Preliminary Studies of the Impact of Diesel Fuel Sulphur on Recommended Oil Service Interval

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ABSTRACT

The service interval of engine oils when used in markets using high sulphur diesel fuel is discussed as a function of the TAN and TBN of the oil. Vehicle trial and engine dynamometer studies on a range of oils with different TBN and specifications where tested to determine the TBN retention of the oils over time. The TBN of fresh diesel engine oil is shown to be the primary property of an engine oil in long drain capability when used with high sulphur fuels. Modern low TBN Western European type passenger car diesel oils are shown to be unsuitable for this type of application and heavy duty diesel engine oils shown to be more suitable for consideration where long drain capability is required.

Key-words: TBN, Sulphur, Recommended Service Interval

INTRODUCTION

Combustion of hydrocarbon fuels in internal combustion engines produces acids. Of particular significance to oil properties, the combustion of sulphur containing fuel produces sulphur oxides, which, in the presence of water vapour, condense to form sulphur acids. Additionally, high temperatures and pressures during combustion result in the production of nitrogen oxides, which in combination with water generate nitric and nitrous acids. These strong acids if not neutralised can cause corrosive wear of critical engine components.

Total Base Number (TBN) in essence is a measure of the buffering capacity of engine oil, and its ability to maintain the alkalinity of the oil. A high TBN indicates the absence of strong acids. The addition of acids during the combustion process leads to a reduction in the TBN of the oil. The capacity of oil to resist this reduction in TBN is a property, which is therefore desirable and is a required property for modern lubricants.

Total Acid Number (TAN) relates to the level of strong acidic components in the oil. It is determined from the amount of base required to fully neutralize the acidic components. Therefore, there exists a complex relationship between TAN and TBN, which can only be understood by considering the dielectric constant of the oil media, and the strength of the acid and base components

However, the acid or base characterization of an oil is not an absolute, but can only be specified with relation to the solvents used in the analysis. Dielectric constant (permitivity) significantly affects the ability of liquids to dissolve ionic compounds. Water has a high permitivity, and as such has the ability to equilibrate the acid and base strengths of ionic species within it. This equilibrium ability therefore reduces the range of acid and base strengths available within aqueous solutions. This relationship therefore indicates the range of acid and base strengths available in non-aqueous solutions (lower permitivity) are therefore greater.

Given this effect it is therefore apparent that the ability of both acids and bases to react is dependent upon the permitivity of the media of which it is held. Acids, which are stronger in low permitivity non-aqueous solvents, are able to titrate weaker bases, leading to a specific TBN value. The use of a weaker acid in the same titration would therefore not lead to the same TBN value. This effect is core to the differences of TBN levels ascribed to particular TBN methods, and hence prevents simple and accurate comparison of results derived using different TBN methods. Analysis therefore should always make reference to the specific method used, and conclusive comparisons only made when using the same analytical method.

RATIONALE

This study arose from work performed to find a suitable oil quality and recommended service interval for vehicles using diesel engines in the Turkish market. The diesel fuel quality in Turkey (Table 1) has a current maximum sulphur limit of 7000ppm. In the urban areas of Turkey the fuel sulphur level is commonly around 5000ppm although diesel fuel samples have been taken in other areas of Turkey with fuel sulphur levels of up to 9000ppm. Clearly this can have a serious impact on an OEM's recommended oil drain interval. Particularly if the initial fill oil is a typical Western European ACEA A1/B1 type oil with relatively low TBN. This type of oil is not designed to operate with high sulphur fuel.

A common technique for determining recommended oil service intervals in those markets where high sulphur fuels predominate is to halve the standard oil service interval when the diesel fuel is expected to contain 3000 to 5000ppm sulphur and to halve this interval again when the diesel fuel is expected to contain more than 5000ppm sulphur. In the past this idea would probably have worked well working from the assumption that markets using high sulphur diesel fuels would, in general, have lower quality oils available for oil service requirements. However that strategy does not necessarily hold true as some developing markets start to demand oil drain extension and the engines are increasingly designed around specific oil and fuel qualities. This can cause problems for the OEM as the vehicles desired fuel quality, lubricant viscosity and lubricant quality requirements may not be supportable in the service market of a given developing market.

Many OEM's, particularly in Europe, have focused on fuel economy as a clear objective for the engine oil specified for new engine developments and have pushed oil specifications towards lower viscosity grades for fuel economy (Bennett et al.). This type of advanced motor oil, with many other parameters rolled into their specification are rarely available in developing markets. These markets commonly still use classic viscosity grades such as SAE 15W-40 with older API heavy duty diesel oil specifications. Unless an OEM can provide a clear need for a particular advanced oil quality and viscosity grade in a developing market, the oil marketers will have little impetus to stretch the available oil qualities in the market.

A proposal has been made for a Worldwide Heavy Duty (WWHD) Diesel Engine Oil specification jointly by ACEA, AAM and JAMA (Otterholm). It is essentially a worldwide minimum performance specification based upon appropriate specifications and engine tests from each of the three organizations that represent the OEM's regionally (Europe, North America and Japan). For light duty diesel engines ACEA leads the way in performance specifications. As light duty passenger diesels enter more worldwide markets then it is expected that these specifications, at least as a base, will be utilised in any specifications applicable to worldwide use. Currently the compromise position is to use the currently available API based heavy duty diesel specified oils in the market and reduce the service interval accordingly, or to create a demand for an improved performance level for that market.

The intention for WWHD is to have several performance levels for the category. This type of approach, when the specifications are utilised in engine development can improve an engines robustness to developing market oil qualities, especially when the engine is destined for a wide variety of applications and markets.

EXPERIMENTAL

VEHICLE TRIAL - Test work was undertaken on a Ford Transit vehicle with the 66kW 2.4DI Duratorque Diesel Engine. A single vehicle was operated by a fleet customer within Turkey on a delivery route within an urban environment. This vehicle was operated over a series of 16000km oil service intervals. At each service interval the oil in the vehicle was drained and a different oil candidate was chosen. Samples were taken from the vehicle at initially 1000km intervals, and on later oil candidates at 2000km intervals. The diesel fuel used was standard pump fuel available throughout urban areas with a fuel sulphur level of 5000ppm.

OIL TEST MATRIX - A matrix of oil qualities and TBN levels were tested (Table 2). Three oils meeting the current factory and service fill Ford specification for Europe (WSS-M2C-913-A) were tested along with a 10W-30 heavy duty diesel engine oil with a TBN level of 12 (ASTM D2896). The Ford specification is based upon ACEA A1-98/B1-98 and ILSAC GF-2 with some additional Ford requirements that cover oxidative stability and fuel economy.

DYNAMOMETER ENGINE TEST - In combination with the vehicle testing, service intervals were investigated for engine dynamometer tests. This was to correlate dynamometer service intervals for high sulphur fuels with those found from the fleet vehicle. This portion of the work centered on the 2.4DI Duratorque 88kW engine, and results presented in this paper are derived from testing on this engine. Oil samples were taken at 20 hour intervals over 100 hour oil change intervals. The operating cycle is predominantly a maximum power cycle. The oil used was Oil D (Table 2) and the diesel fuel contained 5000ppm sulphur.

RESULTS

TBN and TAN were determined using ASTM D4739. This method was used in preference due to the increased accuracy reported by many authors and being generally regarded as more suitable for used engine oils than ASTM D2896. (Armitage et al., Bush et al., Fox et al, Saville et al.).

Figure 1 shows the TAN and TBN results for the four oils in the vehicle trial. The point at which the TAN and TBN levels cross over for each oil is determined as the maximum service interval for that oil. In general this happens and at a TAN and TBN level of around 2 to 3 TAN/TBN. Figure 2 shows the TAN and TBN results for Oil D in the dynamometer study.

Each of the oils from the vehicle and dynamometer studies were also analysed for other common parameters such as viscosity, insolubles, additive elements and wear metals but the only critical failure parameters noted were TAN and TBN.

DISCUSSION

Determination of service interval with respect to TBN/TAN levels using this method can be attributed to the intersection of the two corresponding levels. This intersection has been chosen empirically, however it can be seen from Figure 1 that after the intersection of the two values the plateau level of the TAN begin to significantly increase as the levels of strong acids within the oil rapidly increase.

It is therefore suggested that the presence of a low rate of increase in TAN is therefore indicative of adequate engine protection from corrosive effects of strong acids. Whether this intersection absolutely correlates to the point at where a critical increase in corrosive wear takes place is beyond the scope of this work, however, from the understanding of the nature of acid and base ionic species within the oil it can be suggested that the level of corrosive wear will be linked to the concentration of strong acids available within the oil.

The maximum service interval capability from the vehicle for Oil D is 11,500km (figure1) and the TAN/TBN intersection is 3 $mgKOH^{-1}$. Operation of the dynamometer test generates an intersection at the same TAN/TBN level (figure 2), occurring at 70 hours. This suggests a relationship between the oil behaviour on the dynamometer cycle and that observed in the vehicle test.

A relationship can also be seen, in the vehicle trial, between the fresh oil TBN value and maximum drain capability determined by the intersection of the TAN and TBN values (figure 3). This indicates that the primary factor involved in drain capability when using high sulphur fuels is the TBN of the fresh oil. However, this does not suggest there is no effect from the TBN retention quality of the oil, which requires further investigation.

CONCLUSION

This study highlights a relationship between fresh oil TBN and drain capability when using high sulphur fuels and that the TAN/TBN intersection is a justified metric for determining the maximum drain capability of an oil in high sulphur fuel areas.

It can also be concluded that there exists a potential relationship between the dynamometer cycle and a typical vehicle drive cycle with respect to TAN/TBN and high sulphur fuel. This conclusion generates the need for further investigation to determine whether differing abilities of oils for TBN retention is also a contributory factor and whether this is reflected when using different oil qualities.

To supplement this work a further vehicle study is planned to investigate the drain capability of different oil qualities with the same fresh oil TBN level.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

AAM – Alliance of Automobile Manufacturers.

ACEA - European Automobile Manufactures Association.

JAMA – Japanese Automotive Manufacturers Association.

TAN (Total Acid Number) – The quantity of base, expressed in milligrams of potassium hydroxide, that is required to neutralize all acidic constituents present in 1 gramme of sample. IP 177/94.

TBN (Total Base Number) - The quantity of acid, expressed in terms of the equivalent number of mg of potassium hydroxide that is required to neutralise all basic constituents present in 1 gramme of sample. IP177/94.

Table 1 Fuel Qualities in Western Europe and Turkey

Country / Region	Cetane Number	Sulphur / ppm
Western Europe	51 min	350 max
Turkey	47min (cetane index)	7000 max

Table 2 Oil Test Matrix for Fleet Trial

Oil	Quality	Viscosity Grade	TBN (ASTM D2896)
A	WSS-M2C-913-A	5W-30	6.5
B	WSS-M2C-913-A	5W-30	9.2
C	ACEA B3/E3, API CG-4, MB 228.3, MAN M3275, Volvo VDS-2	10W-30	12.0
D	WSS-M2C-913-A	5W-30	9.3

TABLES AND FIGURES

Figure 1 TAN/TBN vs Oil Service Interval (Vehicle Trial)

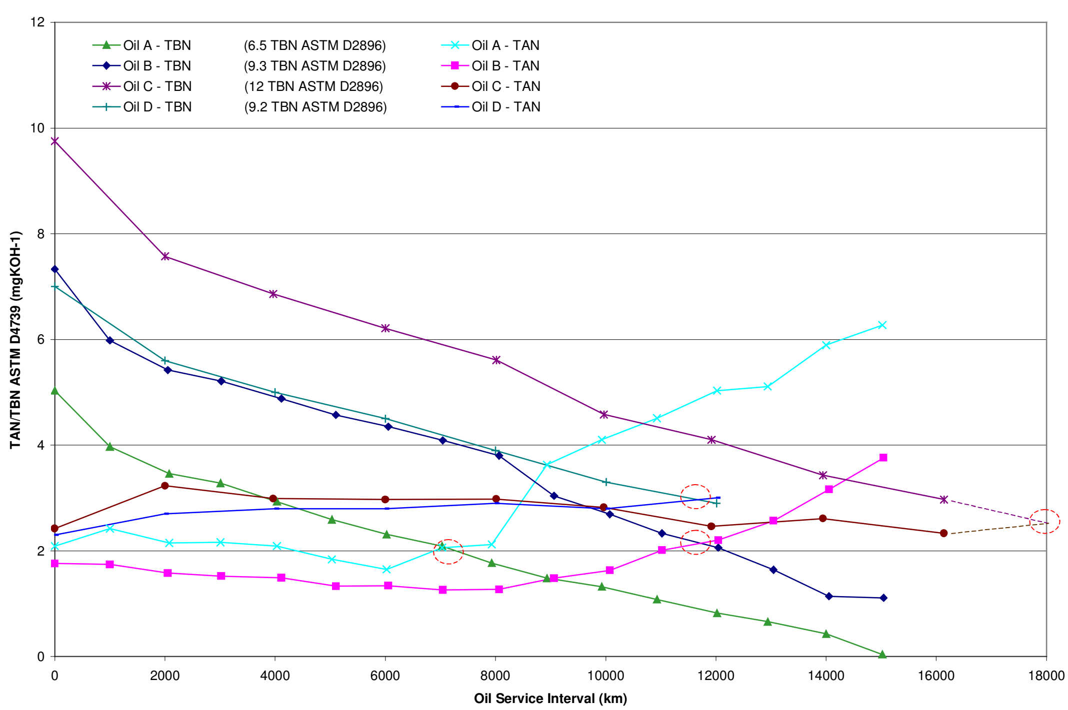

Figure 2 TAN/TBN vs Test Time (Dynamometer)

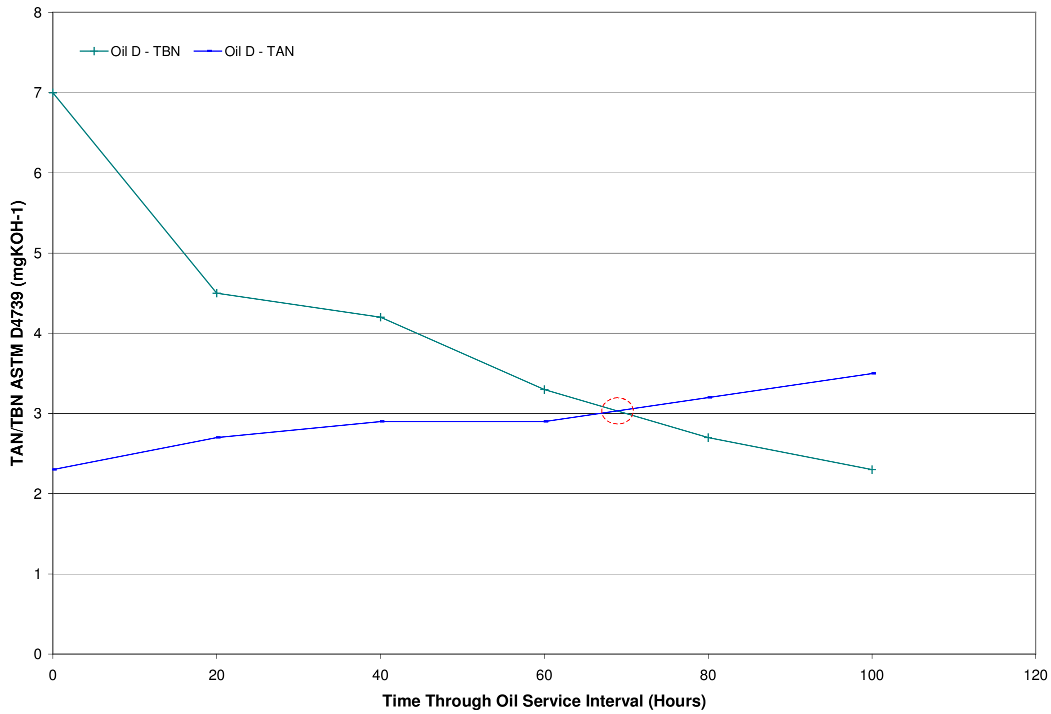

Figure 3 Fresh Oil TBN vs Maximum Oil Drain Capability