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Research Article

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Smart Maintenance in Lathe Machine Shop Through IoT

Venkatesh Begori, Anil Kumar Reddy Chinnagireddy*, Pavan Kumar Penta, Vamshi Ramavath and Harinath Lodinga

[1]*Department of Mechanical Engineering, Vardhaman College of Engineering, Hyderabad, Telangana, India*

***Correspondence to:**
Anil Kumar Reddy Chinnagireddy
Department of Mechanical Engineering, Vardhaman College of Engineering, Hyderabad, Telangana, India.
E-mail: anilreddymechanical@gmail.com

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Abstract

The availability, dependability, and security of their traditional product-focused enterprises must be taken care of while lowering their maintenance costs if manufacturers of production plants and machinery are to maintain their competitiveness. It has been challenging to reach the production equipment during operation and maintenance since it is scattered widely and in accessible but remote places. Artificial intelligence and the industrial internet of things (IoT) support continuous real-time monitoring of the machines to identify wear conditions early and schedule repairs in advance, reducing downtime, lowering maintenance costs, and boosting productivity. During metal removal process surface finish is the major requirement for lathe efficiency. To balance this activity addition of nanoparticles will provide surface finish for lathe tools and work piece. A deployable early warning system called a condition monitoring system uses sensor data to forecast failure and the remaining usable life of the system, assemblies, and its parts. The provision of a condition monitoring system for heavy-duty lathes in machine shops is proposed. This system would process data on the lubricant quality and temperature of the spindle bearings and gears as well as the distance between the tool post and the chuck from the machine parts. The node MCU versions have been thoroughly explored and analyzed, both conventionally and in a specially designed method enhanced using Arduino programming. The objective of this work is to provide remote monitoring and smart maintenance for lathe machine shop through IoT Blynk app, the operator receives messages and SMS about the behavior and performance of the lathe on a continuous basis once lathe is ON. This enables the operator to practice preventive maintenance and to recommend units for replacement as soon as necessary before any serious failure or interruption of the lathe machine happens.

Keywords

Artificial intelligence, Industrial internet of things, Maintenance cost, Condition monitoring, Node MCU

Introduction

The process of preserving machinery, apparatus, and systems in top operating condition in industrial settings is referred to as industrial maintenance. It entails a number of actions intended to avoid equipment breakdown, reduce downtime, and guarantee the effective and secure functioning of industrial facilities [1]. Implementing procedures to lower breakdowns boost uptime, and advance general reliability is known as industrial maintenance, commonly referred to as plant maintenance [2]. In other terms, maintenance refers to any activities that are done to keep assets in excellent operating order. Production activities are also maintained when equipment continues to operate at its predicted capacity [3].

A maintenance plan lowers maintenance expenses, enhances possible uptime, and ultimately boosts profitability. A sustainable maintenance strategy does not include relying on a third-party service contractor to fix malfunctioning parts after the fact [4]. This strategy increases your risk of unplanned downtime due to a sudden, unexpected breakdown in addition to the high servicing costs with third-party contractors [5]. A good maintenance schedule can pinpoint tasks that should be performed to avoid breakdowns altogether, thereby saving your business more money [6]. Surface roughness is the major influencing factor of lathe efficiency, to improve lathe performance surface coating like Al_2O_3 nanocoating is provided on lathe surface which will enhance hardness of lathe surface and increase surface finish. From past research it is evident that nano coatings can provide better hardness and surface finish for lathe beds and tools which will enhance lathe life and reduce the maintenance [7].

Possible faults in lathe

Abrasive wear is the term for the deformation of surface materials between the sliding surfaces as a result of inadequate lubrication when under load. The treatment for this abrasive wear is the use of high viscosity oils. The second phenomenon is misalignment, which happens when the shaft and bearing are not aligned properly [2]. Similar situations occur when the axis, yaw, and pitch pinion gears are out of alignment. Scuffing, the third main fault, is characterized by substantial and quick plastic deformation. When the lubricating film thickness is insufficient for the operating circumstances, localized frictional heating at the surface happens. High friction is created in the contacts during gear mating, which raises the temperature. This failure is primarily due to a lack of lubrication [8]. The fourth issue is broken teeth. When loads are concentrated throughout a gear tooth's length for an extended period of time, the weaker parts of the tooth begin to shatter. Due to increased friction that produces heat and a loss in lubricant, bearing or gear temperatures rise. Finally, there is corrosion, which occurs when surfaces get roughened and cannot move smoothly due to the chemical activity of lubricating oil [9].

Lathe machine maintenance requirements

Regular cleaning is concerned with maintaining the cleanliness of the lathe machine by routinely removing chips, coolant remnants, and debris. To avoid accumulation and guarantee smooth operation, clean the chuck, tool turret, and other parts [10].

- Lubrication advises following the manufacturer's instructions when lubricating the lead screws, gears, bearings, and sliding surfaces of the lathe machine. To avoid excessive wear and friction, use the right lubricants and plan routine lubrication.
- Definition of inspection and adjustment check important parts including the chuck, tailstock, tool turret, and tool holders frequently for wear, damage, or alignment issues. Maintain accuracy and performance by making the appropriate corrections or replacements.
- To maintain accuracy, the lathe machine should be calibrated periodically. This entails examining and making necessary adjustments to the tool offsets, tool height, and tailstock and headstock alignment.
- Belt and motor maintenance is done to guarantee adequate power transmission, check and tension the belts frequently. Inspect the electrical connections and the motor for any signs of wear or damage. In order to avoid dust or debris from impairing engine performance, air filters should be cleaned or replaced as necessary [11].

Experimentation

Fault diagnosis of lathe bed alignment

Fault diagnosis

The identification and resolution of any potential problems that might exist with the lathe bed and screw in a lathe machine is fault diagnosis of these parts. The following are some typical issues and steps for diagnosing the screw and lathe bed [12].

Misalignment

Check for misalignment between the screw and the lathe bed. Misalignment may result in problems like uneven cutting or poor machining accuracy. Additionally, check the alignment of the bed and screw using alignment equipment like straightedges or laser alignment systems. Verify the measurements against the suggested tolerances. If misalignment is found, modifications can be needed, and diagnostic action can be done. For instructions on how to align the lathe machine properly, speak with a skilled technician or the handbook [13].

Excessive noise or vibration

During lathe machine operation, pay attention to any strange noises or excessive vibrations since these could point to underlying problems with the bed or screw. Look for any mechanical problems, such as worn bearings, loose fasteners, or other potential sources of noise or vibration. If necessary, tighten or replace any loose or harmed parts. If the issue continues, seek further diagnostics from a trained technician [14].

Backlash

Examine the screw and nut for backlash, also known as the amount of play or clearance. Reduced accuracy and precision can be the result of excessive blowback. Utilize a dial indicator to calculate the backlash. If there is any play or movement, slide the screw back and forth to check. Diagnostic procedures are available. If severe backlash is found, the anti-backlash mechanism of the nut or screw may need to be adjusted or changed. Consult the lathe machine's instruction manual or get help from an expert [15].

Arduino interface circuit diagram for lathe

The ESP8266 runs on 3V. Tie up the VCC and 3V. Unlike the Arduino, Node MCU has different pins, but we're utilizing 8 pins for our entire circuit. D0, D1, D2, D4, D5, D6, D7, and D8 are the numbers. The turbidity sensor, NODEMCU

ESP8266 Microcontroller, SKU: SEN0189, MLX90614ESF. The connections between the infrared (IR) temperature sensor, SHARP GP2Y0A21YK0F IR distance sensor, 2 channel relay module, LCD display, buzzer, and 9 V battery enable the lathe machine to be maintained intelligently. A turbidity sensor with the SKU: SEN0189 is attached to the Node MCU's D2 pin, Ground terminals, and 3 V power supply. The levels of turbidity, or opaqueness, are measured by the turbidity sensor to determine the quality of the oil. By measuring the light transmittance and scattering rate, which vary with the amount of total suspended solids in oil, it uses light to identify suspended particles in liquid. Additionally, the Blynk app displays the oil quality via a radial gauge and notifies the user if the oil quality changes. The IR temperature sensor, or an IR thermometer, detects an object's temperature by detecting the IR radiation it emits. Its output pin is attached to D3 on the Node MCU. The thermal energy is transformed into an electrical signal using IR thermography principles, which is then processed to produce temperature data. Additionally, the Node MCU's wifi module transmits the generated temperature data to the Blynk app. If the temperature exceeds 300 degrees Celsius, the Blynk app notifies the user that "High Temperature is Detected!! Lathe power supply is shut OFF and Lathe is shut OFF. The 2-channel relay, which is attached to Node MCU's D8 pin, is responsible for this triggering process. Figure 1 shows that the D3 pin-connected IR distance sensor determines the proper separation between the Chuck and Tool post, i.e., the sensor uses infrared light to determine the separation between the sensor and an object. The IR light is reflected by these sensors, and the time it takes for the light to return to the sensor is then measured. The safe distance of the tool post is shown on an LCD screen connected to the microcontroller by an IR distance sensor, and a buzzer attached to the D1 pin of the microcontroller informs the user if the safe distance of the tool post has been exceeded.

Fault diagnosis of lubricant oil sump

A gear box's oil sump is essential for lubricating and cooling the gears and bearings, guaranteeing smooth operation, and limiting wear. Inadequate lubrication, overheating, and probable damage to the gear box components can result from problems with the oil sump [14]. Following are some diagnostic procedures for a gear box's oil sump fault:

- Check the gear box for any apparent oil leaks near the oil sump. On the outside of the gear box, look for oil marks or another residue. In order to stop oil loss and maintain correct lubrication, sump cracks, bad gaskets, and defective seals must be repaired.
- Oil level and quality: Use the manufacturer-recommended method to check the sump's oil level. If the oil level is below the acceptable range, there may be a leak, an incorrect fill, or an issue with oil consumption. Examine the oil's color, consistency, and presence of any debris or metal particles to determine its quality. Oil that has been contaminated or deteriorated may indicate internal problems or insufficient upkeep.
- Oil pressure: Keep an eye on the gearbox's oil pressure. A blocked oil filter, a failed oil pump, or insufficient oil flow from the sump can all cause low oil pressure. On the other side, high oil pressure could be a sign of obstructions or limits in the oil passageways.
- Oil temperature: Check the oil's temperature inside the gearbox. Excessive oil temperature can be a sign of poor sump cooling, which can be caused by insufficient oil flow, blocked cooling passageways, or broken cooling components.

Diagnostics using IoT for lathe machines

A number of components are included in the lathe machine's smart maintenance system to improve monitoring and maintenance procedures. Figure 2 makes clear that the Node MCU ESP8266 microcontroller, which serves as the system's principal control component, is at the system's core. It makes it easier to integrate different sensors and gadgets to ensure effective operation. The turbidity sensor (SKU: SEN0189) is essential for determining how well the fluid used in the lathe machine is working. It gauges the turbidity levels, which represent the fluid's clarity or cloudiness. The sensor offers information about the fluid's quality by identifying variations in turbidity. For instance, the system will generate

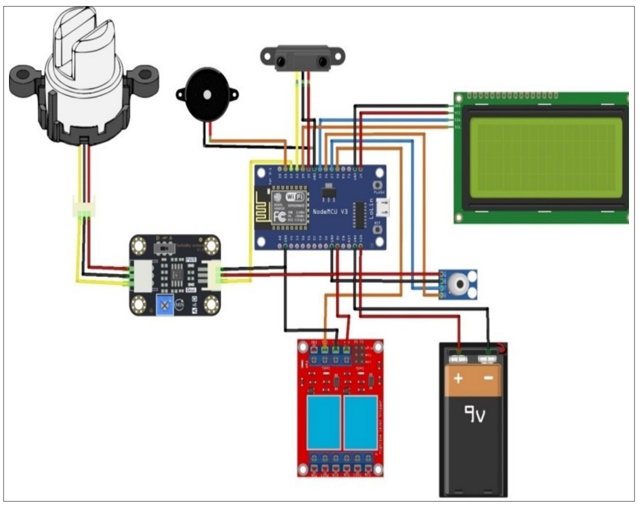

Figure 1: Aurdino interface circuit with lathe machine.

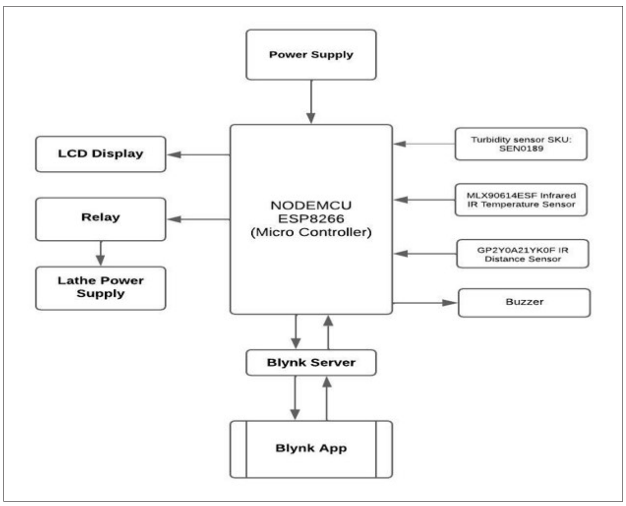

Figure 2: IoT interface block diagram.

a message for the operator to replace the fluid if the turbidity levels rise above a specific threshold, which denotes a reduction in fluid quality. The temperature of the bearings or surfaces of the lathe machine is measured using the MLX90614ESF IR temperature sensor. The sensor precisely estimates the temperature by measuring the IR radiation given off by these things. The 2-channel relay module is activated by the system whenever the temperature rises above a predetermined threshold, such as 300 degrees Celsius. By switching off the power supply to the lathe machine, this relay module prevents potential harm from high heat. The tool post and chuck of the lathe are separated by a distance measured by the SHARP GP2Y0A21YK0F IR distance sensor. The sensor calculates the distance to the tool post via emitted IR light and measuring its reflection. On the LCD display built inside the circuit, this data is shown. A buzzer is also included to provide an audible alert if the distance drops below a safe level. This guarantees user security and avoids chuck and tool post collisions.

A Blynk IoT server is used by the system to allow IoT capabilities. Through a hotspot, the Node MCU ESP8266 communicates to the Blynk server. The server then receives data from the sensors for monitoring and analysis. The Blynk app has an intuitive user experience that presents pertinent information. This has two radial gauges and a label displaying the tool post's travel distance. The temperature is represented by one gauge, which receives data from the IR temperature sensor, and the oil quality is represented by another gauge, which receives data from the turbidity sensor.

The Blynk app receives a signal if the temperature rises above 300 degrees Celsius, which causes the power supply to be turned off. Three distinct colors are used on the oil quality radial gauge to depict various suspended particle concentrations. A notification urging an oil change is delivered to the Blynk app if the oil quality goes into the third category, indicating a larger concentration of suspended particles. In conclusion, a buzzer, an LCD display, a microcontroller, a relay module, and a Blynk IoT server are all included in the lathe machine's smart maintenance system. The system makes sure that operations are both safe and effective by keeping track of fluid quality, temperature, and distance. The Blynk app gives the operator real-time updates and notifications, enabling prompt maintenance measures and enhancing the lathe machine's overall performance and longevity.

Blynk app integration with lathe machine

The IR temperature sensor is a tool that uses the IR radiation that an object emits to detect high temperatures on a bearing or surface. This sensor is mounted in head stock to detect the distance and temperature. The lathe machine shuts off automatically when a high temperature is sensed. A notice that reads "High Temperature is Detected!! Lathe is Switched OFF!!" is also provided to the operator. The sensor continuously measures the bearing's temperature in order to offer real-time temperature information. The Blynk app then shows this temperature data in a radial gauge. The operator can readily keep track of the bearing's temperature status thanks to the radial gauge's visual representation of temperature.

Results and Discussion

Use USB to connect your Arduino board to your computer. Compile and upload your modified program to the board. You can test the IoT interface via the Blynk web dashboard after the program is running on your board. The widgets you added to the dashboard should be visible if you return to the Blynk web dashboard. To see your Arduino board's relevant actions or data changes, interact with the widgets. Figure 3 depicts the logic tree-based operation of the Blynk app.

The safe distance between the tool post and the lathe chuck is determined using the IR distance sensor. The distance between these two components is measured in figure 4 and compared to a set safe distance threshold. A buzzer sounds an alert if the measured distance is more than the safe distance standard. The tool post and the lathe chuck's distance are continuously monitored by the IR distance sensor, which also provides real-time feedback on their proximity. This makes it possible to guarantee that, while operating, the parts keep a safe distance between them. System proactively identifies and informs when the safe distance is exceeded by integrating the IR distance sensor. This feature promotes a safer working environment for operators by preventing potential collisions or

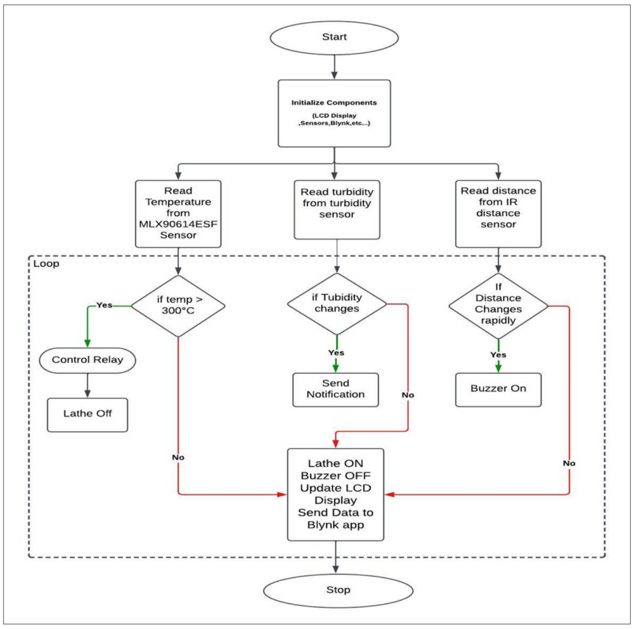

Figure 3: Flow chart for Arduino program.

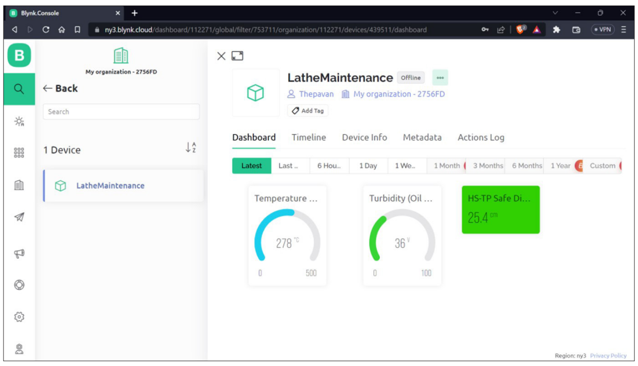

Figure 4: IoT interface for lathe machine in Blynk app.

accidents between the lathe chuck and the tool post. Figure 5 shows notification of reg temperature.

The turbidity sensor is used to check the oil's quality. It gauges how cloudy or turbid the oil is, which may signal a change in its quality. Figure 6 shows how the system sends an alert indicating "Oil Quality has Changed, Please Replace the Oil" when a major change in oil quality is detected. The oil's turbidity levels are continuously monitored by the turbidity sensor, enabling in-the-moment evaluation of the oil's purity. The data is displayed in a radial gauge, where three qualities are denoted by three different colors. This information aids in identifying when oil replacement is necessary because of contamination or degradation. Potential problems like contamination, contaminants, or degradation can be quickly identified by using the turbidity sensor for oil quality monitoring. This preventative strategy makes prompt oil replacement possible, maintaining optimum operation and durability of the equipment or system that depends on the oil.

Conclusion

In conclusion, the addition of various sensors to the lathe machine system, such as the IR temperature sensor, turbidity sensor for monitoring oil quality, and IR distance sensor for monitoring safe distance, has a significant positive impact on the machine's overall operation and maintenance. By monitoring oil quality and warning operators of changes that could require oil replacement, sensors also help to provide a safer working environment. The IR distance sensor also maintains a secure separation between important parts, reducing the possibility of mishaps or collisions. Operators can proactively address any temperature-related concerns with continuous temperature monitoring. Similar to this, the turbidity sensor aids in maintaining ideal oil quality, which in turn maintains the efficient operation and durability of the machinery's parts, such as gears and bearings. Additionally, it assists in periodically informing the operator of the oil quality via smartphone notification. Overall, the combination of these sensors encourages operator safety, makes prompt maintenance measures easier, and helps the lathe machine run efficiently and dependably. The lathe machine system becomes more durable, dependable, and capable of giving optimal performance while guaranteeing a safe working environment by utilizing the capabilities of these sensors.

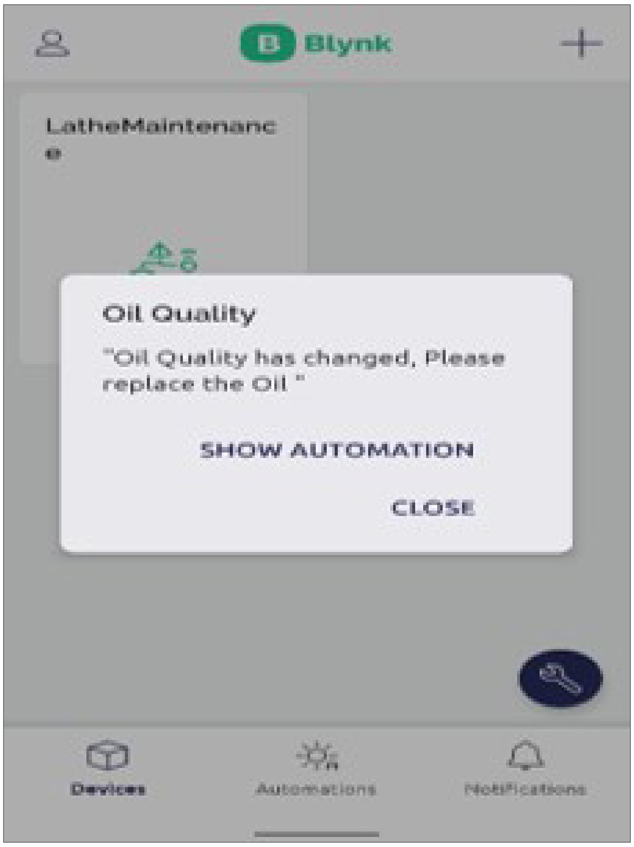

Figure 6: Notification reg oil quality/lubricant.

Figure 5: Notification reg temperature.

Acknowledgements

None.

Conflict of Interest

None.

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