

Building a Filtration and Control System for Auto-Parts Corrosion Oil Immersion System

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Abstract

The purpose of this capstone project was to design and build an immersion system that pumps a rust preventative oil through a filtration system after being applied to protect automotive parts such as camshafts. The system improves a pre-existing immersion system, used by an automotive parts packaging company, that has no filtration means and no control system at all. The new design allows metallic parts, debris, and contaminants to be filtered out keeping the applied oil at a cleaner level. The designed system provides the operator with a feedback on the filters efficiency, using pressure difference across the filter, and recommends maintenance when the pressure drop increases beyond 70% of the initial pressure drop when a new filter is installed. If the filter is not replaced when system maintenance is alerted and the pressure drop keeps increasing, the system will shut off the pump if it crosses 85% pressure drop increase limit. The system was also equipped with an automatic control unit that allows the flow to run ON and OFF which is currently done manually by the company using the system.

This capstone project was conducted by three senior students in the mechanical engineering technology at Purdue Polytechnic, Kokomo location. The project was assessed against ABET learning outcomes and there was significant application and relevance between the students' learning outcomes and the ABET rubrics.

Keywords: filtration, immersion, pressure drop, filtration efficiency, hydraulic capstone.

Introduction

Many automotive parts and components may have bare metal surfaces after industrial manufacturing. Thus, the surfaces should be protected from corrosion during shipping or storage until brought into use or should undergo inter-stage protection prior to any further processing or assembly.

Materials used in the manufacturing of different parts that need to be protected may be ferrous, copper based alloys, aluminum alloys, or other non-ferrous materials.

Many fluids are available that can apply a protective layer on these parts. Sometimes, the temporary protective fluid may perform multiple functions, such as, serving as a lubricant or cleaning fluid. For example, some parts might need to undergo further processing where a lubricant is needed during the formation process, such as during the formation of steel strips. Thus, the fluid

acts as a corrosion preventing fluid and as a lubricant at the same time. On the other hand, the corrosion protection fluid can be used to rinse the machined parts in addition to being used as a protective film for the parts [1].

Material used for corrosion protection can leave a hard or soft film on the manufactured part surface after the protective fluid evaporates [2]. The period of protection ranges from few days to over a year depending on the different characteristics of the protective fluid. Selection of the temporary protective fluid is usually based on the material of the part to be protected, surface finish of the part, time of immersion or application time, application atmosphere or the surrounding environment, and temperature of the surrounding [3].

A current system used by an automotive parts manufacturing and packaging company uses a dip tank to apply Rust-Tek 262 oil based solvent to manufactured camshafts [4]. Any protective fluid that is applied to parts through immersion using a dip tank will experience evaporation, thus, leaving a richer and more concentrated fluid that will tend to deposit an increasingly heavier coating [1]. The current-existing system dumps the used oil after certain period of time and replaces it with new fresh oil despite of the condition and contamination level of the oil or its actual performance in the system. The current system does not have any means for detecting particle concentrations inside the fluid resulting from debris in the surrounding environment or falling out from the parts after being rinsed with the protective fluid. To overcome these shortages, a team of three senior MET students at Purdue Polytechnic, Kokomo location, decided to redesign the system, manufacture and test it. The main objectives were to add a filtration system and a pressure differential that would provide a feedback of the performance of the filter to the user. Other objectives were to add an automatic alert and control means so that the user can perform maintenance to keep the system operating at its optimum conditions. On the learning side, the students covered topics learnt in fluid mechanics, advanced fluid power, and manufacturing in addition to control and measurements techniques. Students' performance were evaluated against ABET learning outcomes, such as, (1) applying knowledge, techniques and skills to engineering technology activities, (2) applying knowledge of mathematics, science, and engineering to engineering technology programs, (3) conducting tests, measurements, calibration and improve processes, (4) problem solving: ability to identify, formulate, and solve engineering problems, (5) effective Communication: ability to communicate effectively, and (6) team work.

Experimental Design and Setup

The existing system uses a dip tank to apply the protective fluid to automotive camshafts through immersion. As mentioned earlier, the evaporation rate would be high due to the usage of a dip tank that can result in a thick and highly concentrated solvent in the tank. This was the main drive behind the design of this system. The main objectives to be achieved by the newly designed product or immersion system are:

- Continuous filtration of ferrous particles coming off from manufactured parts (camshafts), debris and hair from the environment, and particulates from nitrile gloves materials.

- Adding an alert system to recommend system maintenance and fluid replacement after being heavily contaminated, or contaminated to a certain undesirable limit that can be user-defined based on industry recommendations, and not based on the duration of existence in the dip tank.
- Easily accessible and easy maintenance procedures.
- Allows intermittent fluid circulation through the system to allow good contact between the fluid and the manufactured parts.

A primary system layout was thought to mainly include a set of strainers and filters. A pump is needed to circulate the protective fluid through the system. The layout is shown in Figure 1. Two pressure sensors were installed across the filter that would be connected to the alert system. A high pressure drop across the filter would indicate blockage of the filter. If the high pressure differential is triggered, then replacing the filter would be the first maintenance step followed by fluid drainage and to check the contamination level of the oil. A clear pipe section was added after the filter to

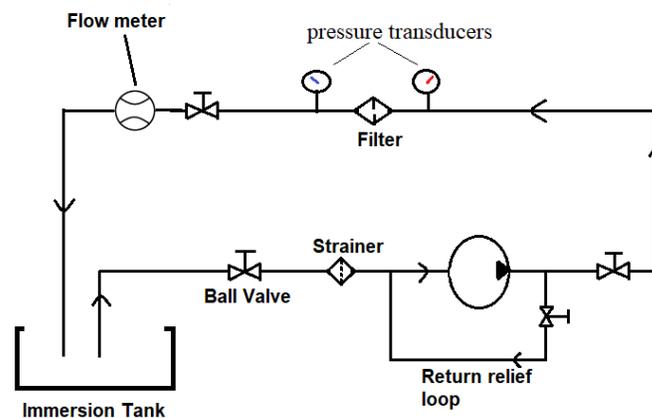


Figure 1. Schematic for the new protective immersion systems

visually check for the qualitative quality of the oil and to check for any significant bubbles formation in the flowing fluid inside the piping system. A flow meter was also added downstream the filter before circulating back to the immersion tank. A bypass line with a glove valve was added around the pump to allow fluid flow control and to relief any excessive pressure on the pump. This would also serve as an auxiliary line if a makeup oil reservoir is to be added in the future.

A stainless steel stand with two shelves was selected to mount the whole system. The upper shelf was used to mount the dip tank whereas the lower level shelf was used to accommodate the pump, control box and any future auxiliary components. The actual assembled system is shown in Figures 4 and 5. The characteristics of each of the main components are summarized below.

Protective Fluid: The fluid should be easily removed from the metal surface after treatment. It should be designed for temporary use and should be easy to remove. Various applications could be thought where the parts need to be protected such as under sun, against radiation fluxes, in a marine environment during shipping or in the presence of specific chemical corrosives in an industrial environment. Solvent and oil based Rust-Tek 262 fluid is used as the corrosion protective fluid. Rust-Tek 262 specifications are shown in Table 1. Rust-Tek 262 was selected by the manufacturer, who uses the existing system, due to its light oily characteristics, flash point temperature of 170 °F, and its ability to stand against high humidity levels and in indoor environments for a period between 12-18 months. This protective fluid can be applied to the manufactured parts through spray, brush, or by immersion.

Table 1. Rust preventative Rust-Tek 262 specifications [4]

Specific Gravity	0.82
Pounds Per Gallon	6.8
Flash Point, °F (TCC)	> 160
Odor	Mild Solvent
Appearance	Amber - Brown Liquid
Humidity Cabinet	60+ days
Film	Very Light Oil

Immersion System: The design selected the immersion type to apply oil to the parts. Since the main product used by the existing system is camshafts, this new design was also designed to accommodate camshafts. Therefore, a dip tank was used in the design of this project. The dip tank was selected based on the size of the camshaft. A sample camshaft was obtained from the company who uses the simple immersion unit without any alert system. The camshaft has a length of 17.52-inch (445 mm) and attached to one of its end is a gear for operating the camshaft once installed. The gear has a diameter of 3.86-inch (98 mm). The camshaft is shown in Figure 2 and the tank is shown in the final assembled product in Figure 4 and Figure 5.



Figure 2. Sample camshaft used in the dip tank

Filtration System: A filtration system was designed as shown in Figure 1 to provide maximum filtration removal efficiency. There are a total of two external filtration units throughout the system. The first unit was a T-line strainer located directly downstream tank exit pipe. The purpose of this preliminary strainer was to filter out major debris such as hair, metal particulates, and dirt to protect the circulation pump from being damaged. This T-line strainer has 316 Stainless Steel Screen, with 50 mesh, and 297 microns. It comes clean in color that help identify the level of contamination qualitatively. The second filtration unit was a Cummins diesel fuel filter (model FF5488) that was used to catch all of the tiny debris and is shown in Figure 3. Pressure gages were installed, during preliminary design, across the filter to check the pressure difference upstream and downstream the filter. At a later stage, the pressure gages were replaced with pressure transducers that were connected to an Arduino to record the instantaneous pressure drop.

Pumping System: To select the pump, the pressure drop in all PVC piping sections, elbows, valves and filters were calculated and found to be approximately 12 psi. The team decided to go with a 120-V, 20 PSI, and 12 gpm fuel transfer vane pump, which is driven by an AC electric motor, to circulate the protective fluid throughout the system. The additional pressure head would ensure proper pumping with high contamination and blockage rate and can accommodate for any additional fixtures to the system in the future. Other reasons for selecting this pump were its ability to pump oil/fuel without any seals' degrading or leakage and its high flow rate which can help rinsing all parts in the tank when performing system maintenance and flushing.



Figure 3. Cummins filter (model FF5488)

Control System: An in-house built PLC unit housed within a 12"×12"×6" waterproof housing was used to control the pump flow, monitor the pressure differential across the filter, and allows provisional space for future system improvements such as particle counter feedback. The main PLC is a Click unit from Automation Direct. It has four digital inputs and four digital outputs. Three of the inputs were connected to three buttons that are housed in a separate enclosure as shown in Figures 4 and 5. The red mushroom-in-shape button is an emergency stop (Estop) that can shut down the system completely at any point in time. The green button activates the system and starts the timers that are programmed in the unit. The red stop button, in the middle between the red mushroom and the green buttons, stops the cycle of the system. Three of the four outputs were used during this phase of the project. One of them fed a red indicator light, another fed a green indicator light, while the third fed a relay that controls an external GFCI outlet. The GFCI outlet is used to control the pump. Timers were programmed and connected to input variable bits to allow the buttons to start and stop the system. A three-minute timer was used as the run time, while another 30 seconds timer was used as the stop time. This would activate the pump for 3 minutes and then shut it off for ½ minute. The ½ minute period allows the flow to settle in the tank since a continuous flow is not required all the time. Anytime when leakage would be detected, the middle red button could be activated to shut the system after completing the 3 minutes run and 30 seconds shutdown cycle. If it is a major leakage or another urgent situation, the mushroom like red button could be activated to halt the system dead and stop any operation to allow immediate intervene. The 4th input port was used by the pressure differential using an output from an Arduino. When a new filter was installed, the system detects and records the pressure drop across the filter. When the pressure drop is 70% higher than its initial value, the red alert light would be lit recommending change of the filter and the oil. If the operator does not change the filter and the pressure drop keeps increasing, the system would shut off the pump completely once the pressure drop is 85% higher than its initial value.

The final assembled product is shown in Figures 4 and 5. Figure 4 shows the whole system labeled, whereas Figure 5 shows the back of the system and the interior of the control box.

To simulate a real system with particles being rinsed and falling down from camshafts, 10 grams of standard ISO particles were injected into the oil dip tank every 6 hours. The system was run for 6 months. Pressure drop was tracked across the filter and will be discussed in the results and discussion section.

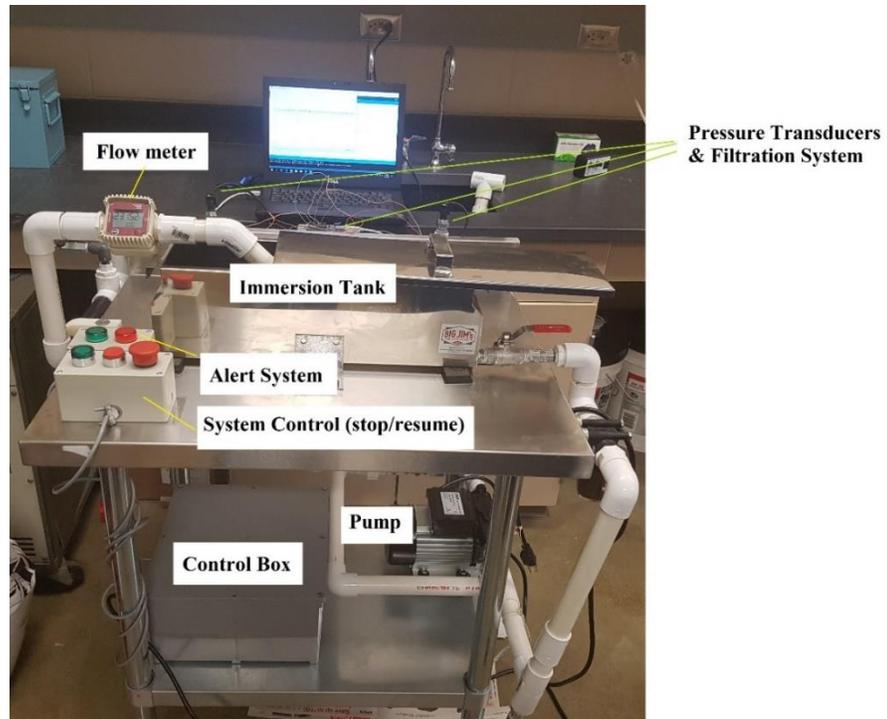


Figure 4. Overall system with all major parts shown

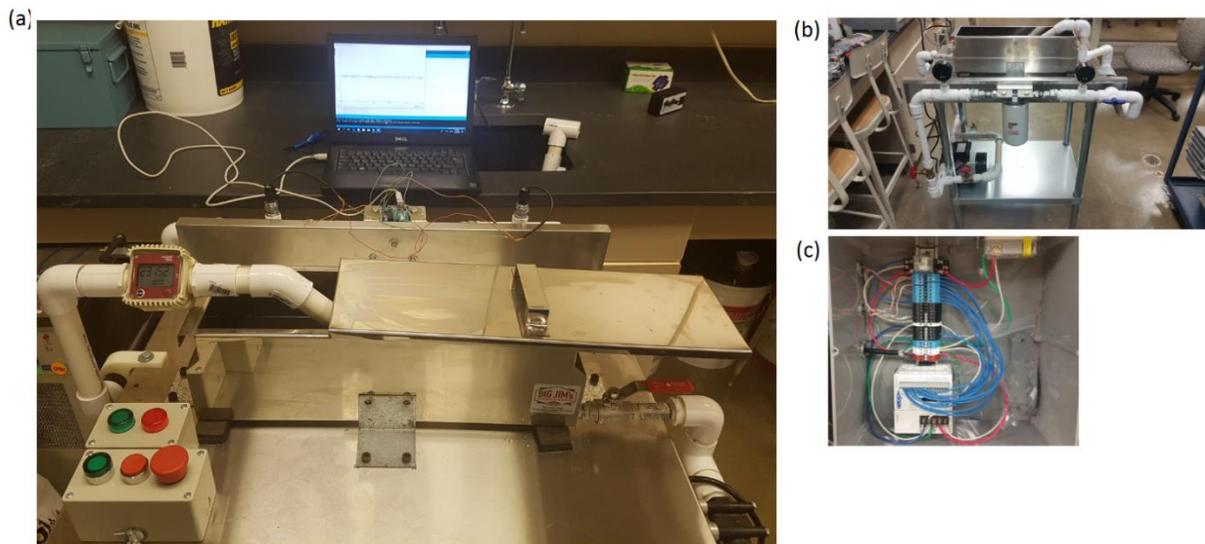


Figure 5. (a) Whole system assembled showing the control box, alarm LEDs, and activation buttons box, (b) back side, (c) inside of the control box

Results

Sample of pressure drop for the intermittent pumping operation (180/30 seconds ON/OFF) for the system is shown in Figure 6. The flowrate is also shown for On/Off operation (right y-axis of Figure 6). Note how the system accurately measured the instantaneous pressure drop and the

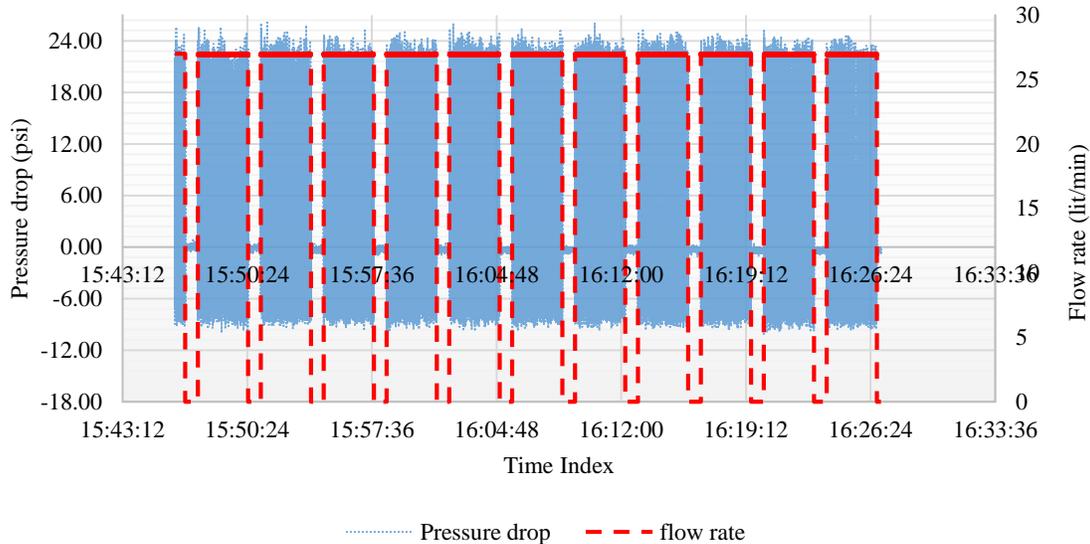


Figure 6. Pressure drop across the filter for 180/30 seconds on/off pump operation and associated flowrate (lit/min)

associated flow rate for each on and off pumping state. This was part of the project objectives which was designing a system that tracks and records the pressure drop across the filter for all pumping flow rates. This would help in providing accurate feedback to the control system.

Discussion

The averages over 15 days for the pressure drop when the pump was operating (ON) were plotted in Figure 7 till the pressure drop hit 70% increase over the initial pressure drop obtained when a new filter was installed. At 70% limit, the red alarm LED light was lit, as shown in Figure 8, warning the user to replace the filter and to perform flushing and maintenance for the system. This would insure that the pumping flow is not affected by the blockage of the filter. Also since the fluids is recommended to be changed, the qualitative cleanness of the oil is expected to be maintained as well. The margin of error associated with the averages of each set of data at a confidence level of 95% is shown along with the averages in Figure 7.

For oil drainage, a ball valve was added to the vertical suction line connected to the pump shown in Figure 4. The drainage valve itself is not shown but it was installed at the bottom of the vertical PVC pipe (right lower side of the figure). To secure accidental opening of this valve, the handle was removed and attached to the pipe which can be installed back anytime the oil need to be drained and flushed.

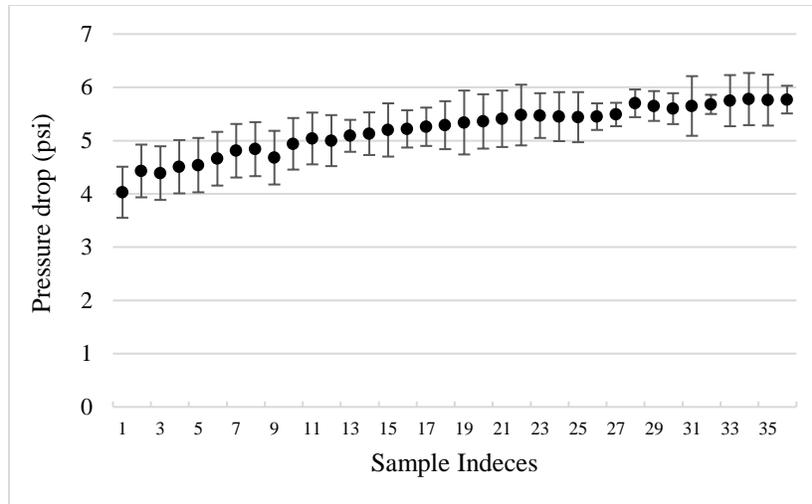


Figure 7. Samples average and margin of errors testing with time index on x-axis representing averages of 15 days

The above shows that the first three objectives were met. The fourth objective, which was achieving intermittent pumping was also met, as shown in Figure 6 and the system accurately tracked the pressure drop.

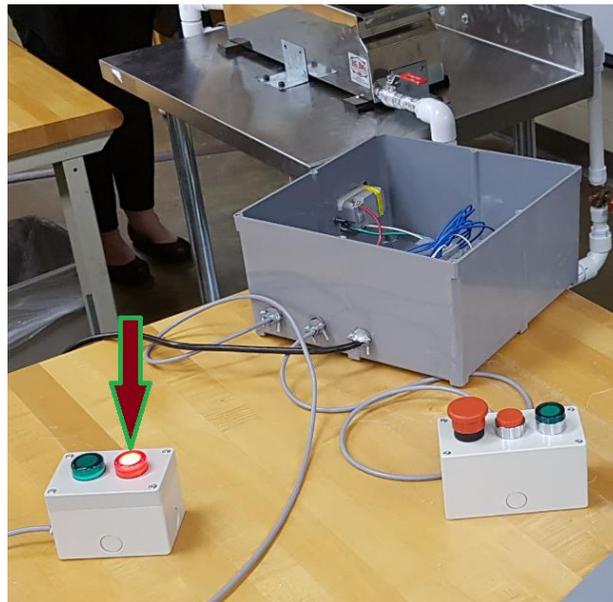


Figure 8. Warning alert light lit after hitting a 70% increase in pressure drop across the filter

Conclusions

This capstone project was conducted by three senior MET students in the School of Engineering Technology at University Name Removed. The project built a new system to update a pre-existing immersion system. The new updated system allows continuous particle filtration through the usage

of a strainer and a filtration system. To keep the system at its optimum performance, an alert system was connected to a pressure differential that measures the pressure drop across the filters. Once the pressure drop crosses a certain limit (70% in this project), a red warning light was lit recommending filter and oil change. The system was allowed to reach to an upper limit pressure drop, beyond which the control unit would shut off the pump. A stop button was also provided which can be used in case of emergency such as leakage.

Temporary Corrosion Protectives are an essential tool in the battle against corrosion and provide the engineer with the opportunity to protect metal components and assemblies with a range of products that are easily removed if required, provide a choice of finishes and methods of application, and a chosen time period for protection. Frequently, the choice of protection is best made holistically, with selection taking into consideration any previous or later processing requirements, and in the light of all circumstances in the use of processing of the item rather than in isolation. Selection of the optimum product or system is often complicated and it is recommended that expert advice be sought before the final choice is made, and users are recommended to discuss potential applications fully with their suppliers.

The team met all the set objectives of the project. Their performance was evaluated against ABET outcomes such as applying math and science to engineering technology, team work, communication skills, and measurements and control.

Future Work

Two future provisions are to be added in the next stages. The first one would be to have a solenoid control valve controlling the flow into the return relief loop. This loop allows better flow control in the system. The other addition is to have an auxiliary oil tank as backup oil and to have the undesired flow from the pump output directed towards it instead of being looped back to the inlet pipe of the pump.

Other future plans include adding a particle counter or a sampling line that would allow studying the level of contamination in the oil downstream the filter and helps in evaluating the system filter performance under various variables. This would be phase II of this project and currently funding proposal are being developed.

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Authors’ Bibliography

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