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Leveraging IoT in Auto Component Manufacturing to Monitor Surface Roughness and Tool Temperature

Abstract: - Surface finish is an important requirement in Auto Component Manufacturing that defines the quality of work piece obtained from turning operations. Thus to reduce downtime due to rejection of work piece for its surface finish a continuous monitoring of surface roughness based on its cutting parameter and vibration signal is required. Similarly it is also important to monitor the cutting tool temperature to have a longer tool life. With the emerging trend of Internet-of-Things (IoT) it has become very easy to collect the required data, storing it, analysing it and also alerting the required personnel through the mobile application, e-mail and SMS. The stored data and analysis could reveals in depth the process, which leaves a large scope for improvement of the system. The paper discusses the implementation of IoT to collect data of vibration signal and cutting tool temperature of dry turning operation, for cutting parameter like 1) spindle speed 2) feed rate and 3) depth of cut for three different material mild steel (MS), brass and aluminium (Al). A correlation was obtained to predict surface roughness and tool temperature. The system developed could give a real time monitoring of surface roughness on a smart phone that can be used as a tool for optimizing the turning process to give improved quality and increased production volume.

Keywords: Internet-of-Things; Auto Component Manufacturing, Dry turning operation; Tool vibration; Surface Roughness

I. INTRODUCTION

For the Auto Component manufacturing process the work order is divided into batches for the shaft turning process. Often the surface finish is measured at the end of the batch completion catching the defects after the fact. Rejection of work piece incurs losses to manufacturer. Tangible losses include:

- Wastage of material and increased cost to order the same.
- Wastage of time (setup time, load time, cutting time and idle time) hampering work flow.
- Labor cost.
- Delay in delivery of product to costumer which could amount to delay fine or cancelling of order.
- Recall cost if rejected by customer

Intangible loses include:

- Decrease in customer loyalty.
- Loss of new customers through referrals.
- Position in the market is at stake.
- Causes a negative branding of your products

All the loses could have been eliminated if the surface roughness information would have reached on time to the worker and also alerted the shop floor manager to make the necessary changes in the operation parameters. This is where IoT steps in to monitor and alert, to get a quality product.

Internet-of-Things promises to be enormous in several ways. The benefits that are motivating and the forces that are driving it are increasing at a tremendous rate. There has been complete change in the way product and processes are viewed, changing the way information is produced, consumed and analyzed. IoT has almost touched all areas be it health, sports, construction, wearable's, etc. making every product a smart product. Other than just contributing to making product smart various studies are being done to capture all details of the processes the product undergoes while being manufactured and assembled. The work done by [1] proposed the tracking of the product life cycle of

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the crankshaft by incorporating RFID tags in the bolts used in it to make it smart. The system developed by [2] could real time monitor the dismantling of a vehicle and capture the details for future use. The work presented by [3] very well points out the use on IoT in the product life cycle energy management and its potential in every step of the life of the products.

II. RELATED WORK

In Auto Component Manufacturing the surface roughness has been formulated as an important design feature in many situations such as precision fit, fastener holes and aesthetic requirements. Along with tolerance, surface roughness also imposes a critical constraint for the selection of machines and cutting parameter for the process planning. The study done by [4] focuses on the various parameters that could influence the surface roughness formation for an ultra-precision machine. It shows an exhaustive study on the various parameters studied by different authors and very well pointed out some key challenges in the study of vibration parameters contributing in ultra-precision machining. It also showed that with advancement in computer and sensing technology this can be overcome but there is a need to do the experimentation and trial cost effectively. In the work done by [5] a statistical model was developed to study the effect of vibration amplitude based on the geometric parameter of the tools and the cutting parameter used. It proved the dominant factors affecting the vibration amplitude was that of the cutting parameters. Vibration study in the feed direction with eddy current sensors was done by [6], a customized tool holder was developed to maintain the direction of the cutting mode as any change in the direction could not be captured by the system. Dry turning operation optimal parameters were identified for getting a desired surface finish was done by [7], the authors investigated the effect of the cutting parameters on the tool stiffness and damping and predicted an empirical model to predict the same. A similar attempt of experimentation was done by [8] to monitor the accelerations in the feed and cutting directions to predict the surface roughness. Surtronic 3+ instrument was used for measuring surface roughness and MATLAB commercial software package was used for the analysis. In the work done by [9] an intermittent turning with minimum quantity lubrication of magnesium was studied for the vibration signal obtained. The behavior of dry turning operation and that of with the intermittent lubrication was observed to be the opposite of each other. But even then the effect of feed rate was more prominent on the vibration. In the experimental study done by [10] piezoelectric sensors are compared with the lower cost analog device sensors to check the feasibility and performance for monitoring the health of the machine was done. The study lacked the information of it implementation done for the application of space craft and has only pointed out that it could be used. Cutting parameter and the tool temperature plays and important role in finding the optimized cutting parameter for work piece was shown in the study done by [11]. In process monitoring of surface roughness using ultra sonic sensors has been studied and the correlation of the same with off line data was done in [12] for a CNC milling machine, which showed an agreeable set of result. In the work done by [13] an online method for the monitoring of surface roughness of a milling process was conducted. The results obtained by the system was quite comparable to the off line system but more accuracy could be obtained if every large sample size would have been selected. In similar lines the work done by [14] showed the online monitoring of the surface roughness done for a ball end milling operation using neural networks. In the study done by [15] infrared thermography sensors were used to measure the tool temperature for a micro-milling process and its effect was seen for the various cutting parameters. An exhaustive review study was done by [16] for the different analytical and experimental methods used for measuring the cutting tool temperature. The study showed that measuring the tool temperature has been one of the important task and has been done in different ways over the years with thermo-couple being one of the best method to measure the temperature at the cutting interface with the best approximation. In the review of literature done by [17] it show various manufacturing process that require monitoring the temperature. And that various methods and sensors are being used based on the application requirements.

This paper presents an approach to IoT system development and implementation in Auto Component Manufacturing to monitor the surface roughness parameter of work piece and tool temperature which could be later used for predicting the tool life on the smart phone during dry turning operation on lathe machine.

III. PROPOSED WORK

3.1 Parameter Selection and Material

Based on the work done by [4-16] it was seen that the parameters that contributed more to the vibration of tool were spindle speed, feed rate and depth of cut and hence these parameters were selected for studying on a V-belt driven Max Cut lathe machine for the dry turning operation for the levels as shown in the Table 1. Work piece used was of three material Aluminum, Brass, and Mild Steel which are the commonly used material for turning operation. The dimension of the work piece considered was of diameter 40 mm and length of 150 mm. High speed single point cutting tool was used for the study in the same position for all the three materials and hence the effect of tool geometry was ignored in the study.

Table 1 - Parameters selected and their level for the experiment

Variable	Symbol	Unit	Level 1	Level 2	No. of Levels
Cutting Speed	S	rev/mm	350	500	2
Feed Rate	F	Mm/min	0.5	1	2
Depth of Cut	D	mm	0.5	1	2

Roughness average (Ra) is widely used in industry for the mechanical components to indicate its surface roughness. Hence Ra is used in this study to indicate the surface roughness. Surface roughness Ra = 1/L x (Y(x)), where L is the sample length and Y(x) is the profile along the direction x. In this study surface roughness was measured using Mitutoyo SJ 201, with sample length 2.5 x 10^-3 mm x 3. A finely pointed probe or stylus is moved over the surface of the work piece, the vertical movement of the stylus caused due to irregularities in the surface texture is used to access the surface roughness of the work piece.

3.2 IoT Components

The different components of IoT system includes hardware and software.

The hardware components are:

- Sensors e.g. proximity, optical, humidity, temperature, accelerometer.
- Micro-controller/ Micro-processor: e.g. Raspberry Pi, Arduino Industrial, ESP 8266
- Type of connection between sensor and micro-controller: wired connection, Bluetooth, zigbee
- Viewing platforms like computer, smart phone

Software components include:

- Gateway access: WiFi, WiMAX (Worldwide Interoperability for Microwave Access), PLC(programmable logic controller)
- Network: IP (Internet Protocol), LEACH (Low-Energy Adaptive Clustering Hierarchy), RPL(Routing Protocol for Low power) , MQTT (Message Queuing Telemetry Transport Protocol)
- IoT platform enabler: ThinkWORX, Thingspeak, Thinger
- Statistical / Analysis software: MathLab, MiniTab

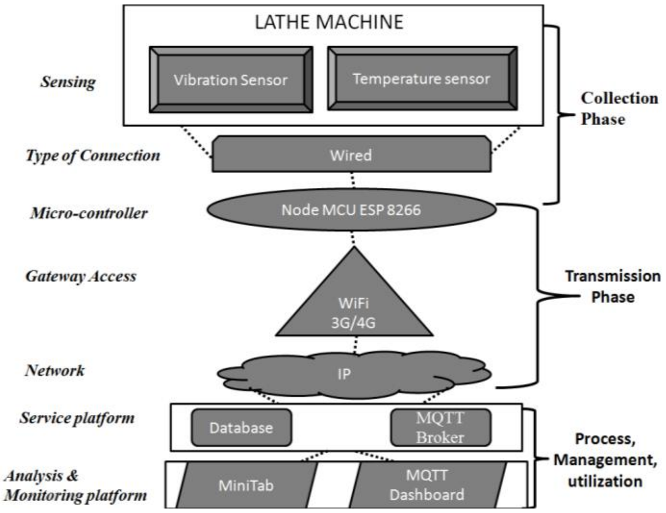


Fig. 1 - Vertical representation of the experimental setup and its phases as modified by [18]

The sensors installed on the lathe machine and the wired connection to the micro-controller form the collection phase of the experimental study. IoT devices are dependent on sensors to sense what is going on in the world and then data is processed to continue the work. These sensors are most important part of devices and hence used extensively in IoT setup. The micro-controller, the gateway access and the network form the transmission phase. The service platform used and the software used to analyze the data to capture the surface roughness and the tool temperature; and the display mode form the process management and utilization phase. Table 2. Shows the hardware components used in this study along with the features.

Table 2 – IoT components used in the study

Component	**Type**	**Name**	**Features**
Sensor	Acceleration Sensor	ADXL345	Voltage: 3.3V, Driver Version: 1, Unique ID: 12345 Max Value: -156.91 m/s^2, Min Value: 156.91 m/s^2 Resolution: 0.04 m/s^2, Data Rate: 100 Hz, Range used: +/- 2 g
	Temperature Sensor	Melexis MLX90614	Non-contact type, Small size and low cost, Easy to integrate Temperature range: -70 to 380°C for object temperature Accuracy : 0.5°C, Voltage: 3.3V, Accessed through I2C
Micro-controller	NodeMCU	Esp8266	Open source IoT platform, Single Board Micro-Controller Memory: 128kbytes, RAM: 4Mb, Power: USB
Connection	I2C	Wired	Different peripherals may share a bus, open-drain/open-collector with an input buffer on the same line,

Placement of Sensors on the Lathe machine:

Sensors were placed on the lathe machine tool post as shown in the Fig.2 with the help of foam tape. Sensors were connected to the micro-controller via I2C communication. The I2C bus is a very popular and powerful bus used for communication between a master (or multiple masters) and a single or multiple slave devices. Different peripherals may share a bus which is connected to a processor through only 2 wires, which is one of the largest benefits that the I2C bus can give when compared to other interfaces. I2C uses an open-drain/open-collector with an input buffer on the same line, which allows a single data line to be used for bidirectional data flow.

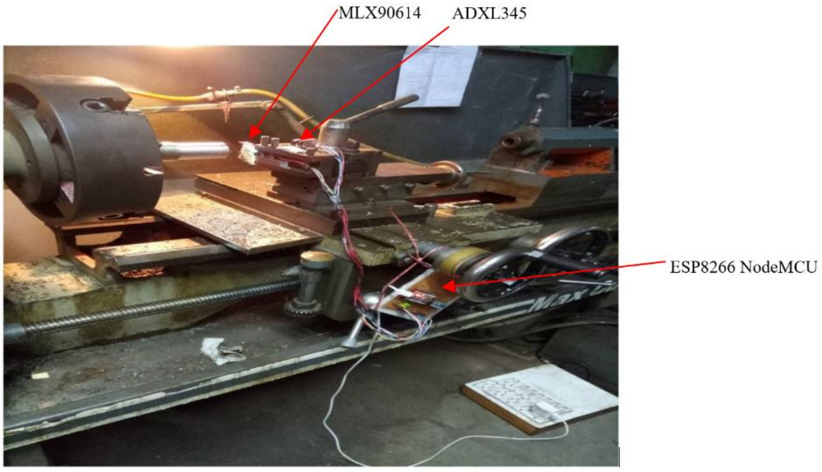


Fig. 2 - Placement of sensor on the lathe machine

3.3 Analysis Procedure

The experimental work consist of two stages: pilot study and implementation in the IoT system. Fig. 3 gives the schematic diagram of the analysis procedure for the experimental work.

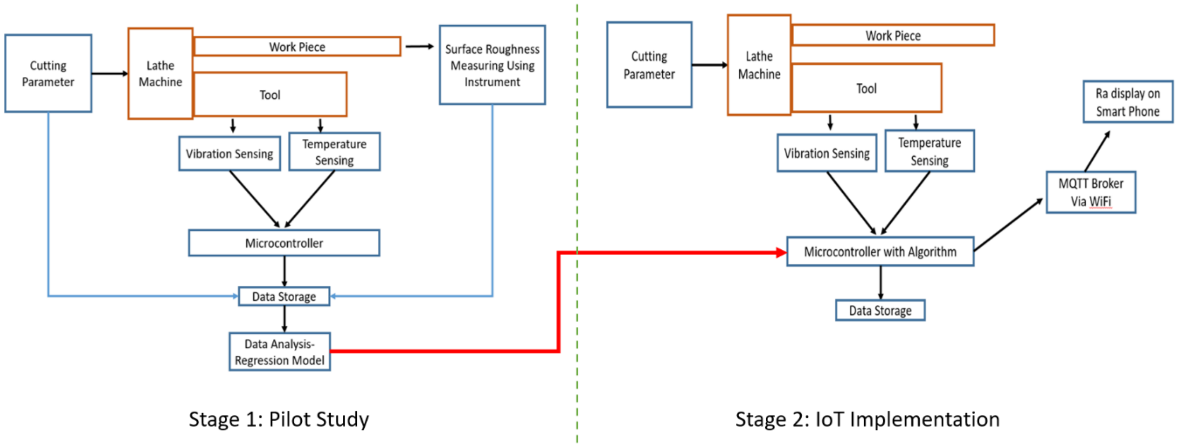


Fig. 3 – Schematic diagram of the experimental study analysis procedure

As shown in the schematic diagram the cutting parameters are set and the vibration and temperature input of tool is taken from the sensors which is read by the micro-controller and the data is stored into the system. A number of tests were conducted where the parameters like spindle speed, depth of cut, feed rate were varied as per the levels set and the corresponding value of acceleration in x, y and z direction and temperature of tool were collected and stored for all the three materials. The surface roughness was measured after each test using Mitutoyo SJ 201 , with sample length 2.5 x 10^-3 mm x 3. Along with the sensor outputs the cutting parameter and the surface roughness measured using the instrument are also stored. Once a number of data is collected for the different combination of the cutting parameters the data is used in the statistical software Minitab for developing the regression model to calculate the surface roughness and the tool temperature.

Table 3 show the data set collected for spindle speed of 350 rpm, feed rate 0.5 mm/min and depth of cut 0.5 mm for the three materials and the x, y and z vibrations measured. The surface roughness was measured using the instrument and was recorded as 5.44µm, 2.89 µm and 2.86 µm for steel brass and aluminium work piece respectively.

Table 3. Set of Data collected for Steel, Brass and Aluminum with average Surface roughness measured as 5.44 µm, 2.89 µm and 2.86 µm for cutting parameter S = 350 rpm, F = 0.5 mm/min and D = 0.5 mm

Time	**Steel**				**Brass**				**Aluminium**			
	X m/s^2	**Y m/s^2**	**Z m/s^2**	**Temp ^oC**	**X m/s^2**	**Y m/s^2**	**Z m/s^2**	**Temp ^oC**	**X m/s^2**	**Y m/s^2**	**Z m/s^2**	**Temp ^oC**
1	0.16	-0.43	11.3	34.67	0.43	-0.67	11.3	33.57	0.94	1.1	11.22	34.03
2	-2.04	-2.12	11.34	42.87	0.27	-0.51	11.3	33.65	1.1	1.1	11.18	34.09
3	0.04	-0.82	11.38	45.31	0.35	-0.43	11.38	33.55	1.33	0.86	11.3	34.63
4	0.16	-0.2	11.22	45.05	0.43	-0.43	11.26	34.55	1.14	1.18	11.06	36.29
5	-0.31	-0.71	11.3	45.03	-0.16	-0.24	11.22	40.07	1.41	1.02	11.22	36.61
6	-0.31	-0.51	11.14	45.51	-0.31	-0.47	11.49	36.29	1.33	1.14	11.34	36.09
7	0.67	-0.51	11.45	51.45	-0.67	-1.29	11.45	37.41	1.1	0.94	11.18	36.55
8	0.16	-0.16	11.26	46.41	0.47	0.63	11.06	40.17	0.39	1.33	11.18	36.97
9	-0.04	-0.78	11.41	46.59	0.67	-0.24	11.3	41.37	1.37	1.1	11.34	36.79
10	0.39	0.16	11.34	46.71	0.39	0.31	11.1	36.41	1.49	1.06	11.22	37.05
11	0.43	-0.78	11.41	47.41	1.65	1.65	11.81	38.63	1.57	0.82	11.18	37.69
12	0.55	-0.2	11.26	47.21	-0.94	-0.94	11.14	40.29	1.29	1.14	11.06	37.79
13	1.02	0.51	11.22	47.03	0.27	-0.12	11.22	40.17	0.94	1.1	11.1	36.71
14	0.43	-0.9	11.49	46.45	0.08	-1.1	11.41	38.53	1.33	1.14	11.22	36.97
15	1.88	0.08	11.34	49.49	0.31	-1.29	11.41	40.27	1.1	1.14	11.26	37.25
16	0.39	-0.51	11.45	50.89	-0.63	-1.29	11.34	36.63	1.26	1.02	11.1	38.01
17	-0.47	-1.73	11.45	47.57	0.39	0.12	11.34	37.43	1.61	0.86	11.26	37.67
18	0.35	-0.16	11.3	47.87	0.55	-0.24	11.18	43.27	1.18	1.02	11.14	38.09

19	0.71	-0.27	11.45	46.49	-0.94	-1.53	11.22	39.01	0.75	1.14	11.18	37.29
20	0.2	-0.55	11.18	46.17	0.2	-1.53	11.69	39.89	0.86	1.22	11.18	37.99
21	-0.24	-0.2	11.1	48.85	-0.43	-0.67	11.34	37.03	1.45	0.94	11.14	36.77
22	1.37	-0.04	11.45	47.05	-0.43	-1.29	11.34	38.19	1.49	0.94	11.34	38.79
23	-0.51	-0.71	11.26	48.25	0	-1.45	11.49	37.79	1.53	0.86	11.34	37.51
24	0.75	0.39	11.14	50.27	0.12	0.71	11.06	40.51	1.73	1.13	11.22	37.67
25	0.63	-0.59	11.49	49.05	0.98	-0.55	11.45	37.19	1.37	1.33	11.3	37.55
26	-0.43	-0.47	11.26	48.37	0.43	-0.39	11.26	39.29	1.06	1.26	11.14	39.37
27	1.57	0.67	11.3	47.85	0.55	-0.47	11.18	40.27	1.06	1.22	11.14	37.19
28	0.08	0.12	11.22	51.89	0.98	1.69	10.83	37.38	1.06	1.22	11.18	37.55

Similarly data was collected for the combination of parameters as shown in Table 4 for each of the material.

Table 4. Combination of parameters used for experimentation with each material

Combination No.	**S rpm**	**F mm/min**	**D mm**
1	350	0.5	0.5
2	350	0.5	1
3	350	1	0.5
4	350	1	1
5	500	0.5	0.5
6	500	0.5	1
7	500	1	0.5
8	500	1	1

Once all the results were collected, a correlation was obtained between cutting parameter speed, feed rate, depth of cut, the vibration parameters based on the average absolute value of the acceleration in x (feed direction) and y (radial direction) and the surface roughness parameter Ra. The tabulated results after obtaining the average value are shown in Table.5 this was imported into MiniTab Statistical software to create a fit Regression Model.

Table 5. Data imported in MiniTab Statistical software

Ra measured	**S**	**F**	**D**	**X abs**	**Y abs**
2.86	350	0.5	0.5	1.200741	1.344815
3.1	350	0.5	1	1.99737	1.195263
1.62	500	0.5	1	0.698333	0.421667
4.91	500	1	0.5	0.952	0.326
3.43	500	1	0.5	0.7308	0.2832
5.78	500	1	1	0.6244	0.3332
3.07	350	0.5	0.5	0.564043	0.706064
2.89	350	0.5	0.5	0.486774	0.768387
2.73	350	0.5	1	0.664	1.029667
2.79	350	0.5	1	0.515	1.072059
6.87	350	1	0.5	1.580455	1.37
6.41	350	1	1	1.8128	2.1188
6.74	500	1	0.5	3.875833	1.983333
2.92	500	0.5	1	1.0572	0.9224
3.07	500	0.5	0.5	1.439565	1.42087
8.78	500	1	1	2.097391	2.132174
10.85	500	1	0.5	1.190476	1.328571
4.66	500	0.5	1	2.737632	2.477105
6.42	500	0.5	0.5	2.160714	1.909524
10.71	350	1	1	1.301951	1.575366
11.41	350	1	0.5	0.595313	0.78625
10.34	350	1	0.5	0.655556	0.694167

5.52	350	0.5	1	1.251207	1.203966
5.91	350	0.5	1	0.969138	1.134138
5.41	350	0.5	0.5	0.581786	0.545714

Considering all three materials the regression equation was developed in Minitab 17. The regression equation that was developed is as follows:

$R_a = 1.03 - 0.00501 \times \mathrm{S} + 8.59 \times \mathrm{F} - 1.41 \times \mathrm{D} - 1.275 \times |\mathrm{X}| + 2.67 \times |\mathrm{Y}|$ (2)

Aluminum: $R_a = -80.57 + 0.1239 \times \mathrm{S} + 12.54 \times \mathrm{F} + 3.049 \times \mathrm{D} + 2.476 \times |\mathrm{X}| + 21.78 \times |\mathrm{Y}|$ (3)

Brass : $R_a = -0.52 + 0.00021 \times \mathrm{S} + 7.52 \times \mathrm{F} - 0.362 \times \mathrm{D} + 0.281 \times |\mathrm{X}| - 0.364 \times |\mathrm{Y}|$ (4)

Mild Steel : $R_a = 7.84 - 0.01025 \times \mathrm{S} + 6.89 \times \mathrm{F} - 5.00 \times \mathrm{D} - 5.41 \times |\mathrm{X}| + 7.45 \times |\mathrm{Y}|$ (5)

Stage two is the implementation of the regression model into the system Arduino IDE was used to build the sensing signal processing algorithm in the micro-controller. The IoT system design layout is as shown in Fig 4. In this stage the process flow is as follows the sensors sense the vibration and the temperature of the tool which is fed into the code built in the micro-controller which s accessed via the WiFi into the MQTT broker and IFTT to display the surface roughness real time on the smart phone for the operator to view and email alert in case the roughness or temperature values exceeded. MQTT Dashboard mobile application was used to monitor the parameters on the smart-phone. Hivemq broker was used for subscribing and publishing the topics.

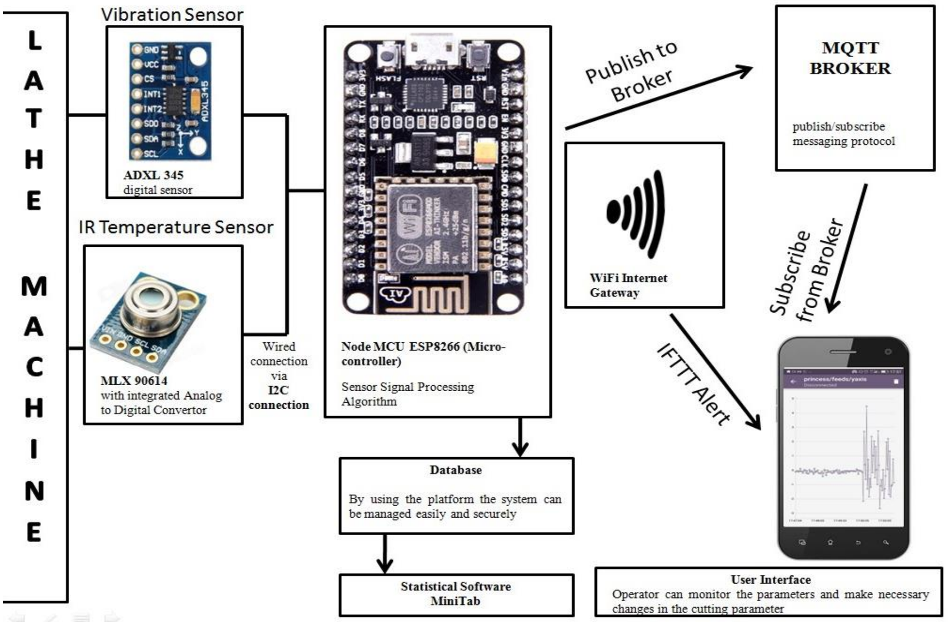


Fig. 4 - IoT system design layout as modified by [19]

The tests were carried out again to monitor the surface roughness on the smart phone. Based on the results that were obtained a level was set to send an alert message via e-mail that could be viewed by the shop floor manager. The network of IoT system operation has been shown in Fig 5. All parameters were saved in the data base. The parameters were collected in one second interval. The time data for the same was obtained from the internet time stamp.

The e-mail alert messages were set as follows:

- If T >110°C Friction between workpiece and tool exceeding.

- If Ra>3.5µm Roughness exceeding the highest limit set

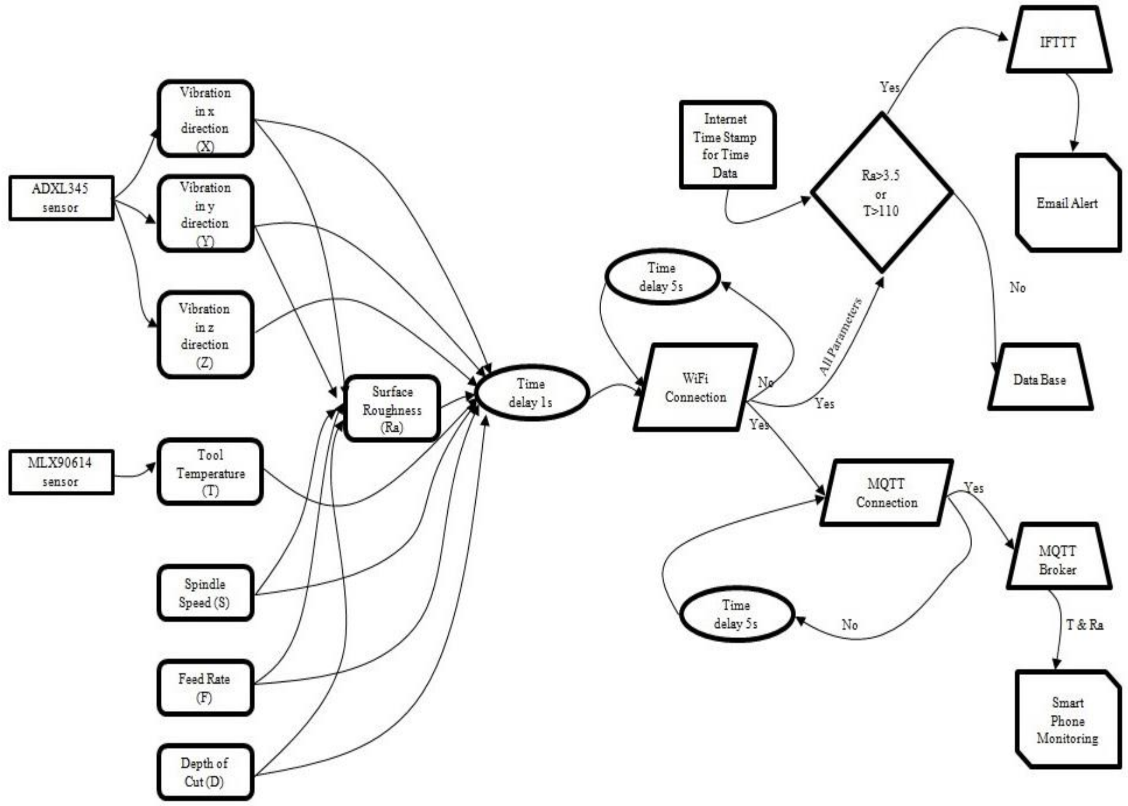


Fig. 5 - Network of IoT system operation, modified from [19]

The data that were monitored on the smart phone could only be viewed when the MQTT mobile application is open. No data was saved on the smart phone. Once the application was closed the data that were scene on the screen would be lost. The viewing in smart phone and the web logging of data were not linked as the internet data consumption for the MQTT is lesser than the web viewing of the parameter. MQTT is a light weight messaging protocol hence the battery consumption for sending, receiving or keeping the connection open is very less compared to the web data logging .

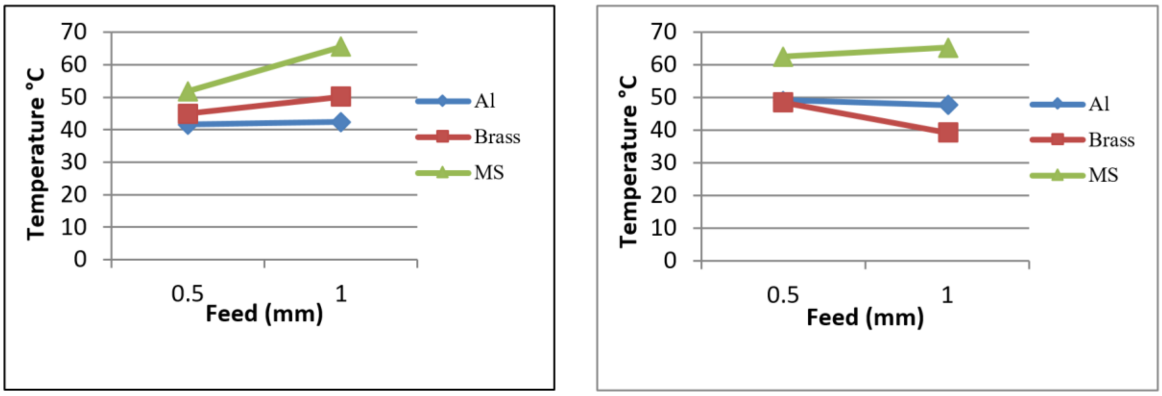
IV. RESULTS

Based on the theoretical calculations it was seen that the error in the theoretical values were exceeding more than 50% of the measured value in many of the cases when a general equation as equation (2) was used without considering material of the work piece. So separate equations were developed for each material of work piece i.e equation no. (3-5) the variation in the surface roughness measured and theoretically calculated Ra varied only by maximum of 12%. The results are shown in Table 6. The results show that it is necessary to consider the material of the work piece and only considering the speed, feed rate, depth of cut and the vibration would not give very good results.

Table 6. Ra Theoretical values and errors considering regression common to all materials and errors considering regression as per the respective material

Material	**Ra (Measured using instrument)**	**S**	**F**	**D**	**X abs**	**Y abs**	**Ra (Theor) as per general eq (2)**	**% Error**	**Ra (Theor) as per material eq (3-5)**	**% Error**
Aluminum	2.86	350	0.5	0.5	1.20074	1.34482	4.92621	72.2	2.85261	0.3
	3.1	350	0.5	1	1.99737	1.19526	2.80621	9.5	3.09232	0.2
	1.62	500	0.5	1	0.69833	0.42167	1.64548	1.6	1.61198	0.5
	4.91	500	1	0.5	0.95200	0.32600	6.06662	23.6	4.90193	0.2

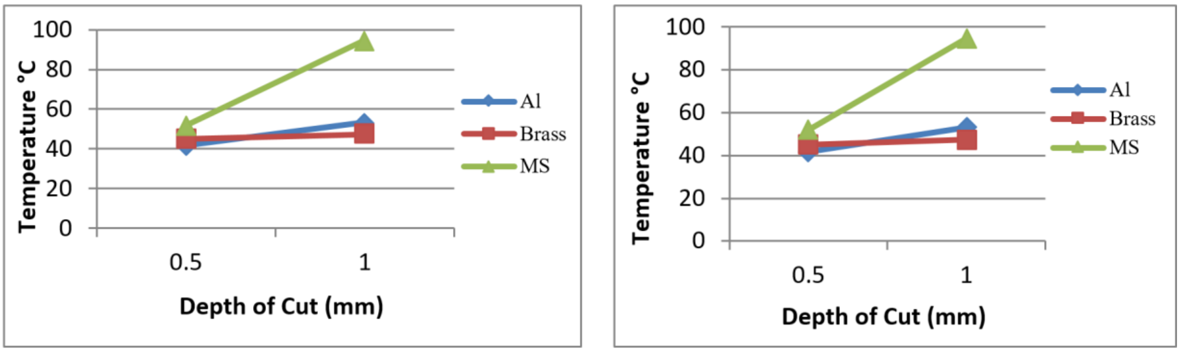
	3.43	500	1	0.5	0.73080	0.28320	6.23437	81.8	3.42206	0.2
	5.78	500	1	1	0.62440	0.33320	5.79853	0.3	5.77211	0.1
Brass	3.07	350	0.5	0.5	0.56404	0.70606	4.03254	31.4	3.03399	1.2
	2.89	350	0.5	0.5	0.48677	0.76839	4.29746	48.7	2.98959	3.3
	2.73	350	0.5	1	0.66400	1.02967	4.06411	48.9	2.76329	1.2
	2.79	350	0.5	1	0.51500	1.07206	4.36727	56.5	2.70599	3.1
	6.87	350	1	0.5	1.58046	1.37000	8.80432	28.2	6.83793	0.5
	6.41	350	1	1	1.81280	2.11880	9.80238	52.9	6.44965	0.6
	6.74	500	1	0.5	3.87583	1.98333	6.76381	0.4	7.29118	7.6
	2.92	500	0.5	1	1.05720	0.92240	2.52488	13.5	2.94432	0.8
	3.07	500	0.5	0.5	1.43957	1.42087	4.07328	32.7	3.05132	0.6
Mild Steel	8.78	500	1	1	2.09739	2.13217	8.72373	0.6	9.14281	4.0
	10.85	500	1	0.5	1.19048	1.32857	8.43943	22.2	10.56238	2.7
	4.66	500	0.5	1	2.73763	2.47711	4.53339	2.7	4.80384	3.0
	6.42	500	0.5	0.5	2.16071	1.90952	4.45852	30.6	6.19649	3.6
	10.71	350	1	1	1.30195	1.57537	9.00274	15.9	10.83542	1.2
	11.41	350	1	0.5	0.59531	0.78625	8.50176	25.5	11.27942	1.2
	10.34	350	1	0.5	0.65556	0.69417	8.17909	20.9	10.26749	0.7
	5.52	350	0.5	1	1.25121	1.20397	3.78080	31.5	4.89802	12.7
	5.91	350	0.5	1	0.96914	1.13414	3.95400	33.1	5.90379	0.1
	5.41	350	0.5	0.5	0.58179	0.54571	3.58178	33.8	6.11561	11.5



(a) **(b)**

Fig. 6 (a) Speed vs Temperature for F=0.5mm and D=0.5mm (b) Speed Vs Temperature for F=1mm and D=0.5mm

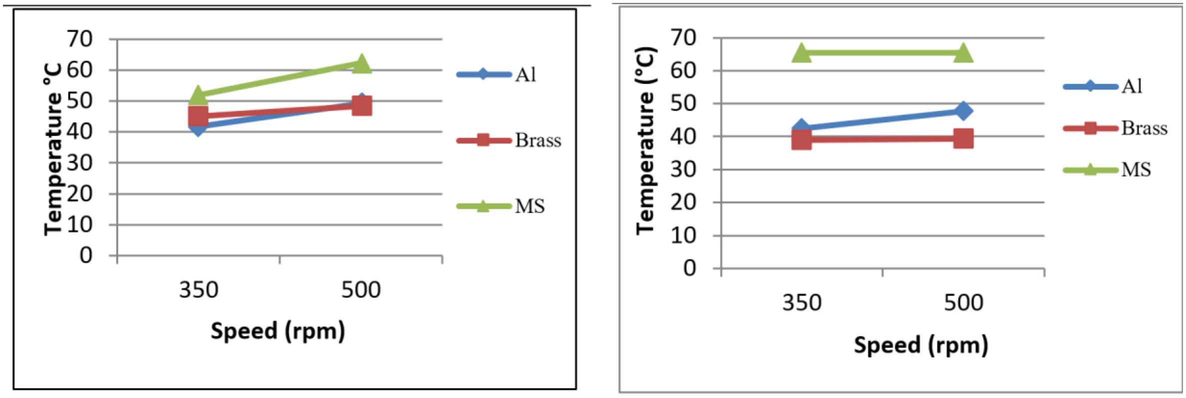
The maximum temperature that was noted during the test was noted and represented graphically in the Fig. 6 (a) and 6 (b) for all the three materials for the two different spindle speed with same depth of cut and change in the feed rate. The results shows that with the increase in the spindle speed and feed rate the temperature at the cutting interface is more. But with the higher feed rate there is a very less variation of temperature with increase in the spindle speed.



(a) **(b)**

Fig. 7 (a) Feed Vs Temperature for S=350rpm and D=0.5mm (b) Feed Vs Temperature for S=500rpm and D=0.5mm

The maximum temperature that was noted during the test was noted and represented graphically in the Fig. 7 (a) and 7 (b) for all the three materials for the two different feed rate with same depth of cut and change in the spindle speed. The results shows that with the increase in the feed rate with same depth of cut the temperature increases. But with the higher spindle speed there is a very less variation of temperature with increase in the feed rate.



(a) **(b)**

Fig. 8 (a) Depth of Cut Vs Temperature for S=350 rpm and F=0.5mm (b) Depth of cut Vs Temperature for S=500 rpm and F=0.5mm

The maximum temperature that was noted during the test was noted and represented graphically in the Fig. 8 (a) and 8 (b) for all the three materials for the two different depth of cut with same feed rate and change in the spindle speed. The results shows that with the increase in the depth of cut and spindle speed the temperature at the cutting interface is more. But with the higher depth of cut there is almost no variation of temperature with increase in the spindle speed.

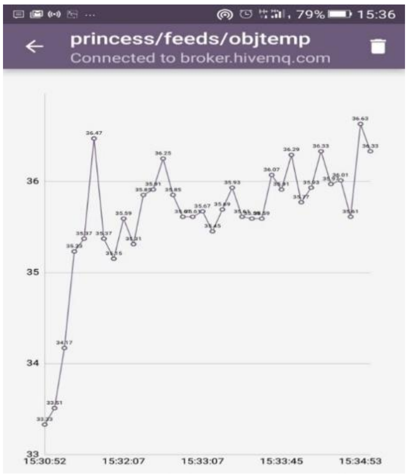


Fig. 9 - Output of Temperature as viewed on Smart Phone as graph

These results show that the cutting parameter that influences the increase in tool temperature is the depth of cut followed by the feed rate and then the spindle speed. This results agrees to the finding in the work by [11]. The operator will be able to view the real time temperature of the tool on the smart phone as a graph as shown in Fig. 9 and based on the observation a rough prediction of the cutting process can be made if the parameters need to be looked into again or no to avoid the rejection due to low quality work.

View 0n Smart Phone	**Measured on the Instrument**
	

Fig. 10 - Output of Surface Roughness as viewed on Smart Phone as graph and measured on Mitutoyo SJ 201

Similarly Fig 10 shows the real time values of surface roughness as observed by the operator on the smart phone and also when measure with the instrument after the turning operation. The model developed gives similar results as that of the surface roughness measured with the instrument after the turning operation.

IV. CONCLUSION

In this paper IoT has been implemented in Auto Component Manufacturing to monitor the surface roughness and temperature of cutting tool. Implementing the same on a smart phone has made it very convenient for the operators to monitor the parameters on real time basis. Surface roughness being one of the most important outputs, monitoring it continuously helps the operator knows how the operation is performing. The system notifies the operator and the shop floor manager immediately when abnormalities are detected during the operation much before it is detected during the quality testing; reducing the loses due to rejection of work piece. The operator has no access to the data base makes the data being accessed secure to certain extend. Only the parameters (MQTT-broker-topic) that are relevant to the operator were fed into the smart phone to access them. The manager or analyst can view the data from any part of the world through secure login into the web based system 24x7. During a turning operation there are a number of rough cuts and one or two finishing cuts. The data available during rough cuts can be used to optimize different parameters of the turning process. During the study same cutting tool was used for the three materials and all the operation, which might not be the case in the shop floor. This difference was not considered during the study, but this can be tackled with separate RFID tags and case selection system in the code for the tool, material, feed rate, speed and depth of cut. Continuous surface roughness measurement guarantees that no product below a defined surface roughness quality level is shipped to the customers. This study demonstrates potential of IoT in Auto Component Manufacturing for improving the monitoring of various machining aspects like surface roughness, vibration, tool life, etc. making it quality controlled, accurate and reliable too

REFERENCES

[1] Diana M.Segura Velandia, Navjot Kaur, WilliamG.Whittow, Paul P. Conway , Andrew A. West, March 2016, Towards industrial internet of things: Crankshaft monitoring, traceability and tracking using RFID, *J. Robotics and Computer-Integrated Manufacturing* Volume 41, p.66–77

[2] Hwa-Cho Yi, Jung Whan Park, 2015, Design and Implementation of an End-of-Life Vehicle Recycling Center based on IoT (Internet of Things) in Korea, *The 22nd CIRP conference on Life Cycle Engineering* 29, p.728 – 733

[3] Fei Tao , Yiwen Wang , Ying Zuo , Haidong Yang , Meng Zhang , 2016, Internet of Things in product life-cycle energy management, *Journal of Industrial Information Integration* 1, p.26–39

[4] S.J. Zhang, S. To, S.J. Wang, Z.W. Zhu, 2015, A review of surface roughness generation in ultra-precision machining, *Int. J. Mach. Tools Manuf*. 91, p.76–95.

[5] M. Subramanian, M. Sakthivel, K. Sooryaprakash, R. Sudhakaran, 2013, Optimization of end mill tool geometry parameters for Al7075-T6 machining operations based on vibration amplitude by response surface methodology, *Measurement* 46(10)

[6] Devillez, D. Dudzinski, 2007, Tool vibration detection with eddy current sensors in machining process and computation of stability lobes using fuzzy classifiers, *Mech.Syst. Signal Process*. 21, p.441–456

[7] M. Thomas , Y. Beauchamp, 2003, Statistical investigation of modal parameters of cutting tools in dry turning, *Int. J. Mach. Tools Manuf* 43, p.1093–1106

[8] O.B. Abouelatta, J. Mádl, 2001, Surface roughness prediction based on cutting parameters and tool vibrations in turning operations, *J. M Process. Technol*. 118, p.269-277

[9] D. Carou, E.M. Rubio, C.H. Lauro, J.P. Davim, 2016, The effect of minimum quantity lubrication in the intermittent turning of magnesium based on vibration signals, .*Measurement*

[10] Swathy. L, Lizy Abraham, July 2014, Vibration Monitoring Using MEMS Digital .Accelerometer with ATmega and .LabVIEW Interface for Space Application, *Int J. of..Innovative Science, Engineering & Technology*, Vol. 1 Issue 5.

[11] Adeel H. Suhail, N. Ismail, S.V. Wong and N.A. Abdul Jalil, 2010, Optimization of Cutting Parameters Based on Surface Roughness and Assistance of Workpiece Surface Temperature in Turning Process, *American J. of Engineering and Applied Sciences* 3 (1): 102-108

[12] S. A. Coker, S. J. Oh, and Y. C. Shirr, 2016, In-Process Monitoring of Surface Roughness Utilizing Ultrasound, *Journal of Manufacturing Science and Engineering, Vol. 120*

[13] PoTsang B. Huang · Huang-Jie Zhang and Yi-Ching Lin, 2017, Development of a Grey online modeling surface roughness monitoring system in end milling operations, *Journal of Intelligent Manufacturing, DOI 10.1007/s10845-017-1361-z*

[14] G. Quintana, M. L. Garcia-Romeu and J. Ciurana, 2009, Surface roughness monitoring application based on artificial neural networks for ball-end milling operations, *Journal of Intelligent Manufacturing, 22:607–617*

[15] S Bagavathiappan, B B Lahiri, S Suresh, J Philip and T Jayakumar, September.2014, Online monitoring of cutting tool temperature during micro-end milling using infrared thermography, *Article in Insight - Non-Destructive Testing and Condition Monitoring*

[16] Marcio Bacci da Silva, James Wallbank, 1999, Cutting temperature: prediction and..measurement methods—a review, *J. Materials Processing Technology* 88, p.195–.202

[17] R. Komanduri, Z.B. Hou, 2001, A review of the experimental techniques for the measurement of heat and .temperatures generated in some manufacturing processes and tribology, *Tribology International* 34, p.653–682

[18] Eleonora Borgia, 2014, The Internet of Things vision: Key features, applications and open issues, *J. Computer Communications*, 54, p.1–31

[19] Dan D. Kooa, John J. Lee, Aleksei Sebastiani, and Jonghoon Kim, (2016) An Internet-of-Things (IoT) system development and implementation for bathroom safety enhancement, *International Conference on Sustainable Design, Engineering and Construction, Procidia Engineering*, 145