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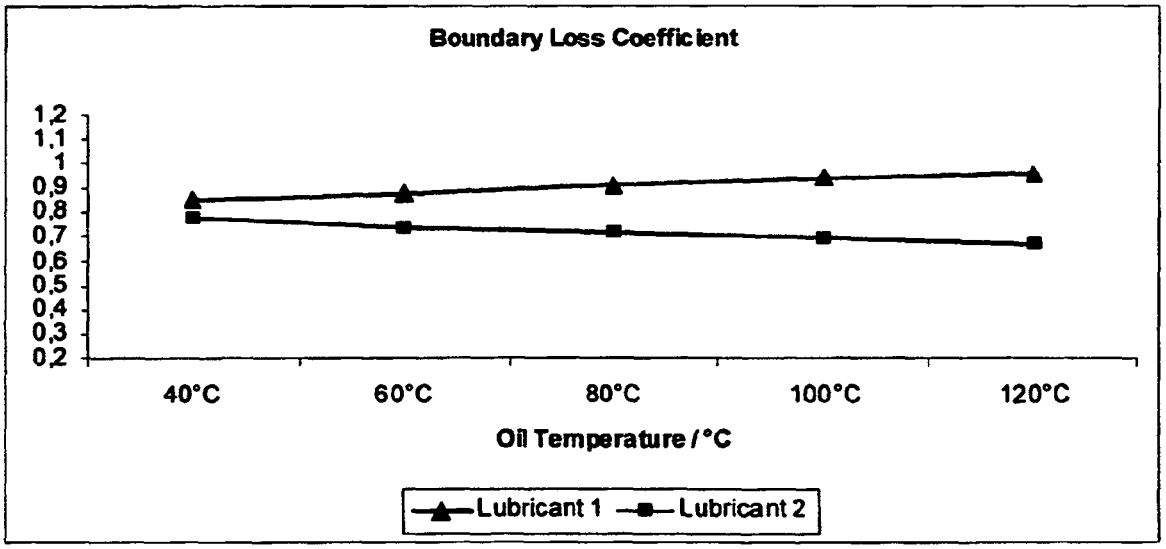
(71) Applicant: **Cognis IP Management GmbH**
40589 Düsseldorf (DE)

(72) Inventors:
- **Scherer, Markus**
  50733 Köln (DE)
- **Rettemeyer, Dirk**
  41836 Hückelhoven (DE)

(74) Representative: **Fabry, Bernd et al**
IP2 Intellectual Property
Bruchstrasse 13
41352 Korschenbroich (DE)

(54) Lubricant with enhanced energy efficiency

(57) Lubricant compositions useful especially for the lubrification of gears, having a boundary loss coefficient X_{LG} of 0.6 to 0.8 measured at temperatures of 40 to 120 °C with a modified method according to DIN 51354, whereby the lubricant composition contains of a base oil a optional additives, whereby the base oil is selected from complex ester, said, said complex ester having a kinematic viscosity at 40°C of greater than 400 and up to 50 000 mm^2/s.



EP 2 345 710 A1

Description

[0001] The present invention pertains to lubricants, in particular to industrial lubricants, including hydraulic oils, lubricants for engines and turbine oils, and especially for lubricants for wind turbines.

[0002] The most important function of lubricants is the reduction of friction and wear. Apart from important applications in internal combustion engines, vehicle and industrial gearboxes, compressors, turbines, or hydraulic systems, there are a vast number of other applications which mostly require specifically tailored lubricants.

[0003] Gear lubrication oils are of particular significance for the transmission. Apart from the important function of lubricating the sliding rolling contacts, the oils also fulfill the task of cooling and removing the friction heat generated in the sliding rolling contacts. There are significant differences between the tribology of gear drives and the tribology of journal and roller bearings, since the lubrication conditions characterizing the sliding rolling contacts in toothed wheels differ from those in journal or roller bearings.

[0004] Gear boxes are widespread in all kind of machines, and accordingly a huge number of different gears are known. With regard to the different kinds of gears different properties of the used lubricants must be fulfilled. An important field of application for gears, as well as for the respective lubricants are wind turbines.

[0005] Wind turbine applications, such as those used in wind farms or wind plants as an alternative renewable source of energy, are increasingly attracting more interest. Wind-electric turbine generators, also known as wind turbines, use the energy contained in the wind to spin a rotor (i.e., blades and hub). As the air flows past the rotor of a wind turbine, the rotor spins and drives the shaft of an electric generator to produce electricity.

[0006] To create this energy using a conventional wind turbine, a gear-box is typically placed between the rotor of the wind turbine and the rotor of a generator. More specifically, the gear-box connects a low-speed shaft turned by the wind turbine rotor at about 30 to 60 rotations per minute to a high speed shaft that drives the generator to increase the rotational speed up to about 1200 to 1600 rpm, the rotational speed required by most generators to produce electricity. This geared solution can result in a torque through the system of close to 2 million Nm. This high torque can put a large amount of stress on the gears and bearings in the geared wind turbine. Wind turbine oils are desired that will enhance the fatigue life of both the bearings and gears in the wind turbines. Gearless direct drive wind turbines have been developed, which have the advantage of having less moving parts to maintain, but have their own drawbacks of generally being heavier and generally being open models allowing cold air to pass through, which may pose an increased risk of corrosion, especially in offshore installations. In any event, it is expected that both types of wind turbines will co-exist for some time. Therefore, wind turbine oils that would enhance the fatigue life of bearings and gears in gear-boxes used in geared wind turbines would increase the opportunities to use the geared solution in the most efficient, reliable and cost-effective manner.

[0007] Lubricants for such applications have therefore to fulfill several different roles. They must work at higher operating loads while helping in reducing temperatures in the gearboxes. They need to avoid fatigue-related damages (e.g. pitting) and wear (adhesion, abrasion, polishing and scuffing) on the gears, while also remaining fitter-friendly (no leaks), non-foaming, water-resistant, and harmless to operators. Also, inasmuch as lubricants in wind turbines gearboxes are often subjected to prolonged periods of use between any maintenance and service intervals, a long lasting lubricant stability is required, so as to provide outstanding service performance over lengthy durations of time. Finally, wind turbines can be located all over the world, on mountain tops, off-shore or along coastlines, in deserts: in addition to longevity issues, said lubricants must also be able to withstand a variety of environmental conditions, including temperature extremes and moisture, in addition to being able to resist oxidation and prevent corrosion.

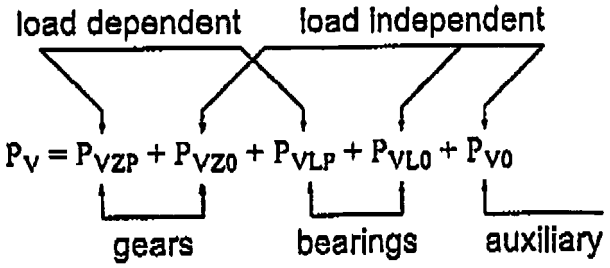
[0008] Furthermore, there is a constant need to enhance lubricity properties of said lubricants, to lower friction, and also lower energy consumption in devices, equipped with such lubricants.

[0009] It was found, that specific selected ester oils will meet all of the above requirements.

[0010] A first embodiment of this invention is therefore a lubricant composition having a boundary loss coefficient X_{LG} of 0.5 to 0.9, and preferably from 0.6 to 0.8 measured at temperatures of 40 to 120 °C with a modified method according to DIN 51354, whereby the lubricant composition contains of a base oil a optional additives, whereby the base oil is selected from esters, said, said esters having a kinematic viscosity at 40°C of greater than 400 and up to 50 000 mm^2/s and being obtained by reaction of: a) polyols and monocarboxylic acids and dicarboxylic acids or of b)polyols and monoalcohols and dicarboxylic acids or of c) polyols and monoalcohols and monocarboxylic acids and dicarboxylic acids.

[0011] The said method for the measurement of the boundary loss coefficient X_{LG} is described in detail in the FVA Information Sheet for the Research Project No. 345, Status June 2003, Annex B to Report No. 3781 and Annex C to Report 3416.

[0012] The lubricants of the present invention are characterized in their specific behavior under load, and especially due to their low frictional losses. The total power loss of a gearbox P_V can be split into losses of gears P_{VZP} and P_{VZ0}, the losses of bearings (P_{VLP} and P_{VL0}) and auxiliary loss sources (Pvxo) like seals or pumps. They can also split into load dependent and no-load losses. According to the following equation 1:



[0013] The loss coefficients indicate the relative losses of oils compared to reference oil. Of greatest importance is the boundary loss coefficient. This coefficient describes the relative load dependent loss compared with a reference at conditions where usually boundary lubrication occurs. The boundary loss coefficient is an indicator for the frictional behavior of especially high viscous oils. Therefore the above mentioned selection criterion of a certain boundary loss coefficient X_{LG} is vital for carrying out the present invention. A figure of for example 0.6 for the X_{LG} means that this lubricant shows a 40 % enhancement of energy consumption towards the reference oil.

[0014] If oils are selected which the above given boundary loss coefficient the energy consumption under running conditions will be lowered. Thus, the use of those esters will enhance the energy efficiency of devices, equipped with these lubricants, preferably of gears in wind turbines.

[0015] The kinematic viscosity of the ester for use is preferably from 800 to 25 000 mm^2/s, especially from 1200 to 10 000 mm^2/s, more preferably from 1300 to 5000 mm^2/s and most preferably from 1500 to 3000 mm^2/s. It has been found that, surprisingly, the use of these esters leads to very low losses in the kinematic viscosity of the lubricant composition after permanent shear. This property makes possible use in lubricants which are exposed to high shear stress.

[0016] It is vital for the present teaching to select only those ester oils which fulfill both the structural as well as the theological properties as given in the above description.

[0017] The esters as described above are in principal known to the skilled man. Reference is made to European patent application no. 2027234 or international publication pamphlet WO 05/019395 of the applicant where these esters and their application as lubricants are described in more detail.

[0018] Although all of the mentioned structures, as far as the other selection criterions are fulfilled will be useful in lowering energy consumption especially preferred are esters of type a). In a preferred embodiment, the lubricant compositions are **characterized in that** the monocarboxylic acids used in the reaction according to a) are branched monocarboxylic acids or mixtures of linear and branched monocarboxylic acids, each of which has a carbon number of from 5 to 40 carbon atoms, where the content of branched monoacid is preferably greater than 90 mol% based on the total content of the acid mixture.

[0019] The monocarboxylic acids preferably have from 8 to 30 carbon atoms and especially from 10 to 18 carbon atoms. In particular, the monocarboxylic acids are selected from the group formed by the following branched acids: 2,2-dimethylpropanoic acid, neoheptanoic acid, neooctanoic acid, neononanoic acid, isohexanoic acid, neodecanoic acid, 2-ethylhexanoic acid, 3-propylhexanoic acid, 3,5,5-trimethylhexanoic acid, isoheptanoic acid, isooctanoic acid, isononanoic acid, isostearic acid, isopalmitic acid, Guerbet acid C32, Guerbet acid C34 or Guerbet acid C36, and isodecanoic acid. The linear acids are preferably selected from the group formed by valeric acid, caproic acid, heptanoic acid, caprylic acid, pelargonic acid, capric acid, undecanoic acid, lauric acid, tridecanoic acid, tetradecanoic acid, pentadecanoic acid, palmitic acid, margaric acid, stearic acid, nonadecanoic acid, arachic acid, behenic acid, lignoceric acid, myristic acid, cerotic acid, mellissic acid, tricosanoic acid and pentacosanoic acid, 2-ethylhexanoic acid, isotridecanoic acid, myristic acid, palmitoleic acid, oleic acid, elaidic acid, petroselic acid, linoleic acid, linolenic acid, elaeostearic acid, gadoleic acid and erucic acid, and the technical-grade mixtures thereof. Preferred branched monocarboxylic acids are isononanoic acid, isostearic acid and 2-ethylhexanoic acid.

[0020] Preferred esters are blends of esters containing more than one acid, preferably, the esters according to the present invention contains dibasic acids, and more preferred mixtures of two or more different dibasic acids.

[0021] In this regard are those dibasic acids preferred which contain 8 to 18 C-atoms. It is a further preferred embodiment in this context to choose branched dibasic acids for the synthesis of the esters. Suitable dibasic acids are oxalic acid, malonic acid, succinic acid, glutaric acid, adipic acid, pimelic acid, suberic acid, azelaic acid, sebacic acid, brassylic acid, thapsic acid and perlagonic acid. Preferred dibasic acids are selected from the group sebacic acid, adipic acid, succinic acid, glutaric acid and isostearic acid. As mentioned above esters based one more then one different acids are preferred. The anhydrides of the dicarboxylic acids are also suitable in accordance with the invention for the reaction

[0022] The alcohol part of the esters is broadly selected from mono- di- or poly alcohols. The alcohols might be linear or branched, saturated or unsaturated, as well as cyclic or aromatic ones too.

[0023] Alkyl alcohols might be in a preferred embodiment being selected from the group of linear or branched, saturated

or unsaturated alkyl mono alcohols with 1 to 31 C-atoms, diols with 2 to 25 C-atoms or polyols. Linear mono alcohols are for example are methanol, ethanol, propanol, butanol, pentanol, hexanol, heptanol, octanol, nonanol, decanol, undecanol, dodecanol, tridecanol, tetradecanol, pentadecanol, hexadecanol, heptadecanol, octadecanol, nonadecanol, eicosanol, heneicosanol, docosanol, tricosanol, tetracosanol, pentacosanol, hexacosanol, heptacosanol, octacosanol, nonacosanol tricontanol or hentriacontasol. In these alcohols the OH-funcnonality is located in the "1" position, but all isomers thereof are also suitable. The same applies in accordance with all kind of branched isomers of the above alcohols. Preferred branched alcohols are the so called Guerbet-alcohols. Unsaturated mono alcohols are for example oleic alcohol, linoleic alcohol, 9Z- and 9E-octadec-9-en-1-ol, (9Z,12Z,15Z)-octadeca-9,12,15-trien-1-ol, (9Z)-eicos-9-en-1-ol, or 13E- or 13Z-docosen-1-ol. Furthermore, diols, preferable glycols, including their oligomers or polymers are suitable alcohols for preparing esters according to the present invention. Ethylene glycol or diethylene glycol, or their oligomers and propane and butane diols are preferred members. Polyols are also suitable alcohol components. Preferred examples are glycerol, oligo- or polyglycerol, trimethylolpropane and pentaerythritol, as well as oligomers or polymers thereon. The most preferred alcohols are pentaerythritol and trimethylolpropane and mixtures thereof, as well as oligomers of these alcohols.

[0024] The present invention is preferably directed to polyol esters and blends thereof having as essential constituents esters of sterically hindered polyols with linear and/or branched alkanols, known as "complex esters".

[0025] The conversion to the reaction products of the complex esters proceeds in syntheses known per se for preparing esters. The preparation of the esters can also be carried out in accordance with the invention by known processes such that free carboxyl groups and/or free hydroxyl groups are present in a controlled manner, and these products with free carboxyl and/or free hydroxyl groups are used in the lubricant composition.

[0026] According to the invention, the free carboxyl groups present may be reacted further with amines to give amides, and the resulting compounds may be present in the lubricant composition as complex esters in the context of the invention.

[0027] The lubricants according to the teaching of this invention contain a base oil and one or more additives. The base oil contains of up to 100 % from esters according to the above description. In general, the complex esters should be present in major amounts, based on the weight of the lubricant, as well as the weight of the total lubricant compositions (including all other ingredients).

[0028] However, certain other known base oil materials may be used also. It is preferred, that the base oil contains from 10 to 98 wt%, preferably from 50 to 95 wt% based on the total weight of the base oil from the ester oils as described before. Based on the total weight of the lubricant the complex ester are preferably present in amounts of 1 to 99.9 wt%, preferably from 10 to 80 wt%, and most preferred from 50 to 75 wt%,

[0029] In the context of the invention, the base oil present in the lubricant composition is understood to mean an oil which is selected also from the group formed by mineral oils, highly refined mineral oils, alkylated mineral oils, poly-α-olefins, polyalkylene glycols, phosphate esters, silicone oils, esters, and also mineral oils of the Solvent Neutral class and mineral oils of the XHVI, VHVI, group II and group III and GTL basestock (gas-to-liquid base oil) classes. The poly-α-olefins may preferably be formed from C6 to C18-α-olefins and mixtures thereof. Especially preferred are poly-α-decenes.

[0030] In addition to the further components mentioned, the inventive lubricant composition may comprise further additives which are selected from the group formed by polymer thickeners, solvents, viscosity index (VI) improvers, antioxidants, corrosion inhibitors, detergents, dispersants, demulsifiers, defoamers, dyes, wear protection additives, EP (extreme pressure) and AW (antiwear) additives and friction modifiers. Such additives may be present in amounts from 0.001 to 15 wt%, based on the total weight of the lubricant. Preferred ranges are from 0.01 to 5 wt%.

[0031] In further preferred embodiments, the inventive lubricant compositions could comprise, as a further component, a polar polymer in a concentration of from 0.5 to 30% by weight based on the total amount of lubricant composition. Preference is given to a concentration of from 1 to 18% by weight and more preferably from 2 to 12% by weight. The polar polymers for use in accordance with the invention are preferably selected from the group formed by alkyl fumarate-α-olefin copolymer, alkyl maleate-α-olefin copolymer, polyalkyl methacrylate, propylene oxide polymer, ethylene oxide-propylene oxide copolymer and alkyl methacrylate-α-olefin copolymer.

[0032] A certain embodiment of the present invention is a lubricant containing as additional oils 1 to 60 wt%, preferably 5 to 45 wt%, based on the total weight of the lubricant, of ester oils, different of those described in claim 1, polyalphaolefins, mineral oils, polymers, polyalkylene glycols, or any mixtures thereof.

[0033] The invention further provides for the use of the inventive lubricant composition, especially in the preferred embodiments, as a vehicle transmission oil, axle oil, industrial transmission oil, compressor oil, turbine oil or motor oil. The present lubricant oils are preferably useful in such applications, where mechanical forces are transferred via direct contact of metal parts of a machine or a gear. Particular preference is given to use as axle oil, clutch oil or industrial and particularly to gear oil applications.

[0034] But most preferred is the use of the lubricants as wind turbine oil, in particular as lubricant for gears in wind turbines.

Examples

[0035] Tests have been conducted to show the enhanced energy efficiency of the lubricants according to the current teaching. In this regard the frictional losses of cylindrical gears were measured in a modified back-to-back gear test rig (see figure 1) according to DIN 51354. The test pinion at the test gear and the test gear are mounted on two parallel shafts which are connected to the slave gear stage. In the slave gear stage, two identical gears to test gears are mounted, so that two equal stages are closing in the power circle. The pinion shaft consists of two separate parts, which are connected by the load clutch. By twisting the load clutch using defined weights on the load lever a defined static torque is applied. The electric motor has only to compensate the frictional losses in the power circle. For the measurement of the loss torque a torque meter shaft is mounted between the electric engine and the slave gear box. The applied load is measured with a load torque meter shaft next to the lead clutch. During the test different operating conditions are applied, the circumferential speed is varied from 0.5 to 20 m/s, the load is varied from no load up to a Herzian stress of 1720 N/mm^2, and the temperature is varied from 40 to 120 °C. The test method uses dip lubrication.

[0036] In the test equipment as described before, two different lubricants have been tested. Lubricant 1 is a commercial available PAO product and is used as comparison, lubricant 2 is an ester according to the present invention, comprising of pentacrythritol as alcohol, and a blend from sebacic acid and isostearic acid.

[0037] The reference oil, used in the test method according to DIN 51354 contains 4% of an sulphur phosphorous additive (Anglamol® 99) and based on mineraloil.

[0038] As could be seen from figures 2 and 3 the inventive ester oil composition show always better performance according to the loss coefficient under load, as well as to the boundary loss coefficient over a broad temperature range from 40 to 120 °C.

Claims

1. Lubricant compositions having a boundary loss coefficient X_{LG} of 0.5 to 0.9, and preferably from 0.6 to 0.8 measured at temperatures of 40 to 120 °C with a modified method according to DIN 51354, whereby the lubricant composition contains a base oil and optional additives, whereby the base oil is selected from esters, said esters having a kinematic viscosity at 40°C of greater than 400 and up to 50 000 mm^2/s and being obtained by reaction of:

    a) polyols and monocarboxylic acids and dicarboxylic acids or of
    b) polyols and monoalcohols and dicarboxylic acids or of
    c) polyols and monoalcohols and monocarboxylic acids and dicarboxylic acids.

2. Lubricant according to claim 1, **characterized in that** the ester is selected from type a) according to the description in claim 1.

3. Lubricant according to at least one of claims 1 to 2, **characterized in that** the acid part of the ester is selected from blends of at least two different dibasic acids.

4. Lubricant according to at least one of claims 1 to 3, **characterized in that** the acid part of the ester is selected from blends of dibasic acids, whereby the diacids contain from 8 to 18 C-atoms.

5. Lubricant according to at least one of the claims 1 to 4, **characterized in that** the acid part of the esters is selected from at least one branched dibasic acid.

6. Lubricant according to at least one of the claims 1 to 5, **characterized in that** the acid part of the esters contain sebacic acid, adipic acid, succinic acid, glutaric or isostearic acid, or mixtures thereof.

7. Lubricant according to at least one of claims 1 to 6, characterized that the alcohol part of the ester is selected from the group glycerol, neopentylglycol, oligo- or polyglycerol, trimethylolpropane, pentaerythritol, and any blends of the said alcohols.

8. Lubricant according to at least one of the claims 1 to 7, **characterized in that** the alcohol part of the ester is selected from pentaerythritol or trimethylolpropane or any mixtures thereof.

9. Lubricant according to at least one of the claims 1 to 8, **characterized in that** it contains from 0.01 to 5 wt% of additives, based on the total weight of the lubricant.

10. Lubricant according to at least one of the claims 1 to 9, **characterized in that** it contains the complex ester in amounts of 1 to 99.9 wt%, preferably from 10 to 80 wt%, and most preferred from 50 to 75 wt%, based on the total weight of the lubricant.

11. Lubricant according to at least one of the claims 1 to 10, characterized that is contains as additional oils 1 to 60 wt%, preferably 5 to 45 wt%, based on the total weight of the lubricant, of ester oils, different of those described in claim 1, polyalphaolefins, mineral oils, polymers, polyalkylene glycols, or any mixtures thereof.

12. Use of a composition according to claim 1 as energy efficient lubricant for the lubrification of gears, preferably of gears of wind turbines.

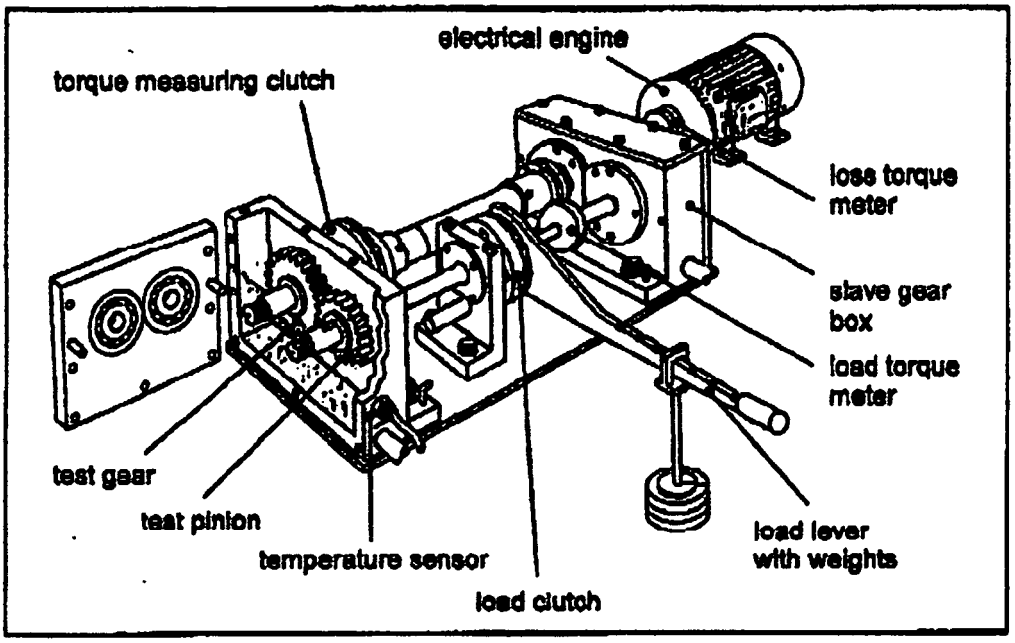
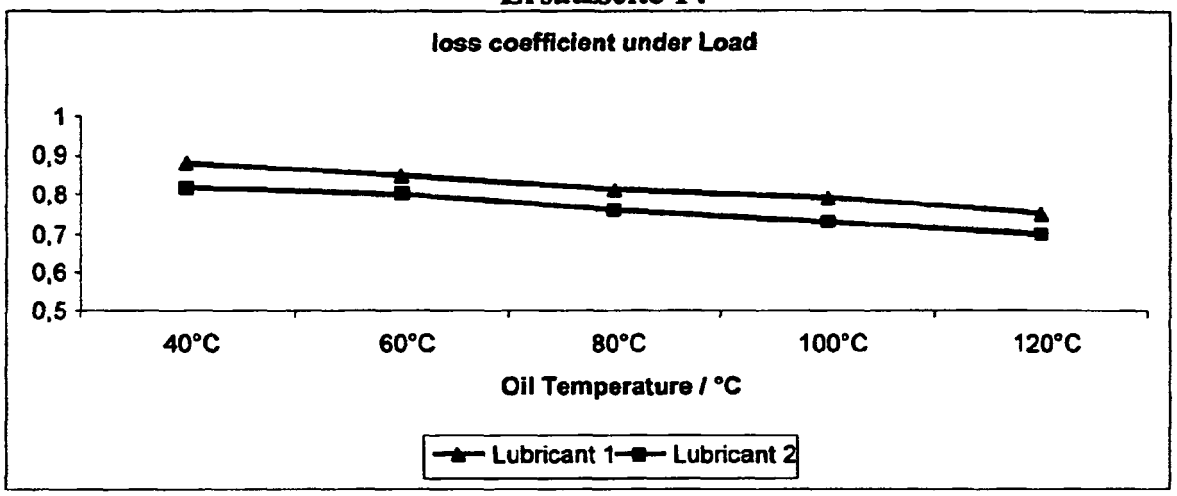
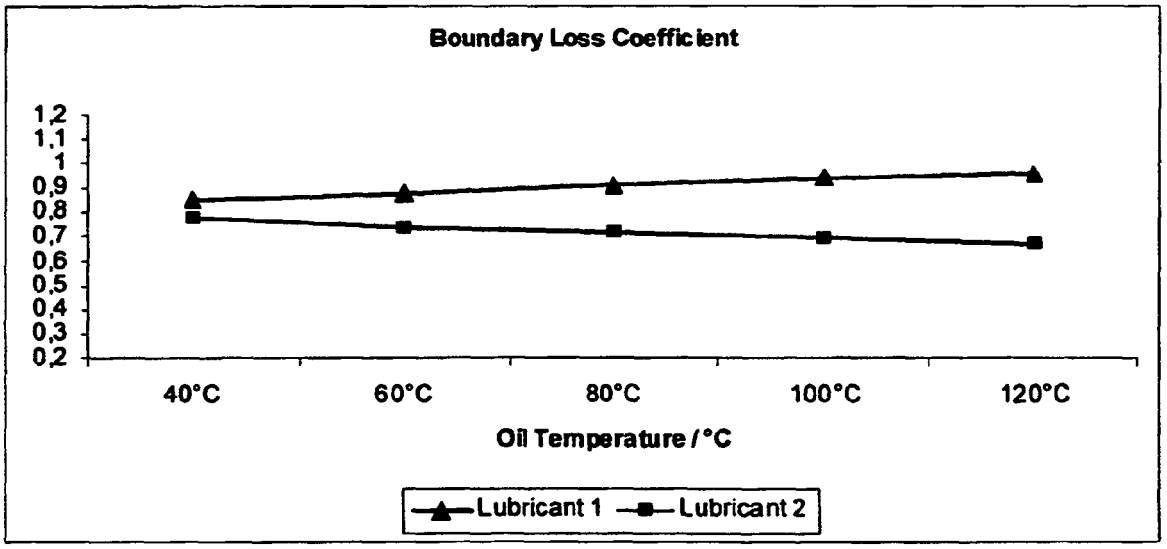

electrical engine
torque measuring clutch
loss torque meter
slave gear box
load torque meter
test gear
test pinion
temperature sensor
load clutch
load lever with weights

Figure 1

Ersatzseite 14





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EUROPEAN SEARCH REPORT

Application Number
EP 10 00 0403

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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C10M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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