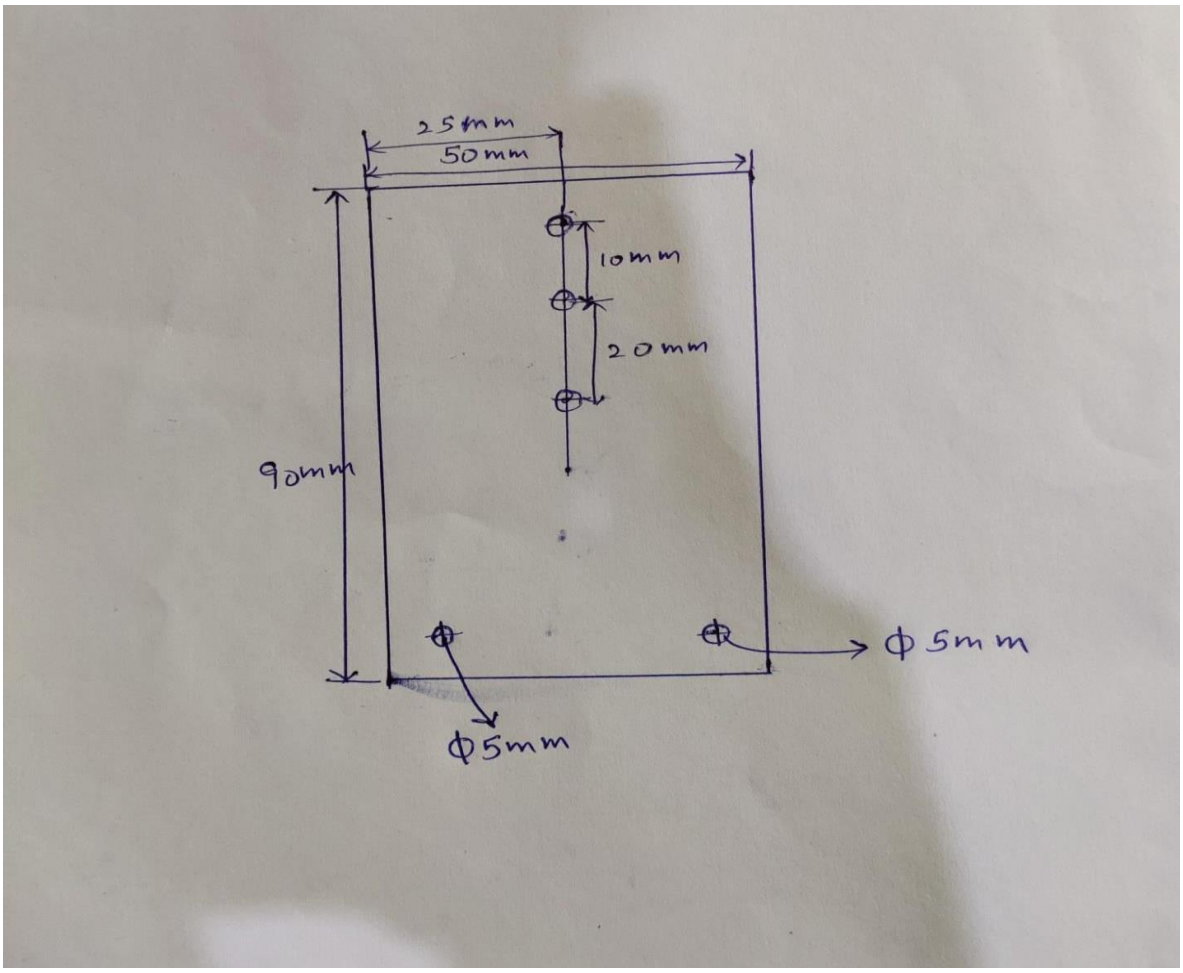

Fig 4.6 support of aluminium extrusion to platform

B. Design made on Pro – E

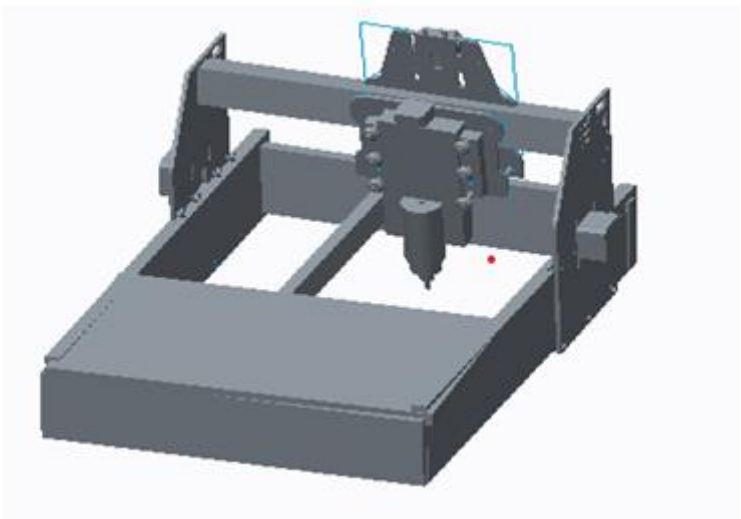

Fig 4.7 CNC router design

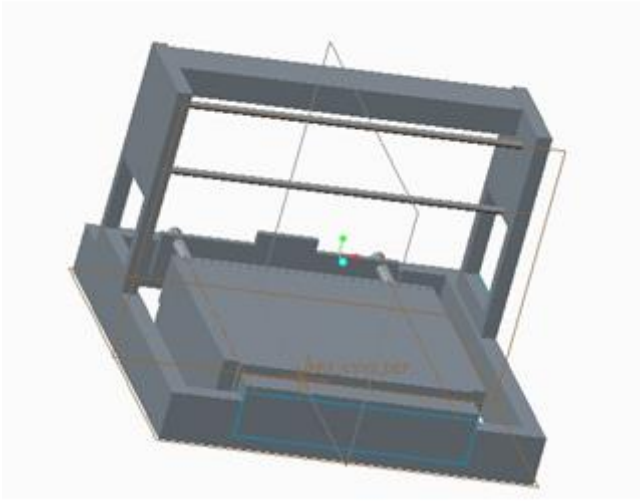

Fig 4.8 design 2

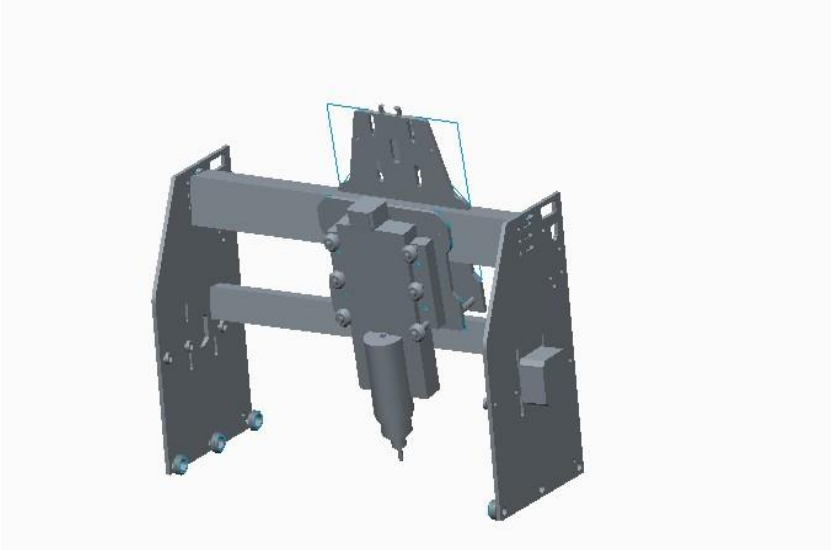

Fig 4.9 View of Gantry

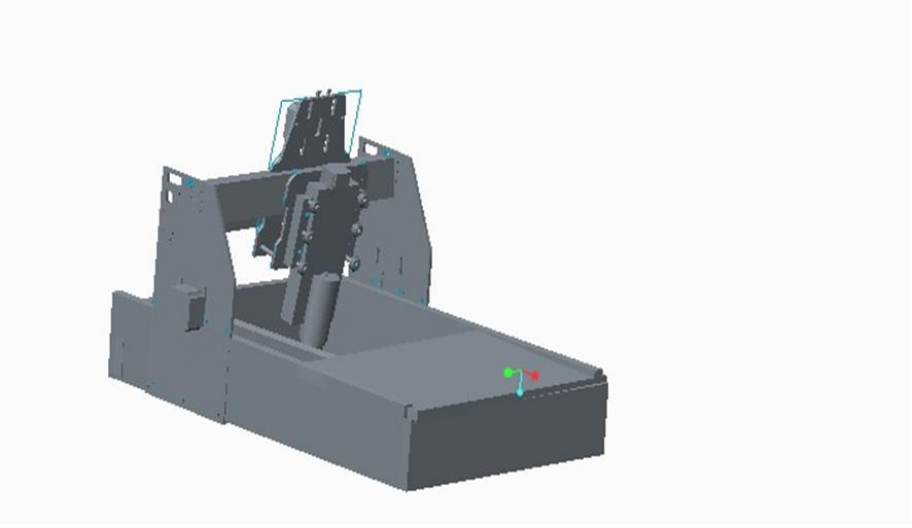

Fig 4.10 CNC router design on probe

This plate is design according requirement of height in z-axis of CNC router we can adjust the height of the CNC router by making different corner support. This plate is made up of aluminium thickness 6mm.We attached the aluminium extrusion and base to this plate. This plate can sustain the weight and vibration of gantry.

V. FABRICATION

Making the design already made in Pro-E into real machine with some more modifications involved

TECHNICAL SPECIFICATIONS

- Machine Footprint: 500mm x 500mm
- Work Area: (X,Y,Z) 300mm x 300mm x 30mm
- Electronics: X-Controller with Grbl installed (USB)
- Input Voltage: 115VAC or 230VAC (selectable)
- Rapid Rate: (X,Y,Z) 8000mm/min, 8000mm/min, 500mm/min
- Spindle: 110-220V 500W Spindle Motor
- Amps: 4.0 Amps
- Voltage : 100 VDC
- Torque : 5000G/CM
- Input : AC110V/220V ± 10%50/60Hz
- Power: 500W
- No load speed: Up to idle up to 12,000 rev / min
- Clamp : 52mm
- Control Software: Universal G-Code sender

A. Installing the Wasteboard:

We have a 500 mm MDF board with us available in the college lab. We have drilled 24 holes of 5 mm diameter for clamping and 8 holes of 5 mm diameter for the mounting of Al Extrusion at the bottom of the board with the drilling machine available in the college workshop. The 8 holes for the mounting of Al Extrusion are counter-sunk from the top of the board by using drilling machine only. We have inserted the threaded inserts in each of the 24 clamping holes from the back side of the board.

We already have some pieces of Al Extrusion of 30mm X 30mm in our college RICC Lab , which we utilizes to make up the base of our machine. We have cutted down the two lengths of Extrusion of 500 mm Length each and one of 456mm length Extrusion. We have attached the each extrusion with MDF Board with the help of 4 X M5 X 12 mm button head cap screws and 4 X M5 pre- assembly insertion nuts. Once the two pieces of Al Extrusion has been fixed, We'll attach the third one i.e. of 456mm Al Extrusion perpendicular to the two main Al Extrusion using a pair of Extrusion connection brackets , M5 X10mm button head cap screw and pre – assembly insertion nuts by first drilling this and the other two lengths. This will help in providing the extra stability to the base of the machine which will further help in reducing the kinematic friction.

Fig 5.1 bed of CNC router view1

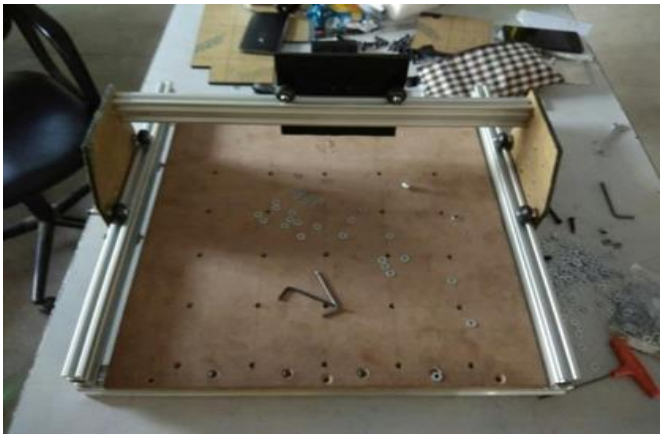

Fig 5.2 bed of CNC router view2

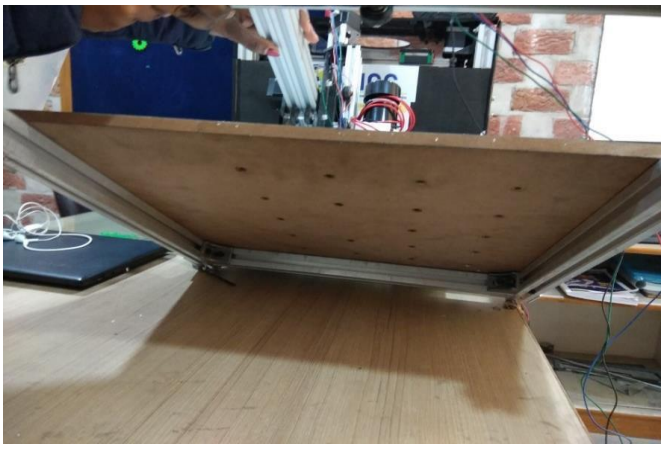

Fig 5.3bed of CNC router view 3

VI. RESULT AND ANALYSIS

We test the CNC router engraving and cutting on plate design first we make the design clip the object for design engrave on platform so it could not move when operation in full process Upload the design file to universal g code sender software

then this software send to design file to the arduino uno using CNC shield v3.

A. Cutting speed test:

In this test we cutting wood by help of design file on MDF board was tested on wood of 6mm thickness area of 120mmx120mm using 3.1mm diameter a end mill bit and spindle of speed 15000rpm power 500watt.first we generate g code of image by using online software cncapp.com and send to controller. The cutting design was SITM on plywood.

B. Engraving system test:

In the engraving system it CNC router system cut the design on wood for certain 2mm depth with the help of spindle of speed 15000rpm spindle speed power 500watt. Image design first on software like cncapp.com then send to the controller.

Figure 6.2 Engrave GEC on ply

Figure 6.3 Engrave MDF

C. Accuracy Test:

The accuracy test was done to check precision of CNC machine in making design which is send to controller. The test input was simple lines of different lengths. The cutting was help of 3.1mm milling bit with spindle of 14000rpm speed and measure the length of different lines and found the 99% accuracy.

Table 3: Accuracy Test

Line No	Design	Measurement Result	Accuracy (%)
1	61mm	61.5 mm	99%
2	63mm	64 mm	98%
3	62mm	62.5mm	99%
4	60mm	60.5 mm	99%
5	64 mm	65mm	98%
6	66 mm	67 mm	98%

D. Depth test:

The depth test was done to check the accuracy of depth of cutting simple lines on different level on CNC router when working by CNC router when working. We create lines by different depth of 3.1mm milling bit and spindle speed of 15000rpm. The depth cut by CNC router is measure by help scale this show that 100% precision accuracy.

Table 4: Depth Measurement

Line No	Depth in design	Measurement Result
1	1mm	1mm
2	2mm	2mm
3	3mm	3mm
4	4mm	4mm
5	3mm	3mm
6	3mm	3mm
7	3 mm	3mm

VII. CONCLUSIONS & FUTURE WORK

A. CONCLUSION:

This is CNC router was built help of ATmega328p and IC4988 that is ARDUINO UNO combined of 4 stepper motors, with 300x300m working area and using the 500watt spindle motor with air cooled. This CNC router is used to make the design on object and cutting the design on MDF with engrave design accuracy around 98.5% and 100% depth accuracy. The four motors on different axis are controlled by help of firmware GRBL library and universal g code sender software. We make the CNC router which is cheap in cost. There is increase of production highly efficient and increase the production for the industry. The requirements of highly precision products demand in the market that's why increase of different small scale machine to manufacture small parts can increase productivity and provide flexibility decrease the cost which is benefit to increase profit. In this thesis make small size three axis CNC router under very low budget.

B. FUTURE WORK:

There are future work to increase the size of prototype of CNC router and use the high powerful stepper motors increase the strength of the frame platform by using different type of material like iron steel. We can also use different servomotors and DC or AC. It also planned to make on large production scale in industry. We can also use for multi axis like 4 axes and 5 axes CNC router. There are different machine made by changing the tool.

1. CNC milling machine
2. CNC drilling machine
3. CNC profile cutter
4. CNC Plotter
5. PCB Board Designing
6. CNC Engrave machine

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