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Improvement in Wear Preventive Characteristics by Re-Additization of Used Turbine Oil

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***Abstract*:**
Industrial lubricating oil works as life blood for rotating equipment's. With up gradation of technology, rotary equipment is required to perform with higher efficiency, which in turn requires efficientlubrication.Although viscosity is the most important property of base oil but there is more tolubricants than just viscosity. During lubrication, the desired oil film between two sliding surfaceshas to withstand high temperature and pressure. Other than that, certain functional properties likeoxidation stability, demulsifying ability, easy release of entrained air in oil, least foam stability, anti-wear & anti-rusting property etc. are of prime importance for specified end-use. Lubricating oil also holds the contaminants & oil varnish along with added additives meant for desired performance. Longlife turbine oil is formulated from premium base stock (API base oil group- II / hydrotreated) alongwith a perfect blend of additive (0.5-2.0%) with a recommended shelf life of five years, but on longterm use of such oil, oxidation of oil (varnish formation) and depletion of other additives take place,as indicated by deterioration in oil performance.
The present study explores the feasibility study of independent additive top up in those used oil at thermal power plant end for the deteriorated properties like wear preventive character and loss in antifoaming ability. Study shows that wear preventive characteristics of used turbine lube oil can be improved from 0.58mm scar diameterto0.43-0.45mm,using ash less multifunctional additive blend (AW-R&O)at a level of 0.5-1.0% from reputed additive suppliers other than lube oil manufacturers in India.Similarly, Anti-foaming additive (PMMA) from other specialty chemical supplier or ST-7011 fromIOCLatoptimizedlevelof0.5-2.0%is capable to control foaming tendency of lubricating oil at <20mlat24.5ºCasperASTMD892.

[***Keywords:*** Lubrication, Additive depletion, API base oil, Hydro- treatment, PMMA, Wear preventive characteristics, Anti-foaming property, multifunctional additive ,additive blending]

INTRODUCTION:

During continuous use of turbine oil in bearinglubrication process in thermal power plant, oil aswell as additives present in it faces stressduetohightemperatureofmetalincontact&pressure.Deterioration of base oil and additive in it takesplace. Also, contact of oil with steam at bearingpart results in increase moisture content in oil due to pressure difference. Since polar additives are having affinity with water, moisture removal processing centrifuge also removes those Additives gradually along with water.
Depletion of additives in used turbine oil is acommon and natural phenomenon. Moreover,duringblendingstageatmanufacturer'send,missing of certain independent additive takesplacebymistakeexceptthebasicblendofantioxidantpackage.Majorindications of specific or gross additive depletion are (i)Foam development and cavitations in lubrication area(ii)Poor demulsibility that in turn retains moistureinoil. (iii) Formation of varnish &resininoilwhichisduetooxidationofbaseoilduetoweakeningoftheprotectiveshield of oil (antioxidant depletion). The least noticedproperty of oil is the wear prevention abilityduringlubricationprocess,whichisagaindue to presence of anti wear additive in oil atappropriate level.

TYPES OF LUBRICANT ADDITIVES

There are many types of chemical additives mixed into base oils to enhance the properties of the base oil, to suppress some undesirable properties of the base oil and possibly to impart some new properties.

Additives typically make up about 0.1 to 30 percent of the finished lubricating oil, depending upon the target application of the lubricant. Lubricant additives are expensive chemicals and creating the proper mix or

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formulation of additives is a very complicated science. It is the choice of additives that differentiates a turbine (R&O) oil from a hydraulic oil, a gear oil and an engine oil.

Many lubricant additives are available, and they are selected for use based upon their ability to perform their intended function. They are also chosen for their ability to mix easily with the selected base oils, to be compatible with other additives in the formulation and to be cost effective.

Some additives perform their function within the body of the oil (e.g., anti-oxidants), while others do their work on the surface of the metal (e.g., anti-wear additives and rust inhibitors).

ADDITIVES DEPLETION

It is very important to understand that most of these additives get consumed and depleted by:
"decomposition" or break down," adsorption" onto metal, particle and water surfaces, and"separation" due to settling or filtration.

The adsorption and separation mechanisms involve mass transfer or physical movement of the additive. For many additives, the longer the oil remains in service, the less effective the remaining additive package is in protecting the equipment.

When the additive package weakens, viscosity increases, sludge begins to form, corrosive acids start to attack bearings and metal surfaces, and/or wear begins to increase. If oils of low quality are used, the point at which these problems begin will occur much sooner.

It is for these reasons that top-quality lubricants meeting the correct industry specifications (e.g., API engine service classifications) should always be selected. The following table can be used as a guide for a more thorough understanding of additive types and their functions in engine oil formulations.

SURFACE PROTECTIVE ADDITIVES ENGINE LUBRICANTS			
ADDITIVE TYPE	**PURPOSE**	**TYPICAL COMPOUNDS**	**FUNCTIONS**
Anti-Wear Agent	Reduce friction and wear, and prevent scoring and seizure	Zinc dithiophosphates, organic phosphates and acid phosphates; organic sulphur and chlorine compounds; sulphurized fats, sulfides and disulfides	Chemical reaction with the metal surface to form a film with lower shear strength than the metal, thereby preventing metal-to-metal contact
Corrosion & Rust Inhibitor	Prevent corrosion and rusting of metal parts in contact with the lubricant	Zinc dithiophosphates, metal phenolates, basic metal sulfonates, fatty acids and amines	Preferential adsorption of polar constituent on metal surface to provide a protective film and/or neutralization of corrosive acids
Detergent	Keep surfaces free of deposits and neutralize corrosive acids	Metallo-organic compounds of barium, calcium and magnesium phenolates, phosphates and sulfonates	Chemical reaction with sludge and varnish precursors to neutralize them and keep them soluble
Friction Modifier	Alter coefficient of friction	Organic fatty acids and amines, lard oil, high molecular weight organic phosphorus and phosphoric acid esters.	Preferential adsorption of surface-active materials
PERFORMANCE ADDITIVES ENGINE LUBRICANTS			
Seal Swell Agent	Swell elastomeric seals	Organic phosphates, aromatics, halogenated hydrocarbons	Chemical reaction with elastomer to cause slight swell
Viscosity Improver	Reduce the rate of viscosity change with temperature	Polymers and copolymers of methacrylates, butadiene olefins and alkylated styrenes	Polymers expand with increasing temperature to counteract oil thinning

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These additives are typically used to protect machine parts from wear and loss of metal during boundary lubrication conditions. They are polar additives that attach to frictional metal surfaces.

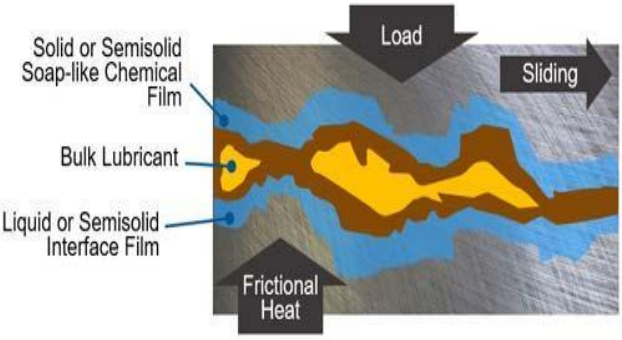

Figure. 1

They react chemically with the metal surfaces when metal-to-metal contact occurs in conditions of mixed and boundary lubrication.

They are activated by the heat of contact to form a film that minimizes wear. They also help protect the base oil from oxidation and the metal from damage by corrosive acids.

These additives become "used up" by performing their function, after which adhesive wear damage will increase. They are typically phosphorus compounds, with the most common being zinc dialkyldithiophosphate (ZDDP).

There are different versions of ZDDP — some intended for hydraulic applications and others for the higher temperatures encountered in engine oils. ZDDP also has some antioxidant and corrosion-inhibition properties. In addition, other types of phosphorous-based chemicals are used for anti-wear protection (e.g., TCP).

LUBRICATINGOILADDITIVESANDITS ROLE:

Additives are of inorganic or organic compounds that are either soluble oil base oil or remainsdispersed / suspended in oil. Three important categories of services are offered by these specialty products. Those are: (1) enhancement of base oil properties with antioxidants, corrosion inhibitors, anti-foam agents and demulsifying agents (2) suppression of undesirable base oil properties with pour-point depressants and viscosity index improvers (3) developing of new properties to base oils with anti wear / extremepressure(EP)additives,metaldeactivators,matrixpropertymodifier,etc.

Present generation turbine lubricating oil uses a blend of multi-functional & ashless additive package. Selected additive package isused with as specific lubricant base stock of desired viscosity. Each selected additive sometimes performs multiple specific functions synergistically with other additives present inoil. Depending on location & seasonal effect,additives are also required to improve viscosityindex and pour point.Overall additive contentin such blended oil varies in the range of 0.5-2.0% in normal cases which may extend upto 5%level depending on requirement of improvement of specific property.

Differentadditivepackagesareformulatedtomeetspecificobjectivesandperformance,focusing on targeted end user like automotivesector and other industries using lubricating oil,hydraulicfluid,gearoil,metalworkingoil,etc.

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WEARPREVENTION&LUBRICATION:

Hydrodynamiclubricationmechanismisoperativebetween surfacesofturbinebearingandturbineshaftthroughthermalandhydrodynamicboundarylayers.Mainpurposeofindustriallubricantsliketurbineoil,hydraulicoil,gearoil,etc.istoprovideproper lubrication between the two rubbing surfaces of moving machinery partandthisismainlydonebythemajorcomponentoflubeoil(baseoil),throughmaintainingathinfilm of oil between them. This oil film lubricates and prevents metal-metal contact in normal situation. In case of heavy machinery, that film is ensured through use of antiwear additives and extreme pressure additives that gets bonded withmetal surfaces and helps to avoid direct contactbetween metals even at high pressure. Typicalmetal based antiwear additives as first intentionare Zinc dialkyldithiophosphate (ZDDP)orzinc dithiophosphates (ZDP).

Presentgenerationadditivepackagesusemultifunctionalaminephosphateordialkyldithiocarbamate based ashless additives. Otherthan the leaders in additive manufacturing fieldas mentioned earlier, Kings Industries (UK)also produces a wide variety of oil additives,optimized&customizedadditiveblendstocompete with current generation. For example ,NA-LUBEAW-6110,as Sulphur less additive provides good antiwear property along with rust protection at a dosage level of 0.1% in oil.

Similarly, NA LUBEBL- 1208 is an ashless additive packageforindustrialoil(applicableforbase oil group- I-IV) shows good performance on overall basis, along with improvement in antiwear behavior of used lubricating oil at adosage of 0.5%.

This test method can be used to determine the relative wear preventive properties of lubricating fluids in sliding contact under the prescribed test conditions. No attempt has been made to correlate this test with balls in rolling contact. The user of this test method should determine to his own satisfaction whether results of this test procedure correlate with field performance or other bench test machines.

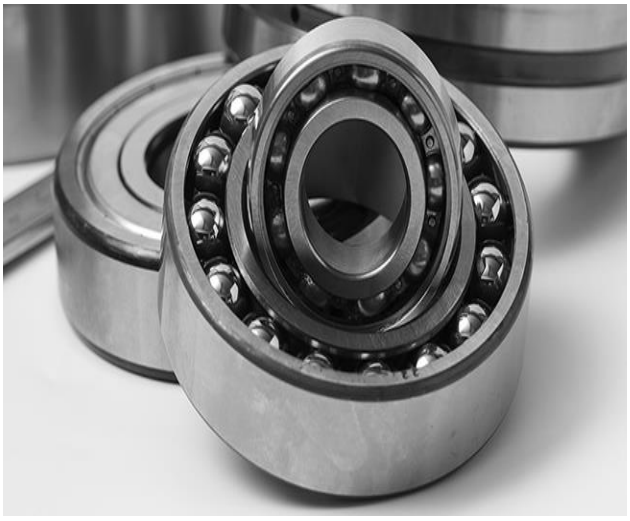
This test method covers a procedure for making a preliminary evaluation of the anti-wear properties of fluid lubricants in sliding contact by means of the Four-Ball Wear Test Machine. Evaluation of lubricating grease using the same machine is detailed in Test Method D2266.

The values stated in SI units are to be regarded as standard. Because the equipment used in this test method is only available in kgf units, SI units in parentheses are for information only.

Manage testing for large fleet studies and condition monitoring of crucial equipment operating in a variety of environments. Long term or short-term condition monitoring sessions available with summary reports for ease of data comparison.

The 4 Ball EP Tester focuses on Extreme pressure (EP) properties and the 4 Ball Wear focuses on wear scar (WS), and coefficient of friction (COF).

4 Ball Extreme-Pressure The measurement of Extreme-Pressure properties of a lubricating grease using the 4 Ball method is designated under the ASTM-D 2596. The purpose of this testing is to determine the load carrying capabilities of a lubricating grease under high load applications like bearings.



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EXPERIMENTAL:

Wearpreventivecharacteristicsstudyasper ASTM D4172 was carried out using Ducom (Bangalore) make Four ball Tester to observe the impact of additive used. Wear element analysis before & after WPC test was done using MOA-IIplus RDE-OES equipment.

IMPACTOFADDITIVEBLEND:NALUBEBL-1208:

Used oil (Servo prime 46)was used for detailed study of various physico-chemicalpropertiesandwearpreventivecharacteristics. FTIR spectrum analysis of oilshowsthatbaseoilusedparaffinictype(P-65.1%, N-30.7% & A-4.1%). Wear preventivetest as per ASTM D4172 was carried out withset parameters at applied load of 392 N (Testconditions: temperature:75ºC, rotation:1200rpm, duration: 1 hour).

Wear status was monitored through PQ indexand Emission spectrometry (RDE-OES) beforeand after of WPC test. It shows no variation inPQIndex(PQ=7)butferrouswearcontent(ppmFe) varies slightly. Iron content in oil increasesslightly after wear test but there is a

When WPC test was carried out with used turbine oil (SP-46) without additive, variation offrictionaltorque(N.m)withtimeshowedthattorquevariesintherange:0.64-0.65witha coefficient of friction: 0.363-0.369

Figure-5: Variationoftorquewithtimeduring4-balltestonusedturbineoilwithoutextraadditive

Figure-6: Fourballtestwithadditive(NA LUBE BL-1208)

Figure-4: Four ball Tester (Ducom) & FTIRInstrumentwithMicroscope(Shimadzu)

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decreasingtrendwithincreaseinadditivecontent(NALUBE BL-1208) from 0.5% to 1.0% as shownintable-4 below.

Effect of NA LUBE BL-1208 on Turbine oil(SP-46)				
Addi-tive (%)	Fe (%)	Scar dia.(µm)	Fric. Torque (N.m)	% decrease inwear
0 (Before test)	0.6	-	-	-
0 (after test)	17.5	584	0.648	-
0.5 (aftertest)	1.9	445	0.635	88
1.0 (aftertest)	1.4	430	0.630	91

Table-4:4-balltestdata&wearwithNALUBEBL-1208

uevariesintherange:0.64-0.65witha coefficient of friction: 0.363-0.369
as shownin figure-5..Measurement of iron content in oil shows thatBL-1208additive

IMPACTOFNALUBEADTCONWEARPROCESS:

AnotheradditivefromKingsIndustries(NALUBEADTC)wastriedatadosageof0.5%& 1.0% with servo prime-46.4-ball test dataand wear measurement is as given in table-5.This additive is also effective and lowers scardiameter on balls by 6-7% at a dosage level of0.5%,comparedto testdata withoutadditive.

EffectofNALUBEADTC onTurbine oil(SP-46)				
Ad-ditive (%)	Fe(%)	Scar dia.(μm)	Fric. Torque (N.m)	% de-creaseinwear
0.5 (after test)	3.4	539	0.645	80
1.0 (after test)	2.8	522	0.643	83

Table-5:4-ball test data & wear with NA LUBE ADTC additive

Wearprotectionasmeasuredthroughwearelementconcentration(ppmFe)inoilbefore& after test, showed >75% decrease in wearwith minor change in frictional torque (0.648 to0.645) against the additive (ADTC) dosage of0.5%asshowninfigure-7.

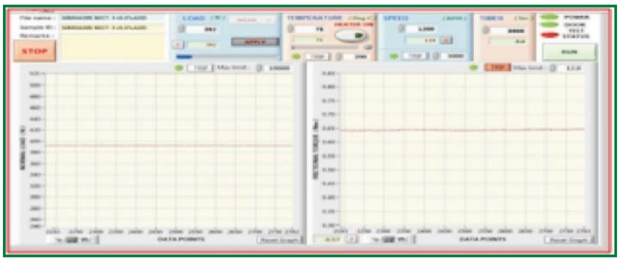

Figure-7: Four ball test with additive (NA LUBE ADTC)

CONCLUSION:

- Degradation or wash out of one or more components of additive package takes place during use of turbine oil in power plant. This causes deterioration in functional properties of oil. Individual a dditive or multi functional additive (AW, R&O) package, compatible to the re sidual additive package already present in used turbine oil can act as protector to base oil.
- The aforesaid additive package (NA LUBEBL-1208) is superior to NA LUBE ADTCin playing wear preventive role w.r.t. scardiameter (15% less / 85 micron) as well as decrease in wear metal loss by further 8% at 0.5% dosage level.

RECOMMENDATION:

Additive package in turbine lube oil is meant for functional property improvement that acts as protective jacket to base oil molecules. It is sacrificial in nature. If turbine oil fails to any diagnostic test, it is due to loss of specificadditive from desired level. In order to gain full functionality again ,re-additization of individual additive or package (as applicable) can be done with support and supply of additive from manufacturer/supplier.

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