University of Victoria
Engineering & Computer Science Co-op
Work Term Report
Term Summer 2021

Automated Coolant Delivery System

JS Foster Corp
Victoria, BC, Canada

Patrick Reed
V00904570
Work Term Report #4
Mechanical Engineering
patrickreed@uvic.ca
08/26/2021

In partial fulfillment of the academic requirements of this co-op term

Supervisor's Approval: To be completed by Co-op Employer

This report will be handled by UVic Co-op staff and will be read by one assigned report marker who may be a co-op staff member within the Engineering and Computer Science Co-operative Education Program, or a UVic faculty member or teaching assistant. The report will be retained and available to the student or, subject to the student's right to appeal a grade, held for one year after which it will be deleted.

I approve the release of this report to the University of Victoria for evaluation purposes only.

Signature: ________________ Position: General Manager Date: 08/27/2021

Name (print): Bryce Flug E-Mail: Bflug@jsfoster.ca

For (Company Name): JS Foster Corporation

Table of Contents

Figures & Tables

1. INTRODUCTION

One way for machine shops to increase productivity, extend tool life, and lower overall costs is the use of coolant while machining various materials. Nowadays, almost all CNC machines will have a coolant tank with automatic coolant delivered via either high- or low-pressure pumps. Over time, the coolant levels in the sump drop. This means coolant must be added to the machines frequently for them to perform optimally.

2. PROBLEM

Currently, JS Foster's means of delivering coolant to a machine is by pouring coolant into a bucket, transporting said bucket to a machine by hand, and then dumping it into the machine. This method is extremely time consuming, as most of the machines require several buckets of coolant per day. Each bucket being hauled through the shop comes with a risk of spilling, which can be hazardous for the employees. Another issue with the bucket method, is that it can make it difficult to maintain an optimal coolant concentration level.

The goal of this report is to decide upon the best possible solution to JS Foster's coolant delivery problem.

3. NEEDS & CONSTRAINTS

The main purpose of the coolant delivery system would to be to reduce operation costs of the business, and there are several factors that affect this. Each of the contributing factors, in order of descending impact, are as follows:

- **Time/Money Saved:** Machinist time is valuable and should be spent setting up, or operating machines so they can run continuously, as this is how a machine shop produces income.

- **Initial Costs:** Potential concepts each have their own unique initial set-up costs associated with it, and in section 4. CONCEPTS we will discuss this in detail. Some examples would be, installing water lines, buying dosing equipment, sensors.

- **Fail-safe:** No design is intended to fail; however, the possibility must be investigated. If a coolant delivery system were to fail, the shop could potential become flooded, which would have significant costs associated with it. "Do-it yourself" options will most likely have more risk compared to an off the shelf option, as it will have gone through much more rigorous testing.

- **Maintaining Constant Concentration:** If machines have varying coolant concentrations over time, this can have negative impacts. If the concentration is too high, then we are using excessive coolant (waste). If the concentration is too low, then expensive tooling may wear out faster, which may in turn cause an increase in scrapped parts.

4. CONCEPTS

This section gives an overview of the current means of delivering coolant to the machines, and possible solutions to JS Fosters coolant delivery issue. For the scope of this report, we will be looking into two possibilities for JS Fosters needs; an off the shelf "all-in one" option, or a "do-it yourself" self-designed option. The current method is delivering coolant by means of carrying buckets to individual machines, this is the only method that does not require waterlines to be installed at every machine. The “do-it yourself option” would require a water powered dosing technology with a terminal and sensors to create an automated coolant delivery system. Lastly, we could order a “all-in one” system like that from FlexxCool [1], which performs all the necessary tasks of an automated coolant system and provides beneficial analytics with it.

5.1 Bucket (Current)

Currently, when filling coolant, machinists will go to the coolant filling area with a trolley that can hold 2 buckets at a time. They then fill these buckets and then bring them to their respective machines; this process can be seen in Figure 1.

Figure 1 - Current coolant filling process

Each bucket takes approximately 100 seconds to fill, and it takes 90 seconds to bring the trolley to a machine and back. Therefor it requires 145 seconds per bucket of coolant needed, and the shop requires approximately 25 buckets of coolant per day. This process involves 100% of a machinist’s time while they are filling coolant. So, the total costs to the shop per day for feeling up coolant can be calculated by,

$$Cost\ per\ day = (\#\ of\ Buckets) \times \left(Hourly\ rate\ \left[{}^{\$}/_{hr}\right]\right) \times (Time\ per\ bucket\ [hr])$$

Which gives,

$$Cost\ per\ day = 25 \times \left(40\left[{}^{\$}/_{hr}\right]\right) \times \left(\frac{145}{3600}[hr]\right) = \ 40.28\,{}^{\$}/_{day}$$

Giving a yearly cost of **10,501$**. However, this value does not include the loss of earnings potential due to the machinist not performing tasks which directly earn the company money, and machines not being able to run 24/7 due to lack of coolant. To compensate for the earnings potential loss, we can set the hourly rate of a machinist to be 55$/hr. Now we have a yearly cost of **14,438.86$**. If a general laborer were to be tasked with filling up the coolant on all the machines, then costs could be lowered to **6,563.12$** per year.

Since there are large intervals in between adding coolant, and the concentrations of the added coolant vary in between fills, filling the coolant by buckets is not an accurate means for maintain specific concentrations.

Since adding coolant by bucket is the current method, it has the benefit of not having any initial costs associated with it. Another benefit would be that it has negligible maintenance costs and almost no possibility of flooding the shop.

5.2 Dosatron with Terminal

The "Do-it yourself" method involves purchasing several key components, a dosing mechanism like the D10MZ14 by Dosatron [2], a microcontroller attached to a screen for data processing, and various sensors.

With this method, a float sensor and an electronically actuated water valve must be connected near the sump of each machine. An example of how this could be setup can be seen in Figure 2.

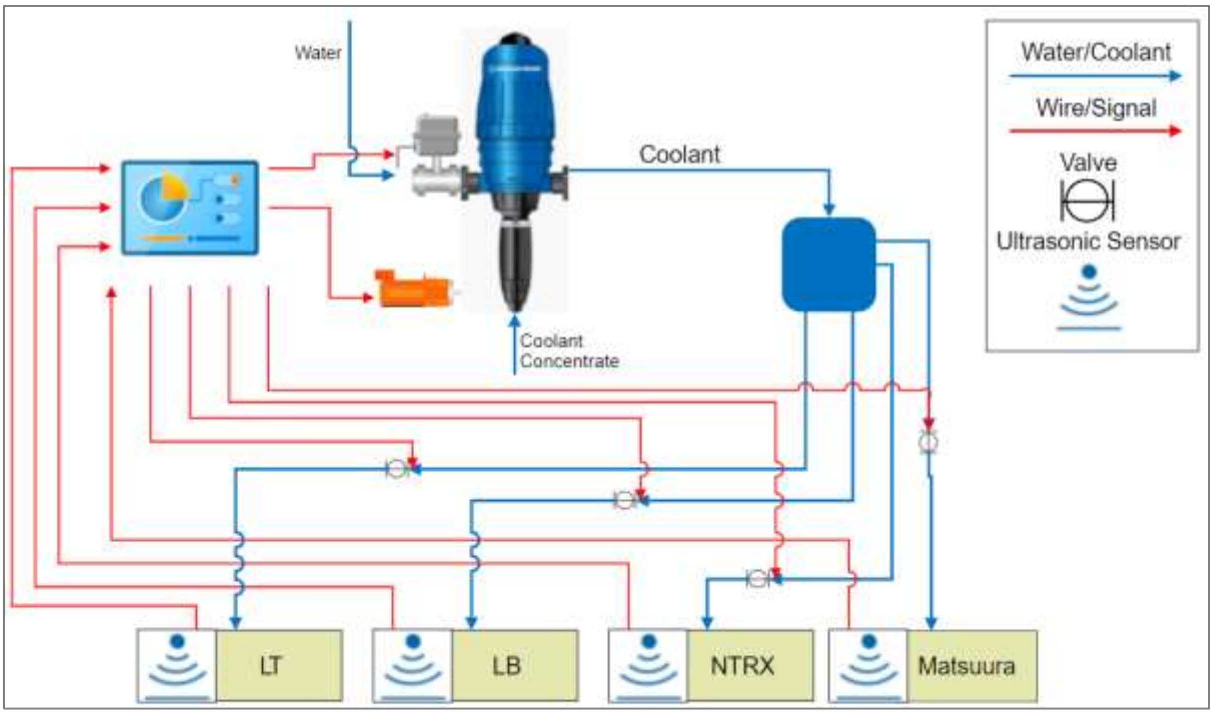

Figure 2 - Dosatron with terminal diagram

There are three main costs associated with this method, the material costs, the implementation costs and installing water lines to each machine.

This method should eliminate hourly costs associated with topping up coolant and the costs of higher initial costs and significant implementation time. The cost of the Dosatron D14MZ10 and the respective industrial plumbing kit are $926.51 US [3]. Assuming the controller would be a repurposed ipad/tablet, we can set the cost around 800$. Ultrasonic level sensors vary in cost, ranging from 300$ to 800$. If this method were to be implemented, further research should be put into determining the ideal sensor, for now we will assume each sensor will cost 550$. Each solenoid valve costs approximately 300$ [4]. So, if we were to implement this method to the four most utilized machines, the LT, LB, NTRX, and Matsuura, we would have a total cost for materials of **CA$ 5,367**.

Implementation costs will mainly be associated with hourly costs of an employee. For this we will give a conservative estimate, as there will be a significant amount of programming and bug fixing involved. With this, we will assume it will require approximately 80 hours of labor for a co-op student at 25$/hr, which gives a cost of **CA$ 2000**. Now considering the material cost, implementation cost and water line installation cost, gives us a total cost of **9,500$**.

This method should work moderately well at maintaining concentration levels in machines, as the coolant added can be set at whatever concentration is determined to be appropriate, but the concentrations at the machines are not actively tracked.

The largest risk potential is associated with this method. If the controller were not to be programmed properly, or a sensor malfunctioned, then the shop would likely become flooded. If this method were to be chosen, determining, and adding extra fail-safe measures would be recommended.

5.3 FlexxCool System

There are several suppliers of "all-in one" systems, but we will be using FlexxCool's system [1] as a representative for these options. If an "all-in one" system was to be implemented, more research should be done prior to choosing the supplier.

With the implementation of FlexxCool's system there would be no manual labor involved with filling coolant afterwards. The only costs associated with this system would be the initial costs and running water lines throughout the shop. After messaging FlexxCool we received a quote for **CA$ 56,417.00** to have the system implemented for all 10 of the shops machines. There were four factors contributing to this quote, these can be seen in Figure 3.

Item & Description	List Price	Qty	Total
19347 **FlexxCool System** PLC control system, dual stage mixing system, I/O for 24 valves & protective enclosure	CA$ 25,997.00	1	CA$ 25,997.00
19327 **4 Valve Manifold** Coolant manifold with 4 valves	CA$ 3,310.00	3	CA$ 9,930.00
17606 **Machine Level Sensor Kit for new systems** Ultrasonic Sensor, Fittings and 25 feet of hose to connect Machine to PVC Pipe & PVC Pipe to Manifold Valves in Flexxcool Cabinet.	CA$ 1,720.00	10	CA$ 17,200.00
Sensor Cable 150 Foot Length - Estimation Cable requirements may change per customer shop layout	CA$ 329.00	10	CA$ 3,290.00
		Sub Total	**CA$ 56,417.00**
		Service Tax	CA$ 0.00
Currency: CAD		**Grand Total**	**CA$ 56,417.00**

Figure 3 - FlexxCool Quote

If we were only to implement this system for our four most utilized machines, we would only need one manifold, four sensor kits and four cable lengths. Thus, we can assume the cost would be approximately **CA$ 37,503**.

FlexxCool's system has multiple fail-safes built in [1] for both the hardware and software which should prevent any potential of flooding. Along with the fail-safes, FlexxCool has various sensors implemented with their system. This allows for beneficial data tracking and notifications of any potential issues or if coolant needs to be ordered.

5. COMPARISON

Since costs, both initial and yearly are the main contributing factor for this project, we will mainly use that when deciding the best concept. We can clearly see that both the methods would be a significant improvement over the bucket method, as the Dosatron would pay for itself within a year, and the FlexxCool system within four.

Now to compare the Dosatron with the FlexxCool system. A few comparisons can be seen in Table 1.

Table 1 - Dosatron Vs. FlexxCool

	Dosatron	FlexxCool
Yearly Cost	0$	0$
Initial Cost	7,367$	37,503$
Fail-proof	Moderate/poor	Excellent
Maintaining Conc.	Moderate	Excellent

Another factor which should be brought into comparison is the data collection of the FlexxCool system. Looking at Table 1, we can see that we must decide how much the extra features are worth with the FlexxCool system, as their product costs roughly 5 times the price of the Dosatron method.

If several fail-safes were added to the Dosatron method, it would be the clear winner. An easy method of adding fail-safes on the hardware side, would be by adding pressure sensors which could then detect any anomalies within the system. Adding software fail-safes would just involve time, so with the pressure sensors costing ~50$ [5] and the time of writing code probably costing 400$, that leaves the Dosatron method as the much cheaper option.

6. RESULTS

Since the Dosatron will not have active coolant concentration tracking, it is important to figure out appropriate concentrations to add to each machine. The reason why we can not add coolant at the desired concentration is because the water evaporates much more quickly than the coolant concentrate. This is likely due to the high-pressure coolant systems vaporizing the water, and/or the coolant heating past the boiling point of water at the tooltip while machining.

To determine the concentration of coolant required by each machine, a two-week study was intended to be performed. The goal for the two weeks was that each time coolant of a known concentration was added, the concentration of the machine was taking before and after. When taking the concentration after adding coolant, a 30-minute waiting period was added to ensure proper mixing of the coolant. However, after one week into the study, several issues with the method of data collection became known. The results from the first week can be seen in APPENDIX A.

The collected data is good for obtaining a general idea of necessary coolant concentrations to be added, but due to several issues, the data likely has a large error associated with it and is not functional for acquiring concrete metrics. Several possible sources of error with the data collection are as follows:

- Coolant not properly mixed
- Difficult to track sump volume while the machine is running
- Unable to track all the coolant being added to the machines
- Machining various materials causes varying results

An important factor to note is that it would take several days of adding coolant to achieve a noticeable change in the coolant concentration of the machine, so in the future once a more consistent means of adding coolant is implemented, then the concentration of the added coolant can be altered until the concentration of the machine coolant stays within a certain range (i.e., vary the coolant concentration added until a status quo is met).

7. IMPLEMENTATION

If the Dosatron method were to be implemented, the following is a list of suggested steps to be taking to integrate the system smoothly:

1. Purchase and install Dosatron.
2. Use to fill buckets at first.
3. Install Terminal, with stepper motor for controlling concentration and solenoid valve.
4. Test terminal functionality/code with buckets as makeshift machine sumps.
5. Add ultrasonic sensor to bucket + test functionality/code.
6. Run waterline and add ultrasonic sensor to singular machine and repeat testing.
7. Add fail-safes/Test fail-safes.
8. Run additional waterlines and add necessary sensors.
9. Test code/functionality.
10. Determine correct concentrations to add to each machine.

An example of step three can be seen in Figure 4.

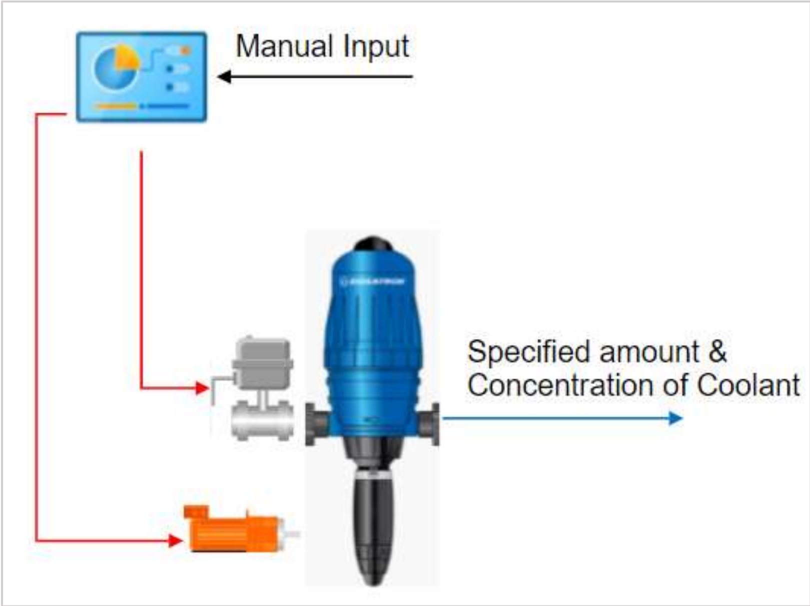

Figure 4 - Step 3 of Dosatron implementation

Once the system is fully implemented then additional features can always be added. The first of which would be a level sensor on the coolant concentrate take that sends a signal to the terminal of when coolant needs to be order. Second, flow sensors can be added to each machine to determine how much coolant each machine is using. Then potentially adding concentration sensors at each machine to allow for more accurate and self-compensating dosing by the automated system.

8. RECOMMENDATION

To satisfy JS Fosters coolant delivery needs, it is recommended that a fully automatic coolant delivery system be developed and implemented using either the Dosatron D14MZ10 or something similar. While such a system is being installed, thorough testing should be performed at several intervals to prevent potential flooding. Once the system is installed and all the functions are operating correctly, then additional features can be added to potential add more cost savings in the future

REFERENCES

[1] FlexxCool, "FlexxCool," [Online]. Available: https://www.flexxcool.com/. [Accessed 20 August 2021].

[2] Dosatron, "Dosatron - Water Powered Dosing Technology," [Online]. Available: https://www.dosatronusa.com/d14mz10. [Accessed 20 August 2021].

[3] Kleen-Rite, "Kleen-Rite Corp," Kleen-Rite, [Online]. Available: https://www.kleen-ritecorp.com/p-35374-dosatron-injector-14gpm-1-100-1-10.aspx. [Accessed 20 August 2020].

[4] Omega, "Omega," Omega Environmental, [Online]. Available: https://www.omega.ca/en/flow-instruments/valves/c/solenoid-valves. [Accessed 20 August 2021].

[5] Grandado, "Grandado," [Online]. Available: https://can.grandado.com/products/pressure-transducer-sensor-5v-0-1-2mpa-oil-fuel-for-gas-water-air?variant=UHJvZHVjdFZhcmlhbnQ6Njk2NDQ1NDc. [Accessed 20 August 2021].

APPENDIX A

Date [month/day/year]		Okuma LT200-MY			NTRX		
		Pre Concentration [%]	Added Volume [gal] / Concentration [%]	Post Concentration [%]	Pre Concentration [%]	Added Volume [gal] / Concentration [%]	Post Concentration [%]
08/03/2021	Morning	9.1	5 / 1.8	9.1	6.0	20 / 2.0	5.0
	Evening	9.5	15 / 0.9	9.2	5.2	10 / 5.3	
08/04/2021	Morning	9.2	10 / 1.5	8.9	7.5	20 / 3.5	5.5
	Evening	9.2	15 / 3.33	8.9	7	15 / 4.0	6.2
08/05/2021	Morning	9			9	25 / 2.7	7
	Evening	9	10 / 0.5	8.8	7.2		
08/06/2021	Morning	9	15 / 0.5		7.8	15 / 1.0	6.5
	Evening	9.2			7.2		
08/09/2021	Morning	9	10 / 0.8	8.9	6.5		
	Evening	9.4			7.5	15 / 1.2	7
08/10/2021	Morning	9.2	10 / 0.2	9	7		
	Evening	9			8		
08/11/2021	Morning	9.4	15 / 0.5	9.1	8.8	25 / 0.7	7
	Evening	9.2			7.5		

Okuma LB3000 EX II			Matsuura MX-330		
Pre Concentration [%]	Added Volume [gal] / Concentration [%]	Post Concentration [%]	Pre Concentration [%]	Added Volume [gal] / Concentration [%]	Post Concentration [%]
9.3	N/A	N/A	6.9		
10	10 / 1.0		6.8		
10.6	N/A	N/A	7		
11.2	15 / 1.33		7		
10.5	10 / 1.0	10	7.2	25 / 5.0	
10.4	10 / 0.5	10	7		
10.4			7.5		
			8		
10			9	30 / 1.0	8.5
10.5	15/1.0	10.3	8		
10.3			7.5		
10			8	25 / 1.2	7.7
10.5			7.8		
10.4			8		