The official journal of the Vibrations Association of New Zealand

Spectrum

Autumn 2023 | Issue 107

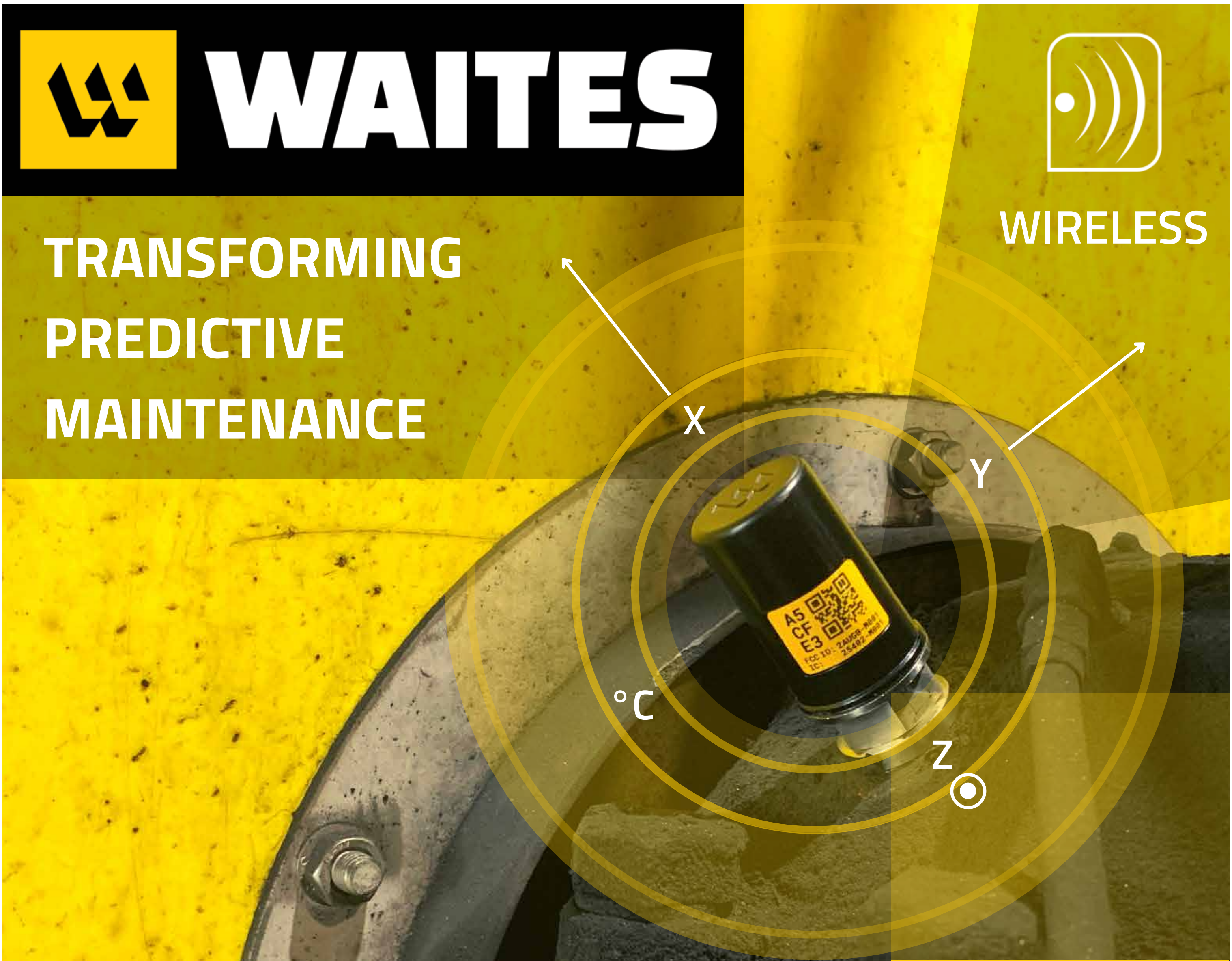
Torsional-Lateral Coupled Vibration in Integrally Geared Compressors

Magnetic Stator Wedges
– Identifying Problems and Solutions

\+ PEOPLE AND THEIR SKILLS DRIVING INDUSTRY

Conference '23

VANZ Trinity Wharf, Tauranga | May 9th–11th



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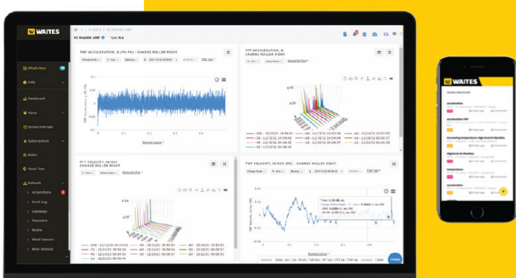

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Issue 107

Web Site: **www.vanz.org.nz**

Conference paper submissions
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VANZ VIBRATIONS ASSOCIATION of NEW ZEALAND

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PRESENTS

Conference '23

'PEOPLE AND THEIR SKILLS DRIVING INDUSTRY'

Trinity Wharf Hotel Tauranga

MAY 9TH, 10TH, and 11TH 2023

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Masterclass outline

The Masterclass aims to provide attendees with the tools they need to describe and identify the functions of electrical machine components, various insulation types in stator and rotor windings, failure mechanisms common to electric machines, and electrical tests sensitive to specific failure mechanisms.

Additionally, attendees will learn;

1. to undertake a visual inspection on an Inservice motor following standard protocols
2. describe a typical core inspection procedure.
3. identify common symptoms of failure mechanisms and their effects on the reliability of electrical machines
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Registrants receive:

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- Course notes (180 pages)
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- Certificate of attendance for masterclass
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With over 40 years experience in rotating equipment, essentially centred on the repair, redesign and maintenance of electrical rotating plant. Mike has developed an intense academic interest in machine failure mechanisms and root cause analysis of electrical machinery failure and has presented papers throughout Australia, New Zealand, United States of America, South East Asia and South Africa.
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We're encouraging new people to present papers at our 34th annual conference this year.

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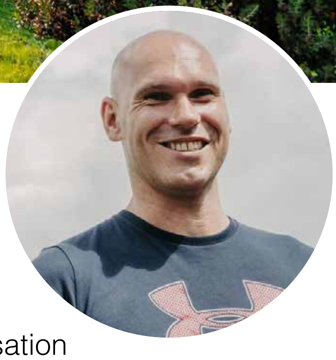

PRESIDENTS' REPORT

By Tim Murdoch, VANZ President

2023 has certainly had a volatile start to the year with cyclones, floods and other crazy events which have made living and working conditions very challenging in many places around the country. I do hope those of you affected by these events are able to get the assistance you require and have a quick recovery.

VANZ conference 2023 is not far away and the committee are doing an amazing job organising every aspect of the conference. Thank you GVS for your amazing support this year and to all exhibitors that have confirmed their attendance. Our line up of speakers for the conference and dinner this year is world class including Andrew Gale, Chris Hansford, Dare Petreski, Dr Iain Epps, Barry Robinson, John Clynes, Dr James Neale and Alex Lawrence.

> **"VANZ conference 2023 is not far away and the committee are doing an amazing job organising every aspect."**

As a welcomed change to this years conference Mike Davis will be running a full day Masterclass on Electrical Machine Familiarisation designed for Condition monitoring, electrical and mechanical personnel. If this is something that takes your interest be sure to check out the programme outline on the VANZ website and book in early as there are limited numbers available for this course.

We are looking forward to catching up with as many of you as possible. It is a great opportunity to learn and network with others in the same areas of interest. If you haven't already, go to www.vanz.org.nz and register your place at the conference and Mikes motors master class. Accommodation is limited at Trinity Wharf so get in quick and use the code word VANZ to get a better rate.

Looking forward to seeing you all there.

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IN MEMORIAM

Patrick Bridson
17 July 1950 – 23 December 2022

The VANZ community would like to pass on their condolences to Patrick's extended family during this difficult time.

Not many people may know, but Patrick was actually one of the founding members of VANZ.

Patrick will be missed by many.

EDITORS' CORNER

Greetings readers! Conference time is rolling around again and VANZ is a hive of activity planning this years' symposium so all who attend can benefit and take away new information and techniques not to mention the latest gadgets to roll out in to the field.

Our conference committee have got a lot in store for us this year as always and our main sponsor this year is GVS! You can register online at **www.vanz.org.nz/conference-2023** check out the website for more updates as conference gets closer and you can also register a sponsorship package.

Many thanks go to all those who are helping to sponsor the event this year with a variety of different support, from trade-stands and networking nights to afternoon teas and lanyards. Also to our continued advertisers who are much appreciated and are all an important part of keeping VANZ going.

In this issue you can read through an article by Mike Davis from EMKE, titled Problems and Solutions with Magnetic Stator Wedges, he'll be conducting a special 1-Day only training event at the conference – the Electrical Masterclass. Also there's an article by Roengchai Chumai from Machinosis Company Limited, titled Identify root cause of torsional-lateral coupled vibration in integrally geared compressor.

Browse through the update from the President's Report by Tim Murdoch, he gives us an idea of what to expect from this years' conference. If you want to puzzle your grey matter then flip through to Carl's Quiz and see how well you score on the latest questions!

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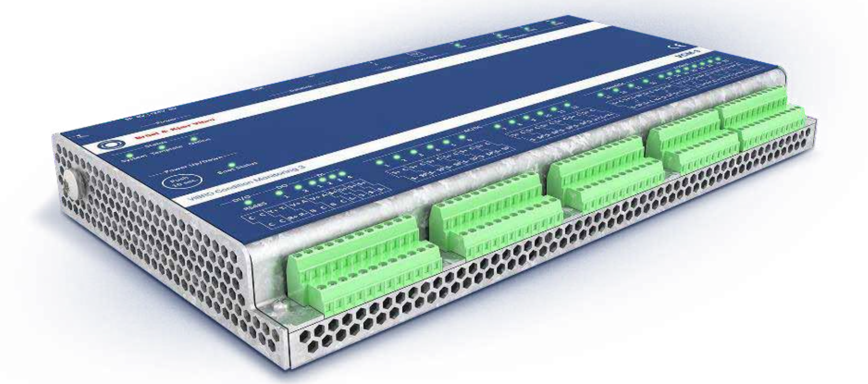

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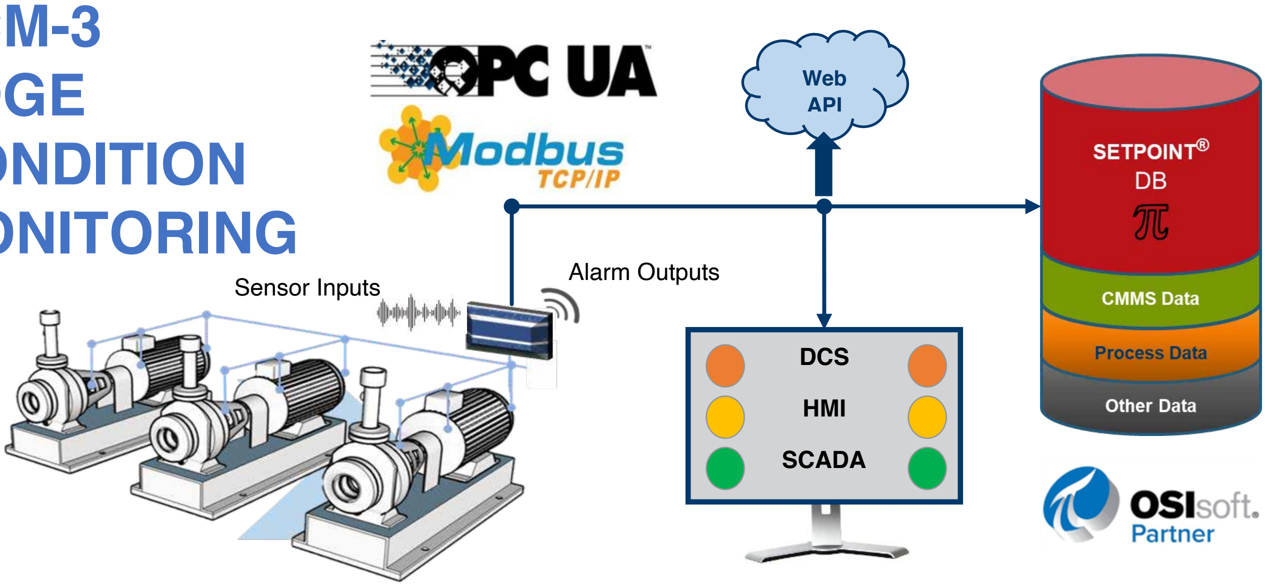

For more information, please refer to BKVibro Website:

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Key Length Considerations

One simple way of practicing PRECISION in our workplace is to ensure that we use keys of the correct length. Keys that are too long or too short are DEFECTS that cause our machines to be out of balance. This causes the machines to vibrate and leads to shorter seal and bearing life.

The best solution for PRECISION is to use a step key, where almost all of the mass of the keyway is replaced. Only the small curved section at the end of the keyway is missing. The next best solution is to use a full height key where its Length is determined by the following simple formula : Length = (A + B) / 2.

Where A is the full depth length of the keyway. This means that the key fills half of the exposed section of keyway in the shaft.

In this way, the mass of the proud section of key is equal to the mass that is missing from the keyway. These types of key configurations *(see fig. 3)* are NOT ACCEPTABLE because they are not balanced!

To complete the picture, it is necessary to have the correct orientation of pairs of keys *(see fig. 4).*

Note that the keyways are at 180 degrees to each other. This is to ensure that any errors in key and keyway length balance each other out. When sending shafts out for balancing, the shaft should be balanced with a full length half key, while rotors should be balanced with a key as shown above..

Fig. 1

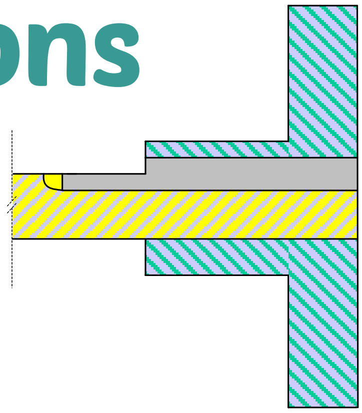


Fig. 2

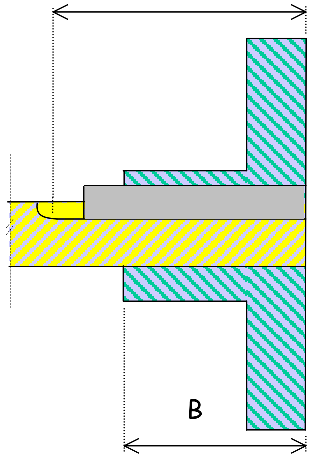


Fig. 3

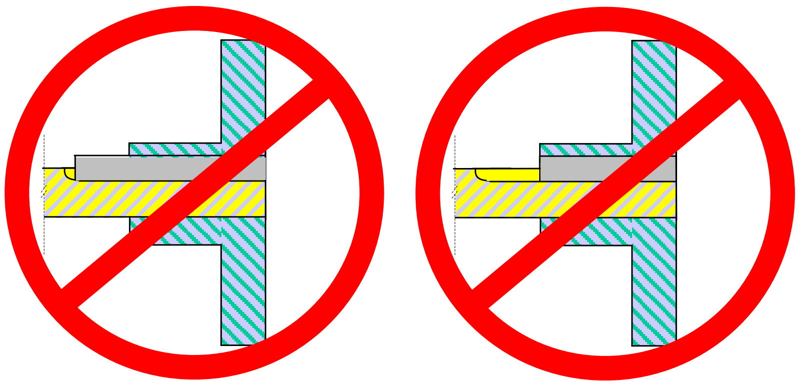


Fig. 4

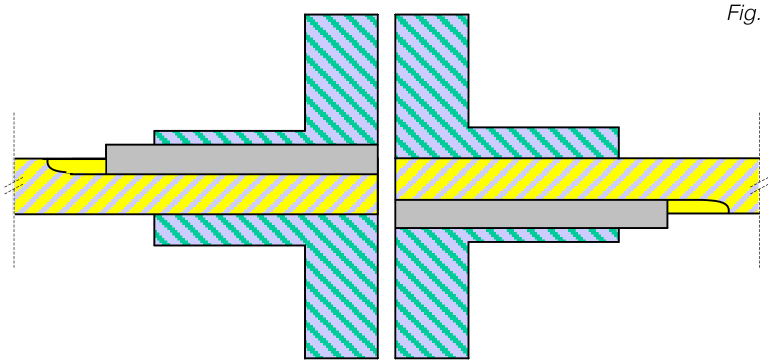
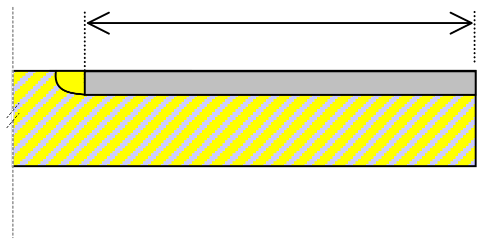


Fig. 5



Article prepared by Bluescope Steel.

LE Reduces ENERGY & WASTE OIL disposal costs in Air Compressors

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US Company Saves $20K+ in Energy Savings Pilot Program

Challenge:
A US company needed to improve its lubrication practices to enhance the company's sustainability efforts. The company's rotary screw compressor and centrifugal compressor were set to be drained annually with no regard for the condition of the oil. They were not set up on an oil sampling program, nor was the oil filtered to keep out contaminants. Effective implementation of lubrication reliability best practices can save energy, minimize maintenance costs by extending drain intervals, and improve the reliability of the equipment.

LE Solution:
The energy savings were quantified by using an Amprobe® device, which measures the amount of electricity flowing through the power lines to the machine. The meter was attached to the load side of the VFD (variable frequency drive) to have an accurate reading of how much electricity the compressor was using. The amount of electricity logged was converted to British thermal units (Btu). All variables that could affect the results of the study were taken into consideration.
A synthetic oil that was in use was changed to a mineral-based oil. Oil sampling was implemented and filtration ports were added. Sampling enables predictive maintenance based on when an internal component might fail or when the oil might lose its additive properties and need to be replaced. Through sampling analysis, filtration opportunities can be identified that will remove contamination to extend the oil life and avoid a costly annual DFR (eight man-hours per machine).

Results:

- ***Energy Savings*** – The fluid friction difference between the old oils and the two new LE oils reduced the amp draw on each machine's motor. Based on amp draw results before and after the lubricant switch, the company estimated its annual energy savings for the two compressors as ***$12,500.00.***

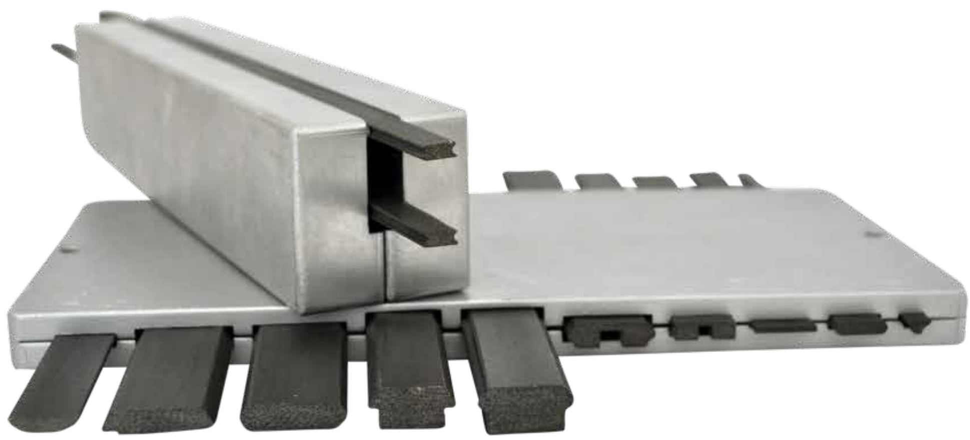
- ***Oil Savings –*** To compare the cost of the old vs new compressor oils, we included the purchase price as well as drain intervals. Extended drain interval savings are due to no longer having to perform an annual drain, flush, and refill process; savings were calculated based on a new five-year drain interval.
  Total annual oil savings for the two machines was **$7939.00.**

- ***Waste Oil Reduction –*** A total of 50 gallons of waste oil annually will not need to be discarded until the next DFR – estimated at once every five years – meaning the company achieved a five-fold reduction in waste oil being discarded.

Total savings, not counting waste oil reduction amounted to $20,439.00 per year.

Chris from LENZ has an extensive background with Air Compressors (Atlas Copco service engineer for 10+ years).

View more case studies here https://www.lubricationengineers.co.nz/testimonials



Problems and Solutions with Magnetic Stator Wedges

The use of magnetic materials for wedging induction motor stator windings has become more prevalent over the last decade. The move to the use of these materials has led to new reliability and maintenance challenges. This paper briefly discusses the function of stator wedging, the historical development of magnetic wedge material, the advantages of using magnetic wedges. Maintenance considerations for magnetic wedge integrity is also discussed.

Function of Stator Wedging

In large electrical machines the stator slots are opened to the width of the slot to allow the fitting of coils. The stator core laminations are punched in a manner to allow the fitting of wedges in rebated landings at the top of the slot.

After coils are fitted and packed in the slots wedges are fitted in the slot landing. The purpose of the wedging is to restrain the coils in the slot against steady state bar forces (100Hz or 120Hz vibration) and transient bar forces (Starting forces are proportional to in-rush current squared).

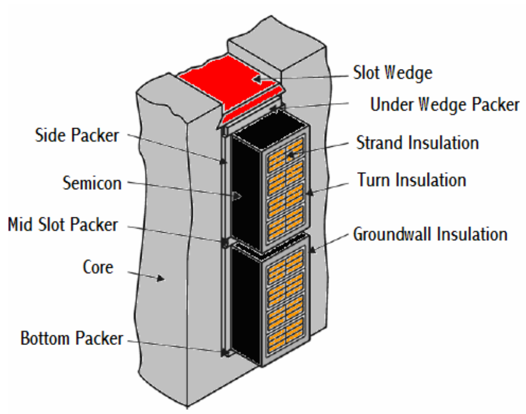


Fig. 1. Typical arrangement of wound stator slot.

Historically the material used for wedging has been non-magnetic - typically an epoxy glass laminated board machined to match the stator slot landing. Increasingly the epoxy laminate is being replaced with magnetic laminate.

Magnetic Wedging

The typical material composition of magnetic wedging is detailed in table below:

Typical Material Composition of Magnetic Wedges	
Iron	70.0 %
Glass Fabric	10.8 %
Binder	19.2 %

The use of this type of material changes the wedge from a magnetically passive characteristic to being magnetically active. As a result of this the normal wedging function of retaining the coils in the slot is changed to one of retaining coils and providing a low reluctance magnetic path across the opening on the top of the stator slot.

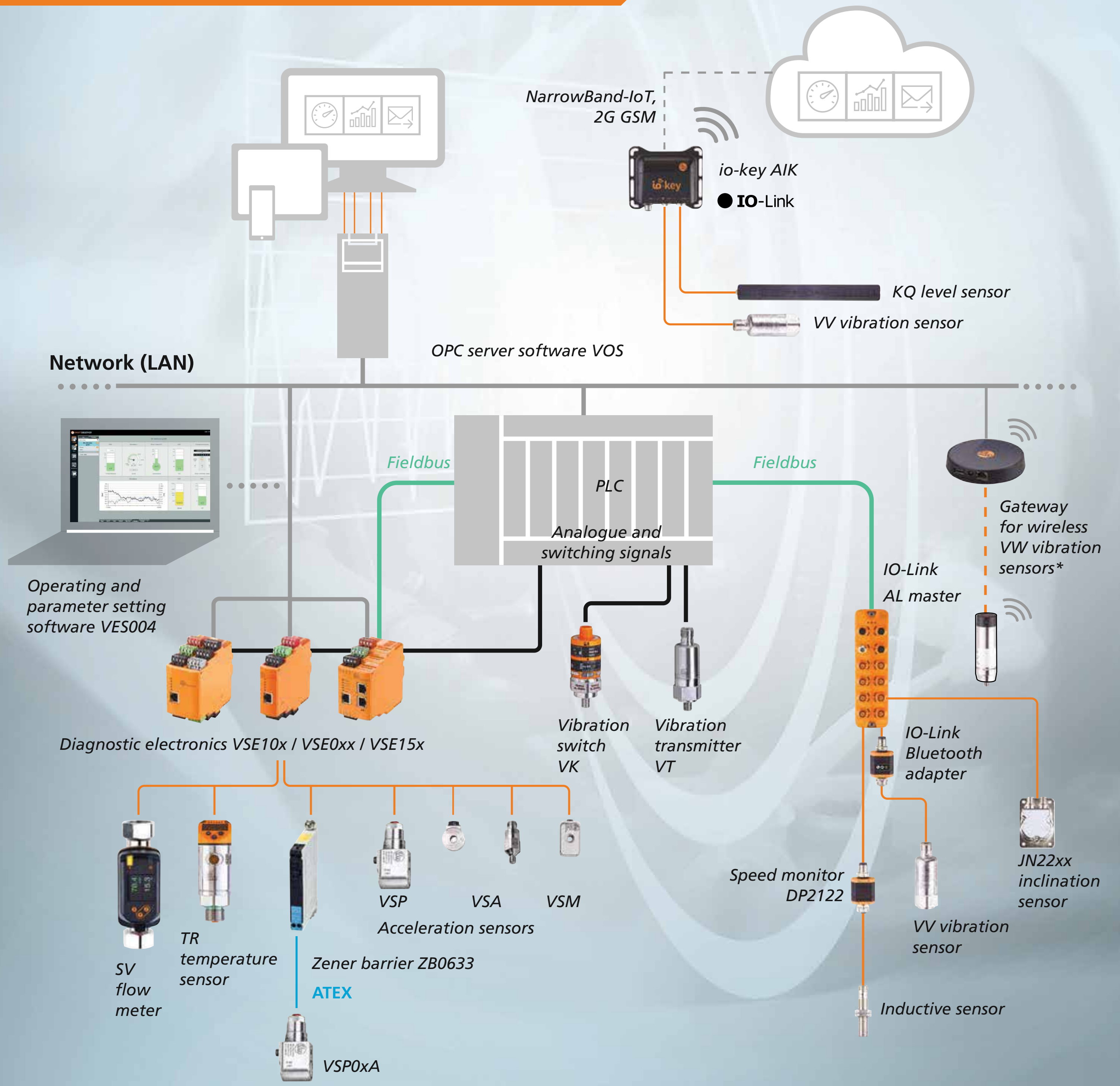
As a result of providing a magnetic closure on the top of the slot the following improvements are achievable;

Continued over page >

Article by Mike Davis.

Plant Condition Monitoring Solutions

From Sensors to ERP



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- Reduced core losses.
- Lower magnetizing current.
- Reduction in zig zag torque.
- Improved Efficiency.

The level to which these improvements are realised has wide variation and is dependant on case by case design parameters of the machine.

In modern machines it could be said that the addition of magnetic wedges is one way manufacturers can reduce the active material content of machines; the others being better insulation and smarter ventilation design. Studies have shown the net result of this trend of reducing active material content for given outputs has led to a 14 times reduction in mass of machines at given outputs in the period of 1920s to 1990s [1].

The machine performance benefits in life cycle power cost associated with using magnetic wedges can easily be lost in additional reliability costs associated with magnetic wedge failure particularly after re-wedging of machines [2].

Given magnetic wedges are subjected to un-remitting magnetic forces throughout operational life the challenge for designers is to apply wedges with considerations for material reluctance, flux densities and physical assembly to prevent looseness developing in service. Meeting this challenge has occupied designers since the 1920s. The figure below shows a magnetic wedging technique patented in 1945 by Fisher. Many such designs exist all aimed at ensuring the magnetic and restraining function of magnetic wedges are preserved throughout the operational life of the machine.

The modern magnetic wedge material design and application approach relies heavily on "gluing" the wedge in position with epoxy resin. The life limiter for wedge systems using this approach is the epoxy resin. In circumstances where localised temperature rise (hotspots) in stator cores occurs through high flux concentration the thermal aging of the wedge bonding epoxy is accelerated.

Epoxy based materials shrink with thermal aging. Once the bonding is compromised the wedges are free to move independently in response to the machine magnetic field. In circumstances such as this wedges vibrate and are progressively reduced to iron powder and debris due to the abrasive nature of the stator slot landings. One fix for this problem is to replace the magnetic wedge material with traditional non-magnetic material. The impact on machine performance in removing magnetic wedges and replacing them with non magnetic wedges range from no change [3] up to a 50% reduction in magnetizing current [4].

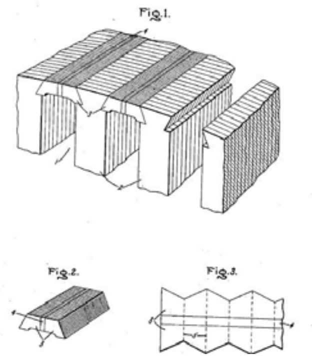

Fig. 2. Early magnetic wedge patent (US Patent No. 2 386 673)

Detecting Failed Magnetic Wedges

Machines with failed magnetic wedges may display one or more of the following operational characteristics;

- Higher no-load current when compared to "type test" value.
- Increased temperature rise.
- Increase in Endwinding Discharge due to the presence of wedge material contamination on the stator endwinding (HV Machines).
- Increase in electrically excited vibration.

Due to the inconclusive nature of the above characteristics as an indicator of magnetic wedge failure it turns out that the most effective detection technique is a visual inspection. The visual evidence for failed magnetic wedges is;

- Ferrous contamination on the stator endwindings.
- Ferrous and glass matting debris in the base of the machine.
- Glass matting debris in the machine primary air circuit ducting.
- Missing wedge sections from the stator slots (predominantly in the middle of the stator slots).

Having detected failed magnetic wedging a maintenance choice needs to be made which can include only re-wedging slots where wedges have failed (Partial re-wedge), completely re-wedging the stator and replacing the wedge material with non-magnetic material. In either case significant reliability risk can result from what appears to be simple maintenance.

Maintenance Considerations

There are important considerations before attempting re-wedging maintenance where magnetic wedges are employed.

Continued over page >

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These include;

Wedge removal – the removal of wedges is high risk maintenance particularly on windings which have been Vacuum Pressure Impregnated. The risk of causing impact damage to stator coil groundwall insulation needs to be evaluated. A low risk approach is to run a saw down the centre of the slot to a depth slightly less than the wedge thickness and collapse the wedge in toward the cut.

Wedge size – It is important when surveying the wedge dimensions that accurate measurements are made. The wedge dimensions should match the profile of the slot landing and maintain the original design thickness. The finished wedge size should allow for a neat fit in the landing whilst applying downward pressure on the coils in the slot.

Vented core – when wedging machines with vented cores attention should be paid to ensuring the wedges are notched at a location corresponding to core vent to ensure no ventilation restrictions occur.

Lamination shuffle – When laminated stator cores are assembled all laminations never align in precisely the same location due to manufacturing tolerances. This results in what is termed lamination shuffle. When fitting wedges lamination shuffle can impact on the fit of the wedge in the slot. The uneven edge of the slot landing serves to take material off the wedge as it is dredged into the slot. The results of this problem can be observed in machines with failed wedges as most wedge portions fail in the centre of the slot – the location of wedges which have been dredged the greatest distance along the slot landing.

Slot length – When fitting magnetic wedges the less force required to fit the wedge the better. Force required to fit wedges can be reduced by reducing the length of the wedges. Careful consideration should be given to ensuring that wedges are fitted in short lengths. In vented cores the butted joints of wedge portions should always be positioned within the core packs.

Bonding material – The fit of magnetic wedges and downward force on the stator coils on their own are not enough to restrain magnetic wedges in the stator slots. To achieve bonding of the wedge to the slot landings epoxy resins need to be applied during the fitting of the wedges. The epoxy used in this application should be of appropriate thermal rating.

Conclusion

The utilization of magnetic wedging systems in induction motors is becoming more prevalent. The

“Careful consideration needs to be applied prior to re-wedging machines after magnetic wedge failure to ensure successful maintenance.”

following conclusions are drawn from experience with magnetic wedge systems:

- Magnetic wedges compensate for deficits in active material content.
- The impact of magnetic wedges on machine performance varies on a case-by-case basis.
- Detection techniques for magnetic wedge failure are limited with visual inspection being the most useful.
- Careful consideration needs to be applied prior to re-wedging machines after magnetic wedge failure to ensure successful maintenance.
- Design efficiency gains through employing magnetic wedges can be a fraction of the reliability cost of failed wedges. ■

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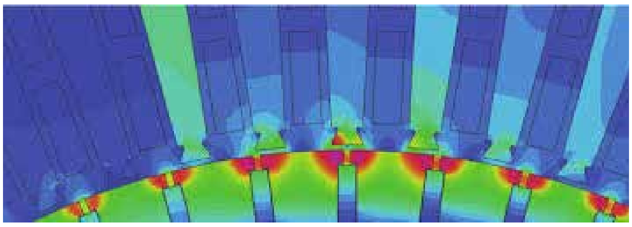

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Identify Root Causes of

Torsional-Lateral Coupled Vibration in Integrally Geared Compressors

This case study demonstrates detection of a torsional vibration problem which was observed as lateral vibration by way of torsional-lateral coupling. The unit is a six (6) stage integrally geared compressor driven by a single bull gear and 12 MW induction motor with a synchronous speed of 1500 rpm. There are three pinion rotors of feed stage 1 & 2 (20,156 rpm), recycle stage 1 & 2 (12,461 rpm), and recycle stage 3 & 4 (14,584 rpm).

> "Give him a maintenance schedule and he will quickly shovel the hard jobs to the backlog and wonder off to do the favoured jobs."

Fluctuating vibration amplitudes were measured on the feed compressor (FC) stages during off-peak operation (after 22:00 hours. each day) while a nearby steel processing plant is in operation, and disappears when its operation is stopped. Detailed vibration analysis was used to identify possible root cause of the fluctuating vibration and to find possible solutions.

The measured vibration at the FC rotor were predominantly at 22.5 Hz, which was found to be due to torsional-lateral coupled vibration through the gear mesh, induced by torque oscillations of the motor rotor. There is a significant relationship between FC fluctuating vibration amplitudes and oxygen consumption of an electric arc furnace (EAF) in the steel plant, hence, power consumption generated fluctuating motor supply current which resulted in motor torque oscillation. Fluctuating supply current to the motor produced air-gap torque oscillations. This produced torsional vibration coincident with the first torsional mode predominantly at the FC rotor.

Introduction

Fluctuating radial vibration amplitudes were reported predominantly at the feed compressor (FC) stages rotor during off-peak operation period after 22:00 to 09.00 hours the next day while a nearby steel processing plant is operated. Alarm and trip vibration set points are 40 and 50 microns peak-to-peak (pp), respectively. Fluctuating vibration amplitudes sometimes exceeded the alarm set point, and disappeared during peak period each day when

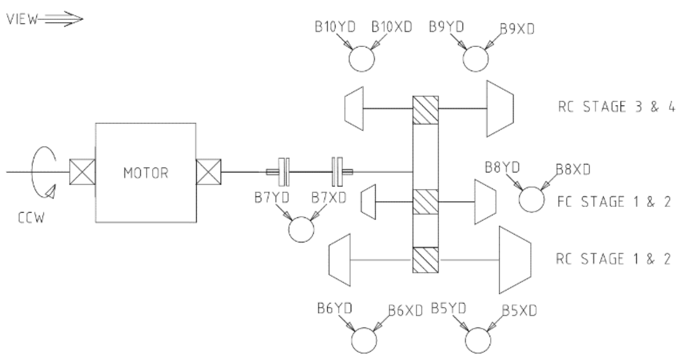

Figure 1 - Machine train and transducers layout showing existing shaft vibration probes installed at each bearing. Note that there is no vibration and keyphaser sensor installed at motor.

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roengchai.ch@machinosis.com

the steel plant operation is stopped. The steel plant is equipped with an electric arc furnace (EAF) to melt raw material. Oxygen gas is injected into the furnace to increase flame temperature. Work steps and instruments used will be discussed in this paper.

Field Measurements
Shaft vibration probes are installed radially at each bearing at +/-45 degrees from vertical, plus a keyphaser, for each rotor to measure vibration, phase angles and running speed. All vibration signals and keyphasers are connected to a vibration transmitter which provides 4-20 mA reading to the machine's distributed control system (DCS) with set points for alarm and danger for machinery protection. Machine train and transducer layout is shown in Figure 1.

Additional sensors and measurement systems are installed as follows.

- Strain gauge and its telemetry system for direct torsional vibration measurement at motor shaft *(see figure 2).*
- Laser keyphaser and reflective tape at motor rotor to measure motor speed and phase angle.
- Current transformer (CT) clamp-on to measure dynamic current supplied to the motor
- Motor current and voltage analysis using Electric Motor Testing analyzer (from PdMA®) to fully analyze power supply quality and identify possible electrical malfunction if any.

Multiple channels vibration analyser was used for data collection setup, processing, storing, plots presentation, and preparing the analysis report.

Data Discussion
Vibration data measurement was carried out covering both peak and off-peak operation periods in order to see different vibration characteristics correlating with dynamic torque and power supply current to the motor. Vibration trends showed that there was significant relationship between radial (lateral) vibration amplitudes measured at feed compressor (FC) stages and dynamic torque oscillation measured at motor rotor using strain gauge and telemetry system.

This is confirmed that fluctuating radial vibration amplitudes noticed predominantly at FC stages is due to torsional vibration excitation generated from motor rotor. It is connected to bull gear which is meshed with pinion shaft of FC stages rotor, hence, torsional vibration can couple to radial/ lateral vibration through gear mesh [1]. There was no significant vibration amplitudes fluctuation observed at all recycle compressor (RC) stages at the same period.

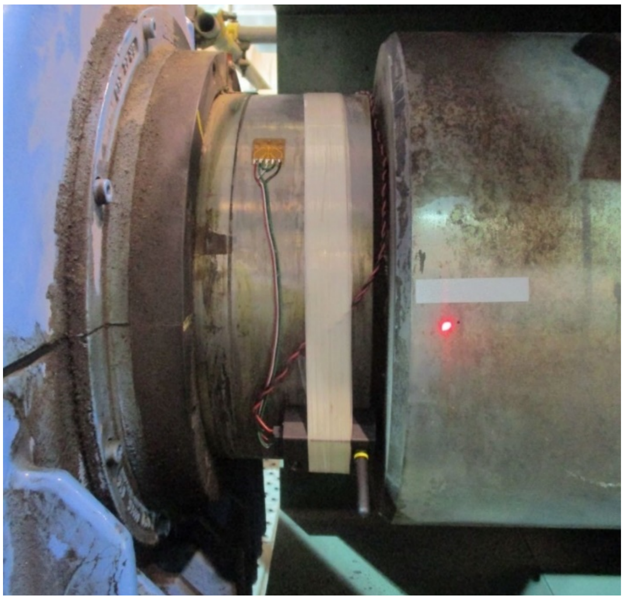

Figure 2 - Strain guage and transmitter installation at motor shaft.

There was also noticed that fluctuating torque and vibration is also coincident with fluctuating power supply current to the motor and it was predominant at off-peak operation period *(see figure 3)*. It was suspected that fluctuating current could induce oscillating air-gap torque at the motor, therefore, fluctuating torsional vibration. There is clear evidence that fluctuating torque and vibration disappear when dynamic current is smooth (or less fluctuation).

However, there was argued that compressor operating load could affect change in motor current, therefore, inlet guide vane (IGV) was checked at the same operation period and found no significant change. Fluctuating dynamic current was not due to change in compressor load operation.

Fluctuating dynamic torque and radial vibration of FC stages was predominantly at 22.5 Hz during off-peak operation *(see figure 4)* with minimum amplitude at peak operation *(see figure 5)* periods with similar waveform pattern. This can be concluded that torque oscillation of motor rotor resulting in radial vibration noticed predominantly at FC stages at frequency 22.5 Hz during off-peak operation period when there is highly fluctuating motor supply current.

Spectrum data versus time of dynamic torque measured at motor rotor and radial vibration of FC rotor were compared in off-peak and peak operation periods in extensive time range are shown in Figure 6 and Figure 7 *(over page)*. Transient data during

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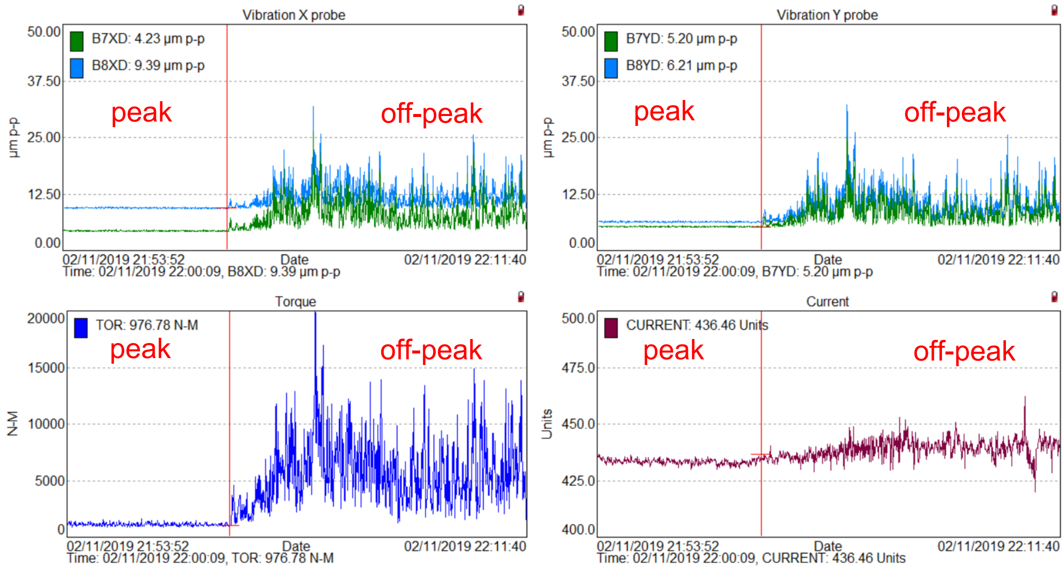

Figure 3 - Trend plots data correlation of vibration data measured at FC rotor, dynamic torque, and power supply current of motor during peak and off-peak operation period.

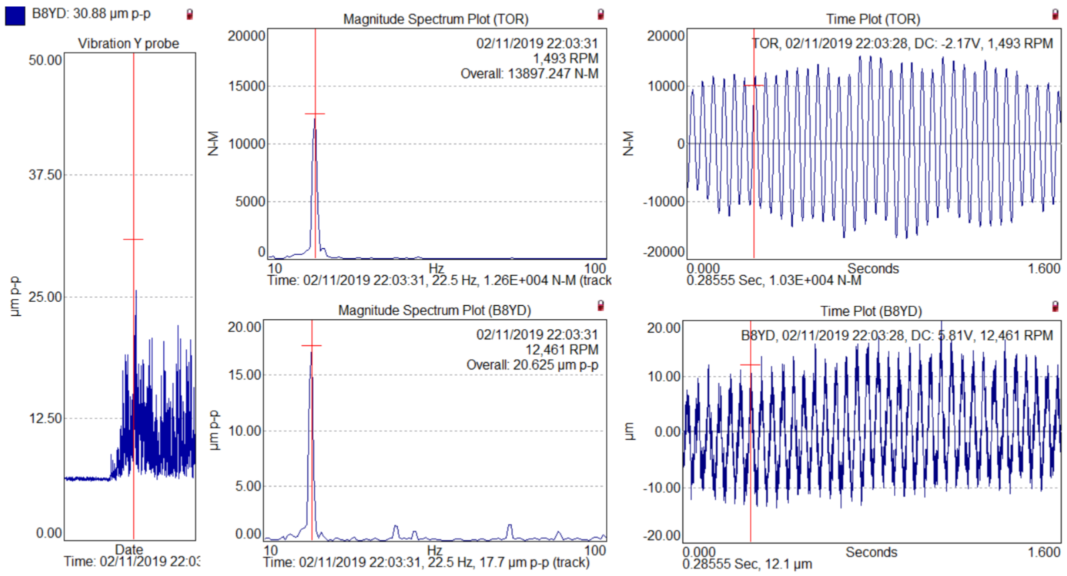

Figure 4 - Waveform and spectrum data of vibration data measured at FC rotor and dynamic torque during off-peak operation.

shutdown is reviewed and found that 21.88 Hz frequency component revealed constant frequency with machine speed independent when the unit ran down for both torque (torsional vibration) and redial vibration *(see figure 8)*. This is a symptom of resonance as it is suspected torsional natural frequency (TNF) is excited by torque oscillation of motor rotor. This is very close to calculated TNF of drive train at 1278 cpm (or 21.2 Hz) with 14.29% separation margin from motor operating speed, refer to Table 1.

As discussed above, fluctuating motor power supply current can result in air-gap torsional oscillation and excite torsional vibration of the drive shafts and/or torsional natural frequency, hence, possible root cause of current fluctuation should be identified. Relevant operating parameters is reviewed (Figure 9). and found that compressor load parameters are constant or no significant change/different between peak and off-peak period, for example, IGV feed and recycle, suction/recycle flow, etc. This is concluded that fluctuating current is not due to compressor load fluctuation.

However, it was found that oxygen vent valve operation (green color curve) has significant relationship with fluctuating radial vibration amplitude measured at FC stages (blue and orange color curves).

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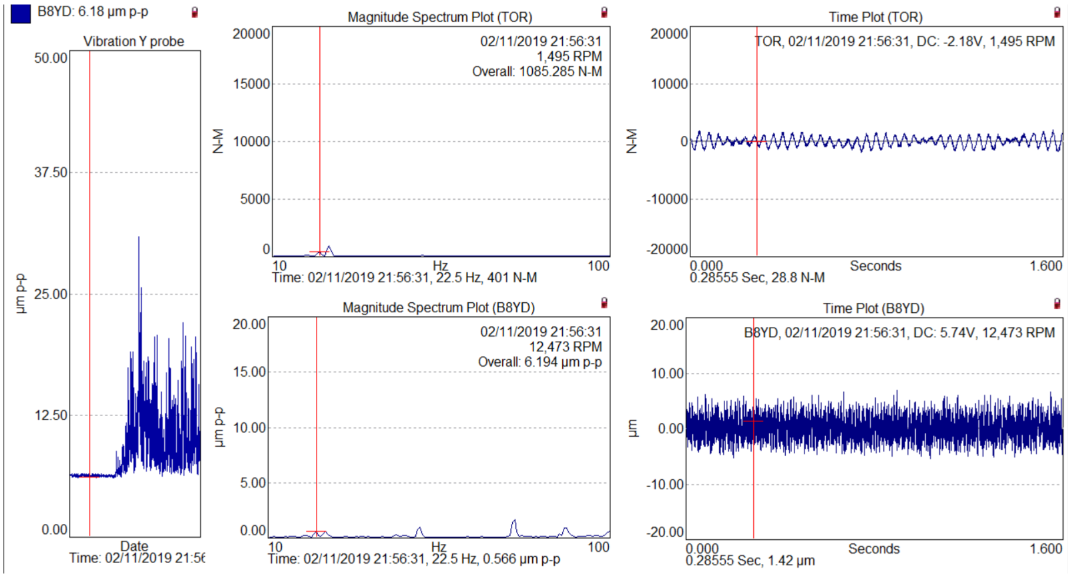

Figure 5: Waveform and spectrum data of vibration data measured at FC rotor and dynamic torque during peak operation.

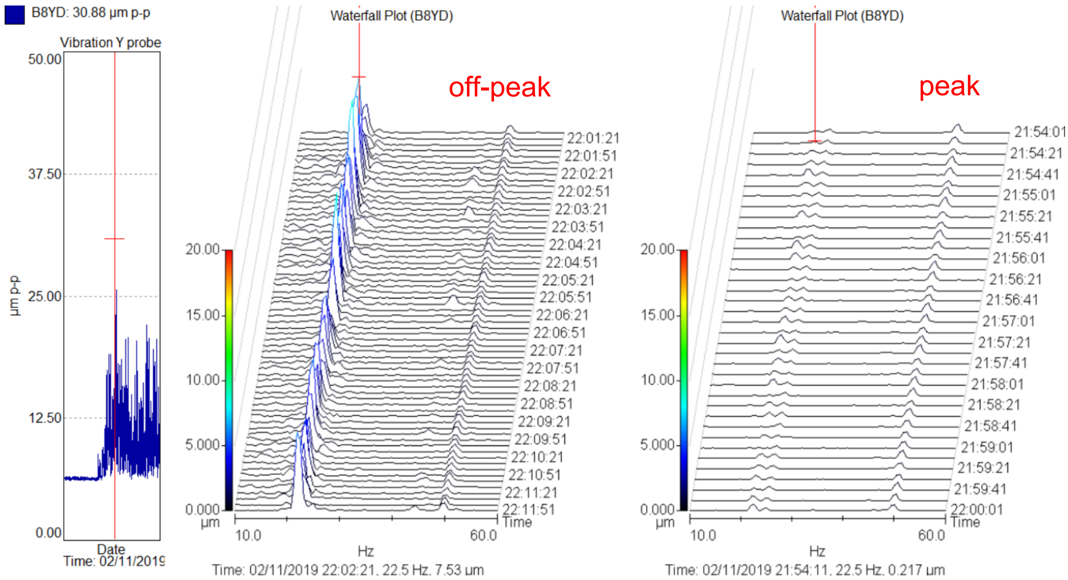

Figure 6 - Waterfall plots of vibration spectrum comparison between peak and off-peak operation period.

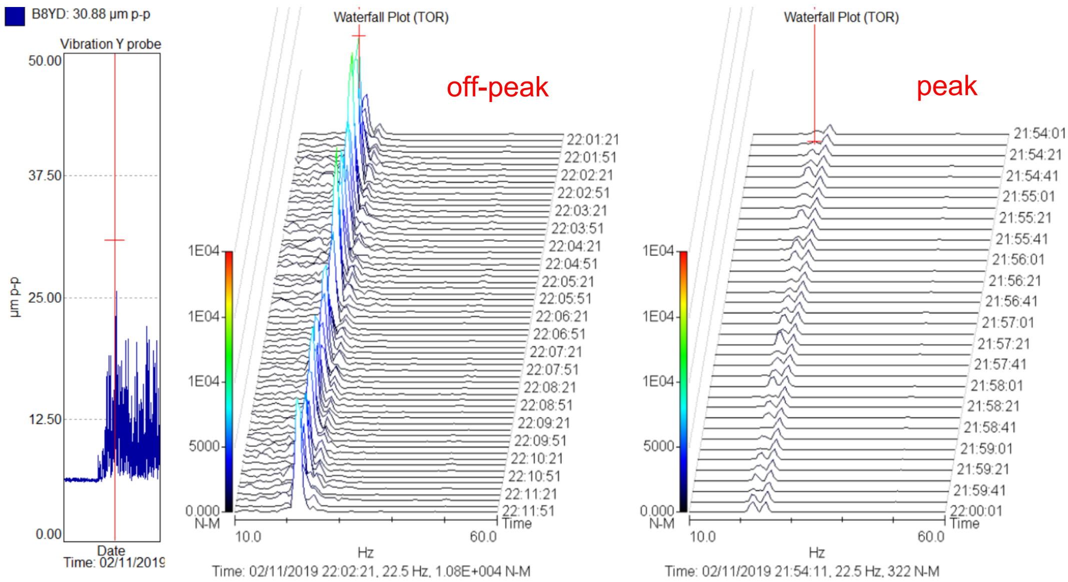

Figure 7 - Waterfall plots of dynamic torque spectrum comparison between peak and off-peak operation period.

1.

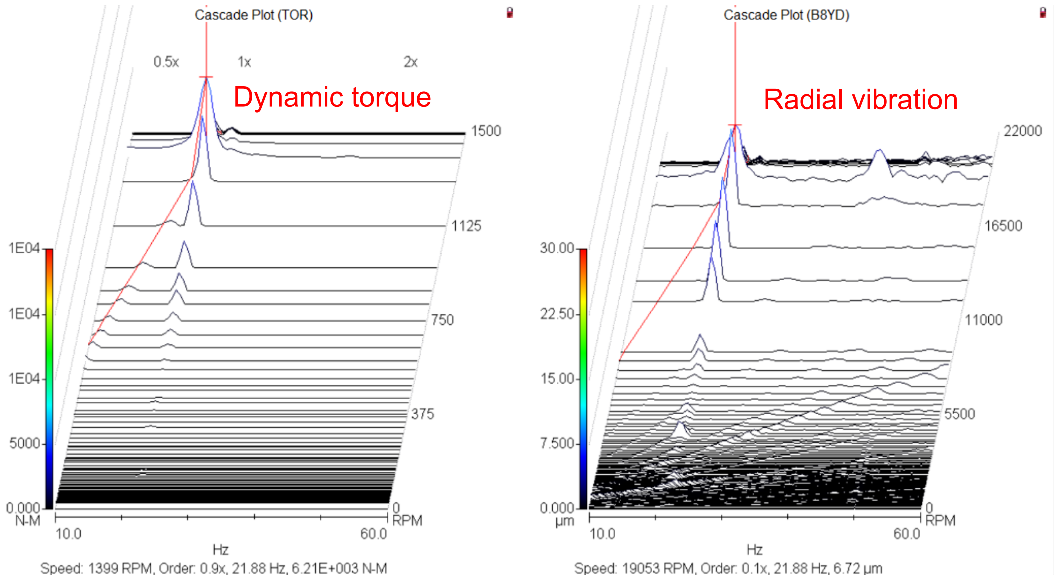

Figure 8 - Dynamic torque (left) and vibration of FC rotor (right) spectrum versus machine speed during transient.

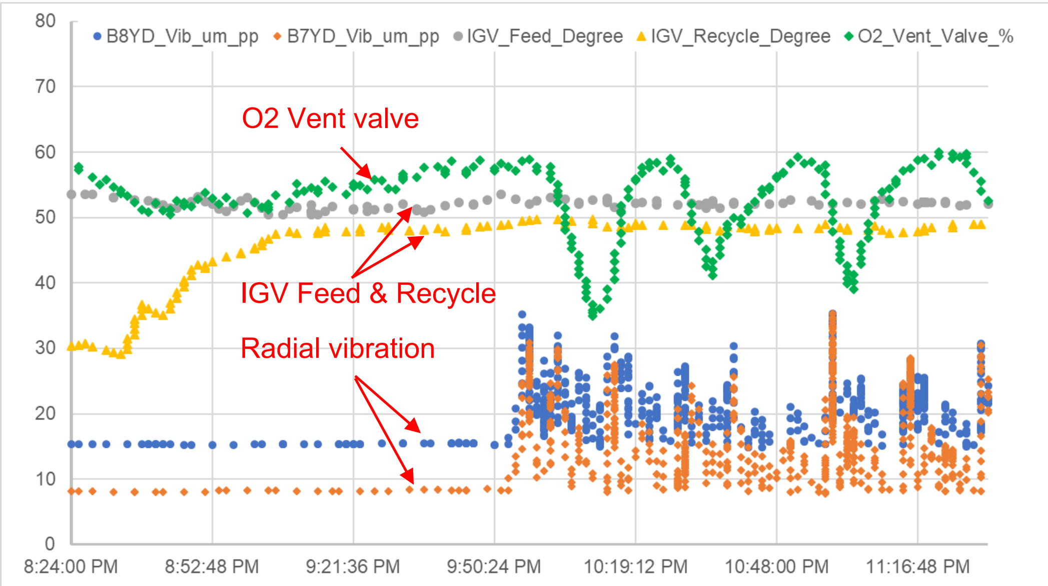

Figure 9 - Trend plots of multiple operating variables correlating with vibration data measured at FC rotor during peak and off-peak periods.

Table of Margins at Max Speed							
Other	**Mode 1**	**Mode 2**	**Mode 3**	**Mode 4**	**Mode 5**	**Mode 6**	**Mode 7**
	1278.867	6795.158	8282.77	13020.55	14319.32	17183.913	19113.547
1	-14.29%	355.44%	455.15%	772.69%	859.74%	1051.74%	1181.07%
2	-57.14%	127.72%	177.57%	336.35%	379.87%	475.87%	540.53%

Table 1 - Calculated torsional natural frequency of the drive train with separation margin from 1X and 2X of motor running speed.

This vent valve controls oxygen consumption to electric arc furnace (EAF) of nearby steel processing plant which is a customer of this gas plant. They are connected to the same electrical network. It can be evidence to support that EAF operation could generate fluctuating current to power supply grid of the motor resulting in torque oscillation, hence, torsional vibration excitation.

Corrective Actions

With findings above, possible corrective action was discussed as followings.

- Fluctuating motor supply current generated from steel plant during off-peak operation should be minimized with smoother or dampener. However, steel plant is a customer of air separation plant and also current fluctuation is less than 10% deviation as specified in the power purchasing agreement (PPA) with power provider.
- There are two machine trains at this air separation plant with almost identical configuration but another train has no issue of torsional vibration excitation. The difference is power supply source to these two machine trains as the one with problem is in the same power grid with steel plant and another uses power supply from another source. However, customer could not change two trains to the same source due to reliability concern as a backup unit is required.
- It is recommended to consult with machine manufacturer if coupling shall be redesigned to shift TNF from torsional excitation and/or change coupling type with more damping element e.g. elastomeric type, etc. Changing drive train TNF is feasible but exciting frequency of air-gap torque is likely to be broadband [1], hence, excitation or resonance problem could not be avoided. For elastomeric type coupling, this can help to dampen amplitude of torsional vibration excitation [2], but it does not eliminate the root cause as well as maintenance and duration of this coupling type might be a concern. The rubber elements tend to degrade over period of time and change its geometry resulting in other issues.
- Check with motor manufacturer for detail study of air-gap torque variation in case of motor current fluctuation. The result can be correlated with field torsional vibration data measured. The approach is to identify possible excitation frequency of air-gap as well as magnitude caused by fluctuating power supply current to the motor and it required special calculation [3].

There was also input from coupling manufacturer that fluctuating torque noticed is not over coupling capability/rating, hence, this is not likely to cause any damage to the coupling. However, another concern was torsional-lateral coupled vibration revealed at FC rotor could trigger trip vibration set points, hence, unexpected trip and lost product plus penalty can occur. The final solution is to change relay logic of vibration monitoring and protection system to avoid nuisance tripping as the trip logic of FC rotor should be voted with other rotors.

Conclusions

Fluctuating radial vibration amplitudes observed at FC stages rotor during off-peak period is due to torsional-lateral coupled vibration through gear mesh. This occurred when EAF of a nearby steel plant is operated resulting in fluctuating power supply current to the motor, hence, fluctuating air-gap torque. Predominant vibration frequency is 22.5 Hz which is close to first TNF of the drive train. Field measurement data shows clear corresponding and supporting evidences of radial shaft vibration, dynamic torque, power supply current, and process variables. Detailed analysis helps to find the root cause and see the problem clearly, then practical solution can be chosen. ■

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TEST YOUR KNOWLEDGE - PART 71 OF A SERIES

1 The vee profiles in a vee-section pulley are found to be worn. A decision is made to replace the pulley, and fortunately there are stampings on the pulley identifying its diameter. The stamping of that information relates to...

a The outside diameter of the pulley
b The pitch diameter of the pulley
c The diameter as would be measured at the bottom of the machined vees
d Both a and b are correct

2 During a single-plane balance job, the balancing program recommends adding 50 grams at location 3 on the impeller (there are 8 balancing locations in this instance – all evenly spaced and on the same pcd). If you cannot add the 50 grams at location 3, which of the following actions would give the same effect?

a Removing 50 grams at location 7
b Adding 35.36 grams at each of locations 2 and 4
c Removing 35.36 grams at each of locations 6 and 8
d Any of the above

3 Steel springs and Air springs can both be used effectively to isolate low-frequency vibrations. What advantage might an air spring isolator have over a steel spring isolator?

a Improved fire resistance
b Higher isolation efficiency
c The air-spring might be more effective at isolating high-frequency vibration (e.g. for noise reduction purposes)
d None of the above

4 A 2-pole motor is coupled to a screw compressor. A velocity spectrum collected from the motor using 400 lines and 1000 Hz fmax shows a vibration peak at about 2 x running speed, or possibly 100Hz (i.e. electrical). It is important that you establish which of the two it is. How might you proceed with greater certainty?

a Collect another spectrum with increased lines of resolution
b Collect another spectrum with a lower fmax
c Collect another spectrum with a higher fmax
d A or B, or (better still) A and B will provide greater clarity

5 A centrifugal fan running at 1200 rpm is belt-driven by a 4-pole motor via 6 x SPB belts. The belts are tensioned correctly using a sonic belt tensioning meter. Which of the following frequencies would likely be closest to the correct belt tension?

a 3 Hz
b 30 Hz
c 300 Hz
d 3000 Hz

6 During an insitu balancing job, the phase was noticed to be unstable. What might cause this?

a Looseness in the rotating assembly of the machine being balanced
b Intermittent/weak signal from the tachometer (due to sunlight, dirty reflective tape etc)
c The once/rev vibration signal has become reduced to a very low level due to the balancing being successful
d Any of the above could cause the phase to be unstable

7 Band alarms are a feature of many vibration analysis systems. What advantages (if any) might they offer over a system that alarms on overall vibration levels only?

a Band alarms could potentially provide much earlier detection of deterioration within the asset
b Band alarms might give more specific information as to the type of fault
c Both A and B are advantages of Band Alarms
d Neither A nor B are advantages of Band Alarms

8 If you suspect that the base-frame of a pump-set is loose on its concrete plinth (resulting in high vibration), how might you go about proving it?

a Take vertical readings on the baseframe and the concrete – a high variance in levels could be indicative of looseness
b Carry out cross-channel phase – one transducer on the structure, the other on the concrete – a variance in the phase could be indicative of looseness
c Often looseness might be confined to one location, so

Answers on page 30

Further enquiries can be directed to: Carl Townsend at Carlton Technology Ltd.
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take vibration readings in the vertical plane at each corner of the baseframe, and possibly mid-points, and compare the vibration levels

d All of the above could be valid approaches

9 Where might the letters TDC most-likely be noted?

a Analysis of reciprocating machines

b Analysis of electrical machines

c Analysis of centrifugal pumps

d Analysis of mixed-flow fans

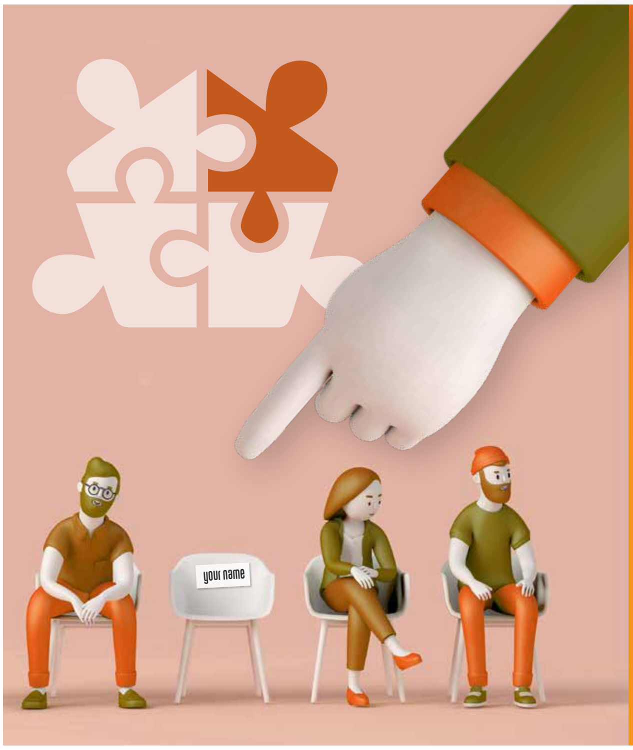
10 To which of the following machine faults would a dynamic absorber be a potential corrective measure?

a Machines vibrating due to looseness

b Machines that are unbalanced but which have no issues with resonance

c Machines that vibrate due to bearing degradation

d Machines that vibrate due to resonance issues



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How many words of three or more letters can you make, using each letter only once? Plurals are allowed, but no foreign words or words beginning with a capital. There is at least one 5 letter word.

15 - Good | **20** - Very Good | **25+** - Excellent

P	E	R	A	O

There is 2 possible 5 letter words above. Can you find them?

WORD LADDER

A Word Ladder has two words in the ladder, one at the top and one at the bottom. You must form a sequence of words going down. On every step of the ladder (1-6), you must unscramble and create a new word that only differs **by one letter** from the word above it until you reach the destination word on line 6.
We've started it off for you...

1 RANSOM
2 ORGANS
3
4
5
6 CRAYON

SUDOKU

To solve, each number from 1 to 9 must appear once in:

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- Each of the nine horizontal rows
- Each of the nine 3 x 3 boxes

No number can be repeated twice in a box, row or column.
Why not time yourself? We've started it off for you...

7	4							2
6	5		1	3	2			9
					4			
		5				7		
9		2	8	7	1			
		7						1
	2		9	1	5			
	8			2			1	
1					3		5	

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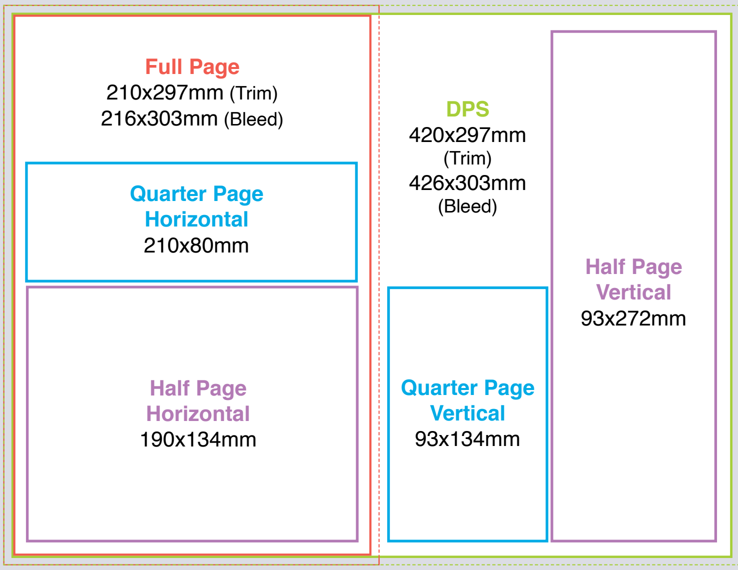

CarltonTechnology
vibration • noise • reliability / engineering support

Word Ladder: 1. random, 2. organs, 3. jargon, 4. trojan, 5. contra, 6. crayon
Word Builder: opera, pared
Carlton Technology Quiz 71: 1B, 2D, 3C, 4D, 5B, 6D, 7C, 8D, 9A, 10D

Knowledge is power. Knowledge shared is power multiplied!

– Robert Boyce

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