Thinking Ahead

Controlling hygienic tank cleaning

Using hygienic sensors to monitor tank cleaning

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Tank cleaning is a time-honoured tradition essential for producing high-quality foodstuffs and beverages. Technological advances in tank cleaning have raised the standards for food and beverage processing dramatically; the most drastic changes have occurred within the last 50 years. To ensure the highest standards of hygiene, more rigorous standards and tougher regulations are now in place not only for the tank itself but for tank cleaning equipment.

The improvements to hygiene standards/guidelines are a direct result of equipment users' demand as well as support garnered through organisations, such as the European Hygienic Engineering & Design Group (EHEDG), which share the common aim of promoting hygiene during food and beverage handling, processing and packaging. The guidelines put forth for hygienic design of food and beverage process equipment essentially put all equipment manu-facturers on a level playing field by establishing minimum standards for equipment quality.

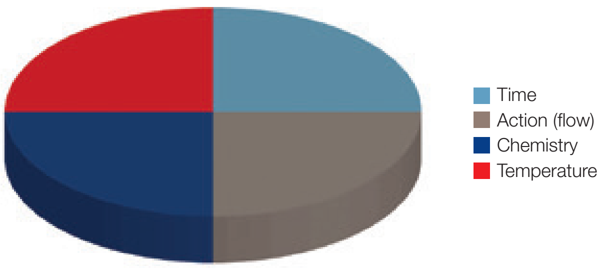
With all equipment being equal, it stands to reason that proper control of the tank cleaning process is the primary way to differentiate equipment based upon the level of cleaning effi-ciency achieved. The objective: to get accurate, reliable and repeatable tank cleaning results after the completion of each production cycle whether continuous process or batch process is used.

There are several ways to achieve the desired tank cleaning results by controlling the tank cleaning process. However, it is important to understand the process of tank cleaning, the various tank cleaning methods and the product contained in the tank before determining the best method of control to achieve optimal cleaning efficiency.

Traditional tank cleaning

There are various parameters that contribute to effective tank cleaning. These are perhaps best described by the “Sinner Circle,” which was developed by chemical engineer Herbert Sinner to illustrate how to obtain good cleaning results.[1] Sinner defined four critical parameters that may be combined in numerous ways and applied to virtually any cleaning task, whether in a pipe, on a floor or in a tank. The parameters are time, action (or flow of cleaning fluid), chemistry and tempera-ture, or TACT for short. All four parameters are important to secure optimal cleaning efficiency; however, how they are combined is decisive in achieving optimal cleaning efficiency.

Figure 1. The Sinner circle illustrating the cleaning parameters of TACT



Herbert Sinner defined four critical parameters – time, action (or flow of cleaning fluid), chemistry and temperature, or TACT for short – which are important to secure optimal cleaning efficiency.

Applying effective chemicals or cleaning agents and optimum temperature to the surface to be cleaned weakens the bond between the soil and the surface to a point where the available force (or action) can remove the soil.[2] The unknown factor is the available force. Time, chemical concentration and temperature can be controlled.

What is the available force, and how is it applied to the surface? This depends upon the method and technology used to distribute the cleaning media in the tank.

One of the oldest methods of tank cleaning, the “fill, boil and dump” approach is still used by many industries for various applications. This simple cleaning method involves filling the tank with water and chemicals and heating its contents to the required temperature. The mixture is kept in the tank for a sufficient amount of time in order to allow the chemicals and temperature to react with the soil. The tank is then emptied or its contents “dumped.” This is a very expensive and time-consuming cleaning method, and the amount of force applied is minimal.

Tank cleaning

Tank cleaning-in-place (tank CIP) is a commonly used cleaning method, which applies force to the tank surface for the removal of soil without having to open and enter the tank. There are three different types of technologies used for cleaning the tank interior:

1. Static spray ball (static cleaning device)
2. Rotary spray head (dynamic cleaning device)
3. Rotary jet head (dynamic cleaning device)

Whilst these technologies are not new, they have been developed and improved over the past 50 years. The technological advances to dynamic cleaning devices in recent years are noteworthy. Some of the technologies have been tested and approved by the EHEDG; however, most of the equipment available today does not have approval from any standards organisation.

All three technologies apply force to the tank surface in different ways and with different degrees of efficiency. The level of efficiency for the different technologies is determined by the impact force (mechanical force) and the shear stress, which significantly differ among the technologies.

Static spray ball

The static spray ball continuously disperses cleaning fluid through each perforated hole from a fixed location in the tank onto a fixed location on the tank surface. As the jets hit the tank surface, they create an area, or footprint, where the impact force and shear stress are active. After impact, the jets change to cascades of cleaning fluid, which run down the sides of the tank, creating a free-falling film. This free-falling film generates shear stress on the interior walls of the tank in an uneven pattern. Here time, chemistry and heat are the decisive factors that determine when the tank is clean. The wall shear stress of the free-falling film is fixed in the range of 1 to 5 Pa, which is comparable to that present in a pipe in which the liquid is pumped at a speed of 1.5 m/s.[3]

Image 1. Alfa Laval Static Spray Ball

The static spray ball gently sprays cleaning fluid onto the tank walls, enabling the fluid to fall freely down the tank wall and provide uneven cleaning coverage.

Rotary spray head

Unlike the static spray ball, the rotary spray head is a dynamic cleaning device. The flow of the cleaning media released from the spray head causes the spray head to rotate. This creates a swirling movement, which enables the fluid to hit the tank surface with an impact force that is higher than the impact force of the static spray ball.

Image 2. Alfa Laval SaniMidget SB Rotary Spray Head

The rotary spray head has a higher impact force and higher wall shear stress compared to the static spray ball. This reduces cleaning time.

The pulsating force and impact created provide a combination of shear stress and variable falling film of cleaning fluid that covers all the internal surfaces of the tank. Compared to the static spray ball, the rotary spray head reduces the amount of cleaning time required to achieve the desired cleaning results.

Rotary jet head

Of the three automated tank CIP technologies, the rotary jet head is by far the most effective because it creates the highest impact force and highest shear stress. The rotary jet head has between one and four cleaning nozzles, each of which disperses cleaning fluid through a well-defined jet. The rotary jet head rotates at a predefined speed to provide a full 360-degree indexed cleaning pattern. This ensures that the tank surfaces are thoroughly covered after a specified interval of time, which is dictated by the actual configuration of the machine.

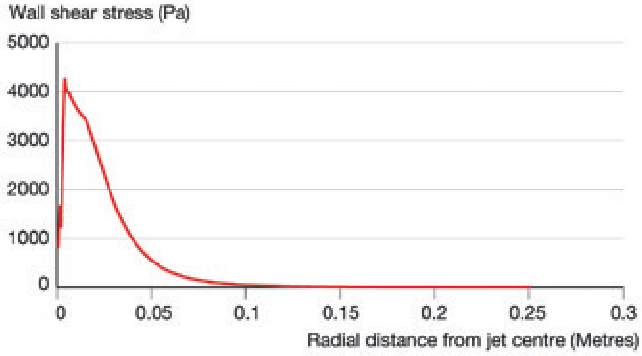
The impact force and subsequent coverage create a footprint that is much larger and wall shear stress that is much higher than that provided by a static spray ball or rotary spray head. The magnitude of the wall shear stress in a rotary jet head footprint is approximately 10^4 Pa and decreases to about 7.5 Pa at approximately 150 mm from the impact centre.[4] This is significantly higher than the wall shear stress of between 1 and 5 Pa in the free-falling film created by a static spray ball.

Image 3. Alfa Laval SaniJet 25 Rotary Jet Head

The rotary jet head is by far the most effective tank cleaning technology available today.

Wall shear stress in footprint creating by impinging jet

Figure 2. Wall shear stress in footprint creating by impinging jet



The wall shear stress in the footprint of an impinging jet from a rotary jet head, with water temperature at 20°C and pressure at 5 bar, is shown.

The water from each jet of the rotary jet head creates a moving footprint on the tank walls in the 360-degree indexed cleaning pattern (as mentioned above). Because of the significantly higher impact force of the rotary jet head and subsequent increase in wall shear stress, it is possible to predict the required cleaning time more accurately when using a rotary jet head.

Chemistry and temperature are therefore no longer the most important parameters for cleaning efficiency. Instead, impact force is the most important parameter. By increasing the impact force on the tank surface, it is possible to reduce the time, flow, chemistry and temperature.

In other words, when using a rotary jet head in most tank CIP scenarios, it is possible to cut the cleaning time required, reduce the amount of cleaning fluids used and realise energy savings because the cleaning fluids do not need to be heated to high temperatures in order to achieve optimal tank cleaning efficiency.

Figure 3 and 4. Comparison of static spray ball and rotary jet head tank cleaning machines

The Sinner circle for tank cleaning with a static spray ball

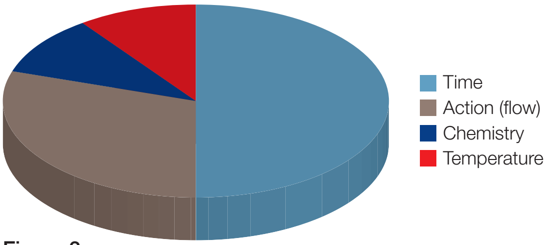


Figure 3.

The Sinner circle for tank cleaning with a rotary jet head

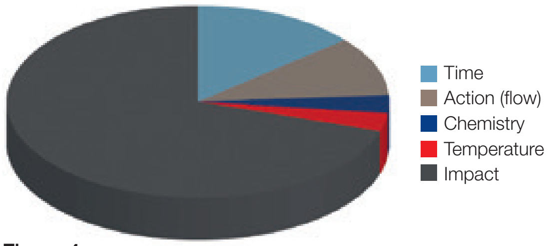


Figure 4.

Adding the impact force of the rotary jet head results in savings in cleaning time, cleaning fluids and energy due to reduced pump running time and less heating time of the tank cleaning fluid.

Reduction of cleaning time by 70% and fluids consumption by 90%

Recent studies[v] indicate how the impact force from a rotary jet head is distributed in the impact area on the tank wall. The highest impact force occurs at the centre of the impact area; it then decreases by approximately 50% at a distance of 40 mm from the centre of the impact area. It is also important to note that the rotary jet head effectively cleans high-viscosity products, such as sticky foodstuffs, using water at ambient temperature in just 15 seconds after the jets hit the tank wall.

In many applications, using a rotary jet head can reduce cleaning time by 50–70% and cut water and cleaning fluid consumption by up to 90% compared to using the conventional fill-boil-dump method or static spray ball technology. It is then easy to understand why so many companies are considering new ways to optimise tank cleaning performance yet maintain control over the tank CIP process.

Ways to control the tank cleaning process

Because uptime is key to production efficiency, optimising tank cleaning performance is critical. It is therefore important to optimise the tank cleaning process to ensure repeatable tank cleaning performance in the shortest possible amount of time.

Although tank CIP systems are automated, these systems still require monitoring and control. Temperature, flow rate and chemical concentration are among the critical tank cleaning process control parameters. However, the performance of the CIP system itself also requires monitoring and control to ensure that it operates according to design parameters. Take the rotary jet head tank cleaning system, for instance; it is important that the rotary jet head clean-ing fluids hit the tank surface with the right impact force in order to ensure optimal cleaning efficiency.

The question remains: Is this possible to ensure validation of the rotation and impact?

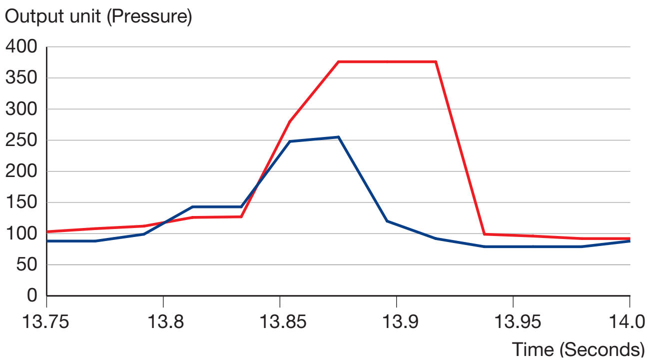
Real-time tank cleaning process control

Process control depends upon reliable real-time in-line measurements using electronic sensors, such as the Rotacheck sensor, to monitor and verify the performance of a rotary jet head and tank CIP. Various such devices are readily available today. However, it is important to consider the response time of the device as well as its ability to register the actual pressure at which the jets hit the tank surface.

Fast response time is critical in order to measure the impact force of the water jets accurately and reliably. A response time of less than 25 milliseconds is considered necessary to register a jet hit against the tank wall; however, the response time for many sensors is too long, exceeding the 25 milliseconds and therefore providing inaccurate measurements. Consequently, the sensors do not measure the entire actual impact and therefore do not properly validate the effect of the jet. Furthermore, the signal remains “high” on the sensor even after the jet has passed and is no longer hitting the sensor.

Registering the actual pressure at which the jet hits the tank surface is equally important. This pressure is the actual impact force that the jet exerts upon the tank surface. If the amount of pressure applied to the tank surface decreases, then the impact force decreases as well. As the pressure decreases so too does cleaning efficiency, which consequently causes the cleaning time to increase.

Figure 5. Jet impact profile of a rotary jet head when passing a Rotacheck sensor



Typical pressure characteristics of a water jet from a rotary jet head at 3 bar and at 5 bar are shown.

Selection of the right CIP process control system

Choosing the right system to monitor and control tank CIP processes can be challenging. It is important to define your objectives for monitoring and control and to understand the available options and advantages.

Basic sensors transmit a simple logic signal to the plant's surface readout (SRO) system or control system, which indicates all jet hits and verifies the operation of the rotary jet head. In addition to signal transmission, some sensors also have a clear visual light signal that is visible to operators on the plant floor. Most are easy to install anywhere on the tank, even on a pressurised tank.

Advanced sensors, such as the Rotacheck+ version which carries the 3-A symbol and has been EHEDG-certified, offer the same advantages as basic sensors but include built-in intelligence. This consists of a teach-in function where the sensor records and stores the unique and actual cleaning pattern for any individual tank cleaning machine based upon its initial cleaning cycle, which has the design parameters (set point) intact.

Every time a CIP process is initiated thereafter, the sensor will compare the actual measurements to the recorded pattern (set point). Operators are immediately alerted during tank CIP if there is any deviation from the initially recorded time, pressure or registration of jet hits. This enables operators to act immediately to remedy the situation, thereby reducing the risk of losing valuable production time.

With the right CIP sensor in place, the process is under control.

Tank CIP process control optimises plant hygiene and efficiency

There are several ways to achieve optimal cleaning efficiency for your tanks. To determine the right tank cleaning method for your process, it is important to define the cleaning criteria, understand the options available and consider the level of cleaning efficiency and process control required. Selecting the right tank cleaning method puts you in control of the tank cleaning process and ensures that the best cleaning results can be achieved in terms of accuracy, reliability and repeatability.

Whilst manual tank cleaning may seem sufficient for some processes, there are advantages to switching to an automated system; these include cleaning consistency, reduced labour costs and increased production time. Enhancing automated tank cleaning processes also has its advantages in terms of less downtime, higher energy savings and reduced water and cleaning fluid consumption.

Image 4. Alfa Laval Rotacheck

Electronic verification tools, such as the Rotacheck and Rotacheck+ sensors, validate the proper function of rotary jet heads during tank cleaning.

The addition of CIP process control systems, whether basic or advanced sensors, can further enhance cleaning efficiency. The only way to validate that an automated tank cleaning system is working effectively is to monitor and verify its performance.

With so much invested in hygienic food and beverage production, the additional expense of hygienic sensors to validate the tank cleaning process seems a small price to pay to ensure the optimal cleaning efficiency.

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About Alfa Laval

Alfa Laval is a leading global provider of specialized products and engineered solutions that help customers heat, cool, separate and transport products such as oil, water, chemicals, beverages, foodstuffs, starch and pharmaceuticals.

Alfa Laval's worldwide organization of 16,300 employees works closely with customers in 100 countries. Listed on the NASDAQ OMX Nordic Exchange, Alfa Laval posted annual sales of approximately 3,45 BEUR in 2013.

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