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Research Paper

Design and manufacture 3-axis portable milling machine

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ABSTRACT: *This paper presents the results of the process of designing and manufacturing machines milling the workpieces at the construction site, this machine can be easily moved to area where the workpieces need to be manufactured. The 3-axis portable milling machine is compact and easy to move, but it still enough rigidity. The parameters calculated during the design process include: speed chain, tool feed chain and whole the kinematic diagram of this milling machine. The 3-axis portable milling machine after successfully manufactured have been widely applied in addition to actual production.*

KEYWORDS: *Milling machine; Portable milling machine; Cutting Process; Kinematic.*

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I. INTRODUCTION

Milling machines are often used for machining planes, complex shaped surfaces, keyways, cutting off, machining round faces, keyshafts, threads, gears. Milling is one of the most widely used and most productive metal cutting methods. Milling machining can achieve accuracy grade 6□7 and Ra = 1.25□0.63

The cutting tools used on milling machines include cylindrical end mills, end mills, disc mills, end mills, profile mills.

According to technological capabilities, milling machines are divided into 2 groups:

- Universal milling machine: Vertical milling machine, horizontal milling machine, bed milling machine, copy milling machine, milling machine with rotary table
- Specialized milling machine: Tooth milling machine, thread milling machine, keyway milling machine, keyshaft milling machine.

However, milling machine is designed to be in factory or manufacturing factory. So they have huge weight and size, up to tons. The parts to be manufactured will be mounted on the machine table.

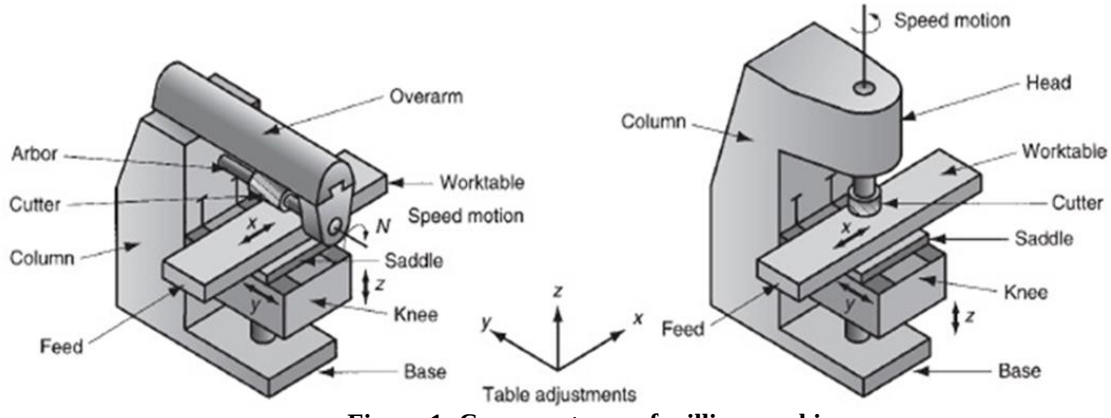

Figure 1: Common types of milling machines

In fact, there are many machine parts that are large in size, or have been attached to structures that cannot be disassembled. When we need to mill them, how do we do?

A milling machine with compact size, light weight, and portability would be an optimal choice.

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There have been many research papers on portable milling machines, for example a research on milling machines made from micro to macro parts [1]. An article written on portable milling machine optimization [2]. An article written on automatic portable 5 axis milling machine [3].

In conducting this study, we researched the aforementioned studies and scoured several websites [4,5] to get an overview of the problem we will be designing. That helps to optimize the design and manufacturing process of our products.

In this paper, we present results of research, design and manufacture of a 3-axis portable milling machine used to manufacture workpieces at the construction site with outstanding productivity and quality. At the same time, the machine is fully automatic, reducing labor, time and processing costs.

II. THEORITICAL BASIS FOR DESIGN

Milling is a cutting machining method in which the chip is removed from the workpiece by means of a rotating tool, the cutting process is maintained due to the reciprocating motion of the workpiece. The axis of rotation of the milling cutter is perpendicular to the direction of the tool feed movement. This is the distinguishing feature between milling and drilling.

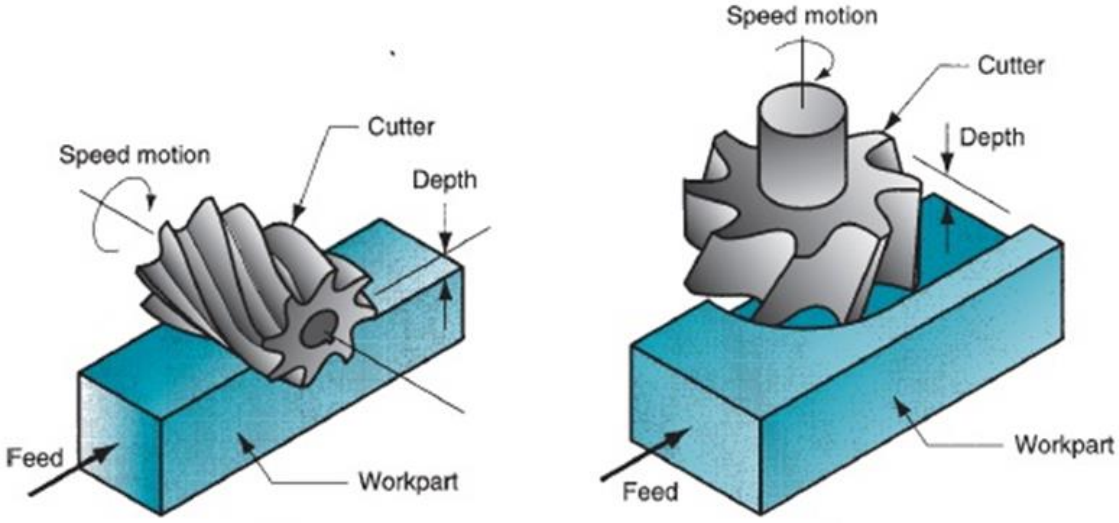

Figure 2: Movements on the milling machine

Normally, movements in 3-axis milling machines include:
- The circular motion of the tool produces the main cutting speed
- Linear motion in the X-direction
- Linear motion in the Y-direction
- Linear motion in the Z-direction

3 linear motion in 3 directions X, Y, Z to maintain the cutting process and act as the feed motion.

Products that are mainly processed on milling machines are planes of different sizes, both of which are straight lines. The generating speed and the standard curve forming speed do not depend on each other, so we drive the 2 chains by 2 independent motors, because there is no common actuator, we only connect the 2 chain structure together. That is, put the speed kinematic chain and the tool feed kinematic chain on the same machine body to create a relationship between the spindle and the table.

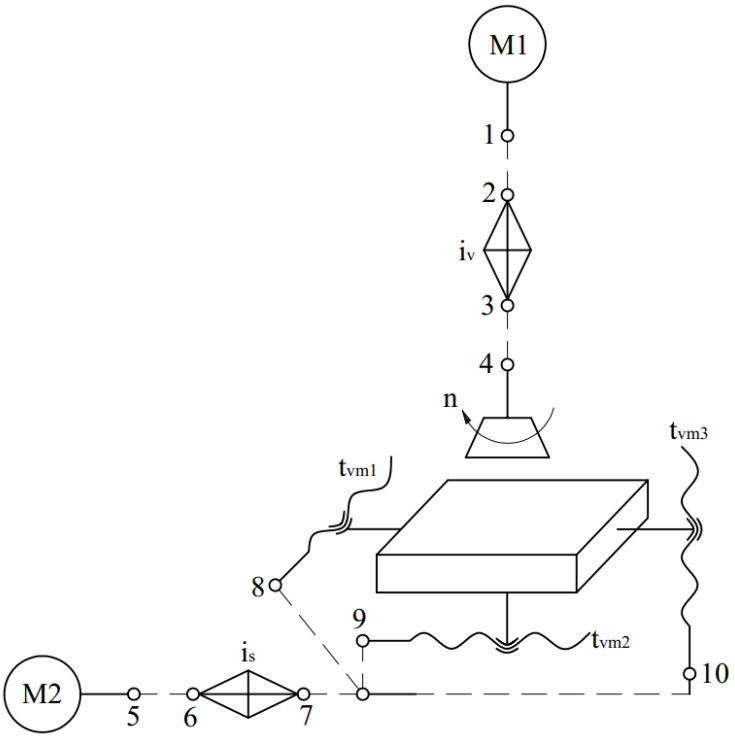

Figure 3: Kinematic diagram of 3-axis milling machine

Speed kinematic chain:

$$n_{motor1}(round/min).i_{12}.i_V.i_{34} = n_{spindle}(round/min)$$

Tool feed kinematic chain:

$$n_{motor2}(round/min)\begin{cases} i_{56}.i_s.\begin{cases} i_{7-8}.t_{vm1} = S_1(mm/min) \\ i_{7-9}.t_{vm2} = S_2(mm/min) \\ i_{7-10}.t_{vm3} = S_3(mm/min) \end{cases} \\ i_{5-12}(M3).i_{12-13}.i_{13-14} \rightarrow rapid\ feed\ speed \end{cases}$$

Basically vertical milling machine is the same as a horizontal milling machine but with some bevel and cylindrical gears added to keep the spindle vertical. And on some horizontal milling machines it is possible to mount the vertical milling head to expand the technological possibilities.

Used to machine flat, horizontal or inclined grooves by turning the vertical milling head to different angles.

III. DESIGN THE KINEMATIC DIAGRAM OF 3-AXIS PORTABLE MILLING MACHINE

Unlike conventional vertical milling machines, 3-axis mobile milling machines need to be compact and easy to move. But it still needs to have enough rigidity, that's why its design needs to be different.

In the speed kinematic chain, we choose direct drive from the engine to the cutting tool. This option helps to reduce power loss and enhance the rigidity of the technology system.

In the tool feed chain, we choose the option of direct drive by handwheel to drive the directions of motion. This makes it easy to manipulate when operating and reduces the size of the machine.

The kinematic design process includes the following steps:

1. Speed kinematic chain:

$$n_{motor1}(round/min).i_{12}.i_V.i_{34} = n_{spindle}(round/min)$$

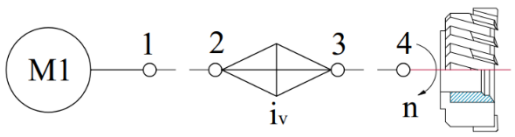

Figure 4: Speed kinematic chain of 3-axis portable milling machine

2. Tool feed kinematic chain:
   - Tool feed movement in the X-direction

     Kinematic equation:
     $n_1(round/min).t_{vm1} = S_1(mm/min)$
   - The tool feed movement in the X-direction is generated by turning the handwheel n_1, the movement is transmitted from the handwheel to the lead screw and then drives the table mounted on the slider.

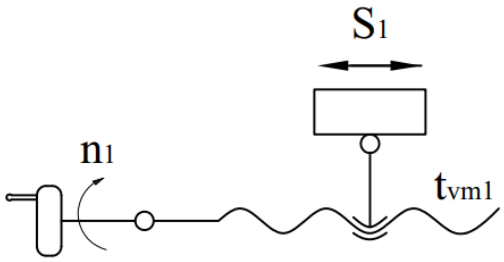

Figure 5: Tool feed movement in the X-direction

   - Tool feed movement in the Y-direction
     The tool feed movement in the Y-direction is generated by turning the handwheel n_2, the movement is transmitted from the handwheel to the lead screw and then drives the table mounted on the slider.

     Kinematic equation:
     $n_2(round/min).t_{vm2} = S_2(mm/min)$

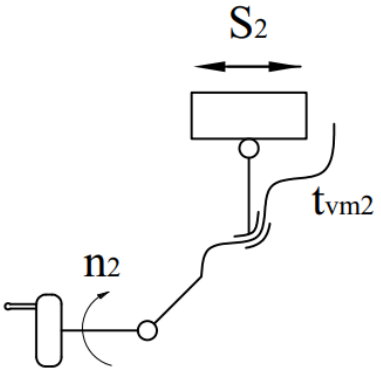

Figure 6: Tool feed movement in the Y-direction

   - Tool feed movement in the Z-direction
     The tool feed movement in the Z-direction is generated by turning the handwheel n_3, the movement is transmitted from the handwheel to the lead screw and then drives the table mounted on the slider.

     Kinematic equation:
     $n_3(round/min).t_{vm3} = S_3(mm/min)$

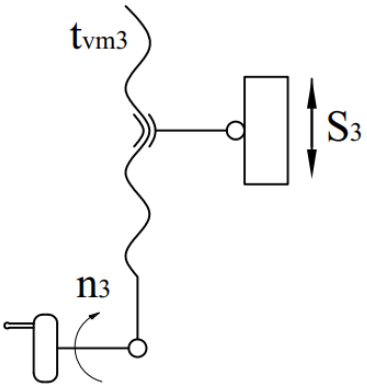

Figure 7: Tool feed movement in the Z-direction

Kinematically coupled kinematic groups together, we get the kinematic structure diagram or kinematic diagram.

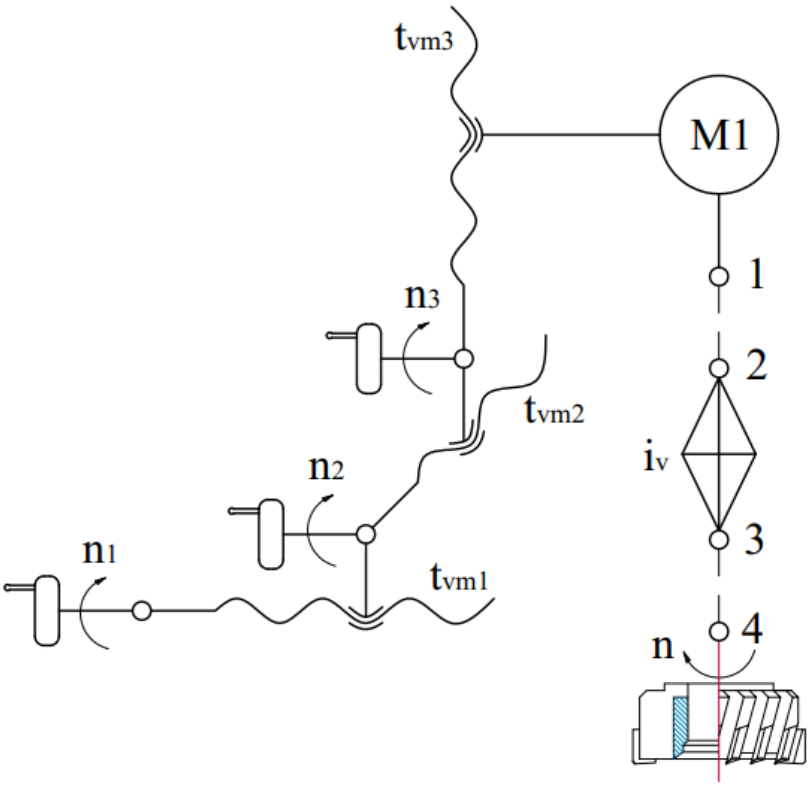

Figure 8: Kinematic diagram of 3-axis portable milling machine

In this design, the X-direction guide way is at the bottom, the Y-direction guide way is above. The Z-direction guide way is at the top. The entire speed chain including the motor, the adjusting link and the fixing links is on the Z-direction guide way.

The kinematic equation:

- Speed kinematic chain:

$$n_{motor1}(round/min).i_{12}.i_V.i_{34} = n_{spindle}(round/min)$$

- Tool feed kinematic chain:

$$\begin{cases} n_1(round/min).t_{vm1} = S_1(mm/min) \\ n_2(round/min).t_{vm2} = S_2(mm/min) \\ n_3(round/min).t_{vm3} = S_3(mm/min) \end{cases}$$

Three movements in three directions X, Y, Z are independent, not related in terms of kinematics. These three movements are only structurally related. During operation, the operator will adjust three tool movements to suit each specific machining surface.

IV. STRUCTURAL DESIGN AND MANUFACTURE OF 3-AXIS PORTABLE MILLING MACHINE

After the kinematic design is completed, the 3-axis portable milling machine is structurally designed and manufactured, as shown in Figure 9, Figure 10 and Figure 11.

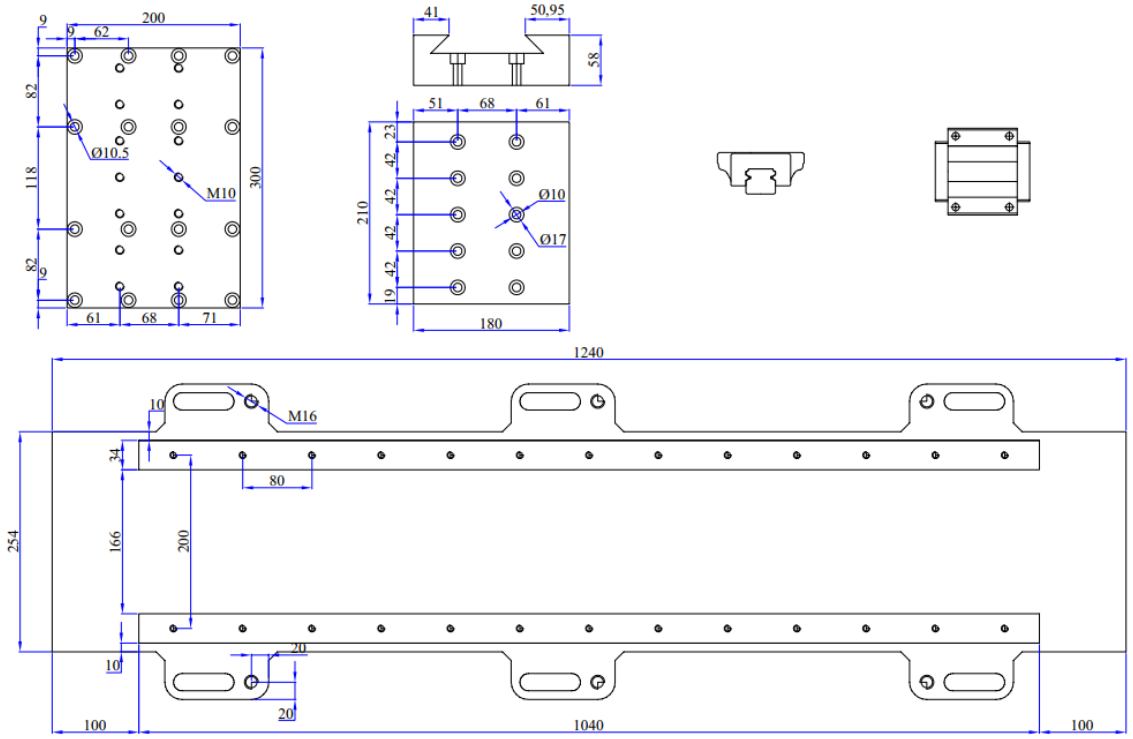

Figure 9: 2D drawing of 3-axis portable milling machine

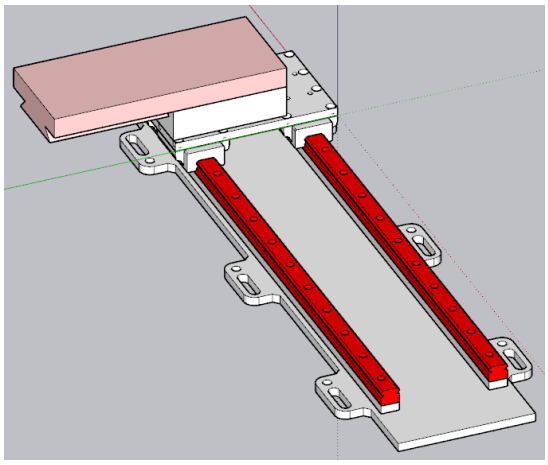

Figure 10: 3D drawing

Figure 11: A photo of 3-axis portable milling machine

V. CONCLUSION

The 3-axis portable milling machine has been researched, designed and manufactured successfully. The machine is designed to manufacture workpieces at the construction site with outstanding productivity and quality. This helps reducing labor, time and manufaturing costs. Products after milling meet technical requirements for quality and progressive. The study calculated the complete design of the kinematic structure diagram of the 3-axis portable milling machine. The results of successful manufacturing of the 3 axis portable milling machine and experimental processing with the calculated parameters achieved the right quality as designed.

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