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TITLE: STUDY AND DEVELOPMENT OF AN AUTOMATED DRILL

STUDENTS` REPORT

Submitted in September 2022

A report submitted in partial fulfilment of the requirements for the award of a degree in Mechatronic Engineering.

ABSTRACT

There are broad applications of high aspect ratios, high quality holes. However, it is very difficult for conventional drilling methods to obtain deep holes, especially with high aspect ratio, while keeping vibrations, forces, and thermal evolution on check. This automated 1-axis drill provide a promising solution for efficient drilling of deep holes with high-precision material removal, reduced cracks or breakage of workpiece, minimized heat-affected zones. Monitoring the system is crucial in determining optimal drilling parameter which can in turn be used in a system control. On the same note, this research analyzes the behavior of PMMA during the drilling action. Finally, the analysis of the material composition could help other students or researchers in studying plastics behaviour to heat and stress.

Key Words: ***Automatic 1-Axis Drill, PMMA, force, vibrations, temperature***

1. Introduction

Drilling is a cutting process that uses a drill bit to cut a hole of circular cross-section in solid materials. Recently, drilling of quality holes in Perspex has gained a lot of research interest especially in thermoplastics and human bones. This study attempts to contribute to this endeavor by proposing to design and fabricate a 1-axis automated drilling machine that will monitor key conditions of the system during operation. To achieve quality drilling, the effects of three sensors will be studied for: drilling force, vibration, and cutting temperatures monitoring. The automated drilling machine and its electronics are designed in CAD and simulated in Matlab. Temperature evolution and stresses on the Perspex are studied using FEA. The collected data in a live feed and simulations done for analysis. Mechanical transmission is done with a stepper motor based on the drilling depth fed into the program. The entire process utilizes mechatronics and various related fields in order to fulfil the drilling objective.

1.1 Problem Statement

Common problems in drilling include chatter vibrations, drill bit breakage, and workpiece damage. This can present challenges in precision drilling applications in the delicate technological drilling and medical industry. This study seeks to use data from force, vibration, and temperature sensors to minimize chatter, and obtain quality cuts without increasing throughput time. Perspex was chosen for study since it resembles the human bone properties.

1.2 Justification

In the medical industry, the drilling of bone is a common procedure in orthopedic surgery to produce holes for screw insertion to fixate the fracture devices and implants. It also helps with fix plates and screws that fastens broken body parts for immobilization. In the recent past, bone drilling has gained popularity following its importance in reduction of tissue damage, a process known as osteonecrosis. PMMA has similar properties to the bone hence this study can be used in orthopedic drilling research.

2. OBJECTIVES

2.1 Main Objective

To design and create a 1-axis automatic drilling machine with a monitoring system of the drilling parameters.

2.2 Other Objectives

- To design mechanical assembly simulations using CAD.
- To program the sensos and actuators for the operation using STM32 Blue Pill.
- To monitor the drilling operation in MATLAB.
- To conduct a Finite Element Analysis on Abaqus.

2.3 Project Scope

Interfacing of all software necessary for the design of the automated one axis drilling machine are bound within the scope of this project. In addition, assembling of the hardware components and whole design architecture also falls under the scope of the project. Finally, some of the properties deemed important and worth evaluating from this project include its efficiency and reliability. Designing of the proposed automated one axis drilling machine is covered in the scope of this project.

3. METHOD

3.1 Steps

In order to achieve quality drilling of holes using optimum conditions such as the feed rate, drilling speed, and drill bit diameter, we had to follow the required steps as follows:

a) Coming up with CAD Models and electrical circuits using software: achieved through Solidworks, Proteus, Fritzing.

b) Simulations of the whole system and its components using Simscape, Proteus, Abaqus and Solidworks:

- Simulations that show how the system would move prior to fabrication,

i. temperature and force simulations of the work piece

ii. Simulations of the electric components.

iii. Mechanical design simulation.

c) Actual fabrication of the rig:

- 3D printing of components such us:

i. pulleys,

ii. electrical cabinet.

- Assembly of all the mechanical parts. Processes included:

i. welding,

ii. bolting,

iii. painting

d) Circuit interfacing of the sensors, actuators and drivers and their programming:

e) PCB fabrication.

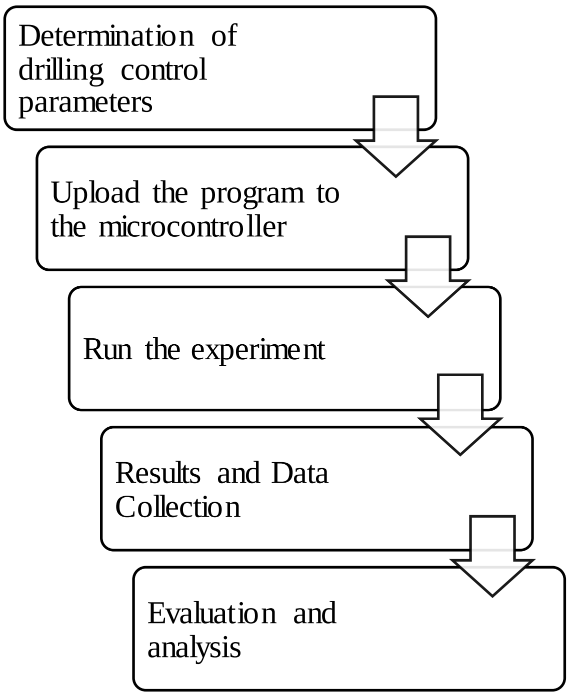
f) Running the experiments and data collection and observation to determine the optimum parameters: Running the motors sequentially to approach the workpiece, drill the PMMA while sensors are collecting data then move back to the original position.

g) Interfacing the digital twin of model.

3.2 Components

- NEMA 17 Stepper motor.
- DC Motor.
- 801S Vibration sensor module.
- MLX0614 non-contact Infrared temperature sensor.
- TB6600 Micro-step stepper motor driver.
- L298N DC motor driver.
- STM32 Blue Pill microcontroller.
- Speed Encoder
- Photoelectric Limit Switch
- Ball screw

3.3 PROCEDURE



3.4 Components

Stepper Motor

One of the main electrical components used in this project is the stepper motor. It contains the carriage that holds the DC motor in position.

Figure 1: A stepper motor

In a stepper motor, the electromagnets are energized by an external control circuit, such as a microcontroller. To make the motor shaft turn, first one electromagnet is given power, which makes the gear's teeth magnetically attracted to the electromagnet's teeth. When the gear's teeth are thus aligned to the first electromagnet, they are slightly offset from the next electromagnet. So, when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one, and from there the process is repeated. Each of those slight rotations is called a "step," with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle. Stepper motors are ideally suited for precise positioning of an object or precise control of speed without having to resort to closed loop feedback. These motors rotate in step-wise i.e., this stepper motor rotates a precise angular distance, one step for each pulse that is delivered to its drive circuit. The motor used in this project work has a step angle of 1.80 per pulse. In order to rotate the motor shaft for one complete revolution i.e., 3600, it is required to supply 200 pulses (360 / 1.80 = 200) to the motor's drive circuit. This drive circuit is then connected to drilling machine, which is the main device of the project.

STM 32 Blue Pill

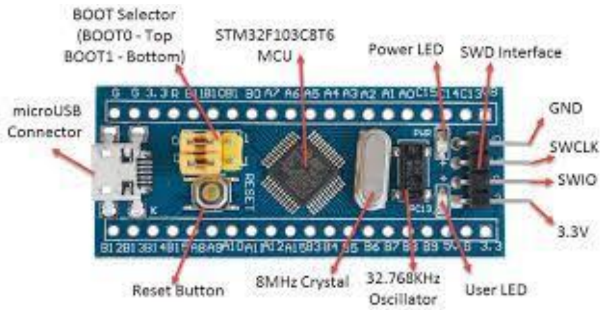
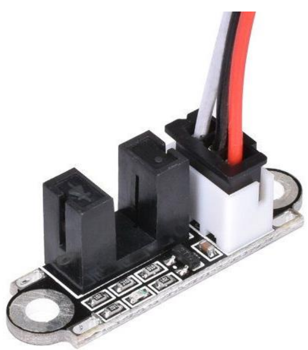


Figure 2: STM 32 Blue Pill

A STM32 is a high-performance development board used as a microcontroller in this experiment. It has a range of I/O peripherals with multiple communication interfaces such as 12C, SPI, and USB. STM32 was used in this experiment as it is cheap, board-friendly, and has a lot of features required for this project.

Photoelectric Limit Switch



A limit switch is integrated in the structure to help to help identify the absolute home position and prevent the stepper motor from damage. This switch is integrated in the microcontroller as an input signal. Whenever the limit switch is activated, active low signal will be generated, based on this signal the microcontroller can recognize the position of drill motor. Thus, the power can be saved to a maximum extent.

4. RESULTS

After the experiment, data from the three sensors was collected. The data was transferred through a live feed to an external computer module and analyzed.

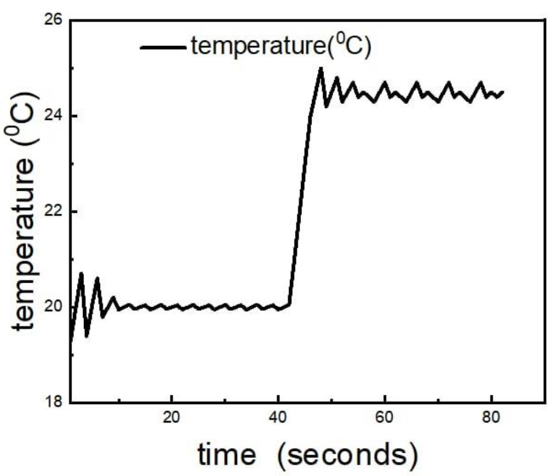


Figure 3: Temperature measured against time

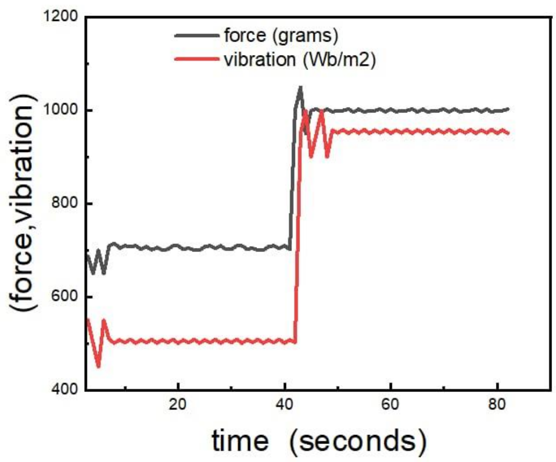


Figure 4: Force and Vibrations against time

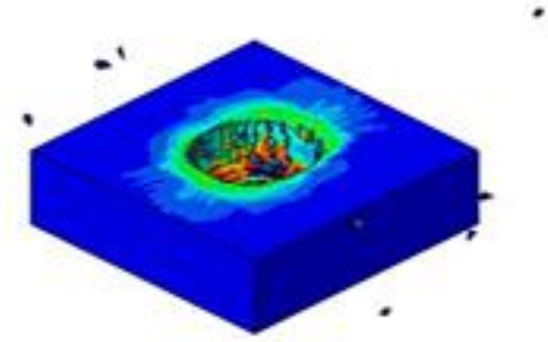


Figure 5: Temperature Evolution against the drilling contours

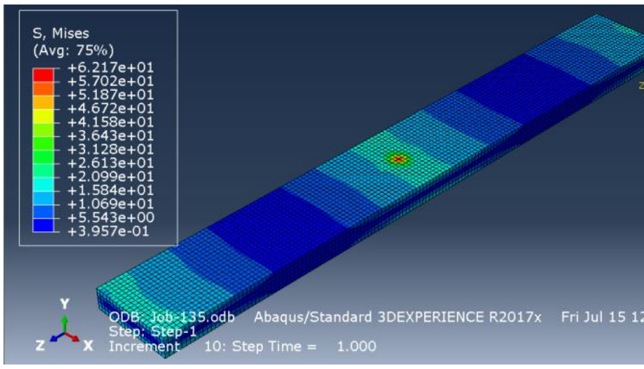
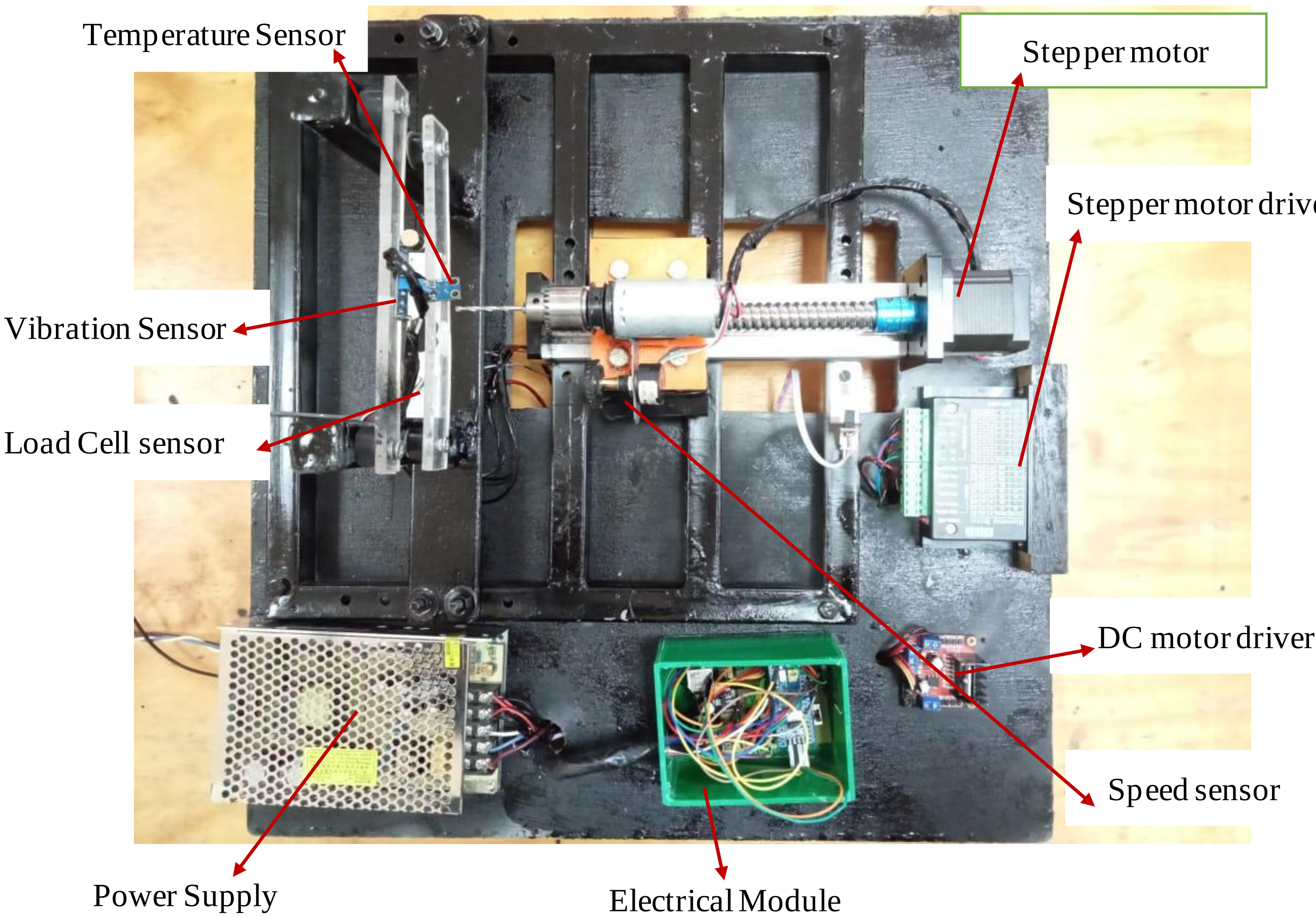


Figure 6: PMMA behavior when subjected to loadings

5. Hardware Implementation



6. CONCLUSION

In this experiment, a 1-axis drill was designed and fabricated as expected. Automation was achieved through efficient programming in STM32 Blue pin. The condition of the drilling action was monitored using the; temperature, force, and vibration sensors. The depth of the holes was determined by the program. The results measured were used as reference data for prospective study.

REFERENCES

[1] Madekar, K. J., Nanaware, (2016). Automatic mini-CNC machine for PCB drawing and drilling. (IRJET), 3(02), 1107-1108.

[2] Sanjaya, G., 2005, Automatic Drilling Machine with 89C51. Undergraduate final project no. 02010741/ELK/2005

[3] Khan, M. N., Ansari (2022). Fabrication and Automation of Drilling Machine by Using Arduino. Vol. 1224, No. 1, p. 012007). IOP Publishing.

[4] Niranjan, G., Chandini, P. (2013). Automated drilling machine with depth controllability. IJSEA. *2*(4), 90-93.

[5] Guangqing, N. (2017). Application of automatic control technology of drilling machine based on PLC. *Acta Technica Csav*, *62*(1), 530

Acknowledgement

To begin with, we would like to thank the Almighty God for his love and unending grace. He has been the guiding light to us throughout our work.

Secondly, our most profound gratitude goes to supervisor ***Dr. Titus Mulembo****, who greatly helped in the realization of this project from conception to completion. His guidance and insights have been fundamental in this project.*

We would also like to pass our gratitude to Mechatronics Lab led by ***Mr. Kibe*** *and* ***Ms. Consolata*** *for the support they have given us during this process. Finally, we wish to thank our peers, colleagues, friends, and parents for their invaluable help.*