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File Note: Open Gear Lubrication and Alignment

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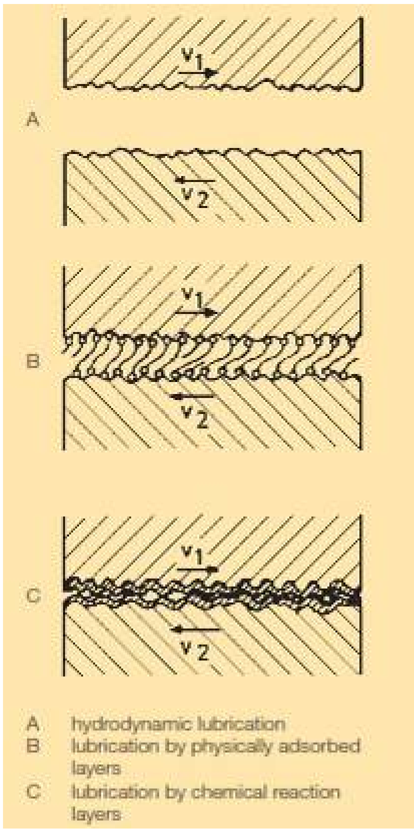
Introduction:
Open Gear drives are a group of gear drives that are usually of large dimension and are most often a single stage reduction. "Open" refers to the lack of a gearbox enclosure that locates and maintains alignment between gears and provides containment and a reservoir for gear oil.
Open gear drives have each of the drive components on separate structures and have independent adjustment for alignment and backlash.
Due to these features, open gear drives face unique predictive maintenance and operational challenges.

1.1Lubrication

Chief in the operational tasks is ensuring that lubricant is applied in the appropriate amount and at the appropriate interval due to the difficulty in completely sealing the gear and pinion, open gear lubricants tend to be applied at frequent intervals to replenish lubricant that has been spend and flung off in the gear guard.

Fig 1. Modes of lubrication



Open Gear Lubicants are usually one of 3 types:

Grease lubricants with maximum base oil viscosity of 2500 cSt and rely on thickeners to provide some adhesion to the gear sets and on solid lubricant additives to reduce friction when the lubricant film thickness is not adequate to maintain separation between the gear surfaces (Fig1 c). Grease open gear lubricants are the most popular type of lubricant in the open gearing market in Australia.

Asphaltic lubricants or residual lubricants: These types of lubricants contain very viscous base oils. So that the fluids can be pumped and distributed onto the gears, a volatile diluent is added resulting in a viscosity of 4000cSt at 40 degrees. These products were the original and standard lubricants for open gear applications until the early 1990's when concern about the effect of the diluents on the ozone layer and possible cancer causing properties caused these types of lubricants to fall out of favour. The current range of residual lubricants do not contain carcinogenous or ozone depleting diluents.

Synthetic Hydrocarbon Lubricants: These types of lubricants are synthesised from feed gas and in the case of open gear lubricants, made into ultra viscous fluids. These fluids range in viscosity

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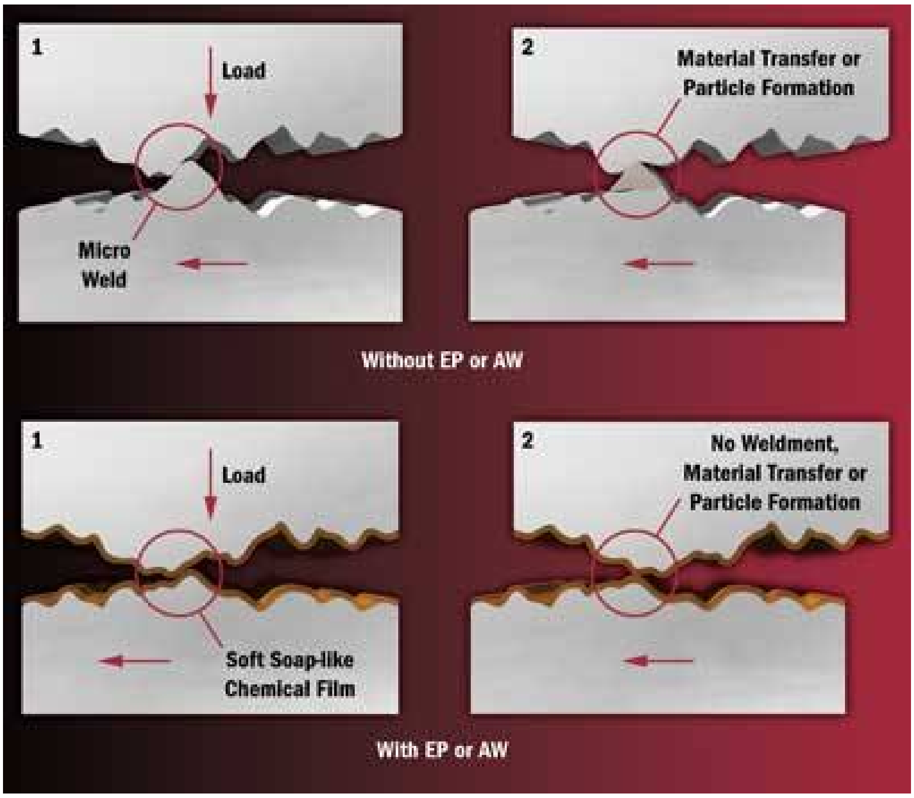
from 10,000cSt to 46,000cSt at 40 degrees. The fluids rely on their high viscosity index (the rate of change of viscosity when compared with temperature) and their low internal friction to allow them to be pumped and distributed rather than relying on reducing the viscosity by use of diluents. A fluid film separating the gear surfaces relies on the relative speed of the gear surfaces (in the sliding region) and the viscosity of the lubricant. In the case of large open gear sets, the speed is very low and a highly viscous fluid is required to generate a sustainable fluid film as illustrated in Fig 1a. A full fluid film is the most beneficial lubrication regime for any mechanism, as it separates the moving components which in turn minimises wear and maximises component life.

1.1.2 Features of Lubricants and Lubrication Regimes

Once a lubrication film has been established (which is dependant on speed and viscosity) then the fluid film won't be compromised because one of the features of hydrocarbons used as lubricants is that their viscosity increases at a faster rate than normal loading stress. Because of this non Newtonian behaviour – gears and bearings that are properly lubricated have very long life spans.

Fig 3 – Boundary lubrication illustration



Increased viscosity – up to a point will increase the lubricant film thickness (after the upper limit of the viscosity is reached a bow wake is pushed into the lubricant and it no longer stays in place to form a lubricating film). Increased lubricant film thickness increases the safety margin preventing metal to metal contact or 3rd body contact (where hard contaminants are caught between the gear components causing abrasive wear).

Where boundary lubrication is present there is no continuous lubricant layer between the moving parts and metal to metal contact actually occurs resulting in constant low level wear known as polishing. Naturally, if one of the conditions changes such as temperature – the viscosity further reduces and the metal to metal contact is heavier increasing the severity of wear experienced.

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Fig 4 Modes of lubrication

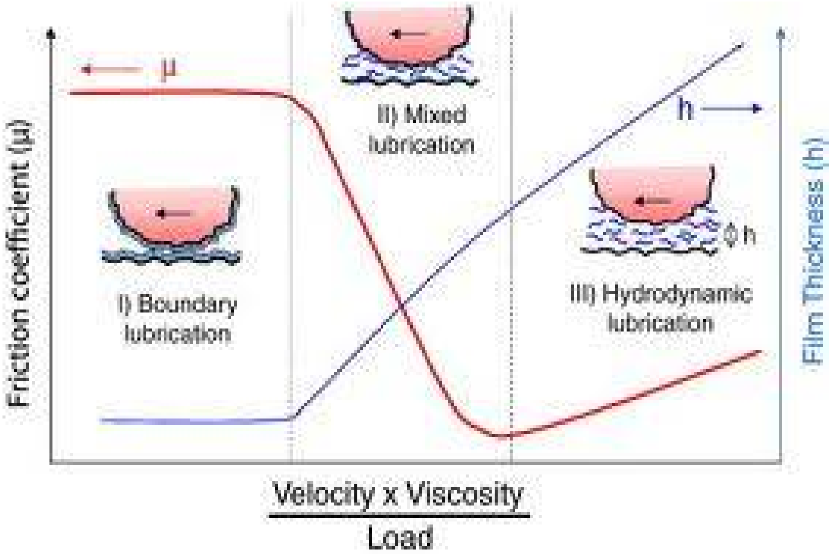
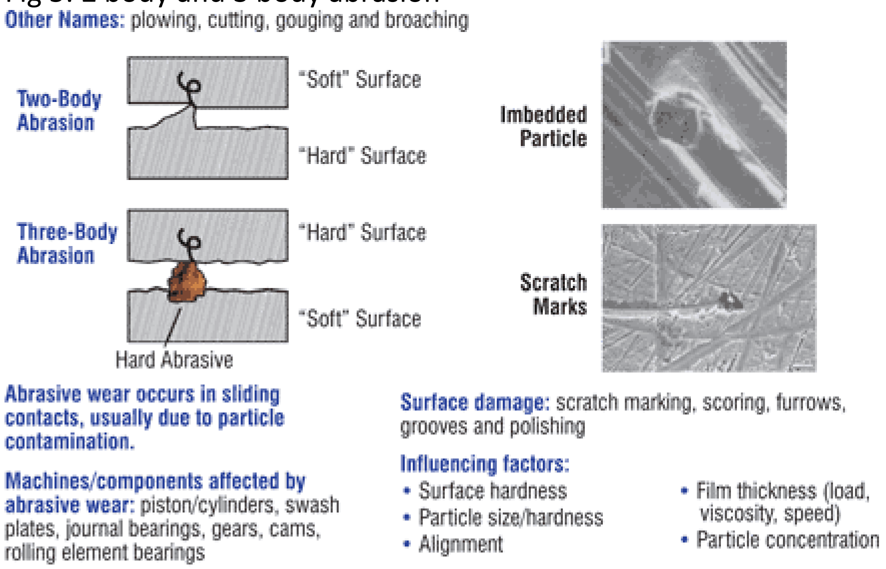


Fig 3 demonstrates the nature of boundary lubrication and in turn the reliance on extreme pressure additives and anti wear additives to prevent escalation to a more severe wear regime. Fig 4 illustrates the relationship between lubrication film thickness and friction coefficient. Fig 5 demonstrates the wear action when contact between moving components occurs and when contaminants or other wear particles become entrapped between the moving components.

Fig 5: 2 body and 3 body abrasion



As can be seen from the illustration in fig 5 a thinner film thickness will produce a more severe wear result as will a greater concentration of foreign particles within the gear mesh. Gear sets are made so that the pinion is harder than the girth gear inevitably, when there is a problem with abrasive wear then it is apparent on the girth gear rather than the pinion. The pinion usually exhibits signs of polishing and the girth gear exhibits evidence of ploughing as illustrated in Fig 5 above.

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1.1.3 Lubrication Systems

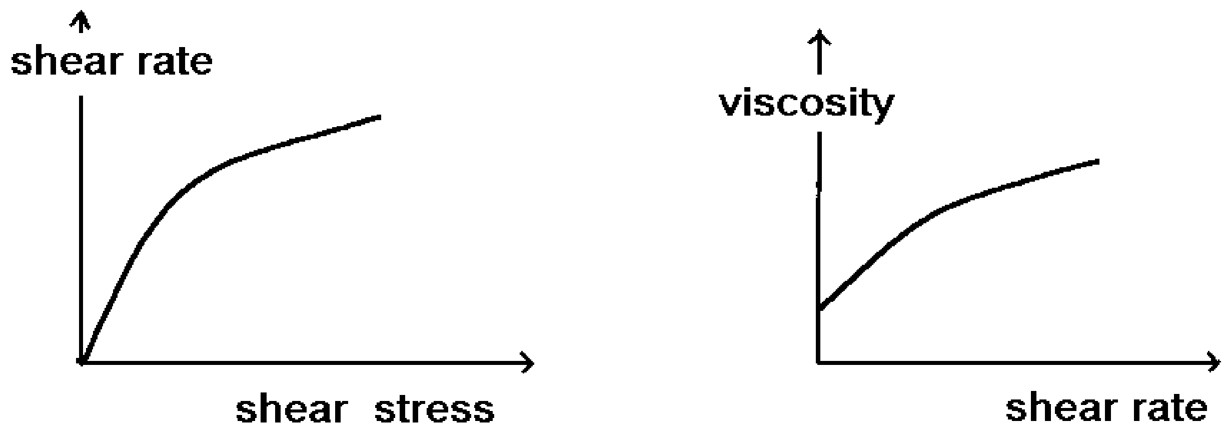
An ideal lubrication regime would be to flood the gears at the point of meshing to ensure a lubricant film is maintained – provided a lubricant of the correct viscosity is used. Applying ample and continuous lubricant at the point of action would be ideal for the machine, however, given the difficulty associated with adequately sealing open gear covers; to keep lubricant in and contaminant out; almost all of the open gear drives in Australia are total loss lubrication systems.

Re-use of open gear lubricant has proven difficult due to the nature of grease as it is the pre-eminent open gear lubricant type. Grease is designed to for total loss systems; the thickeners are stringy long molecules; adhesive additives called tackifiers are added to improve the stickiness of grease. Both of these factors make removing contaminants from grease virtually impossible because the contaminants that must be removed are often the same size or smaller that the thickener molecules and the sold lubricant particles. High viscosity synthetic fluids offer an opportunity to reuse the lubricant following refurbishment – depending on the level and type of contaminant.

Grinding paste: Grease is most often thixotropic meaning that they stay in place until pushed by a suitable sized force at which point they provide less resistance. Practically, this means that greases accumulate in the root of the girth gear teeth where the centripetal force is not sufficient to start the grease moving and it becomes a reservoir for airborne contaminants such as dust.

Lubricants that more resemble oil are not thixotropic, instead they are classified as dilatant meaning that the resistance to shear force increases as the shear rate increases. In simple terms when the lubricant is pushed hard it resists and when acted on by a gentle force (such as gravity) it flows. Fluid type lubricants are useful in that they are more likely to carry contaminants and wear debris away from the gear at the point of action.

Fig 6 Dilatant fluid behaviour



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1.2 Alignment:

Choice of lubricant and re-lubrication interval are the most immediate threats to the well-being of the gear set closely followed by the alignment of the gears. Gear misalignment creates load concentrations due to the uneven load distribution that results.

Fig 6: Alignment \ temperature relationships.

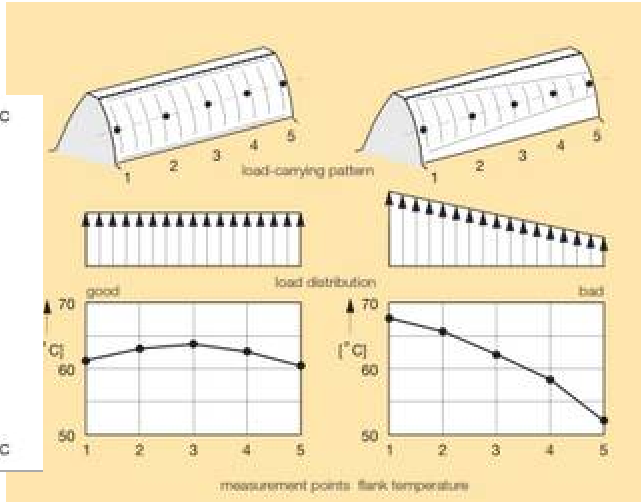

Fig 7 a Thermographic image of Pinion and Girthgear

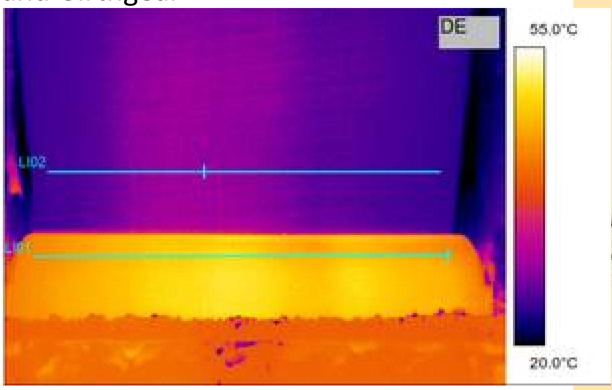

Fig 7b Pinion temperature distribution

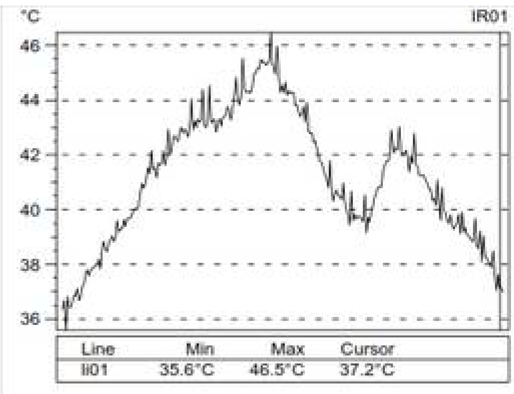

Fig 3c Girth gear temperature distribution

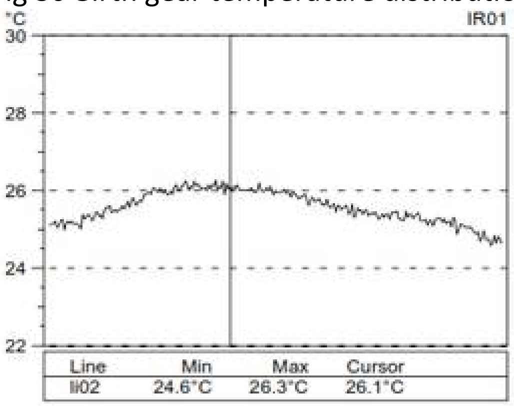

Figure 2 represents a conventional measurement and load regime using an infra red temperature gun and manual data recording. It does paint a picture of the alignment, however due to the discrete nature of the measurement, maxima and minima can be missed. In the case of Figure 3 and b it is clear that the pinion and girth gear set has some form error – possibly due to the technology used in the pinion manufacture or possibly due to uneven lubricant distribution.

Uneven temperature distribution indicates uneven load or uneven friction characteristics and is a powerful fault finding and diagnosis tool.