Computer Control of Z-axis of Drilling Machine that making Hole at Micron Accuracy

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Abstract— *Drilling operations are used widely in industrial applications. In these operations several drill bits having different drill geometry and different tool materials such as HSS and WC are used to obtain the holes at desired surface quality and tolerances. The big problem in drilling operations with drill bits is to achieve a hole diameter at micron accuracy. In order to be able to drill at desired accuracy the main factor is that the drill bit must be moved at constant feed speed and can be adjusted. In this experimental study, a standard workbench based drilling machine have been used and the computer controlled mechanism have been set up to adjust the Z-axis to drive the drill bit at constant speed, so the drilling diameter will be kept at desired tolerance and at the drill axis. The parameters such as feed speed, drilling length, entering and exit speed related to drilling machine tools are adjusted the software written in Visual Studio C#. Communication between step motor control and computer is provided by control card constituted with microprocessor. Also, operation parameters are saved to the memory by EEPROM installed on the circuit and the working of the system is realized without computer connection. By the installed system the drilling holes at micron accuracy (0.18-0.25µ) were achieved in drilling operations carried out at different feed speeds and drilling lengths on the computer controlled Z-axis drilling machine tools.*

Keywords— Drill Bit, Drilling Machine, Hole Diameter Accuracy, Computer Control, Axis Control.

I. INTRODUCTION

Developing technology and workpiece demand at high accuracy in manufacturing technology require micro machining. Machine tools and workpieces machined are miniaturized with micro machining and also material and power consumption are reduced to the lowest level. In worldwide, by means of this industry that getting expanding high efficiency is obtained in source and time usage. Many type of drill bits are widely used in industrial applications. The most important problem in drilling applications is drilling of micro scaled holes and to fix the parts in desired coordinates. The main factor in drilling micro-hole around 0.18-0.25µ at micron accuracy in small diameter is that feed speed must be at constant and also adjustable.

There are several micro hole creating methods are claimed by many authors in their investigations. The holes at too small diameters are formed with. Micro-electro discharge machining (EDM) using water as a working fluid is systematically studied to find its characteristics. As a result, the unique advantages of high removal rate, low electrode wear and consequently higher working efficiency, without formation of carbonaceous materials are found under optimum experimental conditions, as compared with the case when kerosene is used. This was achieved by the choice of suitable combinations of electrode and workpiece materials and electrode polarity. Use of a tungsten electrode with straight polarity is exceedingly good with respect to high removal rate and low electrode wear. This makes it possible to obtain a non-tapered straight micro-hole around 0.1 mm in diameter with a certain anticipative working gap. The advantageous properties of this machining method are effectively utilized to drill deep micro-holes with a ratio of depth to diameter of the order of 10–17 as in the case of 2.9 mm depth and 0.17 mm diameter, which is superior to the limits achievable with both electro discharge drilling (EDD) using kerosene and mechanical drilling with a micro-drill [1].

New drill point geometry, termed the helical drill point, specifically intended for micro-drills, is developed in order to alleviate the disadvantages of existing planar micro-drill points. A mathematical model for this new drill point has been established. It is shown that this model is more general than existing drill point models. The commonly used conical,

cylindrical and planar drill point models are only special cases of the helical model. For uniquely determining the grinding parameters of the new drill point as well as guiding the grinder design, the characteristics, the controllability and the sensitivity of the grinding parameters have been analysed. Finally the geometric characteristics of this new drill point are investigated [2].

At the present time micro-drills with planar point geometry are prevalent in industrial practice. To resolve the problems of planar micro-drills, this paper focuses on issues related to micro-drill point geometry (including the flank and flute) and presents a framework for a technology, built around a computer integrated system, for the design, manufacture, and evaluation of drills in general and of a new generation of micro-drills with curved helical point and flute geometry in particular. It is expected that this technology will support the rapid development of new customized micro-drills to meet specific manufacturing requirements [4].

Typical accuracy provided for ultra-sensitive machine tools is ±1µm using by linear driving systems. These machine tools have some advantages such as high rigidity, high damping rate, sensitive sensors and circuits that ability for operating actuators accurately. For a sustainable future, it is observed that there will be a rapid increase in production and usage of micro devices [8]. In the real timed coordinate controlled system, motion of the axes is performed by step motor and endless screw-gear. Since the system is open circuit the step motor is preferred. Motor driver circuit are controlled by signal coming from parallel port of computer [9].

In other application is that while rotational movements of the platforms have been controlled by the servo motors, linear motion is provided by single acting pneumatic cylinder. Materials pick and place process is carried out by a pneumatic gripper. Axis position control of the system is realized by the multi axis motion controller (Siemens Simotion D-425). Simotion Scout program is used as control software. The designed system has given good results for different operating scenarios [10]. In the same way, 3D milling machine has been designed and assembled. Linear motion of 3-axes of the machine tools are controlled by step motor that its driver is controlled by control card [11].

In this study, in order to drill micro holes at desired tolerances, Z-axis control of the drilling machine (Proxxon MF70) placed on workbench is carried out by step motor attached to the drilling machine. Using a fixing mold is designed to drill the hole in centre of the workpiece and also to place the drilled hole in centre of the drill bit, so centring process that may occur has been removed. During drilling operation, the drill bit can be positioned in any distance from workpiece and the feed speed of the drilling is adjusted as stepless to achieve hole at desired quality (from point of view of tolerance and surface roughness). With the designed control circuit, the hole surface roughness is obtained at the accuracy of 3.6 µm. Communication between step motor control and computer is provided by control card constituted with microprocessor (PIC18F2550).

II. MACHINE TOOLS

Drilling operation is as can be performed with simple drilling tolls and also with modern drilling machine tools having high quality from point view of surface quality, revolution and position control in manufacturing and assembly of the part/system. The holes on the workpiece is drilled one by one or multi drilling can be performed by drilling machine that having multi spindles. In the simple drilling machine, spindle is driven by electric motor by means of belt-pulley and moved down by rotating a lever handle to drill the hole. The modern drilling machines are driven by an electric motor to gear box to turning the spindle speed precisely and position of the spindle and table in X and Y direction are controlled by PLC or computer using step or servo motor.

In this study, a workbench type drilling machine (Proxxon MF70) is used and modified to drill too small holes at desired quality and diameter tolerance (Fig. 1). In drilling operation the important parameters are position of the workpiece on the machine table based on hole centre and linear motion control of the spindle speed precisely. Therefore, this drilling machine is adopted for that purpose.

FIG. 1 WORKBENCH TYPE DRILLING MACHINE TOOL (PROXXON MF70)

III. MICROCONTROLLER

In control of the drilling machine the microcontroller (PIC18F2550) manufactured by Microchip Company is used. The microcontroller is an advanced equipment in the family of PIC18 and used widely for consumer electronic in industry, automotive and medical applications. The technical properties of the microcontroller are given in Table 1. The microcontroller is used in this study because of having USB communication, its speed is equal level for the system demands. For that reason, this item is used in controlling drilling machine and performing connection between control circuit and computer.

TABLE 1
TECHNICAL PROPERTIES OF THE MICROCONTROLLER PIC18F2550

Features	PIC18F2550	Features	PIC18F2550
Operating Frequency	DC – 48 MHz	10-Bit Analog-to-Digital Module	10 Input Channels
Program Memory (Bytes)	32768	Comparators	2
Program Memory (Instructions)	16384	Resets (and Delays)	POR, BOR, RESET Instruction, Stack Full, Stack Underflow (PWRT, OST), MCLR (optional), WDT
Data Memory (Bytes)	2048		
Data EEPROM Memory (Bytes)	256		
Interrupt Sources	19		
I/O Ports	Ports A, B, C, (E)	Programmable Low-Voltage Detect	Yes
Timers	4	Programmable Brown-out Reset	Yes
Capture/Compare/PWM Modules	2	Instruction Set	75 Instructions; 83 with Extended Instruction Set enabled
Enhanced Capture/ Compare/PWM Modules	0		
Serial Communications	MSSP, Enhanced USART	Packages	28-pin PDIP 28-pin SOIC
Universal Serial Bus (USB) Module	1		
Streaming Parallel Port (SPP)	No		

IV. STEP MOTOR AND A4988 STEP MOTOR DRIVER

In this experimental study, a step motor (NEMA 23) that having high power and 200 bipolar step is used. This step motor is having the properties such as the 19 kg.cm in torque, 1.8º in each step (200 step in one revolution), drawing 2.8 A current under 3.2 V in voltage per phase. The control of step motor is done by integrated driver A4988. The application diagram of integrated driver is shown in Fig. 2.

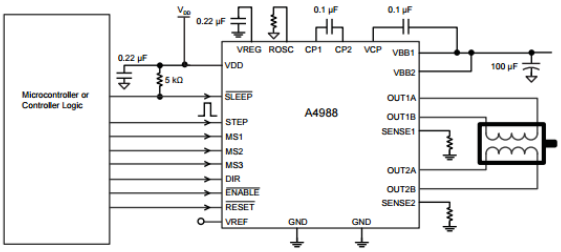

FIG. 2 INTEGRATED DRIVER OF A4988

In order to determine operating speeds of the step motor controlled by microcontroller the signals given in Table 2 have been used.

TABLE 2
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

V. EXPERIMENTAL STUDY AND THE RESULTS

Although drilling machine tools are used for drilling of unsusceptible holes, in this experimental study a drilling machine has been equipped with control equipment to drill small holes accurately. In this application, the step motor is fitted to the system to control Z-axis. To provide position control, Hall Effect sensors (H22A1) are fitted at the beginning of drilling tools moving point and the point that drilling operation is started. The sensors connected to the system are being for eliminating errors that can be occurred and providing system safety. The drilling machine tools and related equipment's fitted on the machine tools are shown in Fig. 3.

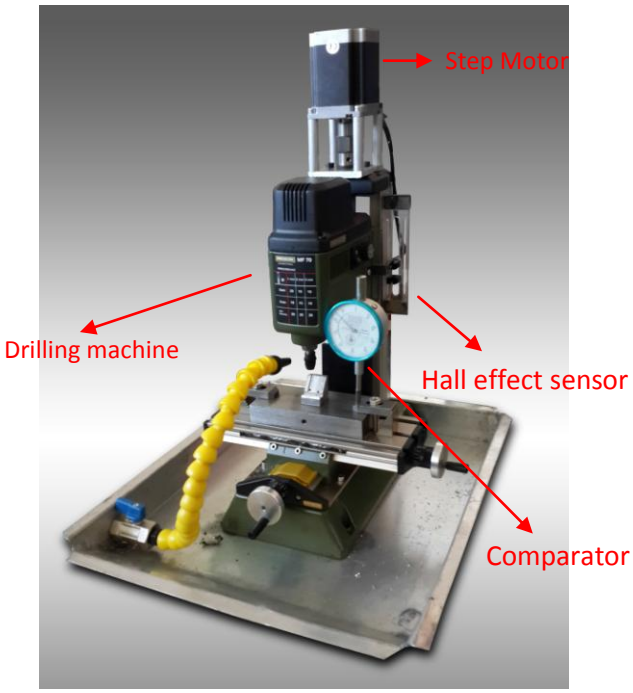

FIG. 3 DRILLING MACHINE AND CONTROL EQUIPMENT'S FOR DRILLING SMALL HOLES

The circuit diagram used for preparing Proteus program that used controlling step motor and introducing communication with computer through USB is given in Fig. 4. As shown in the figure that, the driver Pololu A4988 has been used for speed of step motor. Microcontroller (Microchip PIC18F2550) is used for controlling driver circuit and providing communication with designed interface C#. In addition that using EEPROM 24C02C the working conditions determined are saved to the memory. The photograph of the driver and control circuit given in Fig. 4 is shown in Fig. 5.

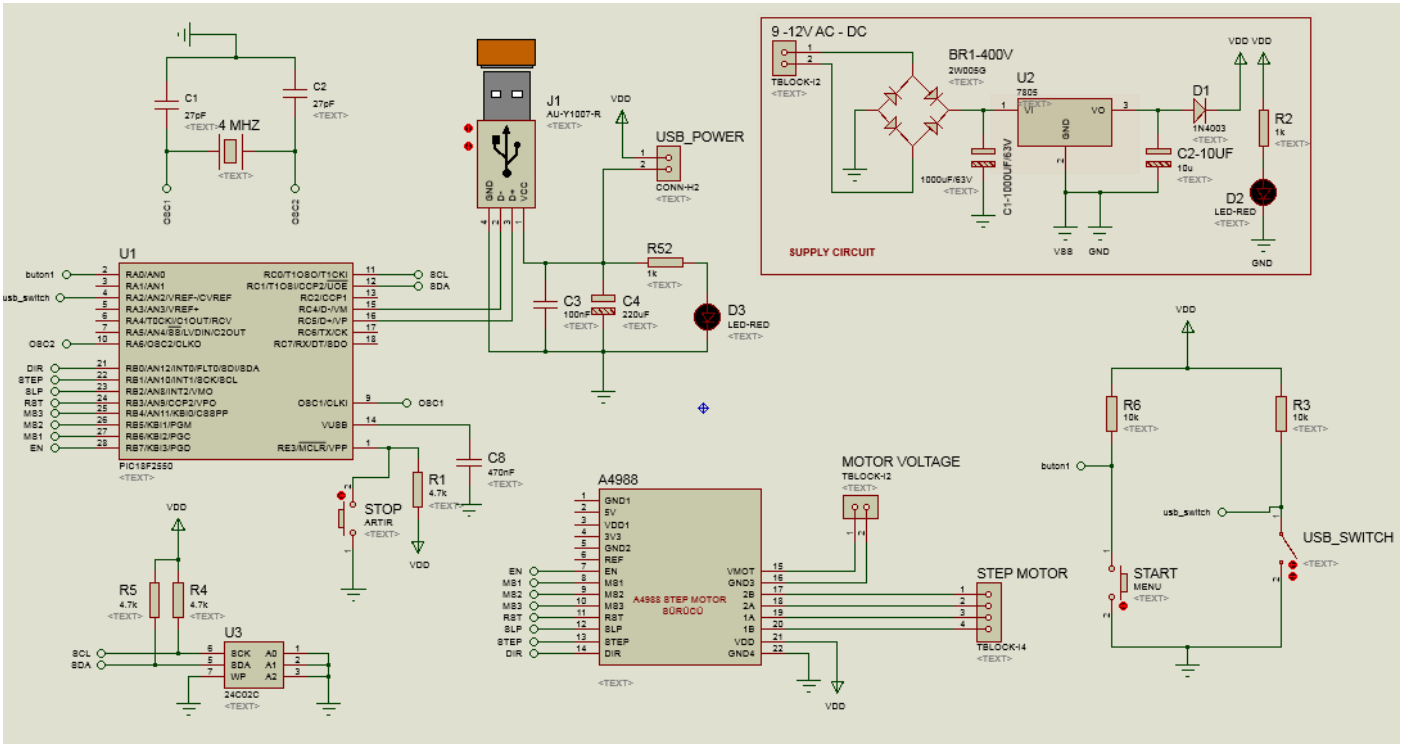

FIG. 4 DESIGNING DRIVER AND CONTROL CIRCUIT

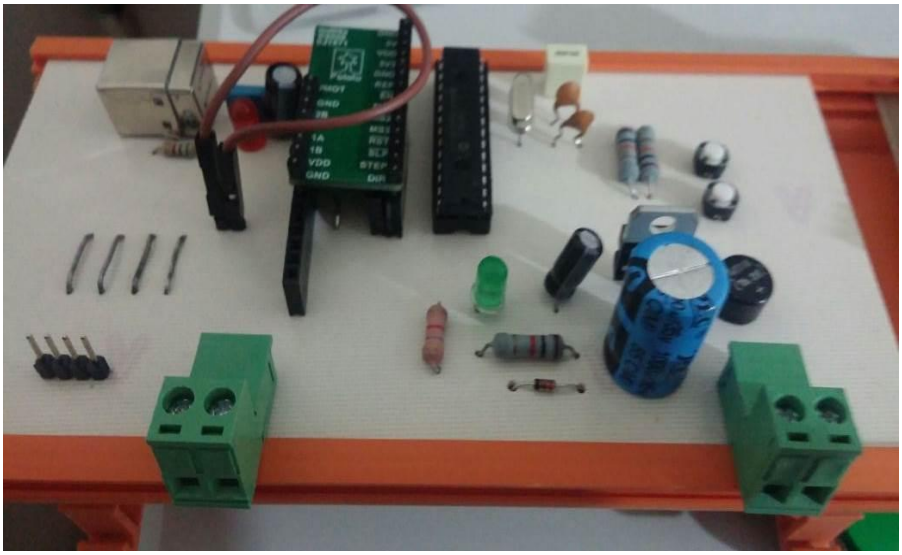

FIG. 5 PHOTOGRAPH OF THE DRIVER AND CONTROL CIRCUIT

Using the circuit in Fig. 5, speed control of step motor and position control are realized. Also computer connection is put into practice with this circuit over USB. The interface software prepared in this study is written in Microsoft Visual C#. As shown in Fig. 6, drilling distance, drilling feed speed, spindle speed and exit speed is adjusted with the software. In interface design, the speeds of the step motor can be changed according to step resolutions as given in Table 2. The accuracy of drilling distance of the system is determined as 3.6º. When the values of the parameters are adjusted the data are saved to EEPROM 24C02C by pushing "save" button. The drilling machine is then operated according to saved parameters.

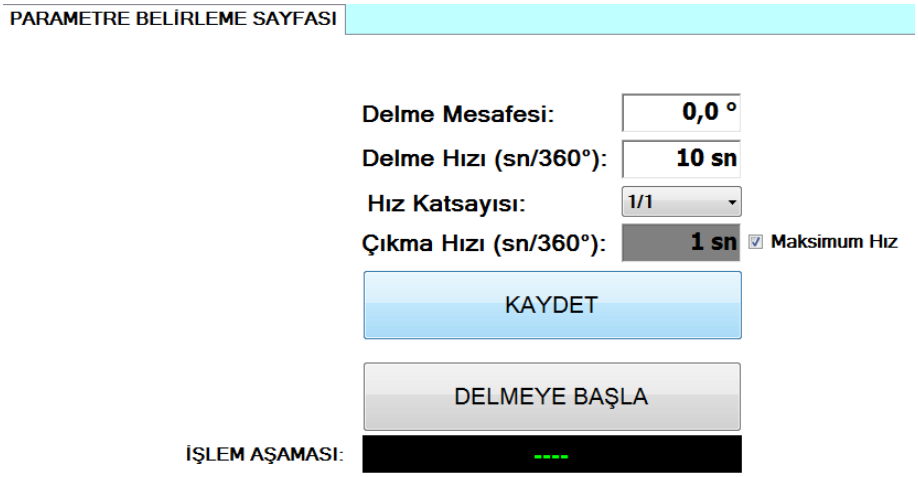

FIG. 6 CONTROL INTERFACE OF THE DRILLING MACHINE

After operating parameters of the drilling machine are determined the system can be operated from computer and on the circuit as well. When the system is started to operation, wherever the spindle of the drilling machine is positioned, the system is turned back to starting point automatically at the exit speed defined and started to moving down from that point. While the drilling machine is moved in Z-axis, drilling operation is carried out at defined feed speed as defined drilling distance when the signal are taken from Hall Effect sensor that defining drilling point. The system has turned back to starting point automatically when drilling process has finished. In order to determine that the drilling machine is drilling the hole in desired drilling angle or not, a comparator is fitted to the column of the machine. In addition if it is desired the motions of the drilling machine can be performed manually by the buttons present on the circuit. It is observed that the system is carried out drilling processes at desired distance in the applications realized at different drilling distances and feed speeds.

VI. CONCLUSION

As a result of the experimental study, a standard workbench type drilling machine used for drilling of unsusceptible holes is converted into the drilling machine being controlled and making the holes accurately. The spindle of the drilling machine (Z-axis) is driven by step motor that having 3.6º in one step. By the designed interface program feed speed, drilling distance, exit speed related to the drilling machine can be controlled and adjusted depends on drilling conditions. As a result of experimental study performed it is seen that the holes drilled on the drilling machine have desired surface quality and distance, expected surface roughness and the deviation of the hole diameter is within tolerance.

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