SYSTEM FOR REAL TIME MONITORING METALWORKING FLUIDS

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Abstract

The paper is focused on describing cutting fluids used in turning, drilling, milling, and grinding operations. It Describes their advantages and disadvantages and methods of maintenance. The automatic measurement system is designed in this article. The system consists of a hardware and software part. The hardware part consists from float shape probe located in the coolant tank. The software part consists of a simple application running in the browser. This system prevents inaccuracies in data acquisition and can work continuously.

Keywords: Real Time Monitoring; Machining; Cutting fluids; Probe

1. Introduction

The importance of cutting environment for metals machining continues to grow and has a significant impact on improving the quality of the surface of the workpiece, tool life and reduce energy consumption [1-4]. Cutting fluids are extensively used to cool and lubricate, flush away chips, and inhibit corrosion during machining operations such as drilling, turning, milling and grinding. [5]. Today, a wide variety of cutting fluids are commercially available. Generally we know four types of cutting fluids [6].

Neat oils consist petroleum or mineral oils that is not dissolve in water. Need oils are generally used for processes such as gear hobbing where cutting speeds and temperatures are low and lubrication and chip evacuation are of utmost importance [8].

Soluble oils are an emulsion composed of fifty to eighty percent oil plus additives that mix with water. Soluble oils or emulsifiable oils are the largest type of fluid used in metalworking. Disadvantages are prone to bacterial formation and low cooling effect [8].

Semisynthetic fluids are similar to soluble oils in that they are emulsions, and similar to synthetic fluids in that they are water-based fluids. However, there is usually 5 to 30% mineral oil emulsified into the water to form a microemulsion. They cool better than soluble oils and lubricants better than synthetic coolants [8].

Synthetic fluids contain no natural oils and offer the benefits of superior cooling. They are also highly resistant to bacteria and typically have double life versus soluble oils. On the downside, they are expensive and inferior lubrication ability usually relegates them to grinding and light duty machining [8].

Depending on the machining operations, properties of the cutting fluid required may be oriented either on cooling, lubricating, or both. The effectiveness of cutting fluid depends on a number of factors, such as types of machining operation, cutting parameters and methods of cutting fluid application [6]. Cutting fluids, specifically the water-soluble types, are all formulated to operate within a certain range of conditions in areas such as concentration, pH, dirt levels, tramp oil, bacteria, and mold. When fluid conditions exceed this range in one or more of these areas, performance problems can develop [7]. It is therefore necessary control the following factors to keep cutting fluids in optimal conditions [8].

Concentration - Water-soluble cutting fluids are typically formulated to operate in a concentration range of 3 to 6%, although concentrations of 10% or higher are not uncommon for heavy-duty applications. Concentration is the most important variable to control. Too low concentration promote corrosion and bacterial formation. Too high concentration can cause skin irritation and foaming [8].

pH - Cutting fluids are typically formulated and buffered to operate in a pH range of approximately 8.5 to 9.5. This is somewhat of a compromise. If the pH ran higher, the fluid would provide excellent ferrous corrosion control, but could have problems in the areas of skin mildness and nonferrous corrosion protection. A lower pH would be good for mildness and nonferrous corrosion control but may cause problems with rancidity control and ferrous corrosion protection. It should be noted that some fluids, especially those used in certain aluminum applications, are formulated with a mix pH in the 7 to 8 range. The pH is also a good, quick indicator of the condition of the fluid. A pH below 8.5 is typically the result of bacterial activity. Additives can be used to increase the pH of a mix. A high pH, greater than 9.5, is generally the result of some form of alkaline contamination, and will affect the mildness of the fluid [11].

Dirt Level - Dirt or total suspended solids (TSS) in a cutting fluid mix include metal chips and grinding wheel grit. Recirculating dirt, whether it is a large quantity of small particles or just one or two large particles, can affect part finishes lead to dirty machines, and clog coolant supply lines. Recirculating metal fines can also lead to rust problems, if they deposit on parts [12].

Tramp oil - The sources of the tramp oil can be hydraulic leaks, way or gear lube leaks, or from lubrication systems that are found on many machines. Tramp oil can be in two forms, free, or emulsified. Free oil is that oil which is not emulsified and basically floats on the top of the mix. Emulsified tramp oil is nonproduct oil, which is either chemically or mechanically emulsified into the product. Free oil can generally be removed by skimmers or belts, while emulsified tramp is much more difficult to remove, even with a centrifuge or a coalescer. Generally, high tramp oil levels will affect a product's cleanliness, filterability, mildness, corrosion and rancidity control [13].

When a metalworking fluid management program is in place, the fluctuation in this variable (correct fluid, concentration, pH, dirt volume, tramp oil, etc.) is reduced and more consistent quality parts can be produced [10]. Properly controlled fluids do not need to be dumped as often. This eliminates costs associated with machine downtime, disposal, and new fluid purchase [9].

Generally diagnostic of cutting fluids can be divided into two categories.

Laboratory testing Many plants will have a set of laboratory screening criteria that a cutting fluids must pass before it can move any further into the plant. Tests such as lubricity corrosion control, and rancidity control are some of the many performance procedures used to screen cutting fluids. Several tests are typically chosen that are known to be key to the success of the product in a particular operation. For example, on cast iron machining applications, a corrosion test using cast iron chips is a typical laboratory evaluation [14-20].

In- Plant testing The most important item in in- plant testing is to establish measurable parameters before the testing begins. With refractometer check cutting fluid concentration. pH test strip or probe is used for finding correct pH value and etc. This values can be capture manually or automatically with real- time monitoring systems. This is the first step in fluid management. It is now necessary to control and maintain that fluid in the work environment to achieve optimum long-term performance [19,20].

2. Design of monitoring system

A monitoring system for automatic collection properties of cutting fluids data is designed. Based on the previous research we are selected the most important characteristics that will be monitored. The system record properties like pH, coolant concentrate, temperature and amount of cutting fluid in the machine sump. Based on this information, the operator or person responsible for fluids can effectively and simple monitor the condition of the cutting fluid. It is also possible to top up the missing volume of cutting fluid or decide to start over with new cooling fluid on the basis of this information. In this way, errors caused by manual fluid control are eliminated (for example wrong read concentration). In this way, errors caused by manual fluid read are eliminated (for example wrong concentration reading). The monitoring system consist of hardware and software part. The hardware part consists a probe placed in the machine sump, which automatically reads the selected properties using built-in sensors. The software part consists of an application that displays

the measured properties of the cutting fluid. Communication between the hardware and software parts is provided via internet network.

2.1 Probe

The float shape probe is located in the coolant tank. The probe swims on the top of cutting fluids and records following data. **Concentration ratio** - with a built-in digital refractometer. The probe for measuring consists of a stainless steel sensing head. The refractometer measuring range is from 0-70% cutting emulsion. Measuring accuracy of this refractometer is 0.2% with automatic temperature compensation. This sensor is located at the bottom of the device. **pH** - with a built-in nonglass ISFET probe. The measuring range is from 2-12. Accuracy is +/- 0.1 pH units. This sensor is located at the side of the device. **Temperature** - for temperature reading is an NTC thermistor used. **Cutting fluid level** - Cutting fluid level with built-in distance optical sensor RFD 77402. This sensor has a wide measuring range from 5 to 200cm. This sensor is located at the top of the device. The sensor works oppositely. Measures the distance from the probe to the top of the machine reservoir. It can determine the amount of liquid in the tank by defining the total tank height. All sensors are shown in Fig. 1.

Fig. 1. Probe for collecting information about cutting fluids

The probe uses a built-in 1450mAh battery as a power source. The most important part of the probe is an electrical circuit containing an energy-efficient soc esp 32, components needed for power management and I/O peripherals to the individual sensors. The esp 32 is made in Espressif and it is a programmable chip. A prototype of the controlling program was written in the Arduino IDE console. The program manages the collection and evaluation of data and ensures communication between the probe and the application. The MQTT protocol for IoT devices is used for communication between the probe and the application. Wireless charging technology is used to charge the device. The QI coil for the charge is located at the bottom of the probe. PDS used in the probe is shown in Fig. 2. A detailed electrical schematic of the device is shown in Fig. 3. The schematic and circuit board were created using Eagle software.

Fig. 2. PCB used in the probe

Fig. 3. Schematic diagram

2.2 Software

The software developed for the probe is a simple tool for managing, viewing and evaluating measured data. Software is basically a web application that can run on your phone, tablet, or computer via a web browser. After logging into the application, the user can view home page with machines equipped with a monitoring system. For each machine, the type of cutting fluid used, the current state of the measured parameters and the condition of the cutting fluid are shown. On the home page, you can add or remove machines in the settings section. In Figure 4, machine park in the Centre of Excellence of 5-axis Machining at the Faculty of Materials Science and Technology in Trnava is shown.

Fig. 4. Home page showing information about the machine in the workshop

After clicking the "More Information" button on any of the machines will display detailed information about using cutting fluid. This page is shown in Fig. 5. This page is divided into four basic part. The first part shows basic information about used cutting fluid and their fill and expiration date. The second part called "Actual data" shows information about the actual measured values of the monitored cutting liquid. The third part called "History" shows a graphical overview of

the monitored values in the past. The entire historical overview can be clearly divided into smaller time slots such as months, weeks, days, and so on. The selected period can be exported to a spreadsheet or as a photo. In the last section with the name "Settings", it is possible to edit maximum and minimum boundaries for each monitored property. It is also possible to select the method of treating used cutting fluid. When selecting "manual", the system only monitors the individual quantities and alerts the operator when the limits are exceeded (if the Notification box is selected). When it is selected automatic mode, the system itself is able to take corrective action like top-up concentrate or top-up Additives like pH (automatic regulation requires a control unit that has not yet been created). You can also save the selected setting.

Fig. 5. Page with detailed information about cutting fluid used in specific machine

3. Conclusion

The article contains a summary of the cutting fluids used in the machine workshop. It describes their advantages and disadvantages and methods of maintenance. Regular maintenance of cutting fluids extends their life. The maintenance process can be divided into the monitoring of selected properties (concentrate, pH, dirt level and etc) and the process of treatment of cutting fluids (top-up emulsion, cleaning the machine sump and etc). So far, in most cases, diagnostics have been performed manually using a hand refractometer, test pH strips, and etc. The automatic measurement system was designed in this article. The system consists of a hardware and software part. The hardware part consists from float shape probe located in the coolant tank. The software part consists of a simple application running in the browser. This system prevents inaccuracies in data acquisition and can work continuously. In the future research will be developed the device for automatic mixing and top-up cutting fluids.

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