Comparison of Exchanger Cleaning Technology Platforms & Control Interfaces

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Abstract

Industrial cleaning has historically been a very labor-intensive, dangerous, and often slow process. The rise of sensors and automation, when coupled with updates machine interfaces, has given birth to a new tier of equipment. Cutting-edge systems offer potential increases in productivity and efficiency by incorporating precision movement, and intuitive operation, which can ultimately aid in reducing error. An additional benefit comes in the form of safety, eliminating the need for manual "hand-lancing." Proper indexing of a lancing system on the tube face of a heat exchanger is a source of such error and practical efficiency. The difference in time spent locating a tractor on a heat exchanger with different controls, as well as via automation, will be explored, and conclusions are drawn.

1. Background & Theory

In modern industrial cleaning, hand-lancing was replaced with mechanized systems that require constant operator interaction. These systems, such as the StoneAge ABX-3L, are composed of a pneumatic-based tractor and positioner. The tractor drives the lances into given exchanger tubes, while the positioner locates the tractor across the face of the exchanger. Historically, these systems do not provide feedback on any form.

While the mentioned equipment platforms work, they require the operator to precisely locate the tractor at each incremental tube via a series of levers, an often tedious process. The difficulty of locating a tractor in a position can be extrapolated by the system and environmental variables, including (but not limited to): poor light, cleaning debris, channel head extrusions, and operator fatigue. Most, if not all, of these parameters are nearly impossible to control, and thus the inefficiencies they induce are inherent to any manually-based exchanger cleaning process. The small time losses when locating a tractor between positions are exacerbated when taken in the context of huge exchangers, ultimately costing the contractor or asset owner time and money. In the extreme case, a misaligned tractor can cause significant damage to equipment and stop a job altogether.

To combat the issues previously described, equipment manufacturers are introducing modern controller designs and sensorized systems. This new paradigm of the human-machine interface gives the operator much more control and potentially eliminates the need for constant and decisive interaction. These state-of-the-art platforms are fundamentally rooted in pneumatic-driven tractors, but employ ergonomic joysticks and buttons, while also the ability to "know" their position via motor encoders or similar sensors. This data can be transmitted back to a dedicated computer, which adds logic control to the entire apparatus. The ability to understand and act on position, when coupled with a known heat exchanger geometry, enables a tube face to be "mapped" or automatically indexed.

The goal of this investigation is to compare a traditional tractor system to that of one with the abilities noted above (improved ergonomic control and the ability to "map" a tube face). While there is often speculation of how beneficial such technology can be, there has been little in the way of quantitative comparisons. By running two systems and multiple control interfaces, along with the incorporation of sensors to log motion, the time savings and potential benefits of the new technology can be understood.

2. Procedure

To begin, the test team procured two comparable cleaning platforms: A StoneAge ABX-3L and ABXS-3L, the latter offering a sensor ecosystem with mapping potential as well as electronic valve actuation (compared to purely pneumatic). This suite of sensorized cleaning products belong to the *Sentinel* product line, and thus all operate in harmony. It should be noted that the mapping capability tested in this study is actively under research and development, while the modernized controller used on the ABXS is scheduled to be commercially available. The benefit of using these two particular systems is the normalization of mechanical variables. The ABX is a predecessor to the ABXS, and both employ the same drive motors, belt system, and general mechanical system architecture. The notable differences are found in the integration of sensors within the tractor and positioner (see figure 1). While the sensors on the tractor offer their own inherent benefit, for the purposes of this study, the positioner encoders are of interest. Further information on all sensors and technology found in the ABXS can be found in StoneAge tools product documentation. Additionally, each system has a radically different operator interface, which will be detailed in the following analysis.

To provide additional comparison benefit, the same drive belt, and the corresponding data acquisition system was used throughout the study. Each system was set up on the test exchanger, which was appropriately outfitted with a channel head extension to emulate the difficulty of real-world cleaning examples (along with the use of live water). Three operators were employed to run the manual system, with the following levels of experience:

1. "Very Experienced" – an individual with an exceptional amount of equipment exposure in the industry as an operator and designer. A user very in tune with the peculiarities of an ABX-3L.
2. "Experienced" – an operator with a wealth of experience in the industry, but perhaps not the recent exposure to equipment on such a detailed level.
3. "Novice" – no prior experience operating equipment.

In addition to the quantitative metrics outlined above, user feedback was recorded with respect to the usability and experience of the operation and noted.

The position of the control box (ABX-3L) was held constant for each user, as well as ambient conditions. The data acquisition system was plumed into the motor airlines to monitor the pressure differential across the motor. This location was chosen to allow the time driving the lances to be measured. Anytime the lances are not being driven can be taken as time used to index the system.

When the manual operation of the ABX-3L was completed, the ABXS-3L and associated equipment was set-up on the same exchanger. In this instance, the "experienced" user ran the machine with the new controller, which will be referred to as *Modern Control* in subsequent visual references. Following this run, the fully mapped tube sheet was programmed into the device and run without any X-Y positional input from the user.

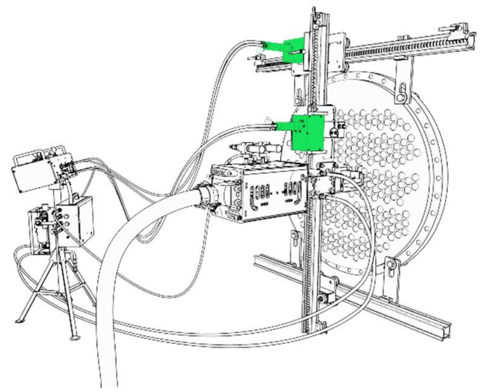

Figure 1: Example ABX mounted on the exchanger. Shaded positioner illustrates where encoders on located on ABXS. Channel head omitted for clarity.

For data logging, a series of simple pressure switches and data acquisition device (DAQ) were used. Two Lefoo LF20 pressure switches acted as a binary indicator of when a tractor was driving lances into the exchanger. The switches were configured in a normally-open (NO) configuration. The result was a 10V high signal when the tractor motor was run in either direction. A LabJack T7 Pro DAQ sampled this analog signal. The LabJack was controlled by a Python script, enabling precise control of sampling rate and data formatting. In an effort to follow best practices for instrumentation, the DAQ was located in a watertight compartment near the system, and a sampling rate of 4 Hz used. The location of the DAQ and simple block diagram can be seen in figures 2 and 3, respectively.

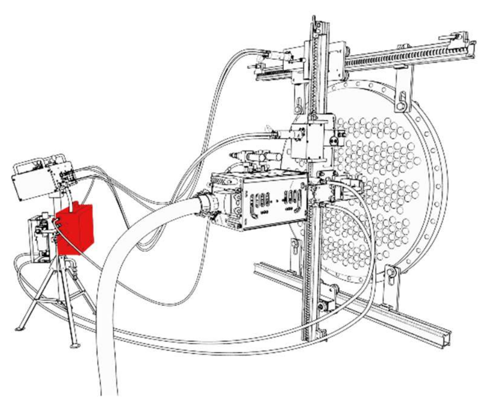

Figure 2: Location of DAQ (shaded, red) with respect to the system.

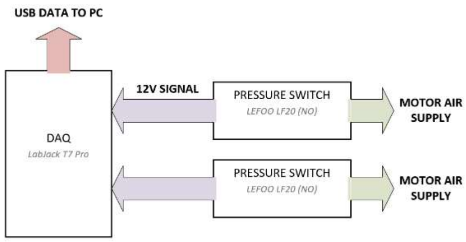

Figure 3: Simple block diagram of pressure switch configuration.

3. Analysis

The overall time spent cleaning, and the frequency of each movement was plotted to understand where the difference in total clean time was rooted. The overall exchanger cleaning times qualitatively look as one would expect from the perspective of traditional cleaning with the most significant improvement being from novice to experienced (figure 4).

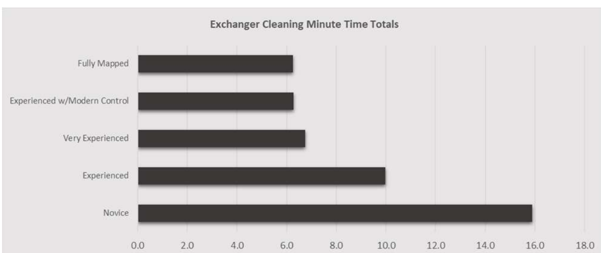

Figure 4: Overall run times of users and systems.

The data also shows how drastic of an improvement the modern controller on the ABXS makes. With this controller, the experienced user was able to reduce their run time significantly, while also gaining the edge on the very experienced user. Additionally, the following feedback was gleaned from the experienced user when comparing the two systems of operation:

"It is possible to focus intensely for a short period; however, this level of focus is not possible for longer jobs, where the difference in controllers, and mapping, would be more apparent. Additionally, the maneuverability and visibility make the ABXS controller far superior."

To understand where this difference comes from, it is worth looking at the specifics of each run. The experienced user on the ABX and ABXS (modern control), as well as the fully mapped ABXS, can be seen in figures 5 – 6. Note the remarkably consistent frequency of the ABXS system in both instances, while the ABX has more erratic behavior, ultimately contributing to the overall longer time epoch.

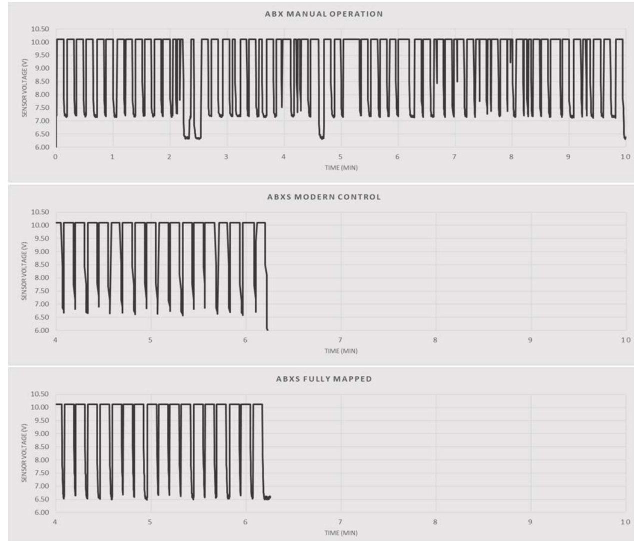

Figure 5: Comparison of an experienced user with a traditional system, Sentinel-based controller, and fully mapped ABXS. The high point of the square wave represents the lances being run via motor, and the low side is the movement of the tractor across the face.

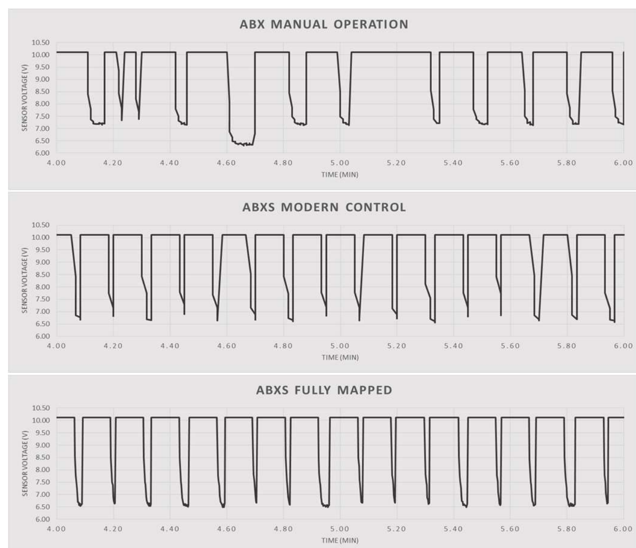

Figure 6: Detailed comparison of an experienced user with a traditional system, Sentinel-based controller, and fully mapped ABXS. Note the consistent frequency of waveform on Sentinel-based systems.

While some of this difference can be attributed to the difference in pneumatic vs. electronic valve actuation, a majority should be accredited to the different operator interfaces. The key differences between operator controls are highlighted in figures 7 – 8.

The ABX levers in figure 7 must be individually controlled by each hand. In contrast, the ABXS controller allows simultaneous control of the system via joysticks and trigger levers. The controller on the ABXS is also much smaller and lighter, allowing the operator to move around and get the best visual line on the exchanger. This is especially important in occluded or stressful situations (such as a channel-head extension).

The overall effect of the modern ABXS controller provides a combination of factors that contribute to the improved speed, as well as a notable lack of fatigue. These differences would only become more drastic with a larger exchanger and overtaxed operator.

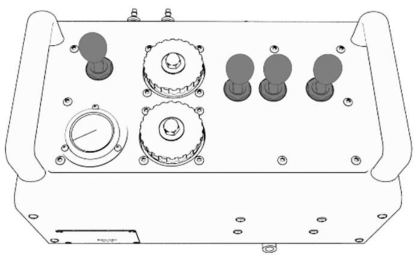

Figure 7: Traditional ABX control, levers are seen in gray.

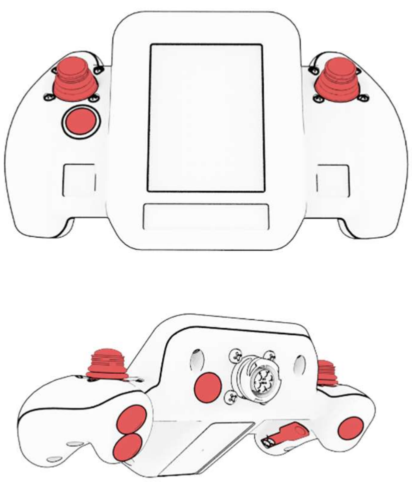

Figure 8: ABXS Sentinel controller with modern controls. Key peripherals are highlighted in red.

4. Conclusion

By setting up two similar platforms, a comparison of the benefit of ergonomic control and sensor technology in heat exchanger cleaning systems was conducted. Data was acquired by means of electronic pressure switches to understand when lances were being driven vs. when the X-Y positioning system was being controlled. The automated system gave precision control, ultimately eliminating the small inefficiencies induced by human operation in the traditional paradigm.

The majority of the benefit, when viewed in the context of the small exchanger tested, was fully realized with the integration of a modern and intuitive controller. Without a doubt, there is a significant improvement to the overall speed of exchanger cleaning, even with an experienced user, with the introduction of the ABXS Sentinel controller. This difference was seen on a small and quick job, and would surely be much more drastic with larger jobs. Additionally, a new operator could potentially have the productivity of an experienced user when operating the system.

Acknowledgments & Further Study

This study could not have been conducted without the support of StoneAge tools with access to a facility, equipment, and test team. The team included Cody Montoya and Jeff Barnes, with support from Cooper Hanley, Dan Szabo, and Brandon French.

While an effort was made to control the experiment as much as possible, there are inherent sources of error. These include motor wear between systems, time of day when the operation took place, electrical noise in the measurement system. These parameters could potentially be corrected in future experiments. Additionally, a more extensive and genuinely fouled exchanger would highlight the differences noted concerning user fatigue and mapping/repeatability benefit.