# Base Oil Evaporation in Grease Lubricated Rolling Bearings

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The film thickness decay in grease-lubricated bearings is determined by a loss of lubricant from the bearing. One of these loss mechanisms is base oil evaporation. In this paper, a model is presented for evaporation where the volatiles leave the bearing by breathing. With the model, the impact of the volatility of base oils and the quality of sealing on the evaporation losses can be quantified.

**Keywords: Evaporation, grease, rolling element bearings**

## Introduction

Evaporation is a mass transfer process in which a material from the liquid state will transform into a gaseous state below the boiling point. This is particularly relevant in grease-lubricated bearings because of the limited volume of oil in the "grease reservoir" that is available for lubrication. Besides oxidation and leakage, evaporation is considered to be one of the loss mechanisms that would have an impact on the grease life in rolling bearings [1]. The evaporation rate is determined by the type of lubricant, temperature, variation of temperature, and vapor pressure. The movement of volatiles from the control volume regulates the net evaporation rate. The loss of volatiles from the control volume can be due to either a pressure difference caused by a temperature variation or due to diffusion caused by a concentration difference. These losses vary as the temperature of the control volume changes. This loss of volatiles from the control volume is called 'breathing'. In this model, all these effects are taken into consideration to estimate the actual loss of base oil from the bearings.

## Methods

2.1. Evaporation modeling

In this model, the influence of thickeners and the additives on the evaporation was neglected. Only the bled base oil is considered to be lost due to evaporation.

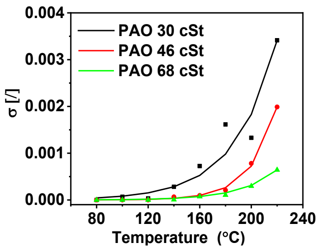


Figure 1 Evaporation coefficient for different PAO oils.

The Hertz-Knudsen equation was used to estimate the evaporation rate of the base-oil.

$$\frac{dn_v}{dt} = \sigma \sqrt{\frac{1}{2\,\pi m\,R\,T}}\left(p_{v,sat} - p_v\right)A \qquad (1)$$

Here $n_v$ is the number of volatile molecules, m is the molecular weight, $p_v$ is the vapor pressure and A is the surface area. The saturated vapor pressure '$p_{v,sat}$' is determined using the Clausius Clapeyron equation. The evaporation coefficient '$\sigma$' is temperature-dependent, which is measured using a thermogravimetric analyzer.

2.2. Determining the loss of volatiles

Three breathing mechanisms were taken into consideration.

2.2.1 Expansion by evaporation (EE)

Evaporation increases the pressure, causing gas to flow out of the control volume. In this mechanism, the flow is therefore only determined by expansion and shrinkage of the air inside the control volume by evaporation (or condensation)

2.2.2 Isobaric Thermal Expansion (ITE)

Here, the flow caused by a pressure difference induced by temperature fluctuations is taken into account.

2.2.3 Diffusion of volatiles (D)

Volatiles will also escape due to the concentration difference. The diffusion loss is calculated using the dimensions of the gap between seal and bearing inner ring and the concentration of volatiles inside the control volume.

The total loss of volatiles is then determined by the contribution from each meachanism:

$$\frac{dn_{v,lost}}{dt} = \frac{dn_{v,lost}}{dT}\Big|_{ITE} + \frac{dn_{v,lost}}{dt}\Big|_{EE} + \frac{dn_{v,lost}}{dt}\Big|_{D} \qquad (2)$$

## Discussion

This model can be used to study the effect of temperature cycles, sealing efficiency of the grease/seal and the type of base oil on the evaporation losses from the bled oil. For example for a bearing with contacting seals, when the temperature reaches a steady-state value, the net evaporation becomes zero since the vapor pressure ultimately will equal the saturated vapor pressure. In that case, the variation of the temperature plays an important role in determining oil loss. The model contributes to predicting grease life, particularly for high temperature and/or low-pressure applications.

## References

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