To:	Steve Hart, Peter Badenhorst
From:	David Farrell B.E. Mech (hons)
Date:	17-08-2023
Subject:	**TCAE COST BENEFIT ANALYSIS AND RECOMMENDATIONS**

INTRODUCTION:

The object of this report is to research the current market data regarding power efficiency and losses associated with pump to motor couplings in particular and assess how much improvement can be gained from the TCAE as a selling feature.

PRODUCTS OVERVIEW:

Thompson Coupling Alignment Eliminator (TCAE):

The major characteristics of the TCAE are the large parallel (up to 17mm), angular (up to 5° per coupling unit) and axial misalignment (up to ±15mm) created by both joints avoiding side load on pump / motor bearings. The main component that drives the AE product features and selling prices is the CV joint and the whole product is based on that part. The product range of 5 different series totaling 92 couplings can accommodate motor sizes from 1KW to 400 KW with no required maintenance for the life of the coupling.

COSTINGS AND POTENTIAL SAVINGS:

There are 4 distinct potential cost savings that are considered in analysing the present use of shaft couplings commonly used in pump/gearbox to motor arrangements. These are:

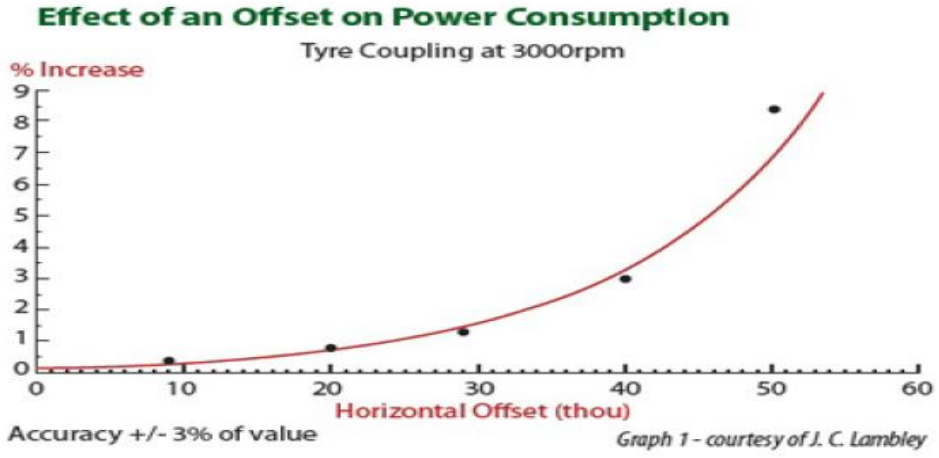
- Initial capital purchase cost of the coupling
- Overall efficiency losses through the coupling due to misalignment
- Plant downtime due to replacement of motors, pumps and couplings as well as premature pump bearing and seal failures
- Preventative maintenance cost of periodic laser alignment services for the shaft couplings.

While it is currently understood that the TCAE coupling maybe slightly higher in initial capital outlay compared to existing gear/grid/elastomeric type couplings the latter 3 savings do provide a more compelling case for plant wide cost savings by switching to the TCAE coupling.

1. Efficiency savings:

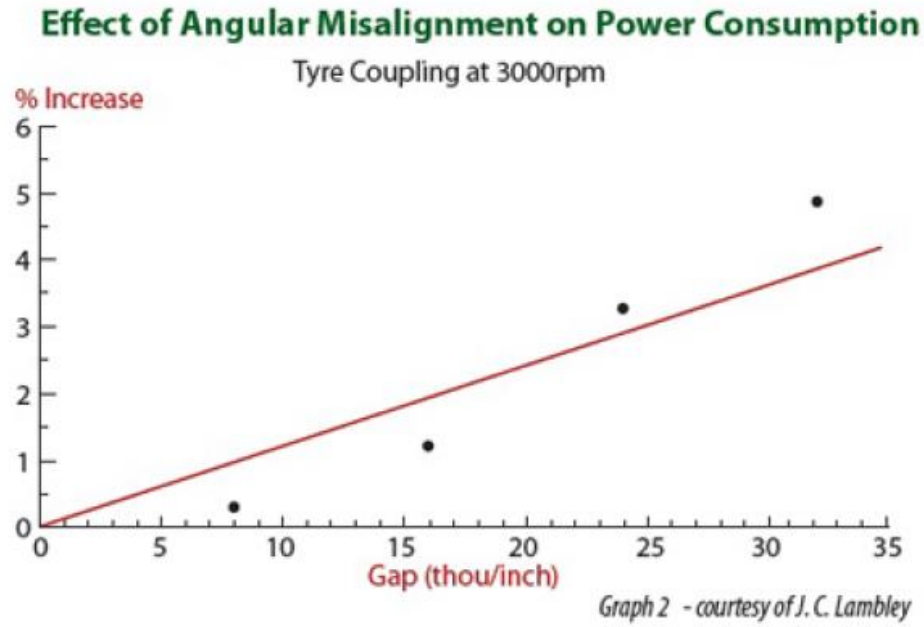
An extensive literature review of the efficiency losses associated with shaft misalignment has been conducted. There have been many independent and university research studies conducted on this subject since the late 1960's and mostly show there are significant losses with coupling misalignment – especially if the alignment falls outside the manufacturer's specifications. Often with grid/ gear and similar couplings the allowable tolerances are quite tight (less than 1 mm offset and 1 degree angular). A recent industry report by the laser alignment advocates showed that more than 90% of machines have shaft misalignment outside their manufacturer's tolerances.

The most significant study by JC Lambley (known as the Runcorn study by ICI Chemicals) showed the effect of shaft misalignment on power consumption as follows: Note the offset distances are in thousandths of an inch. (10 thou= 0.25mm and 40 thou = 1mm)



Graph 1 - courtesy of J. C. Lambley

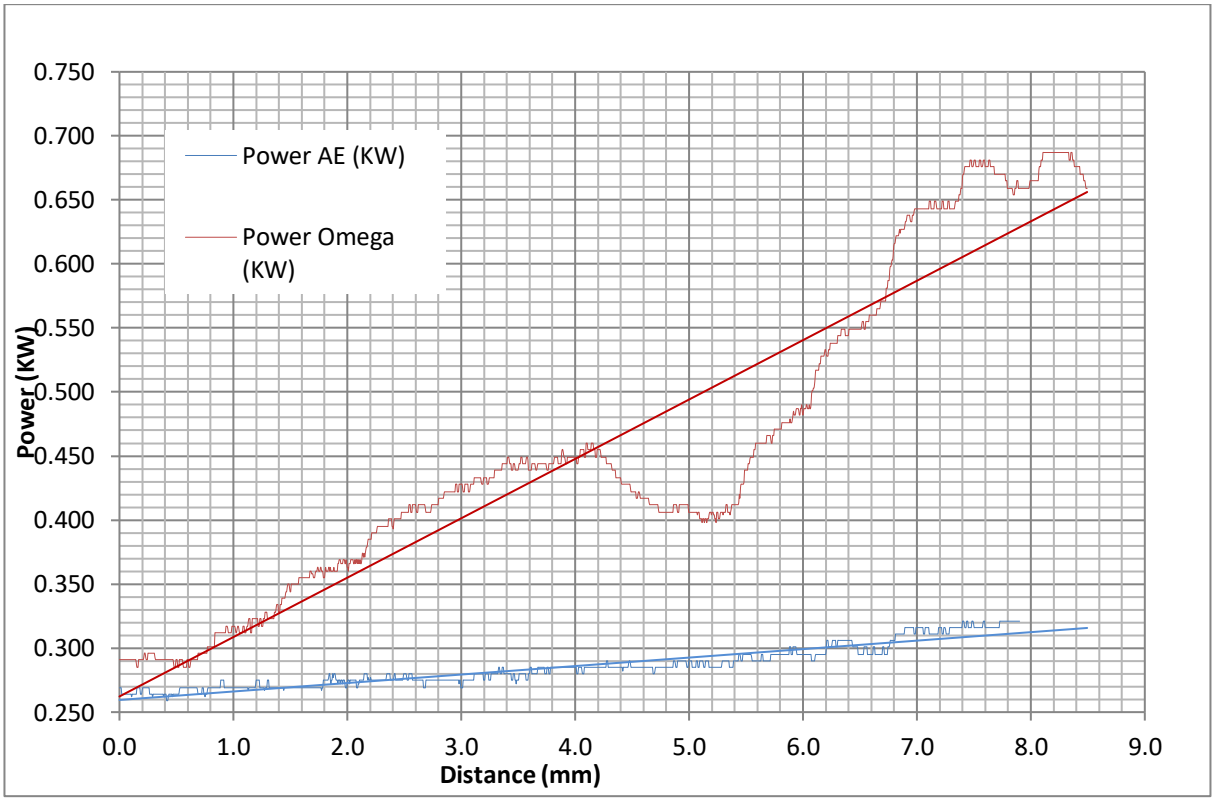
The same author produced the following graph for angular misalignment: Note the angles are in thou/inch (10 thou/inch = 0.5 degs)



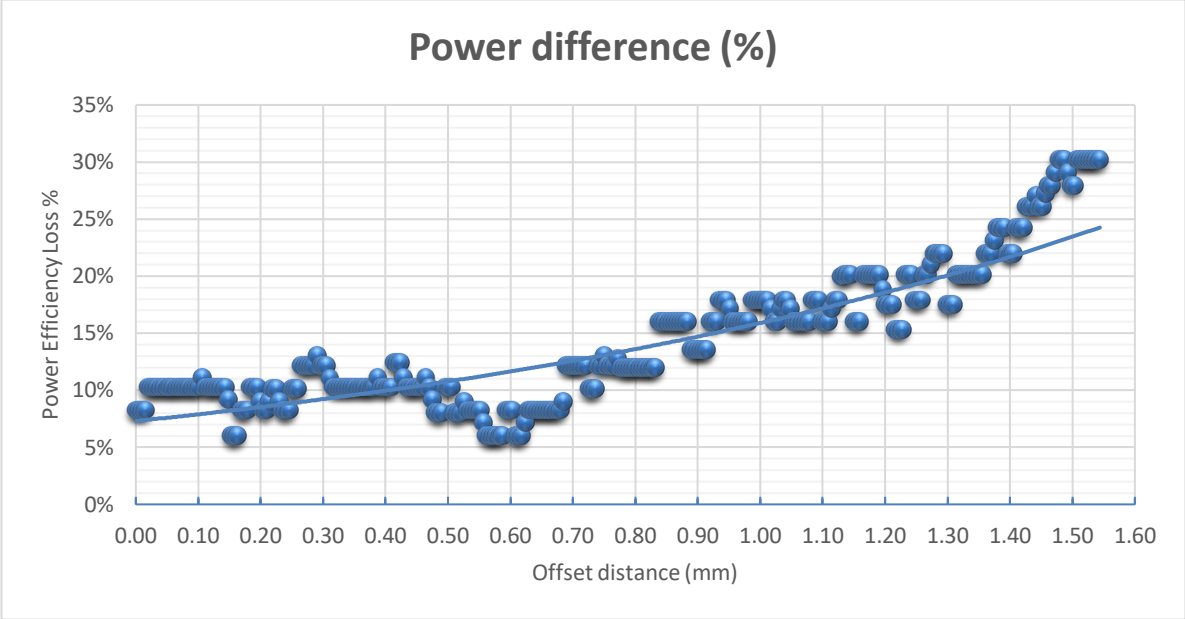
This trend is similarly repeated by other authors with some citing savings between 3% and 10% and 9% being common in old plants in some situations.

Other authors quote very conservative efficiency losses of 1% to 1.5 %

We conducted our own series of test experiments to try and determine the power draw of various couplings. In the following experiment we connected a 3 phase, 0.75 kW electric motor to a generator via a flexible tyre coupling (Omega) and then a TCAE (AE2) coupling. A series of power measurements was recorded after adjusting the offset gap by 0.1 mm increments. The results did show a significant difference in power consumption as follows:



When this is converted to an efficiency difference for just the first 1.6mm offset distance the following graph shows the result:



Clearly it can be seen that a 10% efficiency gain can be made with the TCAE with just a 0.5mm shaft offset.

But in summary the best realistic efficiency improvement that I have found using the TCAE – is **2.3%**, and this after proper laser aligning.

"A ReliabilityWeb.com article, "Shaft Alignment, Soft Foot & Energy Savings," cited studies that show you can get a real energy savings of 2.3% by aligning a loaded machine—and as much as 9% on an unloaded machine. For a plant spending $50,000 per month on energy, that would equal a savings of $1,250-$4,500/month—or $15,000-$54,000 per year."

Even if there is only 1% savings is that significant. (Michael Keohan 04/20/2012 Energy savings, Vigralign Blog) gave the following example.

1% drop on a 480 volt motor running 8400 hours/yr drawing 50 amps (~40hp) with a cost of

$0.07/kWhr

kW Reduction = (480V)(0.5A)(0.92PF)(1.732)/1000

0.38 kW reduction

Total Savings = 8400 hours/yr x 0.38kW drop x $0.07/kWhr = $225 for this one machine Total Plant

savings for 50 machines, averaging 50A, if 50% are misaligned

$5625/yr

This is significant to any Engineer trying to keep operating costs to a minimum.

2. Reduced Downtime Savings

The potential cost savings in reducing downtime from a failed pump seal or motor bearing due to poor coupling misalignment can be enormous especially in a large plant with critical equipment.

There are 2 main type of equipment in a plants operation:

- Critical service equipment
- Non critical items

When considering critical service equipment, a much higher downtime cost would be attributable. This could be anything upwards of $10,000 per hour in some factories where the upstream and downstream processes are directly affected by the stoppage. Take a

san example a large process pump that has a failed bearing due to poor coupling misalignment. The costs attributable to the failure maybe:

- Downtime to isolate the existing pump/gearbox;
- Downtime to fetch the new pump/gearbox from stores;
- Downtime to remove and install the new pump;
- Downtime to re-align the new coupling;
- Downtime to re-energise the pump/gearbox and bring back online.

This total downtime, being conservative, would take 1 hour to complete and if the rest of the process is directly affected is easily a $10,000 direct loss to production.

A Non-Critical item would be a similar pump which is coupled to a standby pump that fulfills the same function as the main duty pump. In this scenario if the main pump fails due to a similar fault as previous the downtime is much reduced due to a simple standby switching arrangement. In such situations care needs to be taken to understand the nature of the business for the intended installation of a TCAE coupling and its proposed cost benefit. The benefits here would be the removal, repair and reinstallation costs of the pump/gearbox, both in cost of parts or new machine and the labour costs involved. All this is drastically reduced using a TCAE coupling.

Other savings are possible with quantifiable costs for reduced bearing life in pumps, gearboxes and motors that are subjected to shaft misalignment conditions.

A published paper has estimated the following:

Estimated time a machine will fail due to misalignment.

Misalignment (Mil/Inch)	Estimated time to failure
0.2	250 months
1	60 months
5	10 months
10	6 months
50	2 months
100	0.6 months
Note Misalignment is mil/Inch (Milradian.) 6" of distance between shafts and 0.2 mil/Inch tolerance is equal to 1.2/1000" of offset at the center of the shafts.	

This can be converted to the following quick rules of thumb for convenience:

If the bearing load on a pump or motor is increased due to mechanical stresses by misalignment it will reduce the bearing life by a factor to the 3rd power.

Or
10% increase in bearing load = 24.9% of bearing life reduction in normal load.
20% increase in bearing load = 42.2% of bearing life reduction in normal load.
50% increase in bearing load = 70.4% of bearing life reduction in normal load.

3. Elimination of Laser Alignment service costs

As many companies realise the benefits of preventative and now predictive maintenance regime, they include a periodic check of the shaft alignments to ensure all is within the desired tolerances.

The last major cost to be identified is the actual cost to perform the continual laser alignment service on the many pumps and motors in a factory. These are often outsourced to specialist companies (such as SKF, Vibralign, PdM Solutions, Easy Laser etc) who charge for an inspection normally 3 or 4 times per year. The operation involves stopping the desired pump/gearbox/motor for a time while the necessary measurements and adjustments are made to bring the alignment back into specification.

In an ideal situation this may take as little as 20 minutes to perform before the pump is returned to service. BUT more often the pump or motor may have SOFT FOOT issues meaning the connected baseplate is not rigid. When this occurs, a technician can spend more time (often hours) to try and correct for poor shaft alignment only to be chasing his tail since the foundations are loose and cannot hold the required tolerances.

In both situations the pump is out of action for a period of time thereby causing loss of production. Added with the service technicians cost (maybe $100 - $150 per hour) equates to an expensive but necessary exercise in maintaining precise shaft alignment.

Enter the TCAE solution:

- No need to maintain the necessary shaft alignment tolerances as with conventional couplings
- Hence no need to employ service technician companies to perform laser alignments
- Hence no need to shut the pump down while such services would be undertaken
- Hence direct cost savings to the company.
- Also reduced forces on the shafts from misalignment means an increased service life of the pump and motor bearings as well as pump seals
- Furthermore a direct saving in production downtime is achieved with reduced problems in pumps and motors
- Finally a direct power efficiency of 2.3% minimal is achievable by switching to the TCAE due to reduced shaft loads from misalignment

References can be supplied to all studies if interested:

David Farrell B.E. Mech (hons). – Engineering Dept. Thompson Couplings Ltd.