

# LIMS DATA COLLECTION AND ANALYSIS FOR MACHINING MONITORING

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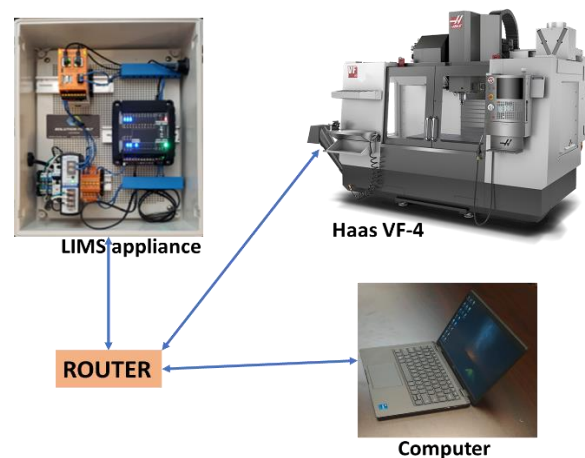
## ABSTRACT

This paper describes the use of a Learning Integrated Manufacturing System (LIMS) appliance for collecting operational data from manufacturing equipment and analyzing the data to monitor process performance. The aim is to optimize operations for the manufacturing facility. A Haas VF-4 CNC milling machine in the Machine Tool Research Center (MTRC) at the University of Tennessee, Knoxville serves as the machine and facility, respectively, for this case study.

## INTRODUCTION

Machining data monitoring, collection, and analysis can be carried out for various reasons, such as minimizing energy consumption [1, 2], where the power usage of the subsystems (e.g., spindle, coolant pump, automatic tool changer, etc.) of a machine are independently analyzed and compared to determine how best to operate the machine. Predictive maintenance of machines can also be improved by identifying degradation more accurately and detecting hidden defects [3]. By monitoring data from acoustic emission, vibration, power, and temperature sensors, for example, manufacturers can detect tool wear, breakage, and chatter [4]. The various techniques for data collection and analysis available to manufacturers today are ultimately geared towards improving environmental, equipment, and economic conditions.

In this study, a router and laptop computer are used to connect a Learning Integrated Manufacturing System (LIMS) appliance to a Haas VF-4 CNC milling machine by creating an ethernet communication network that connects the router, the computer, the LIMS appliance, and the machine. See Fig. 1.



*FIGURE 1. Three ethernet cables connect the router to the Haas VF-4, the LIMS box, and the computer.*

The computer serves as a digital control for accessing data from the machine via MTConnect, through a LIMS software known as Solution Builder®. See Fig. 2. Using Solution Builder®,

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data from the machine can be monitored, collected, and stored in the computer as a CSV file. Solution Builder® also provides various means for data to be exported to cloud servers or monitored via open source cloud-based dashboards, such as Grafana.

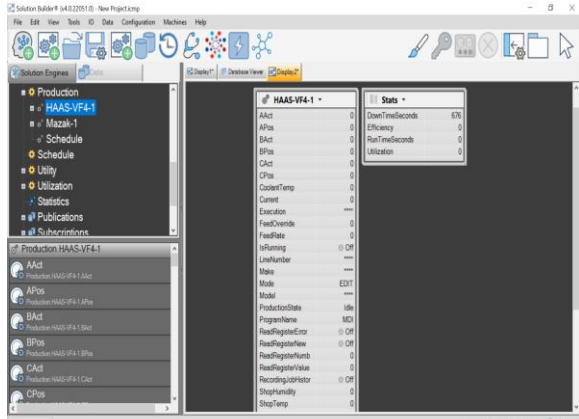


FIGURE 2. Solution Builder® interface showing Haas VF-4 data samples.

It was determined that, for a Haas machine, it is easier to achieve high sampling frequency using a separate data acquisition system than it is to use the MNET communication protocol available with the Haas controller. A desktop application was created to test the Haas MNET interface while monitoring the (X, Y, Z) axis positions. The intent was to determine the highest achievable sampling frequency. The average time from a test of 1000 cycles was 47 ms/read (21.3 Hz sampling rate).

Low sampling frequency machining monitoring using external sensors and controller signals can be achieved on the Haas VF-4 using the LIMS appliance directly. In addition, external sensors can be connected to a separated microcontroller incorporated in the LIMS appliance to collect data at high sampling frequencies. To test a direct connection from the machine to the LIMS appliance, a power sensor (three-phase Rogowski coils) was attached to the three power leads connected to the main circuit breaker in the electrical cabinet of the Haas VF-4 to measure the average current drawn by the machine. To measure the average current of the machine's spindle, the coils were connected to the cables powering the spindle motor only as shown in Fig. 3. The coils were then connected directly to the LIMS appliance. To test a microcontroller-enhanced connection, a Raspberry Pi PICO

microcontroller, with sampling frequencies up to 500 kHz, was used.

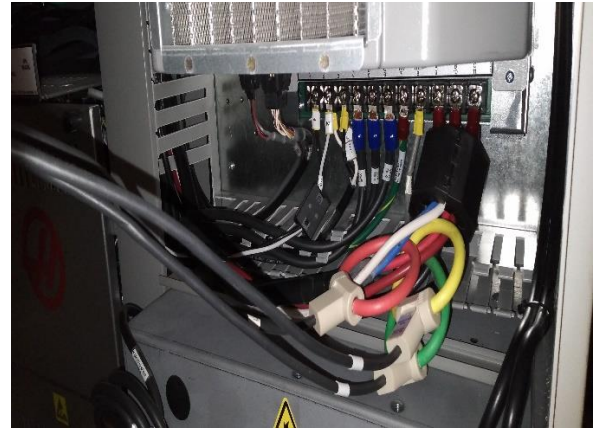


FIGURE 3. Three-phase Rogowski coils (red, yellow, and green) connected to three pairs of cables powering the spindle motor.

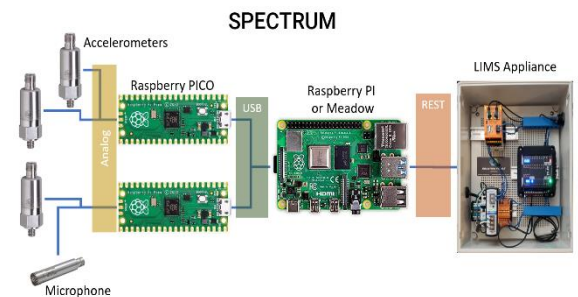


FIGURE 4. SPECTRUM architecture showing component connections.

### SPECTRUM

The microcontroller-enhanced edge computing architecture was selected for a frequency domain evaluation of milling performance, SPECTRUM, which was based on the sensor frequency content. The LIMS appliance is designed around the Raspbian OS (operating system) which provides basic access to I/O (input/output) at minimum sample periods of 100 ms (10 Hz sampling maximum). Monitoring vibration and acoustic signals typically requires higher sampling frequencies (e.g., 50 kHz). A Raspberry Pi PICO microcontroller was selected to serve as the processor for sampling and processing the analog signals from accelerometers and microphones. The Raspberry Pi PICO microcontrollers are capable of sampling up to 500 kHz [5], but the initial sampling rate was set to 50 kHz. The implementation architecture is shown in Fig. 4.



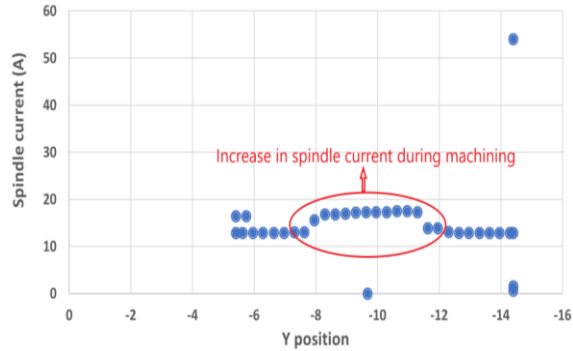


FIGURE 7. Changes in the spindle current with the Y axis position (inches). The cutting time is identified. The spindle speed was 2500 rpm and the feed rate was 508 mm/min.

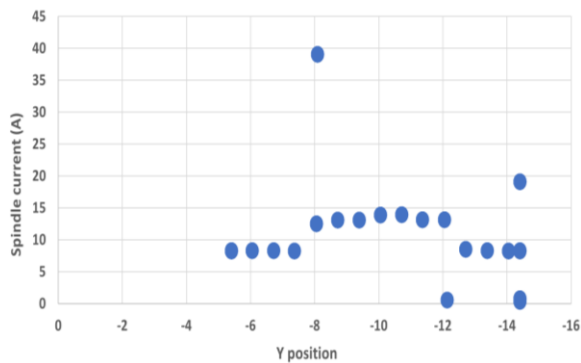


FIGURE 8. Changes in the spindle current with the Y axis position (inches). The cutting time is identified. The spindle speed was 5000 rpm and the feed rate was 1016 mm/min.



FIGURE 9. Grafana dashboard displaying spindle speed and spindle current over a period of 6 hours.

Future work will include new interfaces to enable real-time updating for milling process monitoring. For example, data from the LIMS Solution Builder® software can be monitored via Grafana (a third-party cloud-based visualization web application) as shown in Fig. 9.

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