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Reliability Improvement to High Pressure Gas Compressors.

Introduction-

A client has two reciprocating gas compressors installed, the duty of which is to fill high pressure tube trailers for onward shipping by road to customers.

Despite the product being highly profitable, the client was unable to make full use of the available and proven production capacity from the factory due to the extremely unreliable high pressure compression section on the plant.

Machinery details -

The compressors are two stage double acting reciprocating machines used to boost the gas pressure from 39 BarG to the desired 225 BarG.

The two installed compressors run continuously 24 hours per day and on occasions when there were no tube trailers to fill, the compressors continue to run, filling a high pressure storage facility that acts as a buffer between the machines and the tube trailers.

The compressors were originally supplied as oil lubricated machines with the piston rod packings and piston rings lubricated with mineral oil from a separate lubricator skid.

Due to persistent problems with the lubricated parts, the machines had already been converted to use non-lubricated wearing parts.

Background Investigation-

When originally commissioned the compressors were immediately a source of serious and regular mechanical trouble.

The Cast Iron piston rings and Piston Rod Packing rings were suffering an intolerably short lifetime as were the piston rods and cylinder liners.

The facility had kept quite good maintenance records and reports from various engineers showed that the compressors were having to have the cylinders re-lined and bored approximately every 6 weeks to 12 weeks.

This involved an outage of at least a week each time and was extremely costly in labour and parts usage.

The plant operators on this facility were also responsible for minor maintenance tasks and they were telling me that they were changing first stage suction and discharge valves on most days just to keep the machines operating.

Since the original equipment manufacturer could offer nothing of substance to improve the performance of the machines, the maintenance engineer of the plant had called in a specialist compressor parts manufacturer to see if they could advise of any improvements that could be made.

This specialist company then put forward a proposal to convert the piston rings and piston rod packings to non-lubricated operation using special self lubricating polymer materials.

This modification was duly carried out and the machines improved to the point of generally running around 3months between maintenance overhauls and around 12 months between cylinder relining.

However, the frequently occurring valve problems remained unaddressed.

Examination of the Machinery Parts-

When I attended site to witness the machines being overhauled it became apparent that there were some small changes which would have an immediate impact on the reliability of the machines.

When the cylinders of the machines were stripped down it was notable that there was almost nothing left of the piston rings or bearer bands.

All that was left of the piston rings and bearer bands was small rounded off particles that were trapped between the ring grooves and the cylinder wall.

The pistons themselves were actually in not too bad condition considering the other damage and could be re-used, but the cylinder bores had serious damage from rubbing.

What was very significant though in both the first and second stage cylinders, was that the lubricant injection port was still present despite the lubrication system having been removed.

Both the first and the second stage cylinders had this feature present and what made this significant was that across each lubricant injection port there was a deep, elongated wear scar.

The piston rings, when traversing the lubricant injection ports, were being deformed slightly by the high pressures into the redundant lubricant injection port as the piston traversed past on each stroke.

As the wear scar got bigger, it was damaging the piston rings and causing them to break, eventually into tiny pieces.

The non lubricated piston rod packings were found to be in fair condition, but they were contaminated with oil that had passed through the piston rod oil wiper packings.

The problems with the first stage valves were due to spring wear and breakages.

What appeared to be happening was that the spring coils were touching each other during the valve open/close cycle.

The wire was thinning to the point where the spring would then break.

As part of the change from lubricated to non lubricated operation the valves had the originally specified steel plates replaced with polymer items.

This was a good change and no further problems were encountered with broken valve plates.

Interestingly, the second stage valves which were of a similar design to the first stage valves had sinusoidal springs formed from stainless steel sheet rather than coil springs fitted.

The sinusoidal springs in the second stage valves were never found to have failed.

So it was decided to change the spring type if possible on the first stage valves.

At this stage of machine development the following changes were proposed and implemented-

1 The first and second stage cylinders were relined but both liners this time had the lubricant injection port deleted.

2 The first stage suction and discharge valves were redesigned to incorporate the sinusoidal springs similar to the second stage valves that had never had a failure.

These relatively simple and very low cost changes resulted in the machines running without any interim maintenance for nine months.

Available flow capacity from the machines did, however, deteriorate towards the end of the campaign quite noticeably. This factor led to a review of the machines and a desire for further development work to be done.

Further Investigation-

Thanks to the client facility having very good maintenance records on the machines since installation, it was possible to look into further development for the machines from their position at this time.

The maintenance records were analysed and there were several failure modes which had recurred more than once in the then 6 year operating history of the machines and were candidates to be designed out of the machine.

The issues that were identified for attention were as follows-

1 Premature failure of the gas packings due to oil ingress from premature oil wiper packing failure.

2 Second stage piston nut failure due to fatigue in the threaded area of the piston rod.

3 Ejection of lubricant through the crankcase vent due to over-pressurisation of the crankcase by product gas leaking from worn gas packings.

4 Severe wear out of the second stage piston rings (after the above cylinder liner lubricant injection port deletions were carried out).

5 Breakage and destruction of the first stage bearer band.

6 First stage piston locking device failing and the piston unscrewing from the rod.

In order to realise the full potential of the machines a proposal was put to the client to eliminate all the above issues by further development of the machines.

A package of upgrade work was proposed and accepted that involved the following ground up redesign of the machinery components.

1 The pistons and piston rods were redesigned with the pistons integral to the rods.

2 The assembly when made from one solid piece would not suffer from the attachment problems of the original design.

3 The second stage piston was redesigned to have 16 piston rings 5mm thick by 7mm wide instead of the original 8 piston rings 3mm thick by 3mm wide.

4 The above modification meant the assembly was significantly (about 86mm) longer, but it was allowed for by extending the cylinder liner and cylinder by the same amount. Fortunately, it was feasible to fairly simply extend the existing cylinder and use a longer liner rather than make a complete new cylinder. This was a key aspect of the new design.

5 The bearer band on the first stage piston was made twice as thick and made in two parts to enable it to be fitted to its deeper groove without the risk of breakage.

6 The piston rod was Tungsten Carbide coated in the area swept by the gas packings and oil wiper packings since it was intended that the rod would be in service for much longer

between overhauls and Tungsten Carbide would be resistant to wear during the longer time in service.

7 A splash plate was fitted under the oil wiper packings to reduce the quantity of oil being splashed up into the oil wiper packings. This was to reduce the amount of oil that the wiper packings had to cope with.

8 The oil wiper packings and the packing cups were completely redesigned, using a bronze knife edge design with a very open and free draining cup arrangement. This type of design had a good track record on other machines so it made sense to adopt it here.

9 The gas packings were redesigned in order to give a better piston rod seal for longer.

10. The details of the first stage piston assembly were adjusted to save weight and arrive at a complete new assembly with the same reciprocating mass as the original design.

The above proposals were accepted for implementation and a specialist compressor parts manufacturer was engaged to design and manufacture all the required modified components.

The first redesigned machine was built during a scheduled routine overhaul period and was re-commissioned without difficulty.

The modified machine then ran for 15 months without a single maintenance outage.

As a bonus, due to the much better second stage piston ring sealing this allowed the machine to compress at or above its original design capacity for the entire 15 month period.

The second machine was duly converted in exactly the same way a few months later.

It too ran in a more than satisfactory manner.

Operating experience after two overhauls showed that a slight re-design of the gas packings and oil wipers was required due to higher than anticipated emission from the redesigned gas packings, but having implemented this final change the machines continue to run trouble free with only 15 month overhauls planned talking about 3 days per year.

Conclusions-

In this case two machines had been provided by a well known manufacturer of high pressure reciprocating compressors.

Unfortunately, soon after commissioning it became clear that the machines were simply not up to the job of reliably doing what they were bought for.

It soon became apparent that the original equipment manufacturer had nothing to offer except to keep supplying spares until the warranty period was over.

Fortunately, a specialist compressor parts manufacturer had stepped in and at least got the machines running, but there was still a lot more development potential to be released from the machines.

The first phase of simple modifications clearly demonstrates that in many cases, significant upgrades in machinery performance can be obtained by paying close attention to the root cause of problems in the field and tackling the underlying design issues.

In this particular case, the simple modifications that were done had cost no more than it would have cost for a routine overhaul anyway.

In my experience, this very desirable result can often be achieved by the astute trouble shooter leading to valuable asset improvements being funded from the maintenance budget and hence needing no new capital expenditure at all.

The second phase of modifications carried out, though more extensive in nature, actually cost little when compared to the increase in performance and the reduction in the frequency and scope of maintenance outages.

But the big bonus to this business was that the sales team now had the confidence to sell the proven extra capacity from this production unit into the merchant market at a price premium with the certainty that they were going to be able to supply what they promised.

This was a situation that was simply unthinkable before this upgrade programme was implemented.

The benefit to the business was that before the programme was commissioned, the client shipped six to eight tube trailers a day to customers.

After the upgrades were completed the same client shipped between ten to fourteen tube trailers a day from the same plant.

Needless to say, the payback on the investment was huge and the simple payback could be measured in days.

Follow up-

The machines continue to operate to this day in the condition they were left by myself.

There has been no unscheduled failure of any components installed by the upgrade programmes.

The plant operators can concentrate on other more productive tasks and the maintenance team can plan the maintenance of the machines with a high degree of certainty.

The “annual” overhaul that used to happen about every 3 months for a week at a time and usually revealed extensive damage, is now a schedule every 15 months to inspect and replace consumable parts on the compressors.

In addition, the overhaul now takes about 2 to 3 days rather than the 5 to 7 days that it used to previously.

It is the experience of the author that opportunities like this exist at every process manufacturing facility.

We need to look in the right place with the right attitude and when presented with a premature machinery failure always ask ourselves the question-

“What can we do to prevent this happening again?”

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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.