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Recurring Failure of Sodium Shear Pump due to Seal Lubrication Problems.

Introduction-

The front end of a batch process plant consists of a Sodium Dispersion section.

Despite there being intense business pressure to be on schedule with client deliveries, the plant was unable to operate reliably for more than three to four weeks without a breakdown.

This was both extremely disruptive to production and very expensive.

Plant and Machinery details -

The Sodium Dispersion section of a batch chemical production plant consists of an oil heated, jacketed steel vessel with an electric agitator.

There is an oil filling pump to charge the tank at each batch and a steam jacketed oil/sodium dispersion transfer gear pump to move the batch onto the next stage in the process.

The jacketed tank has a re-circulating shear pump piped from a 2” branch at the bottom of the tank and returning the dispersion to the top of the tank at the side.

The oil jacket is temperature controlled at around 120 degrees centigrade.

Once the charged oil is up to temperature, the sodium is added in the form of 1kg bricks through a hole in the top of the tank with a double interlocked safety trapdoor arrangement.

The shear pump is a two stage pump working on the centrifugal principle, but has special features in that as the oil and sodium pass through the pump the sodium is chopped into small particles as it passes through the pump.

The pump re-circulates the oil/sodium dispersion from/to the jacketed tank until the correct quality of dispersion and particle size is reached.

At this point the sodium/oil dispersion is pumped onto the next stage in the batch process and preparation for the next batch starts.

Background Investigation-

It soon became apparent that this client had been running the unit for about 8 years, but had little in the way of detailed information about the unit.

In particular, there was virtually nothing relating to the repeated failures that had occurred over the years.

All that existed was a few mechanical seal assemblies lying in the workshop that were extremely badly choked with carbonised oil residue and burnt oil residue.

In fact, due to the repeated failures occurring there was a good deal of pressure being brought to bear by the sales department who had a very irate client threatening to take away the business. This would cost the site a significant part of its annual sales revenue.

In fact the situation had degenerated to such a degree that the maintenance department and the operations department were each openly blaming each other for the failures.

The only historical information available was from personal recollections.

As it turned out, one vital piece of the jigsaw was recalled correctly and became a crucial factor in solving the problem.

The failures to this system were not easily rectified since there can be considerable hazard when handling metallic sodium contaminated parts.

It often took in excess of a week to get the plant running again after a failure.

This factor in itself made the effect of the failures considerably worse in that the down stream plant needs three batches of sodium dispersion for each batch of end product. So the entire process rapidly ground to a halt when the dispersion unit failed.

Examination of Machinery Parts-

Initially, the investigation centred on the pump itself.

This was where the failures occurred and they were always characterised by heavy carbonising in the bellows of the metal bellows mechanical seal.

The pump itself is a vertical shaft unit with the pump suction at the bottom, the discharge is on the side of the main pump casing near the top.

The motor is coupled to the pump shaft where it exits via the mechanical seal at the top of the pump assembly.

There is a temperature probe intended to measure seal temperature, but the tip of the probe is nowhere near the actual seal faces and is pretty much a waste of time.

From looking at a cross section of the pump you can easily see that the seal will immediately run dry if there is any interruption to the oil flow into the pump at all.

It was discovered during conversation that the tank had never been inspected internally and I was beginning to suspect that blockages were arising in the outlet nozzle.

I was assured that this definitely couldn't be the case since the system was operating well above the melting point of sodium (97.81 degrees centigrade).

Further Investigation-

I drew together a working party consisting of myself, the Plant Manager, Maintenance Engineer, Chemical Engineer, Chemist and Mechanical Seal supplier.

It was clearly obvious that the mechanical seal area of the pump was becoming grossly overheated and carbonising the oil in the seal area.

This was about the only fact that all could agree on at the outset of the meeting.

Having discussed many different scenarios that could lead to this happening, it seemed likely that the seal was being caused to run dry for at least part of the operating cycle.

However, the meeting concluded that there wasn't a clear reason why this should be so.

I proposed and it was agreed to install a data logger attached to a "clip on" ammeter that would read the amps taken by the motor.

Since what ever was happening to the pump should be reflected instantaneously in the current taken by the motor, we could get a good correlation between the ammeter reading and the running of the pump.

During this period I was spending some time talking to the Operators and getting to know how they all operated the unit.

One of the shift teams remembered that years ago they had changed to a cheaper source of sodium. This was to prove a very important fact.

It was apparent that the five shifts had five very different ways of operating the unit.

There was no real sense to how any of the shifts operated the unit, but they all had good though different ideas.

At this stage the following plan was put into action-

1. Draw up a set of operating instructions precisely outlining exactly the way the unit was to be operated, building on the ideas of the operators too for their support.

2. Ensure the operators understood the procedure and that they were not to deviate from it. This point was vital for the data collection to be meaningful.

3. Log timings at every key step in the process and make any observations such as temperatures, levels, noise etc.

4. Start the data logger each time the pump was started.

5. Every morning, investigate the data logged from the previous days operation.

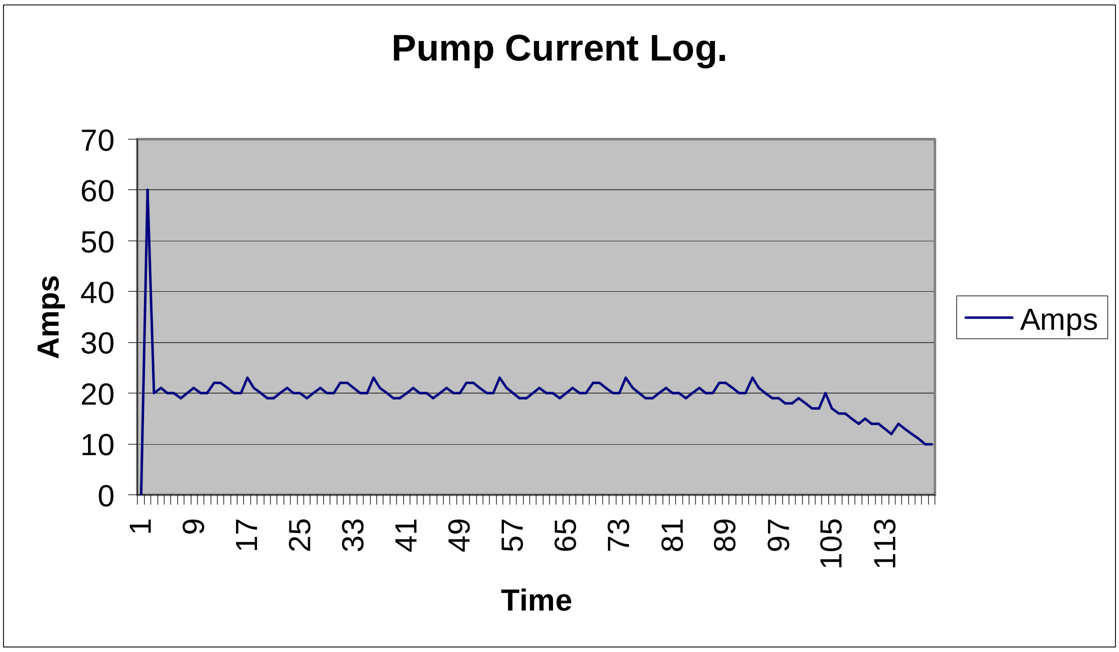
6. Review after a few days operation and plan the next step.

It was immediately apparent that the pump was losing its suction. There were clear signs from the data gathered by the ammeter/data logger combination that after a period of time the amps would fall off.

This could only mean that the pump was doing less work, i.e. pumping less. Therefore, logically, something was restricting the flow into the pump.

The Excel spreadsheet charts below show actual data collected from the pump's motor.

The amps are seen to settle down after the initial start but then drop to around 50% of the "normal" value. This clearly illustrates a fall off in pump load and that the suction of the pump is blocking.



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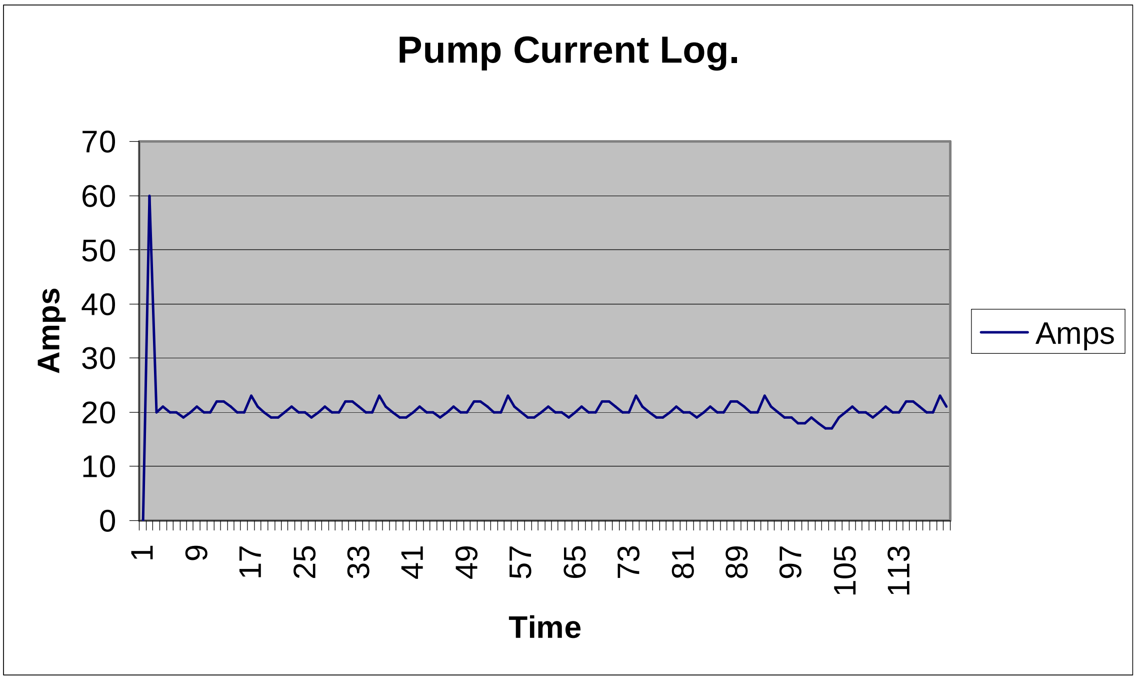
Above, chart showing falling current, suction blocking.



Above, chart showing steady current, no blocking.

In the second spreadsheet chart, the data is taken two months later when we had made changes to the way the pump operates.

It can clearly be seen that there is a solid horizontal trace right across the spreadsheet.

The changes that have been made to the process operation are as follows-

1. The tank was opened and cleaned. A large amount of finely divided metallic sodium was clinging to the sides of the tank and to the instrument probes in lumps. A lump the size of a small rugby ball was clinging to the temperature probe just waiting to fall off and block the pump.

2. The specification of the sodium has been changed from one that contains small quantities of calcium to pure sodium. The price difference is negligible. The calcium level was building up over time in the tank and causing the agglomeration of the finely divided sodium into lumps with the consistency of soft wax. This was what was causing the pump suction to block.

3. The operators all operate the unit in the same way consistently and we can tell straight away from the ammeter traces if any deviation is occurring before it gets serious.

At the time of writing, after several years, there have been no further failures, and no sign of deterioration in the pump or the operation of the unit.

Conclusions-

1 Lack of proper failure and operating records seriously clouded the underlying reasons for the recurring failures of the pumps.

2 Getting the maintenance and operating teams working together quickly got to the root cause of the failures. Conflict between the two functions on site blaming each other was preventing either department taking a sensible ground up review of the problems.

3 Implementing consistent operating procedures and tightly controlled parameters will give warning of failures of a similar nature in the future before they get serious.

4 Scenarios that had been considered but dismissed because they were seen as "unlikely" (blockages, specifically sodium blockages caused by calcium contamination build up in the tank) were underlying the failures of the pump.

5 Buying an inferior, slightly cheaper grade of sodium feedstock was causing hugely expensive problems in the longer term, the ongoing maintenance costs completely dwarfing any of the short term gains from buying slightly cheaper sodium.

6 As in many similar failures of this type, it is the lubrication failure of a mechanical seal that signals the existence of a system fault. Despite the seal being well "over engineered" for the actual duty, it didn't stand a chance of running for its full service life whilst other problems existed.

Follow up-

The dispersion unit continues to function faultlessly.

In fact over time it has been proven that optimising the process operation, fully understanding what is actually happening in the pump/tank system along with consistent operation has pushed the yield and quality to historical highs on the unit.

Now that each shift team fully understands the operating procedures and knows exactly why certain parameters are so critical to the operation, the future trouble free operation of the unit looks assured.

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The motor ammeter is still used to log the running amps of the motor each time the unit is operated and the operators themselves have become quite expert in understanding what certain trends on the ammeter trace mean.

The lubrication of the mechanical seal in the pump has ceased to be an issue and the reliability of the production means that whatever the needs of the client are, they can be met without the pressure and panic that was the normal situation only just a short time earlier.

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About the author-

Stephen H Shakeshaft is a Mechanical Engineer based in the United Kingdom. He is the Principal Consultant and Director of Stephen H Shakeshaft Consulting Ltd., an engineering consultancy specialising in optimisation of existing assets and engineering design of new build projects.

Stephen has over 30 years experience of working at the “sharp end” as well as the “back room” of manufacturing industries with clients in the chemical, utility, metals, industrial gases and pharmaceutical businesses.

Stephen is a registered professional engineer in the UK and is a corporate member of both the Institution of Mechanical Engineers and the Institution of Engineering and Technology.

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The consultancy welcomes contact from all who are interested in plant and machinery maintenance, systems and development.