SPINNER II®

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Oil Cleaning Centrifuge

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Two Technical Papers from Glacier about Additives and Soot

The Effect of Centrifugal Separation on a Modern Lubricating Oils' Additive Package
by Andrew Bowen
Technical Bulletin No. 7/86
September 16, 1986

Soot, High Additive Oils and Filtration
by Neil Graham, BSc PhD
Technical Bulletin No. 8/86
September 9, 1986

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Introduction

In a diesel engine, incomplete combustion of fuel generates large quantities of very small carbon particles that pass the piston rings as blow-by and form a suspension in the lubricating oil. Most of this carbon is smaller than 0.01 micrometers and does not, therefore, interfere in the lubrication of two sliding surfaces. However, certain concentrations of carbon in this form do cause thickening and can ultimately lead to oil gelling where the suspension becomes thixotropic and solidifies. Carbon is also known to impair the function of anti-wear additives. Therefore, it is advantageous to remove fine carbon by filtration.

Element Filters

There are two methods by which element filters may remove fine carbon. Molecular forces cause fine particles to be attracted to one another such that agglomerates are formed of large enough particle size to enable the filter medium to act as a sieve. Alternatively, the same molecular forces cause the fine carbon particles to be attracted to the fibers of the filter medium where they form a permanent attachment thereby remaining in the filter. Thus, while in theory the size of individual carbon particles is too small for them to be collected in element filters, in practice molecular bonding allows for this to take place to a certain extent.

Centrifugal Separators

Centrifugal separators rely only on centrifugal force acting on the fine carbon particles (approximate density 2.4 kg/liter) to separate them from the oil (approximate density 0.9 kg/liter). Molecular forces between the carbon particles and a filter medium are not relevant since there is no medium with which the carbon may form an attachment. Agglomeration of carbon particles is more readily separated under the influence of centrifugal force. Centrifugal separators will effectively centrifuge fine carbon to below 0.1 micrometers in size from the oil, but become less effective as the particle size decreases. Overall, they are more effective at removing fine carbon than media types of filtration that are limited by fiber surface area and absolute pore size (rarely less than 10 micrometers).

Oil Additives

There are two main additives which affect the ability of filters to remove fine carbon from lubricating oil; dispersants, which hold carbon particles of 0.002 to 0.5 micrometers in suspension and detergents which may hold carbon particles of 0.5 to 1.5 micrometers in suspension. Both of these additives work by neutralizing the molecular bond, both between carbon particles and filtration media. In the case of element filters, therefore, agglomeration is prevented and the sieving mechanism cannot take place and the molecular bonding between carbon particles and filter media fibers is also inhibited. Thus media filters become wholly ineffective at removing fine carbon until such time as the additive level becomes overloaded.

The efficiency of centrifugal separation is also affected by the use of dispersant and detergent additives that inhibit the agglomeration of fine particles which would otherwise be readily removed by centrifugal force. This does not affect the ability of a centrifuge to extract carbon but the time taken to do so is related to particle size and therefore will take longer with higher levels of dispersancy.

Conclusions

With today's modern additive packages the best form of element by-pass filter is only really effective at particles down to approximately 7 micrometers in diameter. To extract smaller particles they rely on molecular attraction that is inhibited by dispersant and detergent additives. Carbon particles below 0.1 micrometers in diameter can be extracted from a modern dispersant oil using centrifugal forms of separation.

Introduction

A modern lubricating oil contains many additives performing various functions, such as:

- VISCOSITY INDEX
- IMPROVERS
- DISPERSANTS
- DETERGENTS
- ANTI-OXIDANTS
- ANTI-FOAM
- ANTI CORROSION
- POUR POINT DEPRESSANTS
- FRICTION REDUCERS

All these additives are specifically designed to be totally soluble in mineral oils, and undergo specific tests to ensure this is the case over the wide range of operating conditions likely to be encountered. All evidence suggests that these ACTIVE additives cannot be removed by filtration or centrifugal separation.

Typically, a modern heavy duty truck engine oil will have an additive package made up of:

2-4%	Detergent
0.5-1.8%	ZDP (anti-wear/oxidant)
5%	Dispersant

Detergency/Dispersancy Additives

In the high performance diesel engine the lubricating oil becomes progressively loaded with carbon produced in the form of soot as a result of poor combustion of fuel, particularly at low temperature operation.

Dispersant additives (ashless - non-metallic) are added to the oil to keep this soot which is in the form of very small particles in the range of 0.002 to 0.5 micrometer diameter evenly distributed in suspension in the oil.

There are two mechanisms by which this dispersion is achieved.

1. By a charge repulsion mechanism: The additive possesses special atomic groupings which give the additive molecule positive and/or negative charges, the oil containing this dispersant additive therefore becomes a charged three dimensional body. The small carbon particles are suspended in a 'charged' field by the charged or 'magnetic' effect of the special atomic groupings.
2. By a film barrier mechanism that is explained in Appendix A.

Detergent additives (metallic salts) also prevent the build up of sludge; some by dispersing particles in the 0.5 to 1.5 micrometer range by dispersing particles in the 0.5 to 1.5 micrometer range by the charge repulsion mechanism and some by chemically absorbing the combustion by-products and thereby preventing their accumulation on engine parts.

The objective of both these types of additive is to prevent the adverse effects of sludge formation and oil gellation on working parts; such as deposits on the piston ring belt area/piston skirt and other close clearance engine parts plus oil thickening inhibiting self-priming of the oil pump and casing possible bearing starvation.

As the quantity of carbon increases it will reach a level when the particles either overcome the additive effect and form a sludge or build up to cause oil gellation and viscosity increase. The additives working by a charge repulsion mechanism will remain in solution, however, continuing to disperse the smaller soot particles.

What effect will centrifugal separator have?

Centrifugal separation will extend the usefulness of the dispersant additive by extracting the agglomerated carbon and other debris, leaving the additive to function freely.

Removal of the carbon by centrifugal separation may also remove some DETERGENT additive which has absorbed solid combustion particles and been rendered insoluble. The additive by this stage has performed its required function, being regarded as 'spent' and would be of little value left in the oil. Analysis of deposits from the rotor of a centrifuge will confirm the existence of 'spent' DETERGENT additive by showing levels of metallic ions such as Barium, Magnesium and Calcium and a low overall PH level.

Additive depletion is mainly caused by oxidation and chemical reactions under normal operating conditions, which renders some additives partially or wholly insoluble. These may be removed by centrifugal separation but again they will have no residual activity.

Anti-Wear Additive

Anti-wear additives such as Z.D.P. Work by essentially 'absorbing' or plating onto metal surfaces and sacrificially providing chemical-to-chemical contact rather than metal-to-metal contact under high-load conditions.

Here again the amount of soot suspended in the oil plays a significant part in influencing the performance of the Z.D.P. additive. It has been found that the presence of soot drastically diminishes the oils anti-wear properties and that modern highly dispersant oils contribute to the problem, apparently by keeping the soot agglomerates in more intimate contact with the oil.

Standard four-ball wear tests have shown that the wear properties of engine soot itself are small but that preferential absorption of the active anti-wear additive is responsible for its pro-wear characteristics.

The mechanism by which the soot interferes with the Z. D. P. is thought to be as follows: The soot and additives in the natural state of oil can co-exist; however, the reaction is such that when the Z.D.P. additive decomposes with operation to form a protective layer on the engine moving surfaces, there is an attraction between the decomposed products of the Z.D.P. additive which become preferentially absorbed by the soot products and thus prevent a wear protective 'skin' being deposited on the engines moving parts.

What effect will a centrifugalseparator have?

Centrifugal separation, in removing the agglomerated soot particles will therefore aid the Z.D.P. in performing its function. Some Z.D.P. decomposition products, because they have associated with soot and consequently been rendered insoluble will be extracted by a centrifugal separator but all ACTIVE Z.D.P. is in solution and cannot be removed.

Anti-Acid Additives

Detergents, besides the functions previously described are also strong acid neutralizers, changing combustion and oxidation acids into neutralized salts. The measure of a detergents capability to perform this function is its TBN or Total Base Number. The high the TBN, the more acid a detergent can neutralize. Detergents are available in a variety of TBN's from near zero to over 400 TBN. The best acid neutralizers are not necessarily, however, the best cleanliness promoters.

Where does acidity originate?

There are two main sources of acidity in engine oil which vary in importance depending on engine operating conditions.

1. Sulphur in the fuel (or oil) burns during combustion to form Sulphur Dioxide and Sulphur Trioxide. These pass the piston rings as 'blow-by' together with oxides of carbon and nitrogen. The sulphur dioxide and trioxide ions readily dissolve in any moisture present in the oil to form acid emulsions which if not otherwise treated, accumulate in the oil. Also, these oxides of sulphur form an association with any carbon present. Thus even in the absence of moisture these acid forming compounds tend to stay in circulation in the oil, and accumulate, rather than pass out through the crankcase with other blow-by gasses.
2. At high temperatures, oxidation of the oil can produce organic acids. This process is accelerated by fine metallic particles which act as a catalyst to the process, copper is particularly prone to encouraging acid formation.

What effect can acid erosion have?

Acid leaches lead from a copper/lead bearing matrix leaving a crazed copper surfaced which eventually allows copper to break and spool from the surface leading to catastrophic failure. To protect copper/lead bearings bearings from acid a thin overlay has been developed which is essentially a lead/tin alloy where the proportion of tin is sufficient to protect the lead from acid erosion. However it has been found that the time in the overlay slowly diffuses into the bearing, an effect accelerated by high temperatures. Consequently a nickel layer is deposited between the copper/lead bearing material in an attempt to inhibit the diffusion.

Sophisticated overlays improve the resistance of a bearing to acid attack, however, they are only palliative and by no means provide complete protection. They are vulnerable to abrasion and the combination of abrasive contamination and acidity obviously accelerates wear.

What effect will a centrifugal separator have?

Centrifugal separation will remove moisture from the oil and as such will encourage the sulphur dioxide and trioxide to remain in gaseous form and pass out of the crankcase with other blow-by gases.

In removing fine carbon particles, which the acidic ions are inclined to form or alternatively capture them together with the carbon particles in the rotor bowl.

The detergent additive neutralizes the acids to produce calcium sulphate, which is initially very fine and harmless, but appears to agglomerate to form brittle particles of up to 10 micrometers in diameter. These particles are friable but there is evidence of The ability of a centrifuge to remove fine metallic particles, particularly those of high density copper, which would otherwise catalyze the formation of organic acids, inhibits natural acid formation.

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APPENDIX A

Ashless dispersant additive (succinimide)

A model of a nitrogen succinimide dispersant is shown in Figure A-1. Succinimides contain a polar head; a nitrogen containing polyamine, which absorbs onto soot particles and a polybutene tail which provides a physical barrier to aggregation and keeps the particles suspended in the oil.

Stabilized carbon particles can be represented by ball and stick dispersant molecules clustered around a solid particle. See Figure A-2.

Figure A-3 shows the size relationship of an ashless dispersant absorbed on the surface of a 100 Å (0.01 micrometer) soot particle. The ashless dispersant is quite small compared to even the smallest particle. However, the film of dispersant prevents the coagulation of such small particles into large aggregates which would drop out as engine sludge and cause the oils' viscosity to increase. It has been calculated that a 100 Å particle would be coated with 300 dispersant molecules. However, 30-40 kg of diesel crankcase oil contains nearly a million billion (10^{24}) dispersant molecules.

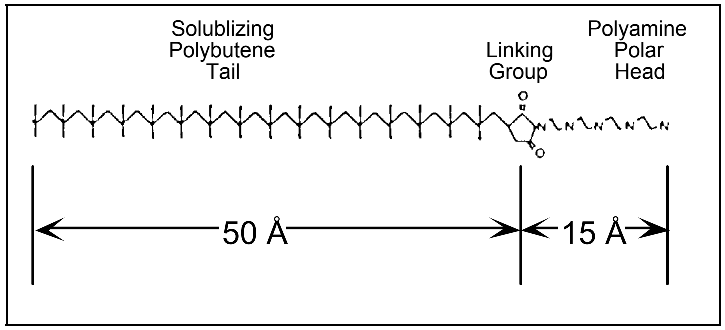

Figure A-1 Ashless succinimide dispersant structure

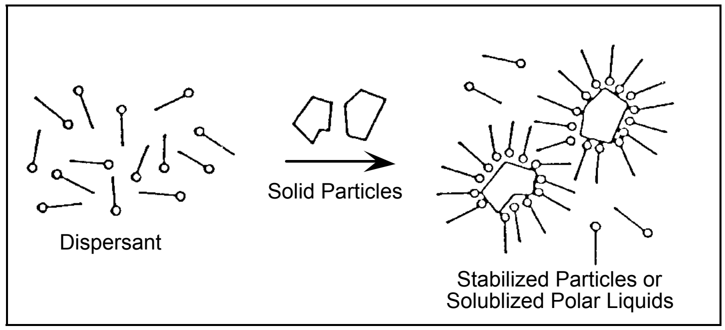

Figure A-2 Process of stabilizing particles of solubilizing polar liquids

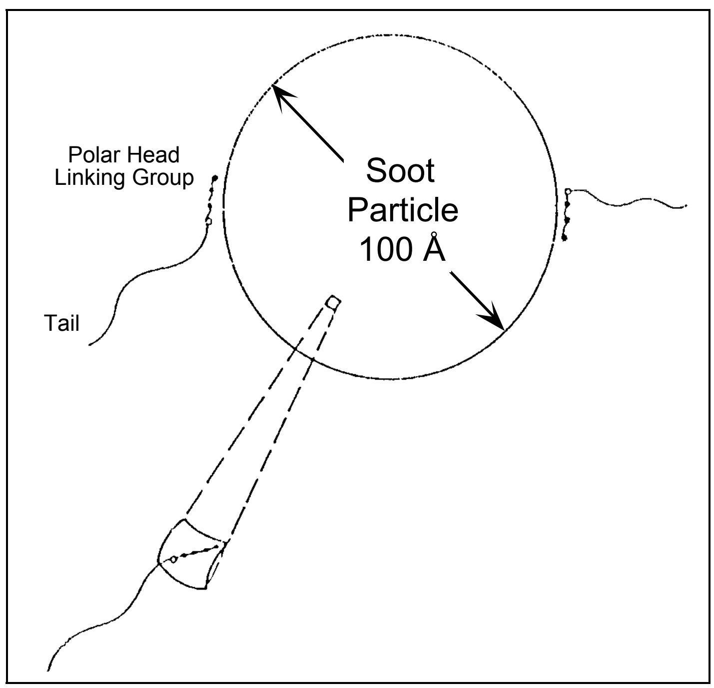

Figure A-3 Dispersancy mechanisim