Machine Monitoring and Data Analytics for Optimization of Manufacturing and Planning using IIoT

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Abstract

The objective of this work is to develop an Internet of Things based system for monitoring and analyzing the equipment in manufacturing facilities. Nowadays manufacturing shop floor contains different types of machining equipment, each having different registered interfaces and communication procedures. Shop managers find it difficult to monitor and maintain their machines. In order to improve productivity, it is desirable to automate the monitoring and analysis of the equipment. This paper introduces an Internet of Things (IoT) aided real-time machine status monitoring platform. Data regarding machine status is being extracted by an Internet of Things Device. This allows to check the current status of the machine, even from remote locations. A demonstrative case is specified to illustrate the possibility and practicality of the proposed system. This would result in better management of equipment and optimization of manufacturing and planning.

Keywords: Machine connectivity, IoT, CNC Machining, Data Analytics.

1. INTRODUCTION

In today's data driven world, data mining and its analysis is key for any business to survive in competitive market. Today, many industries have several manufacturing facilities located in different regions. It is important that each facility should run at its maximum capacity and productivity to seek competitive advantage. In order to do so, the management must have complete manufacturing data available with them in real time. This can be achieved by establishing a network based system, connecting all the facilities including machines, inventories, manpower, and acquiring and monitoring data. In industry data management is important. Manual collection of data and analysis is time consuming and tedious. In order to run factory at its maximum capacity, data gathering is important, so that management can have all the data for better planning. This work is focused on, data acquisition, analysis and interpretation of the results.

Software systems have been playing a valuable role in manufacturing for a few years. The prospect of connecting devices or objects, while giving them the opportunity to share information related to the surrounding environment, is an additional step in the path of creating effective Cyber- Physical Systems (CPSs) [1]. At present, the continuous growth of Internet of Things (IoT) has made significant progress in information technology. This technique has become an important appliance of economic growth over the world [2, 3]. The Internet of things (IoT) is a network where sensors and actuators can communicate through protocols, be identified, located, tracked, monitored and managed intelligently. IoT targets to connect any type of device to Internet and capture the data [4]. First of all, IoT devices are systematically installed in typical manufacturing sites like shop floors so as to get the real-time information. The Device has its own sensor and controller, which senses and captures the data from the machine. Secondly, the sensed and captured information will be organized by a set of data models which are able to recognize, process, and format the key data into a consistent scheme for further usages such as production planning and scheduling. Thirdly, with the standardized data one can easily visualize the real-time status of operational machines. The real-time status monitoring service not only reflects the current conditions, but also shows the historic data through various graphs such as bars, curves, etc. [5]. To reduce time for data gathering and data analysis it is important to create network between all facilities including machines and inventory. This project is aimed at, transforming conventional factories into intelligent factories, so as to achieve maximized output and flexibility while ensuring the quality requirements are met. A data analysis algorithm processes the real time data in the server and determines the current status of the manufacturing facility [6]. It also, helps in taking smart real-time decision of production planning. This system is scalable and can be extended to include every machine in all the manufacturing facilities of a company irrespective of production layout and facilities available. The data gathered from all machines is stored in a central database, which can be used to evaluate the performance of every facility from an hourly basis to monthly basis. This can be used effectively to identify underperforming facilities and machines and come up with suitable improvements.

This lead to close watch on all process, material flow, machine performance to seek higher OEE, reducing shop floor inventory, improving quality, optimize scheduling and fulfilling customer requirement within time. Next section gives experimental methodology and analytics of the data.

2. EXPERIMENTAL METHODOLOGY

The first step was to develop an IoT architecture for data flow between Machine's CPS and the central database. Next step involved Data analysis on gathered data to predict different states of the machine, its performance, inventory flow and all other possible phases in manufacturing plant and then Performance visualization of the selected machine from the shop floor. The sensor and controller in an IoT device senses and capture the data from the machine. Experiments were carried out on HARDINGE VMC 600II milling machine.There were three IoT devices installed at three different location on the machine: first device was installed outside the machine, second was on the spindle head and third device was on the

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worktable. All the three IoT devices provided vibration data along X, Y and Z direction. The performance was evaluated considering various machine status which are shown in Table 1.

Table 1: Machining Condition

1.	Machine On and Spindle Off (Not Cutting).
2.	Machine On and Spindle On at:- a) N=250 RPM (Air Cutting) b) N=500 RPM (Air Cutting) c) N=1000 RPM (Air Cutting)
3.	Machine On and Spindle On (Actual Cutting) at:- a) N=1500 RPM & Depth of cut = 0.05mm b) N=1500 RPM & Depth of cut = 0.5mm c) N=2500 RPM & Depth of cut = 0.05mm d) N=2500 RPM & Depth of cut = 0.5mm

The data was recorded and saved as a text file, which was then imported to excel. The data included X, Y, and Z Vibration data points. The data was analyzed based on Table 1. The experiments were carried out for a particular time interval as per the data required for analysis.

Fig. 1. HARDINGE VMC 600II milling machine

Following Figure 2 point out the IoT device, which was used to Get the data from the machine and analyze it.

Fig. 2. IoT Device

3. RESULTS AND DISCUSSION

From the recorded data, first analysis was conducted considering Amplitude, which provided the maximum extent of a vibration measured from the position of equilibrium. Following Figures 3, 4 & 5 show the average amplitude data calculated based on the recorded value from all the three IoT devices, considering all the cases mentioned in Table 1.

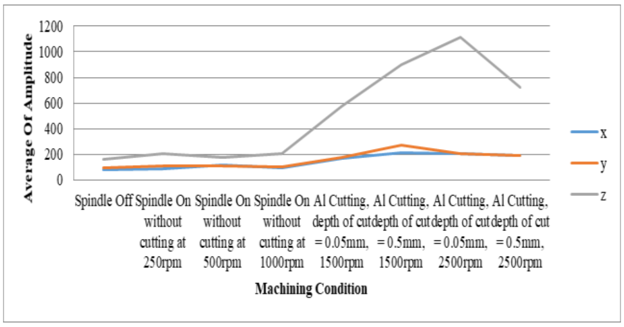

Fig. 3. Average amplitudes at different condition for sensor attached outside machine frame

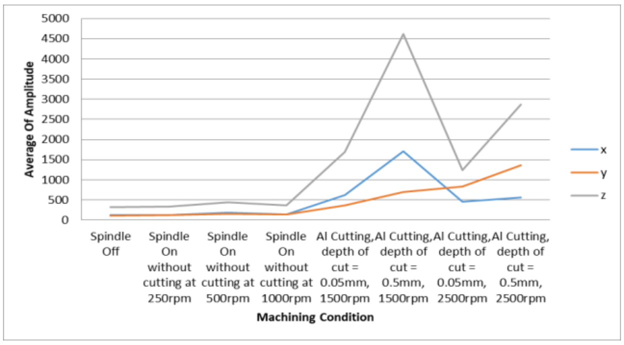

Fig. 4. Average amplitude at different conditions for sensor attached to spindle head

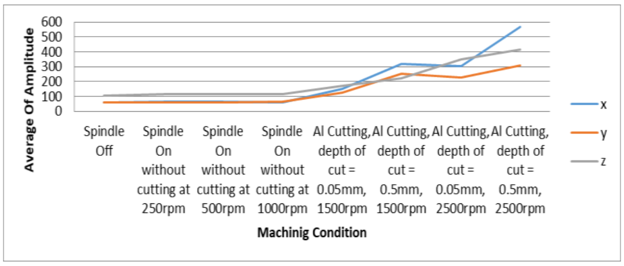

Fig. 5. Average amplitudes at different conditions for sensor attached to work table of machine

From the above figures, it can be observed that there is a significant increase in amplitude level during cutting operation.. Moreover, amplitude level also increased with increase in depth of cut. There was not much change in the data when machining condition was changed from machine off to spindle on. From the figures above, we observed that the IoT device installed at spindle head had more amplitude compared to the rest, so further analysis was done on the data captured from the spindle head to get better results.

Following Figures 6, 7 & 8 include the graph for Machine Off, Spindle On and Cutting On data respectively. In these plots, no. of sampled data point is presented on x-axis and position data in corresponding millivolts (from accelerometer output) is presented on y-axis.

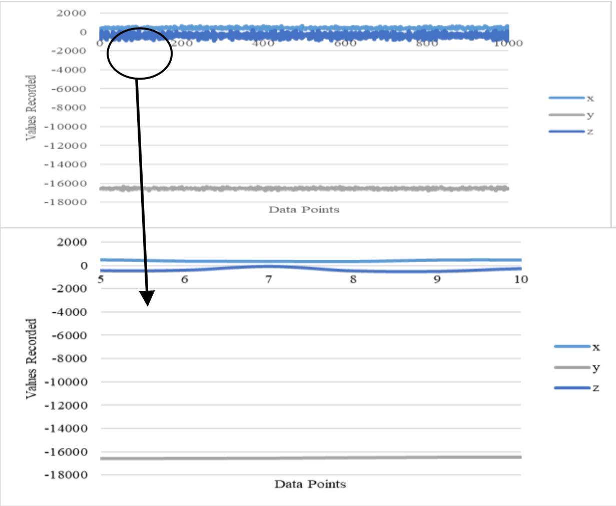

Fig. 6. Data when machine was Off

Overall 1000data points were gathered from the IoT device installed at Spindle Head. It was observed from Fig.6 that when the Machine was Off the vibrations were minimum and thus graph showed almost a straight line.

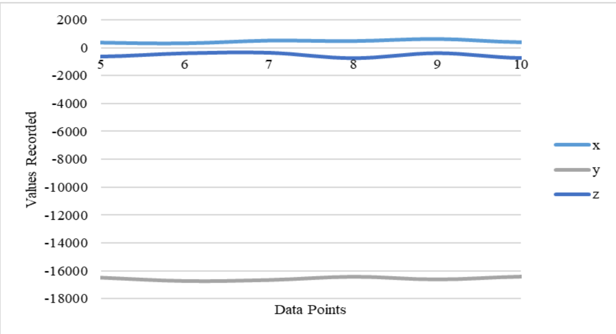

Fig. 7. Data when Spindle was on

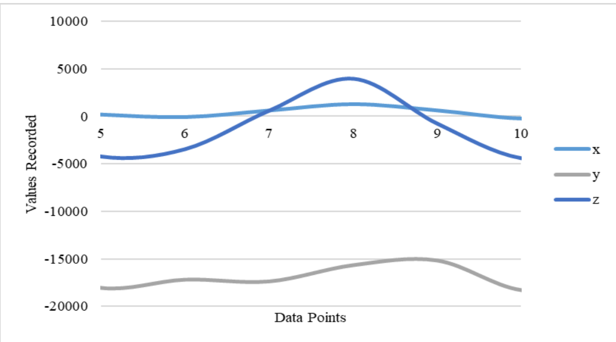

Fig. 8. Data when Cutting was on

Fig.7 shows a slight variation in the data as compared to Fig.6 which indicates that spindle was kept On (Air Cutting). There was not much difference observed in the vibration data in machine Off condition and Spindle On condition. Fig.8 graph showed a tremendous change in the X, Y & Z data which indicated that Cutting Operation was carried out. It is evident that the large amount of vibrations were induced during machining. Conversely we can determine the Cutting On state of the machine from the vibration data. Also it would be possible to predict the duration of Cutting and Non-cutting activities by knowing number of data point and time interval between them.

Figure 9 shows the Standard deviation for each successive 200 data points for position data in Z-direction for all the cases mentioned in Table 1.(Fig.9). The IoT device in this case was attatched to spindle head.

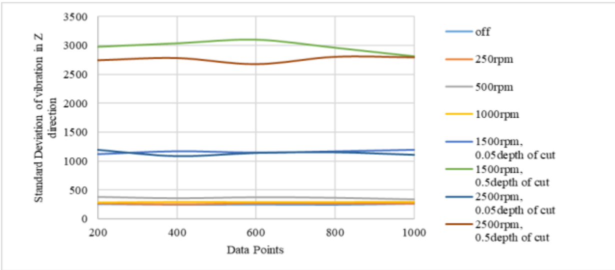

Fig. 9. Standard Deviation

Fig.10 shows the graph which includes comparison between machine Off and Spindle On at 250rpm, 500 rpm and 1000 rpm.

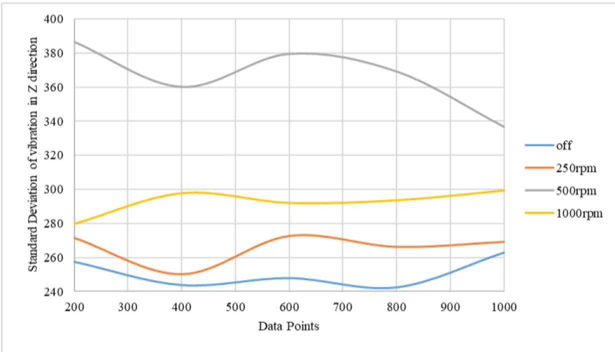

Fig. 10. Standard Devation Graph for Spindle On Data

As the speed of the spindle motor was increased from 250rpm to 500rpm, standard Deviation increased appreciably. Further increase in speed of the motor reduced standard deviation.

Fig.11 shows a comparison between standard deviation for cutting conditions at different speed and depth of cut.

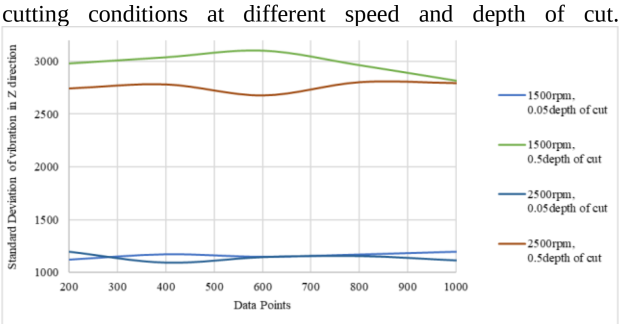

Fig. 11. Standard Devation Graph for Cutting On Data

Figure 11 indicates z-axis cutting values carried at 1500 rpm at 0.05 doc, 1500 rpm at 0.5doc , 2500 rpm at 0.05doc and 2500 rpm at 0.5 doc. There is a little variation when speed was increased, but as the depth of cut was increased, the standard deviation increased appreciably, which implies more vibrations. This shows that depth of cut is proportional to the vibration of the machine. As the depth of cut increases, the vibration of the machine increases. Also depth of cut has more influence on vibration than cutting speed.

Next analysis was done considering RMS values calculated based on the recorded data from the IoT device. From Fig.11 it can be observed that when depth of cut was increased from 0.05mm to 0.5mm there was an increase in Root Mean Square (RMS) value.

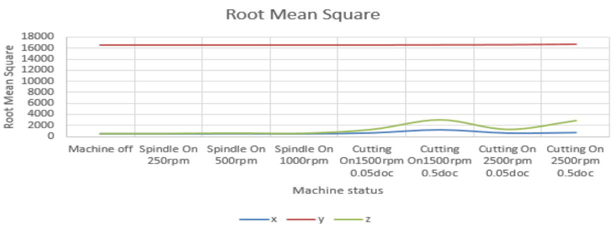

Fig. 12. Root Mean Square at Different Conditions When Sensor is attached to Spindle Head

4. CONCLUSIONS

The outcome of this project would be in the form of a user-friendly web application useful in monitoring the machine performance. Thus, it will result in a substantial increase in the efficiency of the Production, Maintenance, Inventory management, and Quality control outputs. The outputs of data analysis of this project, which are average time between arrivals, average processing time and the average waiting time, can be used to create more complex shop floor models to predict the flow of material in upcoming versions.

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