SMART LATHE MACHINE

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Abstract - *In the present scenario, the lathe machine plays a vital role in the engineering division of the manufacturing industry. While the manual lathe machines are economical, their accuracy and efficiency are not up to the mark. Contrarily, CNC machines deliver the desired accuracy and efficiency but demand a significant investment in capital. In order to address this issue, a smart lathe machine approach to the traditional lathe machine has been developed. It makes use of sensors and actuators that can be managed by the Arduino UNO microcontroller and NodeMCU. Therefore, switching from manual to smart lathe machines can significantly improve accuracy and efficiency while also controlling investment costs, giving the manufacturing industry a much-needed boost. This configuration enables a machinist to inspect the workpiece's dimensions without removing it, as well as display the chuck's speed and other features. Industry 4.0-inspired digital technologies are driving a new business environment that is increasingly sustainable. Purchasing new-generation machinery makes it possible to take advantage of the many advantages of digitalization, including increased productivity, flexibility, efficiency, and quality, reduced resource consumption, and improved worker safety. By combining mechanical, electronic, and software technologies, the traditional lathe machine is transformed into a smart lathe machine. For the sake of novelty, accuracy, and time-decreasing, a conventional lathe machine has been converted into a smart lathe machine by retrofitting to show readings of the dimensions of the workpiece, speed of the chuck, motor temperature, and distance from the headstock to the tailstock, and it can be accessed by the RFID tags only.*

Key Words: Manufacturing, Industrial revolution, IoT, Lead time, Accuracy, Retrofitting, Remodification.

1.INTRODUCTION

A lathe machine uses a cutting tool to remove material from the workpiece's surface. The workpiece is held in the chuck, and the tool feeds material onto the workpiece to perform various operations like cutting, drilling, knurling, deformation, turning, and facing. It is one of the most adaptable and frequently used machines in workplaces, workshops, and educational institutions.

Retrofitting describes the situation in which modern features or technology are added to older systems to update their components and enhance their functionality. This definition covers nearly all of the information about the term "retrofitting" as it also refers to the integration of new features or technology into older systems. When retrofitting is used in reference to traditional lathes, it refers to modernizing the lathe and enhancing its productivity.

Repairing or replacing mechanical parts to the original, as-new factory specifications is known as remanufacturing. The machine will be completely disassembled, cleaned, examined, repaired, and painted. Updates will be made to all electrical, hydraulic, and pneumatic systems. To adapt the machine for a different use, it may also be modified or given mechanical accessories. Remanufacturing will almost always happen at the remanufacturer's location. The main goal of incorporating a smart lathe machine into an existing conventional lathe machine is to enhance it with features such as non-contact workpiece dimension measurement and condition monitoring of the electrical components of the lathe. [1]

The goals of retrofitting consist of

- implementing new manufacturing techniques.
- minimizing machine idling.
- greater speeds.
- decreased tool costs
- friendly service.
- increased output and improved machine control.
- significantly greater repeatability
- to reduce lead time,
- very quick machining cycles.
- high precision.

Retrofitting should be much less expensive overall than buying a new system.

2. Sequence of upgrading

The fig 1 shows the conversion of a conventional lathe into a smart lathe in different stages. There are different stages, from selecting the sensors to programming them and implementing them on the lathe machine.

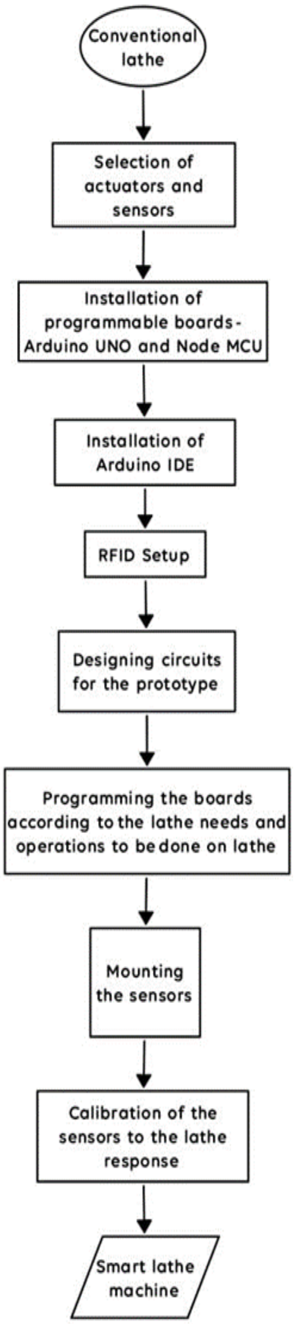

Fig -1: Stages of smart lathe retrofitting procedure

2.1 Sensors and actuators

The fig 2, block diagram, explains the different sensors and actuators connected to the programmable boards such as the Arduino UNO and NodeMCU. The actuators still require a 12V power source even though all the electronic parts are connected to 5V. The microcontroller gathers the sensor data and uses the I2C communication protocol to send it to the LCD. An Internet of Things (IoT) device called NodeMCU can send data in formats that are readable by humans over Wi-Fi. [2]

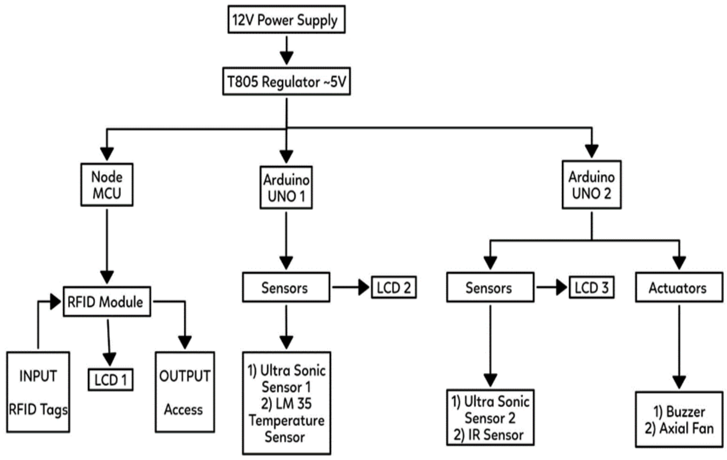

Fig -2: Sensor connectivity to microcontrollers

2.2 Circuit diagram

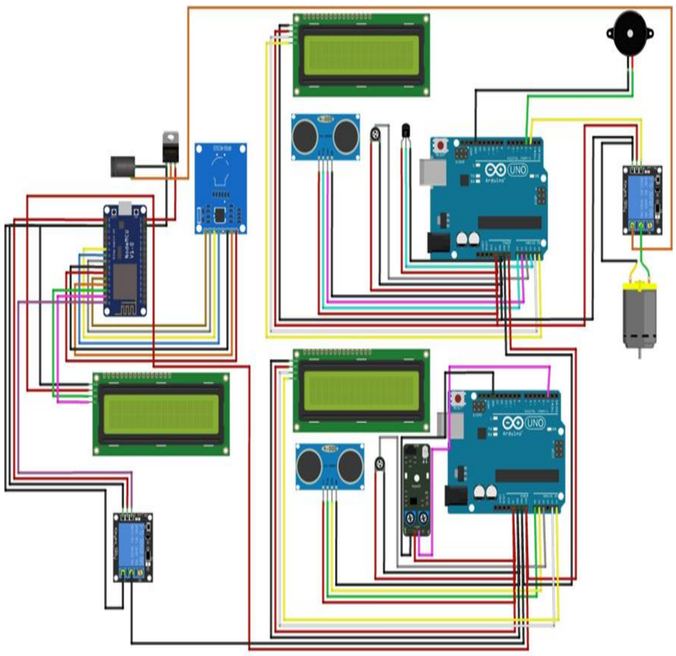

Fig -3: Electronic component connection

The fig 3 represents the connections of sensors, actuators, relays, and other electronic components connected to the Arduino and Nodemcu.

2.3 Software

Arduino is an open-source platform for prototyping that is built on user-friendly hardware and software. Arduino boards have the ability to read inputs, such as light from a sensor or pressure from a finger on a button, and convert them into outputs, such as turning on a motor or an LED. By sending a set of instructions to the microcontroller, the user can instruct the board what to do. The user should do this by utilizing the Arduino Software (IDE), which is based on Processing, and the Wiring-based Arduino Programming Language (based on Wiring). Based on the ATmega328P, the Uno is a microcontroller board.

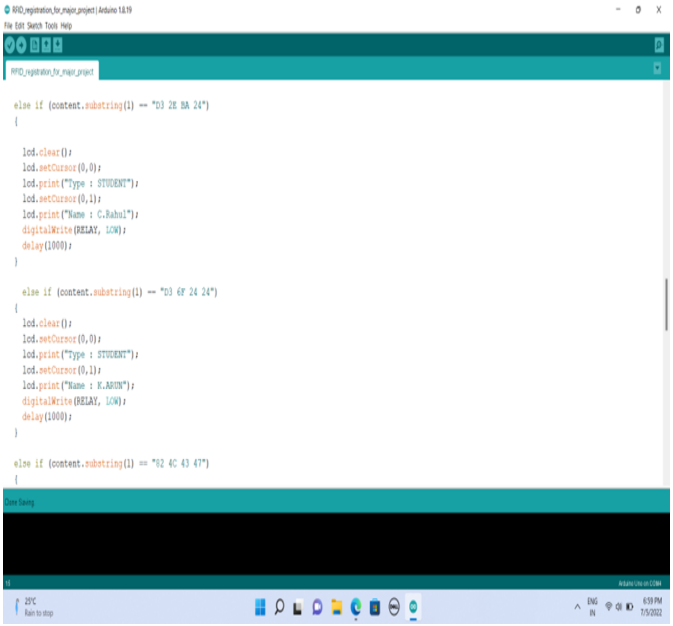

Fig -4: Arduino IDE

2.3.1 Arduino UNO

The ATmega328P microcontroller is the foundation of the Arduino UNO. Comparatively speaking, it is simpler to use than other boards like the Arduino Mega board, etc. The board is made up of shields, other circuits, and digital and analog Input/Output (I/O) pins. The Arduino UNO has 14 digital pins, a USB port, a power jack, and an ICSP (In-Circuit Serial Programming) header, in addition to 6 analog pin inputs. An IDE, or integrated development environment, is the platform on which it is programmed. Both online and offline platforms are compatible with it. The FTDI USB-to-serial driver chip is absent from the Uno, setting it apart from all previous boards. Instead, it uses an Atmega16U2

(Atmega8U2 up to version R2) that has been configured as a USB-to-serial converter. The USB ports on your computer are shielded from shorts and overcurrent by the resettable poly-fuse on the Uno.

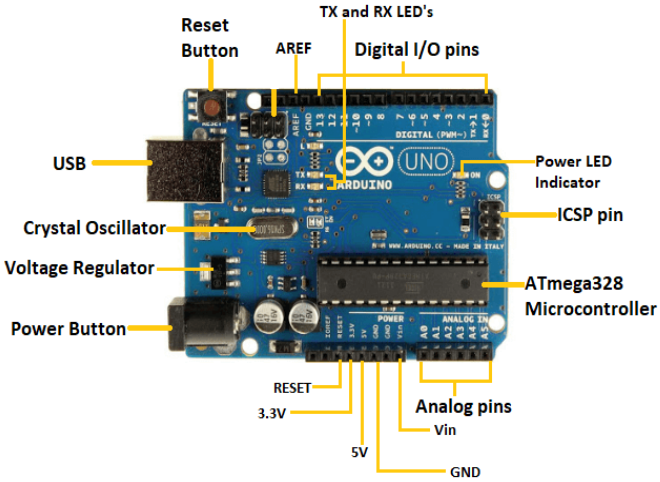

Fig -5: Arduino UNO[5]

2.3.2 NodeMCU

A low-cost System-on-a-Chip (SoC) called the ESP8266 serves as the foundation of the NodeMCU (Node Microcontroller Unit), an open-source environment for developing both software and hardware. The Espressif Systems-designed and -produced ESP8266 has all of the essential components of a computer, including CPU, RAM, networking (Wi-Fi), and even a contemporary operating system and SDK. Because of this, it is a great option for all types of Internet of Things (IoT) projects.

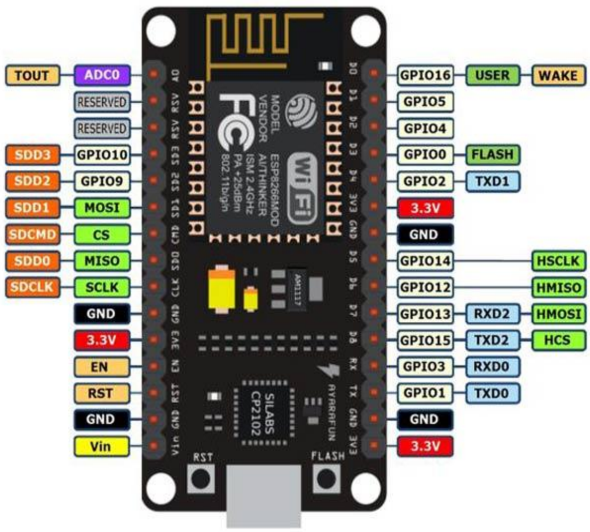

Fig -6: NodeMCU [6]

2.4 List of IoT features

The below figure 7 shows list of IoT features to be given for a conventional lathe machine to upgrade it into a smart lathe machine

S.no	Component	Smart feature	Targeted mechanical elements	Usage description
1	IR detector	Tachometer	Spindle	The infrared sensor will count the rotation when one rotation of the chuck is returned to its initial state, which will be counted as 1 unit. in units of RPM and RPS.
2	ultrasonic sensor	Dimension measurement	Tool post	Measurement of workpiece length is carried out here.
3	LM35 temperature detector	Temperature measurement	Electric motor	The LM35 sensor analyzes the lathe's temperature reading and, once the motor reaches the class-standard temperature, turns off the power automatically.
4	RFID reader	Smart card access	Lathe bed	When a card is tapped near the device, it will display the information of the users who have access to it, and the LCD will print "Access denied" to anyone attempting to use the lathe machine without authorization.
5	An ultrasonic distance sensor	Distance measurement	Head and tailstock	This sensor calculates the remaining distance to be moved based on the distance between the head and tail of the stock.

Fig -7: Smart features given to mechanical elements

2.5 Working algorithm

Step 1) The "Arduino Software IDE" is initialized as shown in Figure 4.

Step 2) Based on the input parameters, the program is written accordingly.

Step 3) Written code must have the requirements of all the sensors that should also be mentioned in the void setup, and sensor information and connections are initialized above the void setup.

Step 4) The actual working model should be written in a void loop so as to repeat the process in a loop manner.

Step 5) Now the coding is compiled. so that it ensures the sketch is free to upload.

Step 6) These codes are transmitted to the Arduino board by means of a USB cable.

Step 7) In the case of Nodemcu, the output of the written code is checked on the serial monitor for debugging purposes.

Step 8) Meanwhile, the workpiece is mounted on the chuck of the smart lathe as shown in Figure 3.

Step9) Now, the Arduino reads the program and, based on the input of the lathe, shows the output on the LCD display to the machinist.

Step10) When the procedure is complete, adjusting the potentiometer to the left and right will show the values of additional parameters, such as spindle speed, motor temperature, etc. [3][4]

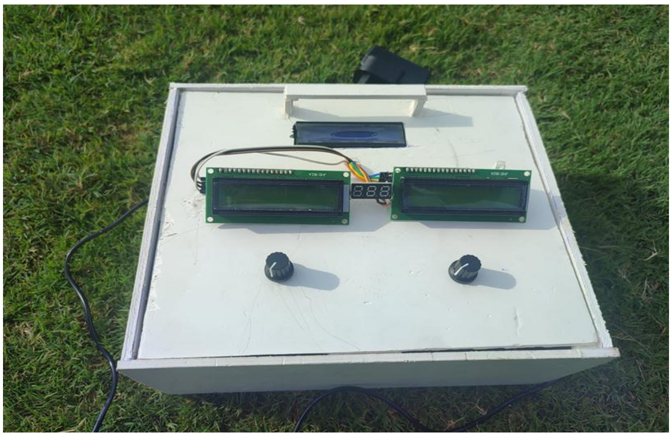

Fig -8: Controller device

3. Working model

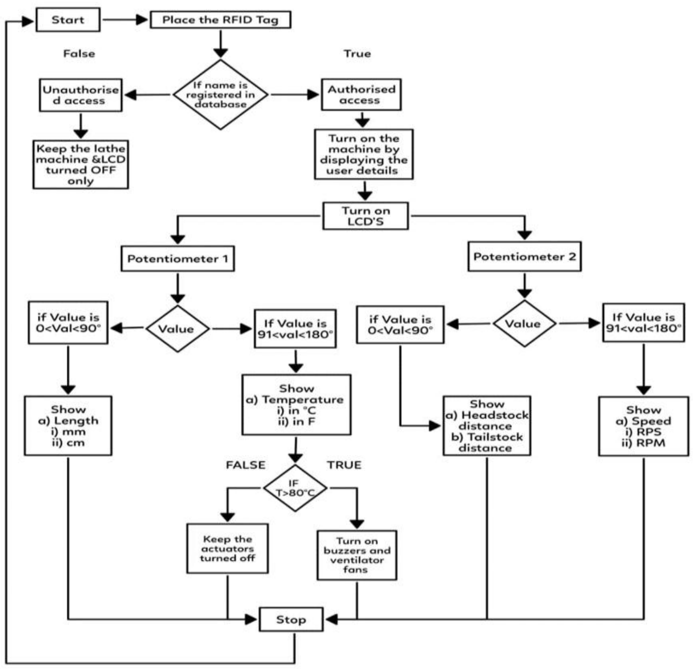

Fig -9: Working model of smart lathe prototype

The above activity diagram (fig 9) shows the working model of the smart lathe machine. Firstly, it will be turned on by RFID access. If there is no access, then the lathe will not turn on. This is for security reasons and also to avoid unwanted people from operating the lathe.

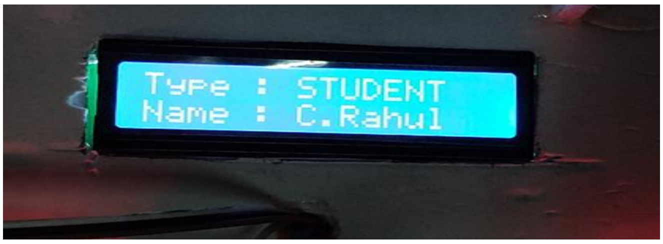

Fig -10: Access authorized

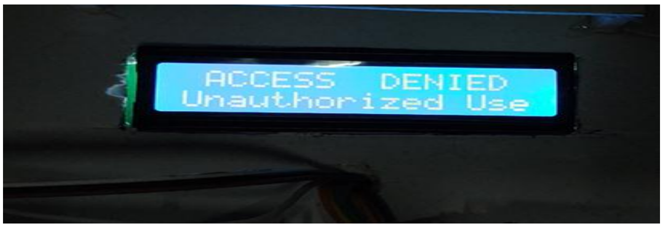

Fig -11: Authorization failed

Due to inadequate training, if someone uses the lathe machine without authorization, they run the risk of damaging it or becoming injured. When the user gains access to the machine, the LCD will turn on and display data from various sensors, including temperature, spindle speed, workpiece length, and distances between the headstock and tailstock. The lathe machine continues to perform all the tasks while it is in use and becomes heated. When the machine's motor reaches a temperature of more than 80 degrees Celsius, it automatically shuts off and sounds a buzzer to let the user know how things are going. The ventilators are also activated at that time.

4. Comparison

Time saved by the smart lathe in comparison with conventional lathe.

S.no	Material	Operation	Lead time(C.L)	Lead time (S.L)	Time saved by S.L
1	Aluminum	Cutting	40	36	4
2	Aluminum	Drilling	30	28	2
3	Aluminum	Facing	10	3	7
4	Aluminum	knurling	7	6	1
5	Aluminum	Turning	10	4	6
Sum			**97**	**77**	**20**

Table -1: Lead time with respect to lathe operations

When using the lathe machine to perform tasks like cutting, drilling, facing, knurling, and turning, an aluminum workpiece is taken into account. When comparing a conventional lathe and a smart lathe, the time required for these operations is noted as the time difference. The smart lathe machine saves 20 minutes as shown in table 1. when compared to a conventional lathe when performing all 5 operations, which takes 97 minutes as opposed to 77 minutes.

This process took the traditional lathe 1164 minutes (19.4 hours) to produce 12 pieces. Keeping the same time for the smart lathe, it produced 15 pieces. which is almost 3 extra pieces at the same time as shown in table 2.

Time taken to produce 1 workpiece	Total time considered (mins)	Workpiece quantity produced for 1164 minutes (19.4 hours)
97	1164	12
77	1164	15

Table -2: Workpiece quantity after 19.4hours

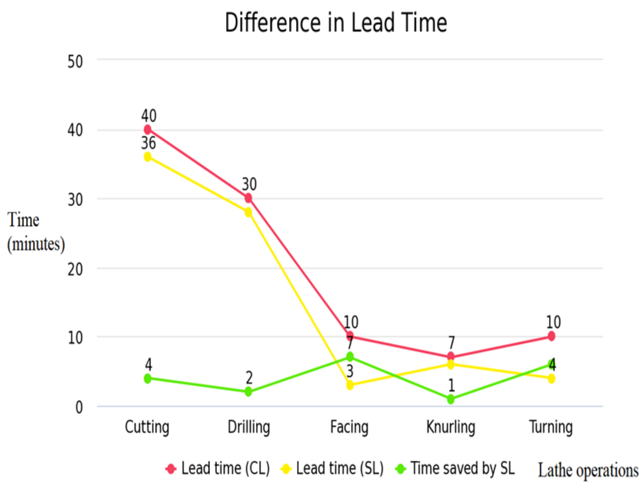

Fig -12: Difference in lead time between CL and SL

The green line in the fig 12 shows how much time the smart lathe machine saves when performing the same operations compared to the conventional lathe machine. The smart lathe has saved 20 minutes in the preparation of a workpiece based on five operations.

5. Results

- Specifications of the workpiece

Specimen	:	Aluminum rod
Total length	:	400mm
Initial diameter	:	200mm

Final diameter : 150mm

Removed diameter : 50mm

Depth of cut : 25mm

Cutting speed : 251.2 m/min

RPM : 500

S.no	Parameter	Formula	Calculation	Value
1	Cutting speed	πDN/ 60	(3.14*200*500)/ 60	251.2 m/min
2	Depth of cut	(d1-d2) / 2	(200-150)/2	25 mm
3	CL/SL ratio	CL value / SL value	22/10	2.2
4	Difference in production	((SL-CL)/SL)*100	((22-10)/22)*100	54%

Table -3: Parameter calculations

The above table 3 shows the calculations of the workpiece before and after the machining. A 25mm depth of cut was given to the specimen, and there was a huge difference in production quantity from two lathes.

S.NO	Smart lathe (Production of workpieces)	Conventional lathe (Production of workpieces)	Depth of cut (mm)	Cutting speed (m/min)	Chuck speed (RPM)	SL/CL ratio	Production difference in %
1	10	22	18	157	500	2.2	54
2	30	43	22	188	500	1.4	30
3	36	48	24	251	500	1.3	25
4	40	50	25	273	500	1.25	20
5	46	63	26	314	500	1.36	26

Table -4: Production difference between CL and SL

The table 4 illustrates the production differences between conventional and smart lathe machines for machining aluminum workpieces (quantity). For a smart lathe and a traditional lathe, respectively, the maximum number of workpieces that can be produced at 100% is 63 and 46. The time required by traditional machines to place the workpiece in the chuck, remove it again, and check the workpiece's dimensions will be significantly greater. This is where the two machines are very different from one another. The workpiece is once more placed into the chuck for additional machining if the employee feels the desired dimensions are not being achieved. However, there is no need to take the workpiece out of the chuck when using a smart lathe. Saving time is achieved by the sensor's ability to display values without making contact. Workers will eventually have the opportunity to machine another workpiece as time permits, which will increase production.

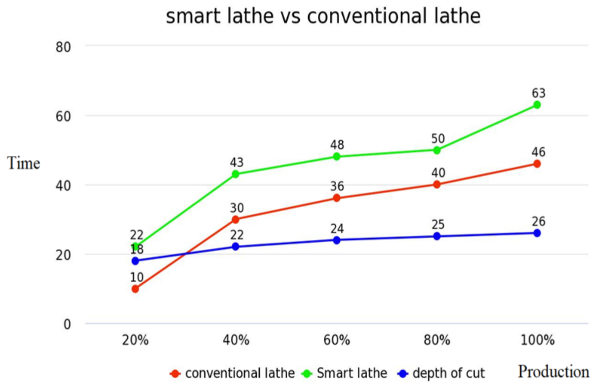

Fig -13: Production difference of smart lathe vs conventional lathe

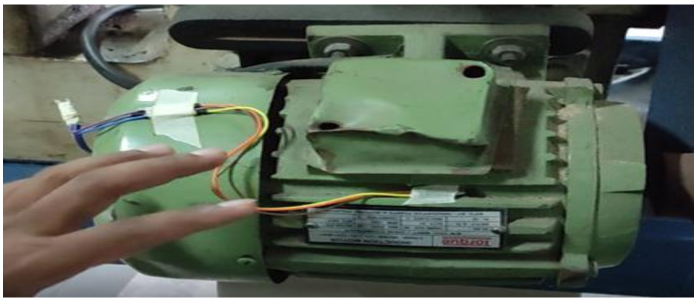

Fig -14: LM35 sensor

Fig -15: Temperature values

Fig -16: Distance between head and tailstock

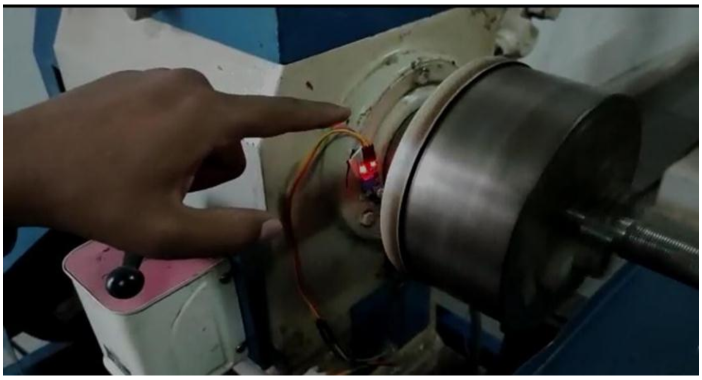

Fig -17: IR Sensor attached to spindle

Fig -18: Speed of the chuck

Fig -19: Workpiece length values

Fig -20: Ultrasonic sensor placed on toolpost

Improvements: The improvements after the lathe machine are upgraded to smart lathe are as follows

1) Worker safety
2) Lead time
3) Non-contact measurement
4) Production rate
5) Security to the lathe

6. Conclusion

Low labor costs and high-quality output are benefits of using a smart lathe machine. The smart lathe machine allows a machinist to control the temperature of the machine and turn it off while he is away. The current work is anticipated to be helpful for the manufacturing industry as well as the research community with regard to cost basis. Through a series of design changes and the use of a retrofitting technique, a conventional lathe machine can be converted into a smart lathe machine. As a result, NodeMCU and Arduino were successful in creating the design for the smart lathe. which, thanks to the collaboration of hardware (Arduino UNO) and software (Arduino IDE), has led to the development of a semi-automated approach to the traditional lathe machine. By adding a few new features to the existing lathe, the newly created Arduino lathe's setup cost is increased; however, when compared to the fully automated/CNC machine, the setup cost is significantly lower. The repeatability and dimensional stability of the manufactured part are achieved due to the relatively high accuracy of the job manufactured in a semi-automated lathe.

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