The Growth of Australian Regenerative Load Testing

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Historically, gearbox original equipment manufacturers (OEMs) and repair organizations have tended to offer their customers 'no-load, full speed' ('spin') tests as a standard performance test. If a 'load test' was specified, the supplier would probably offer a locked torque 'back-to-back' simulated load test, which requires a large investment in tooling to connect shafts of the test and slave gearboxes.

Advances in cost-effective power electronics, however, have enabled businesses to consider the installation of an efficient regeneration system that enables the possibility of load testing industrial gearboxes in the medium power ranges (a power level that typically would have been price-prohibitive to install in many facilities).

Regenerative load testing recycles the energy that conventional load testing methods needed to dissipate. A typical system will utilize two similar-sized motors (one to drive the equipment, the other to generate power) and a speed-matching gearbox (similar in ratio to that of the 'test' gearbox). Systems are designed to suit a customer specification; a low-voltage (480/690 Volt) system can handle electrical power up to about 3.2MW, while larger power requirements need to switch to medium voltage, due to limitations on current at low voltages (Fig. 1).

Motor drives and electrical cabinets are modular, enabling companies to build capability on a budget — starting at 100/200 kW — with the knowledge that it is possible to increase power capacity at a later date by adding drives. When planning an expansion of the test facility, it is important to consider the holistic workshop layout. Consideration must be given to operator and visitor safety, piping and cable management, lube system tanks and pumps, cooling systems, and any increased loadings on the floor plate design, to name but a few.

Energy losses on a typical regenerative test are about 20% of the nominal rated power; these losses are due to the drive efficiency in both motor and generator, plus the gearbox losses from bearings and gear tooth mesh heat. Therefore, a nominal 1 MW test (Fig. 2) would only require approximately 200 kW through the main supply, enabling smaller workshops with a limited power supply to offer significantly higher load capability.

Figure 3 demonstrates power consumption of a typical load test; the plot identifies the test motor (blue), the regenerated power (green) and the consumed power (orange), while stepping up load in 25% increments.

Speed 'matching' is important for efficient generation, as the generator ideally rotates at the same speed as the driving motor to avoid frequency

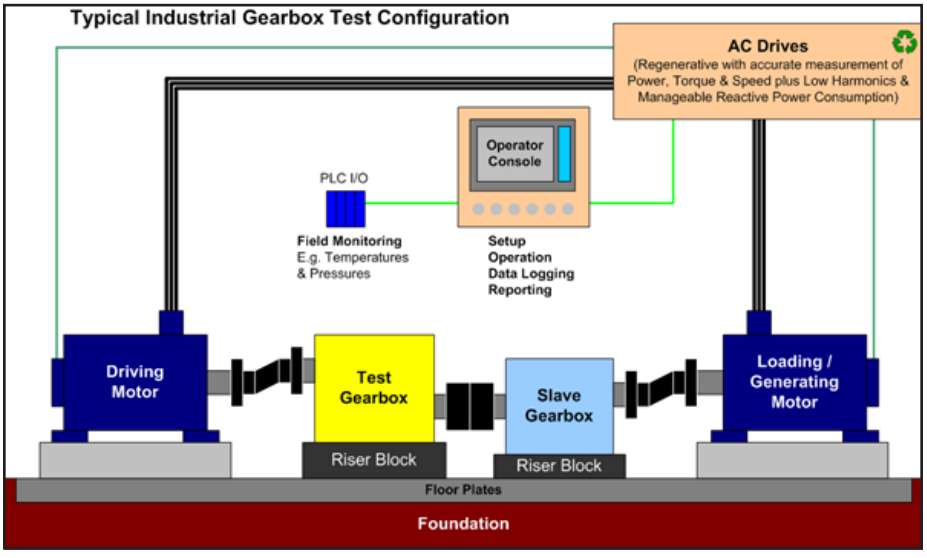

Figure 1 Schematic of a regeneration GearTEST set-up.

Figure 2 1MW-load GEARTest installation at Hoffman Engineering, Perth, Australia.

conversion losses. However, there is a tolerance band of approximately +/- 10% where the efficiency of conversion is reasonable.

It is nevertheless worth noting that for service providers wanting to offer a wide range of test powers and speeds, there will be a requirement to hold a range of step-up/step-down test gearboxes to maximize regeneration benefits.

The regenerative energy saving potential especially pays dividends when testing gearboxes with rated powers over 300 kW. Tables 1 and 2 highlight potential cost savings on annual electricity consumption alone, based on testing two gearboxes a week across a range of powers. It is worth noting that, as electricity costs vary substantially around the world, prices from the U.S., Australia and Germany are used for comparison. All prices are converted to U.S. dollars utilizing purchase power parity figures in U.S. dollars from OVO Energy *(https://www.ovoenergy.com/guides/energy-guides/average-electricity-prices-kwh.html)* as a baseline.

As test powers increase, calculations highlight the significant savings to be made by adopting regenerative technology, and those benefits are magnified significantly in geographical areas where electricity costs are high. However, cost savings alone do not seem to be driving investment strategy.

Over the past ten years in Australia, the 'load' testing of industrial gearboxes has become somewhat of a standard requirement in many repair specifications. It is Australian end-users that have perceived significant value in load testing both repaired and new gearboxes, citing increased reliability and the associated reductions in unscheduled down-time as major factors that save cost over the long term.

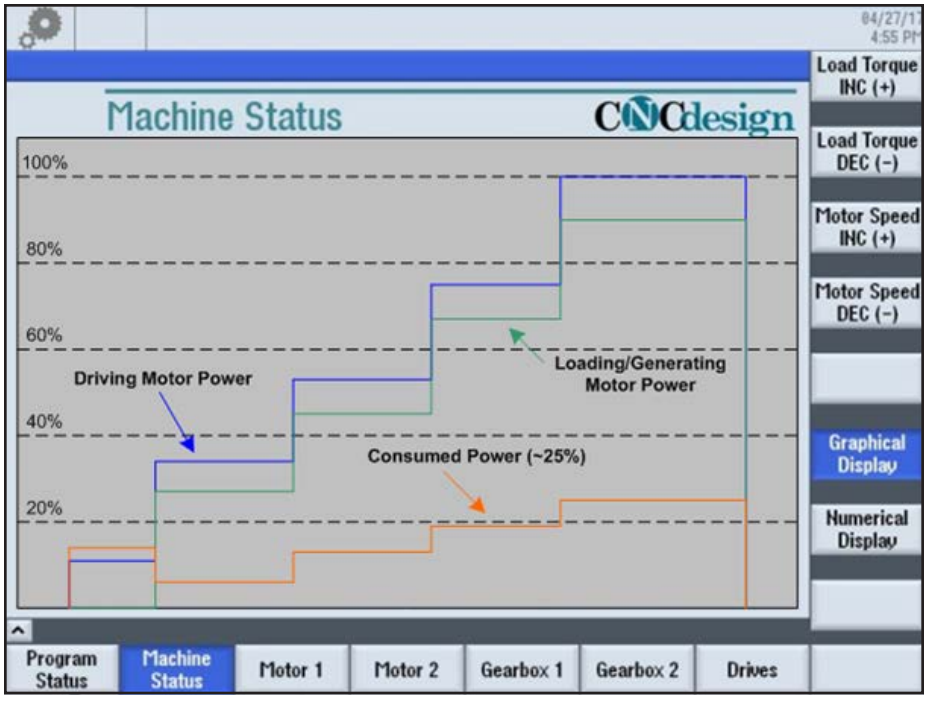

Figure 3 Power consumption.

What is interesting to observe in the Australian market is that the demand for 'load' testing has driven a number of industrial gearbox service providers to make an investment in load test capabilities — some even duplicating capacity to compete at a local state level, rather than rely on a national strategy.

Table 3 identifies the competitive landscape in Australia and the recent growth of the regenerative test capacity. A high proportion of new investments have tended towards regenerative technology for the cost and performance benefits described above.

While it is the Australian mining sector that has pioneered the drive in demand for industrial gearbox load testing for reliability, other industries may benefit from more comprehensive testing, especially in applications where the gearboxes and associated plant have very high installation and maintenance costs; e.g. — marine drives, gear-driven hydro turbines and sub-sea marine turbines.

Future developments in (trademarked) *GearTEST* solutions are focused around Industry 4.0 concepts, with improved sensors for better data acquisition and reporting. Traditional *GearTEST* report parameters such as power, speed, temperatures, pressures and flows are all recorded and processed through the control system, while additional features such as test lube oil condition analysis, shaft alignment features and auto-adjustable mount plates to enable simulation of inclined installations are all possible.

As yet, the cultural shift of end-users specifying load tests does not seem to have gained much momentum outside of the Australian mining sector, but as gearbox repair companies continue to seek new areas of competitive advantage, regenerative load testing capability is a potential area of differentiation that could improve a company's value-added proposition.

Of course as regenerative load testing

Table 1 Cost saving potential: Australia in USD

Gearbox Rated Power (kW)	Test Time (hours)	Average $/ kWh cost (Australia)	Electricity Cost per TEST (With out Regen)	2 Test Per Week - Test Cost Per Year (USD)	Electric Cost with Regeneration (Per Year)	POTENTIAL ENERGY SAVINGS PER YEAR (USD)
100	4	$0.21	$84,00	$7,644.00	$1,490.58	$6,153.42
500	4	$0.21	$420.00	$38,220,00	$7,452.90	$30,767.10
1,000	4	$0.21	$840.00	$76440,00	$14,905.80	$61,534.20
2,000	4	$0.21	$1,680.00	$152,880.00	$29,811.60	$123,068.40
3,200	4	$0.21	$2,688.00	$244,608.00	$47,698.56	$196,909.44
4,000	4	$0.21	$3,360.00	$305,760.00	$59,623.20	$246,136.80
4,500	4	$0.21	$3,780.00	$343,980.00	$67,076.10	$276,903.90

becomes more accessible, it is likely that an increasing number of end-users will specify it in the industrial markets, as well as part load testing rather than the 'spin' test; this may well become the global industry standard, as currently seen in the local Australian market.

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Table 2 U.S. and Germany savings

Gearbox Rated Power (kW)	USA average rate $/kWh	USA Regeneration Savings (USD)	German average rate $/kWh	German Regeneration Savings (USD)
100	$0.12	$3,516.24	$0.32	$9,376.64
500	$0.12	$17,581.20	$0.32	$46,883.20
1,000	$0.12	$35,162.40	$0.32	$93,766.40
2,000	$0.12	$70,324.80	$0.32	$187,532.80
3,200	$0.12	$112,519.68	$0.32	$300,052.48
4,000	$0.12	$140,649.60	$0.32	$375,065.60
4,500	$0.12	$158,230.80	$0.32	$421,948.80

Table 3 Advertised gearbox load test capacity in Australia 2018

Australian Gear Repair Service Providers	Workshop Location	Estimated Year Installed	Rated Power Capacity (KW)	Load Source
Gear Drive Services	Perth, WA	2008	800	ReGen
David Brown Santasalo	Perth, WA	2010	450	ReGen
Hoffmann Engineering	Perth, WA	2010	1,000	ReGen
Wittenbacker (WES)	Perth, WA	2012	600	Dyno
SEW Eurodrive	Mackay, QLD	2015	500	ReGen
Sumitomo	Mackay, QLD	2018	500	ReGen
Siemens	Rockhampton, QLD	2015	3,000	ReGen
Eickoff Australia	Sydney, NSW	2018	1,000	ReGen
David Brown Santasalo	Sydney, NSW	2000	500	Dyno
DCL Engineering	Sydney, NSW	2006	50	Hydraulic
Sumitomo	Sydney, NSW	2014	150	Regen
State Wide Bearings	Newcastle, NSW	2010	90	Dyno
Hoffmann Engineering	Newcastle, NSW	2015	90	Regen
Geared Engineering	Sydney, NSW	2013	50	Dyno

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