

Project Design Issues

An average design will meet specifications, but a great design will also take into consideration points that are beyond just functionality. Product Lifecycle Management (PLM) is a process that is used in design that looks at the different stages of a product's life; this helps the engineers focus on ways to further improve the design, such as modifications that account for universal standards and safety requirements. Team 10 has been tasked with creating a system to monitor tool wear on a six-spindle automatic lathe and send this data to the programmable logic controller on the machine. This document will introduce PLM, and the issues of universal design and safety as it pertains to our Tool Condition Monitoring System.

Product Lifecycle Management (PLM)

Product Lifecycle Management considers each aspect of a product's life cycle, from initial conception down to disposal of the product. Each of these aspects can be broken down further to analyze and investigate possible ways to improve the life of the system. Taking into account the following points will ensure that the final design and automation process achieves its goals and the product development stage has been thoroughly completed. This section briefly summarizes PLM in relation to our project regarding tool condition monitoring.

Design

Our design is currently in a prototype phase and therefore does not meet many design standards that are set for sensing devices as determined by institutions such as IEEE. However, if brought to production, meeting these rigorous standards would be necessary. The standards for sensing devices, which include details such as standard testing procedures or surge protection circuits would need to be met in order to provide accurate data readings while maintaining low

liability. This would ultimately affect the design of the system in relation to design and safety requirements of the machine and process being monitored.

Currently our project is targeting a specific machine, tool, and cutting operation. The market desired would have to be considered when designing a new system. The ability to monitor different types of lathe and machine tools offers options and high versatility within the industry. However, this could be expensive to produce, so narrowing the group of target customers would be necessary to keep a reasonably focused company objective.

A big aspect regarding design is the decision to use sensors from other companies or shift efforts to develop in-house sensors. By examining the current market, it is evident that most companies offer complete monitoring systems for purchase. This includes sensors, hardware, displays/interfaces/controllers, and software. Our current prototype takes a general purpose accelerometer and adapts it to our working conditions. However, It would be in our best interests to design a system completely from analog input to digital output. This allows for a competitive edge in the market and consequentially the ability to increase research and development to optimize the effectiveness of tool monitoring.

Just as we continue to test and develop our prototype, extensive testing procedures would be in store for a tool monitoring system developed. This ensures that the highest level of data acquisition accuracy is achieved and every aspect of the product development has been researched. These tests would include quantitative tests as well as durability tests of components such as sensors and cables.

Production Manufacturing cost of the sensing system involves several components. That is, the sensor, connecting hardware, circuitry, and interfaces. The decision would have to be made whether to manufacture in house or choose separate companies to manufacture components. Initially, will be necessary to buy parts from other suppliers to build the tool monitoring system, including custom components like PCBs. However, in the future it may be

beneficial to manufacture our own parts because it becomes less expensive in high volumes. This will depend significantly on the future applications of our product, as the market for tool monitoring systems is relatively small. Estimating these costs accurately is crucial to earning a profit. The biggest cost would most likely lay within the sensor itself. For our current design project, the majority of the budget was spent on the sensor. This is necessary for a high level of accuracy and durability in the volatile manufacturing environment.

Using high quality materials, especially for the sensor is key to providing a robust system that can withstand harsh environments in machining. To achieve a high accuracy, sensors would need to be carefully produced, paying close attention to inspections to maintain a high level of quality control. End of line (EOL) testing would ensure that parts coming out of manufacturing meet the design specifications. Any parts that fail would be recycled if possible.

Distribution Distribution of sensor systems would primarily occur by mail. This involves all the standard (UPS, FedEx, etc.) distributors and logistics. Coordination between manufacturing and assembly of all components would play an important part in filling orders for customers. This requires having constant records and numbers pertaining to inventory of parts, order requests for manufacturing components, pricing information, and customer needs.

Alternatively, we could offer professional installation instead of allowing customers to equip and configure their machines with the tool monitoring systems themselves. Offering professional installation and setup ensures quality control and maintains excellent customer service. It also eliminates the need to keep track of orders and components on the customer's end, because there would no need to ship systems directly.

Consumption/Maintenance The monitoring system would require some sort of operator training. This could be performed during time of installation or offered through classes. Full documentation would also be available to customers. The main points an operator would be responsible for are: correct usage of the monitoring system, reading and interpreting data, inspecting the system for errors and faulty equipment, sensor mounting procedures, and

configuration/calibration for new tools. Ease of use and functionality is an important goal we are trying to achieve in our system, given the requirement that a person with a high school diploma should be able to operate it.

This system would be a low-maintenance unit. Assuming the system was installed correctly, there should be no physical wear to the components. Using a sensor designed for harsh environments would result in extensive life. Since the power supply and all other hardware would be mounted outside the machine, the longevity of these units are high. The sensor would need to be calibrated on an annual (minimum) basis, to ensure accuracy of measurements. Upgrades could be offered in the form of higher power sensing units and monitoring interfaces that have extended capabilities. For example, for CNC applications, the monitoring system might have the ability to switch or stop the machining process.

Retirement As previously mentioned, because this is a low maintenance system, the lifetime of the system would be for many years. With the only real maintenance needed in calibration, there are no distinct reasons why the lifecycle of the monitoring system should end prematurely, provided the customer takes good care of the components.

Customer support for all systems would be offered, and lifetime warranties on components would increase customer satisfaction and promote customer loyalty. Current sensor monitoring systems are ideal in the fact that they are built for longevity. There are several companies that offer sensor refurbishing, recalibration, and recycling. Offering this service directly would allow for customers to choose to use new sensors, or opt for a cost-friendly option in a refurbished certified unit. It is recommended that sensors and units be recycled. However, some components such as faulty PCBs or cables would need to be scrapped from time to time. This would be done in accordance with EPA standards and typical disposal requirements.

Universal Design Principles (Standards)

Our project must consider many universal design principles should it be put on the market for sale. Major areas include compatibility with various automated machinery, ease of installation, and communication with the host Programmable Logic Controller.

One major universal design consideration is the adaptability of our system to be applied to other various machining equipment. We chose to use a generic industrial grade accelerometer in our design to be applicable to many different machines. While firmware will change from machine to machine in order to interpret data correctly, the design will be able perform well without major hardware changes. Choosing to use a programmable bandpass filter allows for a wide range of vibration frequencies to look for as a cutting tool ages. This allows for the system to be easily calibrated for different machines and cutting operations. With the programmable filter, given enough data and measurements taken as a tool ages, it can be honed in on picking up and detecting the amplitudes of a wide range of frequency bands.

To further increase the adaptability of our system, the cable used to interface with the Programmable Logic Controller that controls automated machinery is an industry standard cable. Our output signal of 0 – 10 volts is a standard voltage output of many sensing elements that communicate with such Programmable Logic Controllers. The type of connector used will be able to interface with most of the PLCs used in the field.

Another important universal design consideration is the ease of installation. We were given the requirement that a machine operator with a high school diploma should be able to easily and successfully install the device on a machine. The accelerometer used has many different mounting options. These include bolting the meter to a part of the tool post, using epoxy, and magnetic mounting. Using these various methods makes the sensor easily mountable on many different types of machines or on lathes with different types of cutting tools. The ease of installation is a major requirement for such a product.

Liability and Safety

Another issue to consider when designing a sensor used in a complex machine, like the six-spindle screw machine, is the liability of the device and the safety concerns that come with operating it. The machine operator's safety is of utmost concern when dealing with such machines. One has to consider how the sensor might affect the control of the machine in terms of sudden turn off or turn on and the interference with the commands of the PLC.

The six-spindle automatic lathe that the tool monitoring system was designed for requires that an operator program machining parameters such as RPM of the part and the feed rate of the tool. For many industrial applications, a similar distance between the machine and the operator is maintained. The tool condition monitoring sensors will be able to detect problems with the cutting tool of the screw machine and subsequently send a signal to the operator through the Programmable Logic Controller (PLC). This allows the device to stop the machine operation at any time to avoid damage caused by the problem found in the cutting tool. This is where the design robustness of the device introduces liability. Sudden, unexpected shutdowns to the machine are not guaranteed to come without damage to the machine itself or the operator. To minimize the risk, the device should only signal the presence of tool wear or breakage and to give the operator ultimate control over turn-off and turn-on of the machine. This comes at the cost of allowing more dependency on human intervention and decreased machine automation.

Furthermore, the issue of liability and safety extends to the safety of the operator within the environment that the sensor is operating. The system should provide data to the operator about when to change tools or inspect the machine, but the operator should always follow standard safety procedures and make sure the machine is completely off before investigating a problem.

Conclusion

PLM is being used to identify possible issues that could affect how our tool condition monitoring device is used. The Six-Spindle Lathe is already subject to its own safety requirements as well as safety requirements for the workspace in which it is located; the design

of a tool wear monitoring system must also meet these safety requirements. The constraints on the design have been decided and approved by the Sponsor in order to meet these requirements, such as mounting locations and size so the device doesn't interfere with normal operation of the machine. Universal design is important if the design is to be modified to extend to other machines, making the design of higher value. Furthermore, using standard components in the design also allows faulty components to be more easily replaced. Overall, PLM analysis has helped explore options to improve the design from different perspectives.