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Is the Gearbox Dead?

Julia Munday

20 Berrydale, Northampton NN3 5EQ, United Kingdom
munday_45@hotmail.com

INTRODUCTION

By 2009 the relatively cheap synchronous permanent magnet gearless machines that had been originally developed for MRL applications were being applied more widely, with many manufacturers offering packages consisting of machines, bedplates and divertor pulleys aimed at the modernisation market and many consultants specifying these systems for low to medium rise buildings because of their perceived benefits with regard to reduced running costs and general eco-friendliness as exemplified by environmental assessment methods such as BREEAM made it a good time to carry out an objective study comparing the capital and running costs of schemes using a traditional geared machine with schemes using a gearless machine for a range of real life modernisation applications.

The Perceived Benefits of PM Gearless Machines. The main points are as follows:

- They are more efficient and can be used with regenerative drives, thus saving energy;
- One machine model can be applied to a larger range of applications than a geared machine thus making it more economical to hold stocks "on the shelf" reducing lead times;
- Cleaner than a geared machine because no oil reservoir is required;
- Machines are designed to be low maintenance and should offer savings on long term maintenance costs.

Possible Disadvantages of PM Gearless Machines. The main points are as follows:

- Most machines are designed for use with new MRL package lifts, i.e. lightweight lift cars and multi-reeved pulleys (2:1 systems being common with 4:1 and even 6:1 systems used for larger capacity lifts) whereas a traditional lift will have heavier cars and 1:1 roping;
- Many packages designed for modernisation use rope diameters and pulley diameters smaller than permitted by EN81-1 to convert existing 1:1 roped systems to multi-reeved systems;
- The machines may need "exotic" arrangements of divertor pulleys to increase the angle of wrap of the ropes on the sheave to achieve traction;

METHODOLOGY

Machine Selection. As each machine manufacturer has developed their own individual methods of machine selection, system calculations were developed from the coursework and the relevant sections of EN81-1 to select the machines. Compliance with the requirements of EN81 with regard to rope diameter and minimum rope to sheave ratios was considered of prime importance. Unfortunately this disqualified some gearless machine ranges from consideration, as they used ropes smaller than 8 mm in diameter. The manufacturers with the widest ranges of machines capable of covering the full range of applications considered (1:1 or 2:1 roped up to and including 2000 kg rated load and 2.0 m/s rated speed) were chosen, namely Alberto Sassi S.p.A. for the geared machines and Leroy Somer for the gearless machines.

Estimation of Energy Consumption. BREEAM is the most commonly used environmental assessment method used in the UK and their methodology used in 2008 made reference to ISO Draft standard ISO/DIS 25745-1:2008[1,2] [1]. The method outlined in draft standard for calculating the theoretical energy usage wasn't good enough as it didn't give any guidance on the estimation of the number of trips per annum and placed undue emphasis on the reduction of the counterbalance ratio. A more comprehensive methodology was found on the Energy-Efficient Elevators & Escalators (E4) website and this was used instead [3]. Figures for the number of trips per annum were taken from the UK section of the E4 interim report [4]. For the gearless machines the energy usage was calculated separately with and without regeneration.

Unfortunately neither publication gave any guidance on estimating the power required when the lift was on standby. It was assumed that the overall standby power for the worst case (i.e. installations without automatic shutdown on idle) would include elements required by the drive, controller & indicators (40 W) [5]; the door gear (15 W per car entrance for powered doors only) [6] and the car lighting (5 kW per 100 kg rated load, double this for hospital lifts).

Estimation of Costs. The capital cost items that needed to be considered for each scheme were:

- The machine and associated rope guards, bedplates & divertors from the machine manufacturer's price lists (Sassi or Leroy Somer).
- Ropes (Gustaf Wolf from Re-ropes Ltd).
- Drives (Control Techniques "Unidrive SP" from Leroy Somer). For the gearless schemes the drive cost was assumed to double if the drive was regenerative.
- Compensation (Dätwyler flat belt type from A&A).

The running costs comprised electricity and maintenance. Electricity was difficult to estimate because of the plethora of available tariffs.EDF Energy's standard domestic tariff for the London area [7] was finally chosen for use as a benchmark. After some discussion with a colleague selling maintenance it was decided to exclude this element from the running costs as the cost of a contract is primarily determined by the age and availability of spares for the equipment, so in this case the cost of a maintenance contract would likely be the same for both geared and gearless schemes.

Applications. The applications were chosen from actual modernisations that had been undertaken by Kone in 2008/2009. These ranged from 2000 kg goods lifts with manual doors in a retail unit to small lifts in residential units and included lifts in offices & hospitals.

RESULTS

With regard to the capital costs in every case considered the geared machine was the cheapest option and the gearless machine with regenerative drive was the most expensive; and the gearless machine with regenerative drive consumed the least energy, the geared machine the most. Further analysis is required to ascertain whether the energy savings made by the use of a gearless machine with regenerative drive can ever be sufficient to offset the increased initial outlay.

Fig. 1 shows the relative costs of each scheme for each of the case studies after 15 years assuming energy costs rise by 10% each year. The case studies were arranged in order of usage, with 1 having the lowest use and 15 the highest. It can clearly be seen that gearless solutions are generally more economical for applications with usage in excess of 300,000 trips per annum. Most of the case studies follow the same pattern, the exceptions being case 2 which had a relatively high rated speed, and case 14 which had an extremely high usage.

The power required of a lift motor depends on the rated load and the rated speed, so comparing the costs against the product of the rated load and rated speed as shown in fig.2 gives a further

[1] Both BREEAM and ISO/DIS 25745-1 have since been updated.

insight into the point at which it would be economically feasible to use a gearless machine in preference to a geared machine.

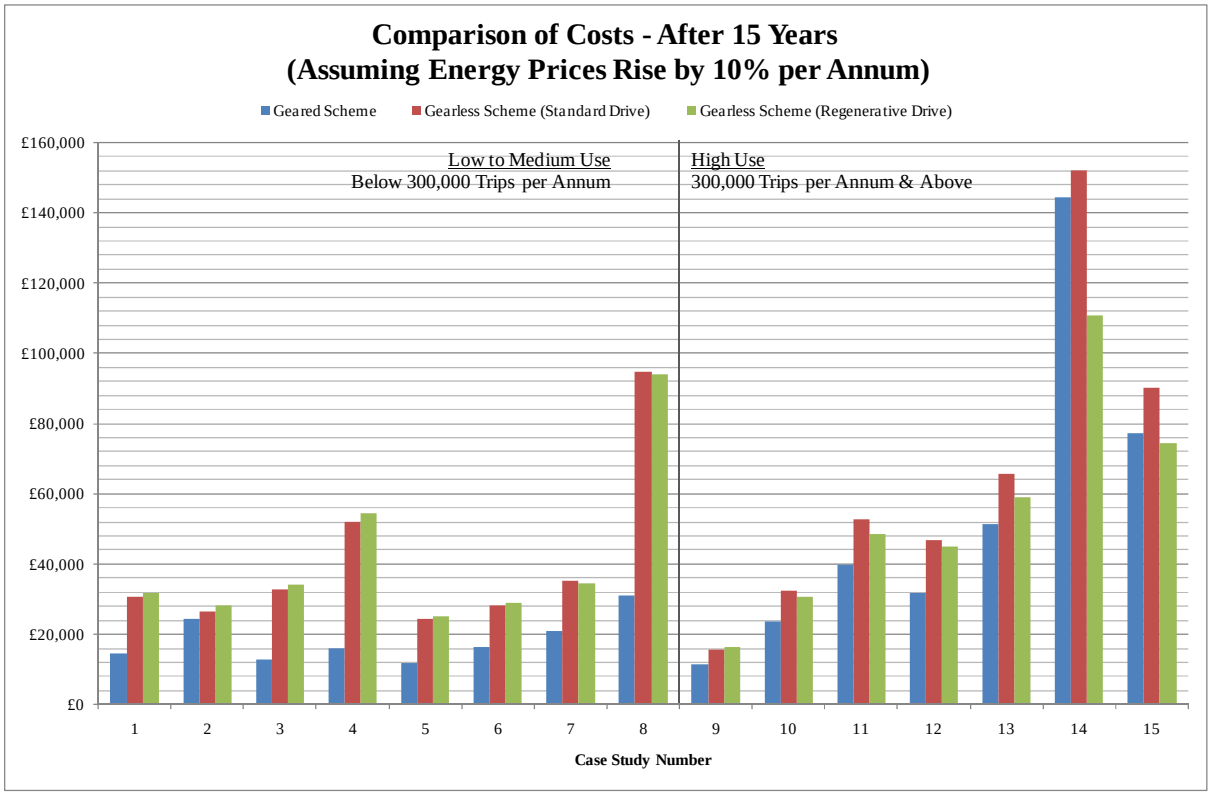

Figure 1

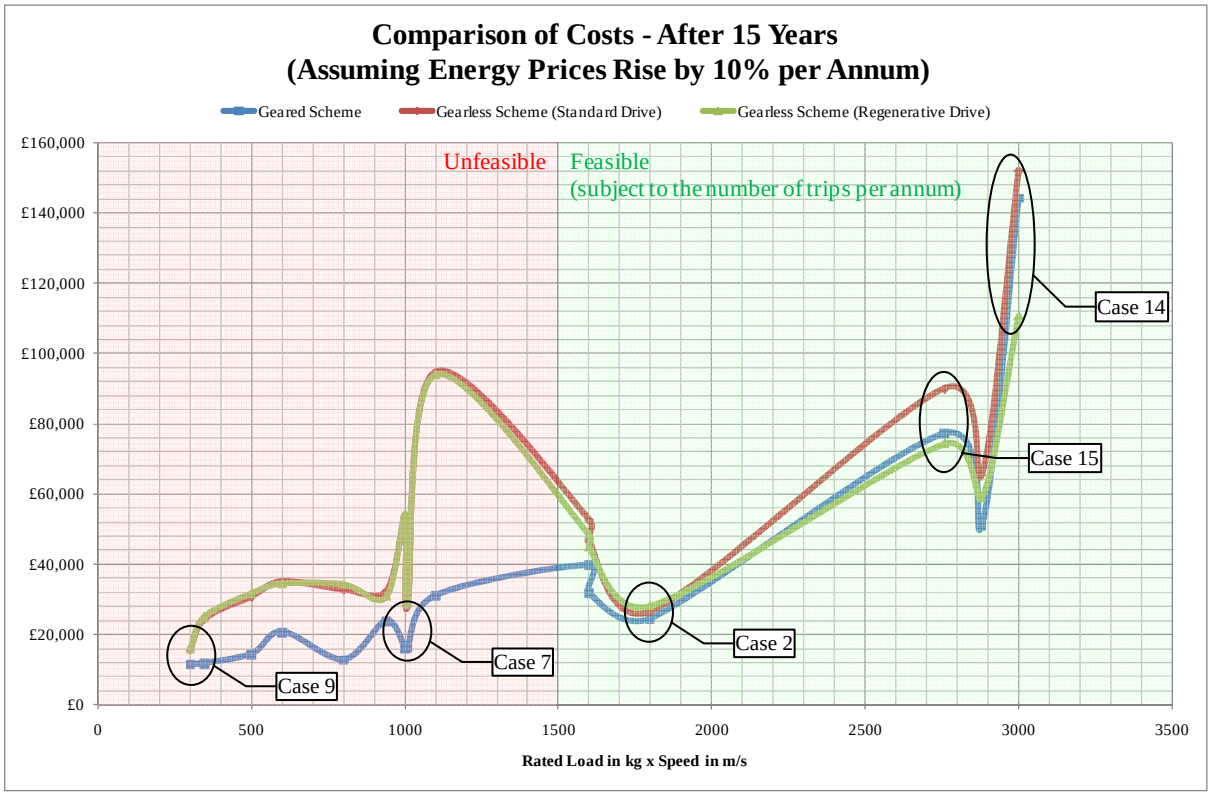

Figure 2

It is informative to look at tab.1 the data table used to prepare fig. 2 for further insights.

Rated Load x Rated Speed (kgm/s)	300	346.5	500	600	800	938.7	1000	1008	1100	1600	1600	1800	2760	2880	3000
Trips per Annum	300,000	50,000	30,000	200,000	30,000	300,000	30,000	50,000	200,000	300,000	300,000	30,000	800,000	300,000	500,000
Geared Scheme	£11,507	£11,827	£14,457	£20,741	£12,809	£23,866	£16,065	£16,239	£31,161	£39,786	£31,878	£24,571	£77,289	£51,184	£144,400
Gearless Scheme (Standard Drive)	£15,764	£24,441	£30,858	£35,099	£32,775	£32,326	£52,215	£28,234	£94,758	£52,712	£46,650	£26,613	£90,108	£65,632	£152,160
Gearless Scheme (Regenerative Drive)	£16,282	£25,206	£31,831	£34,625	£34,335	£30,828	£54,375	£29,106	£94,085	£48,512	£44,921	£28,209	£74,351	£59,131	£110,720
Case Study	**9**	**5**	**1**	**7**	**3**	**10**	**4**	**6**	**8**	**11**	**12**	**2**	**15**	**13**	**14**

Table 1

CONCLUSIONS

As an rough rule of thumb: if the rated speed multiplied by the rated load exceeds 1500 kgm/s a gearless machine is worth considering, but a regenerative drive only where the lift is likely to exceed 200,000-300,000 trips per annum.

Since the completion of the work energy prices have risen substantially and seem set to rise at a greater rate than anticipated, however it is inevitable the price of permanent magnet gearless machines will rise significantly in the near future as the price of the neodymium used to make the magnets has risen tenfold over the past year [8], whilst the prices of geared machines have not risen significantly over this time. Perhaps the worm gear is due for a renaissance!

REFERENCES

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