The quick win - sustainability in tank cleaning applications

Defining the problem

Most businesses these days are considering their impact on the environment. Environmental legislation is here to stay and, likely, is going to get more stringent. Perhaps more importantly, public concern about pollution and global warming is rising meaning the public relations cost of companies that cannot show their green credentials is rising also. This means that the cost of not being environmentally responsible is only going to increase over the coming decades.

The public relations costs of being seen to be not doing one's bit as a company often dwarf the actual fiscal costs of suboptimal energy usage. We now see the relatively modern phenomena of the marketing and PR departments taking an active interest in the efficiencies and waste management practices of their companies. Sustainable and efficient manufacturing processes are no longer the preserve of the bean counters and engineering managers, they now are a marketing and PR issue as well.

As a result, engineers are now receiving edicts from management to cut waste and increase the sustainability profile of the company. Being seen to be green is now a key goal of any manufacturing business. Process engineers are now seeking any way they can to meet their sustainability targets. Of course, water usage is one key metric by which this can be measured. Any savings in water usage are easily convertible to carbon foot print savings. This article looks at methods of optimising tank cleaning systems in order to meet sustainability targets. There are often, as we shall see, some quick wins with regards to efficiencies when it comes to optimising tank cleaning processes.

Sustainable Tank Cleaning

The true cost of water

The true cost of water, both in environmental impact and in fiscal terms, is often under appreciated.

Inlet cost

Firstly, there is the cost of purchasing the water. This cost is going up and will continue to rise as pressure on the world's water systems increase. The cost per m3 of new water to businesses is significant but it's only part of the true cost.

Heating cost

Many applications require water to be heated. This is particularly true in cleaning applications. Water takes 4.2 Kj of energy to heat each litre (Kg) by Co. Its high specific heat capacity means it takes a lot of energy to heat water to the temperatures needed for optimal cleaning.

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Treatment cost treatment

Once the water has been used for a cleaning operation it needs to be disposed of. The cost of disposing of water varies greatly but water used for cleaning operations has particularly high disposal costs. The very nature of the application means the waste water will be dirty and will often contain caustics or solvents used in the cleaning operation.

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are metrics used by the water treatment industry to effectively measure how dirty waste water is. Both measure the oxygen required in reactions to break down the pollutants in the water. The food and dairy industry often have very high BOD levels meaning waster water treatment cost are high per m3.

Chemical cost

The use of alkali caustics to break down oils, fats or greases and acids to break down mineral deposits is common in many tank cleaning systems. These chemicals are not cheap and their usage only adds to the cost of treating the waste water used.

Standard methods of optimisation/energy saving

There are two commonly deployed methods of reducing energy/water usage in tank cleaning systems.

Heat recovery

Many factories produce excess heat in their processes. Good heat management systems can divert waste heat to be used in other applications like cleaning. This "free" heat is a key method in reducing environmental impact and meeting sustainability targets. There is a limit, however, to how much "free" heat is available for cleaning.

Recycle water CIP

Most clean in place (CIP) systems will reuse waste water from previous cleans. The pre-rinse and even main clean can often be performed with dirty water. As long as a final rinse of clean water is used then a hygienic clean can be achieved using mostly soiled water. Of course, there is a limit to how many times cleaning fluid can be recycled in this way. Eventually all the waste liquid will need to be removed from the CIP system.

Other methods of saving

Once heat recovery and water recycling efficiencies have been realised to their full, where next for the environmentally responsible manufacturer?

Optimising the cleaning mix

One still often overlooked saving can be found by optimising the cleaning mix. The basic theory underpinning any cleaning operation is that there are four contributory

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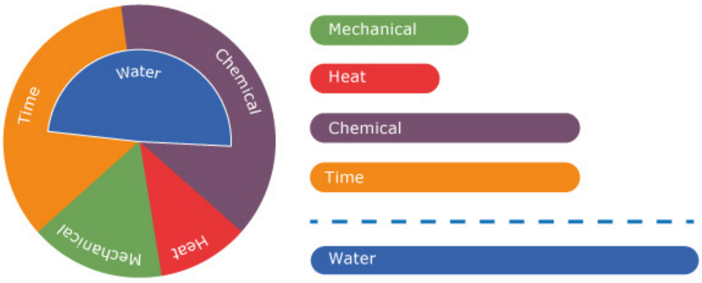
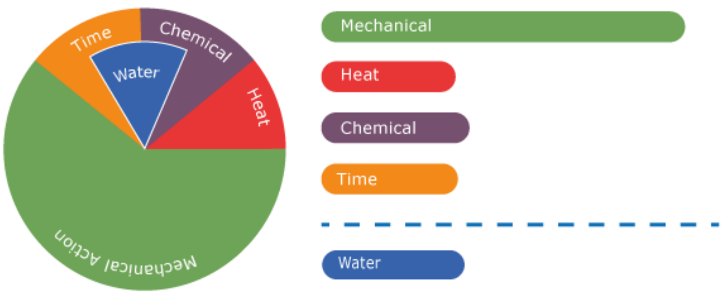
factors in cleaning: heat, time, chemical action and mechanical action. These are represented in a Sinner circle diagram. An increase in one element will mean that the other elements can be reduced without compromising the overall cleaning effectiveness.



Sinner circle for a typical spray ball



Sinner circle for a typical rotary jet cleaner

When looking at this from a sustainability perspective there is a logical choice of which element to increase. Increasing heat, as we have discussed, is only going to increase the environmental costs. Chemical action of course should immediately be seen as a non-starter. Increasing time might seem beneficial but in reality, a time increase in cleaning often means using more water so, again, it's a non-starter if our goal is to improve sustainability. This leaves mechanical action as the obvious "green" candidate to increase.

If we can improve the impact of the cleaning system, then the other elements can be reduced accordingly. This means the same level of cleaning can be achieved with less heat, chemicals, water and possibly in a quicker time too.

Nozzle selection & Mechanical action

When cleaning with fluids the overall mechanical action delivered to the tank wall is dictated by the energy transferred from the pump to the wall. The more efficiently the energy from the pump is transferred to the wall the greater the mechanical action component of the cleaning mix will be.

Nozzle/tank cleaner selection has a great effect on the efficiency of this energy transfer process. With simple spray balls and spinners, most of the potential energy contained within the cleaning fluid is wasted in dispersing the fluid over a wide area. The motion of the liquid between the tank cleaning device and the wall is highly turbulent and dissipated. This has the advantage of spreading out the liquid to cover a wide area but comes at the sacrifice of losing most of the energy available to generate mechanical action. As such, both these styles of tank cleaner have poor mechanical action.

Spinning spray balls fair better than static spray balls and have a modest gain in mechanical action. Matters can be improved by increasing the flow rates by using tank cleaners with larger orifices but, if the goal is sustainability, increasing water usage is clearly counter-productive. Increasing the fluid pressure on such devices is equally futile. Sure, the overall potential energy is increased but, due to the turbulent nature of the flow, this energy is simply wasted i.e. very little of it ends up contributing to the mechanical action component of the clean. Anything much above 2.5 bar fluid pressure supplying spray balls or spinning spray balls is wasted and will do nothing to improve sustainability. Indeed, it will more than likely decrease overall water and energy efficiency.

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Rotary jet cleaners - the green upgrade

The class of tank cleaning heads that can improve mechanical action dramatically are the rotary jet cleaners. These devices produce laminar flow jets which deliver high impact cleaning to each part of the tank as they move through their cleaning cycle. The laminar jet is the key to delivering as much energy as possible from the pump to the tank wall. With this style of cleaner, increasing fluid pressure at the pump means more energy makes it to the tank wall rather than being wasted in generating chaotic and turbulent flow.

The advanced nozzles on these machines mean the fluid stays as a coherent jet for many metres at pressures in excess of 10 bar. Now increasing pressure makes perfect sense from a sustainability perspective. The modest increase in pumping costs to generate this higher pressure is more than compensated for by the sustainability benefits. Because the mechanical action component is so much higher in these machines, chemical action, heat and time can be reduced.

Heat

When swapping to impact cleaning it is unlikely that the temperature of the various wash stages will be reduced. An 80-degree caustic wash will remain at 80 degrees. But, because less fluid will be required to achieve the same cleaning there is simply less to heat, as such the energy cost of heating is reduced dramatically.

Chemical action

Less fluid will be used overall so a corresponding reduction in caustics will occur. The percentage mix of caustics in the fluid will probably remain constant but as less fluid is used overall the amount of chemicals used is far lower. From a sustainability perspective this means less of a cost of water treatment and less of a cost associated with the production of chemicals in the first place.

Time

Another great benefit of rotary jet impact cleaners is that they are very often much faster than other tank cleaning devices. Whilst this does not have any great sustainability benefits it does have some very practical and obvious production benefits for manufactures. Less cleaning time means more production time.

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Cost as a proxy measure for environmental savings

Estimating the carbon foot print savings achieved by moving from less efficient methods of tank cleaning to more modern ones is quite difficult. An approximation of the levels of saving can be made if we use overall cost as proxy measure for environmental impact. This method is not perfect but in the case of tank cleaning it is more or less true that if one reduces cost then sustainability will be increased.

Cost saving calculations

Firstly, the overall water consumption needs to be calculated for each stage of the clean.

Any chemicals used in the caustic stages need to be costed in as well.
The cost of heating the water needs to be calculated. This is straightforward enough using the energy cost to the business in Kwh multiplied by the Kwh needed to raise the water to the desired temperature. This can be modified downwards if heat recovered from another part of the factory is used. So, if 50% of the heat is recovered the overall cost can be halved.

Next the cost of water treatment and disposal needs to be calculated. This will vary greatly depending on the COD and BOD load of the waste water. When water recovery CIP systems are used an estimate of the percentage of recovered water should be made to reduce this cost. So, if only 25% of the overall water used is dumped then this cost can be similarly reduced. This "recovery percentage" can, of course, also be applied to the cost of the initial water and, when caustics are recycled, the cost of chemicals.

Finally, the energy costs required to pump the fluids through each stage of the clean need to be calculated. This can be derived from the wattages of the pump and the time taken. In practice, however, this has a very small effect on overall cost when compared to the other costs. A 2.5Kw pump running for an hour's cleaning cycle only has an energy cost of 35p (at 14p/ Kwh) this is likely less than 5% of the overall cost of cleaning. Any changes in pump duty to a higher pressure, but lower flow rate, are likely to balance out meaning changes in pumping costs will be negligible when compared to the other factors.

When all this is added up together, we get an estimate of the cost of each cleaning cycle. This cost is a reasonable proxy measure for environmental impact.

Example calculations

Spray Ball Cost Per Clean Calculation

Cycle	Cycle Time (min)	Flow rate (l/min)	Cost Of Water	Cost Of Waste Water	°C heated	% of heat recovery	% of water recov-ered	Total cost/m³ water used	Total cost / cycle
Pre rinse	10	314	£1.30	£3.00	0	50%	75%	£1.08	£3.38
Caustic wash	40	314	£1.30	£3.00	60	50%	75%	£5.98	£75.05
Rinse	10	314	£1.30	£3.00	0	50%	75%	£1.08	£3.38
								Total	**£81.80**

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Orbitor Rotary Jet Cleaner Cost Per Clean Calculation

Cycle	Cycle Time (min)	Flow rate (l/min)	Cost Of Water	Cost Of Waste Water	°C heated	% of heat recovery	% of water recov-ered	Total cost/m^3 water used	Total cost / cycle
Pre rinse	10	140	£1.30	£3.00	0	50%	75%	£1.08	£1.51
Caustic wash	20	140	£1.30	£3.00	60	50%	75%	£5.98	£16.73
Rinse	10	140	£1.30	£3.00	0	50%	75%	£1.08	£1.51
								Total	**£19.74**

In the example above current cleaning cycle is performed by and SVSTW 3/4” threaded spray ball running at 314 litres per minute at 2 bar. The cleaning cycle consists of a pre rinse for 10 minutes a caustic clean of 40 minutes and a final rinse of 10 minutes. The caustic clean is at 80 degrees (60 above ambient). It is estimated that 75% of water can be recovered and reused and 50% of the heating can be delivered by heat recovery. The cost of energy is estimated at 14p per Kwh. Fresh water is costed at £1.3 per m^3 and water treatment at £3 per m^3.

This is then compared to a rotary jet cleaner running at 8 bar pressure for example to Orbitor 2 with 6mm nozzles. This has a cleaning cycle of 19.5 minutes and a flow of 140 litres per minute. For pre rinse and rinse cycles a half cleaning cycle can be used on these tank cleaners as complete wetting is still achieved in this time.

As we can see from the above data the cost of each cleaning cycle is reduced by over a factor of 4. One can always argue about the amount of heat and water recovered or the raw cost of power and water, but the basic principle remains solid, the fewer m3 of water used, treated and heated in a cleaning cycle, the lower the environmental impact.

The cost of changing

There will be some initial costs incurred. Spray balls and spinners generally run at around 2 bar pressure. Rotary jet cleaners will operate best at between 8 and 10 bar, so there may be a need to upgrade the CIP pump when swapping over. In terms of flow rates, the rotary jet systems will normally be significantly lower, so the overall cost of pumping (even at the higher pressure) is not going to change that much but there may be a capital expenditure to change the pump to one with a higher maximum pressure.

Rotary jet cleaners themselves are more expensive than spray balls or spinners so that also needs to be considered, again this is a one-off capital expenditure.

Pipework is unlikely to need to be changed. The overall flow rates will generally be lower so the pipework that feeds the existing spray balls or spinners will in almost all cases be enough for the new duty.

Payback

Normally the capex needed to swap over can be paid for within a matter of months. Consider the example above. If we assume a capex of £5000 for a new higher-pressure pump and £3000 to cover the new tank cleaner and fittings, we then have an outlay of £8000 for the new systems. Let's add on £2000 for installation costs for a round £10,000 of capex to swap over to new rotary jet cleaners. If the tank is cleaned once per day, we see a pay back within 161 days so under 6 months. Obviously for sites with multiple tanks all fed by the same CIP system the payback will be much quicker.

Conclusions

Improving the water efficiency of tank cleaning operations can contribute towards an organisation achieving its sustainability targets. In some industries, like dairy, this contribution can be very large whereas in others it is more modest. Spray balls and spinning nozzles are still very commonly deployed which means there is a great opportunity for engineers to meet those sustainability targets. This is a quick and painless win when trying to reduce the environmental footprint of an organisation. The really good news is that the costs of swapping can be quickly paid back and meeting the sustainability targets can also keep the bean counters happy. A win-win situation.