



# Computer Control of Z-Axis Movement in Micro Drilling Machine

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## Abstract

In this study, the automatic control of the feed axis is aimed to drill holes in micron diameters and precision by using a desktop drill. The control was carried out with the Visual Studio C # interface program using the feed rate, drilling depth and exit speed parameters of the drill in one axis. At the same time, the microprocessor control card enables the stepper motor of the drill to be managed and communicates with the computer. Using EEPROM memory, it is possible to work without the need of a computer whose operating parameters are stored in memory. PIC18F2550 microprocessor control board is used to control all components of the machine. In this way, both stepper motor drive and communication with computer are provided. With the designed control circuit, drilling can be performed with 3,6 degree precision. As a result of the drilling process carried out at different speeds and lengths of micron diameter (0.18-0.25 $\mu$ ) drill bits with the system created, it was seen that ideal drilling process could be performed according to the desired quality characteristics of the machine.

**Keywords:** Drill, Micro Drilling, Axis Control.

## Mikro Delik Delme Tezgahı Z Ekseninin Bilgisayarla Kontrolü

### Öz

Bu çalışmada bir masaüstü matkap tezgahı kullanılarak, mikron çaplarda ve hassasiyette delik delebilmek için ilerleme ekseninin otomatik kontrolü amaçlanmıştır. Yapılan kontrol matkabın tek eksenindeki ilerleme hızı, delme derinliği ve çıkış hızı parametrelerini kullanarak Visual Studio C# ara yüz programı ile gerçekleştirilmiştir. Aynı zamanda mikroişlemcili kontrol kartı sayesinde, matkabın step motoru yönetilmekte ve bilgisayarla haberleşme sağlanabilmektedir. EEPROM hafıza kullanmak suretiyle çalışma parametreleri hafızaya kaydedilmiş bilgisayara gerek olmadan çalışma imkanı oluşturulmuştur. Tezgahın tüm bileşenlerinin kontrolü için PIC18F2550 mikroişlemcili kontrol kartı kullanılmıştır. bu sayede hem step motor sürmesi hem de bilgisayar ile haberleşme sağlanmıştır. Tasarlanan kontrol devresi ile 3.6 derece hassasiyet ile delme işlemi gerçekleştirilebilmektedir. Oluşturulan sistemle mikron çaptaki (0.18-0.25 $\mu$ ) matkap uçlarının farklı hızlarda ve boylarda gerçekleştirilen delme işlemleri sonucunda tezgahın istenilen kalite karakteristiklerine göre ideal delme işlemi gerçekleştirilebildiği görülmüştür.

**Anahtar Kelimeler:** Delme, Mikro Delik delme, Eksen Kontrolü.

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## **1. Introduction**

Developing technology in production systems and high accuracy part production demand requires micro precision and machining. With micro-machining, drills take up less space and workpieces are produced at the same standards, waste material rates are reduced and production efficiency is increased and manpower and electrical energy consumption are minimized. With the rapidly growing micro processing industry, high efficiency is achieved in the use of resources and time. Automation systems and production of hole drilling operations, which are widely used in many fields such as automotive, machinery, aerospace industry, are an inevitable result of industrial development. Especially for small holes, hole position and diameters require micron level precision. The most important factor in drilling holes in micron diameters and precision is that the feed rate can be fixed at constant speed and adjustable at certain intervals.

Electrical discharge machining (EDM) is a material forming process that is widely used in the production of parts in the aerospace, automotive and surgical field, which is particularly preferred for difficult to process materials with complex shapes. EDM is one of the most efficient production processes capable of extremely precise production. It is a non-contact thermal energy process used to process electrically conductive components independent of the mechanical properties of the material. Studies in the literature on EDM have shown that process performance can be significantly improved by proper selection of process material and operating parameters.

Due to the difficulty in observing the void space directly, there is almost no literature regarding the quantitative assessment of bubble behavior. Electrical discharge machining (EDM) stated that during drilling of micro-blind holes, the processing medium would gradually deteriorate due to the accumulation of debris and increased concentration density in the narrow space area. They concluded that the bubbles in the cavity area were the main driving force for the exhaust exchange of dielectric fluid and debris.

Take Oliaei horse. [3] stated that it is advantageous to study materials which are difficult to drill and process due to micro-EDM method compared to conventional mechanical micro drilling. In addition to the micro-EDM working principle, they included applications on hard-to-cut materials such as Ti and Ni alloys.

High aspect ratio micro-holes are increasingly used in various applications such as aerospace, medicine and automotive. Take Dongre horse. [4] investigated the properties of micro-hole perforation ( $\mu 100 \mu\text{m}$ ) with super-CW fiber laser on super-alloy materials using experimental methods and numerical modeling. As a result, micro-holes with a diameter of around  $100 \mu\text{m}$  were formed using percussion technique on a 2 mm thick super-alloy material. The demand for high aspect micro-holes is increasing day by day. Functional micro holes are required especially for applications in the semiconductor and biomedical industries. Products used in these areas should contain holes with high contour accuracy and minimal thermal damage. In addition, the materials used in these applications are difficult to process such as super alloys and composite materials. Aslantaş and Kaynak [5] stated that laser processing is an extraordinary method for producing high precision micro properties. Femto reported that the development of pico-second lasers is a method for increasing precision for micro-manufacturing. micro-hole drilling 12 WTi-sapphire using 50-100 fs laser.

Shape memory alloys (SMA) are widely used in the biomedical field due to their unique properties. Among these alloys, NiTi alloys are the most commonly used materials. A method for shaping these alloys is the machining technique. If NiTi alloys have to be machined mechanically, the crystal lattice structure may change and phase conversion may occur. Phase conversion naturally affects cutting forces and tool life. Aslantaş and Kaynak [6] investigated experimentally the milling of NiTi alloy under micro cutting conditions. For this purpose, an experimental setup capable of cutting at high precision and high cutting speeds was used. In this study, the feed rate and chip depth are taken into consideration in a wide range and the output parameters, cutting forces, surface roughness and burr width are tried to determine the chip thickness which is critical for milling the NiTi alloy.

Friction drilling is a non-traditional manufacturing method with the effect of heat generated by friction at the workpiece-tool interface with a rotating tool. The purpose of this method is to increase the length of the connection in thin-walled sheets by means of the sleeve formed at the bottom of the hole. In the study conducted by Özek and Bak [7], it was aimed to investigate the effects of material thickness and tool diameter on the barrel height, barrel wall thickness and micro hardness change in friction drilling method. In experimental studies, it was stated that material thickness and tool diameter had a significant effect on sleeve wall thickness and sleeve height, but micro hardness values did not change much.

In addition to the drilling process, micromachining is also gaining more importance today [8]. Along with the development of computers, the role of the computer in hole processing has also improved. Thanks to computers, the sensitivity of movement and control ability on 3 axes has increased [9,10]. There are many detailed articles and studies on this topic in the literature. Micro machining techniques may also differ in Cnc milling machine design [11, 12]. Parameters such as vibration, accuracy and precision stand out during the process [13, 14]. The efficiency of the system is kept at a high level with the help of refrigerant liquids at the time of operation, resulting in a higher quality machining process [15]. Micro processing methods are applied in the design of manipulators, control of motors and wide range of uses [ 16, 17, 18].

In this study, a desktop drill, which was our own design, was adapted for micro drilling process for accurate positioning and drilling of desired micro precision holes by making some changes. For this purpose, a stepper motor is placed on the Z axis in order to

control the drill movement automatically in the direction of the vertical axis. Thanks to the arrangements made, a high performance drill machine can be drilled at high speed and precise feed values.

## 2. Material and Method

### 2.1. Drilling Machine and Their Components

In this study, a drill machine was designed in which precision drilling operations can be performed with stepper motor connected to our own design drill machine. The general view of the designed machine is given in Figure 1.

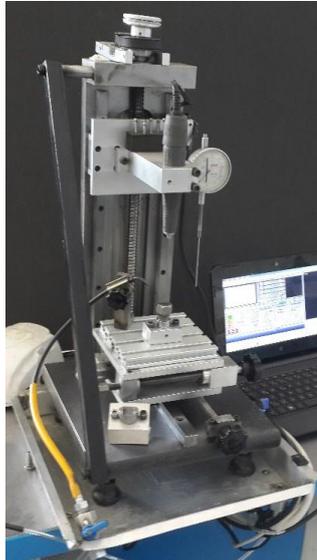


Figure 1. Designed drill machine.

### 2.1. Drilling Machine and Their Components

Figure 2 shows the control board used for communication with the computer in addition to setting the drill speed and position. Mach3 CNC usb control card 3 Axis 200 kHz AKZ250 Leafboy77 usb interface control card is used. The preferred control card for servo motor control has 15 inputs and 15 outputs. Especially because the control card has USB communication and the speed is sufficient for the system, this card has been preferred in this study. This control card is also used to control the drill stand and to establish the connection between the control circuit and the computer.



Figure 2. Mach3 CNC USB 3 Axis 200 KHz AKZ250 Leafboy77 control card.

### 2.1. Step Motor And A4988 Step Motor Driver

In this study, a high power bipolar 200 step NEMA 23 stepper motor of Pololu brand was used. This stepper motor draws 19 kg-cm of torque, 200 steps at a full turn of 1.8 degrees, and draws a current of 2.8 A under 3.2 V voltage per phase. A4988 driver integrated is used to control this stepper motor. The application diagram of this driver integrated circuit is given in Figure 3.

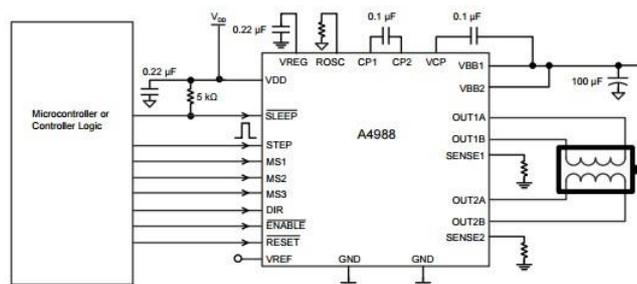


Figure 3. Application diagram of A4988 driver.

The signals in Table 1 were used to determine the operating speeds of the stepper motor controlled by microcontroller.

Table 1. Microstepping Resolution Truth Table.

MS1	MS2	MS3	Microstep Resolution	Excitation Mode
L	L	L	Full Step	2 Phase
H	L	L	Half Step	1-2 Phase
L	H	L	Quarter Step	W1-2 Phase
H	H	L	Eighth Step	2W1-2 Phase
H	H	H	Sixteenth Step	4W1-2 Phase

### 3. Results and Discussion

Although drill lathes are generally used to create holes that do not require precision, a lathe is designed in which precision drilling can be performed. The stepper motor is connected to the system to control the Z axis of the drill stand. H22A1 hall effect sensors are connected to the starting point of the axis of movement of the machine and to the point where the drilling process will start in order to provide position control. These connected sensors are used to eliminate system errors and ensure system security. The schematic representation of the machine and its components used in this study is given in Figure 4.

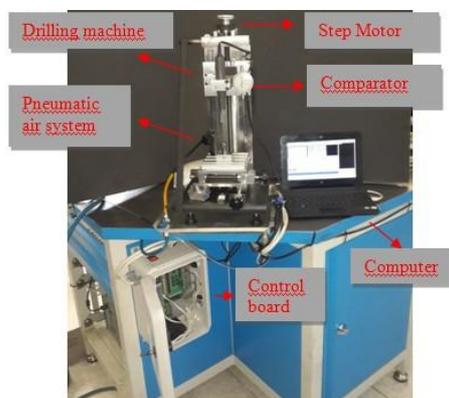


Figure 4. Schematic view of drilling system.

The connection of the stepper motor via a pulley to the infinitely moving screw on the Z axis controls the up and down movement of the drill bit (see Figure 5).

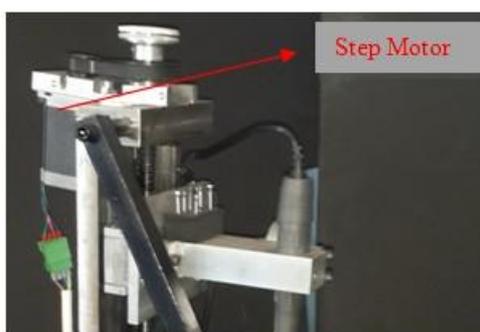


Figure 5. Connection of step motor.

Mach3 CNC USB 3 Axis 200 KHz AKZ250 Leafboy77 control circuit which provides speed control of stepper motor and communication with computer via usb is given in Figure 6.





(a)



(b)

Figure 9. The view of drilled workpiece.

The drilling speed, which is critical in the drilling process, has been determined in accordance with the constant speed value and the resulting hole dimensions have been obtained at the desired tolerance values. As a quality indicator, it was determined by using measurements that the roughness value of the hole has sufficient sensitivity for the purpose of use. The results obtained from the experiments showed that the machine designed to create holes with the designed drill can be used safely.

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