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Internet-of-Things based Turning Machine Tool Temperature Monitoring System

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Abstract: During metal turning (lathing) operations, it is important to study the factors which will affect the tool life. One of the factors is cutting tool temperature as the process is directly related to high cutting tool temperature. The heat energy generated in the primary shear zone and at the tool-workpiece interface will reduce the tool life of the cutting tool, by wearing down the tool tip or causing flank wear. A study was set up to analyse how the temperature at cutting tool tip can be affected by the cutting parameters such as cutting speed, depth of cut and feed rate. Then, the temperature between new tool and a worn tool will be compared to find the influence of flank wear on cutting tool temperature. These measurements are relevant because they can be used to validate the relationship between cutting parameters, tool condition, and cutting temperature. An infrared temperature sensor, MLX90614-BAA series, is connected to the NodeMCU ESP8266 development board with Wi-Fi module, to make an Internet-of-Things based sensor system to measure the temperature. The system is first programmed using Arduino IDE software and then be connected to BLYNK application on mobile devices to monitor the live temperature data during turning process. Results show that the cutting tool tip temperature increases with cutting speed, which is the same as with the depth of cut. Analysis of the average and peak temperature comparison between new tool and worn tool reveals an increment of 10% and above, indicating that worn tool will have higher temperature overall. With an effective IoT based temperature monitoring system, the condition of cutting tool can be easily observed by looking at the cutting temperature to ensure fast detection of worn tool condition.

Keywords: Turning, Cutting Tool Tip Temperature, Cutting Speed, Depth Of Cut, Flank Wear, MLX90614-BAA, Nodemcu ESP8266, Iot-Based Sensor

1. Introduction

In today's world of high technology advancement, the role of manufacturing industries has never been any more important than ever. With the increasing needs for more products to be produced with high precision, technology for mass manufacturing production must always be up to date. The manufacturing function is mainly responsible for applying and working the production system in order

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to produce the product. The use of modern control systems embedded with software systems connected to the Internet can make controlling and monitoring the machines by humans non-physically, possible. This method can be addressed as the usage of IoT (Internet of Things). The IoT can be said as an attempt to put together the physical and digital world, with the use of devices for exchanging and processing information anywhere, anytime [1]. On the other hand, many situations can happen during machining process, such as tool breakage. When a tool breaks or chips during a cut it will create defects in the finished product, and these breaks and chips can usually be related to the cutting temperature. Carrying on with the machining process with a worn tool can increases the friction between the tool and workpiece, hence increasing power consumption. Although heat generation during metal cutting process is unavoidable, the resulting high temperature around the cutting tool tip will damage the cutting tool [2].

When a tool is being used in a cutting process, it will undergo degradation. This degradation is also known as tool wear. Tool wear depends on many factors, such as cutting speed, cutting temperature, and cutting force. Tool wear will define the quality of the metal piece being machined; hence it is very important that tool wear monitoring system is being introduced [3]. There are two main categories of tool wear, which is flank wear and crater wear respectively. The drop in product quality due to tool wear, as well as the increased in product cost due to recurring replacement of tool, are major issues in high speed machining [4].Thus, According to Luo [5], there currently exists 3 methods used to predict the maintenance of sophisticated equipment or machines, which are: reliability statistics, data-driven method and physical modelling method respectively. Heat generation in machining operation hence is a unavoidable phenomenon. However, this heat generated are usually very high, and will bring harm to the cutting tool, especially at the tip area. The total heat generated at the intersection area between the tool and workpiece are distributed where 80% goes to the chips formed, 10% onto the cutting tool, and the other 10% onto the workpiece [6]. Since the past, many attempts have been made to come up with decent temperature measurement system for tool condition monitoring. The widely used methods focus mainly on the use of thermocouple sensors to measure the temperature, where the methods are divided into contact and non-contact [4].

In this study, we proposed a IoT-based Infrared temperature sensor for high cutting temperature measurement which can be controlled and monitored through mobile devices (both Android and IOS) using an application named BLYNK. The objectives of this experiment are to determine the effect of different cutting parameters, such as cutting speed and depth of cut onto the cutting tool tip temperature, to determine the influence that tool condition (new tool and worn tool) will have on the cutting tool temperature under similar cutting parameters, and to establish a IoT based system to monitor temperature at machining tool and collect the temperature data during the turning process. By the end of the research, a working IoT-based cutting tool temperature sensor is expected to be produced successfully, which can detect the changes in temperature at different cutting parameters, as well as different tool condition.

2. Materials and Methods

2.1 Framework of system

In order to achieve the overall requirements which is detecting and measuring temperature data during turning process, the proposed system is planned to establish an Internet of Things based tool condition monitoring system, by using the heat sensor to measure the cutting temperature information. The collected data is then projected onto cloud storage, and then onto mobile devices such as computers, laptops, mobile phones and mobile tablets. The user can view the real-time data of the cutting temperature to detect any sudden spike or drop which might indicate tool breakage or wear condition. With that in mind, a concept framework of the planned system is shown below (Figure 2.1).

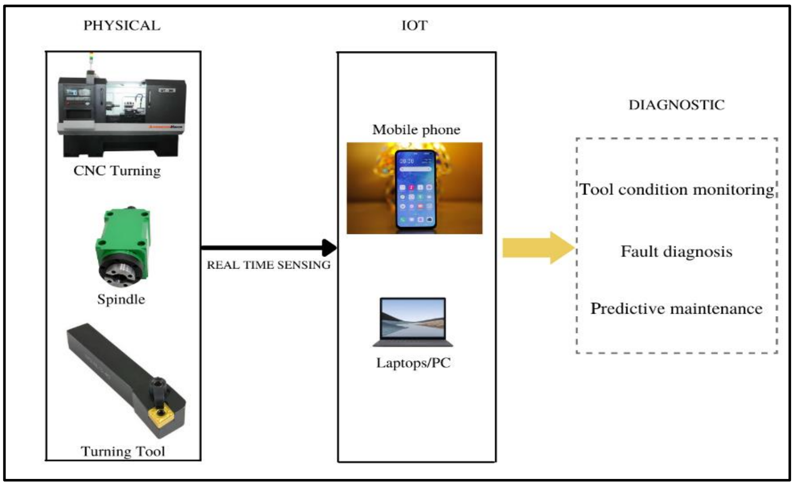


Figure 2.1: Early illustration of proposed system.

After having a concept of ideas on the proposed system, a series of selection and elimination on the system used will be done. In the proposed system, the system will be divided into 3 layers which include: 1) sensor layer; 2) database layer; 3) application layer; and 4) presentation layer. In the sensor layer, a temperature sensor will be used, followed by a database for storing and transmitting data onto the Internet. At the application layer, a software application named Blynk is proposed for receiving data onto mobile devices, allowing users to get real-time data at presentation layer. The explanation and description on the mentioned layers are listed in Table 2.1. The system shall be set up as shown in Figure 2.2.

Table 2.1: Proposed items and characteristics

Item	Choice:	Characteristics
Temperature sensor	MLX90614 non-contact infrared temperature sensor	1. Small size, low cost. 2. Easy to integrate. 3. Sensor working temperature: -40°C to 125°C. 4. Sensor measurable temperature: -70°C to 3 5. 80°C.
Microcontroller	NodeMCU ESP8266	1. Operating voltage 3.3V. 2. Input voltage 7-12V. 3. Small sized module, easy to use. 4. With Wi-Fi connection available.
Program language	Arduino IDE	1. Can be used by all working application software. 2. Compatible with NodeMCU ESP8266. 3. Compatible with MLX90614.
Platform	Blynk Application	1. Platform which is both iOS and Android compatible. 2. An application to control Arduino, Raspberry Pi and so on using Internet. 3. Compatible with NodeMCU ESP8266

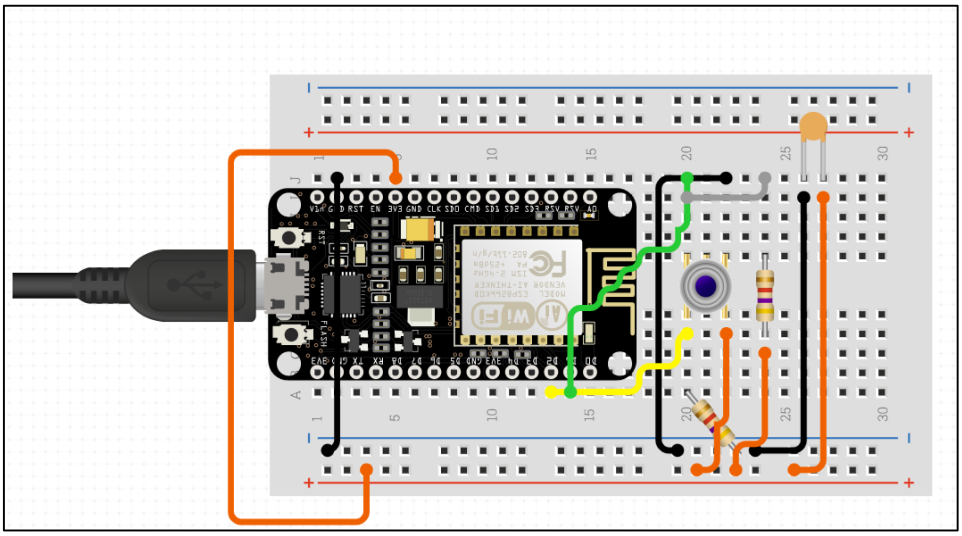


Figure 2.2: Illustration of a complete IoT-based non-contact infrared temperature sensor system

For this experiment, the system proposed mainly focuses on detecting temperature of the tool tip during turning machining process, with the system revolving around the usage of Internet-Of-Things. Hence, NodeMCU ESP8266 which is an open-source Lua-based development board was used. This board comes equipped with Wi-Fi SoC, allowing it to be programmed to directly connected to any Wi-Fi connection. This NodeMCU board acts as a connection hub to distribute power to the temperature sensor, MLX90614, via the 3 Volt power pin, as well as the 0.96" OLED LED display module via another 3 Volt pin. MLX90614 temperature sensor can two temperatures, which are the target temperature and the ambient temperature, respectively. This temperature sensor is connected to digital pin D1 and D2 on the NodeMCU board, as well as the OLED LED display in order for the screen to show the data detected on the MLX90614 temperature sensor. Figure 2.3 shows the setup and connection of the sensors and display on the NodeMCU board.

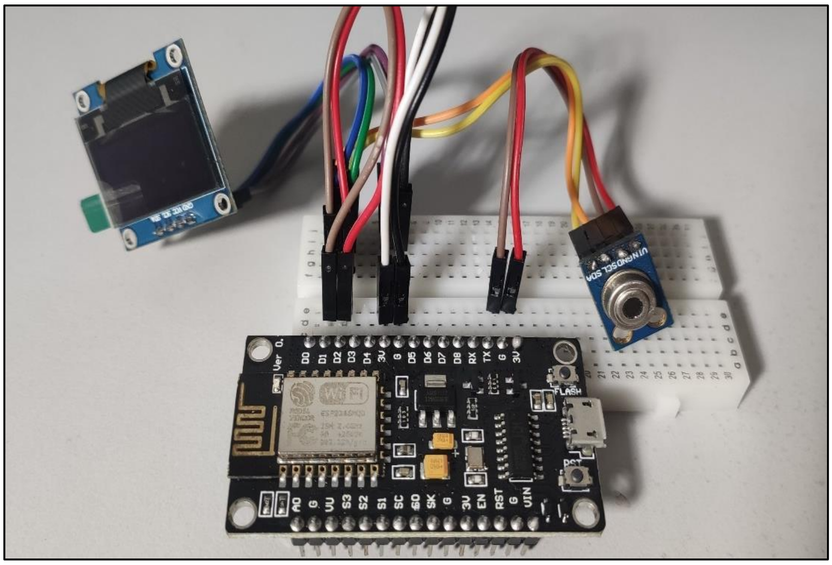


Figure 2.3: Connection of MLX90614 sensor and OLED Display onto NodeMCU ESP8266

Next, after connecting the sensors and the display correctly to their respective pins on the NodeMCU ESP8266 board, the whole setup was connected to the computer via Arduino IDE software so that programming of the microcontroller can be done. A Wi-Fi connection first need to be setup to ensure that the microcontroller can be connected to the device, allowing the sensor to send sensor data continually and periodically via an application named Blynk. Figure 2.4 a) and b) shows the coding used in programming the NodeMCU ESP8266 Wi-Fi so that it can be connected to the Wi-Fi selected, in this case will be the hotspot from the mobile device used. The figures also showed the codes used to program the temperature sensor and the OLED display.

```
Final_Success_Trial | Arduino 1.8.15 (Windows Store 1.8.49.0)
File Edit Sketch Tools Help
Final_Success_Trial
#include <Wire.h>
#include <Adafruit_MLX90614.h>
#include <Adafruit_GFX.h>
#include <Adafruit_SSD1306.h>
#define BLYNK_PRINT Serial
#include <Blynk.h>
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>

#define SCREEN_WIDTH 128    // OLED display width, in pixels
#define SCREEN_HEIGHT 64    // OLED display height, in pixels
#define OLED_RESET -1       // Reset pin # (or -1 if sharing Arduino reset pin)
Adafruit_SSD1306 display (SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, OLED_RESET);

Adafruit_MLX90614 mlx = Adafruit_MLX90614();

double temp_amb;
double temp_obj;
double calibration = 2.36;

char auth[] = "9UEughjalKHug_K90oIg7sNMLrjK7_Pk";    // You should get Auth Token in the Blynk App.
char ssid[] = "Test123";                             // Your WiFi credentials.
char pass[] = "nasiayampenyettt";

void setup()
{
  Serial.begin(9600);
  mlx.begin();         //Initialize MLX90614
  display.begin(SSD1306_SWITCHCAPVCC, 0x3C); //initialize with the I2C addr 0x3C (128x64)
  Blynk.begin(auth, ssid, pass);

  Serial.println("Temperature Sensor MLX90614");

  display.clearDisplay();
  display.setCursor(25,15);
  display.setTextSize(1);
  display.setTextColor(WHITE);
  display.println(" Thermometer");
  display.setCursor(25,35);
  display.setTextSize(1);
  display.print("Initializing");
  display.display();
  delay(1000);
```

```
Final_Success_Trial | Arduino 1.8.15 (Windows Store 1.8.49.0)
File Edit Sketch Tools Help
Final_Success_Trial
  delay(1000);
}

void loop()
{
  //Reading room temperature and object temp
  //for reading Fahrenheit values, use
  //mlx.readAmbientTempF() , mlx.readObjectTempF() )
  Blynk.run();
  temp_amb = mlx.readAmbientTempC();
  temp_obj = mlx.readObjectTempC();

  //Serial Monitor
  Serial.print("Object temp = ");
  Serial.println(temp_obj + calibration);

  display.clearDisplay();
  display.setCursor(25,0);
  display.setTextSize(1);
  display.setTextColor(WHITE);
  display.println(" Temperature");

  display.setCursor(10,20);
  display.setTextSize(1);
  display.print("Ambient: ");
  display.print(temp_amb);
  display.print((char)247);
  display.print("C");

  display.setCursor(10,40);
  display.setTextSize(1);
  display.print("Object: ");
  display.print(temp_obj + calibration);
  display.print((char)247);
  display.print("C");

  display.display();

  Blynk.virtualWrite(V1, temp_amb);
  Blynk.virtualWrite(V2, (temp_obj + calibration));

  delay(1000);
}
```

a) b)

Figure 2.4: The coding used in Arduino IDE a) first half b) second half

2.2 Methods

A sequence of turning experiments were conducted in dry condition using the Lathe Machine M300, modified from [7], with a setup of the proposed sensor system taped near the tool tip and the contact surface between the cutting tool and workpiece, as shown in Figure 2.3. The experiments will be carried out using a High-Speed Steel (HSS) cutting tool bit which can be commonly found, clamped to a tool holder. For the workpiece, a scrap cylindrical mild steel piece with 25mm diameter will be used.

The experiment will be done for both new tool and worn tool, with each tool repeating the experiments 3 times to get the most constant data. 4 cutting speed is chosen based on the capabilities of the machine used, which are 180RPM, 260RPM, 370RPM and 540RPM. Next, the depth of cut chosen are 0.2mm, 0.4mm, 0.6mm, 0.8mm and 1.0mm. The cutting distance is set to be 1.5cm within 60 seconds. The data during all experiments will be monitored using mobile phone devices as well as keep on the database to allow further analysis of the data. After every experiment, the data is collected and will be illustrated into graphs of time against temperature. This is to see the relationship between the condition of the tool and the cutting temperature. This will also validate the capability of the sensor system to monitor tool wear condition through Internet-of-Things based firmware. The parameter for the cutting process is tabulated in Table 2.2 below.

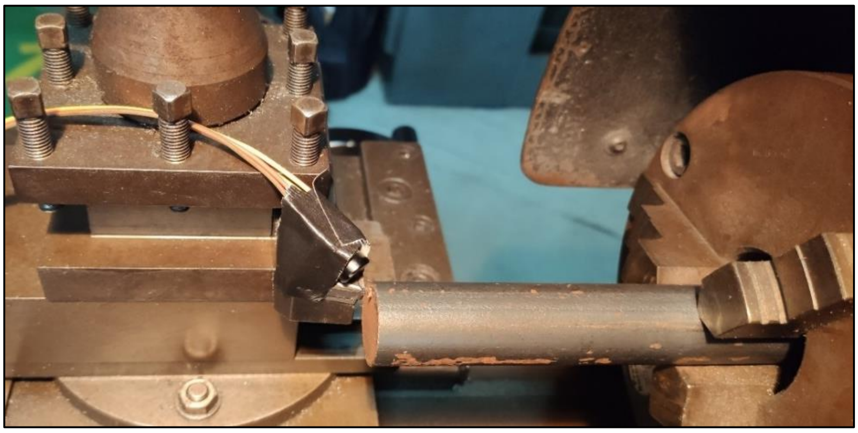


Figure 2.5: Sensor setup on the cutting tool, near the cutting tool tip

Table 2.2: Experimental cutting parameters

No	Cutting speed, (RPM)	Feed Rate, $f = \frac{i}{n}$ (mm/rev)	Depth of cut, d(mm)
1	180	0.083	0.2
2	180	0.083	0.4
3	180	0.083	0.6
4	180	0.083	0.8
5	180	0.083	1.0
6	260	0.058	0.2
7	260	0.058	0.4
8	260	0.058	0.6
9	260	0.058	0.8
10	260	0.058	1.0
11	370	0.041	0.2
12	370	0.041	0.4
13	370	0.041	0.6
14	370	0.041	0.8
15	370	0.041	1.0
16	540	0.028	0.2
17	540	0.028	0.4
18	540	0.028	0.6
19	540	0.028	0.8
20	540	0.028	1.0

2.3 Equations

In order to obtained cutting speed in terms of V_c, some calculations have to be made. The same goes to the feed rate. The formula used will be explained below.

$$V_c = \frac{\pi D_m n}{1000}\ (m/min), \qquad 1$$

$$f = \frac{i}{n}\ (mm/rev), \qquad 2$$

Equation 1 is the cutting speed, V_c, where:

D_m (mm) is workpiece diameter (25mm),

n (rev/min) is main axis spindle speed.

Equation 2 is the feed rate, f, where:

i (mm/min) is cutting length per min (15mm per min),

n (rev/min) is main axis spindle speed.

3. Results and Discussion

3.1 Results

First of all, two cutting tool bits with different condition are chosen. One with no flank wear, and another one with flank wear. Then, the tool bits are magnified (refer Figure 3.1 and Figure 3.2) using Olympus Magnifier Machine SZH10, 15 times magnifying to determine their conditions.

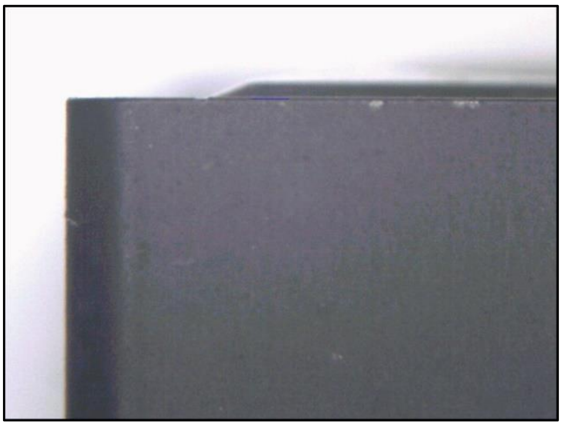


Figure 3.1: New condition tool tip under 15 times magnifying

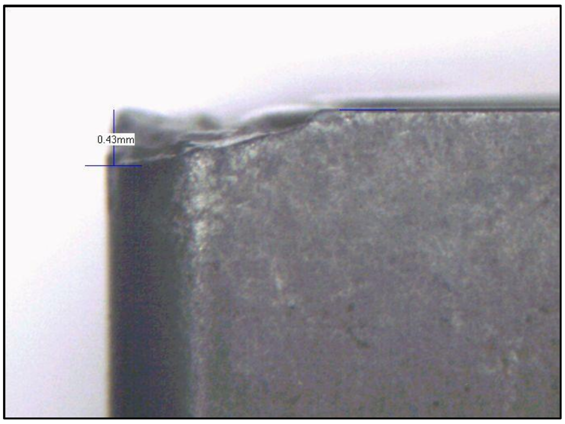


Figure 3.2: Worn condition tool tip under 15 times magnifying

The experiments were done using these two tool bits with different conditions. All experiments were carried out for 60 seconds per set, for both new tool and worn tool. The data obtained are summarized into Table 3.1 and Table 3.2 below.

Table 3.1: Data obtained for new tool tip

No	Cutting speed, (m/min)	Feed Rate, (mm/rev)	Depth of cut, d (mm)	Average Temperature (℃)	Peak Temperature Reached (℃)
1	14.14	0.083	0.2	37.29	42.35
2	14.14	0.083	0.4	51.78	71.13

3	14.14	0.083	0.6	59.06	89.91
4	14.14	0.083	0.8	64.96	93.51
5	14.14	0.083	1.0	68.84	96.18
6	20.42	0.058	0.2	48.65	60.21
7	20.42	0.058	0.4	54.22	74.53
8	20.42	0.058	0.6	58.59	92.15
9	20.42	0.058	0.8	66.24	98.56
10	20.42	0.058	1.0	70.16	104.53
11	29.06	0.041	0.2	51.31	78.51
12	29.06	0.041	0.4	56.54	83.53
13	29.06	0.041	0.6	63.67	95.77
14	29.06	0.041	0.8	72.23	105.55
15	29.06	0.041	1.0	77.91	117.89
16	42.41	0.028	0.2	59.13	86.95
17	42.41	0.028	0.4	65.47	93.59
18	42.41	0.028	0.6	71.84	105.35
19	42.41	0.028	0.8	75.48	112.79
20	42.41	0.028	1.0	79.47	124.79

Table 3.2: Data obtained for worn tool tip

No	Cutting speed, (m/min)	Feed Rate, (mm/rev)	Depth of cut, d(mm)	Average Temperature (℃)	Peak Temperature Reached (℃)
1	14.14	0.083	0.2	42.78	54.57
2	14.14	0.083	0.4	58.65	85.43
3	14.14	0.083	0.6	64.76	96.11
4	14.14	0.083	0.8	70.65	105.63
5	14.14	0.083	1.0	77.95	115.45
6	20.42	0.058	0.2	53.36	78.65
7	20.42	0.058	0.4	62.24	95.11
8	20.42	0.058	0.6	72.00	110.95
9	20.42	0.058	0.8	76.66	117.34
10	20.42	0.058	1.0	86.35	127.97
11	29.06	0.041	0.2	64.06	89.71
12	29.06	0.041	0.4	76.57	109.51
13	29.06	0.041	0.6	81.28	120.73
14	29.06	0.041	0.8	88.61	130.55
15	29.06	0.041	1.0	95.54	140.49
16	42.41	0.028	0.2	77.85	110.45
17	42.41	0.028	0.4	84.08	122.71
18	42.41	0.028	0.6	93.20	137.89
19	42.41	0.028	0.8	105.31	148.74
20	42.41	0.028	1.0	120.72	163.23

3.2 Influence of Different Parameters on Tool Tip Temperature

According to Shimanuki [8], the temperature surrounding the tool tip increases when the relative cutting speed is increased. Cutting temperature is one of the most important aspects of machining operations because it influences tool life. Hence the focus of our experiment will be comparing the temperature obtained on different cutting speed, under different depth of cut.

Two graphs are plotted in Figure 3.3 and Figure 3.4 to show the influence between the two parameters for both new tool and worn tool.

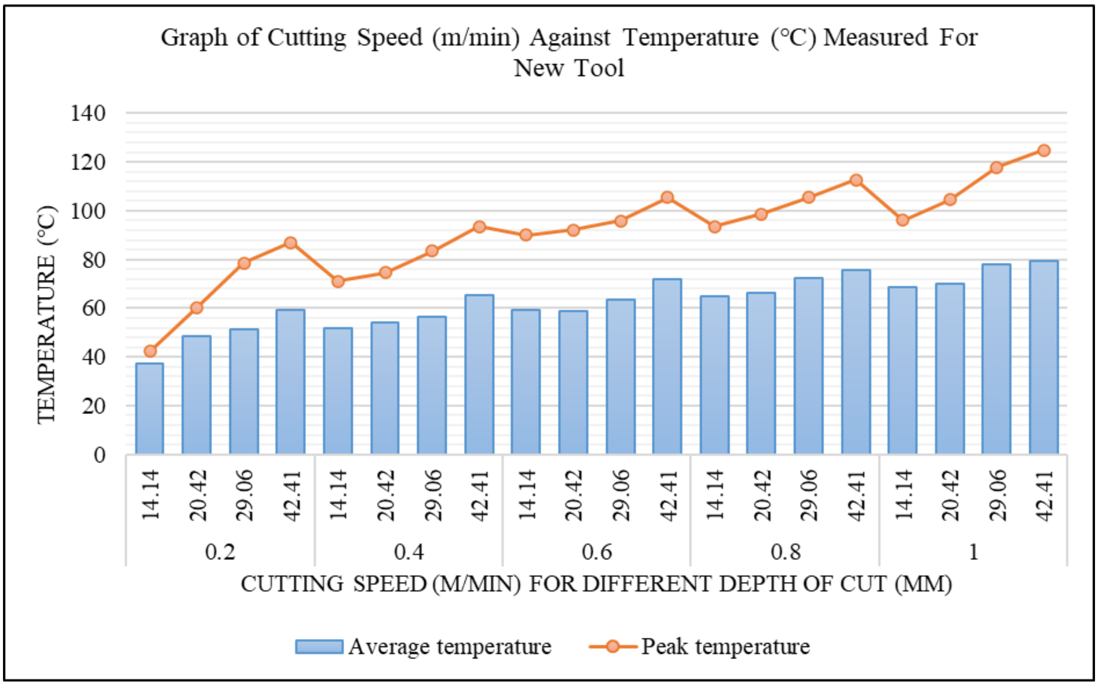


Figure 3.3: Graph of depth of cut (mm) against temperature (°C) measured for new tool

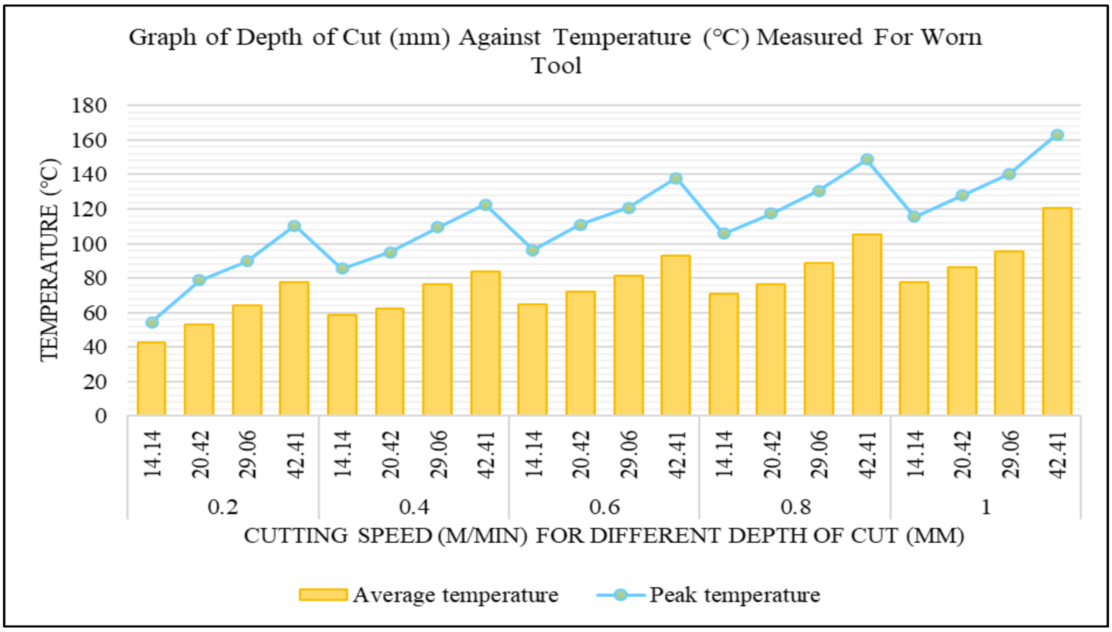


Figure 3.4: Graph of depth of cut (mm) against temperature (°C) measured for worn tool

Continuous and unceasing cutting experiments with different cutting parameters (cutting speed and depth of cut) were done, where the real-time live temperature of the cutting tool tip was recorded to evaluate the relationship. The results are illustrated in Figure 3.3, where the cutting speeds are different while maintaining 5 same depths of cut, which are 0.2mm, 0.4mm, 0.6mm, 0.8mm and 1.0mm respectively. It is noted that both the average temperature and peak temperature showed similar trend, which is increases with the depth of cut, meaning when depth of cut increases, so does the temperature.

The cutting temperature also increases significantly with the rising cutting speed, proving the fact that cutting speed can greatly influence on cutting temperature, as stated by [9]. For instance, when the experiments are kept constant at the depth of cut at 0.2mm, at 180 revolution per min (or 14.14 m/min), the average temperature reached 37.29℃ while the peak temperature reached 42.35℃. At the highest cutting speed of 540 revolution per min (or 42.41 m/min), the average temperature reached 59.13℃ while the peak temperature reached 86.95℃. This trend where tool tip temperature increases when cutting speed increases under the same depth of cut is constant throughout different depth of cut, which are 0.4mm, 0.6mm, 0.8mm and 1.0mm. At the deepest depth of cut of 1.0mm, the average temperature for all cutting speed is the highest which are 68.84℃, 70.16℃, 77.91℃ and 79.47℃ for 14.14 m/min, 20.42 m/min, 29.06 m/min and 42.41 m/min respectively. The peak temperature reached are also the highest at 96.18℃, 104.53℃, 117.89℃ and 124.79℃ respectively. From Figure 4.7, the difference between average temperature for 42.41 m/min and 14.14 m/min cutting speed at 0.2mm depth of cut is 44.60℃.

From the graph in Figure 3.4, it can be seen that the trend is the same as the graph detected in new tool temperature (Figure 3.3). When the cutting speed increased, the average temperature and peak temperature detected also increased. At 0.2mm depth of cut, the average temperature and peak temperature detected at 14.14 m/min cutting speed are 42.78 ℃ and 54.57 ℃ respectively. When the cutting speed increases to 20.42 m/min, the average temperature and peak temperature reached 53.36 ℃ and 78.65 ℃ respectively. At the highest cutting speed of experiment which is 42.41 m/min or 540 revolution per minute, the average temperature and peak temperature for 0.2mm depth of cut also reached the highest, each at 77.85℃ and 110.45℃ respectively. When the experiments were done at 1.0mm depth of cut, the average temperature and peak temperature detected at 14.14 m/min cutting speed are 77.95℃ and 115.45℃ respectively. The difference in average temperature and peak temperature between depth of cut 0.2mm and 1.0mm at 14.14 m/min are 35.17℃ and 60.88℃ respectively. Then at 42.41 m/min cutting speed, the difference in average temperature and peak temperature between depth of cut 0.2mm and 1.0mm are 42.87℃ and 52.78℃ respectively. The same trend can be seen in the rest of the depth of cut at different cutting speed. Proving that temperature at the tool tip is highly dependent on the depth of cut and cutting speed. It can be said that when cutting speed and depth of cut of the turning process increases, the temperature at the cutting tool tip will also increases, same as per mentioned in the experiment done by [10] and [11].

3.3 Influence of flank wear of the tool on the cutting temperature

In this section, comparison between the data obtained for both the new cutting tool and worn cutting tool will be done to show the effect of flank wear on the cutting temperature under various parameters. As tool wear in metal cutting is a hugely significant factor affecting the product surface, therefore it is vital that we can detect tool wear from different aspect, including temperature. Hence, the Figure 3.5 below will show a comparison of average temperature at the same cutting speed and depth of cut for two different tool conditions, in order to determine the influence of flank wear of the tool on to the cutting temperature. Next, Figure 3.6 will display the bar chart for peak temperature comparison.

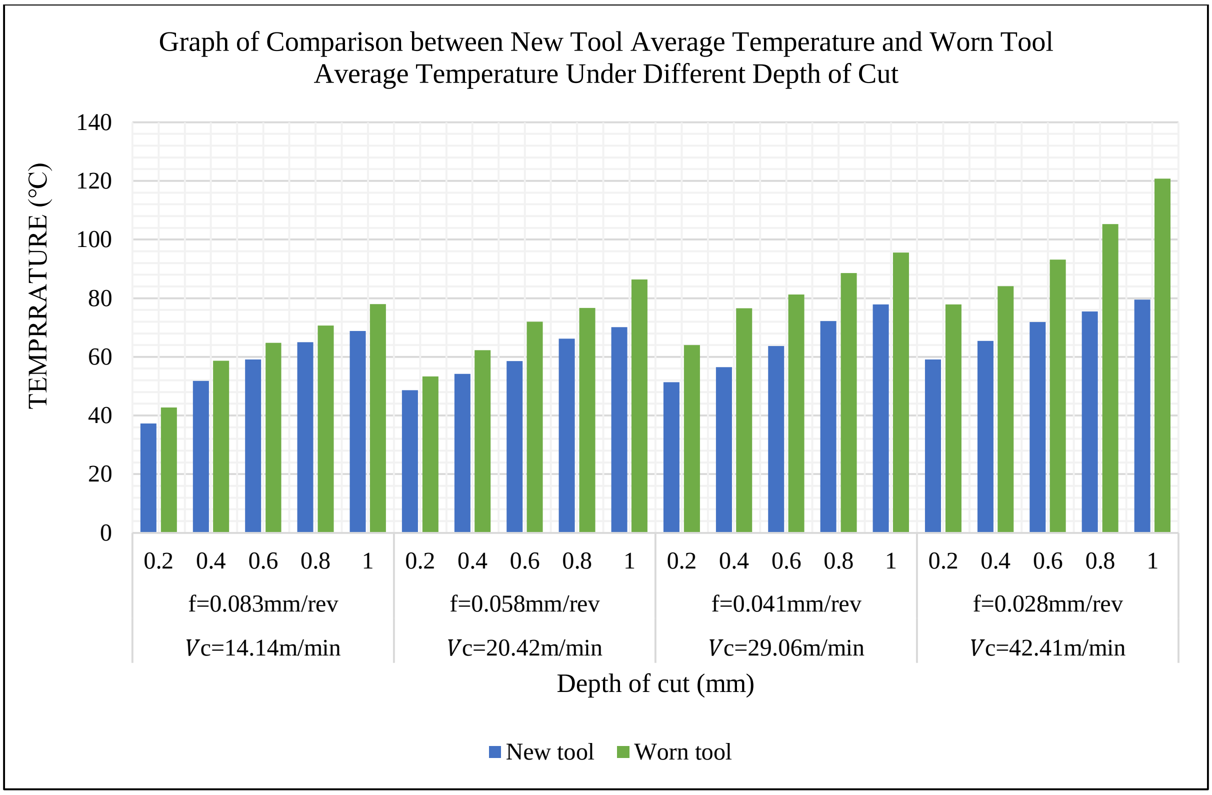


Figure 3.5: Bar chart for comparison for average temperature between new tool and worn tool

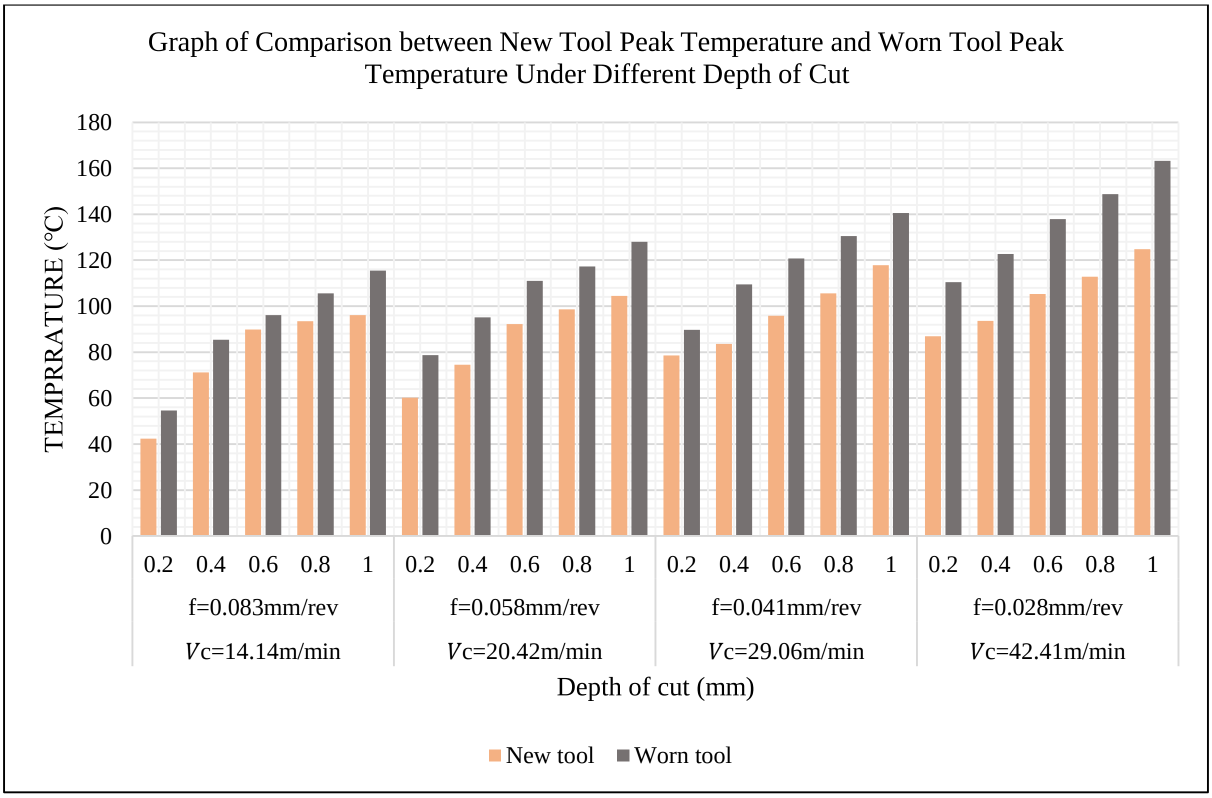
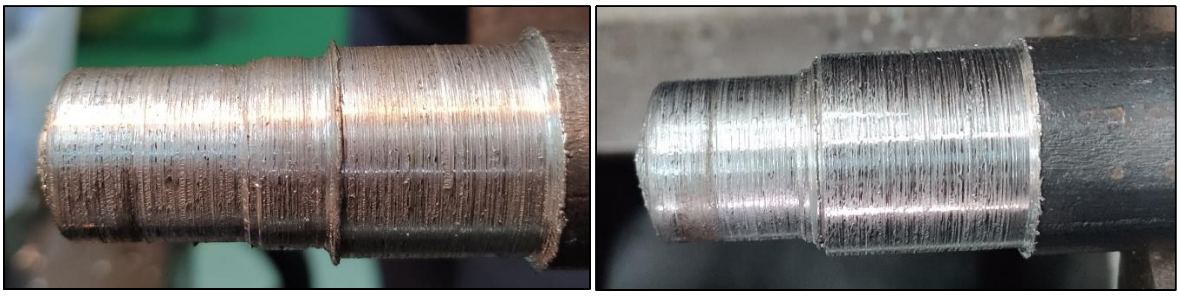


Figure 3.6: Bar chart for comparison for peak temperature between new tool and worn tool

The relationship between tool tip temperature and flank wear of tool during the cutting process is examined in order to determine how can the flank wear affect the tool tip temperature. From both the tables and the bar charts plotted, it is noticeable that the temperature increases as depth of cut and cutting speed increases. However, the most significant change in temperature can still be detected between two different tool conditions. In Figure 4.20, the average temperature recorded at cutting speed of 14.14m/min with depth of cut 0.2mm are 37.29℃ and 42.78℃, for new tool and worn tool respectively. Under the same cutting speed but at depth of cut 1.0mm, the average temperature recorded increased to 68.84℃ and 77.95℃, for new tool and worn tool respectively. The average worn tool temperature recorded is higher than the average new tool temperature by 14.72% at the smallest depth of cut attempted (0.2mm), while 13.23% at the highest depth of cut attempted (1.0mm). Moving onto the highest cutting speed of the experiment at 42.41m/min, the average temperature recorded at 0.2mm depth of cut are 59.13℃ and 77.85℃, for new tool and worn tool respectively. The temperature between this two increased by 31.65%. Lastly at 1.0mm depth of cut, the average temperature recorded are 79.47℃ and 120.72℃ for new tool and worn tool respectively. The temperatures had increased by 51.91%. From the analyzation of bar chart in Figure 4.20, it can be concluded that when cutting speed increased, the temperature difference between new tool and worn tool also increased significantly.

Next, looking at bar chart in Figure 4.21, the same increasing trend can also be seen very significantly. Firstly, at cutting speed of 14.14m/min under depth of cut 0.2mm, the peak temperatures recorded are 42.35℃ and 54.57℃ each, while at 1.0mm, the temperatures recorded are 96.18℃ and 115.45℃ each, for both new tool and worn tool respectively. The peak temperature at 0.2mm had increased by 28.85%, and 20.04%. When the cutting speed had increased to the highest attempted in the experiment of 42.41m/min, the peak temperature reached for 0.2mm depth of cut are 86.95℃ and 110.45℃, for new tool and worn tool respectively. Under the same cutting speed, at 1.0mm depth of cut, the peak temperatures recorded during the experiment are 124.79℃ and 163.23℃, for new tool and worn tool respectively. The temperature had increased by 27.02% and 30.80%, for 0.2mm depth of cut and 1.0mm depth of cut respectively.

During the experiment, heat generation at the cutting tool tip is unavoidable and the resulting high temperatures around the cutting tool tip will cause damage to the cutting tool. Tool with flank wear due to damage will cause uneven finishes on the product surface. The workpiece will also become badly deformed due to the high temperature and blunt cutting tool as seen in Figure 3.7a), compared to a smoother surface without deformation in Figure 3.7b).



(a) (b)

Figure 3.7: Workpiece after cutting with a) worn tool b) new tool

4. Conclusion

In conclusion, the IoT based temperature sensor system was able to be constructed and assembled, allowing the user to connect to the sensor and view the live temperature data using only a mobile device, supported by both Android and IOS devices. The temperature data can also be monitored using Arduino IDE software's serial monitor, providing more means of collecting data to be analyse. This will definitely help retrofitting into old turning machines, allowing small to medium companies and some universities to save costs as no need to replace old turning machines, while giving them opportunities to be exposed to more Internet-of-Things knowledge and skills. Next, from the experimental results, the temperature data obtained was higher under higher cutting speed. Hence, it can be concluded that the cutting temperature is directly dependent on the cutting speed. A faster or higher cutting speed can possibly allow lesser time for heat energy generated on the tool to be transferred onto the workpiece. This heat energy will then stay in cutting tool tip, slowly increasing its temperature while lowering the friction surface contact. The same can be said about depth of cut, as depth of cut also produces the same trend, which is increasing temperature as the depth of cut increases. Lastly, flank wear also can be said will influence the temperature at the cutting tool tip. This is because when a tool tip undergoes flank wear, it will cause the surface quality of the cutting tool tip to deteriorate, which will then increase the contact area with the work piece, thus increasing the heat energy generated. As proof, during the experiment, the average temperature and peak temperature recorded for both new tool and worn tool has significant difference. For instance, at 0.2mm depth of cut, the average temperature of worn tool (42.28℃) is 14.72% higher than that of the new tool (37.29℃) at the lowest cutting speed attempted for the research. For peak temperature at the same cutting speed and depth of cut, worn tool temperature is 28.85% higher than the new tool temperature.

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