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# Influence of nanoparticles dispersion in POE oils on lubricity and R134a solubility

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ABSTRACT

Nanotechnologies offer the opportunity to improve the characteristics of the oil and the oil–refrigerant mixture in refrigeration and air conditioning equipments by dispersing nanoparticles in the oil. Here a study of the influence of the dispersion of single wall carbon nanohorns (SWCNH) and titanium dioxide ($TiO_2$) on the tribological properties of a commercial POE oil is presented, together with the effects on the solubility of R134a at different temperatures. The results obtained showed that the tribological behaviour of the base lubricant here considered can be either improved or worsen, depending on the property (anti-wear or extreme-pressure behaviour), by adding small amount of nanoparticles. On the other hand, nanoparticles dispersion in the base oil did not affect significantly the solubility, suggesting the independence of the thermodynamic properties of the oil from the presence of nanoparticles.



# Influence de la dispersion des nanoparticules dans les huiles POE sur la lubricité et la solubilité de R134a

*Mots-clés* : Systéme frigorifique ; Système à compression ; R134a ; Lubrification ; Expérimentation ; Additif ; Dioxyde de titane-particule ; Polyolester-solubilité

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**Nomenclature**

| | |
|---|---|
| $p$ | pressure (MPa) |
| $T$ | temperature (K) |
| $\xi$ | mass fraction of liquid phase |
| *Subscripts* | |
| R134a | property relative to R134 |

## 1. Introduction

The necessity to continuously reduce the environmental impact of refrigeration and air conditioning applications, through both the selection of environmentally benign substitutes to the traditional chlorinated refrigerants and the reduction of energy consumption during the systems operation, has led to new efforts in the research of alternative technical solutions. In particular, the selection of the optimum lubricant for the new working fluids (*i.e.* hydrofluorocarbons (HFCs) or natural fluids, such as carbon dioxide ($CO_2$)), that are not compatible with the mineral oils, generally used in the past, is still partially unsolved.

A new opportunity to optimise the performance of lubricants from both the thermodynamic and the tribological point of view is given by nanotechnologies. By dispersing solid nanoparticles in a base fluid (*e.g.* water, ethylene-glycol, refrigerants etc. – here the lubricant), a nanofluid (nano-oil in this case) is obtained with modified properties in comparison with the base fluid. It is well described in the literature that the dispersion of solid nanoparticles improves the thermal conductivity of the base fluid, not proportionally to the concentration of nanoparticles. An enhancement between 5% and 160% can be obtained with nanoparticles concentration of the order 1% by volume depending on the base fluid and the nanoparticles type (*e.g.* Assael et al., 2006; Zhang et al., 2007; Hwang et al., 2007; Mintsa et al., 2009; Jiang et al., 2009; Zhu et al., 2009; Godson et al., 2010). This promises to significantly improve the thermal properties (in particular the heat transfer coefficient) and then the thermal efficiency. Thus, the employment of nanofluids could allow the realization of more compact and efficient systems, reducing both the environmental impact and the costs. Moreover, other important thermodynamic, transport and tribological properties can be enhanced by nanoparticles dispersion. Then, in refrigeration and air conditioning applications, nanofluids give the opportunity to have smaller and more efficient heat exchangers, lower refrigerant charges, more reliable compressors, better compatibility between lubricants and refrigerants etc.

However, the information about the properties of nanofluids (except thermal conductivity) are still scarce, frequently contradictory and in some cases the nanofluids show poorer behaviour than the base fluid. Moreover, considering that nanofluids have different characteristics depending on several parameters (*e.g.* material, size, shape and dispersion methodology of the nanoparticles) a huge research effort is required to identify, optimise and commercialize proper nanofluids in relation to the application.

With particular reference to lubricants, several papers have discussed the properties of nano-oils in comparison with the pure lubricant, showing the possibility to get some improvement of thermodynamic and tribological properties and enhance the efficiency of refrigerating machines (*e.g.* Bi et al., 2007; Lee et al., 2007; Wang et al., 2006). However, the information delivered about the characteristics of the nano-oils and the results obtained are not always clear, still fragmentary and insufficient at the moment to properly select and optimise the nano-oil in relation to the application.

To increase the knowledge about nano-oils and enlarge the available database of properties, a study on the influence of nanoparticles dispersion in a commercial lubricant has been undertaken and presented here with the preliminary results. A commercial POE lubricant was used as the base fluid and two different nanofluids were prepared by dispersing single wall carbon nanohorns (SWCNH) and titanium dioxide ($TiO_2$) nanoparticles. SWCNHs are currently one of the most interesting nanostructures belonging to the thriving carbon nanotube family (Iijima et al., 1999). Not yet commercially available, SWCNHs can be produced in laboratory-scale quantities without metallic catalysts and with high purity starting from graphite by laser ablation/vaporization processes or by arc discharge techniques (Kasuya et al., 2002). Some tribological properties and the solubility of tetrafluoroethane (R134a) at different temperatures for the base oil and the two nano-oils were measured and compared.

## 2. Experimental

Three main experimental activities were developed to compare the properties of the oils considered here: nano-oils

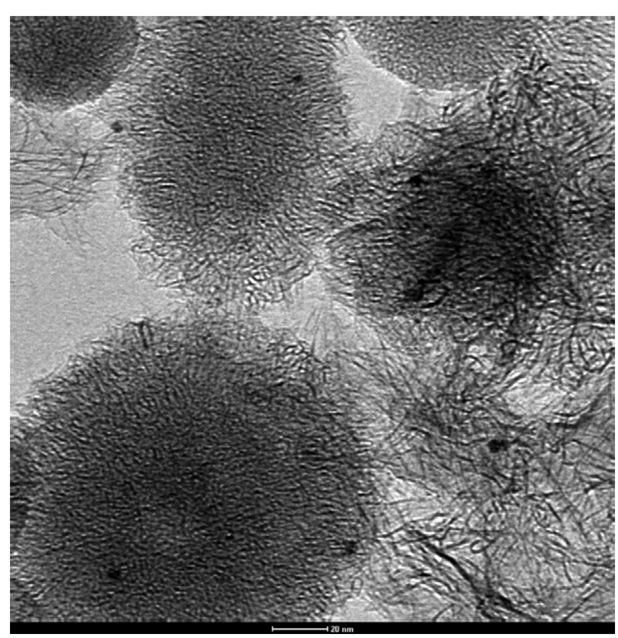


**Fig. 1 – TEM image of SWCNHs.**